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Archaeological GIS Modelling and Spatial Analysis in the Vicinity of Polgár from the Neolithic to Middle Ages

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Abstract: Review article of a PhD thesis submitted in 2022 to the Archeology Doctoral Programme, Doctoral School of History, Eötvös Loránd University, Budapest, under the supervision of Alexandra Anders and András Bödőcs.

The main aim of the PhD dissertation was to examine the archaeological settlement network, its structure, and changes from the Neolithic to the Middle Ages using a statistical and GIS-based approach. The study area is located on the left bank of the Tisza River.

Keywords: microregional settlement pattern, field survey, least cost path network, predictive modelling, land cover

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Aims of the dissertation

The main aim of the PhD dissertation was to examine the archaeological settlement network, its structure, and changes from the Neolithic to the Middle Ages using a statistical and GIS-based approach. The 359 km^2 study area is located on the left bank of the Tisza River between Tiszagyulaháza and Tiszacsege (Fig. 1). Due to previous large-scale archaeological projects (Upper Tisza Project,[1] archaeological works of the M3 motorway,[2] field surveys[3]), the study area is a well-researched region in Hungary. The general aims of the dissertation could be summarized as:

- Composing a time- and cost-effective field survey method aimed at delineating intra-site chronological data with an adequate spatial resolution for regional surveys.
- Detecting changes in shape and size of surface artefacts.
- Analysing land cover changes to delineate survey areas.
- Investigating research possibilities of an “optimal” land cover for creating environmental models for different chronological units.
- Creating archaeological predictive models in lowland areas to examine the effects of the spatial accuracy of different archaeological datasets and the “human factor”.
- Reconstructing and testing functioning least-cost path networks in lowland areas.
- Defining the main characteristics of settlement networks from the Neolithic to the Middle Ages in the study area.

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[1] Chapman et al. 2003.

[2] Hajdú – Nagy 1999.

[3] Füzesi 2007; Füzesi 2009.

Field survey methodology

The general aim of the dissertation was to compose a time and cost-effective regional field walking method which guarantees flexible fieldwork and a GIS-based implementation of the results and can delineate intra-site chronological data with adequate spatial resolution.[4] The basis of the related examination was a 100×100-metre virtual grid projected over the study area. The field survey was conducted in groups of four, walking parallel with each other along the north-south or east-west axis. The spatial position of each artefact (pottery, debris, chipped or polished stone) and visible feature was recorded by handheld GPS, and the finds were packed under individual IDs consisting of the identification numbers of the 100×100-metre units and the swath identification number (100×25 m basic survey unit). During the fieldwork between 2012 and 2015, almost 20 km^2 area was surveyed; the trips targeted both known sites to improve chronological and spatial accuracy and formerly unresearched areas to identify new sites.

Integrating handheld GPS devices into the research and the survey's documentation grid (fitting to the Hungarian projection system, EOV) guaranteed that the surveys could be repeated. Based on the experience gleaned from field practice and the post-processing of the data, it might or could be useful to refine the 100×100-metre virtual grid into a 50×50-metre one for a more precise collection of spatial data, especially on smaller sites. Over the past years, the grid-based survey method has also been integrated into Hungarian research in general and in development-led archaeology.[5]

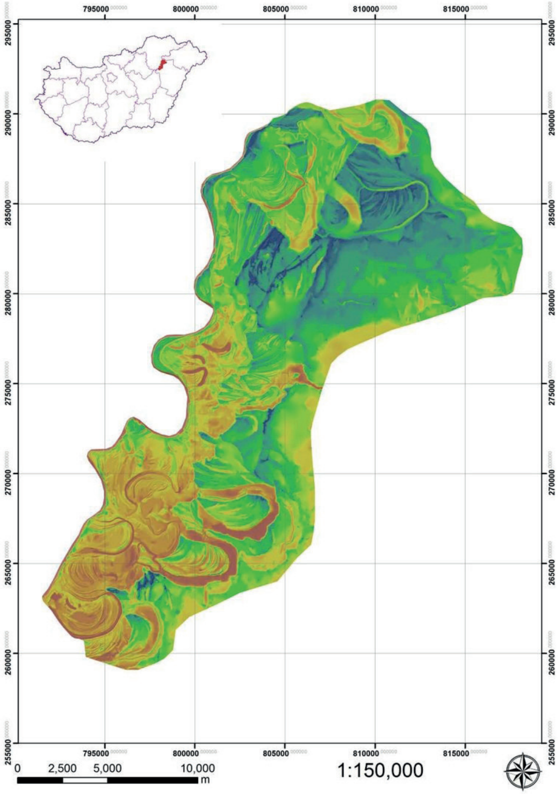

Fig. 1. Location and elevation model of the study area

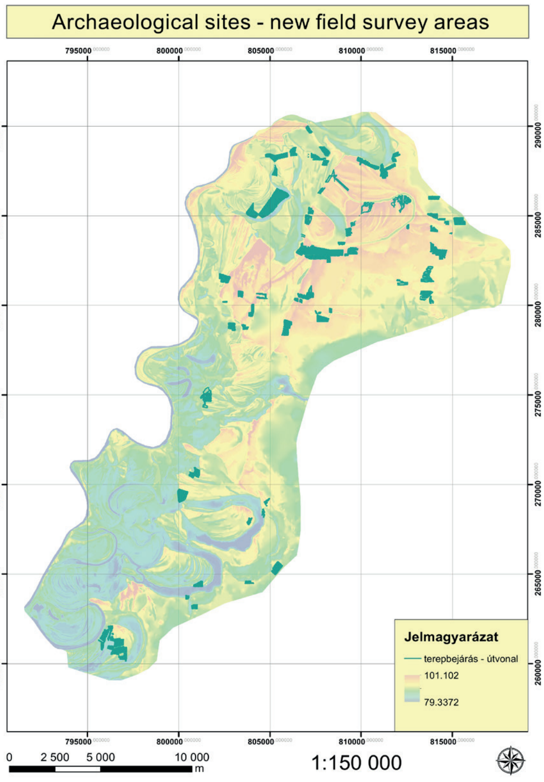

Fig. 2. Field surveys carried out in 2012–2015

Spatial distribution and chronological uncertainty of surface artefacts

The archaeological database comprises 193 previously known and 38 newly identified archaeological sites; 37% of the archaeological sites (231)

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[4] Mesterházy 2013.

[5] Czifra – Fábián 2016; Füzesi et al. 2015; Oross et al. 2020.

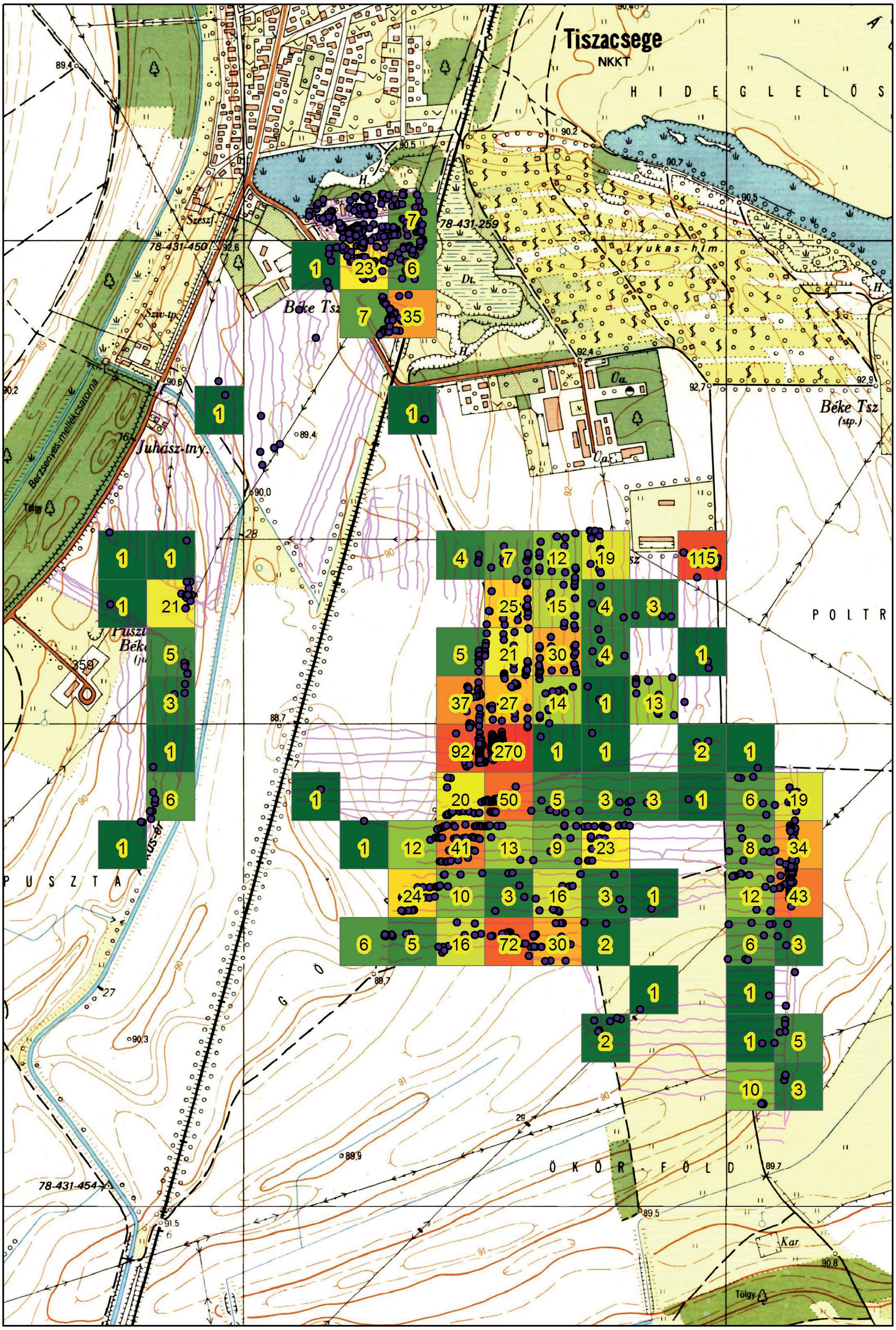

Fig. 3. Field survey results around Tiszacsege

Tab. 1. Distribution of archaeological sites in chronological and size categories based on field survey results

Chronological unit	0–0.5 ha	0.5–1 ha	1–2.5 ha	2.5–5 ha	5–10 ha	10+ ha	sum
PR	90	31	24	11	3	4	163
N	61	19	19	9	2	1	111
MN	28	12	14	7	4	0	65
LN	17	9	8	1	0	1	36
NCA	26	8	4	2	1	0	41
CA	5	8	1	0	0	0	14
ECA	0	6	3	0	0	0	9
MCA	0	2	0	0	0	0	2
LCA	3	12	1	1	1	0	18
CABA	16	2	3	0	1	0	22
BA	20	21	10	2	1	1	55
EBA	3	7	0	0	0	1	11
MBA	1	2	0	0	1	0	4
MLBA	2	0	0	0	0	0	2
LBA	9	10	6	0	1	1	27
LBAEIA	4	0	0	0	0	0	4
BAIA	16	6	4	1	0	0	27
IA	10	13	4	2	0	0	29
SC	8	2	1	2	0	0	13
LT	14	11	1	2	1	1	30
IAS	4	2	1	0	0	0	7
S	70	38	21	5	5	1	140
GMP	27	20	7	1	3	1	59
G	9	5	0	1	0	1	16
AV	14	12	2	2	0	0	30
EAV	1	0	0	0	0	0	1
LAV	1	0	1	0	0	1	3
MA	2	0	0	0	0	0	2
AA	17	22	8	3	2	3	55
EAA	2	9	1	0	0	0	12
MAA	5	7	3	1	0	0	16
LAA	3	7	4	3	0	0	17
LMA	32	13	5	3	0	0	53
sum	520	316	156	59	26	17	1094
sum %	47.53	28.88	14.26	5.39	2.38	1.55	100

were surveyed during the fieldwork (Fig. 2; Fig. 3; Tab. 1). Based on the analysis of 17,287 surface artefacts, two-third of the newly obtained chronological data on these sites proved the presence of previously not identified historical horizons, highlighting the significance of resurveying known archaeological sites. The applied field survey method was suitable for outlining and distinguishing vaguely overlapping sherd distributions of diverse chronological units intra-site. The disproportionateness in the intensity of scatters can be demonstrated by the fact that the spatial units with more than 50 artefacts (5% of all surveyed units) contained 73.4% of all finds recovered in the course of the surveys.

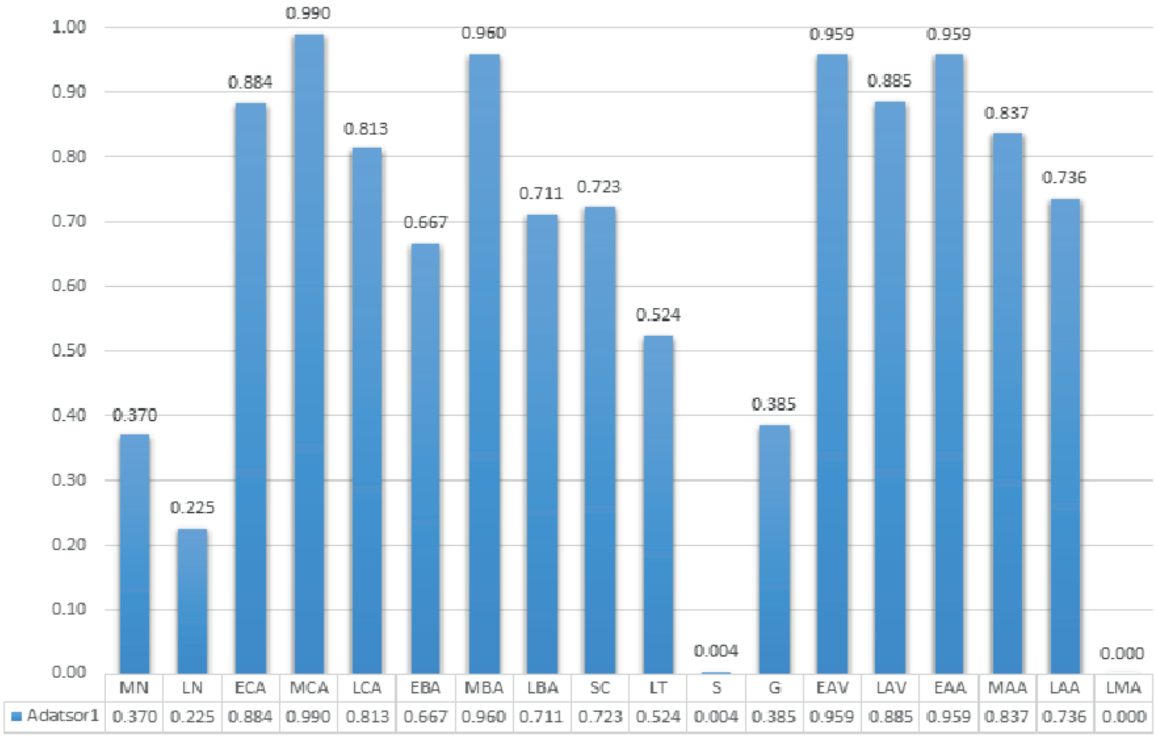

Fig. 4. Overall chronological uncertainty of surface artefacts

The chronological uncertainty analysis[6] of the surface artefacts aimed to define the "chronological value" of the sherds to estimate their identification value. The analysis of ages (2nd chronological level) and periods (3rd chronological level) showed that Neolithic and Sarmatian sherds have the lowest chronological uncertainty (high identification probability); in contrast, Early, Middle and Late Copper Age, Middle Bronze Age, and Avar Period finds have the highest uncertainty values (low identification probability). In general, Árpádian Age finds were easy to distinguish, while the sherd counts of the related finer chronological units were low (Fig. 4).

Size and shape of surface artefacts

The changes in the size and shape of surface artefacts were analysed on 6,600 sherds (Fig. 5). One-third of this sample was collected in 1992–1993 during the M3 motorway field campaigns,[7] while the rest between 2012 and 2015, during the field surveys of the current PhD dissertation. Photographs were taken about several finds at once; these were, in a next phase, georeferenced in a GIS system,

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[6] Crema et al. 2010; Bevan et al. 2012; Crema 2012; Crema 2015.

[7] Hajdú – Nagy 1999.

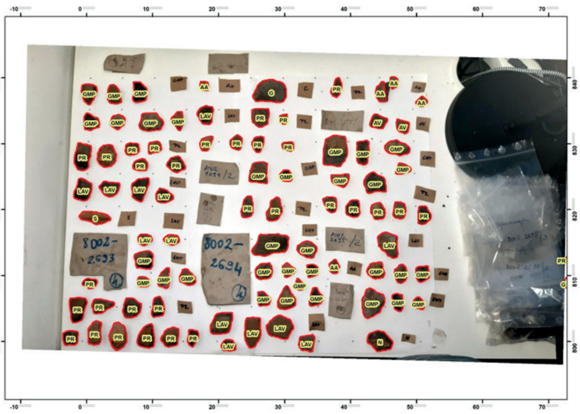

Fig. 5. Results of shape and size analysis in GIS

and the shape of the sherds was vectorized using a multi-step automatized process. Out of the nine tested shape properties, six proved to be statistically independent and became integrated in the size value analysis.[8]

Between 1992/1993 and 2012/2015, the average and maximum size of surface finds halved, which underlines the common knowledge about decaying field material. The minimal sherd size has also decreased, and the quantity of the smallest finds has significantly increased. In the examined roughly 20-year-long interval, shape variables (compactness, rectangularity, convexity, elongation, fractality) did not show significant changes, implying that the fragmentation process started earlier, mainly due to agricultural activity.

A more detailed analysis of the recent field survey results revealed significant changes in the extent and shape of polygons marking the perimeters of artefact distribution related to various chronological units and proved that a more accurate chronological definition, in general, requires a larger sherd size. Therefore, the fragmentation of the artefacts invariably decreases the chance of collecting accurate chronological data. Only 7% of the collected material can be connected to the finest (3rd) chronological level, most of which were Middle Neolithic and Late Avar finds. The shape analysis of all pre-defined chronological units (historical eras, periods, and archaeological cultures) from the Neolithic to the Late Middle Ages showed higher variability, although in a limited threshold zone. Slight differences could be identified that stem from the different technological characteristics of the pottery.

Effect of land cover in non-destructive archaeological research

The short-, middle- and long-term land cover changes influence the suitability and effectiveness of field survey methods. To get an idea about the extent of this issue, we carried out an analysis of changes in land cover in Hungary between 1990 and 2018 based on the CORINE Land Cover 1:100,000 scale databases.[9] The classification framework of the database was merged and simplified to suit non-destructive archaeological usage better. Altogether eight land cover types were defined (artificial areas, arable lands, lands under complex cultivation, forests and shrubs, pastures, waterbodies, and vineyards), and their distribution was calculated in every Hungarian microregion and county (Tab. 2). The results revealed that, within the timeframe of 28 years, 87.7% of Hungary's land cover remained unchanged. The area of arable lands, the primary targets of field surveys, decreased by roughly 2,540 km^2 between 1990 and 2018. Although this decrease is a general phenomenon in Hungary, Szabolcs-Szatmár-Bereg, Nógrád, Pest, Bács-Kiskun, and Csongrád counties are the most affected regions. The area of vineyards and lands under complex cultivation also became reduced minimally. The size of pastures remained almost unchanged, while the proportion of artificial areas (1,017 km^2) and forests (2,429 km^2) increased significantly. Land cover changes show quite different tendencies on a microregional level, while higher-scale alterations between 2006 and 2012 can be connected to Hungary's accession to the EU that promoted the expansion of pastures and forests through specific EU programmes. Conclusively,

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[8] Basaraner – Cetinkaya 2017.

[9] CORINE data.

Tab. 2. Land cover changes by counties between 1990 and 2018

county	area (km^2)	artificial surface			arable land			complex areas			forests			pastures			swamps			waterbodies			vineyards		
		1990	2018	varia.	1990	2018	varia.	1990	2018	varia.	1990	2018	varia.	1990	2018	varia.	1990	2018	varia.	1990	2018	varia.	1990	2018	varia.
Bács-Kiskun	8441	442	468	0.3	4187	3964	-2.64	467	351	-1.38	1462	1885	5.01	1097	1146	0.59	210	167	-0.52	92	96	0.05	483	364	-1.41
Baranya	4428	281	315	0.75	2415	2332	-1.86	151	165	0.31	1189	1295	2.39	213	203	-0.22	37	27	-0.24	44	47	0.09	99	45	-1.22
Békés	5629	301	331	0.53	4461	4402	-1.04	137	88	-0.86	178	236	1.04	464	494	0.53	19	12	-0.13	62	59	-0.07	6	7	0.01
Borsod-Abaúj-Zemplén	7243	550	689	1.92	2949	2712	-3.28	228	170	-0.81	2258	2441	2.53	965	965	-0.01	53	54	0.01	52	56	0.07	188	157	-0.43
Budapest	525	352	372	3.77	67	41	-4.94	12	9	-0.58	55	62	1.37	17	22	0.98	2	1	-0.17	15	15	-0.02	5	2	-0.41
Csongrád	4261	254	291	0.88	2712	2590	-2.86	348	308	-0.94	293	384	2.13	483	557	1.74	31	25	-0.15	74	74	0	66	31	-0.81
Fejér	4357	329	371	0.96	2848	2792	-1.28	118	118	-0.01	544	563	0.42	314	346	0.72	60	45	-0.36	64	68	0.08	79	56	-0.53
Győr-Moson-Sopron	4206	330	379	1.16	2525	2404	-2.88	54	75	0.51	804	890	2.04	288	262	-0.62	91	91	-0.01	56	57	0.03	58	48	-0.24
Hajdú-Bihar	6207	350	411	0.98	3610	3468	-2.29	158	97	-0.98	583	700	1.9	1275	1320	0.73	85	85	0.01	111	110	-0.03	35	16	-0.31
Heves	3636	280	330	1.37	1719	1567	-4.18	68	39	-0.78	952	1000	1.32	334	393	1.62	29	28	-0.02	67	71	0.1	188	209	0.58
Jász-Nagykun-Szolnok	5581	287	317	0.54	4085	4030	-0.99	94	70	-0.44	274	350	1.37	620	614	-0.1	55	55	-0.01	115	124	0.16	49	21	-0.52
Komárom - Esztergom	2264	231	243	0.49	1113	1062	-2.27	48	70	0.96	674	694	0.92	89	124	1.53	9	8	-0.02	46	45	-0.01	54	17	-1.61
Nógrád	2543	197	255	2.28	929	758	-6.73	80	40	-1.58	1085	1178	3.68	220	279	2.33	13	9	-0.17	3	5	0.08	15	18	0.12
Pest	6389	713	845	2.06	2984	2670	-4.92	270	224	-0.72	1649	1835	2.9	503	568	1.01	35	27	-0.13	85	113	0.44	150	108	-0.65
Somogy	6034	357	398	0.68	2732	2555	-2.93	253	229	-0.4	1858	2074	3.58	326	302	-0.4	114	95	-0.31	301	307	0.11	95	75	-0.32
Szabolcs-Szatmár-Bereg	5930	481	607	2.13	3334	2944	-6.58	263	140	-2.07	834	1300	7.85	687	542	-2.45	35	31	-0.06	76	72	-0.07	219	294	1.27
Tolna	3702	272	282	0.28	2311	2279	-0.88	96	103	0.18	698	753	1.49	140	134	-0.18	22	15	-0.19	61	62	0.02	101	74	-0.73
Vas	3335	241	270	0.87	1793	1763	-0.9	81	87	0.16	1022	1060	1.14	155	117	-1.13	7	3	-0.13	2	3	0.03	33	32	-0.04
Veszprém	4491	331	356	0.55	1596	1505	-2.03	59	65	0.12	1482	1567	1.89	545	549	0.07	41	34	-0.17	300	300	0	137	117	-0.43
Zala	3782	287	356	1.82	1335	1328	-0.19	197	172	-0.67	1361	1417	1.46	352	321	-0.82	87	61	-0.67	70	79	0.25	92	48	-1.17
Összesen	92985	6868	7885	1.09	49706	47166	-2.73	3185	2619	-0.61	19255	21684	2.61	9088	9256	0.18	1036	871	-0.18	1696	1764	0.07	2152	1740	-0.44

a continued decrease can be expected in land types that happen to be the primary areas of field surveys, further limiting fieldwork possibilities in the future.

Similar processes and tendencies can be identified in the study area. Based on the CORINE Land Cover 1:100,000 scale and the Hungarian 1:50,000 scale databases,[10] 20–23 km^2 of arable land was turned into forests and pastures between 2000 and 2018. A comparison of the two databases has revealed that only 82% of the land covers matched and remained unchanged.

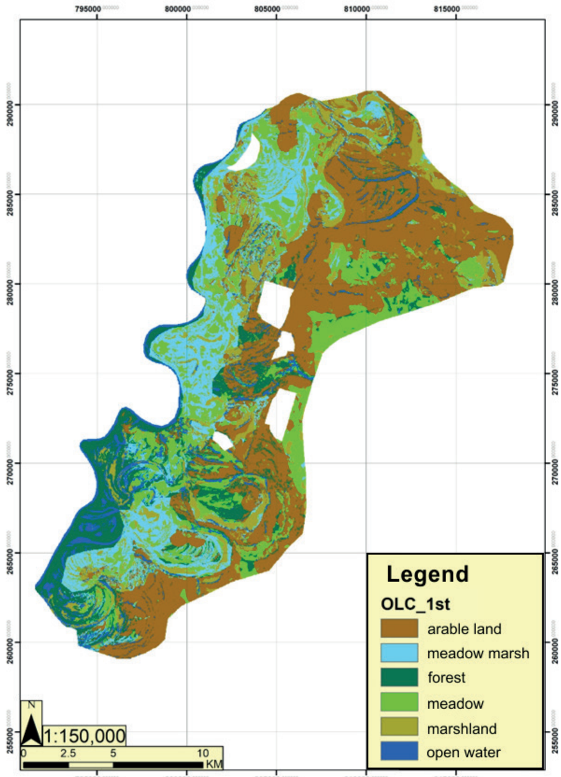

Fig. 6. Primary "optimal" land cover

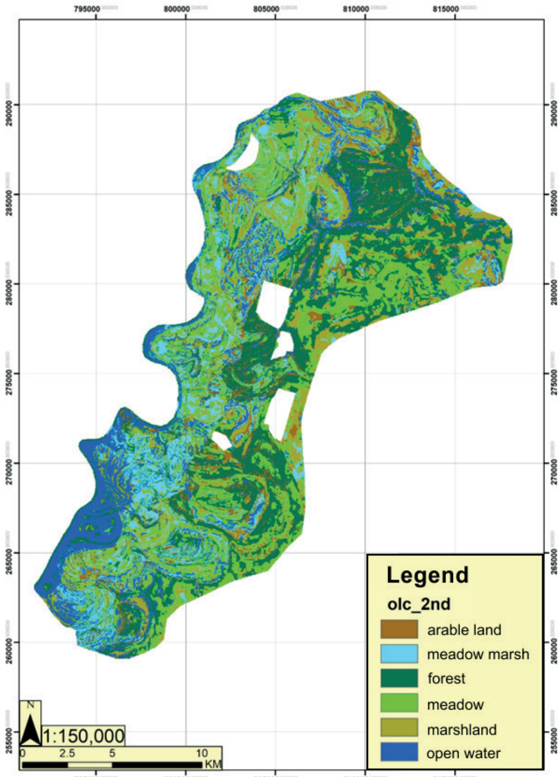

Fig. 7. Secondary "optimal" land cover

Analysis of "optimal" land cover

The maps of the Second Military Survey,[11] prepared at the time of early regulatory works of the Tisza River, have the required geodesical and thematic accuracy to gain additional land cover data about the study area. Diverse aspects of the mid-19th century land cover types, including landform, wetness index, pedology, geology, and distance from the main transport network, were digitized on separate layers and overlapped in a multi-scale spatial model. The research aimed to define the environmental characteristics of the different land cover types. During the analysis, the two-level weighting method of the applied analytic hierarchy process[12] enabled defining the probability values of diverse land cover types (arable lands, forests, shrubs, pastures, wet pastures, waterbodies, swamps) in a 25×25 m resolution throughout the whole study area. Land cover probability maps were overlapped, and primary, secondary, and tertiary „optimal" land cover maps were generated by selecting the first, second, and third highest probability values in every 25×25 m cell. It must be

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[10] CORINE data.

[11] Arcanum 2005.

[12] Saaty – Vargas 2006; Saaty – Vargas 2012.

emphasized that the modelling only examined the environmental properties of the land cover types, while the location of human settlements in archaeological periods, climatic conditions, and economic systems also affected land use preferences. The statistical and GIS analysis results are a first step in reconstructing the land cover types in an archaeological timeframe and estimating the probability of the reconstructions' reliability, which, evaluated jointly with coring and pollen results, might produce finer land cover models.

The primary "optimal" land cover map is dominated by arable lands, although smaller forests and pastures also appear on higher elevations. Gallery forests, wet pastures, and swamps alternate on the floodplains of the Tisza. Secondary and tertiary "optimal" land cover maps are significantly more mosaic and diverse (Fig. 6; Fig. 7; Fig. 8).

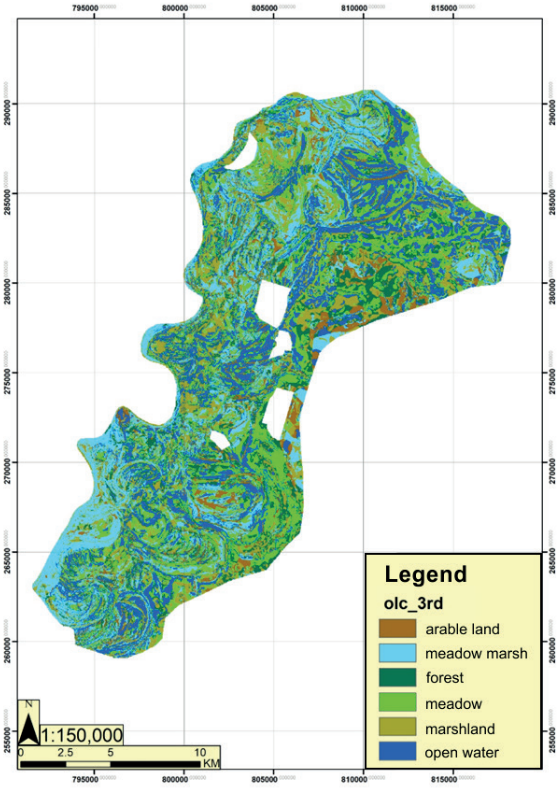

Fig. 8. Tertiary "optimal" land cover

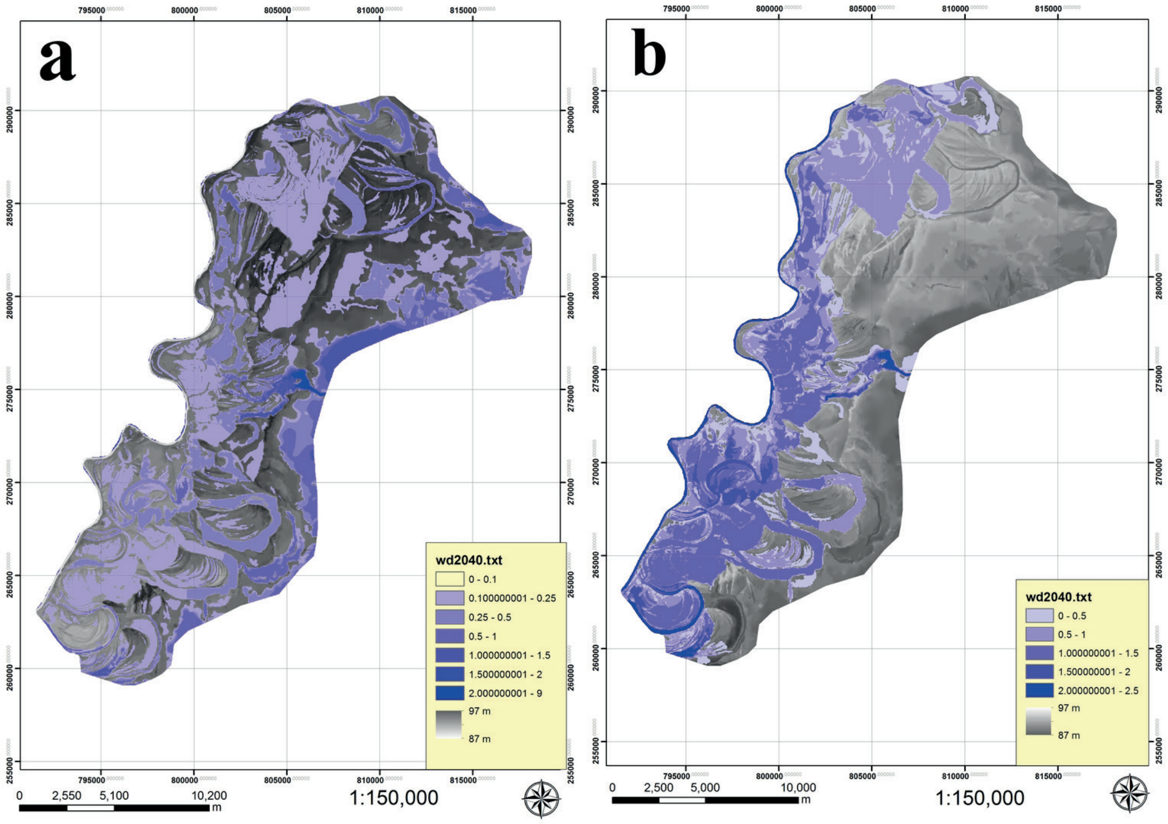

Fig. 9. Results of rainfall-runoff (a) and flood (b) modelling

Tab. 3. Statistical values of the least-cost path networks by chronological categories

wet	Neolithic	Copper Age	Bronze Age	Iron Age	Sarmatian Period	Avar Period	Árpádian Age	Late Middle Ages	Sum
site count	122	48	63	35	116	21	44	27	188
average degree - PL	4.15	3.75	3.87	3.6	4.03	3.43	4.05	3.56	4.21
maximum degree - PL	8	7	7	6	8	6	8	6	8
average BC (norm.) - PL	0.23	0.26	0.22	0.28	0.22	0.33	0.23	0.23	0.18
average CC - PL	1,328	1,058	1,197	1,365	1,217	1,107	1,266	1,308	1,240
maximum CC - PL	2,271	1,924	2,535	2,221	2,054	2,138	2,413	2,437	2,095
average degree - CO	9.26	7.08	8.51	7.89	8.28	7.81	9	8.15	9.77
maxumim degree - CO	25	14	20	14	19	16	17	16	30
average BC (norm.) - CO	0.13	0.2	0.14	0.16	0.16	0.16	0.11	0.11	0.13
average CC - CO	1,100	1,018	974	1,030	1,101	837	1,109	1,197	1,154
maximum CC - CO	2,001	1,851	1,841	1,565	1,878	1,382	2,070	2,070	1,979
average EC - CO	2,579	2,401	2,342	1,936	2,516	1,677	2,497	2,514	2,623

dry	Neolithic	Copper Age	Bronze Age	Iron Age	Sarmatian Period	Avar Period	Árpádian Age	Late Middle Ages	Sum
site count	122	48	63	35	116	21	44	27	188
average degree - PL	4.61	4.17	4.51	4.11	4.66	3.81	4.23	4	4.94
maximum degree - PL	8	7	8	8	10	7	9	6	9
average BC (norm.) - PL	0.3	0.36	0.29	0.27	0.26	0.36	0.36	0.24	0.2
average CC - PL	646	598	618	594	660	445	637	718	689
maximum CC - PL	1,045	1,013	1,163	885	1,055	737	1,176	1,093	1,036
average degree - CO	10.38	7.83	10.79	9.94	11.76	9.9	12.32	9.26	14.77
maxumim degree - CO	23	16	21	18	28	16	21	16	34
average BC (norm.) - CO	0.21	0.27	0.21	0.26	0.19	0.22	0.23	0.24	0.14
average CC - CO	614	586	585	577	633	415	604	685	658
maximum CC - CO	1,009	999	1,113	863	1,010	700	1,136	1,069	990
average EC - CO	1,396	1,359	1,397	1,163	1,398	890	1,399	1,436	1,440

Least-cost-path networks

Regional-scale settlement pattern research primarily focuses on the locations of human occupation areas (archaeological sites); meanwhile, the routes between settlements are often neglected. In the archaeological context, identifying route networks is a complex problem. From a GIS perspective, the current algorithms and equations are highly connected to relief and relief changes.[13] The integration of least-cost-path network modelling in a lowland area could be done based on flood and rainfall-runoff modelling[14] to delineate temporary and permanent flooded areas (Fig. 9). Important result of the modelling process was an archaeologically independent general route network of the study area, created by connecting the points of a standard 1×1 km grid (all-pair method) in wet and dry environmental conditions and selecting the most frequently used 10% of the network.

[13] Gietl et al. 2008; Herzog – Posluschny 2011; Herzog 2014.

[14] Coulthard et al. 2013.

The distance between this all-time “main transport network” and known archaeological sites showed a high correlation; 95% of the sites were within a 400-metre distance from the routes (Fig. 10). Least-cost-path network modelling was carried out for all distinguished archaeological periods in dry and wet conditions, then the importance of routes was analysed by six, while of settlements, by seven parameters (Tab. 3).

The parameter values of each archaeological period (Fig. 11; Fig. 12), partially in accordance with the count differences of archaeological sites, show a cyclical trend in the chronological framework’s structure, symmetry, and route length between sites. In summary, the integration of a combined flood and rainfall-runoff model successfully replaced the relief-based algorithms.

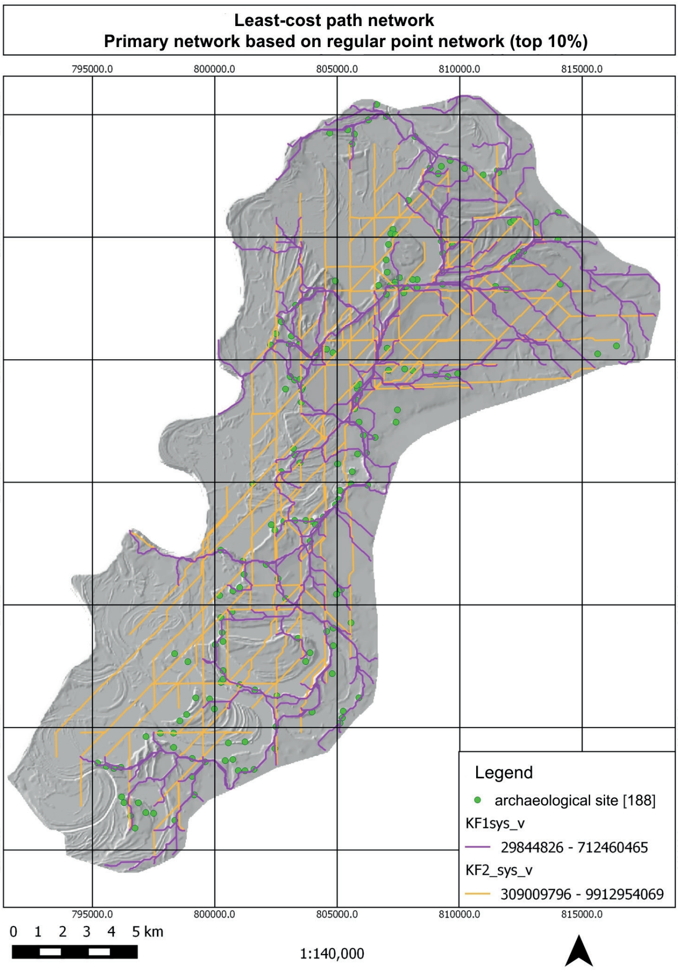

Fig. 10. Main transportation network in dry and wet environments

Archaeological predictive modelling

Further archaeological occupation zones and location choices of known settlements were analysed using archaeological predictive modelling.[15] To adopt the weights of evidence[16] method to lowland environment, 18 evidential themes were tested. With the selected five independent ones (aspect, landform classification, geology, pedology, wetness index, nine models were created (eight chronological ones from the Neolithic to the Late Middle Ages and a cultural resource management one, CRM) in four different model versions, resulting in 36 models altogether. The applied methodology and workflow for the four model versions were unified; only the used data distinguished them from each other. Two of those versions tested the spatial and chronological accuracy of the archaeological site data by either using the archaeological database of the Hungarian National Site Registry with integrated literature or the field survey results with higher chronological and spatial properties. In both cases, the other two model versions integrated the distance from the “main transport network” layer as a sixth evidential theme, testing the effect of the “human factor” in predictive modelling.

Based on the comparison of the periodical models and the CRM versions, it can be stated that by using field survey data with higher spatial accuracy and integrating the distance from main route network, the quality and efficiency of predictive models could be improved (Fig. 13; Fig. 14). As a result, the proportion of medium and high probability zones decreased (compared to the model

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[15] Kohler – Parker 1986; Deeben et al. 2002; Verhagen 2007.

[16] Sawatzky et al. 2009.

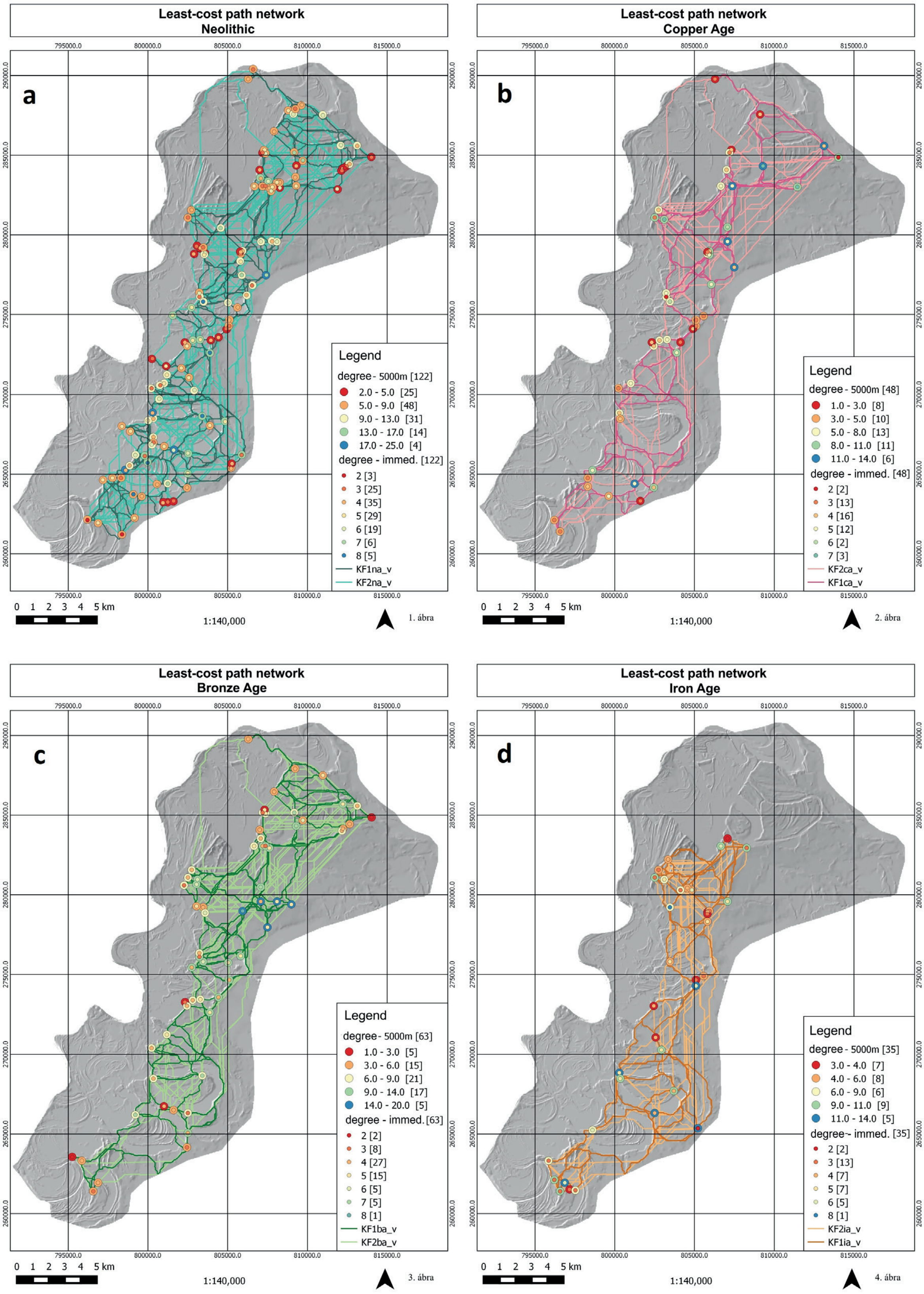

Fig. 11. Least-cost path network of Neolithic (a), Copper Age (b), Bronze Age (c), and Iron Age (d)

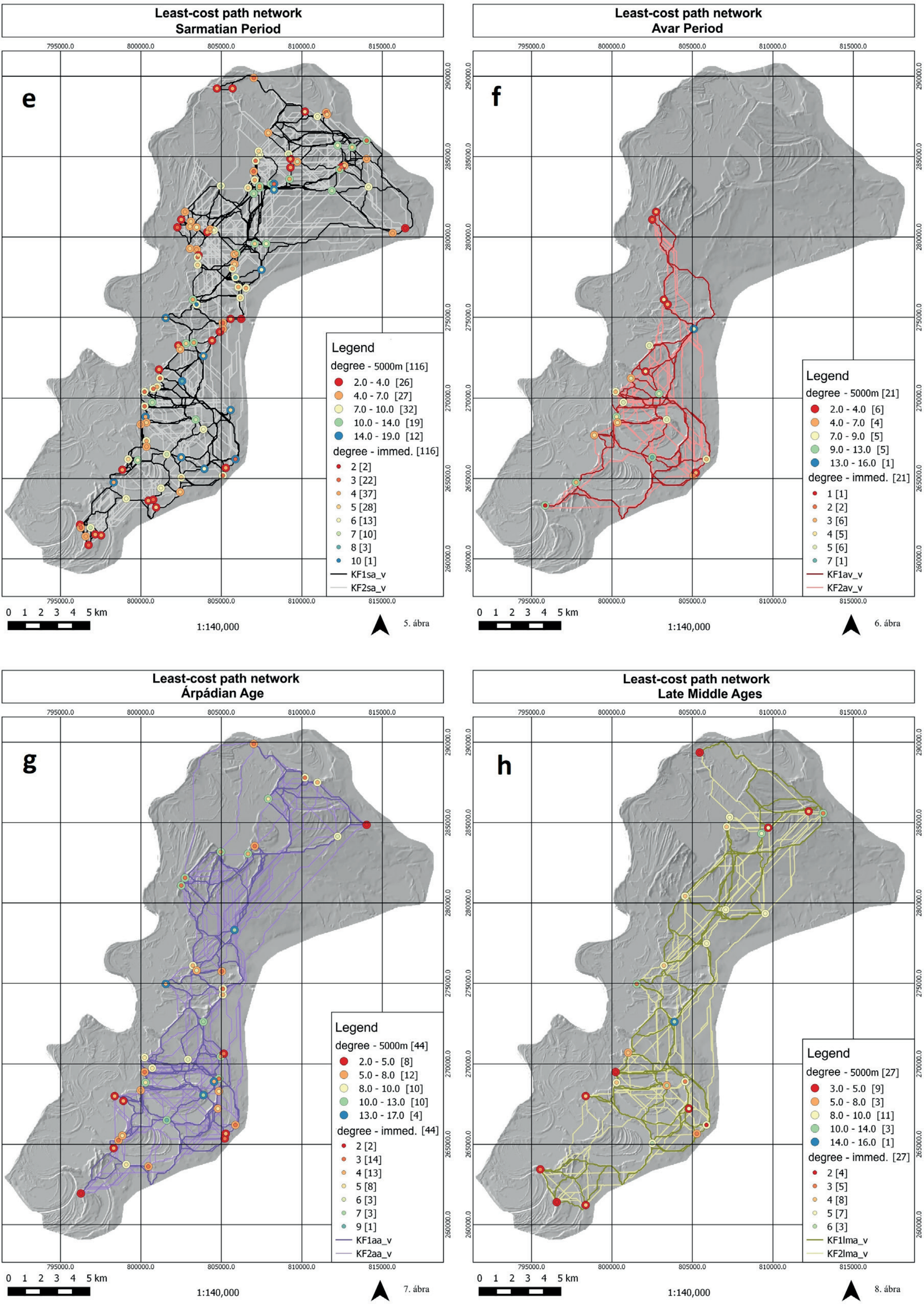

Fig. 12. Least-cost path network of the Sarmatian Period (e), Avar Period (f), Árpádian Age (g), Late Middle Ages (h)

versions) and the number of points representing archaeological sites increased. In the periodical models, a 20–25% area contained 83–93% of the model-building training points and surface artefacts. In the case of the CRM version, which was created by overlapping the chronological models and choosing the highest category in every cell, this ratio was 40% and 90–96%. Latter results also imply the spatial variability of the chronological model's probability zones, referring to altering occupation zones in different periods.

Changes in settlement networks

The first settlements in the study area, in the Middle Neolithic, consisted of single farmsteads and small hamlet-type occupations; because of constant population aggregation, the area became hamlet- and village-dominated by the end of the period. Recent results support the picture outlined by previous research; several sites were identified with low chronological uncertainty, and relatively high artefact count scatters, while some with low count scatters. The identified 112 sites from this period spread throughout the study area.

The emerging tells in the Late Neolithic with more extended horizontal settlements around them (Polgár-Csőszhalom, Polgár-Bosnyákdomb, Folyás-Kígyós-domb) brought about an increased settlement network aggregation, concentrating primarily on the Polgár Island. Despite intensive field surveys, there is still no sign of inhabitation in a large area between the disputable tell at Folyás-Kígyós-domb and Tiszacsege. A new element of the Late Neolithic settlement network was identified at Tiszacsege-Görbe-földek, where a 130-metre-wide enclosure could be identified on satellite images.

The changes in the settlement network at the end of the Late Neolithic and the Copper Age prove that large central places became abandoned, and a new settlement pattern emerged with a roughly homogenous settlement distribution. The identification of Copper Age sites via field survey proved challenging due to the characteristics of the related find material, yielding low-intensity small or medium-size scatters with generally high chronological uncertainty artefacts. Based on the site database, a large proportion of the sites are graves or smaller cemeteries, which are generally poorly identified during field surveys. Therefore, the site count for the whole period is low.

Bronze Age finds were easy to distinguish with low or medium chronological uncertainty, although identifying finer chronological units proved more problematic. Early Bronze Age sites were primarily known from excavations on Polgár Island. The Middle Bronze Age tells and tell-like settlements (Polgár-Kenderföldek, Polgár-Ásott-halom, Folyás-Kígyós-domb(?), Folyás-Bivalyhalom, Újszentmargita-Tuka, Kunszög) do not overlap with the Late Neolithic ones, indicating a different settlement network. The connection between the known large cemeteries around these tells also highlights a different spatial and cultural tradition. Late Bronze Age sites are mainly known from the site database; meanwhile, the southern part of the study area contains only smaller, low-intensity occupations.

The Iron Age settlement network's density is lower than the Bronze Age's. Field survey results indicate that the Scythian and Late Iron Age sites show significant spatial overlap; meanwhile, the absence of sites between Folyás and Újszentmargita is quite conspicuous. Interestingly, finer chronological units show lower chronological uncertainty values in the Iron Age.

The large count of small or medium Sarmatian sites appeared as low-intensity site scatters during the field surveys. The spatial distribution also showed the significant use of "inland" areas away from the edge of the floodplain.

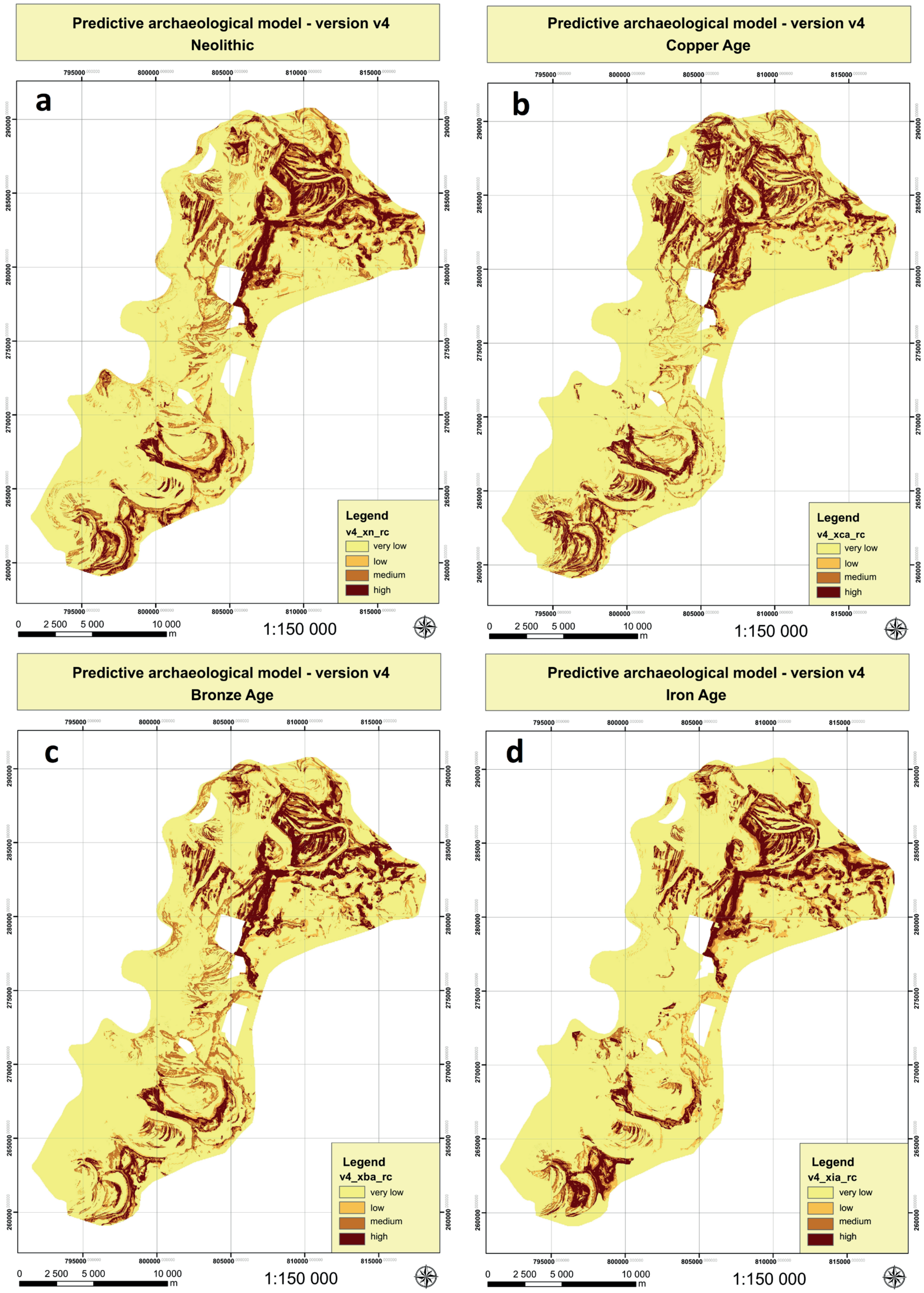

Fig. 13. Results of the archaeological predictive modelling, based on the field survey dataset and by integrating the main transport network layout in the Neolithic (a), Copper Age (b), Bronze Age (c), Iron Age (d).

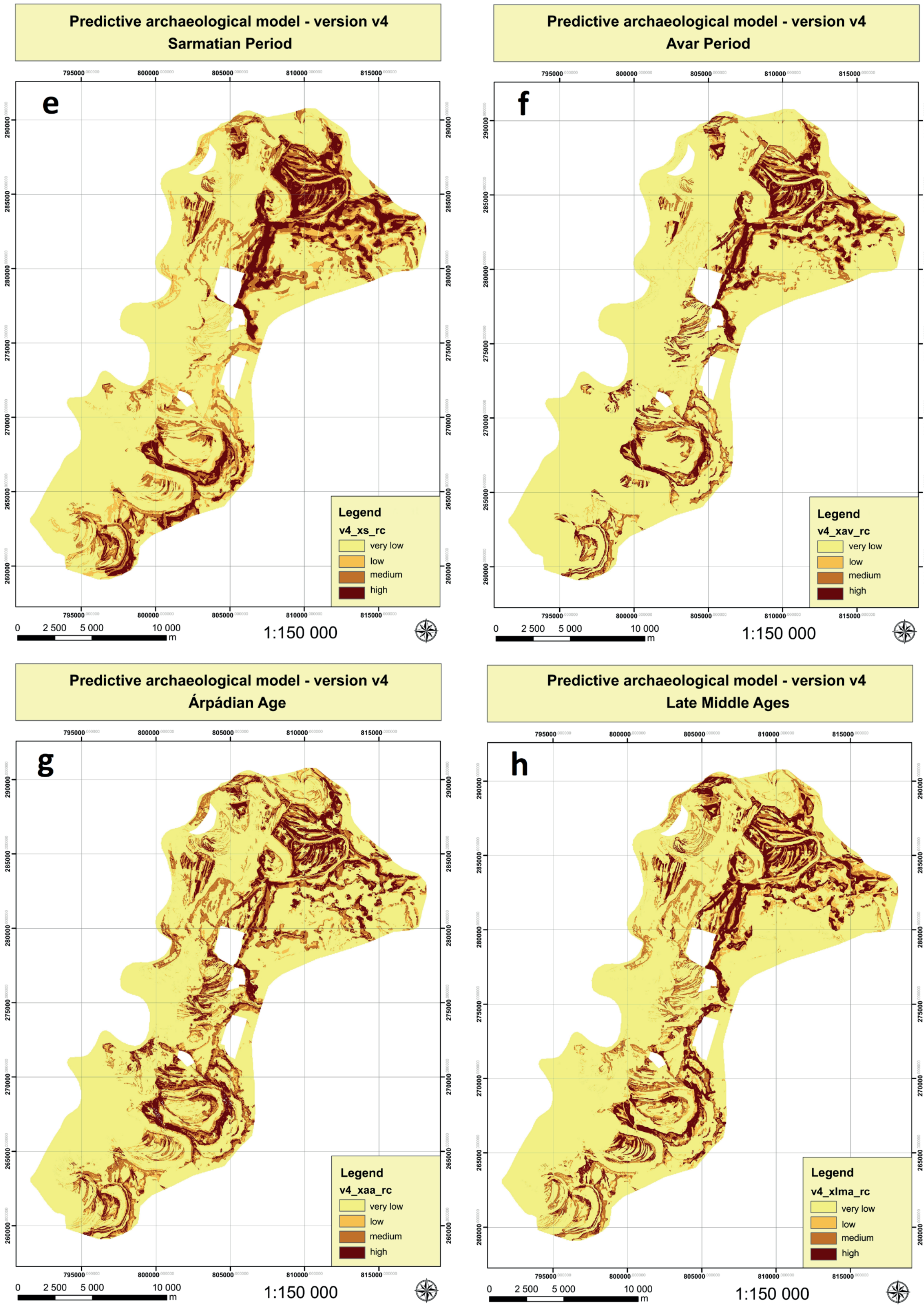

Fig. 14. Results of the archaeological predictive modelling, based on the field survey dataset and by integrating the main transport network layout in the Sarmathian Period (e), Avar Period (f), Árpádian Age (g), Late Middle Ages (h)

Recent research results concerning Sarmatian and Gepid pottery underline that certain sites, identified earlier as Sarmatian, are actually Gepid. Five newly identified Gepid sites prove the existence of such sites in the study area, clearly outlining a larger village in Újszentmargita-Nagy-szögilegelő I. site with four low-intensity scatters around it. These sites appear at the edge of the floodplain on higher elevations, in a location similar to those observed earlier in other parts of the Great Hungarian Plain.

Avar Period sites recorded in the field surveys were mainly relatively small and low-intensity. Due to high chronological uncertainty and low artefact counts, only a dispersed settlement pattern could be identified. Most settlements are located close to the floodplains on higher elevations, although a recent field survey also located smaller settlements inland. The latter results might be relevant to a latest excavation, of an Avar Period cemetery, at Polgár-Görbe-föld-dűlő II.

The dense Árpádian Age settlement network was characterised mainly by low artefact counts, although the finer chronological units had high uncertainty values. Despite the effort, the localisation of the medieval churches of Polgár and Szentmiklós remained unsuccessful. A significant decline in site count can be observed in the Late Middle Ages, while sites located further away from the edge of the floodplain testify to wetter climatic conditions.

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