ALS based forest information for forest fire danger modelling

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1. Introduction

The worldwide increase in large-scale and intensive wildfires as a result of climate change and human activities represents a major challenge for the future (Conedera et al., 2018; Dowdy et al., 2019). The central and northern parts of Europe, including the Alpine region, are currently exposed to a comparatively low risk. However, a future increase in the number, extent and intensity of forest fires is expected here as well. Even though Austria is not commonly regarded as a hotspot of forest fires, dozens to hundreds of fires occur each year (Müller et al., 2015). For modelling the risk of forest fires, information about forest fuel structure is essential as forest structure influences fire behaviour itself but also exerts an impact on fuel moisture, e.g. by shading. However, these components have only been inadequately characterized in forest fire danger assessment systems so far (Müller et al., 2020). In recent years, several studies have demonstrated the assessment of forest structure information based on airborne laser scanning (ALS) data (Hollaus et al., 2012; Leiterer et al., 2013; Lim et al., 2003). Due to the country-wide availability of ALS data, the potential of ALS derived forest structure information was investigated within the CONFIRM project, which aims at developing a pre-operational integrated forest fire danger assessment system at a high spatial resolution of 100 m (Zotta et al., 2020). In this contribution, several forest structure variables are derived from ALS data to serve as input for future forest fire risk assessments.

2. Study area and data

The study area comprises the state of Styria, located in southern Austria. Styria is a mountainous, forest-rich state and comprises a total area of 16,401 km². Forest covers 61.5% of the total area and consists of 82.5% coniferous trees and 17.5% deciduous trees. The dominant coniferous tree species is spruce (*Picea abies*) with 57.8%, the dominant deciduous tree species is European beech (*Fagus sylvatica*) with 7.7% (BFW, 2021). ALS data organised in flight strips were provided by the state administration of Styria. Additionally, meta-data, such as month and year of data acquisition, were available. A digital terrain model (DTM) with a spatial resolution of 1x1 m, derived from ALS data, was available for the entire study area.

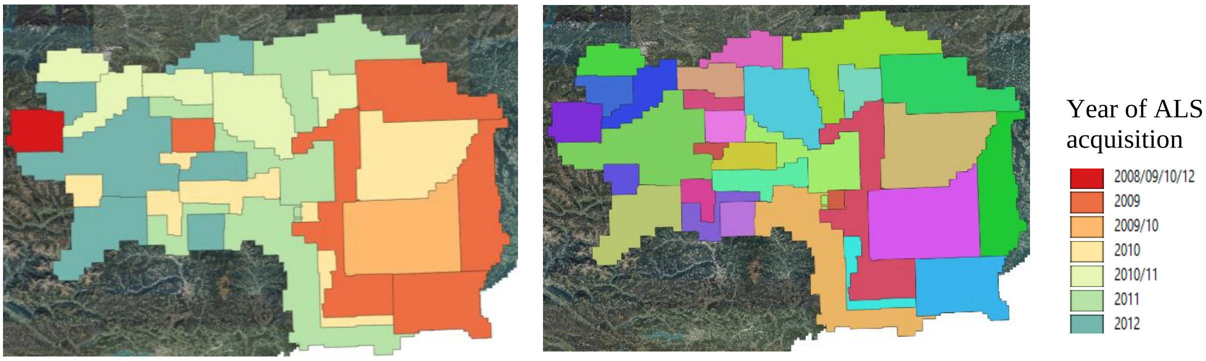

Figure 1: Left: ALS acquisition blocks for Styria. Right: Year of ALS data acquisition for the test site Styria.

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3. Methods

Based on the ALS strips, a digital surface model (DSM) with a spatial resolution of 1x1 m was calculated based on the approach described in Hollaus et al. (2010). This approach uses the benefits of different algorithms and delivers optimal results for canopy surfaces as well as for forest gaps. In addition to the DSM, a normalized digital surface model (nDSM) was calculated by subtracting the DTM from the DSM. The nDSM represents the tree heights. From the DTM, slope and exposition maps were calculated. The ALS data are available in the UTM projection (zone 33, EPSG:32633).

Based on the nDSM, **forest gaps** were derived by applying a height threshold to the nDSM. Every nDSM pixel within the forest area with heights < 1 m was classified as forest gap pixel. The forest area map was provided by the Austrian Research Centre for Forests (BFW)[1] and has a spatial resolution of 1x1 m. The classified forest gap pixels were used as input for calculating the forest gap fraction at a spatial resolution of 10x10 m and 100x100 m. The latter is the target resolution of the pre-operational integrated forest fire danger assessment system. The final forest gap maps represent the percentage of forest gaps within each 100x100 m pixel.

Information on **solar radiation** is important for characterizing the variability of fuel moisture patterns over the whole vegetation period. Based on the DSM, the potential incoming solar radiation was calculated for every month using SAGA-GIS[2]. To minimize processing time, the original resolution of the DSM of 1x1 m² was aggregated to 2x2 m² via bilinear interpolation. The temporal resolution was set to two hours, whereas for each month different start and end times for the modelling were selected. The derived total incoming solar radiation serves as an indicator of the drying out of forest gaps.

Vertical forest structure, e.g. the presence of understory vegetation, is of importance for fire propagation and fire intensity as fire ladders can lead to the conversion of surface fires to crown fires. To characterize the vertical forest structure, the ALS data were analysed using a voxel approach. It is assumed that within the forest area every ALS point (echo) represents a vegetation element. Thus, every voxel (1 x 1 x 1 m³) is checked for the occurrence of ALS points. If ALS points are present, the respective voxel is classified as a filled vegetation voxel. The derived three-dimensional data layers allow a detailed study of the vertical and horizontal forest structure to detect e.g. understory or lower parts of the canopy. The ALS data were processed using the OPALS software package (Pfeifer et al., 2014).

4. Results and discussion

All the described products were derived for the entire area of Styria. As shown in Figure 2, forest gaps are clearly visible in the ALS derived products. The modelled potential incoming solar radiation allows to identify forest gaps that receive a high incoming solar radiation. The seasonal influence on solar radiation is shown in Figure 2 and will be considered in the forest fire risk assessment model. The derived nDSM clearly shows forest gaps as well as stands characterised by different tree heights (Figure 3). The profile through the 3D ALS point cloud, shown in Figure 3, allows identifying differences in the vertical forest structure.

5. Conclusion and Outlook

The study shows that country-scale derivation of forest structure information by ALS data can be achieved in an operational way. For the operational use of the model, three maps for the characterization of the vegetation on 100 x 100 m should be available:

- The characterization of the vegetation with respect to the ignition risk considers potential incoming solar radiation and tree species.
- The characterization of vegetation with respect to fire spread considers data on forest gaps and tree species. The risk of spread is assigned to fire behaviour.
- The characterization of the vegetation with respect to fire intensity considers the forest gaps, fire ladders, and the map of tree species. The fire intensity is also assigned to fire behaviour.

The derived products are an essential input for forest fire risk assessment. Within the CONFIRM project, the novel forest structure information will be combined with meteorological data, remote sensing-derived estimates of tree species and fuel moisture, and socio-economic indicators (e.g. population

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[1] https://www.bfw.gv.at/hochgenaue-waldkarte-waldinventur/

[2] http://www.saga-gis.org/saga_tool_doc/2.2.2/ta_lighting_2.html

density, land use, infrastructure, tourism indicators) to estimate forest fire danger at a high spatial and temporal resolution. The suitability of risk modelling approaches based on expert knowledge as well as on machine learning is currently being assessed.

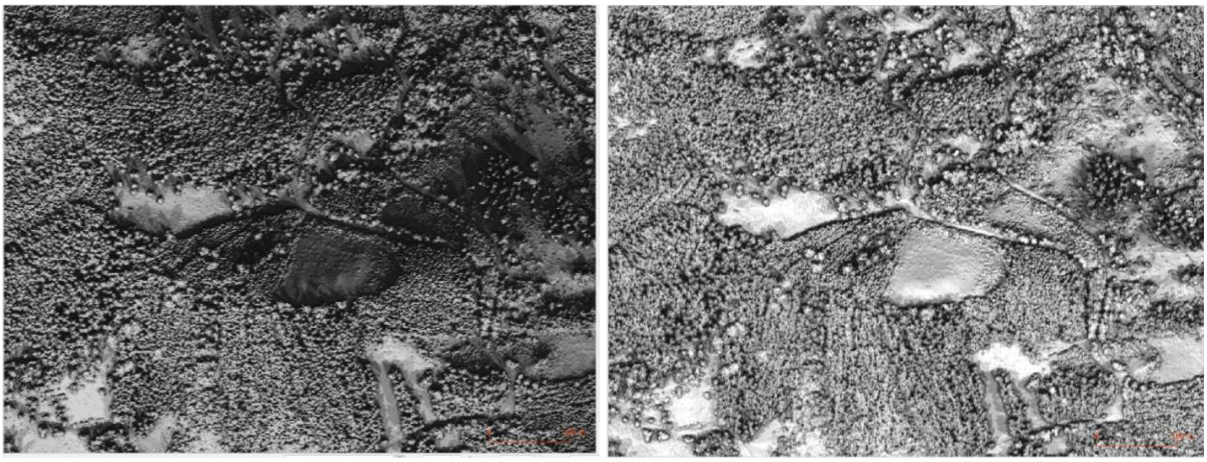

Figure 2: Examples of total incoming solar radiation based on ALS derived DSM, March (left), June (right). Dark pixel values indicate low solar radiation and bright pixel values high solar radiation.

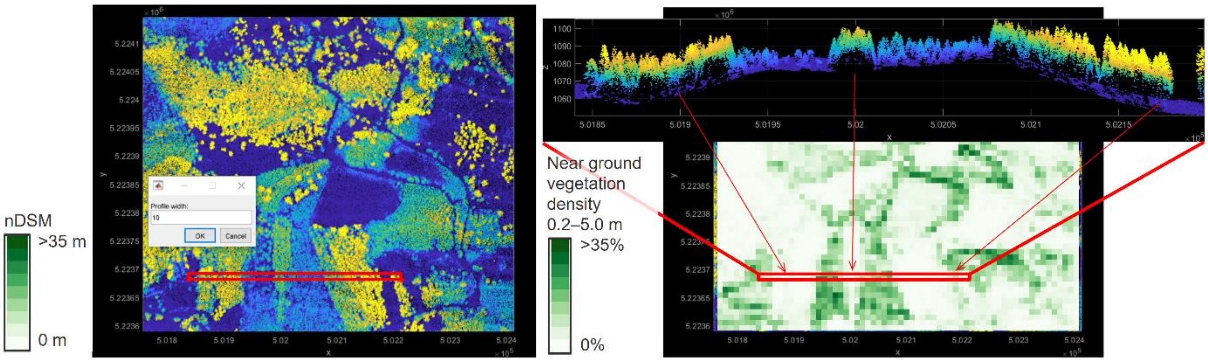

Figure 3: nDSM derived from ALS data (left), near ground vegetation density derived using a voxel approach (right).

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