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Detection of forest canopy gaps from very high resolution aerial images

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ABSTRACT

In Europe, assessment of the ecological function of forests is increasingly important as evidenced by Natura 2000, which has seen the establishment of protected sites that are of ecological importance. The presence of canopy gaps has proved to be a useful indicator of the forest structure and biodiversity in these areas.

Two methods – Object Based Image Analysis (OBIA) and Image Texture Based Analysis (ITBA) – were assessed to detect and quantify canopy gaps and to investigate the influence of forest type on their performance. The research was undertaken in two Natura 2000 sites in Bulgaria. To estimate the gap fractions in the field, 100 square plots (150 m by 150 m) were established. Within each plot, 25 circular sub-plots were laid out in a regular pattern. Gap size within each sub-plot was estimated visually.

The methods were assessed using very high-resolution (0.13 m ground resolution) aerial imagery. For the OBIA method, five parameter settings were tested and the gap fractions estimated on the imagery and compared with the field estimates. Likewise, for the ITBA method, five different settings were tested. In general, both methods overestimated canopy gap fraction relative to the field-based estimates, especially where the gap fractions were relatively small. Larger gaps were more accurately estimated by the OBIA method. Neither method performed well in broadleaved forest. Statistical comparison showed that, overall, the correlations of the estimates from the imagery with field data are only moderate and that there is no significant difference between the two methods.

1. Introduction

While there is widespread concern about the state of the world's forests, the threats of deforestation and forest degradation are not endemic worldwide. In Europe, the forest area has increased since 1990 and by 2015 the area of forest that is protected and allocated to the conservation of biodiversity had increased substantially (FAO, 2016). For centuries, many forest areas in Europe have enjoyed a degree of protection. As long ago as 1079, the New Forest in southeast England was legislated as a "royal forest" and was protected for hunting, mainly of deer (Langton, 2015). In the early 11th century, legislation protected the Vienna Woods (*Wienerwald*) in Austria as a hunting ground until the 16th century when production forestry began to be practised (Kurir, 1977). By the early 19th century, the introduction of forest management planning (*Forsteinrichtung*) was instrumental to the protection of many forest areas in central Europe. Although these measures were designed primarily to ensure a sustained supply of game for hunting and timber for shipbuilding, construction and other purposes, they also meant that the plant and animal life in the forest was protected. It was only in the latter half of the 20th century, however, that the ecological function of forests and the importance of conserving biodiversity became widely recognized and incorporated into forest management plans. The Forest Strategy of the European Union (EU) has identified "protecting forests and enhancing ecosystem services" as a priority so that by 2020, EU Member States "should achieve a significant and measurable improvement in the conservation status of forest species and habitats by fully implementing EU nature legislation and ensuring that national forest plans contribute to the adequate management of the Natura 2000 network" (European Commission, 2015 p14). Since almost half of the Natura 2000 sites are forest (European Commission, 2015), the acquisition of information to support the protection of forests and the monitoring of their biodiversity function is important.

Surveying and mapping has been employed to support forest management planning in central Europe since the mid 19th century (Weir,

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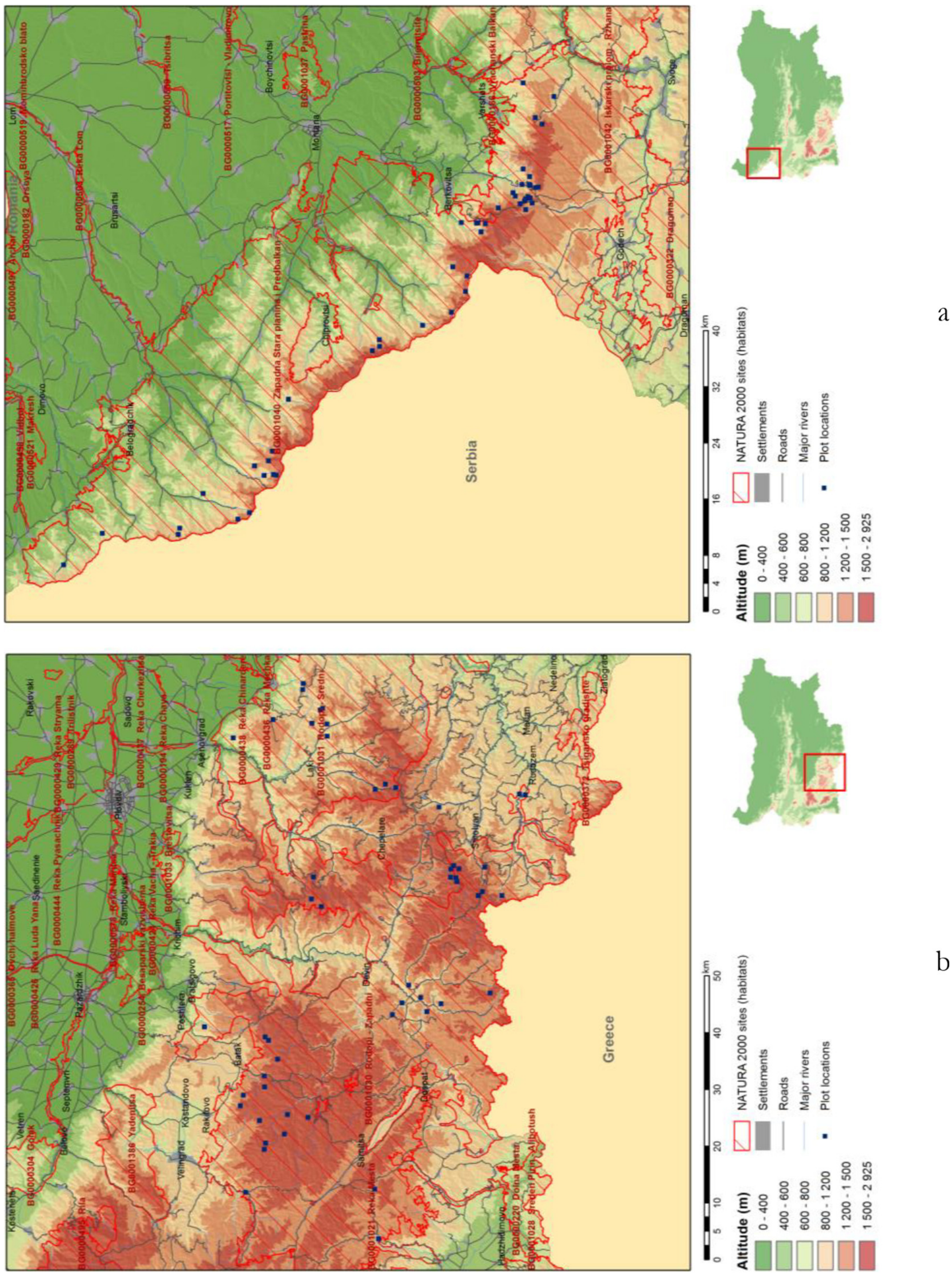

Fig. 1. Distribution of study sites in (a) the Western Balkan Range and (b) the Western Rhodopi Mountains in Bulgaria.

1997) and forest management agencies have also been among the most prolific users of aerial photography and other remotely sensed imagery. In addition to map production, remote sensing is widely used to support inventories for sustained timber production (Weir, 2000). The application of remote sensing specifically to assess forest biodiversity remains challenging and relies on the use of forest structural attributes, such as the presence of canopy gaps, as a proxy (Seto et al., 2004; Boutin et al., 2009; Lung et al., 2012).

Gaps in the forest canopy can be created by a variety of factors including windthrow, fire, disease and logging activities (Runkle, 1989). Because the ground vegetation receives more sunlight than under the surrounding canopy, forest gaps have a different microclimate and are generally richer in plant and animal life than the surrounding forest as a whole. Forest gaps can be detected and mapped by terrestrial methods in which the survey involves measuring the length and the width of the gaps then calculating the area with the assumption that the gap is either circular or an ellipse (Stewart et al., 1991). Forest gaps can also be mapped terrestrially using a hemispherical camera (Schwarz et al., 2003; Bucha and Stibig, 2008). The assessment of forest structural parameters by terrestrial methods, however, is tedious, time-consuming and therefore also costly (Herold and Ulmer, 2001). For extensive areas, the use of aerial photographs or high-resolution satellite imagery is an efficient, and therefore less expensive, alternative (Hobi et al., 2015). In recent years, LiDAR has been