REVEALING HISTORICAL LANDSCAPES BY USING AIRBORNE LASER SCANNING
A 3-D MODELL OF RIDGE AND FURROW IN FORESTS NEAR RASTATT (GERMANY)-

B.Sittler

Institut für Landespflege, Universität Freiburg 79085 Freiburg

benoit.sittler@landespflege.uni-freiburg.de

KEY WORDS: Laser scanning - ridge and furrow - terrain model – medieval landscape - Rastatt

ABSTRACT:

Laser Scanning has been tested to depict and assess fossilized ridge and furrow in woodlands near Rastatt in South West Germany. These corrugated fields, displaying altimetric differences between 30 and 80 cm, are the result of medieval cultivation practices but rare are nowadays those places in the landscape where these remnants still exist at a scale which truly allows us to appreciate how the medieval countryside worked. Near Rastatt, such a field system exceeding 500 ha in size on the Lower Rhine Terrace was converted from arable land to forest during the 18th century, with undulations created by these earthworks being still visible under the forest canopy. Complementing a preliminary terrestrial survey, a cooperation was initiated with the Landesvermessungsamt Baden Württemberg for obtaining more accurate spatial information by testing use of laser scanning, the technique applied by this agency for getting a more accurate DEM of the whole land. Topscan was the company committed with the flight campaigns and delivery of data sets.

Filtering and processing of row data with subsequent use of GIS enabled to generate realistic 3D terrain models, a large scale visualization providing even a realistic view over this ancient landscape, despite forest canopy consisting of mixed stands. The resolution of this data and the relative ease of capture compares favourably with terrestrial mappings, allowing large areas of landscape to be captured as three-dimensional surface data, facilitating therefore a scientific, analytical approach to the landscape.

1. INTRODUCTION

Ridge and furrow earthworks are relics of arable cultivation that were once commonplace and extensive across many parts of Europe (Beresford & Saint Joseph, 1966, Ewald, 1969). They formed because over the years ploughing and hoeing caused the soil to be drawn up into ridges on which crops were grown

Remnants of these corrugated fields may nowadays only be observed in sites where they have not been levelled off by changes in agricultural practices such as when these open fields were converted into pastures or where woodlands was allowed to grow back over what was once this tilled land. Their documentation may provide valuable insights into how medieval landscape worked

Assessing in our landscapes the extent of this archeological resources and promoting the conservation of this vanishing legacy is therefore an important issue to landscape and heritage preservation agencies.

This applies to the forested areas in Central Baden near Rastatt (SW Germany) where arable land containing such earthworks was first abandoned and later converted to woodland within the last three centuries. A preliminary assessment through fieldwalking (Hauger et al., 2000 & 2001) had previously identified the site as being one of the largest contiguous area with such remains of the open field system in the whole South-West Germany but many of the features of this site escaped assessment since microrelief structures are hidden under forest vegetation and could not be depicted.

Given the fact that these features extend over a wide expanse, remote sensing was regarded as a pertinent approach for detailed documentary assessment.. Because traditional aerial photography is limited by the inability of optical sensors to collect information from beneath tree canopies, the purpose here was to test application prospects of the altimetry laser scanning (Lidar technology) for elevation data capture and for detecting and modeling terrain structure of ridge and furrow. As a matter of course, proven usefulness could therefore open new perspectives for assessing in general archeological remains hidden in woodland areas. This would then be a valuable extension of possibilities of remote sensing method in archeology.

.

2. MATERIAL AND METHODS

The laser scanning technology is a relatively new remote sensing approach (Ackermann, 1999) with until now few applications in the field of archeology and landscape studies. Preliminary applications of this new technique were recently considered as promising for digital terrain modeling in wooded areas (Pfeiffer et al., 1999; Hyyppä et al., 2000). In this regard, it was however questionable whether microtopography characteristics as those displayed by ridge and furrow with height differences oscillating between 30 and 60 cm would be detectable at the surface of the forest floor. The site chosen for this case study includes a sandy and dry flat terrace from the River Rhine near Rastatt, some 30 km south of Karlsruhe. It is composed of various stands with older mixed forests (beeches, pine trees and Norway spruces), as well as areas with denser young stands.

The principles and new development of this technique are presented in various other papers (this volume) and do not need more detailed assessment here.

The Laser Scanning DEM Project of Baden Wurttemberg

The Land and Survey bureau of the Baden-Wurttemberg state has adopted the airborne laser scanning technique for the purpose of constructing an accurate DEM for the entire state (Hoss, 1997; Gültlinger et al., 2001). It was aimed at providing comprehensive altimetry data at a resolution of around one meter mesh width in space and less than 50 cm in height. A special demand for such high accuracy was mainly from flood protection agencies, but additional interest emerged also from a wide range of other potential users. The company Topscan was commissioned with the flight campaigns and delivery of data sets. The project started in 2000 and is due to be completed by the end of 2004. Technical details of the flight missions are listed in the table below (tab. 1).

Tab. 1: Topscan laser scanner performance parameters

Altitude	1000m
Scan Frequency	25 Hz
Scan angle	+/- 20°
Wave length	1,55 µ
Strip width	400 m
Pulse repetition	25.000 Hz
Point spacing	1,5 m
Flight velocity	80 m/s

The Rhine Valley including the ridge and furrow site of Rastatt was surveyed during the initial stage of the project and raw data were therefore available for testing its usefulness in assessing this corrugated microtopography. A test site including the core part of this medieval landscape was then selected for the purpose of the present pilot study.

Data processing scheme

The dataset provided by Topscan were first preprocessed by the services of the Land surveying agency. This step included filtering of ground and height points, as well as georeferencing the data in Gauss Krüger coordinate system.

The data made available for this pilot study were in ASCII format. By interpolating the data in Erdas Imagine a DSM was created from the height points (Fig. 1a), while the corresponding DTM was obtained from the ground points (Fig 1b). Subsets and spatial profiles were established to analyze and assess special characteristics of ridge and furrow.

3. RESULTS

The detection of ridge and furrow topography

As a contrast to the scenery in first pulse (fig 1a) that does not reveal any microrelief patterns, the DTM (fig 1b) clearly shows the typical corrugated surface topography of the ridge and furrow.

This is especially evident when visualizing in 3-D images with different viewing directions (Fig 2, below). These figures clearly portray the pattern of the earlier medieval landscapes with the strips and furlongs. Additional structures that may be detected at a first glance include earth mounds seen in the upper left part of figure 1b. In contrast, ridge and furrow structures may no longer be detected in the open landscape with arable land where they have been leveled off. In some of these modern fields, aerial photographs by Braasch (unpubl.) have revealed the ancient pattern as crop marks appearing in the refilled furrows.

Assessing the ridge and furrow

Besides the visual detection of the patterns, another purpose was to assess the sizes (surface area, length, width) and heights of the ridge and furrow. These parameters were determined using the 3 D analyst extension of ArcView 3.2. It involved manual delineation of single furlongs (fig 3). The 3D analyst extension can measure surface area and volume of surfaces. The surface area is measured taking height into consideration. This parameter is different from the 2D planimetric extent of every model. The 2D planimetric surface is a virtually square area when a surface is viewed from above. Surface area on the other hand is the real surface and gives sufficient information about surface roughness and undulation. The greater the difference between the two parameters the rougher the surface is.

The length is determined by measuring the distance across a ridge and the mean width of a furlong calculated by dividing its planimetric area with its corresponding length.

The determination of height proceeded with the establishment of spatial profiles across the ridges. The spatial profiles are later demonstrated in the form of graphs from which height values are easily read (fig 4). Distance is plotted on the horizontal axis and elevation (height) on the vertical axis.

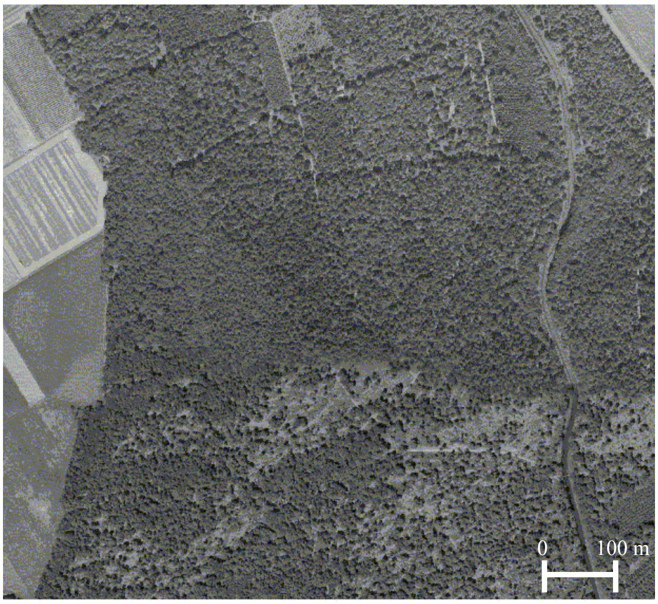

Fig.1a. Scenery of part of the woodlands including ridge and furrow as retrieved from the first pulse data. Height points here mainly relate to the tree canopy, apart from the areas still under cultivation on the left.

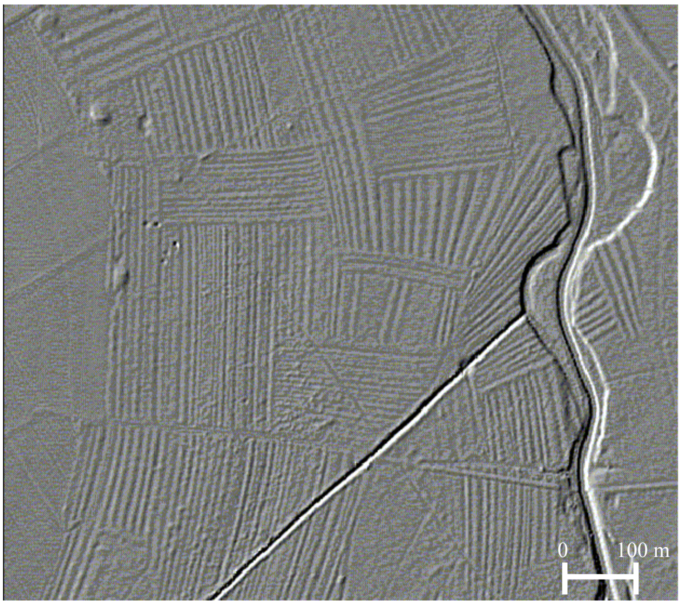

Fig. 1b. Same scenery retrieved from the filtered last pulse data. The 3-D model generated here clearly displays the pattern of the ancient fields.

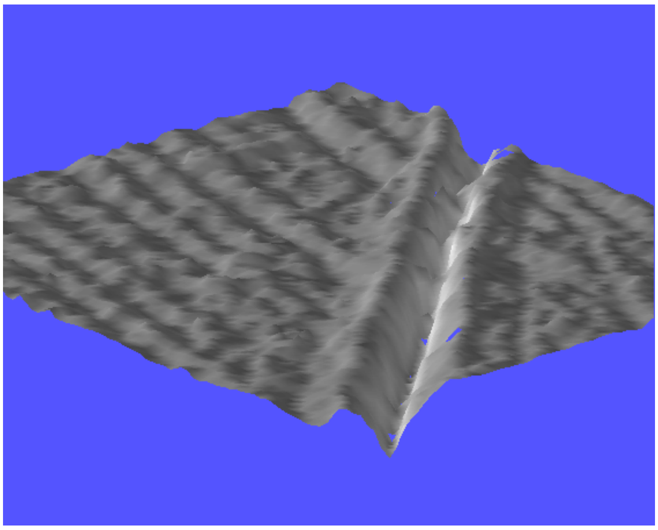

Fig.2. Visualization in 3-D of ridge and furrow as cut by the Hardtgraben ditch digged in the course of the 15th century

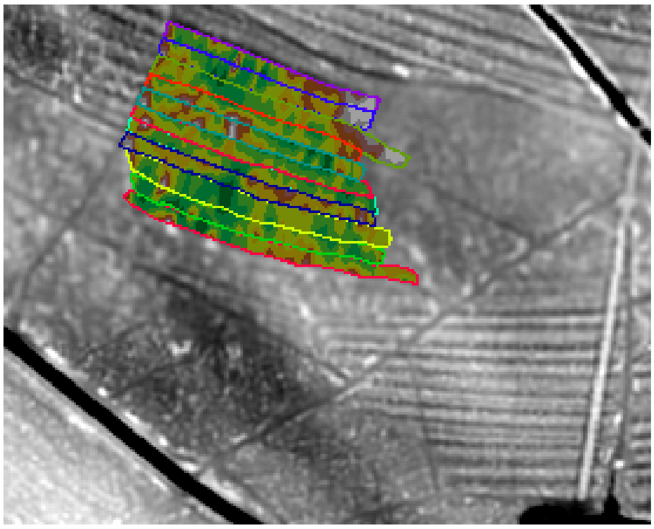

Fig.3. Manual delineation of ridges as polygons to assess dimensions of the single furlongs by using GIS.

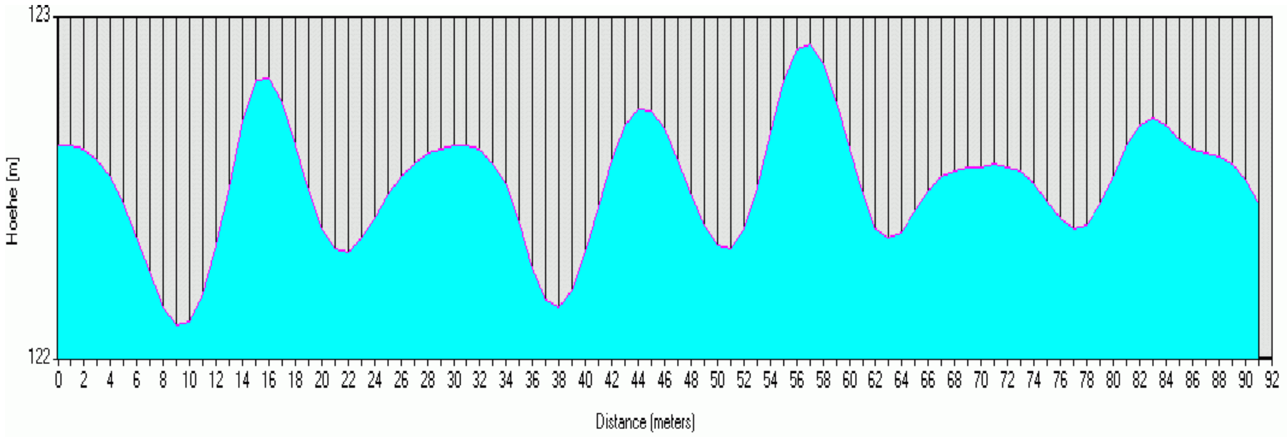

Fig.4. Laser altimeter profile across ridge and furrow, with elevations highly exaggerated when compared to the widths.

4. DISCUSSION & CONCLUSION

The approach adopted here shows that laser measurements do clearly reveal topographic structures like those displayed by these corrugated fields, despite being hidden under a forest canopy consisting mainly of mixed older stands including spruces, beeches and pine trees.

In this regard it is interesting to note that differences in canopy density resulting from the “Lothar” storm in 1999 (fig 1a), apparently did not affect the quality of the DTM obtained (fig 1b).

The filtering and processing of data produces detailed structural morphology of the bare earth beneath dense canopy and creates true-to-life renderings of the countryside. Compared to terrestrial mapping as done in an earlier stage of this project, laser scanning has proved its efficiency in rapidly generating dense accurate digital models of the topography and vertical structures of targeted surfaces.

The accuracy of the measurements still remain to be tested by ground measurements.

More over, while delineation of ridges (polygons) was done by manual digitization on the screen, algorithms could possibly be developed in a further stage to automatically discern the single furlongs and take there measurements.

The visualization of these structures under forest as provided by this technique recalls also in some respect the aerial oblique photographs of ridge and furrow still visible in unwooded countryside under grassland (Beresford & Saint Joseph, 1979) . Compared to the terrestrial mapping (Hauger et. al, 2001) this image unveils many details and structures that were overlooked during these ground surveys. In addition, the position of other structures included in this landscape as revealed by the laser data is quite instructive. As an example, the Sandbach river is shown to cut the ancient pattern of ridge and furrow, indicating that it is of anthropic origin. The same applies of course to the very straight ditch (Hardtgraben) crossing the area: In the present case, as written archives suggest that it was built during the 15 century, evidence is provided that ridge and furrow were generated at an earlier date

The resolution of this data and the relative ease of capture compares favourably with existing data sources, allowing large areas of landscape to be captured as three-dimensional surface

data facilitating a scientific, analytical approach to the landscape.
In terms of costs, minimum entry prices for smaller projects in Germany range from less than 7000 Euro to upwards 20000 Euro depending upon the data provider. But of course, for projects, of only the order of tens of acres, the per acre cost becomes significantly higher due to the fixed sunk costs of mobilizing the lidar sensor. In the case of Baden Württemberg that now disposes on a nearly comprehensive coverage of the land (35000 km2), data may become available through the surveying agency (LVA) at following conditions: 15 Euro/km2 for untreated data and 60 Euro/km2 for end-products usable for DEM generation.
Such conditions provide therefore a very attractive cost-effective alternative for future surveys of remnants of past landscapes. For archeologists in general, it may open historic structures and archeological sites to more visually detailed, accurate and efficient examination and can therefore be regarded as a very useful complement to aerial photographs, especially when forest canopies prevent visual identification of hidden patterns.

5. ACKNOWLEDGMENTS

We acknowledge the various contributions of many persons to the present project. Mr. Hauger (Rastatt) deserves much thanks for setting up this research project. We gratefully acknowledge the Landesvermessungsamt Baden Württemberg and Topscan Company for generously providing us access to their laserscanning data, with special thanks to Mr. Gültlinger who repeatedly offered support end encouragements. Rene Siwe (Remote Sensing Department – Freiburg) also provided technical assistance in applying Erdas-Imaging for terrain modelling.

6. BIBLIOGRAPHY

Ackermann F., 1999, Airborne laser scanning – present status and future expectations. ISPRS Journal of Photogrammetry and Remote sensing 54, 64-67.

Beresford M., Saint Joseph J., 1979, Medieval England – an aerial survey. 2nd edition. Cambridge University Press.

Ewald K.C., 1969, Agrarmorphologische Untersuchungen im Sundgau (Oberelsaß) unter besonderer Berücksichtigung der Wölbäcker.- Tätigkeitsbericht der Naturforschenden Gesellschaft Baselland XXVII, 178 p.

Gültlinger M., Schleyer A., Spohrer M., 2001, Flächendeckendes, hochgenaues DGM von Baden-Württemberg. Mitteilungen des Vereins für Vermessungswesen, 48-2. 63-77.

Hoss H., 1997, Einsatz des Laserscanner-Verfahren beim Aufbau des digitalen Geländehöhenmodells (DGM) von Baden-Württemberg. DVW Mitteilungen, 44-1. 5-26

Hauger K., Riedinger R., Sittler B., 2000. Wölbäcker bei Rastatt – eine Dokumentation zur Analyse und Erhaltung überkommener Altackerkomplexe. Kulturlandschaft – Zeitschrift für Angewandte Historische Geographie. Jg. 10 (2) 113-118.

Hauger K, Riedinger R., Sittler B., 2001. Wölbäcker im Landkreis Rastatt – Auf den Spuren mittelalterlicher Ackerfluren. Heimatbuch des Landkreises Rastatt, 163-172.

Hyyppä J, Pyysalo U., Hyyppä H , Samberg A., 2001, Elevation accuracy of laser scanning-derived digital terrain and target models in forest environment. 20 th EARSel Symposium and Workshops, Dresden, Germany, 14-17 June 2000.

Pfeiffer N., Kraus K., Köstli A., 1999, Restitution of airborne laser scanner data in wooded areas. GIS, 2, 18-21