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Roman settlement pattern and LCP modelling in ancient North-Eastern Pannonia (Hungary)

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Abstract

Roman times are known as an epoch when man subdued nature all over the orbis terrarum, however all humans were and are still bound by certain environmental conditions, therefore in settling a special dichotomy can be observed. In my present study I am analysing the Roman settlement patterns of the North-Eastern part of Pannonia by evaluating field-walking material and results of excavations. The classification of the sites is mainly based on building material and pottery collected on the field. After examining the structure of settlements with the assistance of GIS technologies, I assess how the least cost paths calculated from the relief of terrain influenced settling.

Study area and database

The study area of my present paper[1] extends to the North-Eastern part of the ancient province of Pannonia situated on the modern territory of Hungary *(Fig. 1)*. The borders themselves align with boundaries of modern administrative districts so it does not reflect historic circumstances, although the area was balanced in a way to be equally part of the *territorium* of Aquincum and Brigetio. That is why it consists of the Transdanubian part of the county Pest, except the district of Érd and the whole district of Esztergom and the territory of Buda adding up to 1382 km^2. The study area was part of the huge Hungarian Archaeological Topography Program (Magyar Régészeti Topográfia Program = MRT) during which a systematic field-walking has been conducted since the 1970's. Therefore, thanks to the systematic collection of field material and the evaluation methods of the finished topography volumes, it is possible to interpret data on common grounds.

As all topographic surveys are based on various databases, I also built one using the most up-to-date archaeological information accessible[2] complemented along with literary sources. In my record I summarized all field-walking observations and excavation results which indicated the presence of a Roman settlement. In my present survey I included only those settlements

1 The present study is part of my doctoral research at Eötvös Loránd University, Budapest, Hungary with the title: "Aquincum és Brigetio mezőgazdasági hátországa és a katonaság ellátásának lokális rendszere. The agricultural hinterland of Aquincum and Brigetio and the local system of the army supply". Hereby I would like to express my gratitude to my director of studies, László Borhy who assists me through my studies and also Jessica Hall for proofreading my paper.

2 I hereby say thanks for the assistance of Rita Csákvári director of the Registration Office at the Gyula Forster National Centre for Cultural Heritage Management providing me the actual national archaeological record.

that did not immediately develop next to a military fortress (camp, watchtower, etc.) or those that were in the immediate neighbourhood of Aquincum. All of the sites were in polygon shapes, which did not allow easy handling, so I generated the geometrical centres of the shapes, thus receiving a point representing each. As a result I included 256 possible settlement sites in my survey.[3]

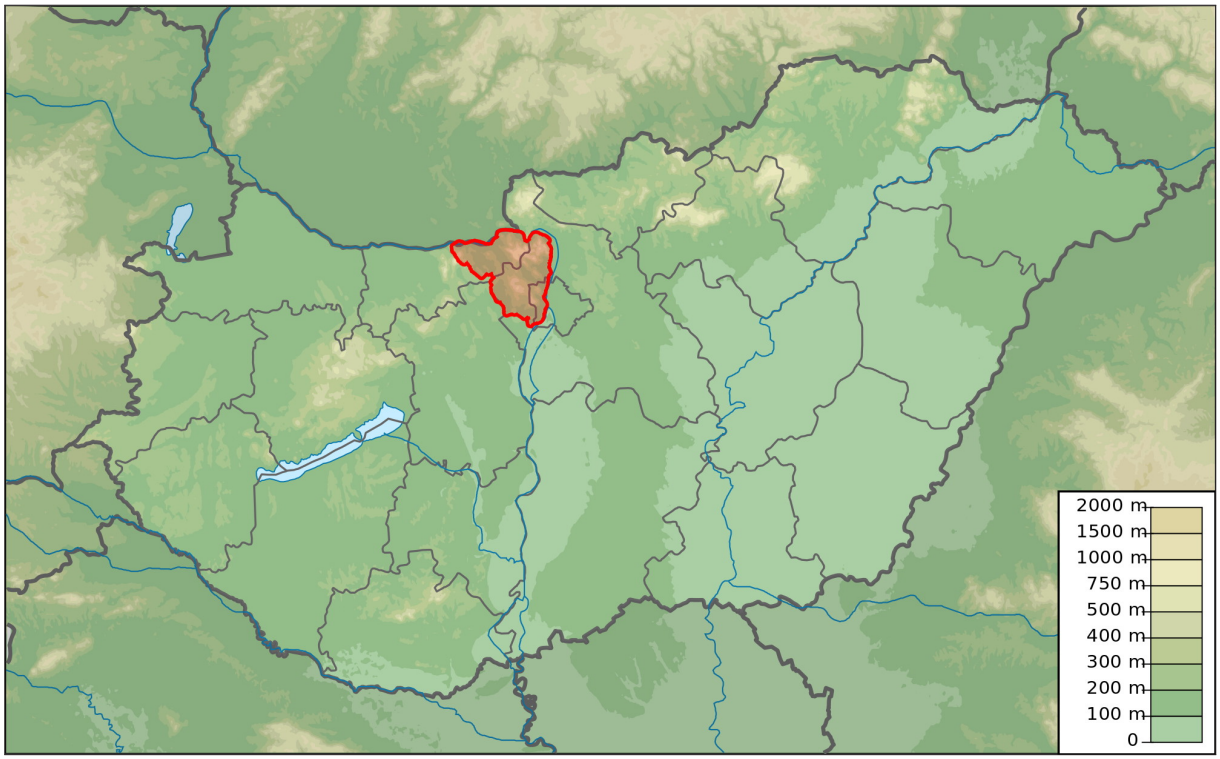

Fig. 1. Location of the study area on the map of Hungary.

The base of a settlement pattern model and its limits

As evident in the inner structure of Roman settlements,[4] between each ancient village, farmstead or city a specific hierarchy can be observed.[5] Certain settlements could obtain a principal role in the human-shaped landscape, thanks to their environmental-, economic- and socio-geographical situation. Since one of the first GIS-based regional studies of the island of Hvar (today: Croatia),[6] in Roman archaeology the number of settlement pattern studies is increasingly growing as GIS technologies enable researchers to compute with and visualize various data. In the past

3 Considering the limits of a publication, no list of the sites is contributed.

4 Hierarchy within Roman rural settlements can be best observed through the system and evolution of the mainly enclosed and self-sustaining *villa*s. The central buildings of the excavated farmsteads (not long after the Roman occupation) were constructed of stone with terrazzo floors, underfloor heating system and most of the time fresco fragments of the decorated inner walls also come to light. These buildings can be distinguished from the more simple buildings of the *pars rustica* only by the archaeological material and their ground plan. E.g. the villa settlement of Baláca (Palágyi 2005, Abb. 1). On the subject of the development of villas under various circumstances see the settlements of Germania Inferior. (Habermehl 2011, 31-96).

5 Under the expression 'hierarchy' we mean a classification, the method of which is based on specific criteria like economic, social, administrative or other factors. The results provide a hierarchical system of discrete groups of settlements.

6 Gaffney – Stančič 1991.

decade, within the frameworks of mainly French-led archaeological projects (e. g. ModeLTER,[7] ArchaeDyn[8]) researchers tried to analyse Roman settlement patterns based on systematically collected field-walking material and various cultural factors. With this information, the focal points, the main "centres" of the rural landscape, could be specified.[9] With the application of this method, the pattern of rural settlements can be more fully understood; for example, the differences between settlements using stone as building material can be proven. This does not always mean the actual hierarchy of a certain period of time,[10] only a classification based on the archaeological material.

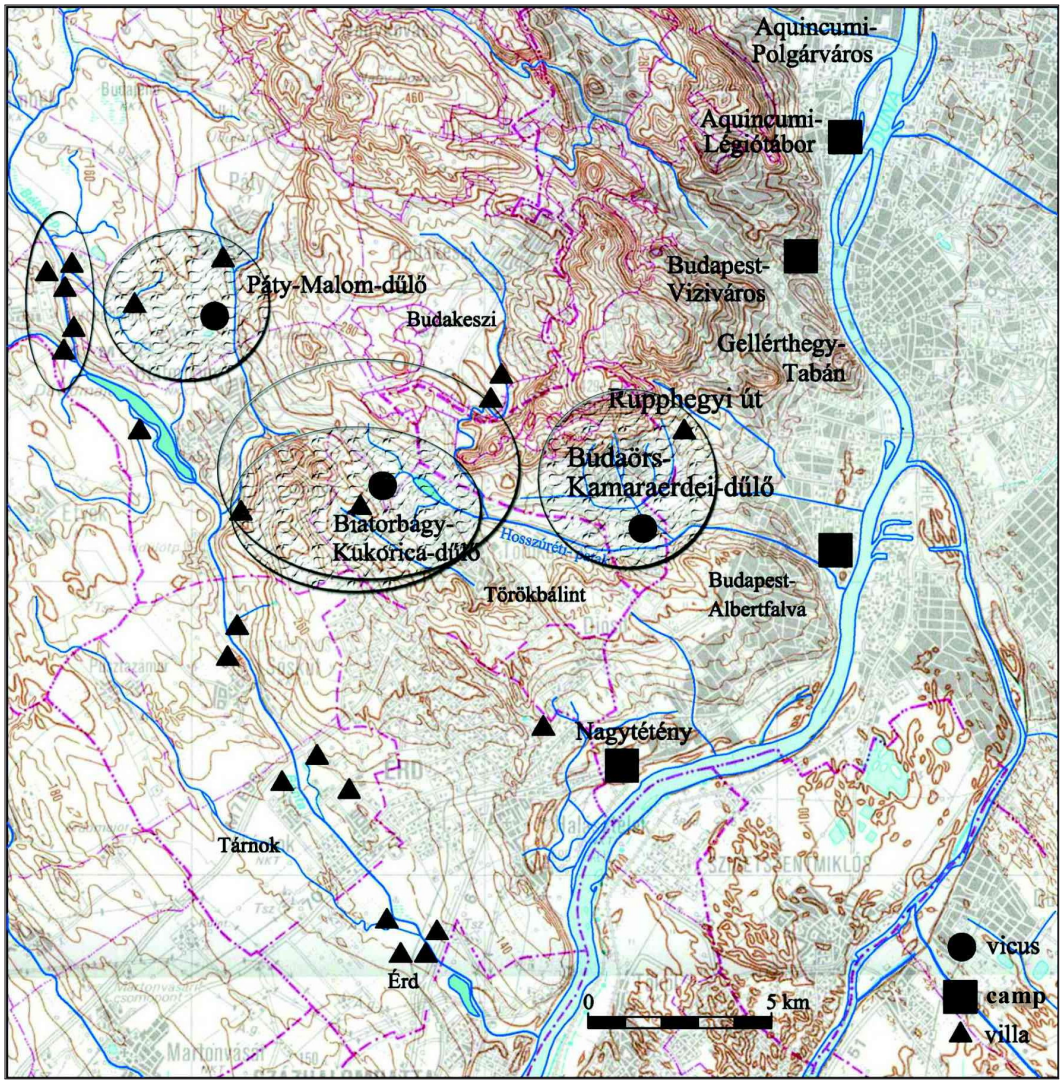

Fig. 2. Roman settlements South-Westward from Aquincum (after Ottományi 2014, Fig. 2.2).

7 Tourneux – Nuninger – Ostir 2006.

8 http://mshe.univ-fcomte.fr/poles-de-recherche/dynamiques-territoriales/axe-1-construction-des-territoires-dans-la-longue-duree/archaedyn

9 On settlement pattern studies using archaeological data (site size, field-walking material etc.) see: Favory – Van der Leeuw 1998; Bertoncello 2002; Bertoncello – Nuninger 2004; Poglajen – Nuninger – Fovet 2008.

10 Although in the provincial hierarchy of *res publicae*, the *municipium* of Mursella was on the second level, based on recent studies it did not exceed an extent of 5-6 hectares, which is relatively small in comparison to the area of 11 hectares of the *vicus* excavated in Budaörs-Kamaraerdei-dűlő is. See Ottományi 2014, 101.

The research of Pannonian rural settlements looks back to a relatively early systematic topographical data collection (Hungarian Archaeological Topography Program),[11] yet only parallel to new excavations the demand for their classification emerged. In their summarizing studies D. Gabler and Zs. Visy make an attempt to determine the type of the settlements based on the field-walking material, but their method is not verified in light of actual results.[12] The main reason for this is the incorrect use of Hungarian archaeological terminology which until recent times did not correctly define settlements with remnants of stone building material.[13] This incorrect custom can be demonstrated with the documented hierarchical system of the settlement pattern of North-East Pannonia. According to epigraphic evidence, the *territorium* of the *municipium* and later *colonia* Aquincum was divided into *pagi* which consisted of the smaller *vici*,[14] therefore the use of Latin terms only on the archaeological appearance of rural settlements neglecting the meaning of their ancient administrative and economic significance can be considered misleading. For that reason the present study tries to elaborate a finding-based hierarchy of rural settlements somehow avoiding and bearing in mind the difficulties of classification according to terminology.

Determining "significant" sites in regard to their find material and building material

Definition of "significant" sites

To better understand rural settlement pattern in North-Eastern Pannonia it was necessary to somehow classify archaeological sites as described above. For various reasons, though mainly due to insufficient data,[15] it was not possible to implement an automated classification method in my model, so a more rough, although in my opinion an equally useful system was applied. I determined all Roman sites to be "significant" which due to their economic weight and their building traditions had a distinctive archaeological appearance. In this case, if the material observed during field-walking or through any other archaeological activity (excavation, etc.) strongly suggested the presence of stone buildings and the find material contained imported or regional pottery, then those sites were considered "significant".

Settlements with and without stone building material

Incorporating cultural factors in settlement topography always includes the danger of projecting the elements of our present concepts and way of thinking back to the past. Yet the archaeological assemblages convincingly reflect the traditions and ideological background of

11 The first archaeological topography database was built in Poland the mid 1960's, in Ireland 1973 and in France 1978. The first comprehensive topographic studies were published in Romania in the 1970's, in Slovenia, Slovakia, and in Croatia in the early 1990's. D. Jankovich-Bésán emphasizes that a research project similar to the Hungarian field-walking technique was rare in 1993; the aim of foreign recording was only to map all sites that were already known not to discover new ones (Jankovich 1993, 29–37).

12 Visy 1994; Gabler 1994; Zs. Visy defined all settlement sites as *villa*s where beside the presence of stone building material any element of distinctive Roman housing (bath, hypocaust, fresco etc.) was found. This is how the above mentioned *vicus* excavated in Budaörs-Kamaraerdei-dűlő *(Fig. 2)* was listed among *villas*.

13 For the determination of the term *villa* and *vicus,* see Ottományi 2007a, 209–219.

14 Kovács 2013.

15 This problem is discussed below.

Roman architecture and residences.[16] It is evident in excavated rural settlements in North-Eastern Pannonia that where the right cultural – the presence of a Romanized population – and economic conditions – wealthy families and good trading potentials – were given, constructions according to Roman lifestyle and taste can be anticipated.[17]

In Northern provinces a multi-layered image of cultural changes was drawn based on the archaeological assemblages, which can be considered a response to the new social, cultural and economic situation arriving with the Roman occupation.[18] The circumstances created in each region differ, but new characters in architecture, burial customs and settlement pattern can be observed. Anyhow all of them can be adapted to the hierarchic Roman way of thinking. As the result of this cultural, economic and social transformation a new and unique language starts to spread out mainly from the military and cities[19] with the aim of self-representation even recreating the elements of formal thoughts,[20] transforming structures present in the rural landscape.

In North-Eastern Pannonia the dispersion of Roman lifestyle can be drawn mainly thanks to grand-scheme excavations.[21] Together with the first stone buildings of Roman cities on the settlements in the hinterland of Aquincum and Brigetio the use of stone as building material appears as early as the 2nd century AD. But even after the Hadrian-period one cannot accredit a self-representative role to any stone building as by that time most of the farm buildings could be partly built of stone. Thanks to the abundant stone resources[22] in North-Eastern Transdanubia, from the second part of the 2nd century AD[23] it depended only on the population, economic potential and state of Romanization of a certain settlement to acquire stone building material.

Considering the aforementioned criteria and according to French research methods I built my database to record all traces of stone building material gained by archaeological activities, which mainly means debris (stone, *tegula*, *imbrex*) observed on field-walking. This includes the apparent risk, as I have already emphasised that in absence of any excavations the field-walking material can be insufficient to determine the age and function of a certain stone building.

16 In Roman architecture spaces of self-representation, monumentality and usefulness all in one can be traced through imperial constructions, military fortresses oriented towards the enemy and in case of city dwellings and *villa*s.

17 Already in the early period of the 2nd century AD parallel to nearby military fortresses and cities we can count with buildings completely made of stone or just stone foundations with loam walls, but with an authentic Roman ground-plan. E. g. Tokod-Erzsébetakna (Mócsy 1981), *vici* South-Westward from Aquincum *(Fig. 2)*, Solymár-Krautgarten-dűlő (Kocztur 1985) and settlements of Pomáz etc.

18 Habermehl 2011, 79.

19 Many examples can be found in North-Eastern Pannonia for veteran auxiliary soldiers settling in the rural landscape. It is possible that even they were recruited from the formal villages of the autochthon population and they returned with a new Roman lifestyle which also served as self-representation for them. See Mráv 2012a, 541–544. The connection between the cities i. e. Aquincum was also strengthened by city magistrates, regarding this the case of M. Antonius Victorinus can be mentioned (Kovács 2014, 313).

20 In the assemblages of Romanized tribal elite's wagon graves, representing Celtic beliefs a completely Roman assortment of objects (Mráv 2014) and insignia (Kovács 2003; Mráv 2012b) can be found.

21 See: *Fig. 2. - vici.*

22 In the environment of Aquincum coarse limestone was quarried in Sóskút and travertine in the Buda Hills (Gellért Hill: Pető 1998; Budakalász: Torma 1982). In the Gerecse Mountains probably many quarries were used (Török 2008, 145, 148–149). It is also assumed that in the Holdvilág-árok (Pomáz, Pest County) volcanic rock was quarried. See RKM 2004, Nr. 318.; RKM 2005, Nr. 327.; RKM 2006, Nr. 283.

23 In each excavated above-mentioned *vici (Fig. 2)* no later than the Antonine period stone buildings are erected. See Ottományi 2014, 104.

With the help of the recorded data, I created a group of sites which possibly had a stone building or a stone foundation on their territory. I associated all settlements with this group where during the field-walking not only stone material, but also *tegulae/imbrices* or traces of mortar were found[24] and also those where stone walls were excavated or documented.

Pottery sherds and economic relations

Besides defining sites with stone buildings, it was necessary to insert more factors in my model that imply the economic significance of a certain site. The most suitable resources were pottery gathered during field-walking, other archaeological activities or collections, as their great amount and rich literature provide abundant information regarding the relations of rural settlements. I tried to map those sites that were in lively commercial and economic relations with the military and/or cities along the Danube.

First the following sherds of imported ceramic vessels were collected in the database:

- sherds of Samian ware (from Italian to ware from Westerndorf/Pfaffenhofen)
- *amphorae*
- Italian thin-walled pottery and their imitations
- rough-cast indented beakers *(Faltenbecher)*
- Raetian ware

In the second category such widespread vessel forms and specific ware were chosen which were associated with regional economic relations. Most of the time their place of production cannot be precisely determined, but the system of their decoration motifs and appearance are beyond the local pottery industry. Their presence presupposes a Romanized environment. The potteries are the following:

- direct imitations of imported ware (see note 31)
- vessels made under the influence of imported ware (i. e. *pannonische Glanztonware*,[25] imitations of Samian ware, stamped pottery[26])
- pottery with marbled decoration[27]
- mortaria[28]

24 Sorting Roman sites according to building material was first systematic in the volumes of Archaeological Topography of Hungary (MRT) in which each non-military settlement with an anticipated stone building was listed as a *villa*. See note 12.

25 They are mainly characterized by vessels imitating forms of imported pottery (Ottományi 2012, 212–213).

26 Main production sites of stamped pottery in North-Eastern Pannonia were the cities of Aquincum, Brigetio and Gorsium (Maróti 1985, 124).

27 The type can be found in the *vicus* of Budaörs together with pottery from Aquincum or imported vessels, its production can be linked mainly to cities, see Ottományi 2012, 223. It becomes widespread in Pannonia thanks to Western not regional influence (Ottományi 2007a, 150).

28 The disperse of this type of vessel is in connection with the Roman diet, and their production can be associated with the military and cities. See note 35.

- painted pottery
- pottery with painted and dentated engraving decoration[29](jars, pots, beakers, bowls – pottery with painted stripe decoration from Brigetio[30])

All ware were listed in the group of potteries with a regional dispersion which were produced imitating and under the influence of imported vessels, or those which were either made of local material (i. e. *terra sigillata* imitations,[31] stamped pottery[32]) or borrowed their decoration techniques from the military (marbled decoration) or Celtic pottery customs (painted stripes). Besides these, I listed the *mortaria* to the regional potteries, as they reflect a Roman way of diet which primarily spread from cities and the military.

The route of ceramic vessels is not known in detail, but in the case of Samian ware after comparing the excavation and epigraphic material, it seems evident that the primary destination of the vessels was the Pannonian military. Besides them only the wealthy city, *villa* and *vici* dwellers could afford the expensive *terra sigillata*. It is highly probable that commercial businessmen owned a store and magazine in the greater military and city centres (i. e. Aquincum, Brigetio) where they transported private orders. From these stores through yet unknown commercial channels vessels were delivered to users including rural settlements.[33] All other imported merchandise can be linked to this trade line. Although *amhora*s were probably transported to the rural settlements the same way as *terra sigillata*, their presence could embody a specific category as they cannot be considered as table ware for daily use, but rather served as packaging for foodstuffs.[34] As *mortaria,*[35] *amphora*s also represent a Roman way of diet as various kinds of foodstuffs like wine, olive oil, fish sauce (*garum*) and fruits were transported in them mainly from the Mediterranean. Their occurrence marks a significant economic centre that had a lively connection with city and military populations.

Summarizing the archaeological record a total of 59 significant Roman settlements could be determined in the Roman North-East Transdanubia many of which may have kept an intensive economic relationship from the early Imperial era until the 4th century AD with the military camps along the *limes* and the cities of Aquincum and Brigetio. This complex connection is more fully emphasized by the epigraphic material of city magistrates and military personnel from rural context.[36]

29 In some cases field-walking reports contain terminology not used by modern publications. The naming of the "Pátka-type" vessels is no longer used, they are known for their *terra sigillata* form (Drag. 24/25 and 44.) and other terminology (Ottományi 2007a, 148).

30 The origin of vessels with painted stripes, dentated engraving decoration is the city and legionary fortress of Brigetio on the *limes* (Bónis 1970).

31 Under the imitations I mean not only potteries in form of a *terra sigillata*, but also those which try to imitate the slip. This includes stamped fine wares (Nagy 2014) and also Samian ware-like potteries (Vámos 2012).

32 Maróti 1992, 317–318.

33 Gabler 2006, 104–110.

34 On ancient resources of the packaging role of *amphorae*, see Peña 2007, 47–51.

35 Ottományi 2012, 236. To reconstruct the actual use of *mortaria* organic residues from the wall of Britannic vessels were recently analysed. Research came to the conclusion that all residue found in Iron Age vessels is a match of the one found in Roman *mortaria*, thus not the diet – the composition of the dishes – itself, but the way of preparation changed (Cramp – Evershed – Eckhardt 2011). This notion can be supplemented with the tendency that, in many cases, with the arrival of various import foodstuffs, even the diet could have also changed. See van der Veen – Livarda – Alistair 2008.

36 Kovács 2014, 303.

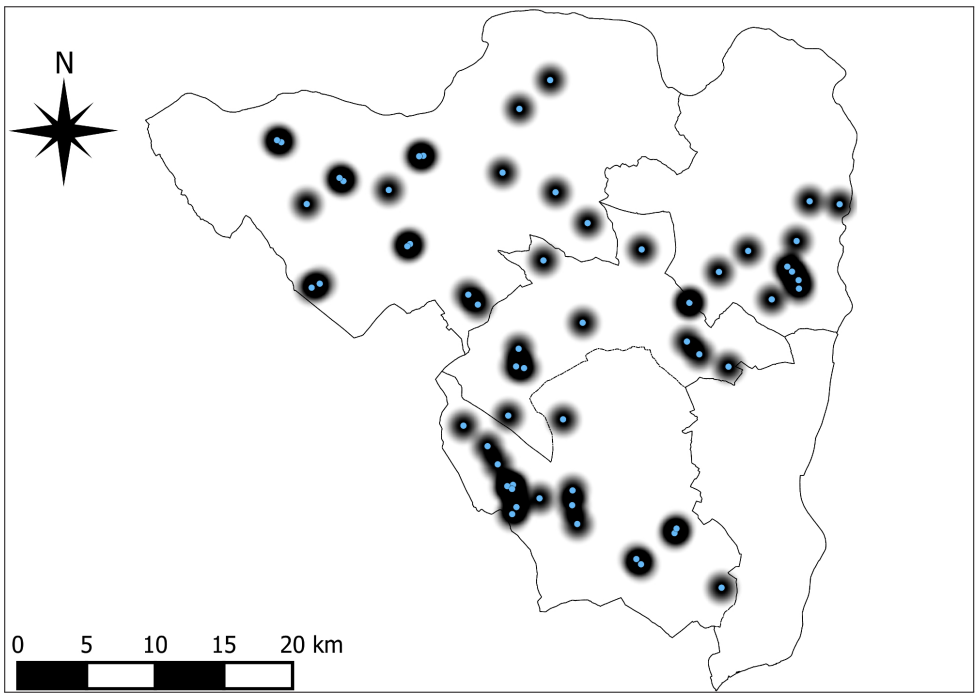

Fig. 3. Kernel density map of significant sites with a search radius of 1559 meters.

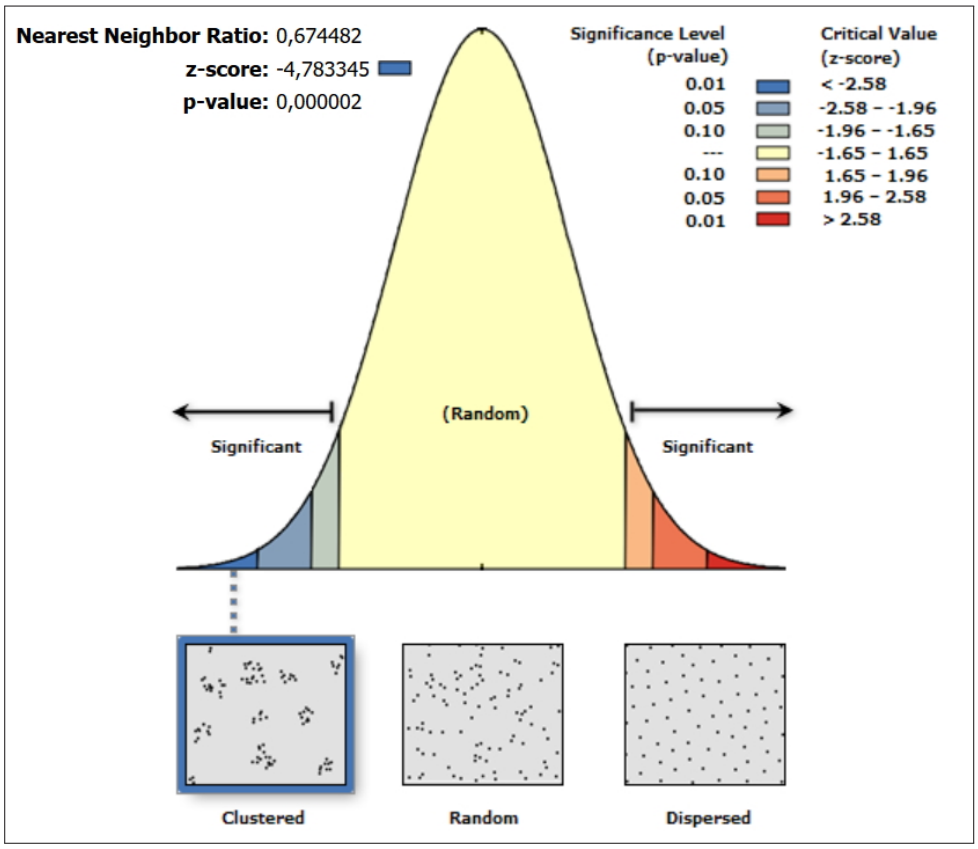

Fig. 4. Result of the nearest neighbour analysis.

Significant sites and settlement pattern

After determining the significant settlements, I analysed the density and accumulation of these sites, thus outlining the economically and culturally prominent areas of the studied landscape. In parallel with methods of settlement geography[37] several maps were created using the kernel density algorithm. During the survey, based on the density and spatial locus of the points (i. e. sites), each pixel of the maps received a value expressing the chance of their occurrence.

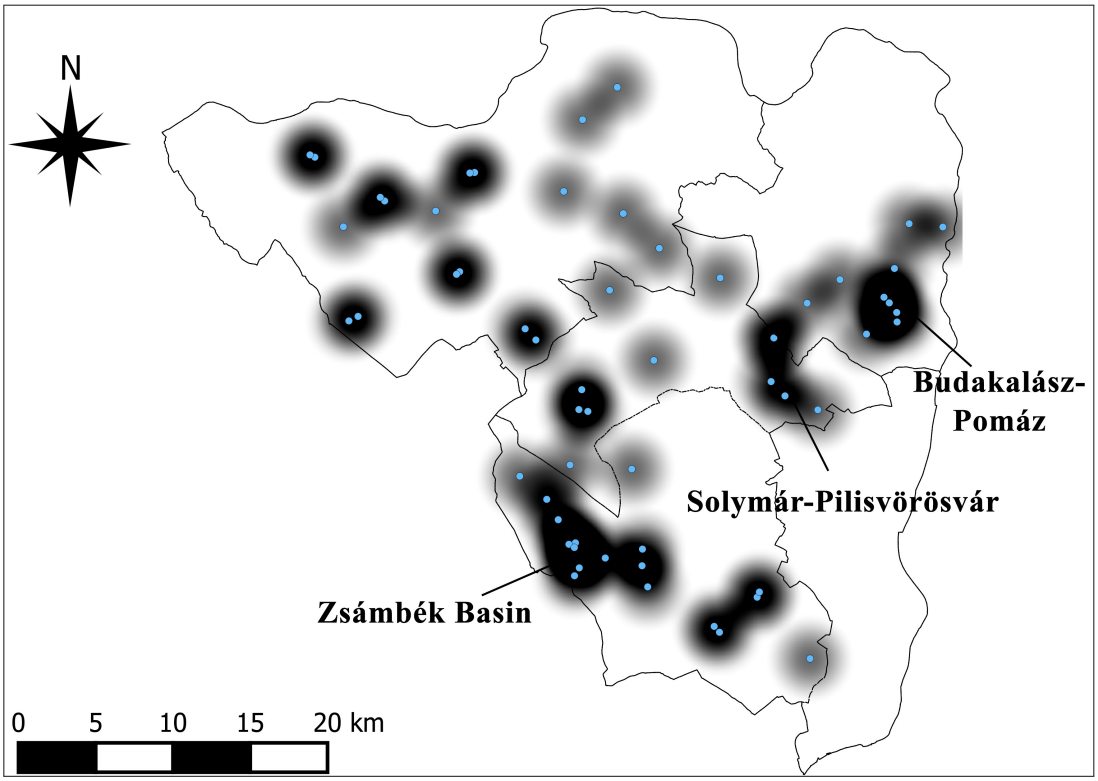

Fig. 5. Kernel density map of significant sites with a search radius of two Roman miles, 2963 meters.

Many approaches are known to illustrate and define settlement density,[38] in my present study I used nearest neighbour analysis.[39] The analysis conducted on the 59 sites has shown that the observed mean distance between nearest neighbours is 1559 meters, so with the utilization of this data the first map using kernel density algorithm was created. It shows separate settlement blocks consisting of two or three sites in many times *(Fig. 3)*. The nearest neighbour ratio (Rn) can demonstrate any order in this settlement pattern and describes what factors played a role in its development. With the module of ArcMap 10.1 I received a nearest neighbour value of 0.674482 that was proven to be statistically significant, meaning more than a 99% chance that the settlement pattern has a tendency towards a clustered system, in the evolution of which "the presence of points with a prominent role and local attractions"[40] played part *(Fig. 4)*.

37 Telbisz et al. 2014, 280, Abb. 7.

38 Visualizing density based on the distances calculated from each neighbour, see Lovász 1977; Gyenizse 2006; Gyenizse 2010. On density calculations only by giving the number of settlements per area, see Telbisz et al. 2014.

39 Regarding the mathematical background and limitations of nearest neighbour analysis, see Nemes Nagy 1998, 136–138. It is necessary to mention that as this analysis is a statistical calculation of probability it gives significant results only when the number of elements is high, which according to studies, must be more than 50 items.

40 Nemes Nagy 1998, 137–138.

This result shows that even among the significant sites we need to expect some settlements which had heavy impact on the development of the settlement pattern. I need to refer back to the assumed regularity observed by K. Ottományi namely that the three excavated extensive Roman settlements near Aquincum are six kilometres apart from each other. Using this information and with the assistance of the kernel density algorithm conducted on the 59 significant sites a new density map was created. I set the search radius to two Roman miles that is equal to 2963 meters.[41] From the map it is apparent that in the area of Budakalász-Pomáz and in the Zsámbék Basin significant settlements are more densely located,[42] besides which the area of Solymár and Pilisvörösvár can be set out *(Fig. 5)*. It is necessary to emphasize that it is quite easy to disjoint them from each other, but it is hard to tell which of the prominent sites had a leading role in the settlement block.

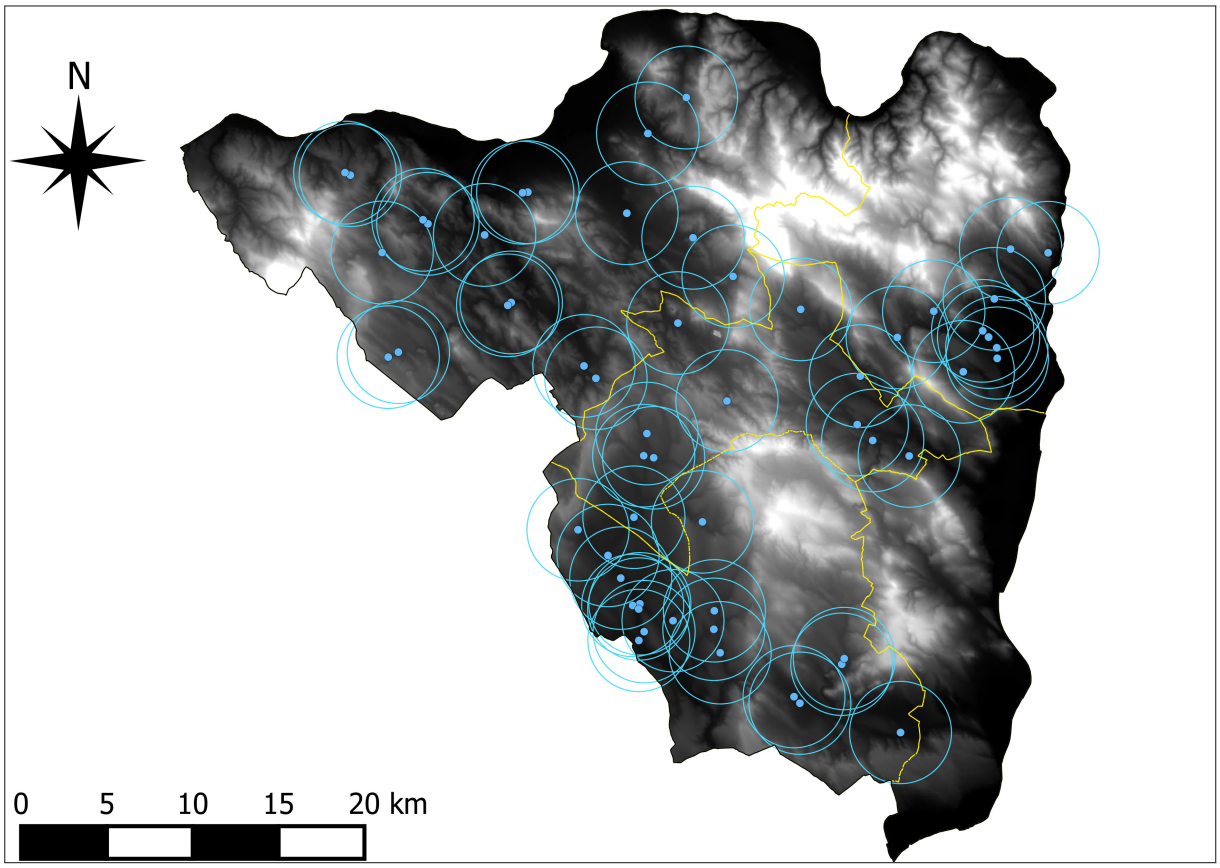

Fig. 6. Buffers around significant sites with two Roman mile radius.

Keeping in mind the regularity associated with Roman settlement, as a next step I created a circular buffer around all significant sites with a radius of 2963 meters each *(Fig. 6)*. With this result the regularity in the settlement pattern was not visible therefore I merged those sites together which were really close to each other and were in the same density focus,[43] so after a manual selection an apparently regular system could be drawn *(Fig.7)*. Buffer zones in the district of Esztergom only cross each other in some cases; only centres along the diagonal

41 Using the Capitoline foot as base measurement (0,2963 m) two Roman miles are equal to 2963 meters, 2×5000 feet (*pes*).
42 Ottományi 2007b, 275–276.
43 Nearly in all cases the two points representing the sites were considered as endpoints of a closed line section and the midpoint became the new point standing for both of them.

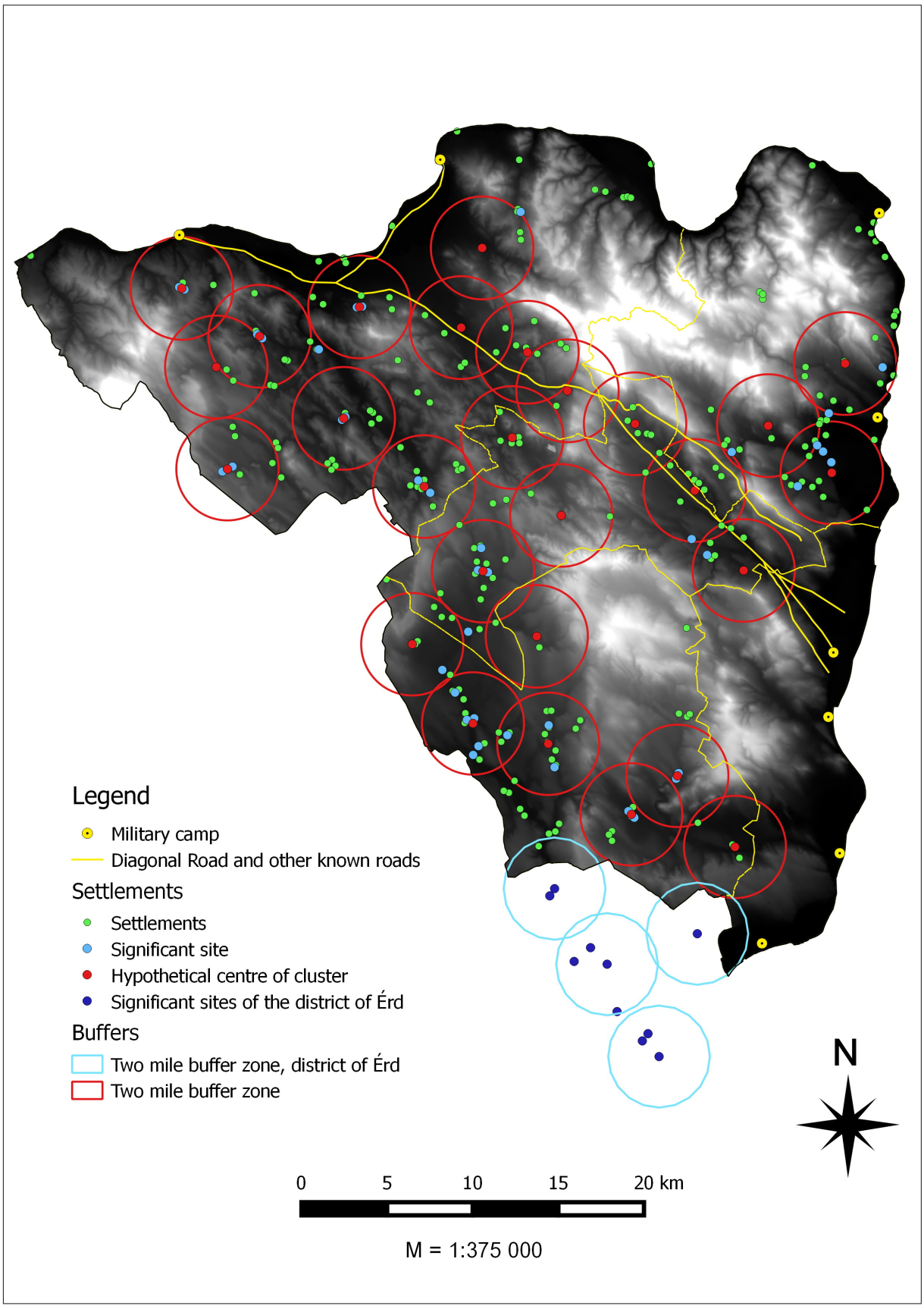

Fig. 7. Summary of significant sites, hypothetical centres and known roads.

road connecting Aquincum and Crumerum[44] are more densely located. This can also be observed in the district of Pilisvörösvár. In the Western area of the district at the foot of the Gerecse Mountains, the landscape is not so densely populated, which can be the result of the lines of local roads.[45] In several cases some of the significant sites fall outside the borders of the buffer zones. These settlements were at the outskirts of important centres and they cannot be definitely linked to any of them.

In Roman times the evolution of the settlement pattern was not only influenced by human factors (i. e. distance and regularity), but also by environmental and economic conditions. A good example can be the significant sites adjacent to Budakeszi as they evolved along the Budakeszi-árok, practically on the borders of the Budakeszi Basin, at the foot of the Csíki Hills. Their location can be explained with the nearby East-West running road starting from the military camp of Albertfalva towards Páty through Budaörs. This neighbourhood was important economically, but the small settlement cluster was not the only one with broad connections in the Budakeszi Basin, as in the area of Budakeszi during canalization works, an *amphora* was found in addition to the adjacent lying wagon grave representing a wealthy Romanized family in the area.

Although according to our present knowledge there were no stone buildings in Roman Budakeszi, so they cannot be listed among the significant sites. This can only mean that in some cases the centre of a geographically closed settlement cluster can be placed for some reason near the borders of the region. Extending the model to the modern district of Érd, it further demonstrates its accuracy. All significant sites of the area can be fit into three separate clusters with a significant site in the middle *(Fig. 7)*.

Settlement pattern and least cost paths (model)

Settlement pattern was also determined by roads which not only shaped economic relations, but also everyday life. However, as their importance cannot be questioned there is always the general problem, that regional and sub-regional roads are almost completely unknown. With the assistance of literary sources, maps and remote sensing technologies, this hiatus can be diminished but only in special cases can these roads be recorded.[46] On the present territory of Hungary the number of known Roman roads is a bit scarce, from the studied area only some segments of the diagonal leading Aquincum-Brigetio road is archaeologically provable.[47]

In order to study whether the line of the diagonal road[48] respected the environmental, especially the geographical features of the terrain or if its course was mainly influenced by human

44 For its line see *Fig. 7.*

45 See next chapter.

46 On the territory of the Roman colony of Savaria (Szombathely) roads or the trenches of roads an assistance of a *centuria* grid reconstruction created and handled in a GIS system proved to be a useful tool in finding them. (Bödőcs 2014).

47 One of the segments of the diagonal road sketched by the 7th volume of Archaeological Topography of Hungary in the county of Pest was proven by an excavation at Pilisvörösvár, Sima-dűlő in 2008 (RKM 2008, Nr. 319). On the earliest phases of the road, see Láng 2005.

48 The course of the diagonal road was sketched according to the national archaeological sites' database.

planning[49], I used the Least Cost Path Analysis (LCP) as a digital path modelling tool.[50] Recently Zs. E. Pető in her paper[51] already made an attempt to draw the most ideal (least cost) path between the medieval Óbuda and Esztergom using the free source ASTER GDEM Ver. 2 digital elevation model and according to her observations the generated path was mainly following the Roman diagonal road. In my present study I tried to create a model that is closest to the already known course of the diagonal road between Aquincum (Óbuda) and Crumerum (Nyergesújfalu).

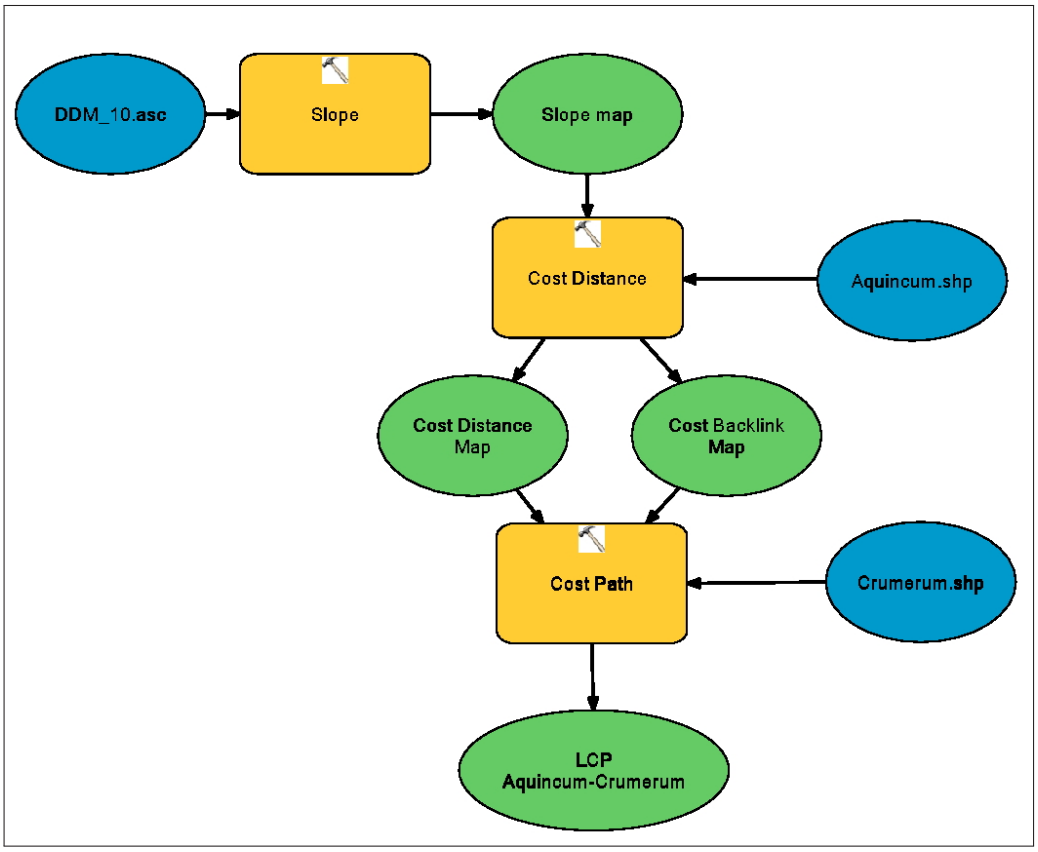

Fig. 8. Summary of the model before reclassification.

During my research I used a digital elevation model with a 10×10 m resolution to obtain as precise data as possible. The basic assumption of LCP (least cost path) modelling is that the most ideal paths are those, where one could travel the furthest with the least energy consumption during a certain timeframe. As it takes more energy to go up a slope than choosing a more level path, slope map can be the basic cost layer of any LCP model. The cost distance and cost back link maps were generated from the cost layer with an input source point to which each least accumulative cost distance and the values of the cost back link raster were measured. Therefore, as a first step, I created the slope map using the built-in algorithm of ArcMap, then

49 *Centuriatio* probably played a prominent role in building the first Roman roads and it did not necessarily align itself with environmental features; also the course of waterways could be altered (Bödőcs – Kovács – Anderkó 2014). Besides this, it was no obstacle for Roman engineers to cut a timber structure road into solid rock when the Imperial interest was at stake. A perfect example for this is the tow-path at the Iron Gate (Djerdap-Serbia) on the Danube (Mócsy 1982).

50 On rich bibliography and some essays on the topic, see Polla – Verhagen 2014.

51 Pető 2014.

I generated the cost distance and cost back link map with the source point of the legionary camp of Aquincum *(Fig. 8)*. With these maps a rasterized path could be calculated between Aquincum and Crumerum. The course of this path is nearly a perfect match of the medieval *via magna*,[52] but it is not running the same way as the Roman diagonal road *(Fig. 9)*.

As a second step I did a manual multi-layered experiment by creating cost maps of the basic slope raster with different reclassification methods. I received the closest LCP route to original after the program reclassified the slope values into six groups created with the Jenks natural breaks classification method. As a result I received a basic model that is on some occasions nearly perfectly precise, but it can also be quite inaccurate in some area *(Fig. 9)*.[53]

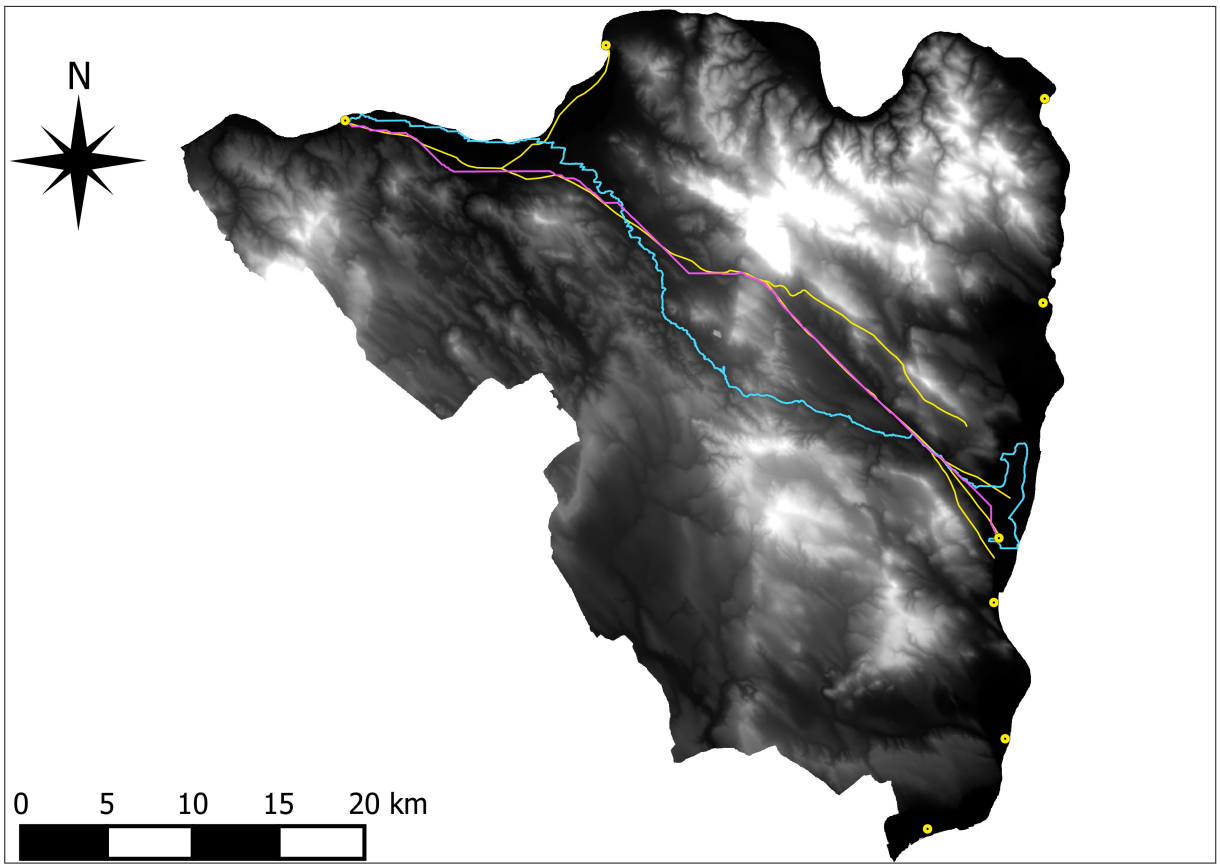

Fig. 9. Course of the known diagonal road (yellow), LCP before reclassification (blue), LCP after reclassification (purple).

After finding the most promising model it became possible to determine the least cost paths across the study area. I chose some of the centres of the significant settlement clusters located on the borders of the study area or in a special geographical position to be the starting points of the generated paths *(Fig. 10)*. Besides this I mainly chose centres with find material from the early 2nd century assuming an early occupation. From these centres I launched least cost paths to the three main military camps of the North-Eastern Transdanubia, Aquincum (Óbuda), Crumerum (Nyergesújfalu), and Solva (Esztergom) as they were possibly dominant in determining the road system of the area. The sites I chose were the following:

52 See note 51.
53 See the possible explanation below.

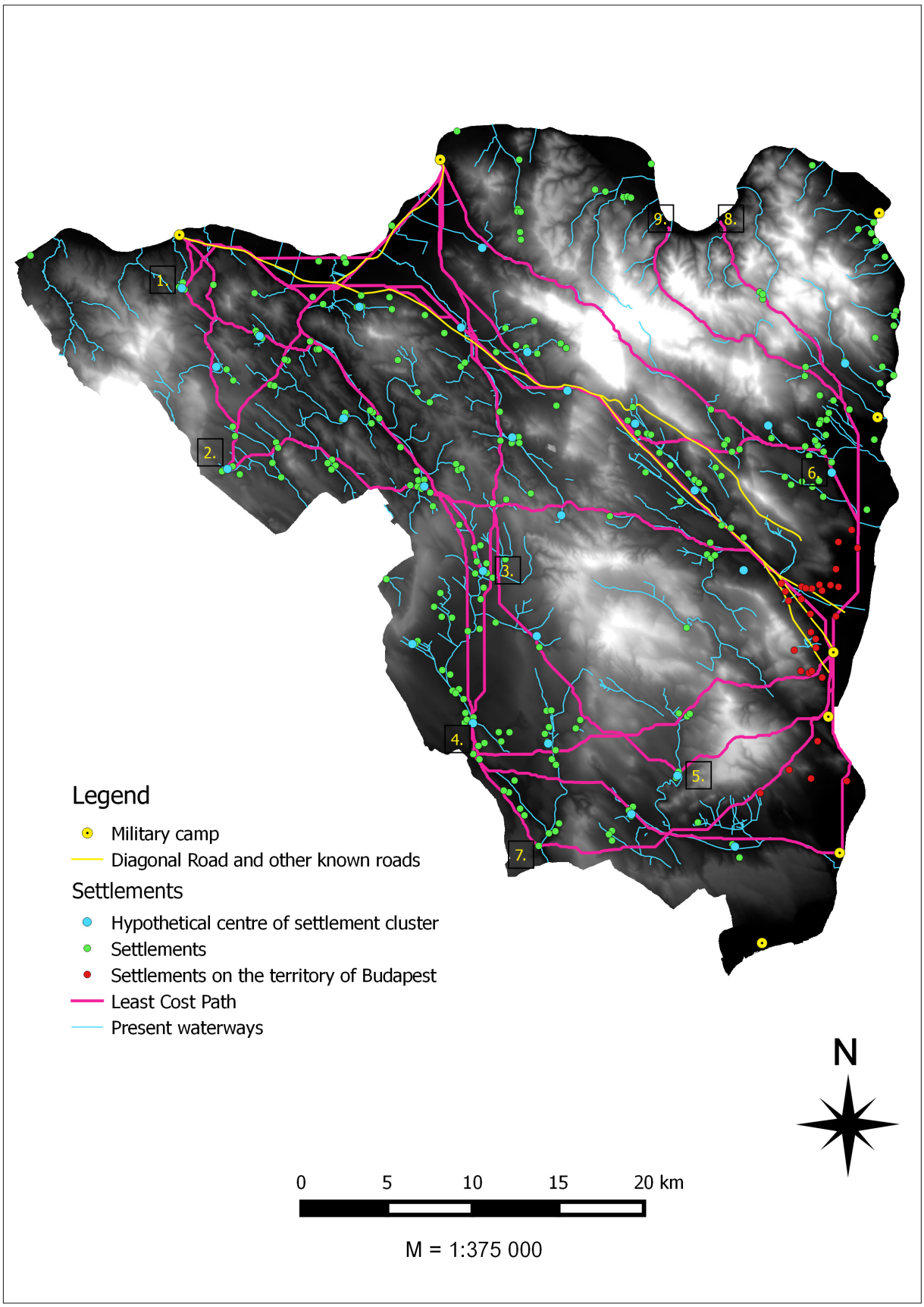

Fig. 10. Summary of least cost paths and hypothetical cluster centres after reclassification.

1. Nyergesújfalu-Rábl-völgy[54]
2. Bajna-Bódis-rét[55]
3. Perbál-Kukorica-dűlő[56]
4. Herceghalom-Üres-tarisznya[57]
5. Budakeszi-Mittlere-Theilung-Äcker[58]
6. Pomáz-Zdravlyák[59]
7. Biatorbágy-Bolha-hegy[60]
8. Visegrád-Lepence[61]
9. Dömös-Bartók Béla utca[62]

The system of least cost paths aligns itself mostly with the present streams, which is not surprising given that the most suitable slopes are mostly next to the watercourses. The most important observation is that besides the diagonal road another North-South running way could be detected, which starting from Zsámbék meets the *limes* road on the territory of Tokod. Besides this, another road can be assumed with a track starting on the territory of Máriahalom and leading towards Aquincum crossing through Tinnye, Piliscsaba, Pilisszentiván and Solymár.

We cannot tell whether sub-regional Roman roads followed the track of the modelled paths, although we can get some assurance. In case the system is projected on the First Topographic Survey[63] of the Habsburg Empire it is clear that most of the segments can be matched with the 18th century roads of the area *(Fig. 11–12)*. It is debated for some time now whether road remains near Dobogó-kő are of Roman or medieval origin *(Fig. 13)*.[64] All my LCP model can prove is that the least cost path's course from Pomáz to Esztergom (purple) goes through the village of Pilisszentkereszt and it is precisely on the known segment of the road in question. I also tried to launch a path to Dömös from the point where the path crosses the Kovács-patak. It is not a perfect match, but clearly a promising example.

Clearly the net of the LCP paths does not sum up the sub-regional road system of the North-Eastern Transdanubia, but connecting it to the settlement pattern of the region it seems more probable, that significant sites developed all along or quite near the least cost paths of the region. This is also supported by other sources as coin hoards, graves, epigraphic material and also milestones.

54 Horváth – H. Kelemen – Torma 1979, Nr. 15/22.
55 Horváth – H. Kelemen – Torma 1979, Nr. 1/45.
56 Dinnyés et al. 1986, Nr. 14/9.
57 Dinnyés et al. 1986, Nr. 1/6.
58 Dinnyés et al. 1986, Nr. 4/3.
59 Dinnyés et al. 1986, Nr. 23/3.
60 The last three sites were not „significant". I only chose them to model connections with the border areas of the study area (Dinnyés et al. 1986, Nr. 1/45).
61 Boruzs 2013.
62 Kelemen 1994–95.
63 http://mapire.eu/hu/map/collection/firstsurvey/?zoom=6&lat=47.89034&lon=14.76556
64 http://sirasok.blog.hu/2010/04/13/osi_utak_a_pilisben

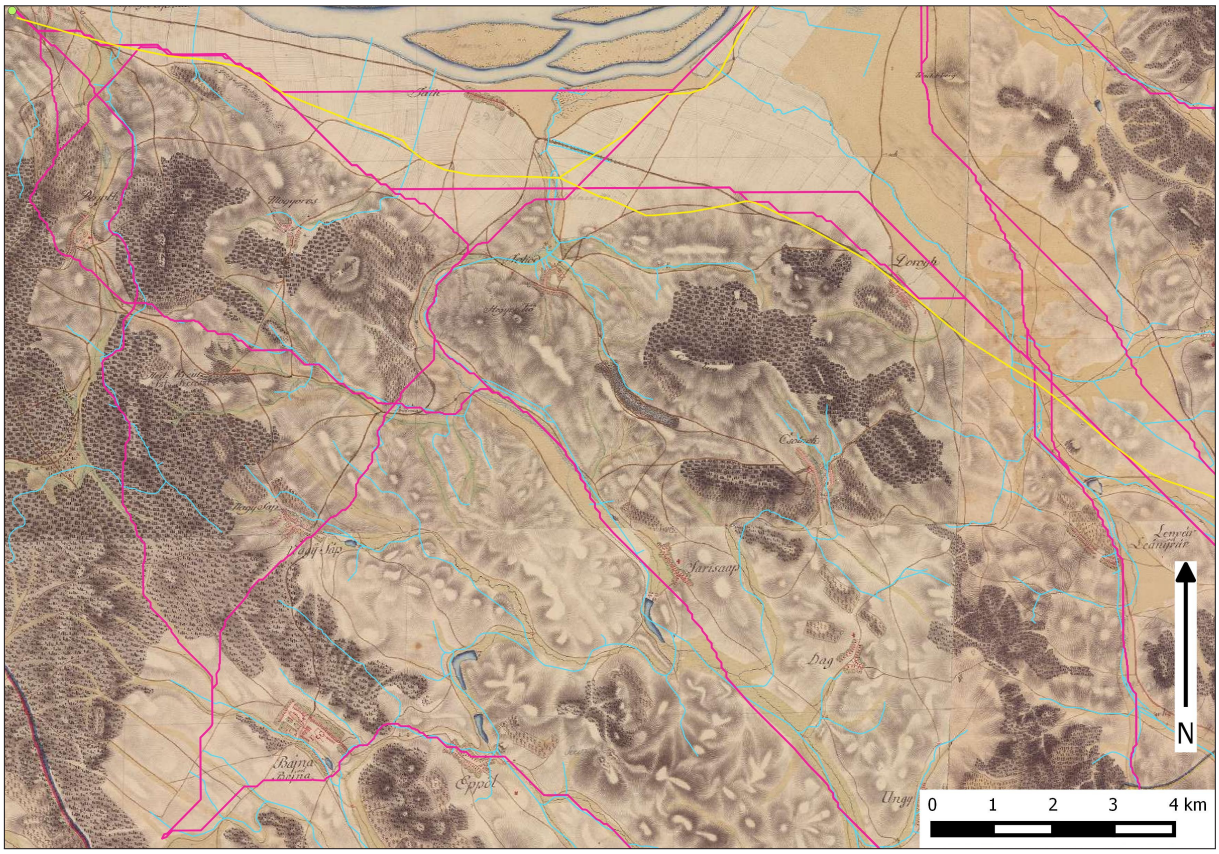

Fig. 11. Least cost paths in relation to roads of the First Topographic Survey in the district of Esztergom.

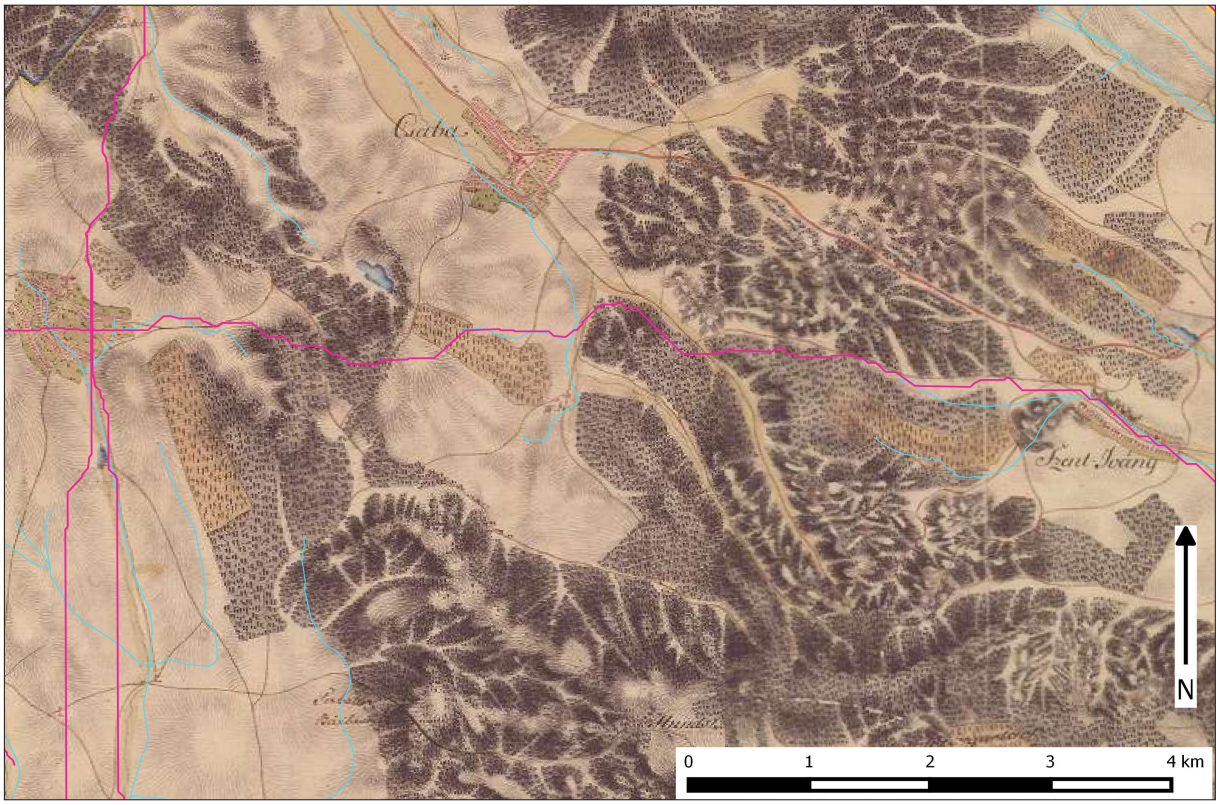

Fig. 12. Least cost paths in relation to roads of the First Topographic Survey on the territory of Piliscsaba.

Setbacks of the settlement pattern and LCP model

The model described does not answer many questions and the results cannot always be clearly interpreted. First of all, we always need to calculate with the fragmented picture we get through the archaeological material, non-balanced research and the low number of useful features applied in a model. Besides this, defining the centres of the significant settlements' clusters was based on a preconception, and the regularity observed in the results seems to be correct in the district of Esztergom and the South-Eastern part of the study area, but it is not certainly in place along the diagonal road or North from Budapest. In the territory of Pomáz according to the find material and epigraphic sources veterans were settled in the early phase of Roman occupation,[65] therefore settlements in the area did not necessary follow the same development as other parts of North-Eastern Pannonia.

The number of applied features (stone material, import/regional pottery) in the settlement pattern model was really low. The sizes of the Roman sites were not recorded separately from sites of another era; therefore I could not use these attributes for classification. As I did not have any direct contact with the find material of the field-walking projects, the time of existence could not be given with any confidence.

During LCP modelling it became clear that the elevation model I used is not suitable for precise work in areas with low relief. On this terrain tracks become completely straight and angular. Besides this it is necessary to note that the landscape South from the Gerecse Hills is not included in the present study. As a result it is possible, that the road running from South to North got behind the Nyakas Hill from the West, not the East. Until certain evidence supports it, least cost paths cannot be interpreted as real or existing roads.

Conclusion

Using stone as building material on a settlement in the North-Eastern part of Pannonia was indeed the indicator of Romanisation and wealth when it was found together with import or regional pottery from the 1st–3rd century AD. Using these criteria, I classified Roman settlement sites to be significant from an economic, social and cultural point of view. The aim was to better understand the distribution of significant sites and it seems that they built up individual settlement clusters. Their disposition only by applying the observations done on the excavated *vici* South-West of Budapest seems to be somehow regular. This tendency can be taken in parallel with the settlement pattern of Germania Inferior where *vici* developed every twenty kilometre,[66] although in Pannonia this distance may only be of six kilometres. This question still needs to be studied and cleared in the future.

The settlement pattern of the area developed probably along the geographical conditions of the study area. Relief determined not only the line of least cost paths, but also the economic conditions of a certain settlement. Dense settlement clouds existed along the least cost paths and also watercourses. Least cost paths seem to have also contributed to the rapid spread of Roman culture, lifestyle and wealth in the rural landscape.

65 Ottományi 2007b, 263.
66 Jeneson 2013, Fig. 6.19.

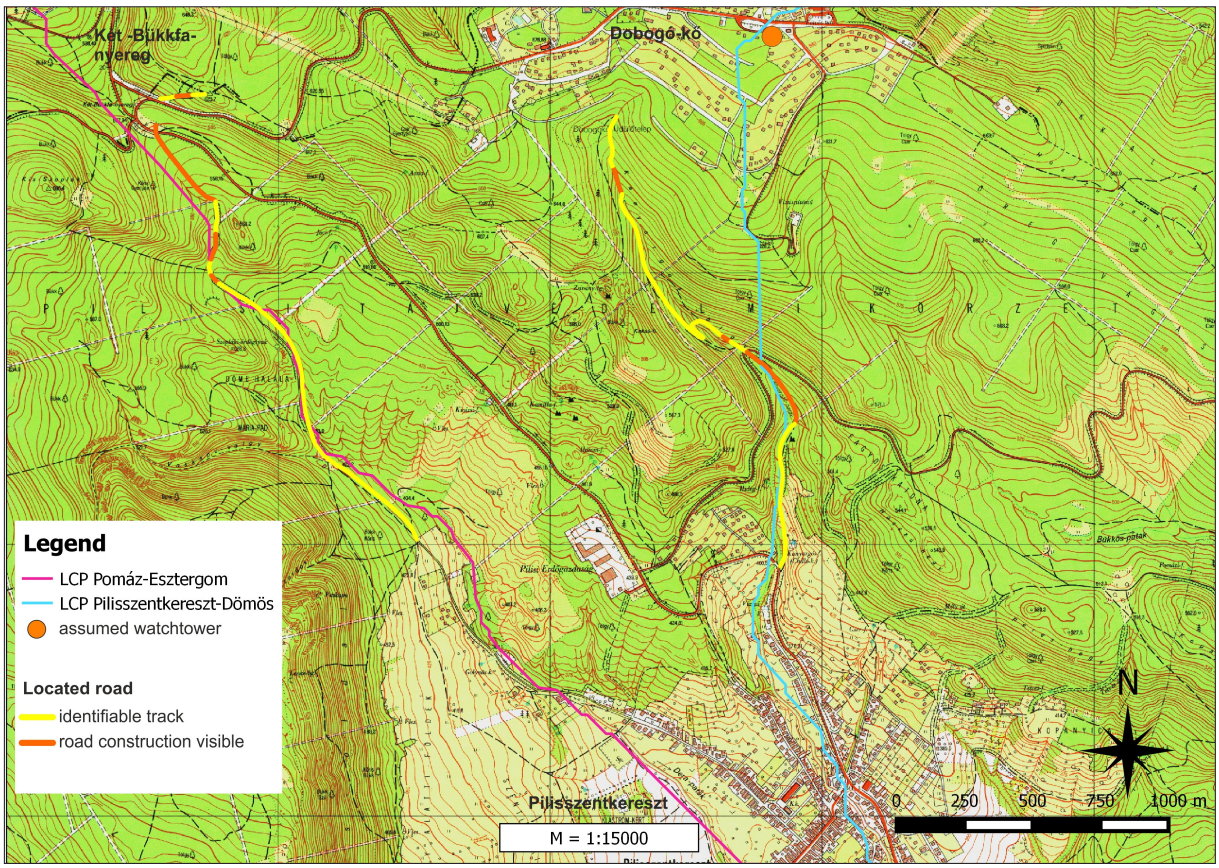

Fig. 13. Roads in the neighbourhood of Dobogó-kő
(based on http://sirasok.blog.hu/2010/04/13/osi_utak_a_pilisben Fig. 2).

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