LIDAR – High Resolution Raster Data as a survey tool

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ABSTRACT

The Article will show the different ways in which LIDAR-Data is used by the Landesamt für Denkmalpflege. The emphasis is on high resolution digital terrain models (DTM) that will replace, or at least contribute to, the classic survey and mapping data for site surrounding areas as especially used in the Atlas-Projekt. Additionaaly the Data is used to identify visible historical structures and to provide additional knowledge for an interpretation of a known site.

INTRODUCTION

With the available LIDAR-data it is possible to produce highly accurate DTM. The Method is described by H. Kamermanns (this book) and the data available for south-western Germany was described by Benoît Sittler (this book). The main objective of our ongoing work is to identify settlement structures of known sites. Settlement-structures are complex, compared to burial mounds and therefore cannot (as yet?) be discovered by pattern recognition, because there is no pattern that could not also be modern. Ramparts, ditches and trenches are the common structures that can be identified by a DTM. They are unspecific in shape, but the first visualized data of the outer settlements of the Heuneburg led to some new discoveries and thus led to a research program funded within the EU CULTURE 2000 programme in which geophysical methods, aerial photography and traditional survey should be combined with the LIDAR-data based DTM to define possibilities and limitations of the data. The project is still work in progress but there are first results which will be demonstrated in the following text. Parallel to this, the data is used to support traditional rescue excavation of the Landesamt as well as the Atlas Projekt whose aim it is to measure and describe all still-visible archaeological structures in Baden-Württemberg. This project, running for the last 25 Years was one of the main survey and mapping projects in Baden-Württemberg. Because of this, the high resolution DTM will lead to the biggest changes in this work.

METHODICAL ASPECTS

The first question to answer is: what makes a DTM with LIDAR-data different to other DTM's? It is just a matter of accuracy. The difference is shown in the table below and visualized in a hillshade fig. 1. The gridwidth allows identifying even barely visible structures in open ground and light woods.

Table 1 – Accuracy of different available DTM's.

DGM250	Gridwidth 200 m +/- 26 m	Height 1 m +/- 20 m
DGM50 M745	Gridwidth 30x20 m +/- 26 m	Height 1 m +/- 20 m
DTM project Baden-Württemberg	Point spacing between 0,5-1 m	Elevation accuracy +/- 0,15 m
SRTM 1	Gridwidth 90 m	

The combination with interpreted maps, shown in fig. 2, gives one the possibility to find formerly unseen structures. Because of the amount of data, LIDAR-data is most useful in small, defined areas. In general the LIDAR data is gathered in winter to ensure that the biases caused by vegetation are as low as possible. One exception was made in 2003, because the exceptionally hot summer gave an unexpected possibility to see all the old river beds of the Danube near the Iron Age hillfort Heuneburg in upper Swabia. En passant the changes in the data according to the vegetation could be visualized in comparing the different datasets. It made clear that regardless of the season, scrublands are the most biased region. Combined with steep ravines or trenches, bushy areas cause faults of up to 75 cm in height.
Modern buildings are a second data problem; whether they are transfered into no-data areas or interpolated, the trace of the modern building stays visible in any visualization of the data. The land surveying office of Baden-Württemberg is trying to correct the errors by hand, but this method is costly and time consuming. In September 2005, the complete dataset for Baden-Württemberg should be available, but only as automatically corrected data. By when the manually corrected data will be available isn't even projected by now. Anyhow, it seems to be, that there is a niche for classical surveying and

mapping in the non-open areas and for upstanding structures. First attempts have shown that archaeological evidence (in this case the Roman estate near Ödheim, done by M. Gültlinger, Landesvermessungsamt Baden-Württemberg), corners and small upstanding structures, will be mapped more clearly by a handmade measurement. Elongated structures will come out more clearly than winding ones. More recent interferences like quarries and those described by I. Herzog (this book) can change the landscape and make it difficult to reconstruct historic settlement structures. In any case, the LIDAR-dataset represents the present landscape and is therefore no direct representation of the historic settlement area.

THE EARLY GERMANIC SITE „REISSWAG", LAUDA-KÖNIGSHOFEN (TBB)

The site is situated on the banks of River Tauber. Surface collections revealed, among other pre- and protohistoric periods, a Germanic settlement of the 2./3. Century AD, only 30 km outside the Roman borders. Because of collections of burned animal bones and burned Samian ware in the surroundings of a slightly longish knoll or ridge about 150 m southeast of the settlement, the knoll at the end of a slight ridge was thought to be a Germanic Ritual Site. The Landesamt für Denkmalpflege Baden-Württemberg has been conducting a rescue excavation on the site since 2004. The LIDAR-data was available after the end of the first campaign and was used to revisit the interpretation of the site, because it was not clear whether the presumed offering place refers to the knoll, or vice versa. The excavation revealed at least one pit containing burned bones and Samian ware at the foot of the knoll, but the remains on top of it were too few und too uncertain to be identified. Much clearer than on the site, it can be seen in the LIDAR-data that the "knoll" is only the end of a ridge near Point 202,0. Looking at the similar structures in the surrounding fields, it becomes clear that the ridge is part of a former path system now slurred by repeated ploughing. The aspect of these ridges is similar to the one of the modern paths, which are clearer, though. The probability that the knoll is some kind of "offering hill" or even a burial mound, is therefore low.
A second benefit of the DTM of this site is the visibility of former quarries which appear as uneven areas, although they are already refilled and almost invisible in the landscape. One of these quarries lies southwest of the offering place at the end of the river terrace and corresponds, as the DTM shows, roughly with the contour lines 190 and 195. The extent of this quarry is important for the judgement of superficial finds, because archaeological structures have long been destroyed in the circumference of the quarry, which, however, was later refilled with soil from an urnfield site, so that the surface of the former quarry now contains urnfield shards. The ridge and the quarries were not visible within the topographical maps of different scales. A hillshade based on a 0,5m grid was used to visualize the LIDAR-data. This was combined with different thematic maps and validated on site. The visibility of smaller structures depends on the angle of the light and the factor of superelevation that is used to produce the hillshade.

THE HEUNEBURG – POSSIBLE USES FOR LIDAR-DATA IN THE AREA SURROUNDING THE EARLY CELTIC LORD'S RESIDENCE

The greyscale picture of the area surrounding the Heuneburg, the early Celtic lord's residence on the Upper Danube, shows separate terrain features in great detail. A total area of 20 square kilometers was surveyed with the LIDAR method. Conditions were exceptionally good after the extremely hot and dry summer of 2003, since old sinuosities and creek-beds, especially in the old Danube valley, were showing prominently and could be shown by LIDAR-data and be charted in detail at the same time.
The digital terrain model constructed with the LIDAR-data can, in conjunction with a high-water simulation for the Danube valley, give telling insights into landscape possibly cultivated in early and pre-historical times (fig. 3).
Thus, significantly larger areas free of high water can be shown, especially towards the centre of the valley, which can be regarded as potential settlement or burial areas, as impressively illustrated, for instance, by the Hallstatt settlement in the direct neighbourhood of the Bettelbühl necropolis on a gravel ridge largely free of high water in the middle of the Danube valley meadow. The length of the Roman road running north through the centre of the Danube valley shows as a dike free of flooding in the simulation as well.
In addition, the area scan can be a relevant aid in choosing excavation sections, especially for the fortifications surrounding the Heuneburg and its outlying fortifications (fig. 4).
The walls and ditches are partly very easily recognisable on site; partly they can only be traced by aerial survey and, especially, LIDAR-data. Smallest differences in elevation often cannot be recognised as archaeological structures on site. Thanks to the financial support by the EU Culture 2000 Programme, parts of those structures shown by area scan are being examined and checked by archaeological soundings. Since there has long been uncertainty as to the actual age of these fortifications of the Heuneburg, and since it had even been universally accepted as certain in the last decades that they date from the Middle Ages, specifically targeted excavation sites chosen on the basis of the area scan produced definite signs that a significant part at least of the outlying fortifications date from the 6th century B.C., that is from the time of early Celtic settlement of the Heuneburg.
In addition, the LIDAR-data for the archaeological Fieldwork conducted since spring 2004 within the Priority Program 1171 of the Deutsche Forschungsgemeinschaft in the area of the outer fortifications of the Heuneburg are an important

aid, providing an up-to-date basis for charting and visualizing excavation-specific detail. Examples are the charting of the excavation sites or the inlay of the measuring grid and its projection into the area model. This enables data taken by the Total station to be directly projected as entries into the area model.
Documentation of old area structures, e.g. the above-mentioned old river-branches and former sinuosities, old roadways, landmarks or barriers, in conjunction with archaeological remains visible with LIDAR-scan, and findings and results of archaeological Fieldwork, afford an excellent basis for judging historical interpretation of landscape cultivation.

FORTIFICATIONS IN THE OUTER AREAS OF THE HEUNEBURG

The digital elevation model has also proved its capabilities in respect to the ditches in the outer areas of the Heuneburg, which have only been partially examined so far. In certain spots on site, readily recognisable elevation differences have allowed to trace extensive fortification in form of a rampart and ditch. These ran from a valley indentation leading from the Danube lowland to the heights and ran for nearly 300 m Southwest before hooking South-Southeast (fig. 5, 1), where their traces got lost in the terrain after about 500 m. But during excavations it turned out that the fortification branched out into two fortified lines running Southeast and Southwest respectively (fig. 5, 2.3). The latter seemed to run in a straight line to a *Quelltopf* on the Western slope of the ridge and then, turning south there, to lead back to the heights (fig. 5, 4). In addition, differences in height had been levelled to the extent that no impression could be formed of the further course of the ditch.
When more corresponding ditches were found on the ridge west of the Heuneburg during geomagnetic prospection (figs. 5,5-12), it quickly transpired that the extent of the ditches could be followed over large distances on the basis of the magnetogramme (fig. 5,10.12). However, the low definition of the relief alone was not sufficient to recognize the defensive fortifications as such. Subsequently, even the fortifications north of the woods could be connected to the sectors found in the south via a well-preserved depression in the woods (fig. 5, 14). In addition, it could be seen on the basis of the LIDAR-scan that at the Western foot of the ridge another line of fortifications seems to be hidden, connecting the sectors on both sides of the woods. Thus, the fortifications in the outer areas of the Heuneburg show the new possibilities afforded during prospection as well as the limitations of the method. Thus, completely levelled remains are still undetectable through LIDAR-scan, while secondary structures such as field boundaries (fig. 5 a), old roadways (fig. 5 b), and even different growth signs of receding fields (fig. 5 c-f) dominate the picture. Insofar as archaeological remains only appear in insignificant level differences in surface relief, individual cases often allow only vague statements, while the greyscale picture of as LIDAR-scan clearly highlights objects with clearly visible level differences. Thus, the method widens our options in such cases where relief differences on site cannot be perceived with the naked eye, but can be shown with digital picture imaging (slanted illumination, different solar positions, etc) in an elevation model. Even when no certain results can be achieved, independent methods for cross-checking are often available. In this particular case, as well as the result of geomagnetic prospection and observation on site over the course of many years, these were the *Urkarten* (first land register maps) of the topographic land survey (ca. 1820-1830). These show the ditch complexes coinciding with parcel-limitations (fig. 6, 1.10), old forest boundaries (fig. 6, 8.13.16) or unusually broad and long strips of wasteland (fig. 6, 15.4), thus the remains of the by now largely levelled fortifications must still have been visible as boundary markers two centuries ago.
The Fortifications in the outer area of the Heuneburg thus highlight in an exemplary fashion the value of digital elevation models for archaeological research.

CONCLUSIONS

First of all there is a general limitation, which is common to all DEM. Only visible structures will be found, therefore, even with the high resolution data, standard survey methods will not be replaced. Especially settlement structures show up as a result of an interpretation, which makes an automatic recognition unlikely, and other sources of information are needed to gain an interpretation out of the data. Besides, it is a very cost efficient and promising addition to the existing data sources. Because the dataset includes whole Baden-Württemberg, research areas can easily be widened and the quality of any added data is equal to the rest.
The examples show how ongoing Fieldwork can be supported by a DTM. The LIDAR-data gives us the resolution that is necessary to work with in small areas and we showed how the decision-making process as well as the interpretation of the results could be improved by using DTM, based on LIDAR.

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FIGURES

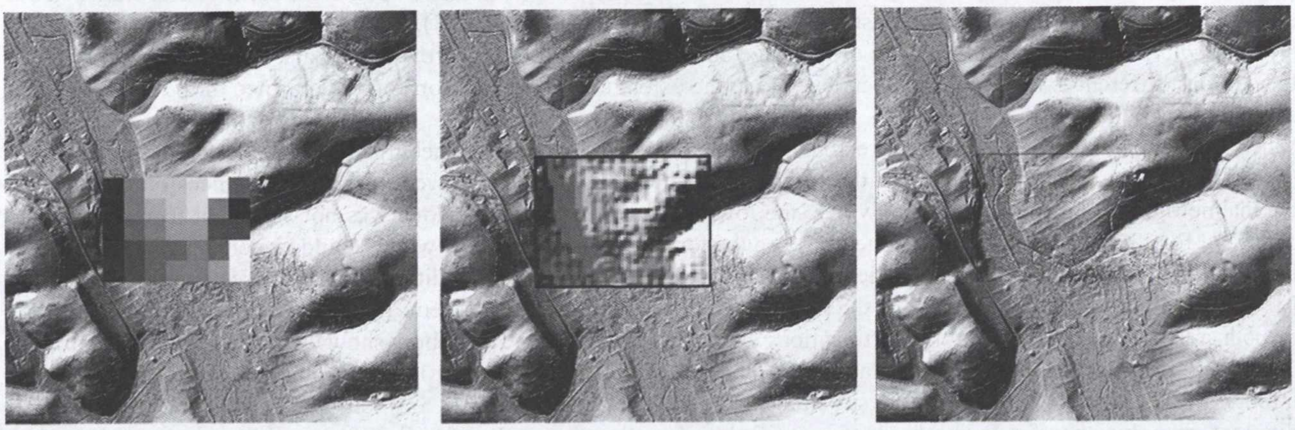

Fig. 1a, b and c – a) shows a DTM 250 of "Reisswag" put into a LIDAR-Dataset, b) shows the same site with a DTM50 M745 and c) is the site as full LIDAR-data. The DTM's are contributed by the Bundesamt für Kartographie und Geodäsie.

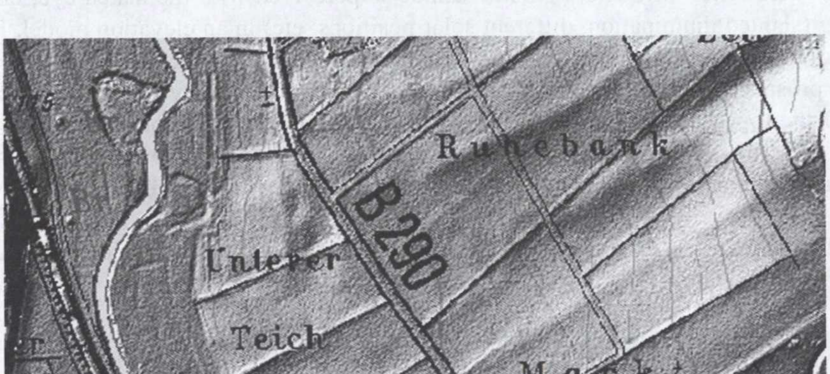

Fig. 2 – DTM of "Reisswag", Lauda-Königshofen.

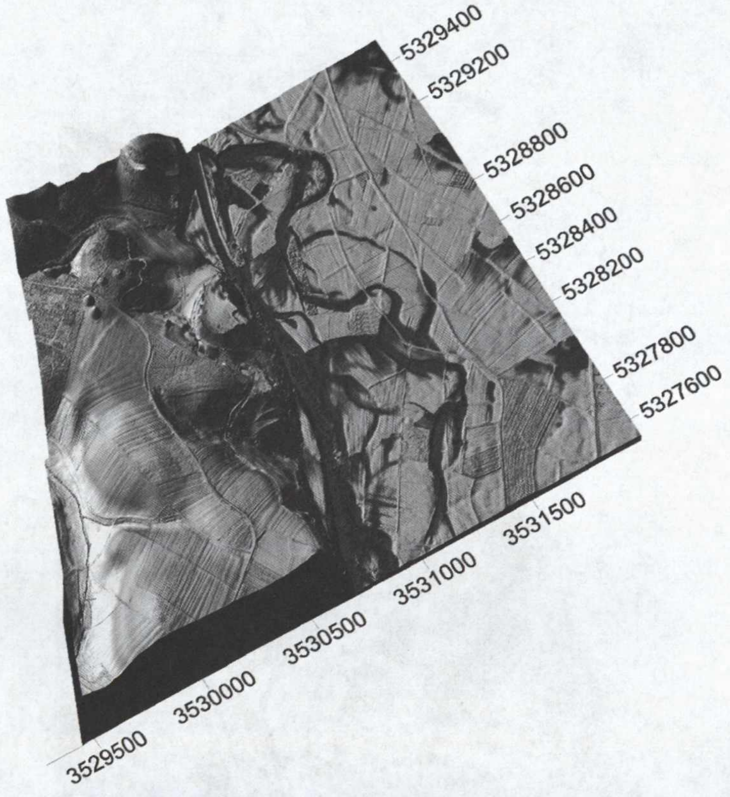

Fig. 3 – Danube valley mid height flood-simulation.

Fig. 4 – Heuneburg excavation areas.

Fig. 5 – Heuneburg-Außensiedlung, archaeological structures.

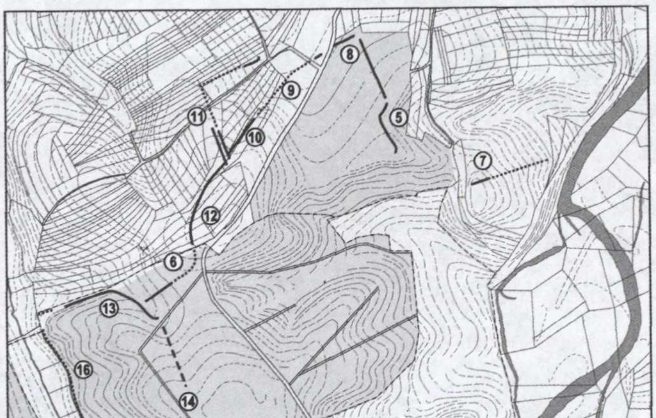

Fig. 6 – Heuneburg-Außensiedlung, archaeological structures that affect modern boundaries.