International Journal of Applied Earth Observation and Geoinformation 53 (2016) 64–75

Contents lists available at ScienceDirect

International Journal of Applied Earth Observation and Geoinformation

journal homepage: www.elsevier.com/locate/jag

Extracting cross sections and water levels of vegetated ditches from LiDAR point clouds

Jennifer Roelens[a,*], Stefaan Dondeyne[a], Jos Van Orshoven[b], Jan Diels[a]

[a] Division of Soil and Water Management, Department of Earth & Environmental Sciences, KU Leuven, Celestijnenlaan 200E – bus 2411, B-3001 Leuven, Belgium

[b] Division of Forest, Nature and Landscape, Department of Earth & Environmental Sciences, KU Leuven, Celestijnenlaan 200E – bus 2411, B-3001 Leuven, Belgium

ARTICLE INFO

Article history:
Received 26 April 2016
Received in revised form 29 July 2016
Accepted 5 August 2016
Available online 11 August 2016

Keywords:
LiDAR
Ditch
Cross section
Intensity
RGB

ABSTRACT

The hydrologic response of a catchment is sensitive to the morphology of the drainage network. Dimensions of bigger channels are usually well known, however, geometrical data for man-made ditches is often missing as there are many and small. Aerial LiDAR data offers the possibility to extract these small geometrical features. Analysing the three-dimensional point clouds directly will maintain the highest degree of information. A longitudinal and cross-sectional buffer were used to extract the cross-sectional profile points from the LiDAR point cloud. The profile was represented by spline functions fitted through the minimum envelop of the extracted points. The cross-sectional ditch profiles were classified for the presence of water and vegetation based on the normalized difference water index and the spatial characteristics of the points along the profile. The normalized difference water index was created using the RGB and intensity data coupled to the LiDAR points. The mean vertical deviation of 0.14 m found between the extracted and reference cross sections could mainly be attributed to the occurrence of water and partly to vegetation on the banks. In contrast to the cross-sectional area, the extracted width was not influenced by the environment (coefficient of determination R^2 = 0.87). Water and vegetation influenced the extracted ditch characteristics, but the proposed method is still robust and therefore facilitates input data acquisition and improves accuracy of spatially explicit hydrological models.

1. Introduction

Process-based spatially explicit hydrological models are highly dependent on accurate information about the location and dimensions of drainage networks. However, such data are usually lacking for minor water courses such as agricultural drainage ditches and road ditches. These play a key role in reducing waterlogging and water erosion, purifying water, improving groundwater recharge and they support uncommon species such as temporary water invertebrates that are not recorded in any other water body types (Williams, 2004). Ditches vary greatly in type of shapes, materials and vegetation cover (D'Ambrosio et al., 2011; Peeters et al., 2014). Since recent studies have shown the high sensitivity of the hydrologic response of a catchment to the morphology of ditches cross sections, automated characterisation of ditches would be of significant benefit for hydrological modelling (Buchanan et al., 2013; Carluer and Marsily, 2004; Miller, 2003; Moussa et al., 2002).

Cross sections of water courses can be measured by several field survey techniques. Field surveys often require significant human resources and funding, and therefore result in a poor longitudinal resolution of the measurements along the water course (Dietterick et al., 2012). A promising alternative to ground-based measurement of cross sectional profiles are three-dimensional point clouds produced by airborne light detection and ranging (LiDAR or laser mapping) systems. LiDAR is an important and efficient technique for the acquisition of area-wide elevation data at sub-meter horizontal resolution (Bowen and Waltermire, 2002). LiDAR-derived datasets have already been used for detection of drainage channel networks (Bailly et al., 2008; Cazorzi et al., 2013; Hooshyar et al., 2015; Passalacqua et al., 2012), assessment of water levels (Hopkinson et al., 2011; Magirl et al., 2005) and water depths (Pan et al., 2015). To date, LiDAR technology allows describing some physical characteristics of stream channels, such as depth, width and area that are in close agreement with ground-surveyed features (Cazorzi et al., 2013; Dietterick et al., 2012; Faux et al., 2009;

* Corresponding author at: KU Leuven (University of Leuven), Department of Earth and Environmental Sciences, Celestijnenlaan 200E – bus 2411, B-3001 Leuven, Belgium.

E-mail address: jennifer.roelens@kuleuven.be (J. Roelens).

http://dx.doi.org/10.1016/j.jag.2016.08.003
0303-2434/

Miller et al., 2004). This can be achieved for larger channels, but it is unclear whether equal accuracy can be obtained for smaller ditches.

Furthermore, current hydrological applications and assessments of cross-sections do not use the original LiDAR point cloud but rather start from rasterized digital elevation models (DEM) or Triangular Irregular Networks (TIN) derived from these point clouds (Caroti et al., 2014; Dietterick et al., 2012; Miller et al., 2004; Podhoranyi and Fedorcak, 2015; Roub et al., 2012). The reduced horizontal resolution of the DEM as compared to the original point cloud density can be an impediment to extract small elevation variations in the cross-sectional profiles. Höfle (2007) reported advances by directly analysing three-dimensional point clouds to maintain the highest degree of information without prior filtering and interpolating the discrete elevation measurements and applied it to observe glacier features and detect building and roof facets.

The objective of this paper is to propose and evaluate an automated approach to cross-sectional profiles of small vegetated drainage ditches and their characteristics such as cross-sectional area, width, presence of water and water level from original LiDAR point clouds. Furthermore, a method is proposed to classify the extracted cross-sectional profiles based on the presence

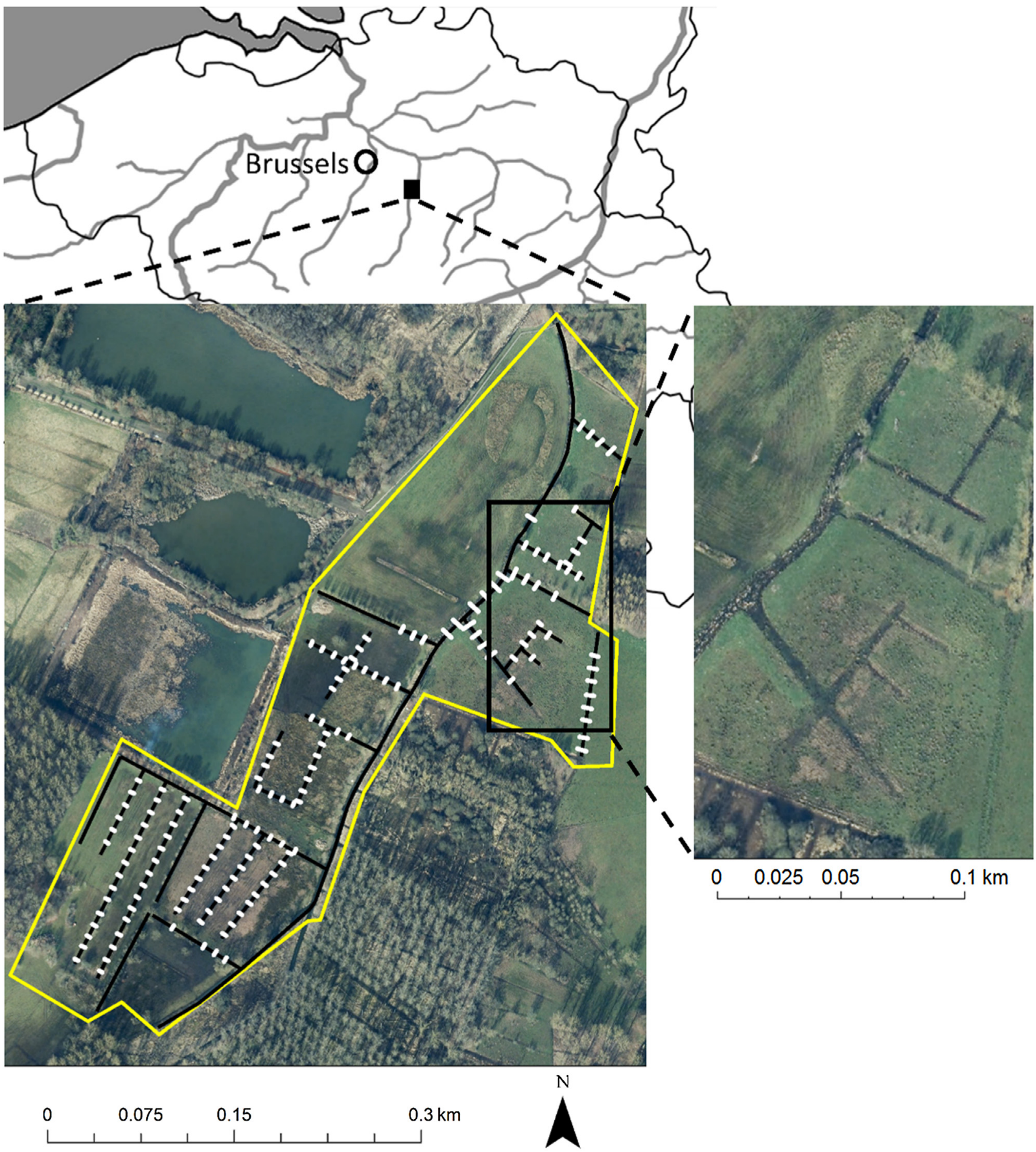

Fig. 1. Location and aerial photograph of the study area. The inset shows the study area bounded by a yellow polygon. The measured ditches and cross sections are represented with black and white lines respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)