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A New Perspective on Neolithic Sites in the Dubičiai Microregion Using a GIS Spatial Analysis

Eglė Marcinkevičiūtė

The article analyses the Dubičiai microregion, which is distinguished by the abundance and diversity of its Stone Age settlements, and presents the possibilities provided by GIS Spatial Analysis in reconstructing this microregion's Neolithic landscape, distinguishing conditions that affected the selection of the Stone Age settlement sites, and determining the locations where the greatest possibility exists for the discovery of new, not yet known Neolithic settlements.

Keywords: Dubičiai microregion, Neolithic settlements, GIS Spatial Analysis, palaeolandscape, environmental variables, predictive modelling.

Straipsnyje analizuojamas akmens amžiaus gyvenviečių gausa ir įvairove išsiskiriantis Dubičių mikroregionas, pristatomos GIS erdvinės analizės teikiamos galimybės rekonstruoti šio mikroregiono neolito laikotarpio kraštovaizdį, ištirti sąlygas, nulėmusias akmens amžiaus gyvenviečių vietos pasirinkimą, ir nustatyti vietas, kuriose didžiausia tikimybė aptikti naujų, dar nežinomų neolitinių gyvenviečių.

Reikšminiai žodžiai: Dubičių mikroregionas, neolitinės gyvenvietės, GIS erdvinė analizė, paleokraštovaizdis, aplinkos veiksniai, prognozinis modeliavimas.

INTRODUCTION

The Dubičiai microregion (Varėna District Municipality) is distinguished by an abundance of diverse Stone Age settlements. This microregion began to be investigated archaeologically in the late 19th century. Landlord Wandalin Szukiewicz conducted searches for Stone Age settlements and collected finds on the banks of the Rivers Ūla and Katra and on the shores of former Lakes Pelesa and Duba. The settlement descriptions and maps he presented have not only yielded valuable information about the archaeological heritage of the Dubičiai microregion, but have also allowed the landscape, which had previously existed and was greatly altered in the 20th century, to be imagined and reconstructed (Шукевич В., 1893; Szukiewicz W., 1901). The archaeological excavation of Neolithic settlements and the search for new sites have been conducted intensively in the second half of the 20th–early 21st centuries.

The Dubičiai microregion has attracted the attention of not only archaeologists, but also geologists, who have devoted considerable space in their works to geomorphological, palaeogeographic, and palaeoecologic analyses of the Dubičiai microregion, have conducted palynological and diatom analyses, and have reconstructed the formation processes of the lakes (Stančikaitė *et al.*, 2002; Balakauskas *et al.*, 2012). Nevertheless, despite these diverse analyses, it is difficult to perceive and reconstruct the palaeolandscape in which the Neolithic inhabitants had settled. The sandy plains and peaty meadows currently found in the Dubičiai microregion make it difficult to imagine that large lakes had previously existed there (Fig. 1). A spatial analysis using GIS has not only helped to reconstruct the landscape but has also allowed natural environmental variables that affected the selection of habitation sites to be analyzed and the most favorable locations, i.e., those which hold the greatest possibility for the discovery of as yet unknown Neolithic settlements, to be determined.

RESEARCH AREA

The Dubičiai microregion is on Lithuania's southeastern border with Belarus. On the west, the microregion is surrounded by continental dunes, most of which run parallel to the Katra valley (from the vil-

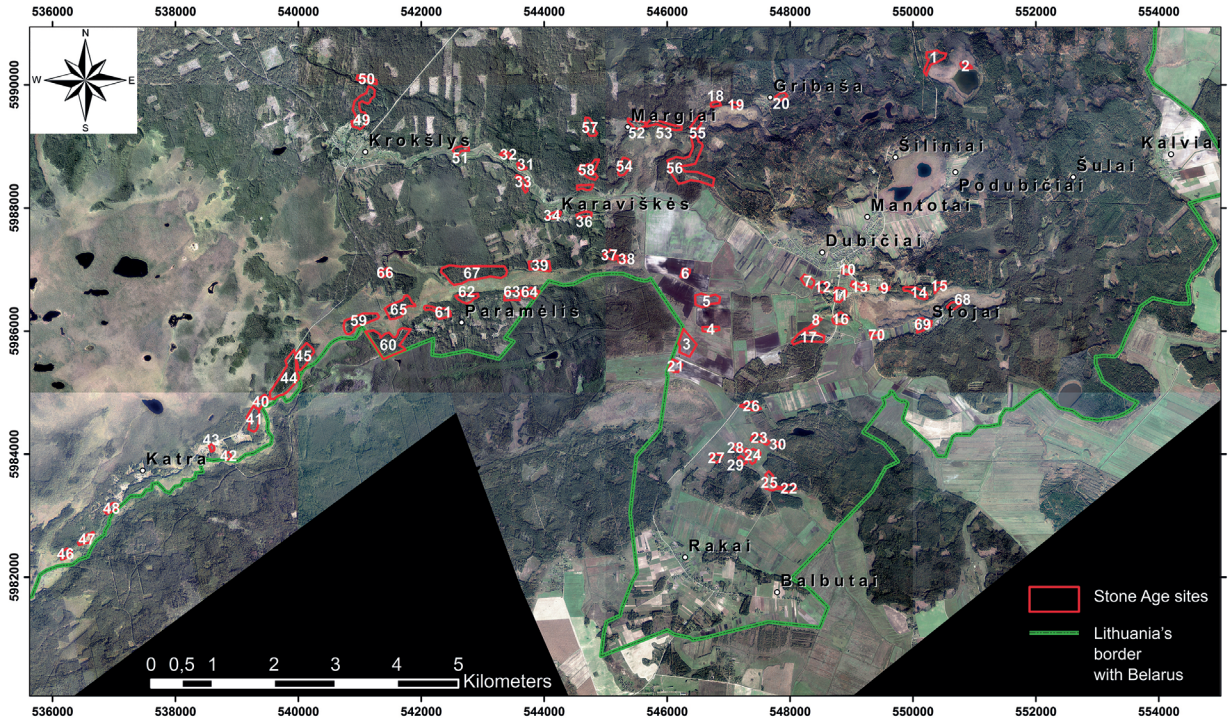

Fig. 1. The currently known Stone Age sites in the Dubičiai microregion. Basis: a 2012 aerial photograph. For a list of the Stone Age settlements, see Table 1. Composed by E. Marcinkevičiūtė.

1 pav. *Dabar žinomos Dubičių mikroregiono gyvenvietės. Kartografinis pagrindas – 2012 m. aerofotonuotrauka. Gyvenviečių sąrašas pateiktas lentelėje. Sudarė E. Marcinkevičiūtė*

lage of Paramėlis), which drains the microregion. On the northeast-east and, in part, the south, the region is bound by the old highlands, which were heavily damaged by the last Weichselian glaciation (the Nemunas) and the foot of which is covered by sandy-gravelly layers deposited by glacial meltwater. The central part of the Dubičiai microregion, i.e., the Katra lowland, has been strongly affected by thermokarst processes, renewed in the late glacial period and furrowed by various-sized proglacial valleys, that run in diverse directions. The studied area covers approximately 186 km^2 in the watershed between the Rivers Ūla and Katra on the edge of this sandy plain. The area is fairly level with elevations ranging from 121 to 179 m above sea level a.s.l. (Fig. 2) and is packed by thermokarst hollows and proglacial valleys. The aspect ratio analysis shows a fairly even distribution of the downslope direction in the microregion, but, probably owing to the flow direction of the glacial meltwater, somewhat more of the slopes are oriented to the south–southeast and north–northwest. The slope gradient ranges from 0 degrees in flat areas to 36.86 degrees in the N part of the studied area. The highest location in the microregion is a hill, which lies to the N–NW of Dubičiai village and is an erosional, hilly fragment of the ancient relief (Stančikaitė *et al.*, 1999, p. 69).

RECONSTRUCTION OF THE BODIES OF WATER

Up until the late 19th century, lakes were an important element of the Dubičiai microregion's landscape. In the late 19th–early 20th century, owing to the erosion of the Ūla river channel, part of the Katra river drainage basin was captured by Ūla River and the water from Lakes Matarai, Pelesa, and Duba gradually drained into Ūla River. Lake Duba alone shrank over 50 years from 221 ha in 1850 to 20 ha in 1900 (Česnulevičius, Švedas, 2010, p. 148). The drainage of the remnants of the old lakes was completed in 1958–1959 through melioration. A landscape of meadows and pine forests now predominates in the Dubičiai microregion; only some names of the Stone Age sites: Dubičiai Island (Lith. *Dubičių salaitė*), Margiai Island (Lith. *Margių sala*), and Lakeshore (Lith. *Paežerys*) allude to the big

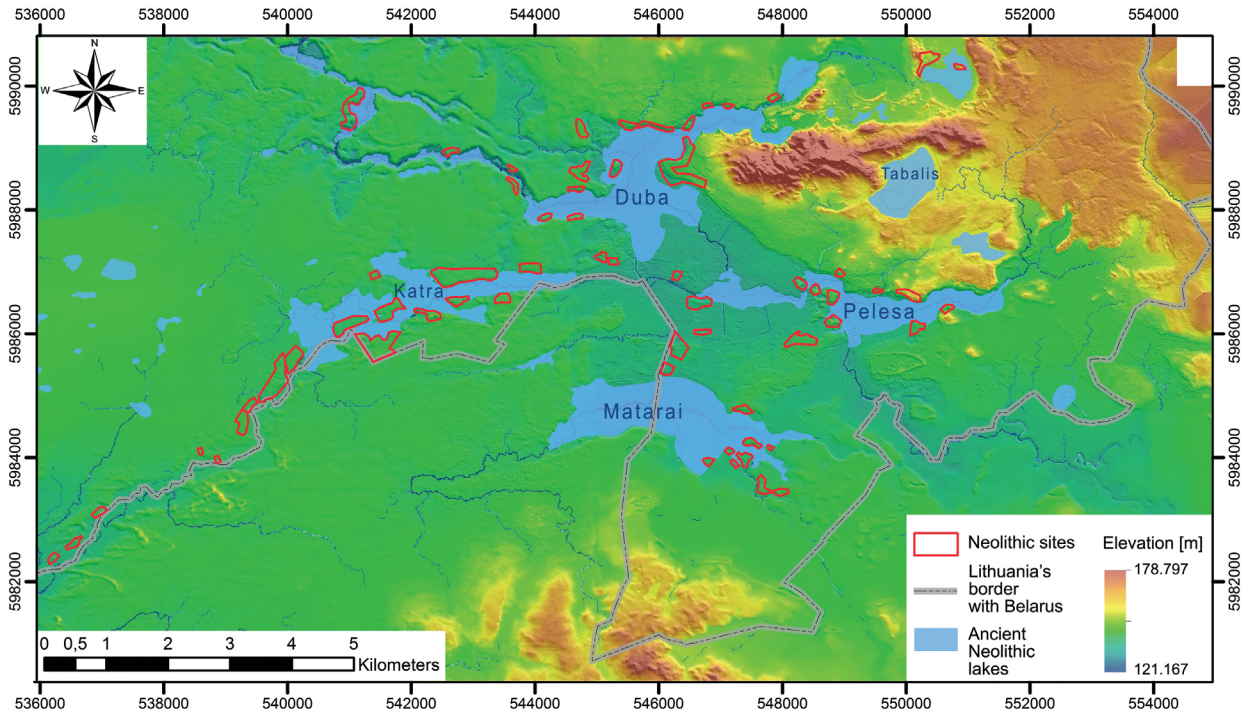

Fig. 2. A digital elevation model of the analyzed area. The reconstructed lakes and rivers are marked. Composed by E. Marcinkevičiūtė.

2 pav. *Analizuojamos teritorijos skaitmeninis reljefo modelis su pažymėtais rekonstruotais ežerais ir upėmis. Sudarė E. Marcinkevičiūtė*

bodies of water that existed there up until the late 19th century.

The large lakes of Duba, Pelesa, and Matarai formed at the sites of chunks of ice in an active thermokarstic zone. During the peak of the last glaciation, the Weichselian (Nemunas), the studied area lay at the edge of two glacial lobes. In the vicinity of Merkinė, Nemunas River inundated the marginal moraine belt and the glacier's edge, its waters spreading out widely into the glacier-free territory, the eastern part of which became the present-day lowland of Katra River.

On the basis of the geomorphological, palynological, and diatom analyses, it was determined that up until the Allerød Oscillation a high water level of roughly 128–130 m a.s.l. had existed, but the aeolian processes and the universal drop in the water level that began in the Allerød Oscillation had caused the water level of Lakes Duba, Pelesa, and Matarai to fall to 125–126 m a.s.l. (Balakauskas *et al.*, 2012, p. 122). The lowest recorded water level was in the Preboreal, but an abrupt rise is noticeable in the first half of the Boreal, even to as high as 130 m a.s.l. During 9520–9290 cal. BP, the water level again fell significantly to roughly 127 m a.s.l. (Balakauskas *et al.*, 2012, p. 125). Marked changes in sedimentation are noticeable throughout the Atlantic. A rise in the water level is shown by the diatom assemblages, which display a predominance of planktonic species, from 8100 BP when the water level reached 129 m a.s.l. The previously discrete lakes merged and once again formed a single large eutrophic palaeobasin. Based on the results of the diatom analysis, the water level of Lake Pelesa remained high, at about 130 m a.s.l., in the Early Subboreal but later fell to 124–125 m a.s.l. (Stančikaitė *et al.*, 2002, p. 403).

During the Stone Age, the lakes must have been one of the most important variables influencing the selection of habitation location in the Dubičiai microregion. The significant water level fluctuations that have been presented by geologists in their works are almost entirely indiscernible when looking at the location of the Stone Age settlements; Final Palaeolithic, Mesolithic, Early–Middle Neolithic, and Late Neolithic heritages

have been discovered at the same place in the majority of the settlements. The incidence of settlements at an elevation of 126–138 m a.s.l., or roughly 130.5 m a.s.l. on average, in the Dubičiai microregion during the Neolithic when the lake's water level was 129–130 m a.s.l. signifies that part of the area of the settlements must have been under water. Therefore, the hypothesis that they could have been pile settlements should not be rejected. In analyzing a similar natural landscape in East Lithuania's Kretuonas microregion, which still has large lakes, it has also been observed that the majority of the settlements had been founded right beside the water despite the fact that they must have been seasonally inundated (Marcinkevičiūtė, Šatavičius, 2013, p. 560). It is likely that in order to mitigate the fluctuations in the water level, pile buildings were erected at places in the settlements in both the Kretuonas and the Dubičiai microregions. It should be noted that sand, in which wood and other organic materials survive especially poorly, predominates in the Dubičiai microregion.

On the other hand, it is not very likely that the large Late Neolithic-Early Bronze Age settlements of Margiai, Barzdis Forest, or Karaviškės were founded several hundred meters from the peaty shallow shores of Lake Duba in the second half of the Subboreal, when the water level of Lake Duba was roughly 124–125 m a.s.l.

The shores of the ancient Neolithic lakes, which predominantly had a water level of about 128 m a. s. l. (with a ±0.5 m seasonal fluctuation), were reconstructed (Fig. 2) on the basis of the results of the geological investigations, a digital elevation model, and the location of the Stone Age settlements known in the Dubičiai microregion. These bodies of water must have been flowing lakes that were well fed by rivers. During the last 150 years, the channel network has changed significantly, which has led to the disappearance of the huge lakes of Duba, Pelesa, and Matarai. A series of several mid-19th-century events contributed to the erosion of the River Ūla: circa 1830, the beginning of a drop in the water level of Lake Duba, which belonged to the Katra catchment basin, the 1841 collapse of the Rudnia foundry dam, and the general effect of the erosion of the River Nemunas on the River Katra (Linkevičienė, 2009, pp. 1238–1239). As a result, the flow direction of the upper Katra changed, and its tributaries – the Nočia, Kaniavėlė, and others – began to discharge into the Ūla. Lakes Duba, Pelesa, and Matarai, which lay in the territory captured by the Ūla, disappeared in less than a 100 years. The landscape was further altered by Soviet melioration, which completed the area's drainage and converted the small rivers into melioration channels. A flow accumulation model created using SAGA GIS 3.0.0 software on the basis of the digital elevation model was used to reconstruct the former channel network.

THE NEOLITHIC SITES

In the 1960s, the systematic excavation of Stone Age settlements began in the Dubičiai microregion with Dubičiai 1, 2, 3 (Римантене, 1966), Barzdis Forest (Margiai 5) (Rimantienė, 1999a), and Margiai 1, 2 (Rimantienė, 1999b) settlements. The majority of them were non-stratified, multi-period sandy sites with an abundance of material from various Stone Age periods, mostly flint finds. For example, more than 1000 flint artifacts were discovered in 1 m^2 at Margiai 1 settlement (Rimantienė, 1999b, p. 130). Some of the finds from this site are connected with the Final Palaeolithic–Mesolithic, but about half consist of Neolithic finds, including isolated pig, horse, and small ruminant (?) bone fragments and tools (stone hoes and small handstones), which should be associated with Late Neolithic agriculture (Rimantienė, 1999b, p. 158). At the turn of the 21st century, the settlements of Karaviškės (Piličiauskas, 2012), Gribaša (Grinevičiūtė, 2002), Katra (Girininkas, 2000; Brazaitis, 2000), and Paramėlis (Šatavičius, 2005) were excavated. The Dubičiai microregion is still being archaeologically surveyed in the search for new settlements. A problem concerning names and numeration has occurred in registering this microregion's settlements. A large part of the Stone Age settlements registered by different archaeologists since the late 19th century have several names: an object is listed under one name in the Register of Cultural Property, while the investigator has published it under another name or investigated the same object as a new, yet unknown settlement. In an effort to systemize the information from all of the investigations that have so far been con-

ducted in the Dubičiai microregion, the earlier information identifying the same settlements by different names was reviewed and combined. In addition, the territory included in the settlement sites was checked on the basis of the information from the field evaluations and the physical relief maps.

70 Stone Age settlements occupying a total of 2.766 km^2, i.e., 1.49% of the entire area in question, are currently known in the analyzed area. Of these, 63 have Neolithic cultural layers: 62 from the Early–Middle Neolithic and 44 from the Late Neolithic. The settlements vary greatly in size: from 4873 m^2 (Kajutis-Matarai 9) to 223550 m^2 (Margiai 5 (Barzdis Forest) Settlement) (Table 1). More than half of the settlements (including those in peat bogs) have been discovered during the last 20 years during field evaluations and surveys conducted by E. Šatavičius (Šatavičius, 2006).

An attempt was made to analyze the Early–Middle and Late Neolithic settlements separately, but the majority of the sites possess heritage from both periods. On the other hand, it must be acknowledged that the dating of the majority of the settlements is preliminary. Even in the more broadly excavated settlements, the more precise dating and cultural attribution of the discovered pottery and flint inventories is a cause for discussion. It should be pointed out that compared with the rest of Lithuania's territory, the highest concentration of settlements connected with the Globular Amphora and Corded Ware cultures occurs in this microregion (Brazaitis, 2005, pp. 222, 236). It would seem that these settlements, which were inhabited by non-local, immigrant farmers and animal breeders, should have been founded at new sites, which were perhaps separated by the natural landscape from the earlier Neolithic settlements. In actuality, the absolute majority of the heritage connected with the Globular Amphora and Corded Ware cultures has been discovered at settlements that had existed prior to these cultures. The location of the settlements in the microregion as well as an intrasite analysis of them (Marcinkevičiūtė, 2010) show the continuity of the settlements right up to the Bronze Age. The large areas occupied by the settlements or the fairly thick cultural layer discovered in them probably reflect less the population density and more a long habitation period when the area occupied by the settlement was expanded in some direction in order to take advantage of a clean area uncontaminated by household waste or a periodic, perhaps seasonal, relocation to a nearby area and a subsequent return. The settlements were located at distances of 183–987 m from one another, the average distance being ~631 m. The impression has formed that the population in the Dubičiai microregion was fairly sedentary during the Neolithic, only low scale mobility being very likely. The absolute majority of the Stone Age settlements in the Dubičiai microregion are currently located in meadows or forests/forest margins. Therefore, the role of the former lakes in selecting the settlement sites has usually not been evaluated. Previously, the discovered flint inventory was often interpreted as agricultural or hunting tools, but fishing must have been a no less important food source. The new technologies probably spread from southern regions into the Dubičiai microregion via the rivers, perhaps even by (or more precisely, up) Katra River, which is connected with Nemunas.

ENVIRONMENTAL VARIABLES

In order to investigate the conditions influencing the selection of Neolithic habitation sites, an analysis of the palaeolandscape was made. Nine environmental variables were created and examined using GIS applications: elevation above sea level, a terrain ruggedness index, the slope length and steepness factor (Ls factor), direct solar radiation, distance to the reconstructed lake shores and channel network, a topographic wetness index, altitude above the channel network, and a visibility index. The value of each environmental variable was analyzed in the Dubičiai microregion as a whole and in the area occupied by each Neolithic settlement. In order to evaluate and statistically substantiate that the selection of the settlement sites was not random, a layer of 137 background points covering all of the territory without any archaeological objects was additionally created alongside the 63 Neolithic settlements. Marine Geospatial Ecology Tools, which interface with the R statistical software, were plugged into ArcGIS and used to perform statistical calculations and create density histograms (Roberts *et al.*, 2010).

Table. A list of currently known Stone Age sites in the Dubičiai microregion, their chronology, site size (m^2), and the environmental variable values at the settlement sites. Composed by E. Marcinkevičiūtė.

***Lentelė**. Dabar žinomos Dubičių mikroregiono akmens amžiaus gyvenvietės, jų chronologija, teritorijos dydis (m^2) bei aplinkos veiksnių reikšmės gyvenviečių teritorijose. Sudarė E. Marcinkevičiūtė*

No.	Name	Area	Perimeter	X coordinate of centroid	Y coordinate of centroid	Chronology				Elevation above sea level	Terrain ruggedness index	Ls factor	Direct solar radiation	Distance to lakes	Distance to rivers	Topographic wetness index	Altitude above channel network	Visibility index
						Palaeolithic	Mesolithic	Early-Middle Neolithic	Late Neolithic									
1	Budos-Dumblis	57759,94	1285,62	550336,25907	5990419,52704	yes	yes	yes	no	136,97	-0,01142	0,63178	36,42053	131,82	341,37	6,89672	2,0552	0,18739
2	Budos-Dumblis 2	11116,73	463,47	550856,18361	5990310,04596	no	yes	yes	no	135,37	0,21037	0,13131	33,75200	22,66	321,80	8,60520	0,2637	0,01397
3	Dubičiai 1 (Salaitė)	26968,35	645,54	548290,31448	5986809,83795	no	yes	yes	yes	129,20	0,35074	0,54303	34,59031	96,69	110,02	7,67344	0,8257	0,49236
4	Dubičiai 2 (Paežerys)	13390,24	451,49	548924,15926	5986975,70766	yes	yes	yes	yes	132,34	0,25115	0,60028	39,27299	98,65	126,45	6,69203	0,8789	0,54057
5	Dubičiai 3	34437,99	715,99	548812,69505	5986593,46985	yes	yes	yes	yes	131,17	1,02562	0,79406	35,01481	58,79	189,52	6,26960	2,5551	0,51913
6	Dubičiai 4 (Bonos pilis)	19087,63	509,77	548531,42754	5986711,34310	no	yes	yes	no	130,23	1,19071	0,88477	30,96882	48,37	90,05	6,17857	1,6627	0,62733
7	Dubičiai 5	22549,84	716,55	549131,57566	5986724,17297	yes	yes	no	no	130,79	0,51405	0,45777	37,83432	66,71	113,60	7,33817	0,8220	0,31827
8	Dubičiai 6 (Nuolabedis)	38948,16	964,35	550064,49051	5986626,43210	yes	yes	yes	yes	137,48	1,84892	0,95745	40,64868	104,01	240,72	6,49278	5,7432	0,66391
9	Dubičiai 7	18035,57	633,30	550425,47564	5986729,47643	no	yes	no	no	137,40	1,79090	1,53359	43,87564	66,79	225,09	6,26860	4,5382	0,46674
10	Dubičiai 8 (Hillfort)	35211,26	755,66	548817,78873	5986194,59003	yes	yes	yes	yes	130,52	0,78085	0,76503	32,61925	57,10	251,09	6,31713	1,8702	0,59191
11	Dubičiai 9	71691,62	1425,39	548299,90050	5985897,61199	no	yes	yes	no	130,50	0,18451	0,12915	33,46540	457,27	619,26	7,78918	0,9760	0,40132
12	Dubičiai 10	13163,43	605,20	548412,07635	5986129,70518	yes	yes	no	no	129,60	0,22328	0,16125	34,96123	272,79	433,38	6,78712	0,5286	0,22268
13	Dubičiai 11	7759,06	419,66	549536,61953	5986695,63904	no	no	yes	no	131,88	0,54752	0,68379	37,37525	103,86	86,19	6,08845	0,7908	0,50355
14	Dubičiai-Draciliškė 1	75976,64	1144,38	546318,15033	5985784,91572	no	no	yes	yes	129,27	0,06677	0,19818	34,08639	491,61	134,83	8,25917	0,4566	0,25164
15	Dubičiai-Draciliškė 2	19395,66	662,40	546706,63089	5986029,21077	no	yes	yes	no	128,95	0,09015	0,16635	33,89203	520,24	445,36	7,25354	0,4121	0,18518
16	Dubičiai-Katra 1	64205,85	1082,72	546638,87855	5986501,14926	no	yes	yes	no	128,84	0,26613	0,14756	33,82967	99,45	112,07	7,98914	0,4796	0,26873
17	Dubičiai-Katra 2	16585,92	512,83	546294,37929	5986941,39110	no	yes	yes	no	128,85	0,29835	0,12144	35,28179	432,25	148,60	7,39741	0,4172	0,23159
18	Gribaša 1	10178,67	426,36	546787,86105	5989684,88970	no	yes	yes	yes	131,00	0,50317	0,96786	42,55395	43,33	304,12	6,47181	1,1973	0,18251
19	Gribaša 2	9473,37	420,70	547119,44371	5989676,88032	no	yes	yes	no	130,71	0,40734	0,86336	43,61095	40,31	196,75	6,27018	0,4079	0,14528
20	Gribaša 3	14615,21	492,60	547859,05595	5989812,08722	no	yes	yes	yes	133,43	1,24491	0,90528	38,04216	131,75	67,21	6,29292	3,8540	0,19632
21	Kajutis-Matarai 1	29100,51	663,12	546136,42081	5985425,62635	no	no	yes	yes	129,02	0,17246	0,16699	34,72404	119,07	89,05	7,94991	0,3173	0,19284
22	Kajutis-Matarai 2	27037,29	748,12	547500,98202	5984238,54770	no	yes	yes	yes	130,15	0,43795	0,16644	34,97675	25,69	147,98	7,13209	0,8400	0,31953
23	Kajutis-Matarai 3	33874,75	849,15	547391,03879	5983984,87560	no	yes	yes	yes	129,67	0,16380	0,06700	34,75969	50,20	138,84	8,23425	0,2744	0,19539

Table (continuation)
Lentelės tęsinys

No.	Name	Area	Perimeter	X coordinate of centroid	Y coordinate of centroid	Chronology				Elevation above sea level	Terrain ruggedness index	Ls factor	Direct solar radiation	Distance to lakes	Distance to rivers	Topographic wetness index	Altitude above channel network	Visibility index
						Palaeolithic	Mesolithic	Early-Middle Neolithic	Late Neolithic									
24	Kajutis-Matarai 4	36540,52	964,67	547681,03250	5983538,14333	no	yes	yes	yes	130,63	0,16319	0,15794	35,21074	295,15	75,46	7,83067	0,7836	0,24549
25	Kajutis-Matarai 5	26941,21	768,54	547367,58353	5984776,19287	no	yes	yes	yes	130,83	0,28244	0,22615	37,65306	61,97	275,36	7,68855	1,1576	0,35974
26	Kajutis-Matarai 6	15459,96	499,63	546802,54091	5983940,18233	no	yes	yes	no	129,76	0,17139	0,06694	34,04884	29,27	82,71	7,82497	0,3904	0,19194
27	Kajutis-Matarai 7	11295,7	408,72	547144,05330	5984107,25664	no	no	yes	yes	129,55	0,15158	0,05171	34,11321	23,46	207,29	7,92938	0,2238	0,19713
28	Kajutis-Matarai 8	9670,26	410,90	547227,01429	5983903,12857	no	yes	yes	yes	129,38	-0,04846	0,06038	34,37269	43,48	211,76	10,89389	0,0245	0,09228
29	Kajutis-Matarai 9	4873,06	290,99	547801,22290	5984162,67770	no	yes	yes	no	129,44	0,03893	0,03558	34,39256	34,65	115,28	9,92584	0,0749	0,07872
30	Kajutis-Matarai 10	20264,59	584,64	547981,06338	5983445,61335	no	yes	yes	yes	131,17	0,32799	0,17126	35,88947	195,25	69,44	7,29270	0,9287	0,27831
31	Karaviškės I	17381,05	641,77	544666,86247	5988336,67219	no	yes	yes	no	130,91	1,18102	0,65635	41,25127	43,48	224,74	6,91763	2,3900	0,43738
32	Karaviškės II	17893,69	611,46	544651,54514	5987889,01454	no	yes	yes	yes	128,74	0,40792	0,72806	26,35563	30,26	205,90	7,33667	0,8822	0,26175
33	Karaviškės III (Katros ištakos)	20440,12	601,04	545080,25927	5987235,39632	no	yes	yes	yes	130,03	0,26718	0,39583	36,71446	477,97	304,86	6,65742	0,9558	0,47010
34	Karaviškės IV	14382,59	495,11	545264,97255	5987169,72703	yes	no	yes	yes	129,75	0,28638	0,16755	35,94352	370,21	235,43	7,80334	0,6385	0,24067
35	Karaviškės V	47905,56	960,66	543933,72289	5987062,36037	no	yes	yes	no	130,80	0,27565	0,11522	35,86332	95,49	306,13	8,19549	0,9700	0,33276
36	Karaviškės 2	9021,07	417,02	543627,91106	5988666,16671	no	yes	yes	no	130,75	1,44873	0,54276	38,60865	356,43	73,12	6,18427	1,9513	0,27651
37	Karaviškės 3	9169,48	495,57	543387,26953	5988868,42856	no	yes	no	no	130,26	1,37970	0,40899	37,70058	136,96	40,19	5,92351	1,5762	0,24062
38	Karaviškės 4	19866,19	751,32	543659,82683	5988403,41688	no	yes	yes	yes	130,82	1,14073	0,28076	31,99494	268,63	95,80	6,64836	2,5003	0,20834
39	Karaviškės 5	17589,1	559,42	544166,34153	5987879,95728	no	yes	yes	yes	128,94	0,78720	0,39223	31,57084	38,72	131,82	6,65422	0,9870	0,05879
40	Katra 1	27542,52	721,80	539392,38316	5984844,52143	yes	yes	yes	yes	130,99	0,16114	0,11309	35,25488	1057,24	91,27	7,88534	0,3720	0,28635
41	Katra 2	56462,82	1052,56	539275,88824	5984569,21785	yes	yes	yes	yes	131,71	0,18638	0,09506	34,65081	1318,49	159,12	8,29983	0,9142	0,40826
42	Katra 3	7781,1	360,18	538867,12518	5983971,55372	no	yes	yes	yes	131,25	0,36204	0,14847	37,00677	1284,34	108,12	7,14853	0,7885	0,20589
43	Katra 4	6829,12	330,46	538594,62621	5984102,99855	no	yes	yes	yes	131,58	0,28438	0,04559	35,15340	986,41	240,73	7,92856	0,5182	0,19240
44	Katra 5	160389,9	2009,21	539804,00896	5985236,80410	no	yes	yes	yes	130,75	0,01457	0,15371	35,22213	529,77	174,67	8,91202	0,3314	0,37212
45	Katra 6	72230,77	1122,94	540090,80691	5985594,41797	no	no	yes	yes	130,91	0,16833	0,10760	34,98921	186,79	124,33	8,23163	0,4728	0,29743
46	Katra 7	18233,01	546,33	536212,12965	5982378,51336	yes	yes	yes	yes	129,69	0,27876	0,13076	34,96705	2682,87	148,87	7,05944	0,4079	0,06171
47	Katra 8	23177,46	727,81	536552,25687	5982617,94701	yes	no	yes	yes	129,87	0,09092	0,08670	35,37337	2325,28	134,90	7,97671	0,4365	0,03968
48	Katra 9	21999,21	618,84	536957,48991	5983120,51102	no	yes	yes	yes	130,52	0,23831	0,11040	35,62677	1691,73	84,88	7,94596	0,6453	0,05455

Table (continuation)
Lentelės tęsinys

No.	Name	Area	Perimeter	X coordinate of centroid	Y coordinate of centroid	Chronology				Elevation above sea level	Terrain ruggedness index	Ls factor	Direct solar radiation	Distance to lakes	Distance to rivers	Topographic wetness index	Altitude above channel network	Visibility index
						Palaeolithic	Mesolithic	Early-Middle Neolithic	Late Neolithic									
49	Krokšlis 1	108873,5	2064,26	541039,66268	5989612,22623	yes	no	no	yes	129,28	0,73953	0,65383	36,29010	59,26	164,31	7,30432	1,5293	0,19826
50	Krokšlis 2	23465,55	808,23	541110,67738	5990087,00766	yes	yes	no	no	130,35	1,18900	1,00073	42,24180	47,20	79,76	6,71211	1,5469	0,27607
51	Krokšlis 5	20791,37	674,71	542635,84513	5988945,36219	no	yes	yes	no	129,95	1,19030	0,25129	36,58283	78,39	117,16	7,32640	0,9435	0,10558
52	Margiai 1	28470,76	742,22	545505,99060	5989365,65363	yes	yes	yes	yes	130,96	0,50687	0,41529	39,14040	74,43	153,96	7,39764	1,2842	0,39108
53	Margiai 2 (Gribaša 4)	39354,15	1304,39	545951,14874	5989344,91448	no	yes	yes	yes	130,34	0,25098	1,11704	45,25119	42,20	92,34	6,69399	1,2963	0,53842
54	Margiai 3 (Margių sala)	37808,5	771,09	545304,42425	5988670,88012	yes	no	yes	yes	128,77	0,69816	0,52142	34,76348	30,88	201,71	7,19736	0,7782	0,51316
55	Margiai 4	23672,78	673,70	546493,32182	5989384,44103	no	yes	yes	no	130,07	0,86019	0,69378	37,78230	45,96	132,53	6,11170	1,0789	0,29954
56	Margiai 5 (Barzdžio miškas)	223549,5	3341,24	546357,06986	5988675,85552	yes	yes	yes	yes	130,77	0,30385	0,44291	34,67935	98,45	399,32	7,75031	0,7997	0,57501
57	Margiai 6	34824,29	802,79	544748,09099	5989307,45894	no	yes	yes	no	132,54	0,64866	0,19261	33,72895	493,92	346,64	7,41394	2,5745	0,54287
58	Margiai 7	53268,76	1267,05	544736,79550	5988616,65795	no	yes	yes	no	131,00	0,47798	0,29552	32,78304	281,76	300,44	7,17458	2,0371	0,52102
59	Paramėlis 1	92892,03	1464,03	540981,57502	5986150,96717	no	no	yes	yes	130,21	0,02519	0,02650	34,84565	42,65	151,89	9,72464	0,0777	0,16081
60	Paramėlis 2	181988,9	2311,27	541463,72700	5985815,47392	yes	yes	yes	yes	131,27	0,09661	0,19614	34,01469	136,46	356,34	8,16662	0,7296	0,56868
61	Paramėlis 3	42979,09	1096,40	542300,37167	5986309,01813	yes	yes	yes	yes	131,47	0,39609	0,45344	34,06362	66,99	129,96	6,93873	1,4653	0,63820
62	Paramėlis 4	35135,6	883,80	542744,77053	5986536,59749	no	no	yes	yes	130,64	0,34125	0,18668	33,66143	49,61	162,40	6,95455	0,8362	0,22378
63	Paramėlis 5	31897,46	722,39	543481,00765	5986568,75699	yes	no	yes	yes	131,41	0,42648	0,27320	31,95816	88,69	162,16	7,23176	1,9057	0,49889
64	Paramėlis 6	30811,82	784,07	543768,75457	5986617,05684	yes	yes	no	no	131,29	0,51902	0,34301	32,44979	75,29	129,28	6,43686	2,1209	0,57152
65	Paramėlis 7 (Krokšlis II)	87515,36	1396,74	541634,31306	5986374,74518	no	yes	yes	yes	130,57	0,15919	0,13374	34,55822	38,69	166,39	7,85280	0,4866	0,37869
66	Paramėlis 8 (Paramėlis, Krokšlis)	14902,43	493,01	541410,69511	5986948,45962	no	yes	yes	no	130,90	0,20238	0,14169	34,12122	84,41	443,20	7,49344	0,7604	0,27360
67	Paramėlis 9	220708,8	2430,87	542826,14978	5986939,93206	yes	yes	yes	yes	130,75	0,17160	0,11906	34,89709	110,65	156,54	8,08812	0,6560	0,31664
68	Stojai 1	18168,23	559,31	550661,19836	5986408,16082	yes	yes	yes	yes	131,73	0,32969	1,08186	28,55677	51,12	115,06	6,57206	2,8075	0,35459
69	Stojai 2	34947,69	816,79	550162,58252	5986104,06840	no	no	yes	yes	130,07	0,38011	0,20577	33,06653	78,82	255,50	7,37789	0,8605	0,20873
70	Stojai 3	16161,01	576,55	549409,75530	5985937,15706	no	yes	no	no	128,86	0,03505	0,10124	33,44786	44,75	210,17	9,20433	0,1488	0,07027

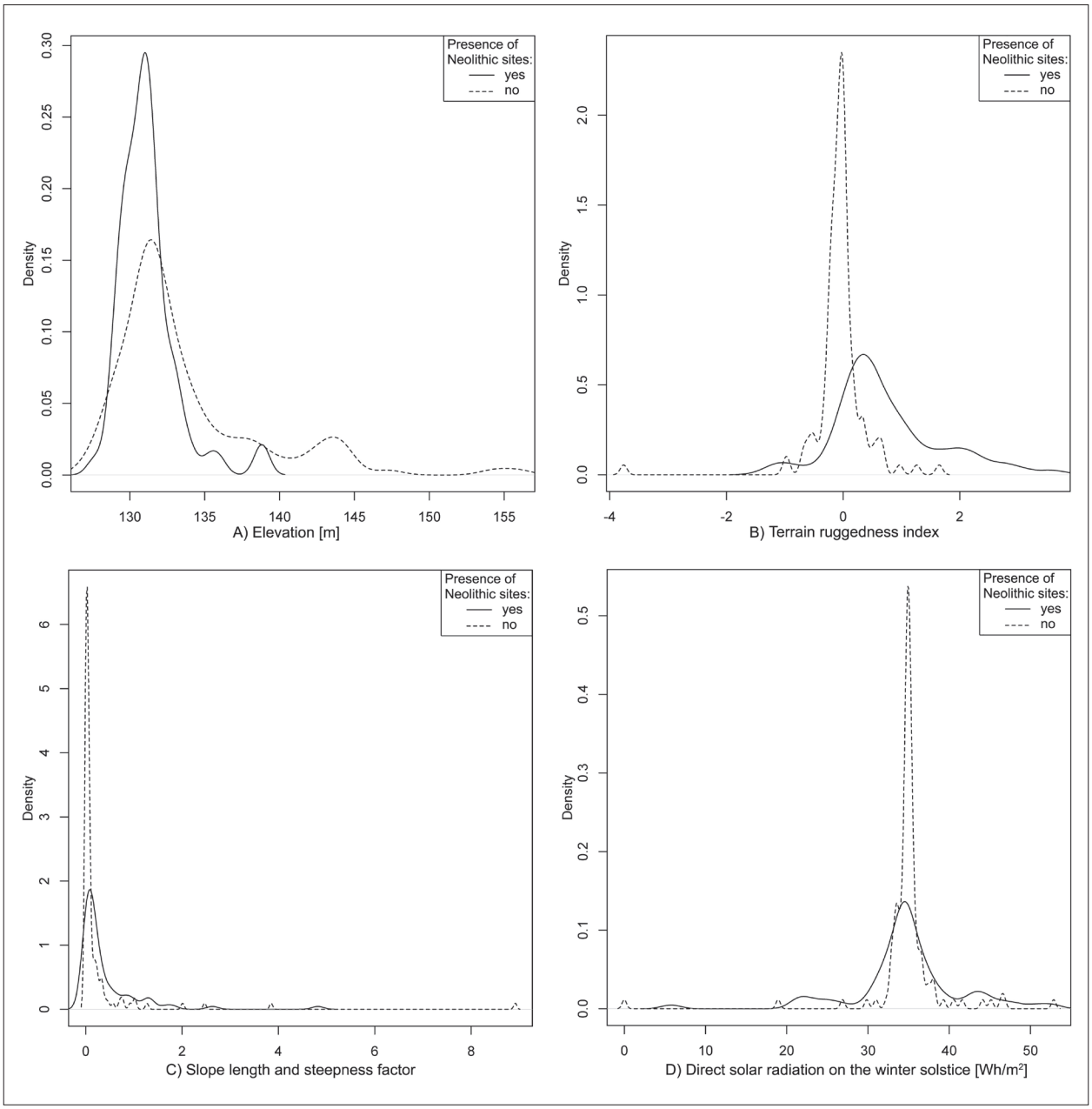

Fig. 3. Density histograms of the environmental variables at locations with a Neolithic settlement present/absent: a) the elevation above sea level; b) the terrain ruggedness index; c) the slope length and steepness factor; d) direct solar radiation. Composed by E. Marcinkevičiūtė.

3 pav. *Aplinkos veiksnių pasiskirstymo neolitinių gyvenviečių buvimo / nebuvimo vietose tankio histogramos: a) pagal skaitmeninį reljefo modelį; b) pagal reljefo raižytumo indeksą; c) pagal šlaitų statumo ir nuolydžio ilgumo faktorių; d) pagal tiesioginę saulės apšvietą. Sudarė E. Marcinkevičiūtė*

Based on the LiDAR data (©National Land Service under the Ministry of Agriculture of the Republic of Lithuania), a digital elevation model (DEM) with a 10 x 10 m cell size (spatial resolution) was created using the ArcGIS 10.3 software. Based on the DEM, other environmental variable raster layers were created and examined. In analyzing the average elevation above sea level of the area occupied by each Neolithic settlement, it was determined that the Neolithic settlements occur from 128.74 m to 137.48 m a.s.l. The average elevation of all of the settlements was 130.75 m a.s.l. No differences were discerned in separately ana-

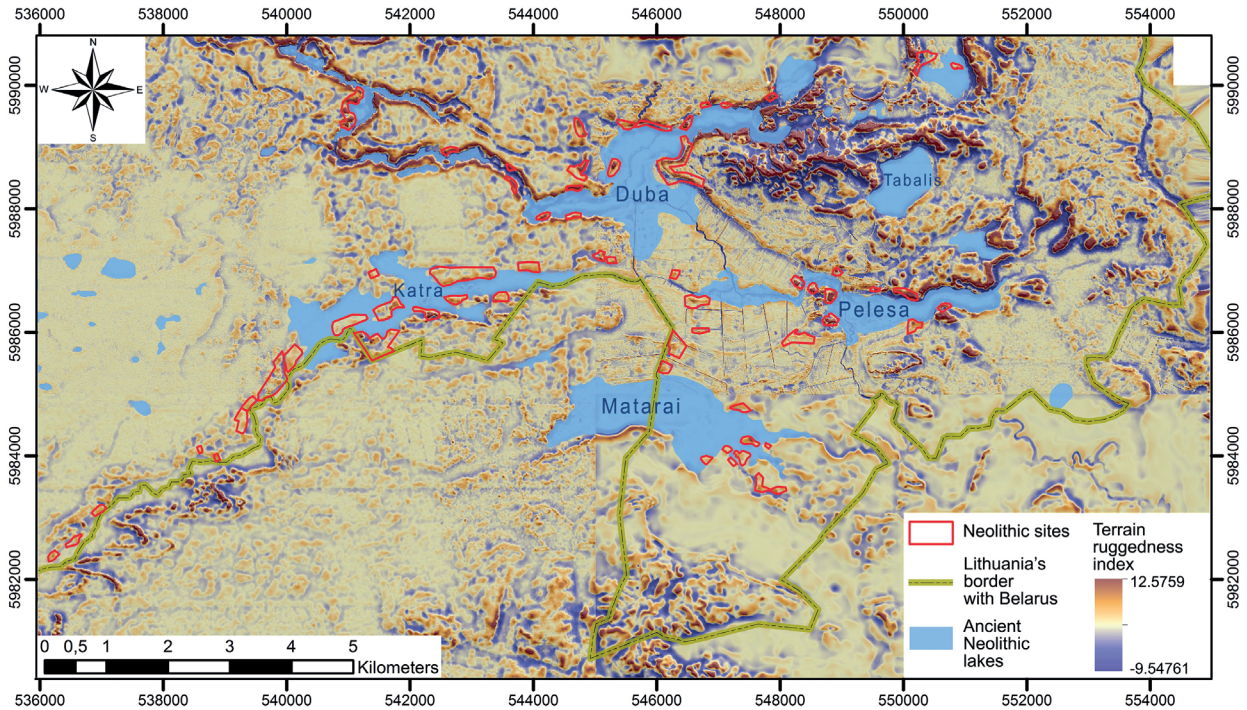

Fig. 4. Map of the terrain ruggedness index. Composed by E. Marcinkevičiūtė.

4 pav. *Reljefo raižytumo reikšmių žemėlapis. Sudarė E. Marcinkevičiūtė*

lyzing the Early–Middle and Late Neolithic settlements, but by using a density histogram to compare the DEM value distribution between the presence/absence of archaeological sites, it is seen that the settlements are all concentrated at ~130 m a.s.l. (Fig. 3A).

The terrain ruggedness index was calculated using ArcGIS focal neighbourhood statistics, an analysis of the changes in the height of all of the neighbouring cells in a radius of 100 m, and a raster calculator equation. The relief in Dubičiai microregion is fairly flat; therefore, values close to 0 predominate; only on the river banks and, in the north-eastern part of the analysed area, the ruggedness of the highlands was noted: from –9.54761 in hollows to +12.5759 at the highest places (Fig. 4). At the Neolithic settlement sites, the terrain ruggedness index ranges from –0.05 to +1.85 with an average of ~0.465. Based on the density histogram for the presence/absence of archaeological sites, the settlements were founded at locations with insignificant rises in elevation wherever the values predominating in the Dubičiai microregion approach 0 (Fig. 3B).

The slope length and steepness factor (Ls factor) is a measure of the sediment transport capacity of overland flow and describes the effect of topography on soil erosion. With increasing slope steepness and slope length, the transport capacity of surface runoff rises. The Ls factor was calculated using the TAS GIS 2.0.9 software. In the analyzed area, low values of under 0.5 predominate, only on the N slopes of the highest hill in the Dubičiai microregion were values of over 100 obtained (Fig. 5). At the Neolithic settlement sites, the Ls factor values are from 0.026 to 1.534 with an average of ~0.376. The density histogram of the Ls factor values for the presence/absence of archaeological sites and the terrain ruggedness index show that the settlements had been founded at somewhat elevated locations with little slope length or steepness (Fig. 3C).

The ArcGIS software was used to calculate the direct solar radiation on the winter solstice, the shortest day of the year when the least sunlight reaches the northern hemisphere. The greatest direct solar radiation value (up to 89.862 Wh/m^2) was recorded on the S slopes of the highest hill in the Dubičiai microregion, while the N slopes of this hill received no direct solar radiation (values close to 0 Wh/m^2) (Fig. 6). Theoretically, owing to the warmth provided by the greatest solar radiation even during the winter, the

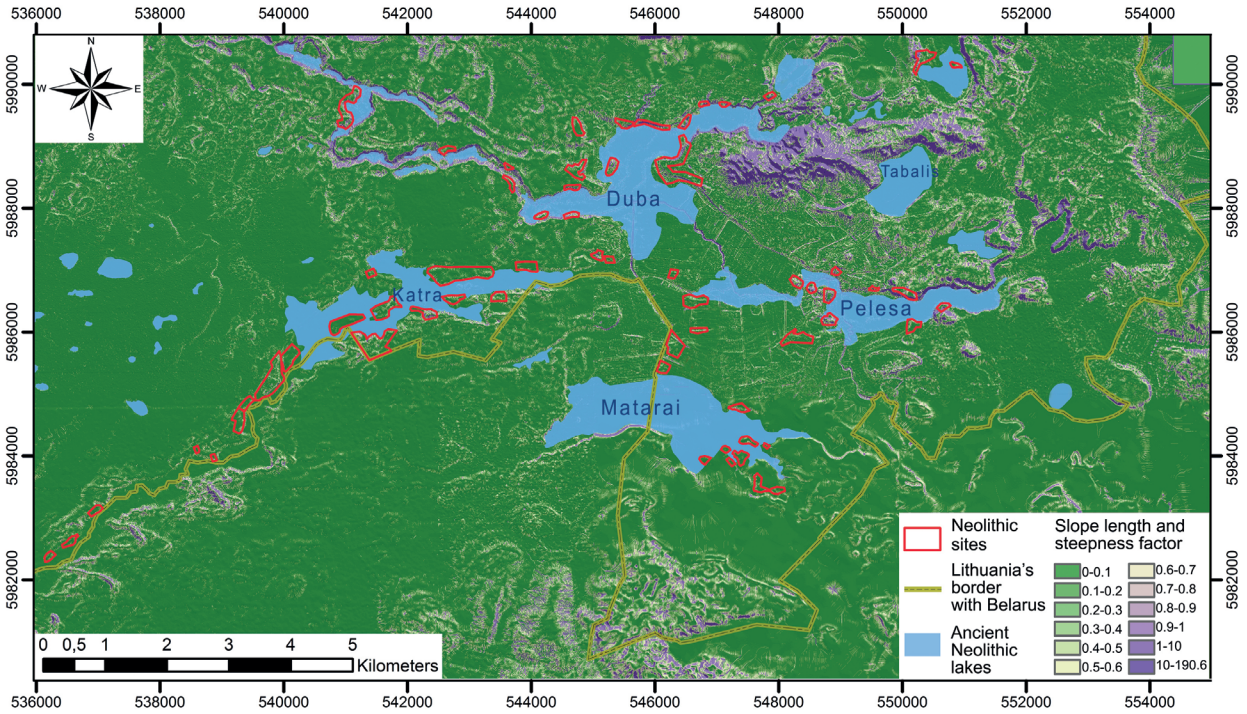

Fig. 5. Map of the slope length and steepness factor. Composed by E. Marcinkevičiūtė.

5 pav. *Šlaitų statumo ir nuolydžio ilgumo faktoriaus reikšmių žemėlapis. Sudarė E. Marcinkevičiūtė*

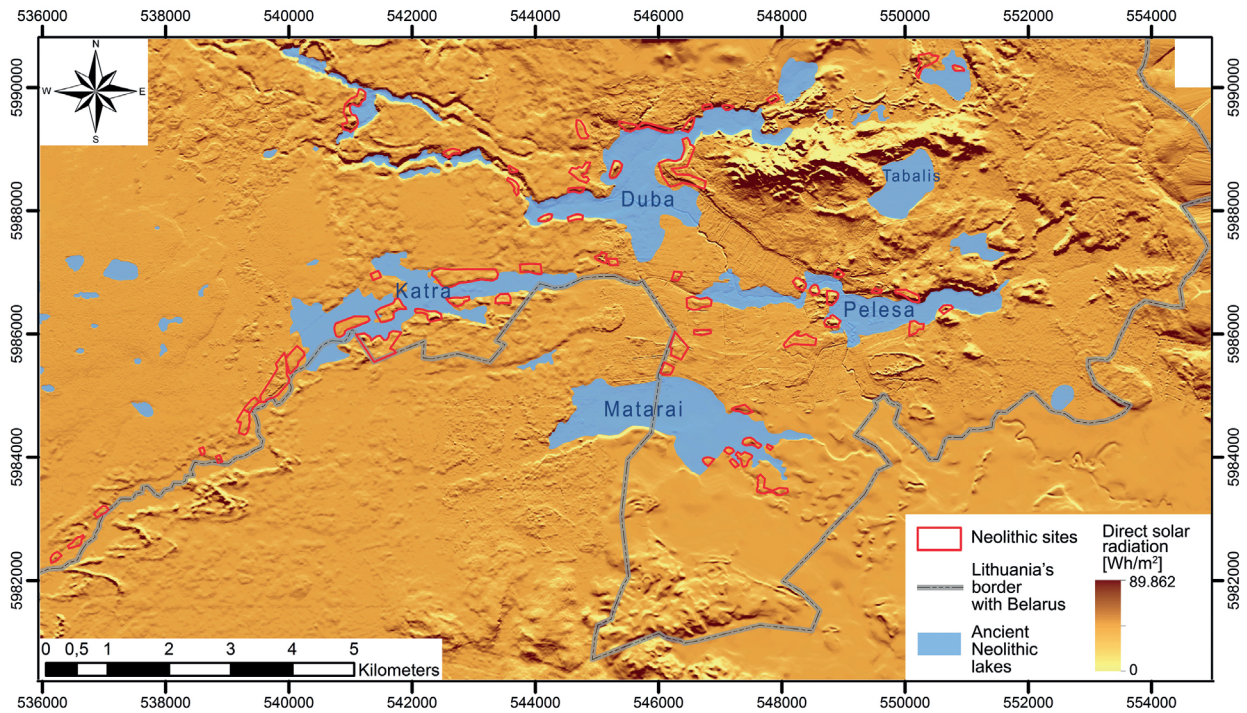

Fig. 6. Map of the direct solar radiation on the winter solstice. Composed by E. Marcinkevičiūtė.

6 pav. *Tiesioginės saulės apšvietos trumpiausią metų dieną žemėlapis. Sudarė E. Marcinkevičiūtė*

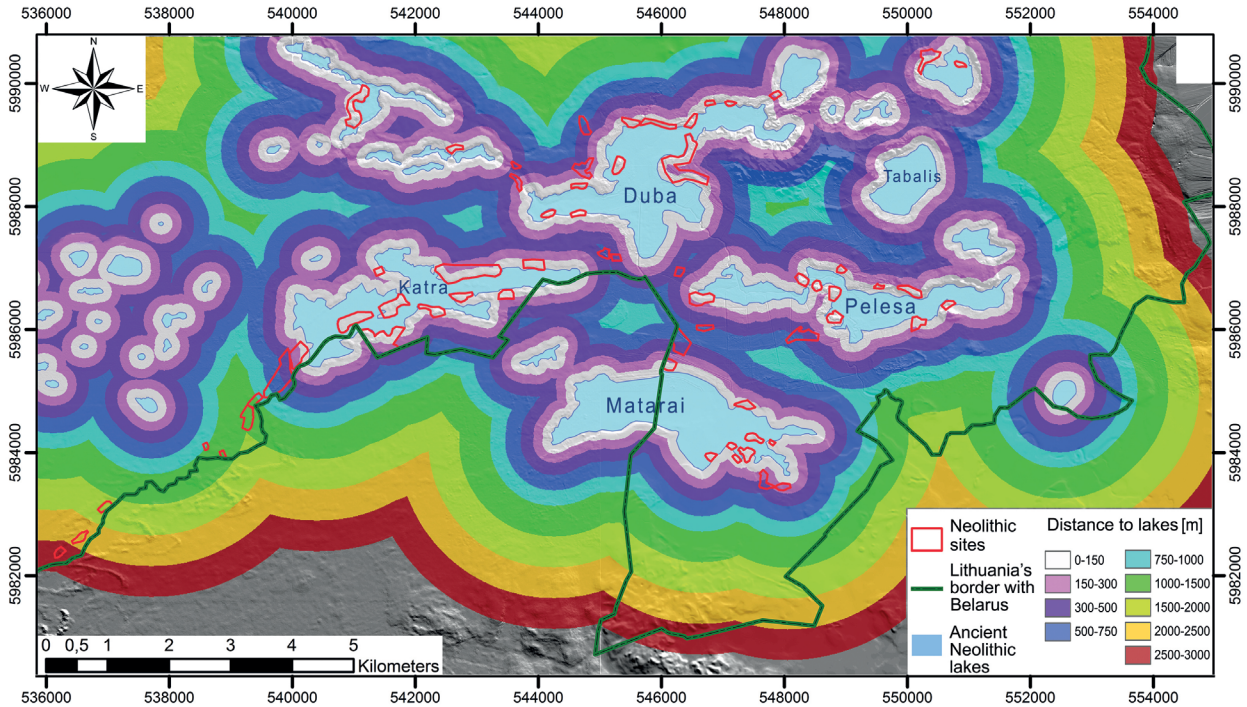

Fig. 7. Map of the distance to the reconstructed lake shores. Composed by E. Marcinkevičiūtė.
7 pav. *Atstumo iki rekonstruotų ežerų krantų žemėlapis. Sudarė E. Marcinkevičiūtė*

most favorable place to live should have been the S slopes of the highest hill, but the long distance from bodies of water and the windiness at this high location determined that this locality was not inhabited. At the Neolithic settlement sites, the direct solar radiation values ranged from 26.36 to 45.25 Wh/m^2 with an average of ~35.56 Wh/m^2. Based on the density histogram for the presence/absence of archaeological sites, no differences in the direct solar radiation were discernible (Fig. 3D).

In analyzing the distance from the Neolithic settlements to bodies of water based on the layers of the reconstructed lakes (Fig. 7) and rivers (Fig. 8), a distinct influence of bodies of water on the selection of a settlement site is discernible (Figs. 9A, B). Of the 63 Neolithic settlements, 42 were within 150 m from a lake shore, 15 were 150–500 m from it, and only six were over 500 m away, but all of them were within 150 m of the channel network.

The topographic wetness index and the altitude above the channel network (vertical distance to the channel network) were calculated using SAGA GIS 3.0.0 software. Both of these environmental variables reflect the local water level and the site's wetness. Theoretically, the most favorable locations for founding settlements are considered to be well drained sites that do not flood when the water level fluctuates. The topographic wetness index shows fairly even surface drainage and low soil wetness (Fig. 10), but based on the altitude above the channel network, the bulk of the Dubičiai microregion is within 1 m of the local channel network (Fig. 11). At the Neolithic settlement sites, the topographic wetness index ranged from 5.92 to 10.89 with an average of ~7.41, the altitude above the channel network from 0.02 to 5.74 m with an average of ~1.15 m. Based on the density histogram for the presence/absence of archaeological sites, it was noticed that although the majority of the settlements were close to water, drier sites, where the topographic wetness index was somewhat lower (Fig. 12A) and the elevation above the water level was somewhat higher, were selected for settlements (Fig. 12B).

The visibility index, calculated using Whitebox GAT 3.3 software, allows the visibility of the entire analyzed microregion's landscape to be determined, i.e., the grid cells in the visibility index raster contain visibility

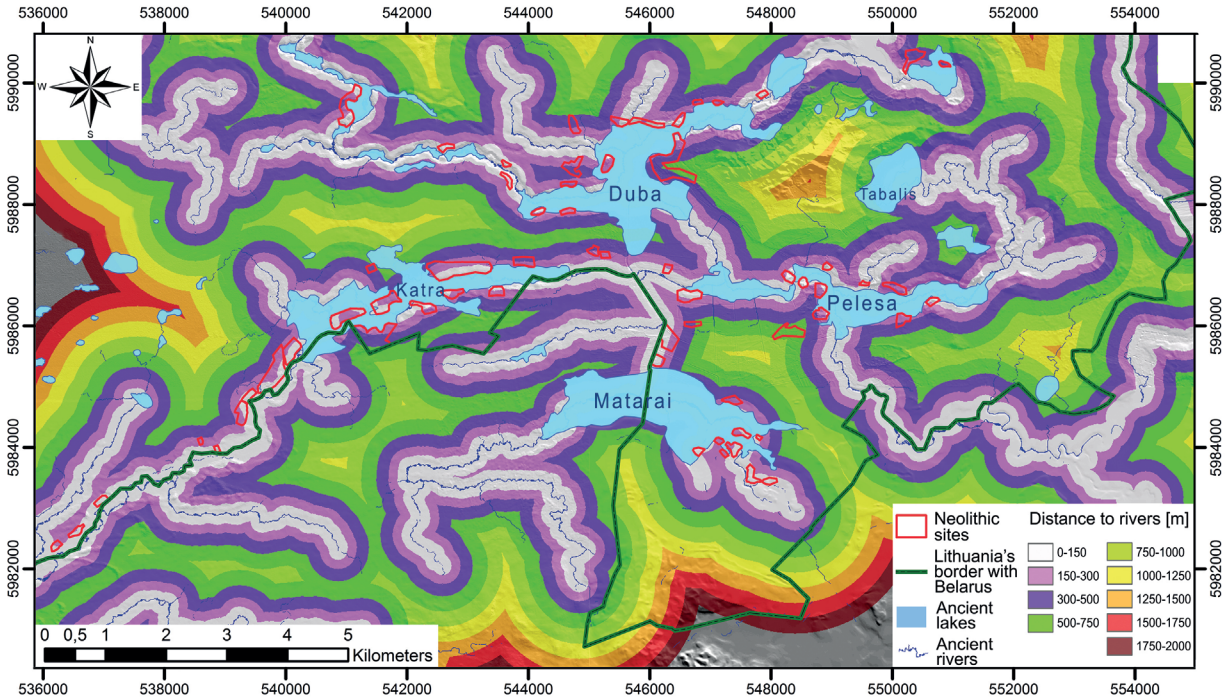

Fig. 8. Map of the distance to the reconstructed channel network. Composed by E. Marcinkevičiūtė.

8 pav. *Atstumo iki rekonstruoto upių tinklo žemėlapis. Sudarė E. Marcinkevičiūtė*

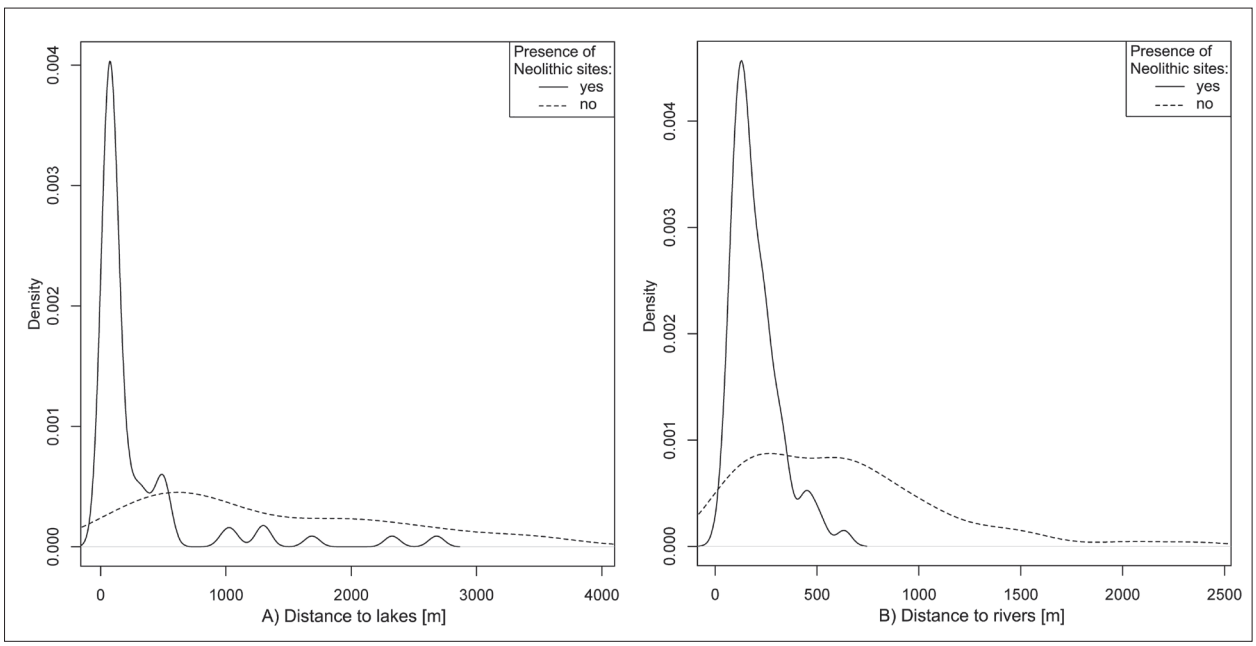

Fig. 9. Density histograms of the distance to lake shores (a) and the channel network (b) at locations with a Neolithic settlement present/absent. Composed by E. Marcinkevičiūtė.

9 pav. *Atstumo iki ežerų krantų (a) ir iki upių tinklo (b) tankio histogramos neolitinių gyvenviečių buvimo / nebuvimo vietose. Sudarė E. Marcinkevičiūtė*

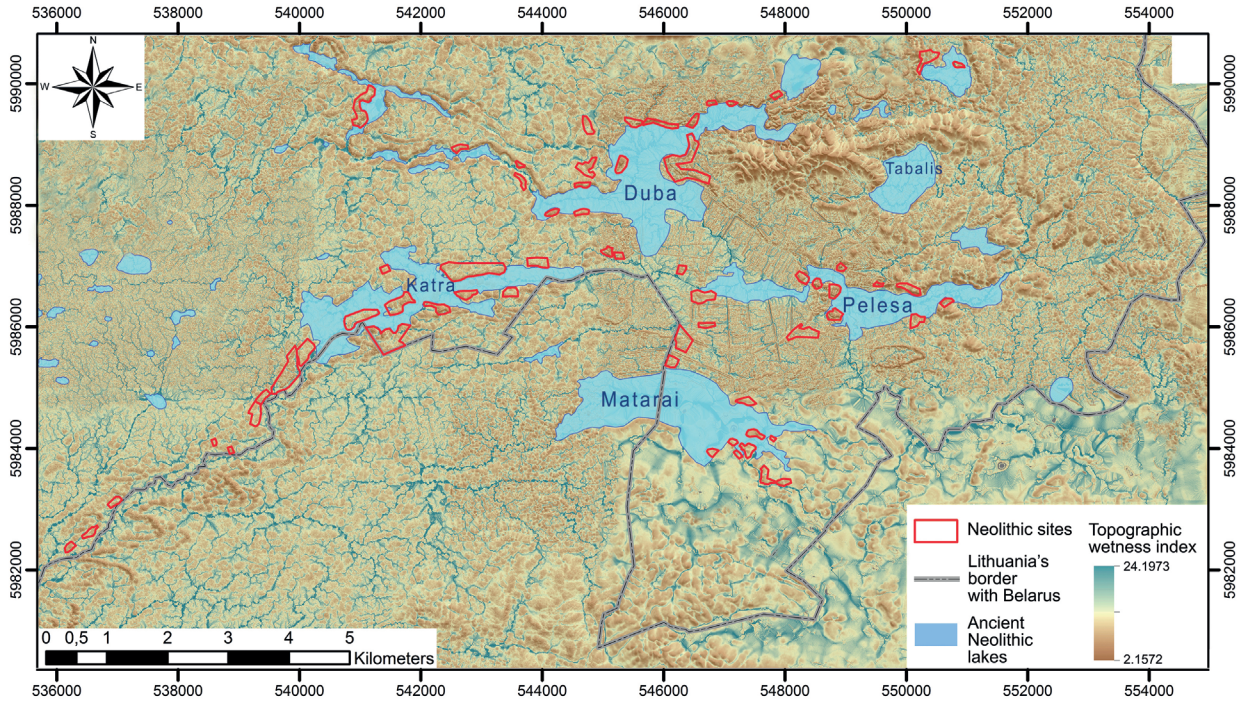

Fig. 10. Map of the topographic wetness index. Composed by E. Marcinkevičiūtė.

10 pav. *Topografinio drėgmės indekso reikšmių žemėlapis. Sudarė E. Marcinkevičiūtė*

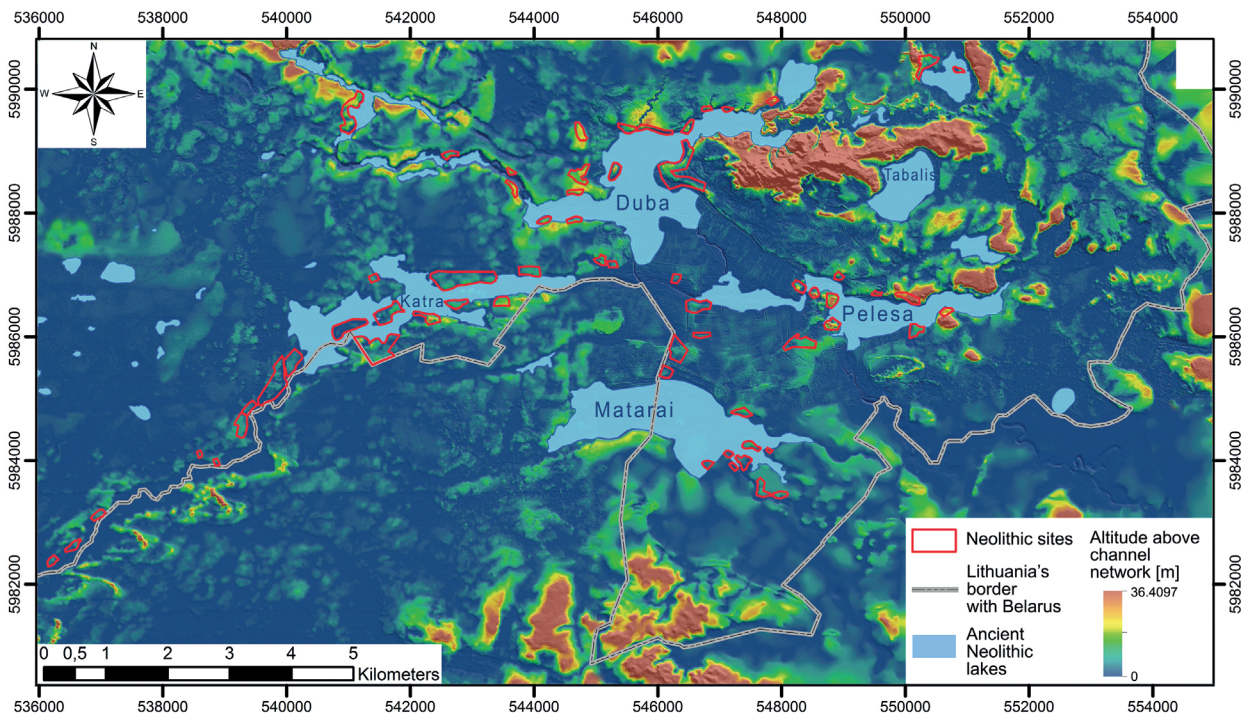

Fig. 11. Map of the altitude above the channel network. Composed by E. Marcinkevičiūtė.

11 pav. *Altitudės virš hidrografinio tinklo reikšmių žemėlapis. Sudarė E. Marcinkevičiūtė*

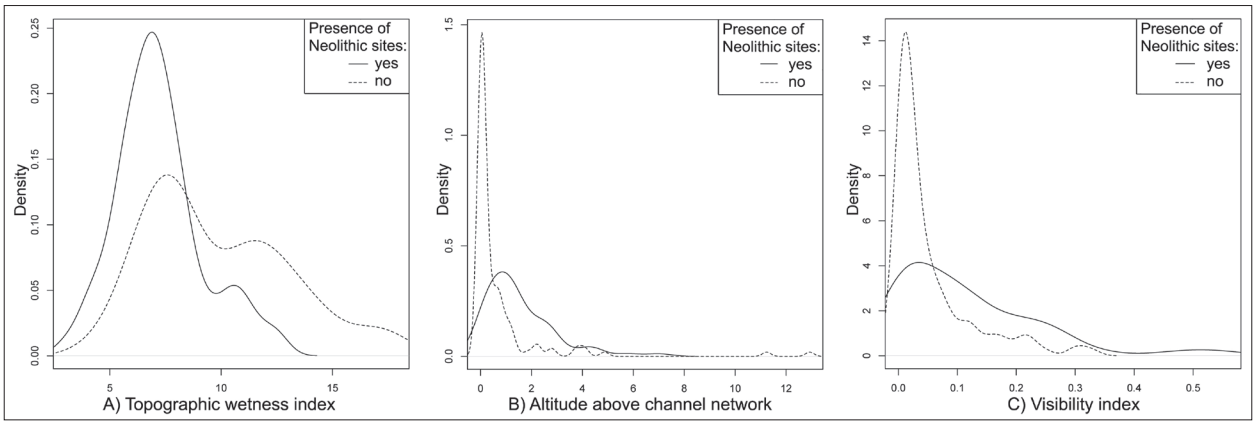

Fig. 12. Density histograms of the environmental variables at locations with a Neolithic settlement present/absent: a) the topographic wetness index; b) the altitude above the channel network; c) the visibility index. Composed by E. Marcinkevičiūtė.

12 pav. *Aplinkos veiksnių pasiskirstymo neolitinių gyvenviečių buvimo / nebuvimo vietose tankio histogramos: a) pagal topografinės drėgmės indeksą; b) pagal altitudę virš hidrografinio tinklo; c) pagal matomumo indeksą. Sudarė E. Marcinkevičiūtė*

values that express the proportion of the area visible from that site. In the Dubičiai microregion, more than half of the analyzed territory is visible from the region of the highest hill in the N part and from the highlands in the S, part of which are in Belarusian territory (Fig. 13A). At the Neolithic settlement sites, the visibility index values range from 0.014 to 0.664 with an average of ~0.312. Based on the density histogram for the presence/absence of archaeological sites, it was noted that the locations with better visibility were selected for settlements (Fig. 12C). In order to evaluate the intervisibility of the Neolithic settlements, a visibility analysis was performed and the area potentially visible in a 5 km radius from each settlement in the Dubičiai microregion was analyzed. It was determined that from each settlement, a minimum of one neighboring settlement site was visible, but where the settlement density was greater, over 30 neighboring settlements could have been visible, including, for example, 39 from Margiai 5 (Barzdis Forest) Settlement and 41 from Karaviškės IV Settlement (Fig. 13B). It is, however, important to mention that in analyzing the visibility, vegetation was not evaluated. Dense forests greatly reduce visibility, but during the Neolithic, it is likely that forestless areas already existed. Based on the palynological data, signs of a fairly intensive forest burning are already noticeable for the Mesolithic and especially the Neolithic (Stančikaitė *et al.*, 2002, p. 406).

An attempt was also made to analyze another important natural environmental variable, i.e., the Dubičiai microregion's topsoil, which should reflect the most fertile locations best suited for agriculture as well as light, well-drained soil best suited to settlements. Unfortunately, the topsoil vector layer of this microregion has been created only fragmentally and owing to the lack of data, a thorough analysis of the incidence of topsoil was impossible. The study area belongs to large Aeolian formations that formed on a limnoglacial sand base. Slightly podzolized, sod-podzolic soil predominates in the region, and, at the former lake sites, peaty deep topsoil from the valley bogs. Based on the palynological data, the first grain of *Cerealia* pollen was discovered in sediments deposited circa 6500 BP in Lake Pelesa and circa 5900 BP in Lake Duba (Stančikaitė *et al.*, 2002, p. 406). Nevertheless, the loamy sand that predominates on the surface was hardly favorable for the earliest practice of agriculture. It is more likely that first animal husbandry occurred in wet meadows and broad lake floodplains.

PREDICTIVE MODELLING

Predictive modelling is a complex of spatial–statistical methods used to determine the locations where the greatest possibility of discovering archaeological objects exists and to analyze the incidence of such loca-

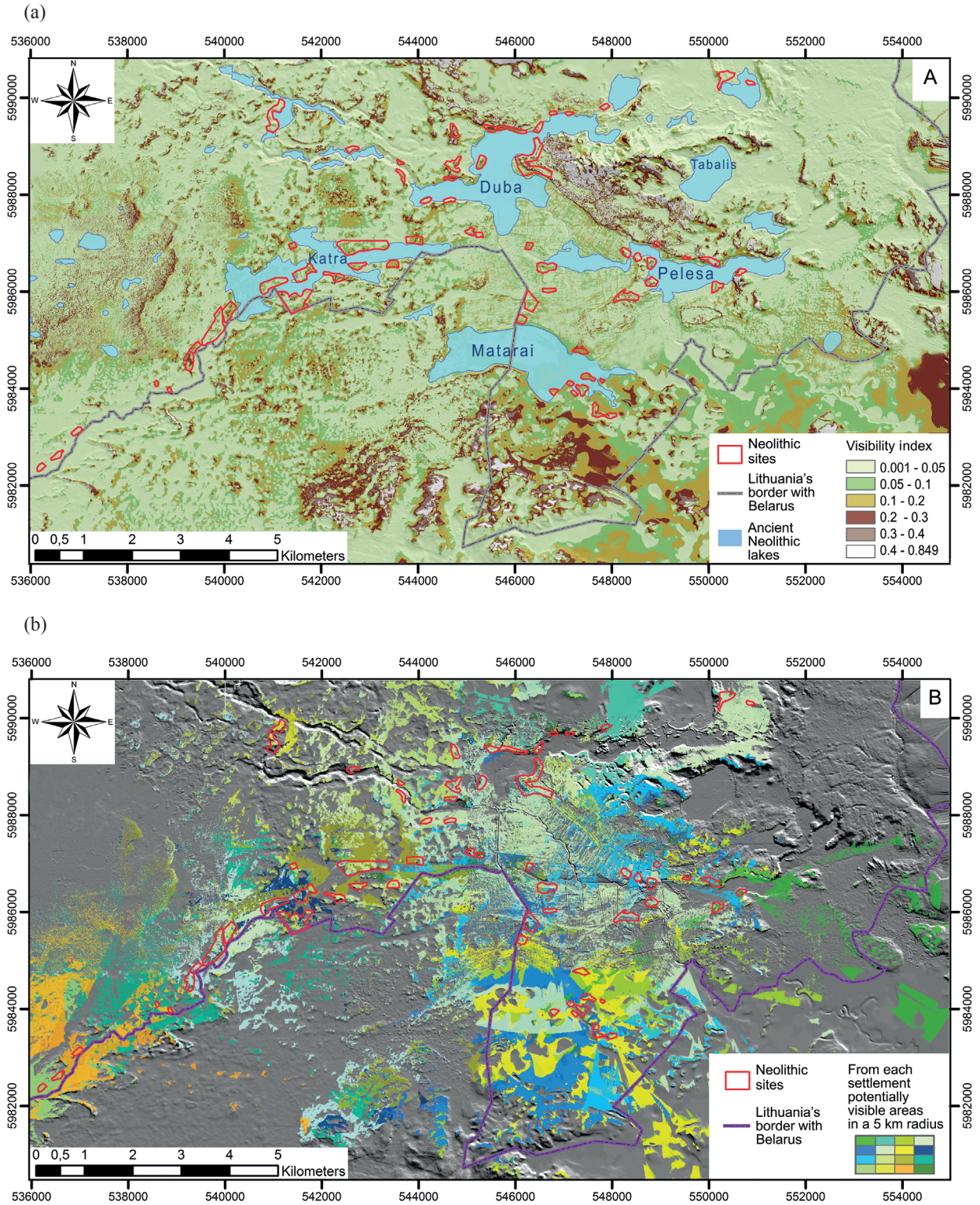

Fig. 13. A map of the visibility index values in the analyzed area (a) and a map of the visibility from each Neolithic settlement in a 5 km radius (b). Composed by E. Marcinkevičiūtė.

13 pav. *Matomumo indekso reikšmių analizuojamoje teritorijoje žemėlapis (a) ir matomumo iš kiekvienos neolitinės gyvenvietės 5 km spinduliu žemėlapis (b). Sudarė E. Marcinkevičiūtė*

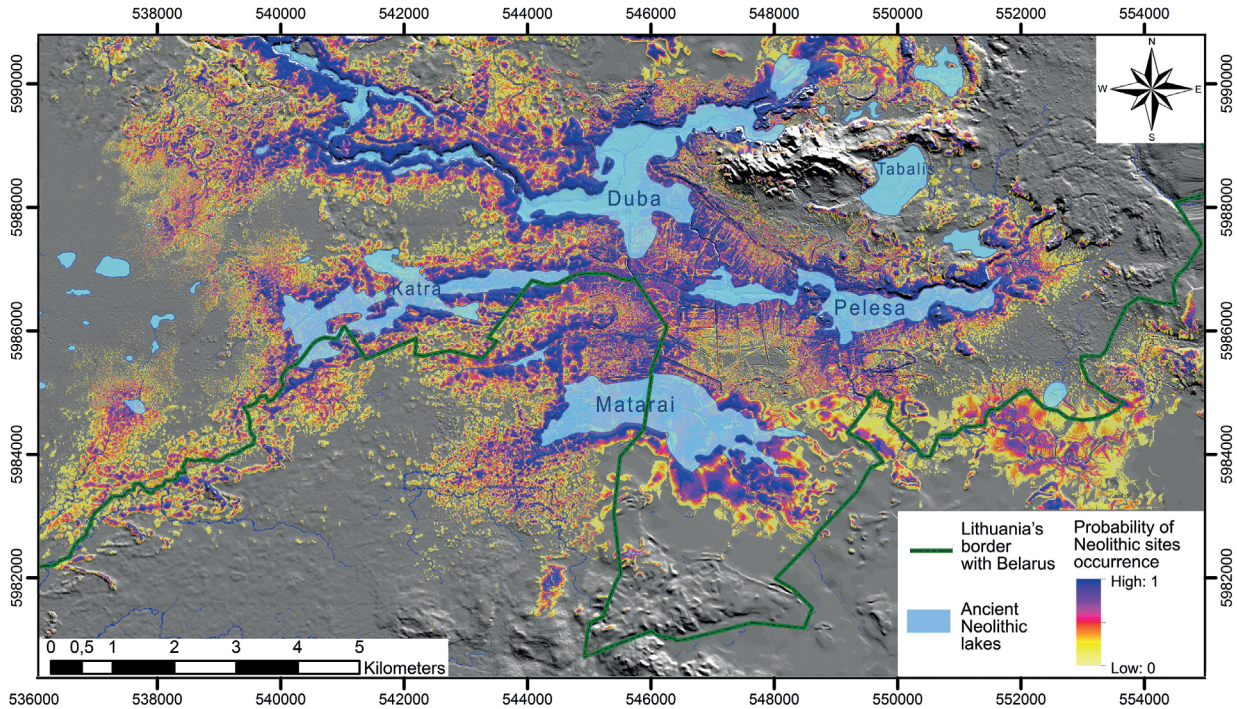

Fig. 14. A probability map for the occurrence of Neolithic settlements. Composed by E. Marcinkevičiūtė.
14 pav. *Neolitinių gyvenviečių egzistavimo tikimybės žemėlapis. Sudarė E. Marcinkevičiūtė*

tions in the natural environment. This is one of the GIS analyses that are very broadly employed, improved, and discussed in archaeology. Deductive or inductive approaches can be used. The former is based on theoretical assumptions about the location best suited for habitation, the archaeological site information being used only for testing purposes, while the latter compares known site data within a study area with datasets of environmental variables and then extrapolates the correlations to areas where no site information is available, usually by means of logistic regression. The logistic regression modelling method allows one to calculate the influence of each analyzed environmental variable in creating a predictive model, shows the probability for the presence/absence of archaeological sites, and allows one to check the model's reliability. The generalized additive model selected for the predictive modelling of the Dubičiai microregion is one of the logistic regression models, which can be fairly successfully used for the predictive modelling of archaeological sites (Łuczak, 2013; Marcinkevičiūtė, Šatavičius, 2013). This model is a non-parametric extension of the generalized linear model, a flexible and automated approach to identifying and describing non-linear relationships between variables and response terms. To create the model, the significance of each environmental variable is automatically calculated on the basis of the Akaike information criterion and the best suited variable combination selected, thereby improving the model's quality. Nine environmental variables were used for the modelling: elevation above sea level, the terrain ruggedness index, the slope length and steepness factor, direct solar radiation, the distances to lakes and rivers, the topographic wetness index, the altitude above the channel network, and the visibility index. In the beginning, a generalized additive model fitting 80% of the randomly selected data for the presence/absence of a site (training data) was created. It was determined that the six most significant variables were elevation above sea level, the distances to lakes and rivers, the terrain ruggedness index, the topographic wetness index, and the visibility index (p-value < 0.0001), while the altitude above the channel network was less significant (p-value < 0.05), and direct solar radiation and the slope length and steepness factor were not significant. Only significant variables

(first seven) were selected for the final model. The employed model was tested using the data from the remaining 20% of the sites (testing data). Its accuracy was determined using the area under the receiver operating characteristic curve (the area under ROC curve). The closer the value is to 1, the better the model's ability to predict the presence/absence of archaeological objects and the less random it is. The accuracy of the predictive model for Neolithic settlements in the Dubičiai microregion was very high as the area under ROC curve was 0.974. After the model fitting and testing procedure, a probability map for the occurrence of archaeological sites was generated (Fig. 14). Although seven environmental variables were employed in the predictive model, it is seen from the probability map that bodies of water had the greatest influence on the selection of habitation sites. Despite high probability prediction values, all predictive models have to be verified by a field survey and improved. Despite the reliability of the theoretical statistics, the results must be evaluated cautiously, because the variables selected for analysis reflect present-day or reconstructed natural conditions that could differ significantly from those that existed in the past.

CONCLUSIONS

Southeast Lithuania's Dubičiai microregion, which is distinguished by the abundance and diversity of its Stone Age settlements, especially Neolithic ones, was selected for the analysis. In ancient times, several large lakes, namely the Duba, Pelesa, and Matarai had existed in this region, but disappeared in the early 20th century.

Despite the abundant and multidisciplinary scientific information regarding this region, information that would help in understanding the settlement patterns and the factors that may have influenced the selection of sites in the past is still lacking. In order to understand the incidence of Neolithic settlements in the palaeolandscape, GIS applications, as well as geological and archaeological data, were used to reconstruct the ancient bodies of water.

The settlements in the Dubičiai microregion were systemized and the extent of the area they occupied and their chronology were checked. There are 70 Stone Age settlements, 63 of them Neolithic, in the research area. Various environmental variables were analyzed at each settlement site. Any attempt to distinguish environmental variables characteristic of only Final Palaeolithic–Mesolithic, Early–Middle Neolithic, or Late Neolithic settlements was groundless. Many of the Neolithic settlements also had early layers and it would appear that the variables affecting the selection of habitation sites remained the same from the earliest period right through to the Bronze Age.

A palaeolandscape analysis was performed in order to study the conditions that influenced the selection of Neolithic settlement sites. In using density histograms to analyze the environmental variables at those locations where there were Neolithic settlements and those where there were none, the influence of the distance from bodies of water, the elevation above sea level, the terrain ruggedness index, the topographic wetness index, the visibility index, and the altitude above the channel network was noticed.

The significant environmental predictors were used to create a generalized additive model to predict the probability of a Neolithic site existing at a specific location. Predictive modelling is an important and useful method not only in the search for new archaeological sites, but also in the analysis of the settlement patterns and the environment. The very accurate predictive model and probability map that were created and tested reflect the especially large influence that bodies of water had in the selection of Neolithic habitation sites.

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LITERATURE

Balakauskas L., Taminskas J., Mažeika J., Stančikaitė M. 2013. Lateglacial and early-Holocene palaeohydrological changes in the upper reaches of the Ūla River: An example from southeastern Lithuania. *The Holocene,* 23/1, p. 117–126.

Brazaitis D. 2000. Katros 2-oji gyvenvietė. *Archeologiniai tyrinėjimai Lietuvoje 1998 ir 1999*, p. 5–8.

Brazaitis D. 2005. Agrarinis neolitas. *Lietuvos istorija. Akmens amžius ir ankstyvasis metalų laikotarpis, 1*. Vilnius: Baltos lankos, p. 197–250.

Česnulevičius A., Švedas K. 2010. Palaeogeography and evolution of the Dubičiai glaciolacustrine basin in southern Lithuania. *Estonian Journal of Earth Sciences*, 59/2, p. 141–150.

Girininkas A. 2000. Katros 1-oji gyvenvietė. *Archeologiniai tyrinėjimai Lietuvoje 1998 ir 1999*, p. 12–14.

Grinevičiūtė G. 2002. Gribašos 4-oji akmens amžiaus gyvenvietė. *Archaeologia Lituana,* 3, p. 5–33.

Linkevičienė R. 2009. Impact of river capture on hydrography and water resources: case study of Ūla and Katra catchments, south Lithuania. *The Holocene,* 19/8, p. 1233–1240.

Luczak A. 2013. Using predictive modeling methods as a way of examining past settlement patterns: an example from southern Poland. *Colloquium. Non-destructive approaches to complex archaeological sites in Europe: a round up*, 15–17/1/2013, Ghent University, Belgium.

Marcinkevičiūtė E. 2010. Daugiasluoksnių archeologinių objektų erdvinė analizė. *Lietuvos archeologija,* 36, p. 87–102.

Marcinkevičiūtė E., Šatavičius E. 2013. Archeologinių vietų prognozinis modeliavimas taikant GIS. A. Merkevičius (sud.) *Metodai Lietuvos archeologijoje*. Mokslas ir technologijos praeičiai pažinti. Vilnius: Vilniaus universiteto leidykla, p. 551–584.

Piličiauskas G. 2012. The Karaviškės 6 Stone and Bronze Age Site. *Archaeological investigations in independent Lithuania. 1990–2010.* Vilnius: Lietuvos archeologijos draugija, p. 17–20.

Rimantienė R. 1999a. Barzdžio miško gyvenvietė. *Lietuvos archeologija*, 16, p. 171–208.

Rimantienė R. 1999b. Margių 1-oji gyvenvietė. *Lietuvos archeologija*, 16, p. 109–170.

Roberts, J. J., Best, B. D., Dunn, D. C., Treml, E. A., Halpin, P. N. 2010. Marine Geospatial Ecology Tools: An integrated framework for ecological geoprocessing with ArcGIS, Python, R, MATLAB, and C++. *Environmental Modelling & Software,* 25, p. 1197–1207.

Stančikaitė M., Guobytė R., Šeirienė V. 1999. Aerofotografinis bei paleobotaniniai tyrimo metodai ir galimybės juos taikyti archeologijoje. *Lietuvos archeologija*, 16, p. 67–78.

Stančikaitė M., Kabailienė M., Ostrauskas T., Guobytė R. 2002. Environment and man around Lakes Dūba and Pelesa, SE Lithuania, during the Late Glacial and Holocene. *Geological Quarterly*, 46/4, p. 391–409.

Szukiewicz W. 1901. Poszukiwania archeologiczne w pow. Lidzkim i Trockim (gub. Wileńska). *Światowit*, 3, p. 3–30.

Šatavičius E. 2005. Paramėlio 2-oji gyvenvietė. *Archeologiniai tyrinėjimai Lietuvoje 2003 metais*, p. 22–24.

Šatavičius E. 2006. Žvalgymai ir žvalgomieji tyrimai Rytų ir Pietų Lietuvoje. *Archeologiniai tyrinėjimai Lietuvoje 2004 metais*, p. 291–305.

Римантене Р. 1966. Стоянки раннего неолита в юго-восточной Литве. *Древности Белоруссии: материалы конференции по археологии и смежных территорий*. Минск, с. 54–62.

Шукевич В. 1893. Реферат В. К. Шукевича об археологических местностях в Лидском и Тракском уездах. *Труды Виленского отдела Московского предварительного комитета по устройству в Вильне IX Археологического съезда*. Вильнюс, с. 96–97.

NAUJAS POŽIŪRIS Į DUBIČIŲ MIKROREGIONO NEOLITINES GYVENVIETES TAIKANT GIS ERDVINĘ ANALIZĘ

Eglė Marcinkevičiūtė

Santrauka

Dubičių mikroregionas (Varėnos r. sav.) išsiskiria įvairių laikotarpių akmens amžiaus gyvenviečių gausa. Archeologiškai jis pradėtas tyrinėti XIX a. pabaigoje. XX a. antroje pusėje–XXI a. pradžioje intensyviai kasinėtos neolitinės gyvenvietės ir ieškota naujų objektų. Dubičių mikroregionas domina ne tik archeologus, bet ir geologus. Nemažai dėmesio geologų darbuose skirta Dubičių mikroregiono geomorfologiniams, paleogeografiniams, paleoekologiniams tyrimams, atlikti palinologiniai, diatomėjų tyrimai, rekonstruoti ežerų formavimosi procesai. Tačiau, nepaisant įvairių tyrimų, rekonstruoti paleokraštovaizdį ir suvokti gamtinės aplinkos sąlygas, kuriomis kūrėsi neolito laikotarpio gyventojai, nelengva. Siekiant nustatyti neolitinių gyvenviečių pasiskirstymą paleokraštovaizdyje, naudojant GIS kompiuterines programas ir geologinius bei archeologinius duomenis, rekonstruoti senieji vandens telkiniai. Ežerai

rekonstruoti apie 128±0,5 m aukštyje virš jūros lygio pagal skaitmeninį reljefo modelį, upių tinklas rekonstruotas pagal vandens tėkmės modelį (2 pav.).

Analizuojant Dubičių mikroregioną, akmens amžiaus gyvenvietės buvo susistemintos, patikslintos jų teritorijos ir chronologija. Tiriamoje teritorijoje yra žinoma 70 akmens amžiaus gyvenviečių, iš jų 63 neolitinės (1 pav., lentelė). Kiekvienos gyvenvietės teritorijoje analizuoti įvairūs gamtinės aplinkos veiksniai (2, 4–8, 10, 11, 13 pav.). Mėginimai išskirti aplinkos veiksnius, būdingus tik finalinio paleolito, mezolito, ankstyvojo–vidurinio arba vėlyvojo neolito gyvenvietėms, nepasiteisino. Daugumoje neolitinių gyvenviečių buvo ir ankstesnių laikotarpių sluoksnių. Panašu, kad gyvenamosios vietos pasirinkimą lemiantys veiksniai išliko tokie patys nuo ankstyviausiųjų laikų iki pat bronzos amžiaus pradžios.

Siekiant suvokti sąlygas, lėmusias neolitinių gyvenviečių vietos pasirinkimą, buvo tiriamas įvairių gamtinės aplinkos veiksnių pasiskirstymas teritorijose, kur yra ir kur nėra neolitinių gyvenviečių. Aplinkos veiksnių duomenis analizuojant pagal tankio histogramas, nustatyta, kad, renkantis gyvenamąją vietą, buvo svarbus atstumas nuo vandens telkinių, absoliutusis aukštis, reljefo raižytumo, topografinis drėgmės ir kraštovaizdžio matomumo indeksai, taip pat altitudė virš hidrografinio tinklo (3, 9, 12 pav.).

Atrinkti reikšmingiausi gamtinės aplinkos veiksniai buvo pritaikyti kuriant apibendrintą adityvųjį loginės regresijos modelį, skirtą prognozuoti vietas, palankiausias įkurti neolitines gyvenvietes. Prognozinis modeliavimas yra svarbus ne tik nustatant potencialias vietoves, kur reikėtų ieškoti naujų archeologinių objektų. Jis leidžia analizuoti bei vizualizuoti informaciją apie archeologinius objektus ir juos supančią gamtinę aplinką. Sukurtas ir testuotas Dubičių mikroregiono prognozės modelis bei archeologinių objektų aptikimo tikimybės žemėlapis (14 pav.) atspindi ypač didelę vandens telkinių įtaką renkantis gyvenamąją vietą neolito laikotarpiu.

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