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ANALYSIS OF LATE PLEISTOCENE AND HOLOCENE AEOLIAN LANDFORMS AND PHASES OF SAND MOVEMENT IN INNER SOMOGY

Theses of Dissertation

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1. Introduction, aims

While aeolian research in arid regions and deserts has been carried out since the 19th century (e.g. Philips 1882, Rae 1884, Cornish 1897, Davis 1899, Beadnell 1909, Keyes 1912, Bagnold 1941) scientific investigation started later in semi-arid and dry regions in the temperate zone (Cholnoky 1902, Kádár 1935, Thorp és Smith 1952, Borsy 1961, David 1977). In the second half of the 20th century, computer technology developed rapidly, resolution and availability of airborne and satellite imagery increased dramatically and travel to remote areas became easier, which supported a new phase of aeolian research.

There is an increasing demand and scientific aim to be able to predict changes in the aeolian environment. To be able to build reliable models cause-effect relationships, feedback cycles and the physical laws of sand movement need to be well investigated and fully understood. This can only be achieved through interdisciplinary research that focuses on investigating the complex interdependences of climate change – including precipitation, wind direction, wind velocity and wind permanency –, sand supply, grain size, soil type, vegetation and moisture content (Hugenholtz et al. 2010, de M. Luna et al. 2011, Barchyn és Hugenholtz 2012, Hugenholtz et al. 2012, Barchyn et al. 2014).

Inner Somogy is the third largest sand dune area in Hungary, which was formed on the alluvial fan of the paleo-Danube (Marosi 1970). Yet, in contrary with the two other aeolian regions, Inner Somogy is not in an elevated position, but lays lower than the surrounding landscape which results in a positive inflow of ground water that creates a unique environment, therefore the effects of climate change are different. Previeling wind direction is also different in Inner Somogy, here northernly winds formed the region, while other alluvial fans where subject to the effects of north-easterly winds. The first scientific investigation of this unique landscape was carried out by Cholnoky (n.d.) who described a large blowout–residual ridge–hummock form-assemblage. Marosi (1970) determined that the original grain size distribution of the alluvial fan was only partially modified during aeolian rework, and identified illuviation laminea, sand veins and wedges which indicate periglacial climate during the last ice age and also suggest that formation of the aeolian landforms terminated in the Weichselian. He also described parabolic dunes and classified the negative forms. Lóki (1981) created a detailed geomorphological map of Inner Somogy. All three authors argued that the main period of dune formation took place during the Weichselian glaciation, and landforms stabilised during the Late Glacial Maximum and were only modified by areal erosion in the Holocene. Sebe et al. (2011) argued that aeolian erosion was the prevailing formation factor during the glacial period of the Pleistocene and described Marcali-ridge – a wedge-shaped loess plateau dividing the two sand covered regions of Inner Somogy – as a yardang, however identifying dune types and dating the periods of sand movements were not part of their study.

The main aim of my research is to analyse the geomorphology of East Inner Somogy following the classical investigation of landform–material–process.

The aim of this research was to answer the following questions:
1) What type of landforms can be identified in East Inner Somogy?

What types of positive and negative landforms can be identified from topographic maps? Can the identified forms be classified according to their spatial distribution or morphometric parameters? What are the characteristic landscape patterns of the classes? Can landscape metric indices applied in the study of the spatial distribution of geomorphological forms? What relations can be identified between the spatial distribution of the landforms, the relief of the region and the location of valleys?

In this part of the study the aim was to identify the characteristic landforms of the region and investigate their spatial distribution as determine the spatial pattern and erosional and accumulational ratio of the region and imply to environmental condition at the time of dune formation.

2) When were the main phases of active aeolian formation and sand movement?

When were the main periods sand movement in Inner Somogy that can be determined by luminescence (OSL) dating? Beyond the main formation phase, when and where did local aeolian formation occur? How thick aeolian deposits were deposited during the active phases? What grain size was transported during the different sand movement periods?

The aim of the luminescence (OSL) dating is to determine the age of sand movements when the different classes of sand dunes deposited, and also to investigate the conditions when the forms were modified.

3) What are the grain size characteristics of the aeolian sediments and how complex is the internal structure of the landforms?

How does the grain size distrubiton of the sand dunes change along the wind direction? Do morphometric classes of landforms also differ in their grain size? Are there any changes in grain size along a borehole in a form? Can the locally samples data be extended to larger areas using GPR? What are the main characteristics of sand deposits? What were the building steps which led to the current shape of a form?

Grain size distribution analysis was carried out to determine the conditions of sand dune deposition. The scale of the sampling also allows investigation of sand deposited in pulses, soil formation which occur between active aeolian phases and newly activated sand supply. The aim with the GPR surveying was to extend the borehole data and study the internal structure and bounding surfaces of the dunes.

4) When and to what extend did climate change and anthropogenic activity influence the landscape development in Inner Somogy?

Does the measured OSL data and determined aeolian phases correlate with previously published paleo-climate reconstructions? Did the sand movement periods occur during the dry and cold phases of the Pleistocene and dry and warm phases of the Holocene? Can it be determined if the aeolian phases where climate induced? What classes of formed stabilised during these active periods? What are the grain size characteristics of the different sand movement phases and how thick was the deposited sand in each phase? Can the aeolian periods that occurred during wet climate conditions be related to archaeological findings and therefore determine they were anthropogenic induced? During which historical period did sand movements occur? Did different types of forms deposited during these times? What are the grain size and structural characteristics of the dunes formed as a result of human disturbance?

With all these, the aim is to describe the landscape evolution of East Inner Somogy, therefore investigate the complex relationships that form and modify the landforms of this region.

2. Methods

2.1. Identification and classification of aeolian landforms

Aeolian landforms were identified in ArcGIS on a 1610 km^2 research area using 1:10,000 scale topographic maps (1981-1989). The landforms were located by outlining their base line, then their morphometric parameters where calculated in a GIS database. The following parameters were calculated for the positive forms: area (A_p), length of arc (L_{arc}), length of chord (L_{chord}), height (H), average width (A_p/L_{arc}), curvature (L_{arc}/L_{chord}); and for the negative forms: area (A_n), depth (D), length (L_n), width (W).

The position of positive forms reveals dune hierarchies, in some areas positive forms stabilised in groups, often connected or superimposed. Five hierarchy levels were identified in Inner Somogy: simple dunes with no level of superimposition and hierarchy levels 1-4 superimposed on each other.

During the classification of positive forms using their morphometric parameters, first, curvature was used to classify non-crescentic forms where length of chord (L_{chord}) could not be calculated or is equal with length of arc (L_{arc}). Crescentic forms were further classified based on the length of arc to classes of (1) L_{arc} >1000 m, (2) L_{arc} = 160-1000 m and (3) L_{arc}< 160 m. Large forms (L_{arc} >1000 m) were further separated to subclasses of A_p/L_{arc} >250 and A_p/L_{arc} <250; while medium sized dunes (L_{arc} = 160-1000 m) have subclasses of A_p/L_{arc} >110 m, 110 m >A_p/L_{arc} >62 m, and A_p/L_{arc} <62 m. the smallest crescentic forms (L_{arc} ≤160 m) were not classified further.

Negative forms were first classified by their area and large forms were separated (A_n>83 000 m^2), then length/width ratio was calculated to created subclasses of smaller forms, which created the groups of round (L_n/W< 2), oval (2 < L_n/W < 4) and elongated (L_n/W > 4) forms.

2.2. Landscape metrics in Geomorphology

One of my research aims was to quantitatively describe the spatial distribution of the aeolian landforms, investigate the differences between form classes and their spatial characteristics. Aeolian sand dunes and deflational depressions can be interpreted as patches in the landscape which allows the use of landscape metric analysis methodology – with limitations –

to quantitatively investigate their spatial distribution. For the analysis, the geodatabase of positive and negative landforms was used. New landscape indices were calculated in ArcGIS 10 with Patch Analyst 5.1 (Rempel et al. 2012) and vLATE 2.0 (Land and Tiede 2003) extensions and further parameters were added using spreadsheets. To analyse the distribution of the forms the study area was dissected into 1.0 km^2-size hexagonal units. The landforms were converted into points, which were always located within the original form, usually close to the summit of the dune-head or in the deepest part of a negative form. Therefore, the hexagonal units did not cut through the forms, so all of them were examined just once. The hexagonal units were grouped for analysis using the Natural Breaks method, which creates groups by defining the breakpoint of the distribution curve.

2.3. Luminescence (OSL) dating

Samples were corrected from each hierarchy level and morphometric classes to measure the age of sand deposition using optically stimulated luminescence dating. Altogether 22 samples were analysed which provided data to determine the age of sand movements and identify which forms developed in the different phases of aeolian activity. The measurements were carried out following the Single Aliquot Regeneration (SAR) protocol and the equivalent doses were determined using RISØ TL/OSL DA-15 instrument with beta radiation source of 0.114 Gy/s dose rate.

2.4. Grain size analysis

Morphometric classes were also sampled at 17 locations at every 10 cm to collect sand for grain size analysis. The data can reveal the transported sediment characteristics of each aeolian movement period which determines the environmental conditions prevailing at the time of deflation and accumulation. The collected 345 samples were analysed with Analysette 22 MicroTec plus laser diffraction grain size analysing instrument. Combined Udden-Wenthworth scale was used for grain size classification (Blott and Pye, 2012) and statistical parameters were calculated according to the method of Folk and Ward (1957) in Gradistat (Blott and Pye, 2001).

2.5. Internal structure of the aeolian forms

GPR (ground penetrating radar) was used to determine bounding surfaces and fine sediment structures so the morpho-dynamics of the landforms can be studied. In this research, a GSSI radar with 200 MHz antennae was used to record 15 surveys with length of 86-445 m which included longitudinal and cross sections of the identified dune classes. Survey locations were chosen to include the sites of grain size analysis and OSL sampling. RADAN-GSSI software was used for interpretation of survey data.

3. Results

3.1. Aeolian landforms of East Inner Somogy

3.1.1. Altogether, 4403 positive and 2911 negative aeolian landforms were identified in East Inner Somogy.

3.1.2. Superimposition, i.e. the hierarchy of sand dunes was identified not only in deserts, but also in semi-arid regions. In East Inner Somogy, 5 hierarchy levels were determined: the isolated simple dunes and superimposed dunes creating hierarchy level 1-4.

3.1.3. Seven morphometric classes were identified using the morphometric parameters of the positive forms. 26% of all forms are elongated ridges, but the most common landforms are parabolic dunes which were further classified based in their size and degree of infilling. The large, partially filled parabolic dunes (L_{arc} = 1024–12 912 m, A/L_{arc} = 256–1246 m) indicate moderate sand supply. This dune type constitutes merely 0.95% of all dunes but covers 4% of the study area and most of them of them belong to the hierarchy level 1, only a few to level 2. The large, unfilled parabolic dunes (L_{arc} = 1002–6391 m, A/Larc = 46– 250 m) indicate limited sand supply during their formation. Almost 8% of all dunes belong to this class, but due to their unfilled shape, they cover only 4.9% of the study area. Almost all of them belong to hierarchy level 2, though some members appear in hierarchy level 3.

The medium-size parabolic dunes (1000 m >L_{arc} >160 m) are one magnitude smaller than large forms and were further classified to three sub-classes based on the A/L_{arc} ratio. The medium-size filled parabolic dunes refer to abundant sand supply during their formation. Representing ca. 20% of all dunes, the members of this class have diverse size (L_{arc} = 161–997 m, A/L_{arc} = 110–1023 m) and occupy 4.7% of the study area. They are scattered all over the study area, some are located on the heads of large parabolic dunes, and some appear in rows perpendicular to wind direction, but the majority (ca. 90%) belong to hierarchy level 2. The medium-size partially filled parabolic dunes (L_{arc}

= 161–998 m, A/L_{arc}= 62–109 m) developed when the sand supply was moderate. They are the most abundant forms (22%), though due to the reduced amount of accumulated sediment, they cover only 2.3% of the study area. These dunes appear in hierarchy levels 2–4, though most of them (90%) belong to level 2. Sediment supply was limited when the medium-size unfilled parabolic dunes (L_{arc} = 161–995 m, A/L_{arc} = 21–6198 m) formed. They represent only 11% of all forms and cover only 0.5% of the study area. They mostly belong to hierarchy level 2, but some appear in levels 3 and 4.

The smallest crescentic dunes are hummocks (L_{arc} = 28–159 m). They represent only 11% of the forms and cover only 0.3% of the area. This class often appears on the highest surfaces of larger dunes and mostly builds up the hierarchy level 4.

3.1.4. The negative forms were classified into four morphometric classes based on their morphometric parameters. The smallest forms are blowout holes which are round-shaped and represent 50% of all forms. The volume of this class is the largest so most of the deflated sand was blown out from these small forms as moisture content was high during the aeolian phases and it prevented further large-scale erosion. Oval-shaped blowouts formed where sediments were drier and sideways erosion of small holes was possible. This is also an abundant form as 42% of all depressions belong to this class. Elongated blowouts developed where sand could be eroded for some distance parallel with wind direction. However, environmental conditions rarely favoured their formation, only 5% of all forms are elongated blowouts. Deflation hollows are the largest negative forms, they represent only 3% of all depressions, as humid climate did not allow erosion from large patches.

3.2. Morphological zones and spatial pattern of the study area

3.2.1. Location of the hierarchy levels of positives forms determine morphological zones in the region. There are three areas where the full extent of superimposition (hierarchy level 1-4) developed, so accumulation dominated at these locations and they were identified as northern, central and southern accumulational zones. The rest of the region can be interpreted as an erosional-transportational zone or matrix into which accumulational zones are imbedded and is characterised by transportational forms belonging to simple dunes and hierarchy level 1 or 2. Accumulational zones are in an elevated position compared to their surroundings and the level 1, large, partially filled parabolic dunes provide their base. The average dune density here is 5.1 form/km^2 and dunes cover 59% of the area of the zones. On contrary, form density is only 2.5 form/km^2 in the erosional-transportational zone with dunes covering only 16% of the area.

3.3. OSL dating of aeolian landforms

3.3.1. Based on OSL dating, the oldest sample is 21.22±1.54 thousand years old, while the youngest was deposited only 0.23±0.03 thousand years ago. Thus, the aeolian activity in Inner Somogy can be reconstructed from the Last Glacial Maximum until the end of the Holocene. Sand movements did not terminate at the end of Pleistocene, formation of dunes continued throughout the Holocene (Kiss et al.2012).

3.3.2. Large, partially filled parabolic dunes in hierarch level 1 formed durng the Last Glacial Maximum and proved the base of the landscape. Presumably, aeolian activity was widespread and continuous during Late Pleistocene, however its intensity gradually decreased. During the Oldest Dryas large in size, but only unfilled parabolic dines stabilised, then medium-size, filled parabolic dunes formed in the Younger Dryas. At the beginning of the Holocene, aeolian activity gradually declined. During the Preboreal and Boreal phases sporadic formation of large and medium-size parabolic dunes occurred. The surface remained stable during the other parts of Holocene. Only small scale local sand activity was determined in the Subboreal and Subatlatic phases when new forms developed as a result of anthropogenic disturbance.

3.4. Grain size distribution and internal structure of sand dunes

3.4.1. The large parabolic dunes consist of deposits with varied grain size characteristics which were presumably deposited during several sand movement periods.

3.4.2. The grain size is coarser closer to the current surface of the dunes indicating stronger winds during formation. During the Holocene, dense vegetation stabilised the landforms and only stronger winds could create new dunes.

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3.4.4. Sand deposits in hummock dunes are mostly homogenous which is an indicator of fast formation or these dunes.

3.4.5. In deflational hollows silty and sandy layers alternate. During wet periods, muddy bogs formed at the bottom of depressions while during dry periods sand layers covered these sediments in varied thickness.

3.4.6. The coarsest samples were selected from each borehole and their d_{90} values indicate that sand deposits are coarser in the northern part of the region (d_{90}=382-446 μm), then grain size decreases towards the central parts (d_{90}=241-419 μm), while it becomes coarser again in the south (d_{90}=242-616 μm). These results are in contrary with previous research which found continuously decreasing grain size towards the south.

3.4.7. Average values of the morphometric classes become gradually coarser from the large parabolic dunes (d_{90mean} = 353 μm) through the medium-size ones (d_{90mean} = 385 μm) to the hummocks (d_{90mean} = 499 μm). Therefore, as the size of the form decreases, their grain size increases, referring to limited sand supply and simultaneously denser vegetation, which restrict the spatial distribution of aeolian activity.

3.4.8. Plotting OSL ages and d90 values of the samples shows that older forms are characterised by finer grain size distribution, then transported grain size gradually became coarser. However, it is important to note that anthropogenic induced young sand movements only occur locally in disturbed areas. Probably, due to wind-tunnel effect the wind speed was high, thus coarse material could also be eroded and transported. However, it was transported only a very short distance and deposited soon unclassified.

3.4.8. GPR surveys show consequently deposited sand layers and prevailing wind direction and depositional sequences can be interpreted. Bounding surfaces reveal that the dunes were forming throughout several aeolian phases. Sequential sand movements modified the original dune, smaller forms where covered while secondary erosion created local depressions which were later filled with sand.

3.5. Landscape development of East Inner

3.5.1. In accordance with previous paleo-climate and paleo-botanical research, the most widespread and intensive aeolian formation in Inner

Somogy took place during the Upper Pleniglacial. Seven analysed samples determined sand deposition in this period (OSZ575:16.25±2.12 ka, OSZ272: 17.02±2.23 ka, OSZ572: 17.12±2.47 ka, OSZ271: 17.42±2.77 ka, OSZ858: 18.52±1.11 ka, OSZ273: 20.48±1.02 ka, OSZ857: 21.22±1.54 ka), and the data covers the entire late glacial (16.25±2.12 ka – 21.22±1.54 ka). Large, partially filled parabolic dunes belonging to hierarchy level 1 formed in this phase which indicates intense deflation and abundant sand supply so aeolian forms could freely form. At the same time, large, unfilled parabolic dunes representing hierarchy level 2 formed superimposed on level 1 dunes, implying a decline in aeolian activity. Grain size data reveal that during the Last Glacial Maximum finer (OSZ857: d_{90} = 232 μm, OSZ273: d_{90} = 224 μm), then later during the Upper Pleniglacial considerably coarser (OSZ858: d_{90} = 390 μm, OSZ271: d_{90} = 410 μm) sand deposited. The main geomorphological structure of the region formed in this period, large dunes creating the bases for the accumulational zones stabilised and aeolian formation was active throughout the area.

3.5.2. During the Ságvár-Lascaux Interglacial widespread sand movement took place the southern (OSZ271: 17.42±2.77 ka, OSZ572: 17.12±2.47 ka, OSZ272: 17.02±2.23 ka, OSZ575: 16.25±2.12 ka) and central (OSZ858: 18.52±1.11 ka) parts of the region. However, the intensity of aeolian formation decreased as large, unfilled and medium-size, partially filled parabolic dunes stabilised. Presumably, vegetation cover was still scarce in Inner Somogy allowing continued aeolian activity despite the mild climate, however, it was less intensive.

3.5.3. Based on the results from this study Bolling and Allerod Interstadials cannot be separated as Oldest Dryas sand movement could not be determined because considering the errors of the measured ages they cover the full length of the Late Glacial (OSZ269: 11.94±1.29 ka, OSZ268: 13.86±1.93 ka, OSZ570: 14.73±0.98 ka). Although average ages show that during the Older and Younger Dryas medium-size, filled parabolic dunes formed in the centres of the accumulational zones creating hierarchy level 3. Formation of infilled dunes indicate abundant sand supply, while their elevated location (level 3) imply that level 1 and 2 stabilised previously during the humid interstadials. The rapidly changing environment during the short period of Late Glacial induced the deflation of large quantities of sand, but the sediment stabilised quickly which resulted in the formation of smaller, but more infilled dunes. Scarce vegetation was present only in patches where large-size dunes could still form, but with limited sand supply they were all only unfilled (OSZ571: 13.23±1.71 ka). Transported grain size decreased (OSZ269: d_{90} = 388 µm, OSZ268: d_{90} = 389 µm) which also emphasise declining wind power. The OSL age of the loessy sediment covering the studied longitudinal ridge in the western part of the region is 13.31±0.74 ka (OSZ856), so it has a similar age as the dated medium-size parabolic dunes in the central part of the area. Therefore, while parabolic dunes were migration southward in the centre of the region, the fine grains of the deflated sediment deposited at the boundaries covering previously stabilised forms.

3.5.4. At the beginning of the Holocene, during the preboreal phase climate was getting warmer, but little precipitation limited the formation of closed vegetation cover which allowed further sand movement. In Inner Somogy simple dunes stabilised in the erosional-transportational zone (OSZ860: 10.77±0.71 ka, OSZ859: 11.11±0.64 ka). Large and medium-size parabolic dunes could still form, however with decreasing sand supply only unfilled and partially filled dunes stabilised. These formed stabilised during transportation and the deflated sand could not become part of larger dunes or accumulational zones. As a result of declining aeolian activity, sediment was only transported on a short distance and its grain size also decreased (OSZ859: d_{90} = 269 µm).

3.5.5. Only one dated dune deposited during the transition period between the boreal and Atlantic phase (OSZ267: 8.24±1.24 ka). Presumably, climate was drier during the boreal phase in Transdanubia creating favourable conditions for local sand movement, however as climate became humid at the beginning of the Atlantic phase, the deflated sand stabilised very rapidly. Aeolian activity only occurred in small patches but was intensive locally as a filled dune was dated from this period. On dry climate the elevated heads of larger dunes probably remobilised and a new, 3rd level dune formed. At the same time, wind velocity was sufficient to transport relatively coarse grain size (OSZ267: d_{90} = 367 µm).

3.5.6. The OSL age of the medium-size, infilled parabolic dunes located in an elevated position in the northern accumulational zone is 2.99±0.19 ka (OSZ855), so it stabilised during the Subboreal phase. At this time

Bronze age population migrated to Transdanubia and their activity was so intensive, it allowed the formation of infilled parabolic dunes. The grain size of the locally transported sediment was coarser A (OSZ855: d_{90} = 382 μm) than sediments from previous aeolian phases, which might be a result of increased wind velocity locally enhanced by wind-tunnel effect from nearby forest clearances. However, the transported sand could have also been sourced from the deeper layers of the alluvial fan and only travelled short distance.

3.5.7. The youngest dated forms stabilised during the Subatlantic phase, in the 17th and/or 18th century (OSZ265: 0.23±0.03 ka, OSZ266: 0.32±0.07 ka, OSZ264: 0.30±0.15 ka). Presumably, as a result of overgrazing or change in agricultural methods sand was deflated locally and deposited forming a small, level 4 hummock dune. Very coarse grain size indicate that sand was transported only a short distance (OSZ265 d_{90} = 461 μm). GPR surveying showed that on the humid climate of this period sand deflated as a result of anthropogenic disturbance was deposited in sand sheets. The formation of new landforms was only possible in the elevated, therefore dry heads of accumulational zones where small, coarse grained hummock dunes formed locally.

Summary, Theses

1. Superimposed dunes and their hierarchy levels were identified on the studied semi-arid aeolian region, previously similar hierarchy levels were only described from arid regions and deserts.

2. OSL dating of superimposed dunes and analysis of GRP surveys prove that several aeolian sand movement phases occurred.

3. Landscape ecology methodology, landscape metrics analysis can be used – with limitations – in geomorphological research to quantitatively describe the spatial distribution of landforms. The characteristics of morphological zones were investigated and compared in Inner Somogy using landscape metrics.

4. In certain environmental conditions loess deposition can occur during sand movement periods. During the Dyras phases parabolic dunes were migrating in the central parts of East Inner Somogy, while the deflated finer grains were deposited as a loess blanket covering previously stabilised landforms at the boundaries of the region.

5. Decreasing dune size and their coarser grain size indicate that aeolian activity gradually became limited to local patches while stronger winds were needed to mobilise the moist sand.

6. Sand movement phases during the Upper Pleniglacial, Late Glacial, Preboreal and Subboreal phases determined in Inner Somogy correlate with aeolian period identified in other regions. Therefore, climatic conditions and vegetation cover allowed widespread aeolian formation in the Carpathian Basin at the end of the last glacial. However, sand movements dated at 8,24±1,24 ka (Boreal phase) and at 0,30±0,15 ka (Subatlantic phase) occurred only locally as a result of less dry local climate and the disturbance from anthropogenic activity.

Publications related to the dissertation

Kiss, T., **Györgyövics, K.,** Sipos, Gy., 2012. Homokformák morfológiai tulajdonságainak és korának vizsgálata Belső-Somogy területén. Földrajzi Közlemények 136 (4), 361-375.

Györgyövics, K., Kiss, T., 2013. Dune hierarchy and morphometric classes of the parabolic sand dune association of Inner Somogy, Hungary. Studia Geomorphologica Carpatho-Balcanica 47 (1), 31–48.

Györgyövics, K., Kiss, T., Sipos, Gy., 2014. Grain size distribution of stabilised aeolian dune sediments in Inner Somogy, Hungary. Journal of Environmental Geography 7 (3-4), 49-58.

Kiss, T., Hernesz, P., Sümeghy, B., **Györgyövics, K.,** Sipos, Gy., 2014: The evolution of the Great Hungarian Plain fluvial system – Fluvial processes in a subsiding area from the beginning of the Weichselian. Quaternary International 388 (19), 142-155.

Györgyövics, K., Kiss, T., 2016. Landscape metrics applied in geomorphology: hierarchy and morphometric classes of sand dunes in Inner Somogy, Hungary. Hungarian Geographical Bulletin 65 (3), 271-282.

Györgyövics, K., Kiss, T., 2016. Belső-Somogy eolikus homokformáinak térbeli elemzése tájmetriai paraméterek segítségével. Tájhasználat és tájvédelem – kihívások és lehetőségek. VI. Magyar Tájökológiai Konferencia előadásai. Budapest, 42-53.

Györgyövics, K., Katona, O., 2016. Mennyiben pontosíthatja a georadaros vizsgálat a homokterületek geomorfológiai kutatásának eredményeit? Komplex tanulmány egy belső-somogyi homokbuckán. A Kaposvári Rippl-Rónai Múzeum Közleményei 04. 5-12.