SAGVNTVM

PAPELES DEL LABORATORIO DE ARQUEOLOGÍA
DE VALENCIA
EXTRA-13

WOOD AND CHARCOAL
EVIDENCE FOR HUMAN AND NATURAL HISTORY

ERNESTINA BADAL – YOLANDA CARRIÓN – MIGUEL MACÍAS – MARÍA NTINOU
(COORDINATORS)

VNIVERSITAT DE VALÈNCIA
FACULTAT DE GEOGRAFIA I HISTÒRIA
Departament de Prehistòria i d'Arqueologia

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AIRBORNE LASER SCANNING OF HISTORICAL WOOD CHARCOAL PRODUCTION SITES – A NEW TOOL OF KILN SITE ANTHRACOLOGY AT THE LANDSCAPE LEVEL

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***Summary**: We have tested if airborne laser scanning data are useful to find historical wood charcoal production sites in the field, especially in forested areas with a dense tree canopy. Therefore we have evaluated digital elevation models (hillshades) based on these data, (1) considering potential kiln site structures at an 1-km²-testplot and verifying them in the field, (2) testing the visibility of a large number of kiln sites already localized and (3) systematically recording potential kiln site structures at the hillshade images for a large pilot area. Thousands of such sites are recognizable by airborne laser scanning and very high kiln site densities could be established. Exact information could be provided on their geographical positions and distribution patterns. Airborne laser scanning is a valuable tool for kiln site anthracology, facilitating the field work considerably, increasing the efficiency and precision of the site records and highlighting the high historical significance of wood charcoal production. Moreover, it underlines the outstanding scientific potential of anthracological kiln site studies. The large number of analysable sites provides a unique chance to obtain new information on the historical forests and the human impact therein with fine spatial resolution at the landscape level.*

***Key words**: Black Forest, charcoal burning, forest history, kiln site, LiDAR.*

INTRODUCTION

Past fuel supply was heavily dependent on wood charcoal production. Historical sites of charcoal burning (wood charcoal kiln sites) with their distinct anthropogenic ground surface structures and their charcoal layers are widespread in the landscapes, especially in mountainous forest regions. In many areas of western Central Europe they are the most frequent and most important remnants of past wood use and forest exploitation. The wood charcoal macroremains contain comprehensive dendrological and dendroecological information. Therefore anthracological studies of historical charcoal kiln sites are a main key to local forest and land use history, providing results on past fuel wood use and past human impact with fine spatial resolution at the landscape level (Ludemann 2002, 2003, 2011).

However, to establish such studies and results the knowledge of the exact geographical position of a large number of historical wood charcoal production sites is required. Unfortunately these sites generally are not recorded in written sources or in historical maps and they are not visible in the usual aerial photographs and by traditional methods of remote sensing. Up to now time-consuming field surveys had to be under-

taken to localize them in the landscape. Indeed, some years ago a new tool has become available for our investigations, airborne laser scanning (ALS, airborne LiDAR), offering completely new and innovative options which we have begun to verify systematically for a large pilot area. We want to know in which cases and to what extent the historical wood charcoal production sites are recognizable by laser scan techniques.

STUDY AREA AND METHOD

Hillshade images with maximum resolution (1 m-grid; vertical resolution < 0.15 m) calculated from the LiDAR data (digital elevation model, DGM1m; FVA/LGL 2011) were evaluated systematically, focusing on the visibility of historical wood charcoal kiln sites. The visual interpretation of the high-resolution digital elevation model from the point of view of kiln site anthracology follows a hierarchical three-step approach:

(1) Verification of a km²-testplot: A forested landscape section of one km² was selected of an area of which a high density of potential kiln site structures was visible. The potential kiln site structures were identified and mapped at the corresponding hillshade image. Then the identified structures were verified by field surveys.

(2) Verification of known kiln sites: A large number of historical wood charcoal kiln sites had already been detected and recorded in the course of many years of previous kiln site anthracological field work. Their

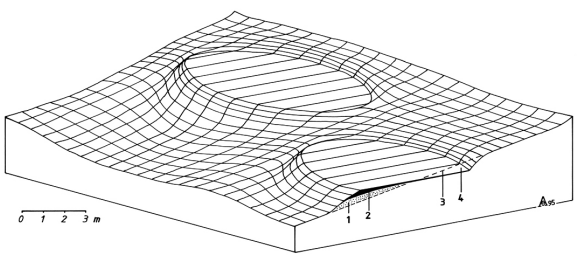


Figure 1. Anthropogenic relief features of two historical wood charcoal kiln sites, schematically. Characteristic field surface structures at a slope. Kiln sites type A: circular terraces with a diameter of 8 to 12 m, soil accumulation downhill (1), charcoal layer (2), original ground level (3) and soil removal uphill (4).

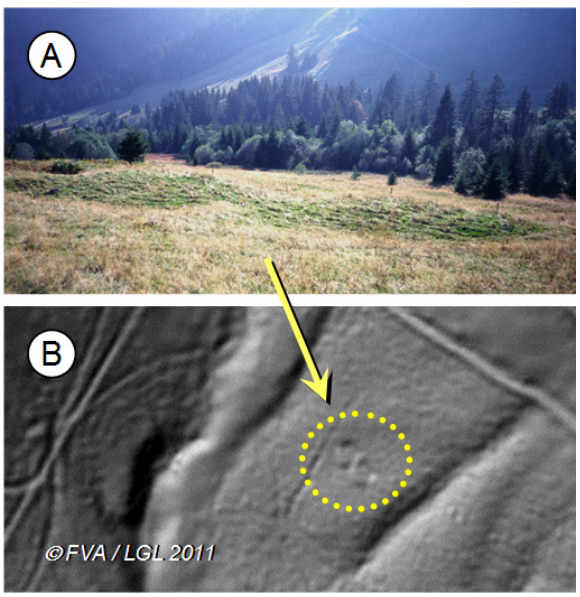


Figure 2. Anthropogenic structure of two historical wood charcoal kiln sites at a slope (Type A, cf. Fig. 1). A: Sites K 590 and K 591 in the field. B: The same kiln sites at the LiDAR-based hillshade image.

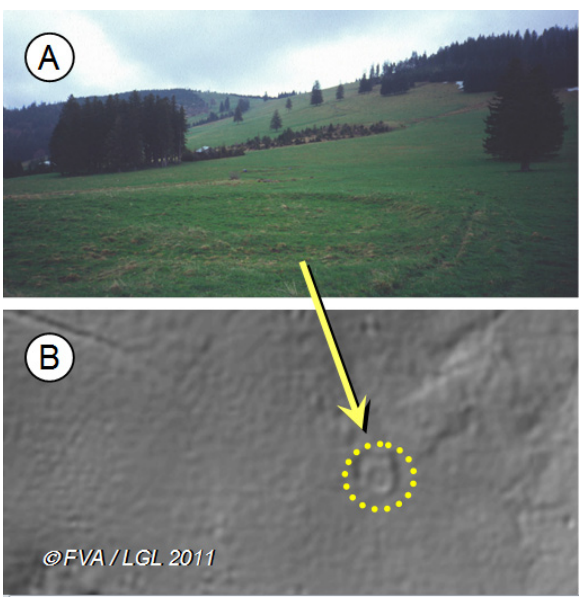


Figure 3. Relief features of historical wood charcoal kiln sites in flat landscapes. Type B with a circular embankment or crater-shaped structure. A: Site K 538 in the field. B: The same kiln site at the hillshade.

visibility at airborne LiDAR-based hillshade images was verified for our main study area (Southern Black Forest) and neighbouring regions in Southwest Germany.

(3) Record of potential kiln site structures: In our main investigation area, we are systematically recording potential kiln site structures at the LiDAR-based hillshade images. In this area a maximum number of historical charcoal kiln sites was already known and an even larger number of still unknown was expected. This successful but also time-consuming work is still in progress.

RESULT AND DISCUSSION

(1) Testplot: Looking for historical wood charcoal kiln sites within the one km²-test area, we had identified 124 very well visible structures (potential kiln sites) by our first visual interpretation of the corresponding hillshade image. Verified by field surveys, 104 of them are really historical charcoal kiln sites, 20 are other similar anthropogenic or natural relief features, originating from forest management activities, natural erosion processes, windfall, etc. (Fig. 4). Moreover, it has to be highlighted that in the course of the field verification 49 further kiln sites could be detected in this area. Looking at the hillshade image again afterwards, we found out that many of these additional kiln sites are also visible – more or less clearly – at the hillshade. Consequently our first identification of potential kiln site structures at the hillshade was too cautious. Moreover, the visual interpretation needs some experience. On the other hand we found sites in the field, which indeed are not visible at the hillshade

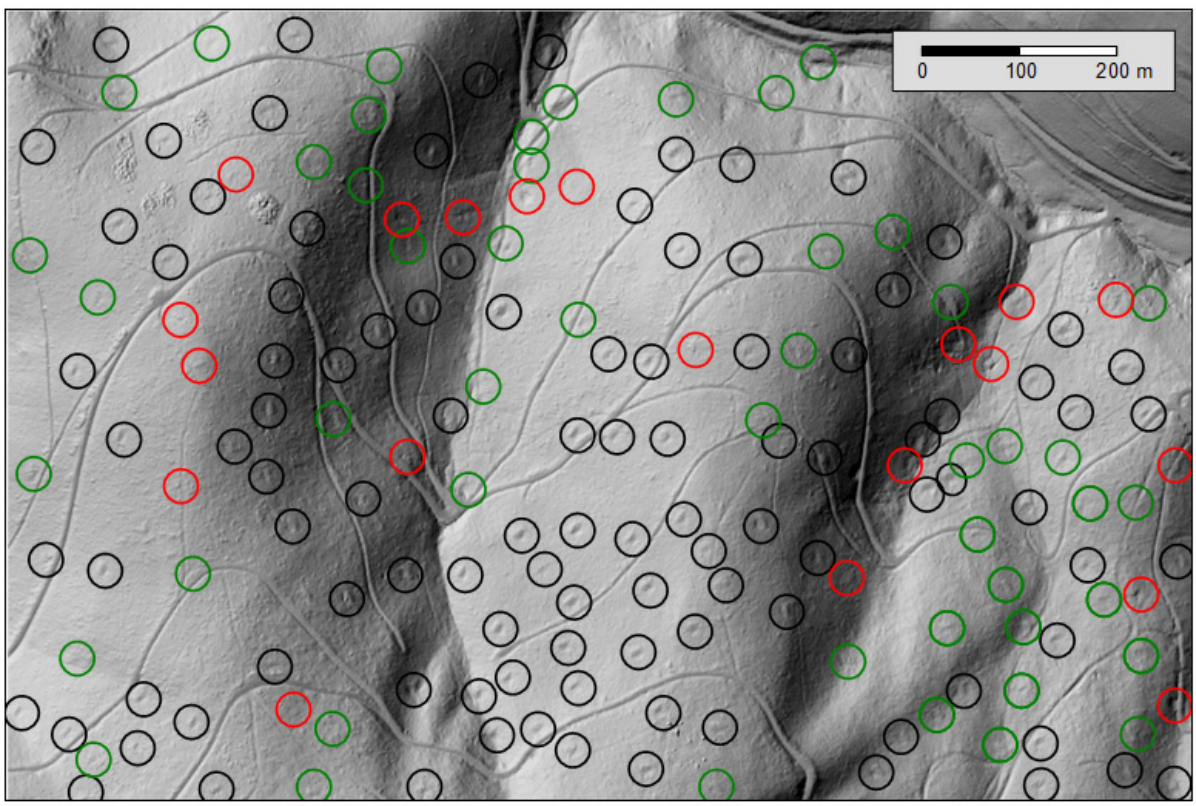


Figure 4. Testplot of a landscape section of one km² in the southwestern part of the Black Forest. Total number of kiln sites verified in the field n=153. Black: Potential hillshade structures verified (104). Red: Potential structures not verified = no kiln sites (20). Green: Kiln sites recorded additionally in the field (49); many of them are also visible at the plot and have been overlooked by the first interpretation (hillshade © FVA/LGL).

image and cannot even be visualized by airborn laser scanning. This is particularly the case when the characteristic kiln site structure was heavily modified or even destroyed, e.g. by forest road construction or natural erosion processes by water or rockfall. All in all 153 kiln sites could be verified within the square kilometer of the test area. 146 of them are visible at the hillshade, 125 (82%) very well, 21 (14%) less distinctly, while only 7 kiln sites (5%) are not visible.

(2) Verification of known kiln sites: 2448 historical wood charcoal kiln sites had already been detected and recorded in the course of previous field work in Southwest Germany. Testing their visibility at hillshade images, we found that the large majority of them, nearly 2000 sites (81%), indeed is visible, even in forested areas. 1326 (54%) are visible very well, 668 (27%) less easily. 19% (454 sites) are not visible. However, using a LiDAR-based site prospection, only very well visible sites are useful to find unknown sites, for those kiln sites, which have been visible less distinctly, could only be identified unequivocally at the hillshades after their detection in the field. It should be verified if even better results could be provided by using more specialized methods of data processing (e.g. Hesse 2010).

Two characteristic types of kiln site structures could be distinguished (Kiln site type A and B, cf. Figs. 1–3). Type A is the most common one, predominant in the western parts of the Black Forest where steep slopes dominate the landscape. Kiln site type B as well as sites with intermediate structures can be found especially in the eastern parts of the Black Forest and in other areas with smooth relief features and plain ground surface.

Despite the large number of already known sites, we were sure that they are only the smaller part of the historical charcoal kiln sites really preserved within the study area. This expectation is highlighted and even exceeded by step 3 of our LiDAR verification.

(3) Record of additional kiln sites: The systematic evaluation of the LiDAR data provides a very large number of (potential) kiln site structures additionally. Considering the exemplary field verifications (cf., steps 1+2, testplot and known sites), we are sure that most of them really are historical wood charcoal kiln sites. Exact information on the geographical position could be provided for all of them. Maximum kiln site densities of more than 150 sites per km^2 could be established, so that the average distance from site to site in such areas comes to less than 100 m (cf. Figs. 5 and 6).

Figures 5 and 6 give the preliminary result of the ongoing evaluation of the LiDAR data set. In the area considered, large parts of the Southern Black Forest, 2024 kiln sites at a total number of 360 km^2 had been detected without using LiDAR and recorded within about 20 years of kiln site anthracological studies. By using airborne LiDAR this even large number could be quadrupled within a short time (9115 sites at 679 km^2) and we are far from finishing the LiDAR-based kiln site prospection and verification in this area. Cautiously estimated and taking into account the results of the field studies, we are sure, that at least 10,000 historical kiln sites are well preserved within the Southern Black Forest.

Moreover, considering the exemplary field surveys and previous field work, we expect that there is a remarkable number of kiln sites which could not be detected at the hillshades. This could be due to (1) bad

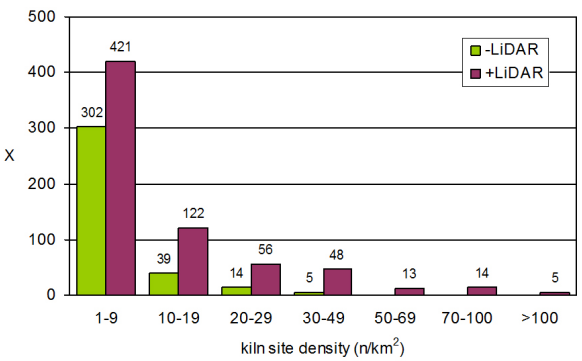
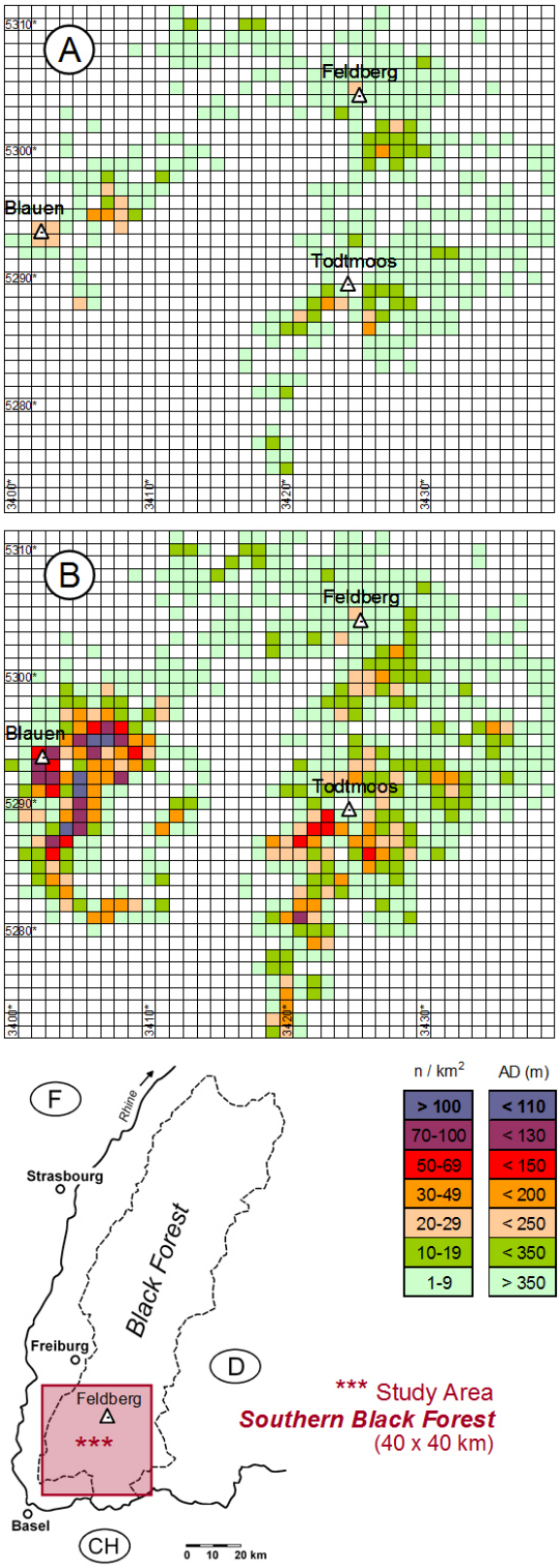


Figure 5. Number (X) of km^2 with a distinct kiln site density (kiln sites n/km^2) in the Southern Black Forest recorded by previous field studies (green) and including potential LiDAR structures (red) (preliminary result, record in progress). Total km^2 with kiln sites: 360 (green), 679 (red).



conservation, e.g. by erosion, forest road construction, wood transport etc., (2) heterogeneities of the ground surface or vegetation, e.g. dense herb or shrub layer, (3) problems with the laser scan data, e.g. flight too late in the spring, when deciduous trees already had developed their leaves, or (4) less distinct anthropogenic structure and weak anomalies of the ground surface.

Consequently, field work could not be substituted completely by airborne laser scanning. Field work is still necessary for the verification of LiDAR-visible structures and for finding not visible sites.

CONCLUSION

Airborne laser scanning is a valuable tool for kiln site anthracology, providing exact information on the geographical position of the historical sites, facilitating the field work considerably and increasing the efficiency and precision of the site records. Kiln site distribution and density indicate the high significance of wood charcoal burning in the past. Moreover, it underlines the outstanding scientific potential of kiln site anthracological studies for forest history and vegetation science. The large number, wide distribution and high densities of historical kiln sites provide a unique chance to obtain new exact information on the ancient forests and the changes therein with fine spatial resolution at the landscape level. Impressive examples of local and regional scale results and of the high spatial resolution of kiln site anthracology have already been given (e.g. Ludemann 2002, 2003, 2010, 2011; Ludemann *et al*. 2004).

Figure 6. Kiln site density (kiln sites n/km²) in the Southern Black Forest. A: Verified by field record without LiDAR survey (total n=2024 kiln sites). B: Including LiDAR survey, verified and potential kiln site structures (total n=9115 sites; preliminary result, record in progress). AD Average distance of sites. *Gaus-Krüger-km²-grid, 40x40 km, 1600 km²).

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