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THEMATIC SESSION

Archaeology and digital technologies -

Exchange of best practices, with particular reference to the European Convention on the Protection of the Archaeological Heritage (revised, Valletta, 1992)

- BELGIUM - FLANDERS -

The development and application of very high resolution lidar derived maps for the mapping and management of archaeological features and landscapes

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Introduction

The vast possibilities of the use of Airborne Laser Scanning (ALS, more generally known as LiDAR) data for the mapping of the archaeological and cultural historical landscape, are widely acknowledged (for example Devereux et al. 2005; Doneus et al. 2008). In Flanders (Belgium) the widespread availability of LiDAR data of increasing quality and resolution goes back to 2004 (De Man et al. 2005; Meylemans et al. 2017). In 2015 the most recent full covering LiDAR scan of Flanders was realized, and distributed as 1 m resolution rasters. Systematic screening of these maps and derived visualizations (hillshade, grey- and colourscale, sky view factor, etc.) has resulted in the discovery of a large number of geomorphological, archaeological and historical sites and features (for example *Celtic Fields*, barrow monuments, drainage patterns and structures, pleniglacial polygon networks, etc. (overview in Meylemans *et al.* 2017). Although the readily available 1 m resolution data generally provides ample resolution for the identification of these features, the raw ALS data from the 2015 scans also allows the development of rasters with mean 0,25 m raster resolution. Such 'very high' resolution products allows taking archaeological and cultural historical mapping and evaluation to another level, with possibilities in high precision mapping of features and structures, and equally high precision assessing of the impact of subrecent (for example forestry) activities on archaeological and cultural historical sites. However, the manipulation of this raw data requires some technical knowledge, and is rather time consuming, (Kokali & Hesse 2017; Meylemans & Petermans 2017) which often clearly proves to be a threshold for a large number of archaeologists and other scholars. Because of this threshold, two readily available high resolution LiDAR (hillshade and skyview factor) maps were created and made publicly available, covering the whole of Flanders, i.e. some 13.500 square kilometers.

Both these products have been made available for everyone to use through several online GIS-portals (https://geo.onroerenderfgoed.be; https://www.geopunt.be) and related WMS services.

Technical aspects

The LiDAR campaigns undertaken in the winter seasons of 2013 to 2015 provide a point cloud with a minimal density of one 'last return reflection' per 0,5 m². Due to the longitudinal overlap of 50% between the flight strips, a good coverage from at least 2 different angles to identify smaller structures is obtained. This results in a vast point cloud with high accuracy (RMSExy = 10 cm and RMSEz = 5 cm), which is stored in LAS- tiles of 500 by 500 meter. This point cloud has been classified into ground, non ground and water points.

For the creation of 'intuitively' readable LiDAR derived maps two visualization methods were chosen that are (beside grey- and colourscale imaging) the most used in archaeological practice:

hillshade and sky view factor. The combination of these two methods provide very 'directly readable' visualizations on different scales, on which larger geomorphological features are mainly visible through the hillshade visualization, and foremost small topographic features are well visible through the sky view factor analysis. In order to achieve this, several experiments were conducted with different parameters such as the search radius, the azimuth direction and inclination of the sun, and height exaggeration. These experiments were conducted on differing topographical situations (very flat to hilly landscapes), in search of a method that provides a 'mean best fit' for the differing topographical situations in Flanders.

This resulted in a multidirectional hillshade 0,25m resolution raster with 8 directions (from 202,5° tot 360° azimuth), with a solar inclination of 35° and vertical elevation factor of 2. Using the 8 directions visualization has the advantage that all structures independent of the solar azimuth will be highlighted.

The sky view factor 0.25 m resolution raster model is build up from 16 directions, with a very tight 2,5m search radius (to foremostly map local variations on the micro- and mesotopographical scale), with a high noise filter and no height exaggeration.

Licensing and distribution

The data were made available under the "*modellicentie voor gratis hergebruik*" (model license for free data use): http://data.vlaanderen.be/id/licentie/modellicentie-gratis-hergebruik/v1.0), a license written by and for the Flemish Government, similar to the 'Creative Commons Attribution' (https://creativecommons.org/licenses/by/4.0/). Under this license, widespread reuse is made possible, free of charge for both commercial and non-commercial use, with minimal restrictions apart from correct attribution. As a legal requirement the only post-processing that was necessary before publishing the new derived products was blurring certain areas of Flanders that are designated as 'military domain'.

For distribution of the data existing publication channels were used. The original raw data can be downloaded through the *OpenLiDAR* portal of *Informatie Vlaanderen* (https://remotesensing.vlaanderen.be/apps/openlidar/).

For the multidirectional hillshade and the sky view factor WMTS renderings (http://tile.informatievlaanderen.be/ws/raadpleegdiensten/wmts?request=getcapabilities&service=wmts&version=1.3.0) have been provided because these have proved to offer much better performance than WMS services. Through these WMTS services any user with a desktop GIS client can access the DTM products quickly and easily.

Users who are not familiar with desktop GIS software can consult either the Flanders Heritage *geoportal* (https://geo.onroerenderfgoed.be) or the more general Geopunt website (https://www.geopunt.be) by *Informatie Vlaanderen*. Both of these geoportals offer a simple web interface to geographical data. Apart from an easy to use and navigate map, they make viewing the multidirectional hillshade or sky view factor as simple as clicking a few buttons on a website.

An example application: the mapping and preservation assessment of bronze- and iron age features

Since the development of the several DTM products a wide variety of sites and landscapes have been screened, delivering a large amount of archaeological and cultural historical features (overviews in Meylemans et al. 2017; Meylemans & Petermans 2017). Particular cases where the high resolution DTM images are delivering vastly important new insights are the mapping of so called 'Celtic Fields' and prehistoric barrow complexes, of which we provide a synthesis in the following paragraphs.

Mapping Celtic Fields:

The first mapping initiatives of so called 'Celtic Fields' (agricultural landscapes dating from the Iron age period) in Flanders date from the 1970's and '80's, and were based on aerial photographs (cf. overview in Creemers *et al*. 2011). The evolution and ever increasing resolution of the DTM products in Flanders resulted in the last decade in a growing number of identified and well preserved Celtic Field complexes, foremostly situated in forests and former heathlands (Creemers *et al*. 2011; Meylemans 2018; Meylemans *et al.* 2015). With the screening of the recent high resolution hillshades and sky view factor adaptations we believe that the majority of these complexes have now been identified and mapped (fig. 1; fig. 2), notwithstanding some smaller patches of Celtic Field plots might still have been missed. This, combined with the aerial photography data, results in a striking distribution pattern restricted to the Campine area of Flanders. Moreover, when combined with other archaeological data of Iron Age sites, such as burial grounds, trial trenching and excavation data delivering settlement sites, and palaeo-environmental data, several regions appear with distinct clustering of these data. These combined data thus suggest the existence of several regions with a higher rate of occupation in the (early) Iron Age period. These regions are in part seemingly related to environmental aspects, i.e. distinct higher ridges of plateau situations, and sandy soils with a slightly higher silt fraction than in the rest of the coversand area of Flanders (Meylemans 2018). The nature and density of the areas with Celtic Fields, burial grounds and settlements demonstrate the presence of intensely occupied and long lasting cultural landscapes, of which the origins can be traced back to the bronze age and in some cases the late Neolithic periods (Creemers et al. 2011)

The availability of the high resolution LIDAR data has instigated new efforts in the research of the *Celtic Field* complexes, mainly oriented towards the development of efficient management strategies.

Mapping Prehistoric barrows:

In Flanders the first excavations of barrow sites date from the second part of the 19th and the first part of the 20th century, although systematic research of these complexes only started after WWII (cf. overview in De Mulder 2011). Instigated by forest management projects and illicit pillaging, several barrow complexes were excavated in the 1970s and 1980s. More than one thousand of levelled barrows have been mapped through aerial photography from the 1970's onwards (overview in De Reu *et al*. 2013). In the last few decades research and excavations of barrow sites were mainly carried out in light of preventive archaeology (for an overview: Meylemans 2019).

This combined data seem to demonstrate several clusters of barrow complexes, for example on the Campine plateau, the Campine ridge (*Kempische heuvelrug*), and the cover sand ridge of *Maldegem-Stekene* (De Reu *et al*. 2013). As was already mentioned above, these clusters of barrow complexes often coincide with the presence of the Celtic Field complexes in the immediate vicinity (e.g. Meylemans 2018).

The high resolution LiDAR products are adding valuable new information to this barrow dataset, resulting in the detection of previously unknown barrow complexes (for example Meylemans & Deforce 2018; fig. 3), 'new' barrows and earthwork structures on already knowns sites, and even the detection of barrow types which were previously undocumented in Flanders, such as so called 'disc barrows' (fig. 4a, b).

A good exemplary case of the increasing capabilities of the several generations of the LIDAR recordings and -processing is the area of *Heverleebos* near the city of Leuven, where surveys at the end of the 19th century revealed the presence of at least 24 prehistoric barrows and/or Roman tumuli (fig. 5). A survey based on the first generation DTM recordings managed to locate and identify 11 of these barrows (Adriaenssens 2007; De Bie & Adriaenssens 2009). A recent survey, with the use of the high resolution hillshades however, resulted in the mapping of 23 of the 24 structures identified in the early 20th century, as well as the identification of 2 to possibly 7 previously unrecorded barrows (Meylemans *et al.* in prep.). In some cases in the areas with clusters of barrows also other features appear, such as earthen banks structures. Whether these are related to the barrow complexes has to be subjected to further field research.

Evaluation of the preservation state of sites:

The high resolution processing of the LiDAR data not only enables the detection of a large number of previously unknown features, but even allows with a high level of detail the evaluation of the preservation state of these monuments and their surroundings, and the impact of earlier and recent forest management works.

Very obvious examples of such impact is apparent in the previously mentioned *Heverleebos* area, where a.o. harvester tracks, forest management works, and the impact of deforestation practices is clearly visible in the vicinity and on the barrow monuments (fig. 6-12). In several of the barrow monuments also damage related to tree- throw features, pillage shafts (often pits located in the center of the barrow), and burrowing animals, is apparent (fig. 6, 9, 10). In several of the *Celtic Field* complexes as well the damage of forest management practices is obvious (fig 2b.), with practices such as mechanical removal of the fertile top soil resulting sometimes in a complete erasure of the *Celtic Field* banks.

Conclusions

The increasing capabilities of LiDAR surveys and the production of high resolution derived products is clearly an enormous merit and an obvious 'gamechanger' in the mapping and evaluation of several archaeological site types and structures. In this paper we demonstrated this with the mapping of prehistoric structures such as Celtic Fields and barrows, which demonstrate in some cases the presence of vast stretches of 'fossilized' and well preserved prehistoric cultural landscapes. This allows to set up research strategies on the landscape level, as well as to provide a new framework for the embedding and interpretation of other archaeological information sources.

This new information also clearly raises issues concerning the management and preservation of this archaeological resource in forest management practices. In any case the online dissemination of the lidar data importantly raises awareness of the presence of this valuable heritage to the general public and the owners/managers.

Figures

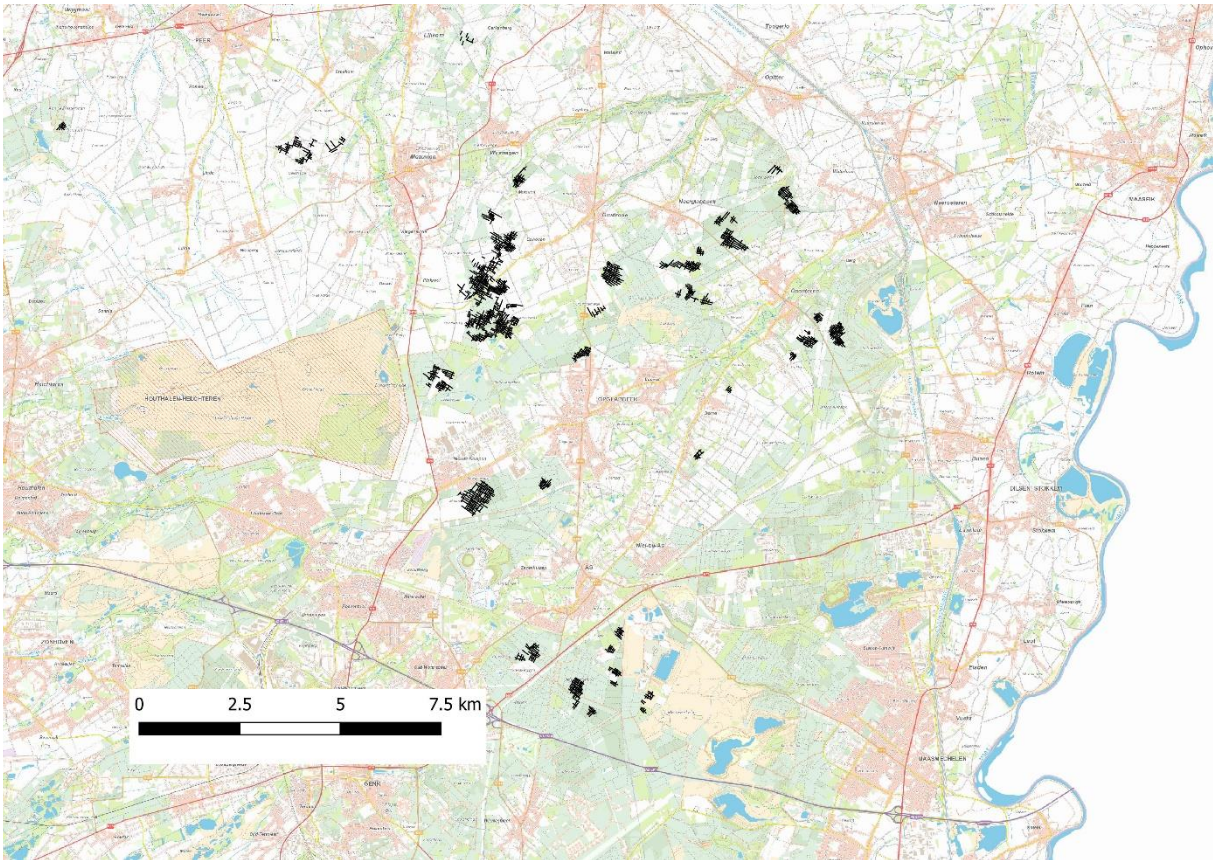

Fig. 1: Spread of Celtic Fields (in black) on the central part of the Kempens Plateau based on LIDAR data.

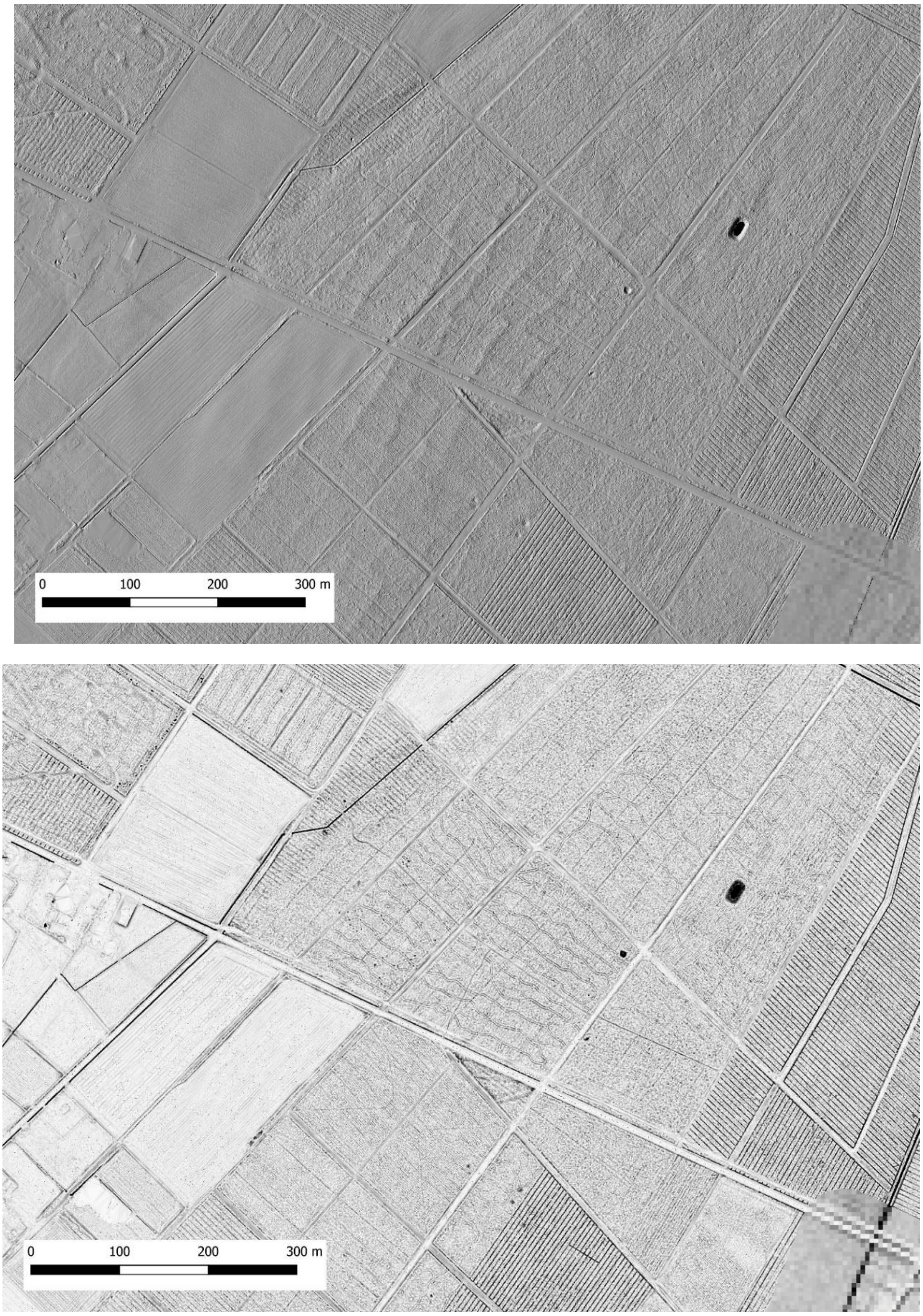

Fig 2 a & b: 0,25m resolution hillshade (a) and sky view factor (b) adaptations of area with Celtic Field structures in Kolisbos (community of Pelt). The hillshade clearly shows the Celtic Field walls in detail, while the sky view factor image shows the rather heavy impact of harvester tracks in the same area.

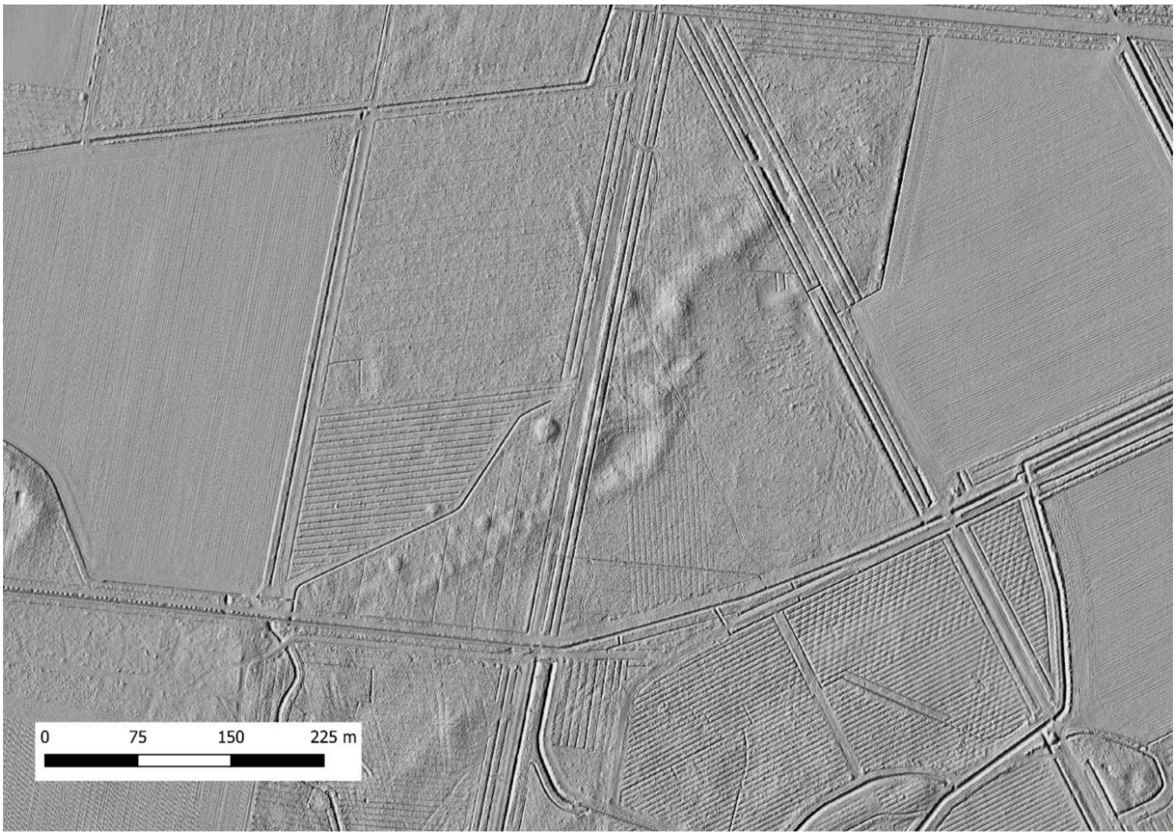

Fig. 3: Previously unknown barrow complex in the area of Postel (community of Mol, prov. of Antwerp). 0,25m resolution Hillhade.

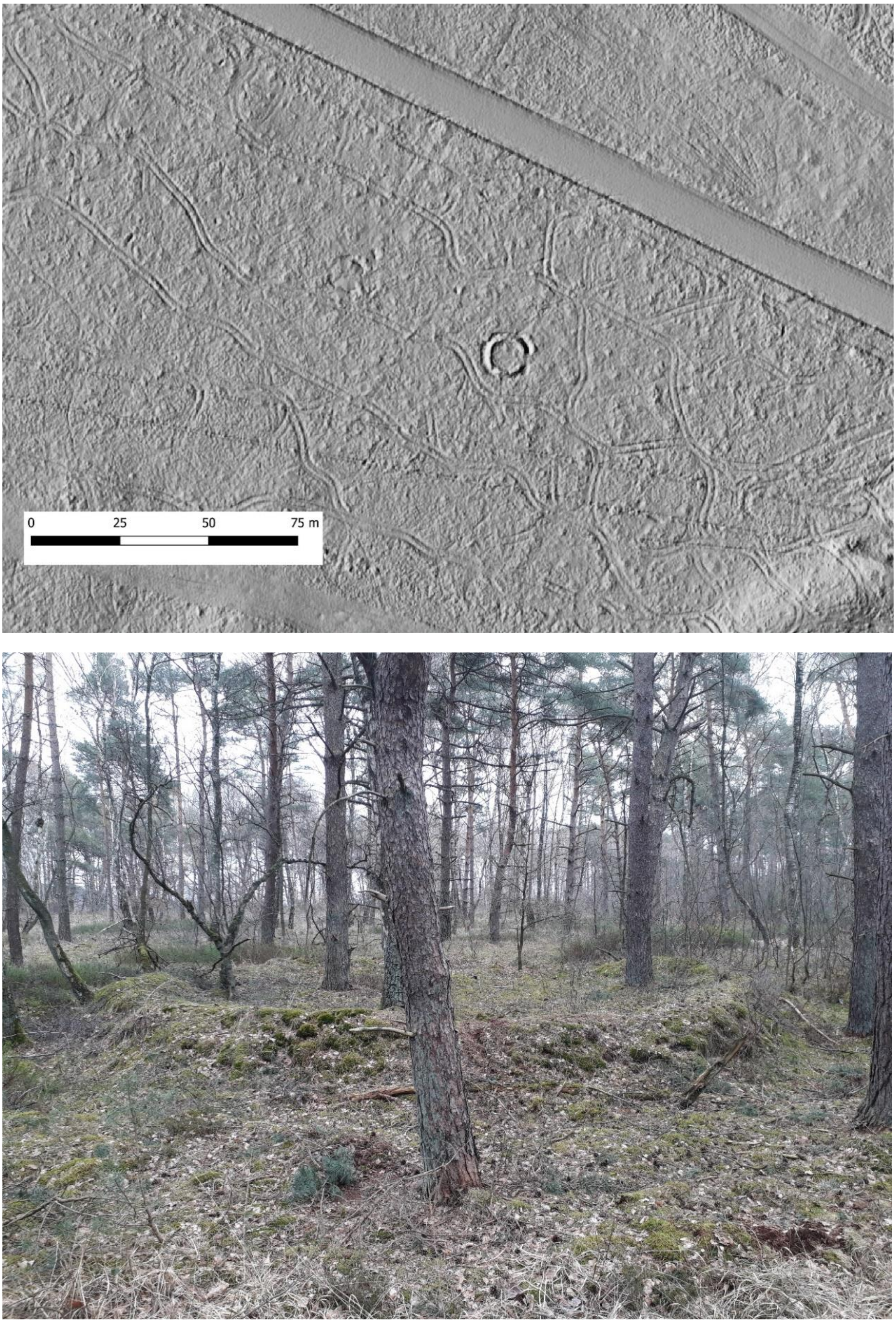

Fig. 4a, b: Probable prehistoric 'Disc barrows' in forest, 0,25m resolution hillshade (a) and photograph of the easternmost structure (b).

Fig. 5: Spread of prehistoric barrows in Heverleebos based on high resolution LIDAR data.

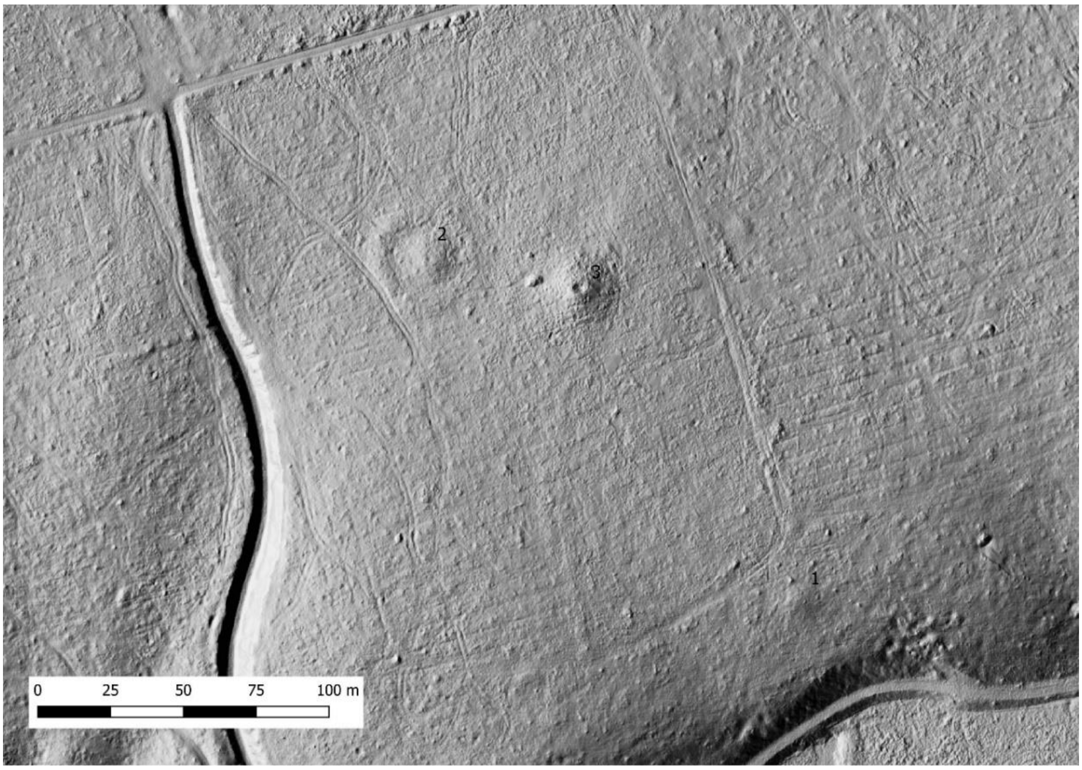

Fig. 6: Area with three barrows in Heverleebos, with clear impact from harvester tracks on and in the vicinity of the monuments, forest management works, and a central pillage shaft on the eastern barrow. Barrow '1' was previously unknown.

Fig. 7: Harvester tracks in the forest of Heverleebos near prehistoric barrows 1 to 3.

Fig. 8: Impact of tire tracks on the edge of the ring wall feature of barrow 2 in Heverleebos.

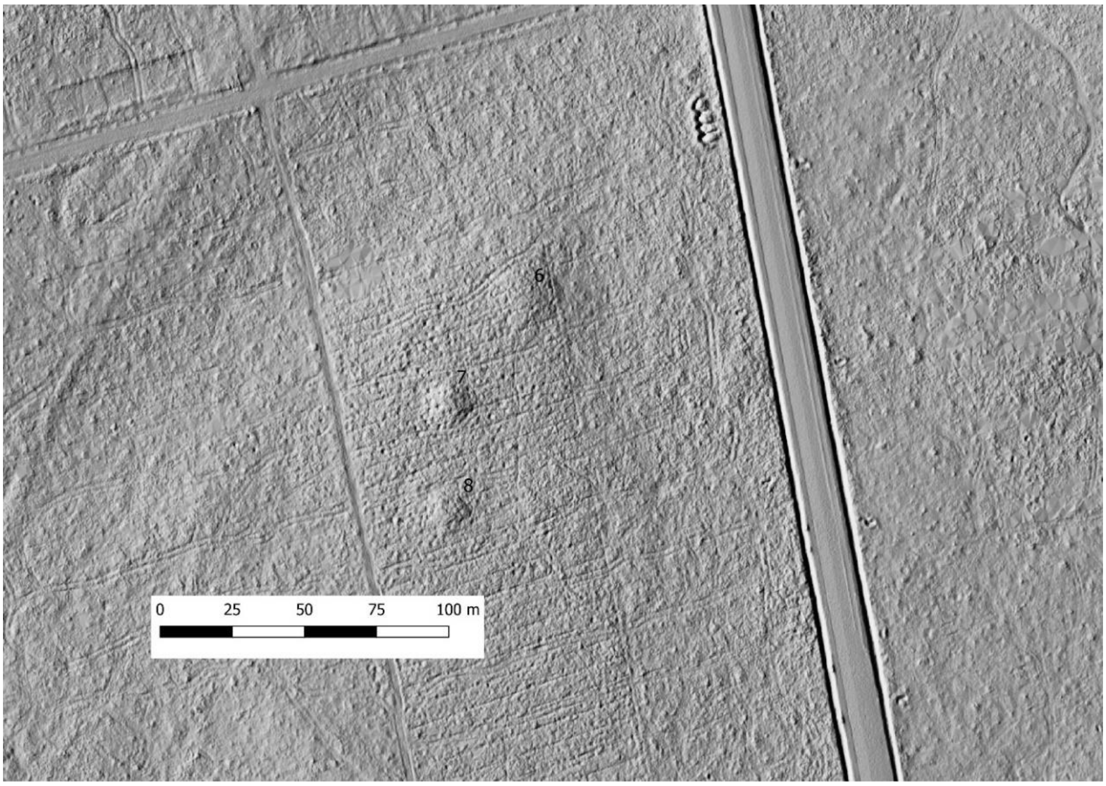

Fig. 9: Impact of forest management works and small pits (animal burrowing) on barrows in Heverleebos.

Fig. 10: Traces of animal burrowing on one of the barrows in Heverleebos

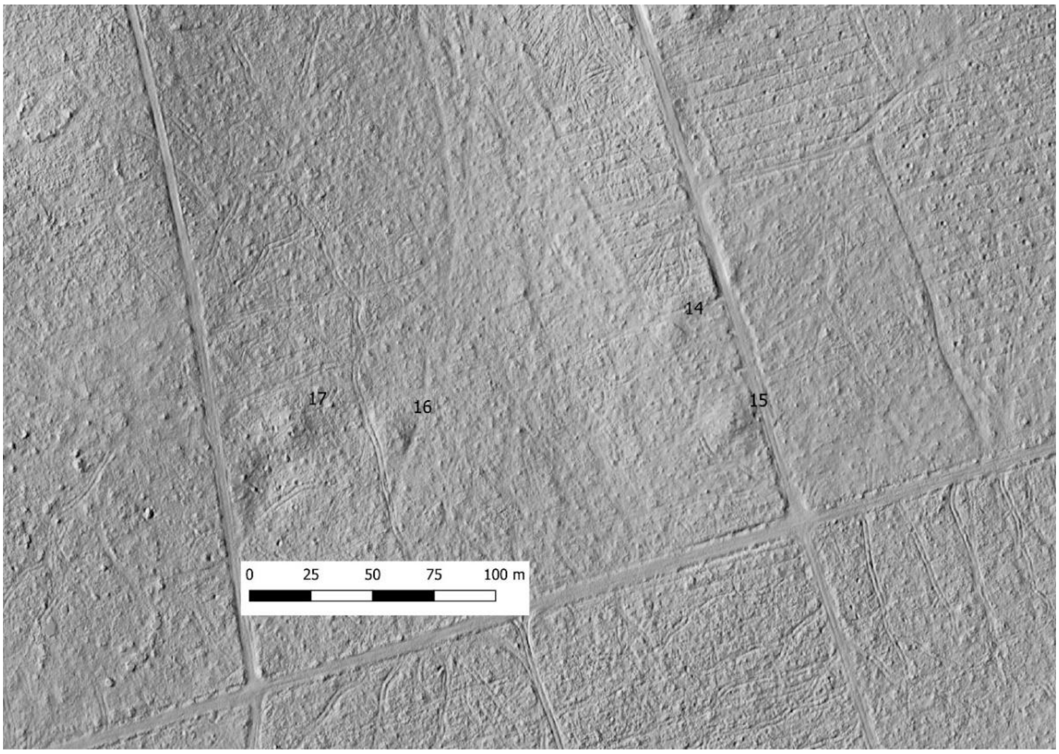

Fig. 11: Cluster of barrows in Heverleebos, with impact of harvester tracks on one of the structures (barrow 16), and other traces of forest management works.

Fig. 12: Impact of harvester tracks on barrow 16 in Heverleebos.

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