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Geospatial Technologies for Investigating Roman Settlement Structures in the Noric-Pannonian Borderland

Selected Aspects of a New Research Project

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Abstract: A new research project, currently in the application stage, wants to contribute to research into the settlement structure of the Roman empire in the territory of Flavia Solva (Noricum/Southeast Austria).
In a preview of the project, we present new methods to combine state of the art spatial analysis and remote sensing on the one hand, and archaeological evaluation of find-spots on the other hand, integrating geospatial and archaeological data from diverse sources and qualities.
Based on this data model, descriptive statistical methods are employed to characterize the status quo in a designated test area in Southeastern Noricum, and to implement geographical concepts by GIS-analytic methods to gain new insights from the combination of thematically related layers. The result of this first attempt is the establishment of a sound geospatial and geostatistical workflow in a multidisciplinary approach of the involved researchers for the project, which can be used as a basis for further analysis with special focus on the spatial aspect.

Keywords: Settlement Archaeology; Landscape Analysis; Geostatistics; GIS

Introduction

This article forms part of the basic outline of the research project “IDA-ProSe – InterDisciplinary Analyses of Patterns of Roman Settlements”, currently in preparation for application at the Austrian Science Fund (FWF). The goal of the project is to clarify the Roman age settlement structure in the province Noricum, in particular the Southern part less influenced by the military presence near the Danube *river borderline*.
The focus of the first stage of the project is the valley of the Lassnitz in Western Styria, tributary to the principal river of Southeast Austria, the Mur. It covers an area of c. 300 km^2 on a length of slightly over 20 km, and is enclosed by the 2000 m high Koralm in the West and lower hill ranges parallel to the river course to North and South.
In 1995, the Austrian Federal Railway company started work on the Koralm railway line in this valley, a part of the currently largest building project in the Austrian rail infrastructure. The well-known density of archaeological find-spots along the Lassnitz valley necessitated a close cooperation from the planning stage on between the developer and heritage protection authorities, represented on site by ARGIS Archäologie und Geodaten Service (FUCHS et al. 1997).

The research resulted in the best-documented area-wide dataset on an enclosed settlement area in Austria to date, containing findings ranging from Neolithic to modern times. Publication work on several (geographical and chronological) aspects of these findings is ongoing; as part of these, the proposed project IDA-ProSe will cover the research on Roman remains.

Objectives

So far, the settlement pattern of rural Noricum has been difficult to ascertain. While the general pattern and also the density of Roman settlements are well-known in other areas of the Roman empire, e.g. in the German mining areas (WENDT & ZIMMERMANN 2010), the amount of known rural settlements in perialpine Styria (an area of over 3500 km2) so far ranged around 30; consequently, a rather low settlement density was assumed (MODRIJAN 1969, ZÖHRER 2007, LAMM & MARKO 2012).
Contrary to this assumption, the new findings in the Lassnitz valley clearly show a regular pattern of rural settlements distanced roughly 1.5 to 2 km from each other, in some cases less than 1 km. This pattern in a minor side valley without transit traffic routes, ground resources or other visible reasons for an unusually high population density throws a new light on settlement density and distribution in Southeast Noricum in general. To clarify and substantiate these new results, the project IDA-PRoSe intends to use sophisticated GIS technology in order to provide a high resolution reconstruction of the valley in Roman times in a cooperative effort of archaeology, geology, botany, and geotechnology, and from this to develop a set of rules to visualize the spatial distribution of Roman settlement in the wider area, and the relationships between the single sites.

In a first step to this end, all available data will be collected and introduced into appropriate GIS layers, ranging from 19th century find reports, the archives of the local museums and the Bundesdenkmalamt database, and advice on building from the ancient writers on the one hand, to descriptive data from various scientific points of view, such as geology, geomorphology, or biology on the other hand. Examples for those layers include the geological map of the Lassnitz valley, water supply, ground relief, and traffic infrastructure; further aspects to investigate will be pre-Roman structures, or cultic locational factors. All of these will be evaluated and weighted according to their apparent importance in influencing the choice of building site.

Geographic setting of the Lassnitz Valley

The investigation area is situated on both sides of the middle sector of Lassnitz Valley (20 km), which is embedded in the tertiary alpine foreland of Western Styria (Fig. 1). The area consists primarily of elongated ridges and flat valleys, which can have a broad extent (up to 2–5 km) along the main rivers of Kainach, Lassnitz, and Sulm. The western boundary of the study area is situated at the edge of the alpine mountains rim of the Koralm near the town of Deutschlandsberg (370 m). The upper (western) part of the Lassnitz River has cut into the crystalline basement of the Alpine Koralm mountains in form of a narrow, deep valley. From Deutschlandsberg downwards the Lassnitz River is fanning out with an ENE direction in a wide valley bottom. Due to the isolated ascending Wildon Buchkogel (550 m), which is partly formed by paleozoic limestone, the Lassnitz Valley changes its direction south of Schönberg (295 m) towards SE. The Lassnitz

River finally flows along the eastern boundary of the Leibnitz Basement to the south and into the main Mur River. The main tributaries of the Mur River (Lassnitz, Sulm, Kainach) in the Western Styrian Foreland have their upper catchment in the Koralm mountains (2140 m, crystalline rocks), the lower part of the rivers have been eroded in the tertiary sediments of the Styrian Basin, which consist of long ridges with a max. height between 400–450 m. In the individual valleys quaternary sediments of different ages were formed.

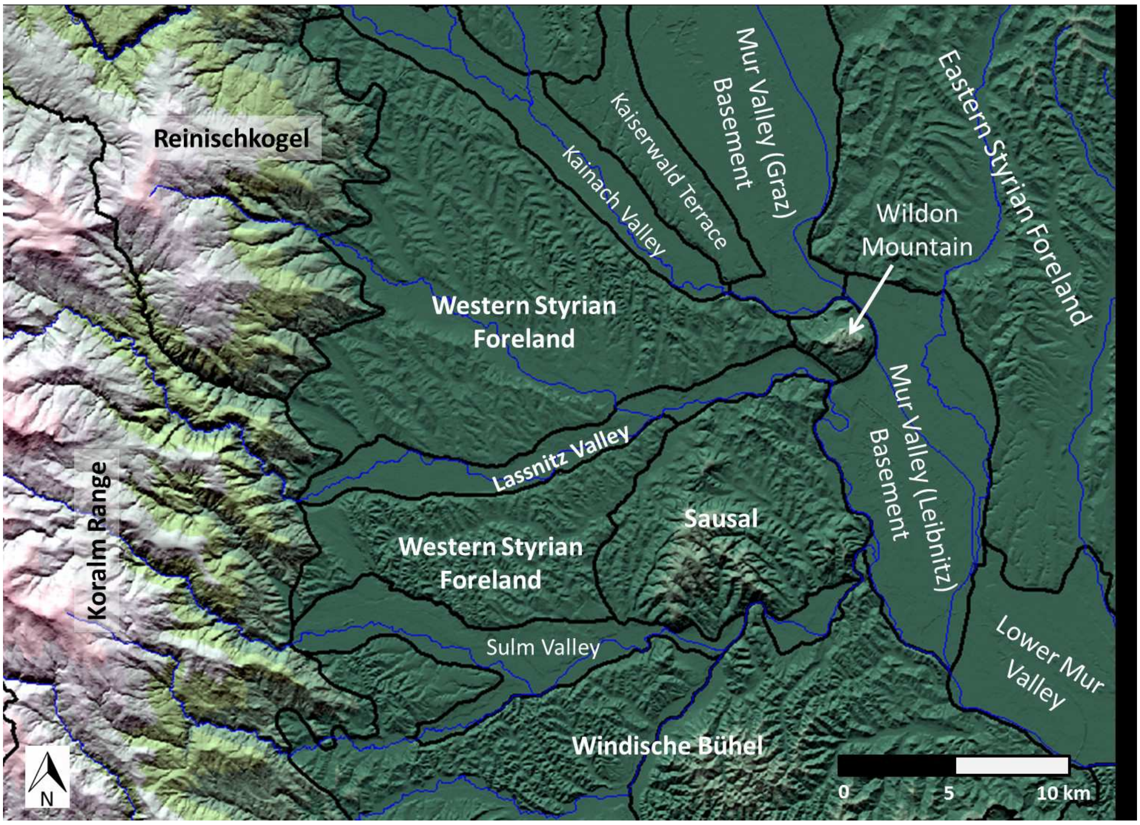

Fig.1 – Landscape Units of Western Styria (Data Source GIS Steiermark, own drawing)

The western part of the Lassnitz Valley is accompanied to the north and south by the Western Styrian Foreland. From the mouth of the Gleinz River at Zehnsdorf (the main southern tributary) the valley is accompanied briefly by the northern foothills of the Sausal. The Sausal (Demmerkogel: 671 m) itself is called a small mountain range with great cultural and natural landscape autonomy (Lieb, 1991). At the hamlet of Mollitsch (410 m), paleozoic sediments as a part of the Sausal Crystalline borders the Lassnitz Valley on the south, while in the eastern part of the valley (near the main Mur River basement) tertiary sands occupy the accompanying ridges.

Quaternary landscape development

For the scope of the project the quaternary landscape development is particularly important, since in addition to the geological embedding in the Tertiary Western Styrian Foreland, also climatic influence factors (such as the alteration of cold and warm periods, and the effects of post-glacial climate variability), and finally human settlers have shaped the landscape of the Lassnitz Valley (Fig. 2). The mighty valley bottom of the Lassnitz bears no relation to the relatively modest rivulet of nowadays. During the cold periods (Pleistocene until about 12.000 BP) the studied section of the Lassnitz Valley was under the climate influence of the periglacial zone. According to PASCHINGER (1974), the timberline of the pleistocene period was lower than today at a height of 500 m a.s.l. or even lower. For this reason the adjacent mountain ridge area was characterized by an intense frost weathering and high debris production, which was transported downwards by the rivers. These mighty gravel sediments along alluvial cones filled up the foreland valleys during this cold period, and were cut again in the following warm periods (UNTERSWEG 1983).

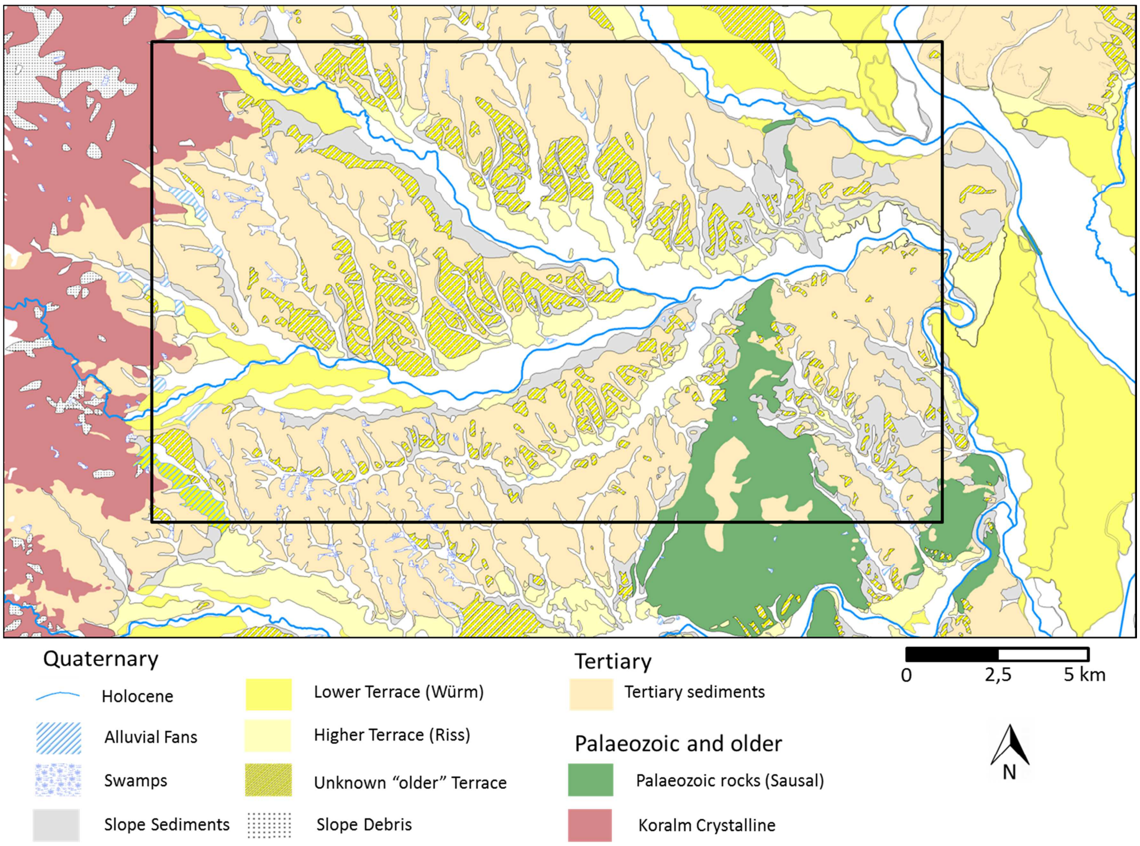

Fig. 2 – Geological sketch map of the investigation area (Data source: GIS Steiermark, own drawing)

Due to the multiple interactions of accumulation and erosion during the Pleistocene alluvial cones were trenched again. A sequence of nested terraces occurs. The Pleistocene gravel deposits in the Western Styrian Valleys are formed much more modest in size and in extent compared to the large alpine rivers of Mur and Drau, which had huge glaciated areas in their upper catchment. For this reason, there is often a lack of large and highly visible terraces on the Kainach, the Lassnitz and Sulm Valley (LANA 1991). After EISENHUT (1983) the upper part of the investigation area is formed by a wide alluvial cone from the Würm period, which is situated at the border between the alpine mountains and the foreland. However, the sediments are diving down under the younger floodplain sediments very soon. These areas are attributed to the low terrace system. Gravels from the Würm period are dominating the main Mur Valley, whereas these sediments lie mostly under the recent flood sediments in the Western Styrian Valley bottoms. Remains of these gravels are found only slightly above the recent flood plain of the Lassnitz River, where they are covering brown soils instead of the floodplain soils. These brown soils provide best conditions for intensive

agricultural use. This higher valley bottom is also a preferred settlement area, especially along the Lassnitz Valley between Deutschlandsberg and Gross St. Florian (QUEHENBERGER 2001).
In the Lassnitz Valley the occurrence of higher terrace remains can be observed mainly to the northern part of the valley near Oberbergla, Petzelsdorf and north of Gussendorf; in the wedge between Stainz- and Lassnitz Valley at altitudes of 330–340 m (QUEHENBERGER 2001). An aeolian sedimentation was involved in the design of the morphological Lassnitz Valley as well. From the sparsely vegetated gravel fields in the valley bottom fine material was blown out and deposited in the upper parts of the accompanying areas during cold periods. Today, relicts of this sedimentation can be found in pseudogley soils on higher terraces. In contrast to the Mur Valley, where the lowest terrace system is corresponding to the Würm period (from 71.000 until 12.000 BP) the lowest terraces in the Lassnitz Valley belong to the older Riss period (200.000 until 130.000 BP), while aeolian sediments can be assigned to the Würm period.
During the Late Glacial Period (18.000–12.000 BP), there was a final, strong revival of solifluidal processes in the Tertiary Styrian Foreland (RIEDL 1961). The reactivation of geomorphological processes and the associated accumulation can be observed by a fine sediment cover of alluvial cones, the embankment of the subrecent floodplain and the formation of lower slope trains, alluvial fans, dents, ravines and small valleys (EISENHUT 1965). With the ending of the cold period a lessening of the strong material replenishment can be observed from the beginning of the Holocene (EISENHUT 1965). The Holocene normalizes the water balance of the river, the huge sedimentation expires and the Lassnitz River cannot dominate the whole valley any longer. The Lassnitz River now cuts into the gravel sediments, extends its erosion laterally and creates a narrow flood plain with changing meanders (EISENHUT 1965), no longer able to provide a continuous “recent flood plain”. During floods it undercut the meandering curves and built up a natural river dam, which is typical for the alpine foreland in this area. These processes continue until the implementation of extensive regulations between 1959 and 1979. Nowadays only during snowmelt in springtime and heavy rainfall during summer time, floods can occur at the recent valley bottom.

The climatic Roman optimum and land cover

The main geomorphological processes during the Roman Empire are focused on the small floodplains of the Lassnitz River and its tributaries, and, depending on the land use intensity, on erosion processes on hill slopes. The centuries before the Common Era were characterized by weak solar activity. After these colder periods with huge migration activities, throughout Central Europe trees show very large growth homogeneity; growth structure in all trees was the same, indicating no local drought or storm events. There was a balanced climate without severe weather anomalies for about 200 years (SIROCKO 2012). In general, the time of the Romans is described as the “Roman Climatic Optimum” or “Roman Warm Period”. The climatic situation during the Roman Empire is comparable to the situation of today. In Central Europe a climatic deterioration began in and lasted until the 9th century. There is a general temperature deterioration in the range of 1–1.5°C, which is mainly inferred from indirect evidence and statements of the tree line in the Alps, glacier advances, changes in coastlines and the deterioration of conditions for growing corn and wine. More details of the development of the climatic condition can be found in MCCORMICK et al. (2012). BEHRINGER (2007) refers to the manifold consequences of this climatic deterioration: a dramatic population decline, frequent crop failures and famines, epidemics and animal diseases evoked a period of uncertainty in Europe.

It is supposed that during the Roman period the investigation area was subjected to an intensive land use, with cultivated land on the margins of the valley bottom and on flat and gently sloped hill areas. The recent floodplain and steep slopes of the tertiary ridges and hills were covered by natural forest vegetation, whereas higher areas on the valley bottom and alluvial fans and flat areas as well as gentle slopes on the ridges were occupied by agricultural structures. The investigation area was dominated by mixed broad leaf forest, which was attractive for Romans settlers. The Romans brought from the Mediterranean familiar tree species, such as sweet chestnut (Castanea sativa), horse chestnut (Aesculum hippocastanum) and walnut (Juglans regia). In addition, they used the robust wood of chestnut in vineyards (cf. KÜSTER 1996). In the context of settlements, the forests were exploited for timber during a long time. Therefore the beech tree (Fagus sylvatica) was decimated and the hornbeam (Carpinus betulus) was promoted. This effect is perceivable from the mid-1st millennium BC in most Central European pollen diagrams (KÜSTER 1994). Longer existing settlements were mainly founded in the Roman period. For these settlements good building material (timber and stone) was essential. Fir stands were available in higher regions, in the investigation area they can be expected on the wide slopes of the Koralm. Besides wood, limestone from the tertiary sediments (near Wildon and Ehrenhausen) and granite/gneiss from the Koralm are the dominant building materials.

Archaeological characteristics of the investigation area

During most of the Roman era, perialpine Styria was dominated by the municipium Flavia Solva in the Leibnitz basin of the Mur valley, with the rest of the territory occupied by rural settlements, such as vici and villae. Traffic infrastructure can be expected mostly along the river courses. A particular feature of local culture different from most other regions of the Roman empire was the custom of tumulus graves, the so-called Noric-Pannonian grave mounds (PALÁGYI 1990, URBAN 1984). Otherwise, the sites of settlements and their associated graves in the Austria Romana are connected like in other provinces of the Roman Empire and cannot be found in the settlements itself (with the exemption of special burials like the suggrundaria (BERGER 1993). The reason for burying outside the settlements in Roman times goes back to the Law of the Twelve Tables (Table X, 5th century BC), resulting in the construction of necropoleis along the arterial roads. These necropoleis are common throughout the Empire and are especially well known outside towns like Flavia Solva. The graves usually start at the town borders and are aligned along the road, sometimes in more than one row, for several hundred meters (FUCHS 1980, FUCHS 1987, PAMMER-HUDECZEK & HUDECZEK 2003). They contain different kinds of graves like mausolea, barrows and simple urn graves between them.

The analysis of necropoleis in the area of Flavia Solva and its surroundings shows that 60% of the known burials are connected to roads, and 80% are situated in areas useable for agriculture or building (valley bottom and margin). Favored orientations along the roads were WNW, SW and E of settlements; when roads were not the decisive factor for any reason, the graves were built in the directions W and SW. The distance between settlements and graves ranges between 10 (at Flavia Solva) and 950 m, but a third of all graves can be found in the distance between 200 and 400 m. (FUCHS 1987)

Method I: (Semi-) Automated identification of grave mounds

A first investigative step into the archaeological landscape of the Lassnitz valley is based on the observation that a spatial correlation can be proposed between the locations of settlements and grave mounds. Therefore the method used in this context consists of two complementary approaches which ideally can supplement each other: The first approach focuses on the (semi-)automatic identification of grave mounds in the Lassnitz valley area; the second approach encompasses the delineation of potential Roman settlement areas mainly based on the assessment of the ancient agricultural writers, and the translation of their statements into terms of Geographic Information Systems. — While the usefulness of the information gained from these writings for reconstructing actual conditions of ancient agriculture, in particular outside their mediterranean places of origin, is doubtful and still a matter of extensive debate (DIEDERICH 2007), certain basic characteristics mentioned in the texts can be found to correspond to conditions in rural settlements in statistically significant proportions (cf. e.g. MOOSBAUER 1997 for NE Raetia).
Despite the rapidly advancing technology, the ground check is still the most important tool for the acquisition of archaeological relevant surface features. But, because it is costly in terms of time and money, in many cases expenses can be dramatically reduced by a visual pre-selection of hi-res LiDAR Elevation Data derivatives. This potential of digital terrain analysis in archaeological research is already well described, e.g. by researchers like DUBAYA & RICH (1995), DEVERAUX et al. (2005), and DONEUS & BRIESE (2006). As this kind of investigation often still has to be performed by visually inspecting the data, (semi-)automation of the workflow or at least the contrast enhancement will considerably accelerate the interpretation of surface structures. In that context the prior ranking goal of this approach is not the compilation of absolutely correct results but the production of quicklooks. In this scope of functions the method of choice has to meet the following requirements: good overall performance, easy handling, ready integration into existing Geo-IT environments, ubiquitous applicability, comprehensible underlying concept and self-explanatory results.

CHALLIS, FORLIN and KINCEY (2011) have compiled a catalogue of six different methods for analyzing digital surface models by the means of hillshading: Constrained color shading (1) uses the knowledge about the elevation range of the features of interest for identification of relevant objects, but the method is limited by the terrain roughness; standard GIS slope analyses (2) provide information about terrain parameters like steepest slope or biggest gradient (rate of slope changing per length unit) to show abnormal surface features. In combination with solar insolation models (3, quantifying the amount of sun's energy on the ground) the latter can be used to generate illumination models (4), which usually are much easier to interpret than other graphical representatives of 3d data (i.e. contour line maps). Principle Component Analysis (PCA), the fifth technique to be mentioned in this context, is based on the geo-statistical analysis of a sequence of hillshade models covering the same investigation area but illuminated from different insolation azimuths. The result of this relatively complex method can be understood as a kind of accumulated description of surface features. Last but not least the local-relief models (LRMs, 6) can be used to eliminate the topographic "longwaved" variation of the relief to carve the "shortwaved" artificial (archaeologically relevant) objects out of the natural surface. To make these complex approaches more accessible to a broader community KOKALJ et al. (2011) and HESSE (2013) both developed special toolboxes heavily influenced by the Local Dominance and the Local Relief Model idea.

Detailed example: Lassnitz Valley

This approach shall be exemplified in greater detail on one particular dataset, the ALS terrain model of the Lassnitz valley. It represents a combination of concepts which tries to combine the benefits of methods 2, 3 and 6 to assemble an optimized workflow for the recognition of grave mounds (and eventually associated settlements). Fundamental elements of the underlying concept are the following facts: because of their distinct shape grave mounds can be easily identified in the landscape, visually as well as automatically (i.e. via geometrical parametrization). Furthermore, grave mounds are indicators for human settlements in the vicinity, which provides a handle on identifying settlement patterns in the research area.

In addition to the ALS database, the publicly available digital terrain model of Styria with a resolution of 10 m was used to delineate information for optimal quantification of the topographic variation within the investigation area. Evaluation and calibration of the findings was possible through the results of a “traditional” visual examination of the ALS model (TIEFENGRABER 2012).

In a first step a 10m terrain model was used to gather information about the investigation area’s immanent surface trend. After this pre-parametrization which is done by quantifying the terrain ruggedness (Riley et al. 1999) the process’ workflow continues with the extraction of a point shape carrying the according height value taken from the underlying ALS terrain model. The official dataset of Styria has a resolution of 1 m per square and has an extension of 21000 x 13500 cells. According to the threshold value derived from the results of the pre-parametrization, the point’s coordinates in the test site were sampled with an equidistance of 20 m to 20 m. To create a “mask” for effective elimination of as many of the natural terrain features as possible from the Digital Surface Model a subtraction model with the same resolution and coverage as the ALS has to be generated which best represents the natural character of the relief. Due to the structure of the sampled point cloud this is done by interpolation based on the inverse distance weighting approach. This method produces smooth surfaces but also acts as an exact interpolator; the search radius (delineating the working area of the interpolation) has been determined as triple value of the points distance. In addition, a power value of 0.4 has been chosen to prevent overweighting of observations nearby the newly created grid cell.

The data preparation work package is finished by subtracting the newly created raster from the original ALS raster. The resulting raster appears flattened as much as possible, leaving the artefacts ideally accentuated (Fig. 3).

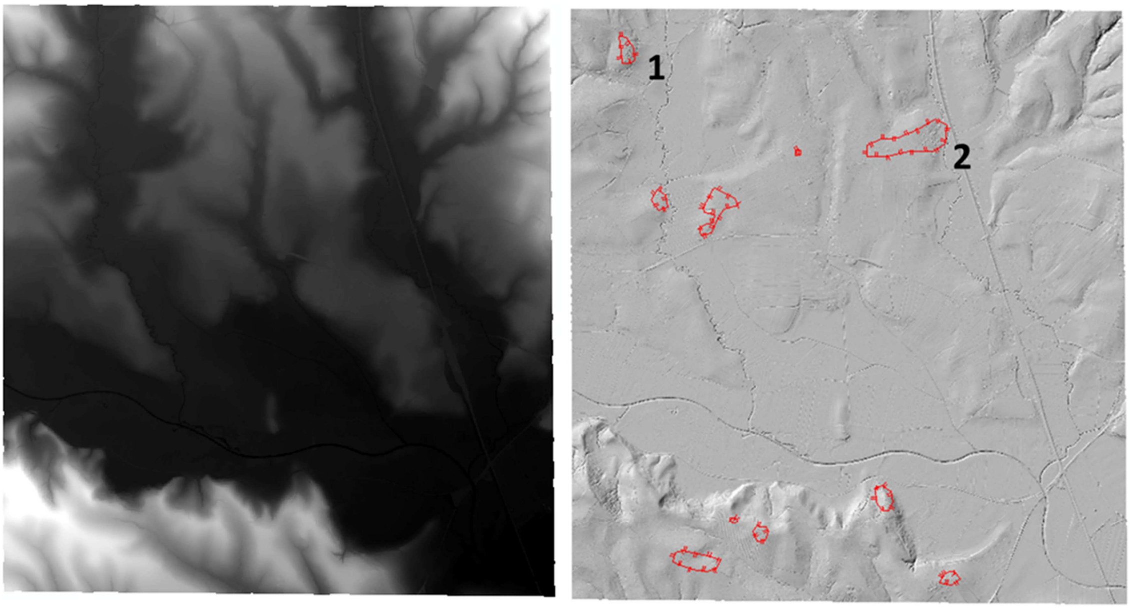

Fig. 3 – Comparison of original ALS (left) and hillshade of the flattened result (right). The numbers mark additional test sites, red hatched lines indicate assured archaeological sites/grave mounds. (Data source: GIS Steiermark)

For the intended (semi-)automatic recognition an additional parametrization of the objects has to be done. According to the findings of prior investigations in Styria a grave mound generally can be described as nearly circular, with a diameter of 40–50 m (i.e. equivalent to 40–50 pixels in the ALS) and a characteristic conical elevation profile. These properties can be used to define a set of rules to enable GIS-based identification of grave mounds. In the 3D-domain height values, neighborhood relations and specific profile curvature behavior describe peaks and conic structures while sinks within these peaks eventually indicate already robbed graves. In the 2D-domain the baseline of the mound appears as a polygon offering more metrics; the area can be used to classify the feature as appropriate for a grave mound or not. Furthermore, the fractal dimension of the shape – expressed as perimeter of the polygon related to area – describes the grade of similarity of the feature to a circle. The formula Area = perimeter² / 4*pi provides the circular perimeter for any given polygon area. As a concomitant effect of the method the flattened ALS dataset can be enriched by contour lines, a feature which supports readability and explanatory power of the ALS (Fig. 4).

So far the application of those rules within a GI-System allows the automatic identification of 3D objects whose characteristics follow the requirements defined by the rules (i.e. meet the shape definition of a grave mound). By this, objects like the graves in the lower right section of the burial ground shown in Fig. 4 can be easily identified (even if robbed). The method of course reaches its limits if – because of special environmental circumstances – the rule set is not applicable (i.e. immersed grave, or grave partially or totally covered by sediments, as shown in Fig. 4 beneath the heads of the blue arrows and in Fig. 5).

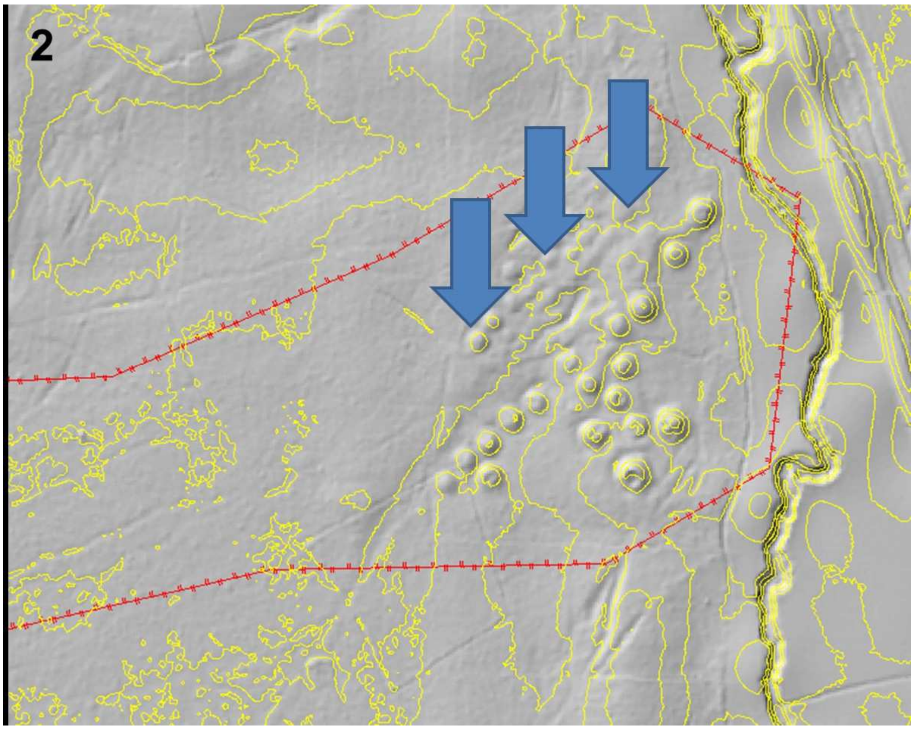

Fig. 4 – Detail of test site 2 (magnified view of the same dataset as in Fig. 1). The blue arrows indicate an aggregation of grave mounds; equidistance of the yellow contour line: 1 m (Data source: GIS Steiermark)

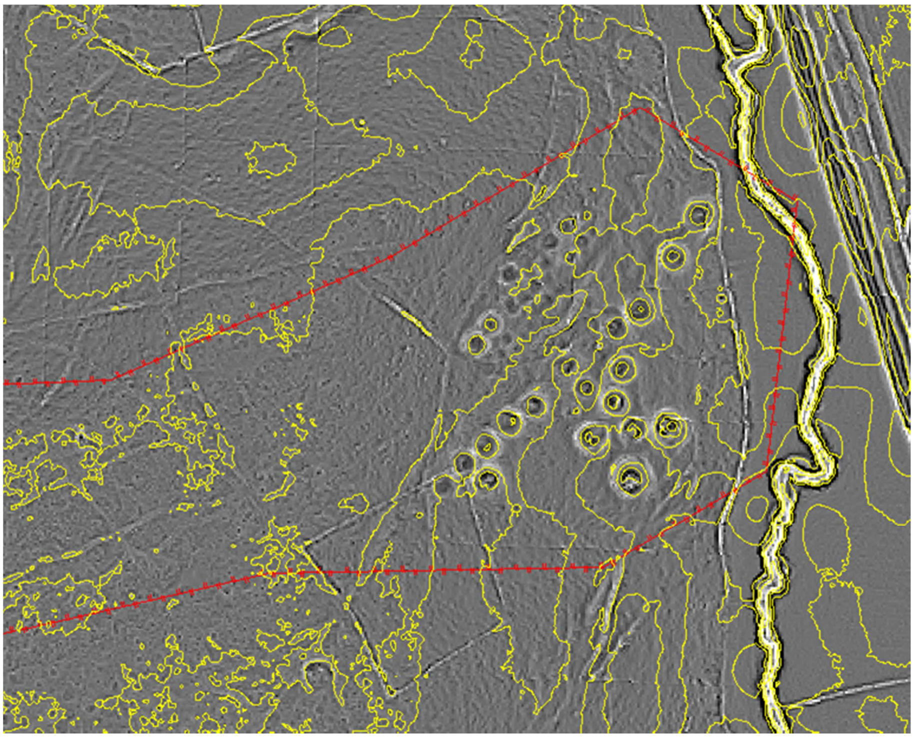

Fig. 5 – "Signature" of grave mounds (darker grey nuclei) and mostly delineated by yellow contour lines; note the boundless nuclei as potential graves but lying outside/lower than the observed contour line interval's "resolution" (Data source: GIS Steiermark)

Furthermore, due to the lack of appropriate data layers (land use land cover), the approach is not able to recognize the age of the feature. Fig. 6 shows a good example of a mis-classification. The shape-oriented algorithm identifies the feature as grave mounds, while visual examination shows it to be two heaps of bark or saw mill shavings.

Fig. 6 – Two features interpreted by mistake as grave mounds (left) and in reality (orthophoto) (Data source: GIS Steiermark)

Method II: Identification and delineation of rural settlements

In contrast to method I, which is based on the rule set for grave mounds applicable on ALS datasets, the second method proposed here has a more traditional origin in the preceding analysis of the writings of ancient authors. Their findings and recommendations for establishing and managing a “villa rustica” are outlined in Tab. 1 (for the problem of classification of rural sites, in the German research tradition generally summed up under the term villa (rustica), cf. WITCHER 2012).

Preparing this information for the following analyses has been done mainly by aggregation (i.e. elevation related topics, water related topics, etc) and classification. Here the problem of missing exact threshold values has been avoided by the use of a coarse rationing point system with at most 5 parameter values (5 = very suitable, 4 = suitable, 3 = neutral, 2 = less suitable and 1 = not suitable) based on the analysis of well-known sites, special knowledge about the local situation or analogies (i.e. in case of fertile soils). So far relief-based parameters like exposition, slope and curvature, hydrology (as far as known), geological and pedological aspects and fragments of the ancient transportation network were implemented in the database and analyzed. Unfortunately important data describing the historical land cover or (extremely relevant for the subject) historical watercourses are still omitted or the subject of ongoing research. For clarity reasons the results of the analyses are visualized in separate maps (Fig. 7, 8, and 9) which cover most of the investigation area of about 25 x 17,5 km (= 437,5 km²). In order to make interpretation and orientation more comfortable, information layers with modern data (water courses and populated places and place names) as well as confirmed ancient settlements are added to the hillshaded relief.

Author	Recommendations (Characteristics)
Vitruvius (I,4–5; VI,1)	raised terrain east or west exposition distant from swamps fertile soil good traffic infrastructure
Cato (I,2)	protected from weather fertile soil south exposition at the foot of a mountain available manpower source of water near market, or traffic infrastructure
Columella (I,2–5)	healthy climate fertile soil level and inclined ground east or south exposition traffic infrastructure main house near the level part quarry and water source nearby protected from weather, on hillside on slight elevation (safe from floods) available water source near, but not directly on road exposition „towards sunrise at equinox“
Varro (I,2; I,4; I,6–7)	ground resources near street healthy area (climate, winds, swamp) slight inclination (for drainage)

Tab. 1 – Recommendations of ancient authors for establishing and managing a *villa rustica*

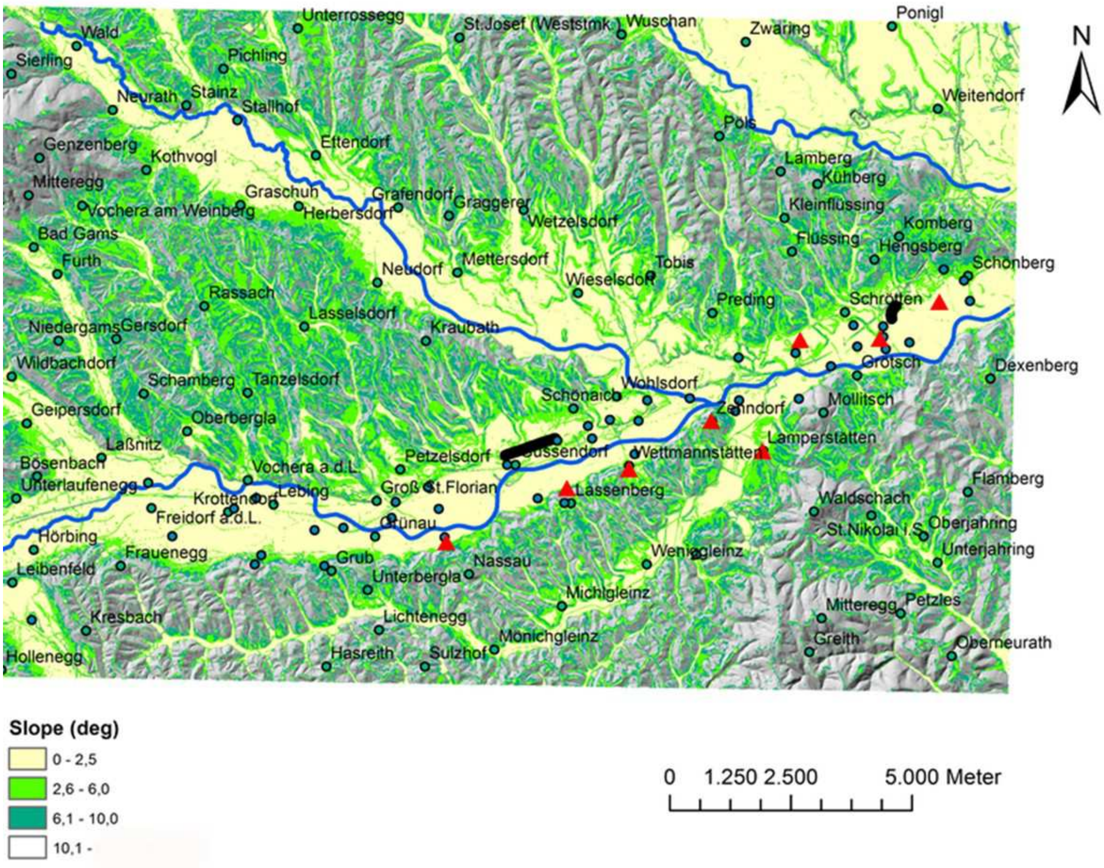

Fig. 7 – Map showing the slopes in the investigation area in degrees (worst and second worst degree class combined in one); the green dots with black boundary locate the modern settlements and their names, red triangles mark the locations of confirmed ancient sites, the short black lines in the eastern part of the map show excavated ancient road segments (Fuchs 2006). Note that the known ancient settlements are located at the flat or nearly flat valley plain (0–2,5 deg) or on the northward hillslope (2,6–6,0 deg) (Data source: GIS Steiermark).

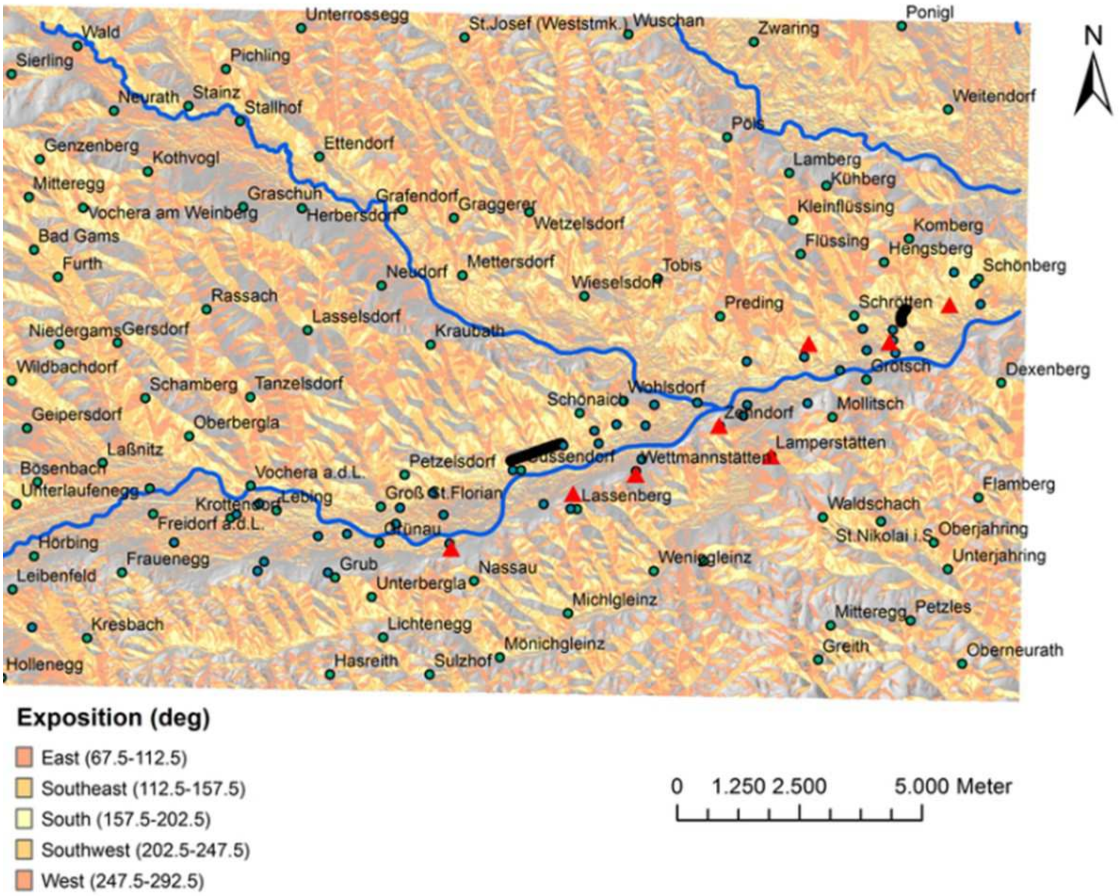

Fig. 8 – Map showing the exposition in the investigation area in compass directions and in degrees. Note that the color ramp is “grouped” around the mostly preferred southward orientation (yellow) so that the same color indicates the same degree of preference. The north direction is omitted. (Additional information same as in Fig. 7) (Data source: GIS Steiermark).

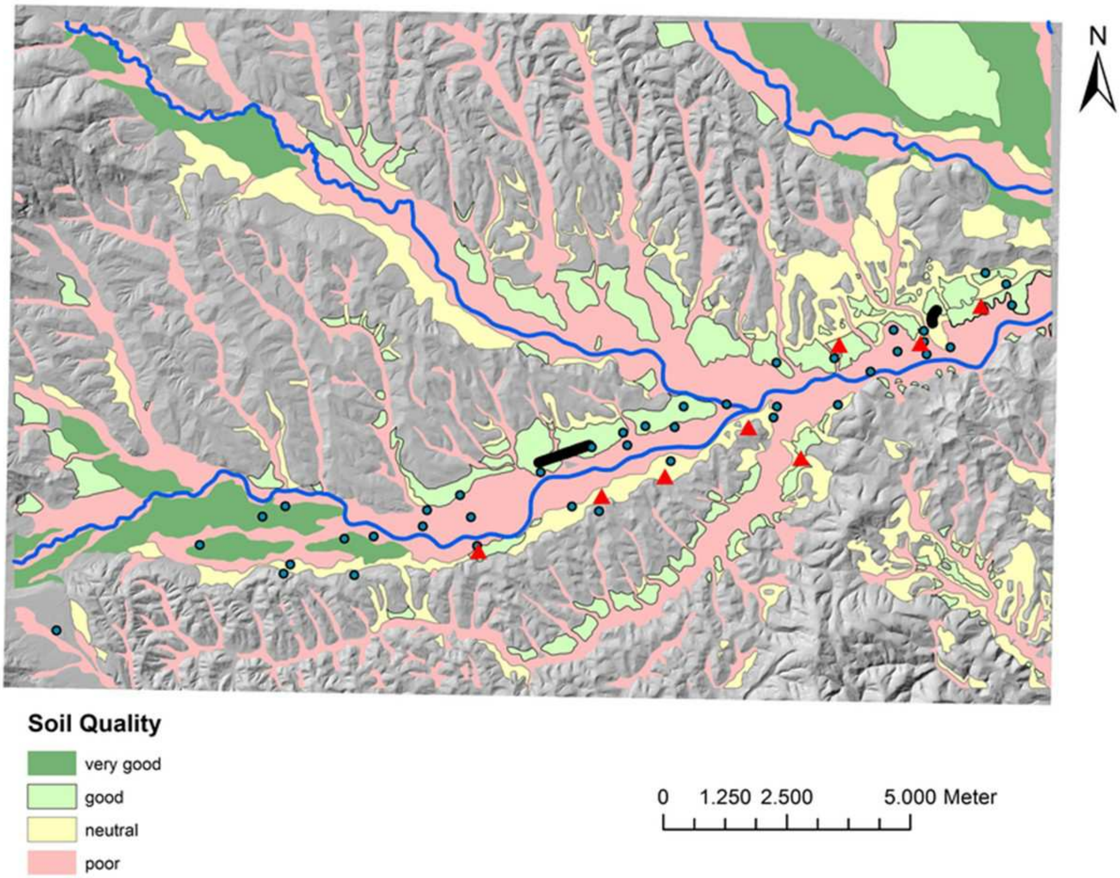

Fig. 9 – Map of the soil quality in the investigation area according to fertility types derived from geological and geomorphological conditions (after EISENHUT 1965) (Additional information same as in Fig. 7) (Data source: GIS Steiermark).

Conclusion

The objective of this paper is threefold: to test the assumption that there exists a definable spatial connection between human settlement and grave sites; to locate these grave sites (semi-)automatically for faster evaluation of investigation areas or confirmation of existing databases, and to identify potential, still unrecognized Roman settlement areas. In summary, it can be said that the approach described under section “Method I” seems to be suitable for the fast analysis of larger investigation areas. The results produced in this way widely overlap with the results of the visual examination of ALS data. Throughout the whole Lassnitz valley area, the semi-automatic approach has found up to 10 additional potential sites. Although additional data layers (like land use, etc) will prevent false positives of modern features, most of the sites have to be verified by a survey team, but – and that currently seems to be the biggest advantage – the method will allow a faster identification of prospective areas.

The approach proposed in Method II deals with the development (more exactly the translation) of a system of rules for controlling a GIS-based suitability analysis for rural settlements. Until now the results in this section fully correspond to the results coming from other sources (i.e. excavations, catalogue of archaeological artefacts, etc). Therefore, a first approximate (and mainly based on aspects of the natural environment) delineation of potential villa sites can be carried out. This delimitation will be narrowed step by step by the integration of additional data layers like reconstructed historical land cover or historical water courses, and by the ongoing research on the ancient transportation network of the region.

References

BERGER, L., 1993. Säuglings- und Kinderbestattungen in römischen Siedlungen der Schweiz – ein Vorbericht. In: M. STRUCK, ed. Römerzeitliche Gräber als Quellen zu Religion, Bevölkerungsstruktur und Sozialgeschichte. Internationale Konferenz vom 18.–20. Februar 1991 im Institut für Ur- und Frühgeschichte der Johannes-Gutenberg-Universität Mainz. Mainz (Archäologische Schriften des Instituts für Ur- und Frühgeschichte der Johannes-Gutenberg-Universität Mainz; 3), pp. 319–328

BEHRINGER, W., 2007. Kulturgeschichte des Klimas – Von der Eiszeit bis zur globalen Erwärmung. München, Beck

CHALLIS, K., FORLIN, P., and KINCEY, M., 2011. A Generic Toolkit for the Visualization of Archaeological Features on Airborne LiDAR Elevation Data. Archaeological Prospection, 18, 279–289

DEVERAUX, B. J. et al., 2005. The potential of airborne lidar for detection of archaeological features under woodland canopies. Antiquity, 79, 648–660

DIEDERICH, S., 2007. Römische Agrarhandbücher zwischen Fachwissenschaft, Literatur und Ideologie. Berlin u.a.: De Gruyter. (Untersuchungen zur antiken Literatur und Geschichte; 88)

DONEUS, M., and BRIESE, C., 2006. Digital terrain modelling for archaeological interpretation within forested areas using full-waveform laser scanning. In: M. IOANNIDES et al., eds. VAST 2006: The 7th International conference on Virtual Reality, Archaeology and Intelligent Cultural Heritage, Nicosia, Cyprus, 2006. Proceedings: Eurographics Association, pp. 155–162

DUBAYA, R., and RICH, P. M., 1995. Topographic solar radiation models in GIS. International Journal of Geographic Information Science, 9(4), 405–419

EISENHUT, M., 1965. Sedimentationsverhältnisse und Talentwicklung an der mittleren Laßnitz (Weststeiermark). Mitteilungen des naturwissenschaftlichen Vereins Steiermark, 95, pp. 5-15.

FUCHS, G., 1980. Die römerzeitlichen Gräberfelder von Flavia Solva. Diss. Graz

FUCHS, G., 1987. Die römerzeitlichen Gräberfelder von Flavia Solva. In: E. POCHMARSKI, G. SCHWARZ and M. HAINZMANN, eds. Berichte des 2. Österreichischen Archäologentages im Schloss Seggau bei Leibnitz vom 14. bis 16. Juni 1984. Graz (Mitteilungen der Archaeologischen Gesellschaft Graz; 1), pp. 74–82

FUCHS, G. et al., 1997. Ein Modellfall für die Zusammenarbeit zwischen Planung und archäologischer Denkmalpflege am Beispiel der Koralmbahn Graz–Klagenfurt im Abschnitt Werndorf–Deutschlandsberg. Fundberichte aus Österreich, 36, 269–280

FUCHS, G., 2006. Die römische Straße im Laßnitztal, Weststeiermark. Ein Forschungsbericht. In: E. WALDE and G. GRABHERR, eds. Via Claudia Augusta und Römerstraßenforschung im östlichen Alpenraum. Innsbruck: Innsbruck University Press (Ikarus; 1), pp. 439–456

HESSE, R., 2013. Visualisierung hochauflösender digitaler Geländemodelle mit LiVT. eTopoi Journal of Ancient Studies, to be published

KOKALJ, Z., ZAKSEK, K. & OSTIR, K., 2011. Applications of sky-view factor for the visualisation of historic landscape features in lidar-derived relief models. *Antiquity*, 85, 263-273

KÜSTER, H.-J., 1994. The economic use of Abies wood as timber in central Europe during Roman times. Vegetation, History and Archaeobotany, 3, 25–32

KÜSTER, H.-J.,1996. Geschichte der Landschaft in Mitteleuropa: von der Eiszeit bis zur Gegenwart. München, Beck

KÜSTER, H.-J., 1998. Geschichte des Waldes – von der Urzeit bis zur Gegenwart. München, Beck

LAMM, S., and MARKO, P., 2012. Römerzeitliche Villen in der Steiermark. Schild von Steier. Beiträge zur Steirischen Vor- und Frühgeschichte und Münzkunde, 25, 25–41

LANA, B., 1991. Hochwässer im Raum Weststeiermark und ihre Beziehung zum Siedlungsausbau. Diss. Graz

LIEB, G. K., 1991. Eine Gebietsgliederung der Steiermark aufgrund naturräumlicher Gegebenheiten. Mitt. Abt. Bot. Landesmus. Joanneum Graz, 20, 1–30

MCCORMICK, M., et al., 2012. Climate Change during and after the Roman Empire: Reconstructing the Past from Scientifc and Historical Evidence. Journal of Interdisciplinary History, XLIII:2, 169–220

MODRIJAN, W., 1969. Römerzeitliche Villen und Landhäuser in der Steiermark. Graz. (Schild von Steier Kleine Schriften; 9)

MOOSBAUER, G., 1997. Die ländliche Besiedlung im östlichen Raetien während der römischen Kaiserzeit. Stadt- und Landkreise Deggendorf, Dingolfing-Landau, Passau, Rottal-Inn, Straubing und Straubing-Bogen. Leidorf: Espelkamp. (Passauer Universitätsschriften zur Archäologie; 4)

PASCHINGER, H., 1974. Steiermark. Steirisches Randgebirge, Grazer Bergland, Steirisches Riedelland. Sammlung geographischer Führer, Berlin-Stuttgart.

PALÁGYI, S. K., ed., 1990. Noricum-Pannoniai halomsírok = Norische-Pannonische Hügelgräber. Az 1988. október 21-i várpalotai tanácskozás előadásai = Vorträge der Varpálotaer Tagung vom 21. Oktober 1988. Veszprém: Megyei Muzeumi Igazgatóság

PAMMER-HUDEZCEK, Y., and HUDECZEK, E., 2003. Neue Befunde aus der Gräberstraße von Flavia Solva. Fundberichte aus Österreich, 41, 448–471

RILEY, S.J., DEGLORIA, ST.D. & ELLIOT, R., 1999. A Terrain Ruggedness Index That Quantifies Topographic Heterogenity. Intermountain Journal of Science, Vol. 5, No. 1–4, 23–27

QUEHENBERGER, 2001. Landschaftsökologische Darstellung des Lassnitztales zwischen Deutschlandsberg und Preding. Dipl. Graz

RIEDL; H., 1961. Ergebnisse einer Taluntersuchung in der Oststeiermark. Mitteilungen des naturwissenschaftlichen Vereins Steiermark, 91, 97–104

SIROCKO, F., 2012. Wetter, Klima, Menschheitsentwicklung – Von der Eiszeit bis ins 21.Jahrhundert. 3rd ed. Darmstadt, Wissenschaftliche Buchgesellschaft

TIEFENGRABER, S., 2012. Large Scaled Area Lidar-Data Analysis at the Example of Styria, In: BÖRNER, W., UHLIRZ, S., DOLLHOFER, L., eds. 16th International Conference On “Cultural Heritage And New Technologies” Vienna, pp. 115–121

URBAN, O. H., 1984. Das Gräberfeld von Kapfenstein (Steiermark) und die römischen Hügelgräber in Österreich. München: Beck. (Münchner Beiträge zur Vor- und Frühgeschichte; 35)

WENDT, K. P., and ZIMMERMANN, A., 2010. Zur Bevölkerungsdichte in den römischen Rheinlanden. In: M. AUFLEGER, ed. Braunkohlenarchäologie im Rheinland. Entwicklung von Kultur, Umwelt und Landschaft. Kolloquium der Stiftung zur Förderung der Archäologie im rheinischen Braunkohlenrevier in Brauweiler vom 5.–6. Oktober in Brauweiler. Weilerswist: Ralf Liebe (Materialien zur Bodendenkmalpflege im Rheinland; 21), pp. 87–90

WITCHER, R. E., 2012. 'That from a long way off look like farms': the classification of Roman rural sites. In: P. A. J. ATTEMA and G. SCHÖRNER, eds. Comparative Issues in the Archaeology of the Roman Rural Landscape. Site Classification Between Survey, Excavation and Historical Categories. Portsmouth, Rhode Island (Journal of Roman Archaeology Supplementary Series; 88), pp. 11–30

ZETINIGG, H., 1973. Die artesischen Brunnen der Südweststeiermark. Berichte der wasserwirtschaftlichen Rahmenplanung, 26, Graz

ZÖHRER, K., 2007. Villen und ländliche Anlagen im Stadtgebiet von Flavia Solva. Dipl. Graz

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