UAS-based dead wood mapping in a natural deciduous forest in mid-Germany

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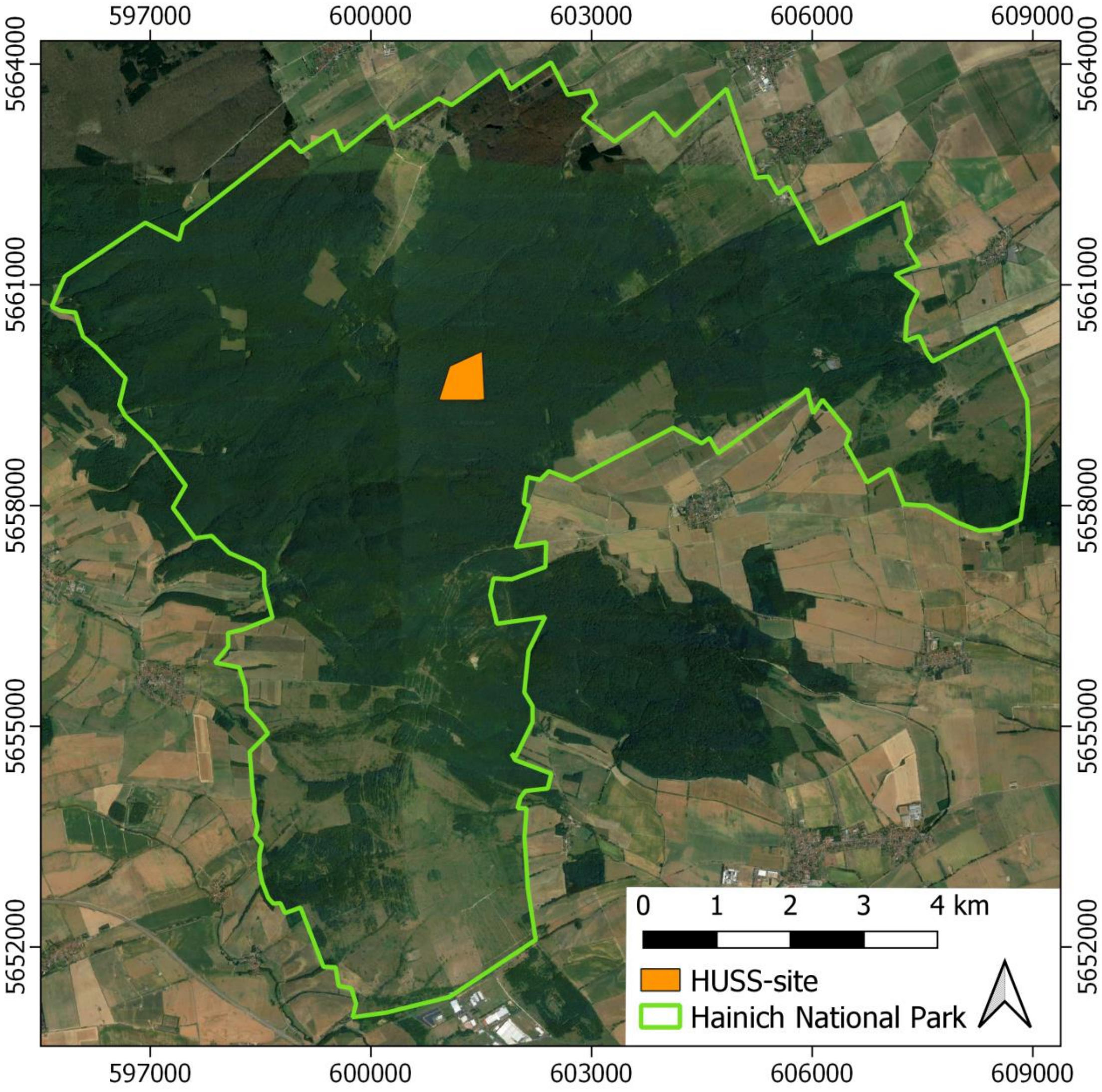
Background and Motivation

- Utilization of UAVs for the acquisition of ultra-high resolution imagery has heavily increased
- Images can be recorded almost at any time and at low cost
- Image parameters can be determined: of spectral channels, overlap, geometric resolution...
- Stereoscopic image processing enables 3D reconstruction
- UAV data gathered high interest in the forestry community → structural and spectral features can be delineated → forest monitoring and inventory can be supported using UAV data

- In this study, use of DJI Phantom 4 Pro RTK imagery to map dead wood is investigated

Test area: HUSS-site within Hainich National Park (UNESCO World Heritage)

- Dominated by beech, other tree species: ash, alder, sycamore maple, hornbeam, Wych elm Common and Sessile oak
- Unmanaged (primeval-like) forest
- Home for a wide variety of flora, fungi and fauna (around 10.000 species)
- Soils developed from shell limestone
- Coarse dead wood debries features various stages of decomposition



Test area: HUSS-site within Hainich National Park (UNESCO World Heritage)

- Major cause of dead wood is wind throw
- Dead wood definition (by Hainich National Park Administration): Dead trees or their parts with a length of at least 2 m and a diameter greater than 0.15 m

Dead wood examples of HUSS Site within Hainich National Park

UAS and Mission Parameters

UAS	DJI Phantom 4 RTK
Frequencies used for RTK	GPS: L1/L2 GLONASS: L1/L2 BeiDou: B1/B2 Galileo: E1/E5a
Positioning accuracy	horizontal: 1 cm + 1 ppm vertical: 2 cm + 1 ppm
Image sensor	DJI FC6310R (Bayer), 1" CMOS 8.8 mm/24 mm (35 mm equivalent)
No. of pixels/ pixel size	5472 x 3648 / 2.41 µm x 2.41 µm
Field of view	84°
Mechanical shutter	8 - 1/2000 s
Data format	JPEG, EXIF with 3D RTK CDGNSS location

Image: drohnen.de

- Take-off and termination from near-by flux tower

Parameter	Setting
Time (UTC+1) of first shot	10.36 pm
Wind speed	0.5-1.0 ms^{-1}
Clouds	overcast (8/8)
Mission duration	25 min (2 batteries)
No. images	578
Image overlap (front/side)	85% / 80%
Flight speed	5 ms^{-1}
Shutter priority	yes (1/360 s)
Distortion correction	yes
Gimbal angle	-90° (nadir)
Flight altitude over tower	100 m
ISO sensitivity	ISO400
Aperture	F/5.0-F/5.6 (exposure value -0.3)
Geometric resolution (ground)	4.18 cm
Area covered	0.579 km^2

- Five check points installed in natural glades to assess geometric accuracy of SfM-based model
- Deviation between the check point and model below 5 cm at all points
- RMSE < 3.5 cm

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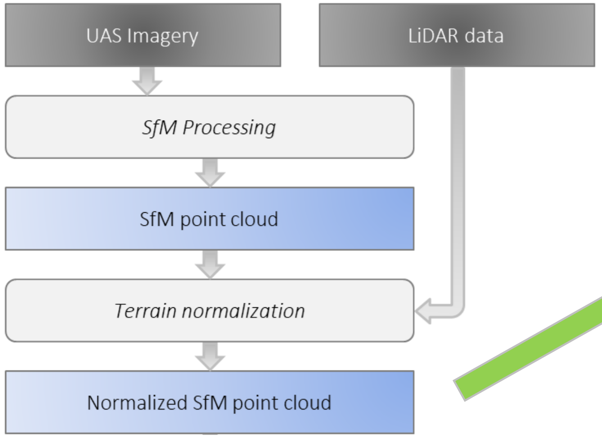

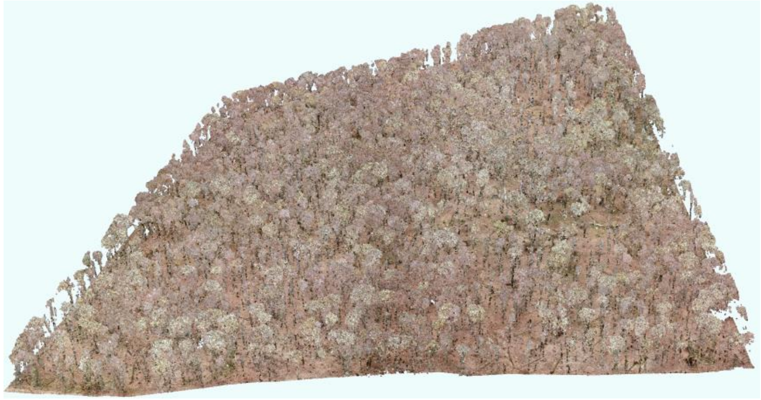

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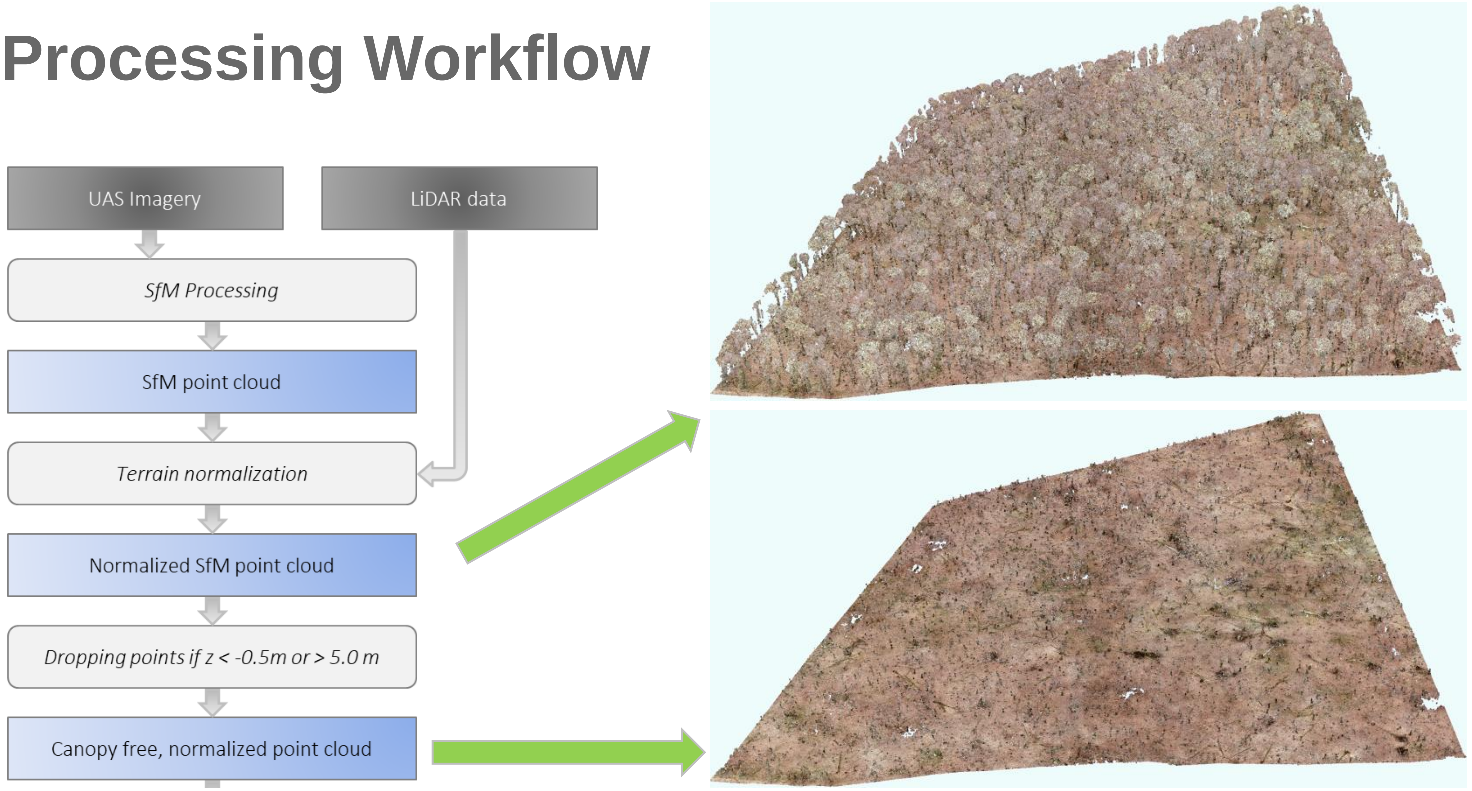
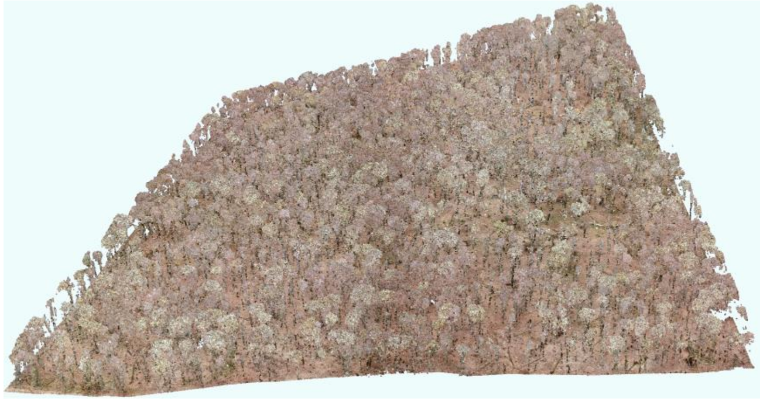
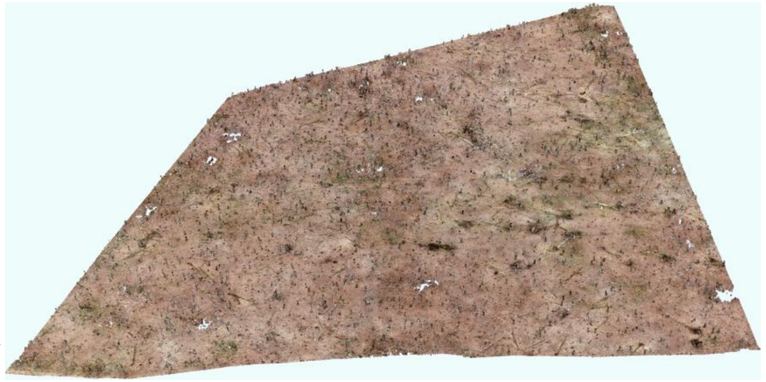
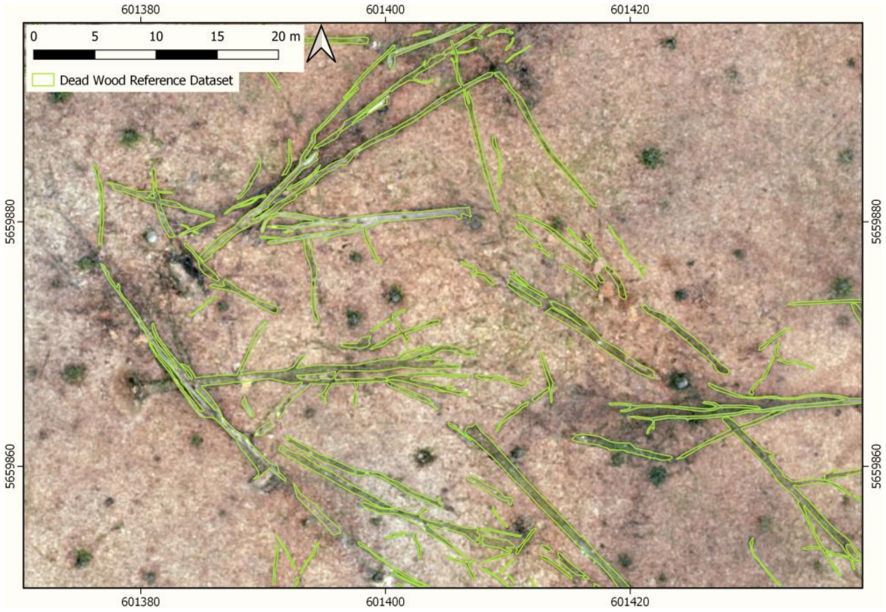


Processing Workflow

UAS Imagery
LiDAR data
SfM Processing
SfM point cloud
Terrain normalization
Normalized SfM point cloud
Dropping points if z < -0.5m or > 5.0 m
Canopy free, normalized point cloud
Rasterizing point cloud
Canopy free orthomosaic
Digitizing dead wood
Dead wood reference data







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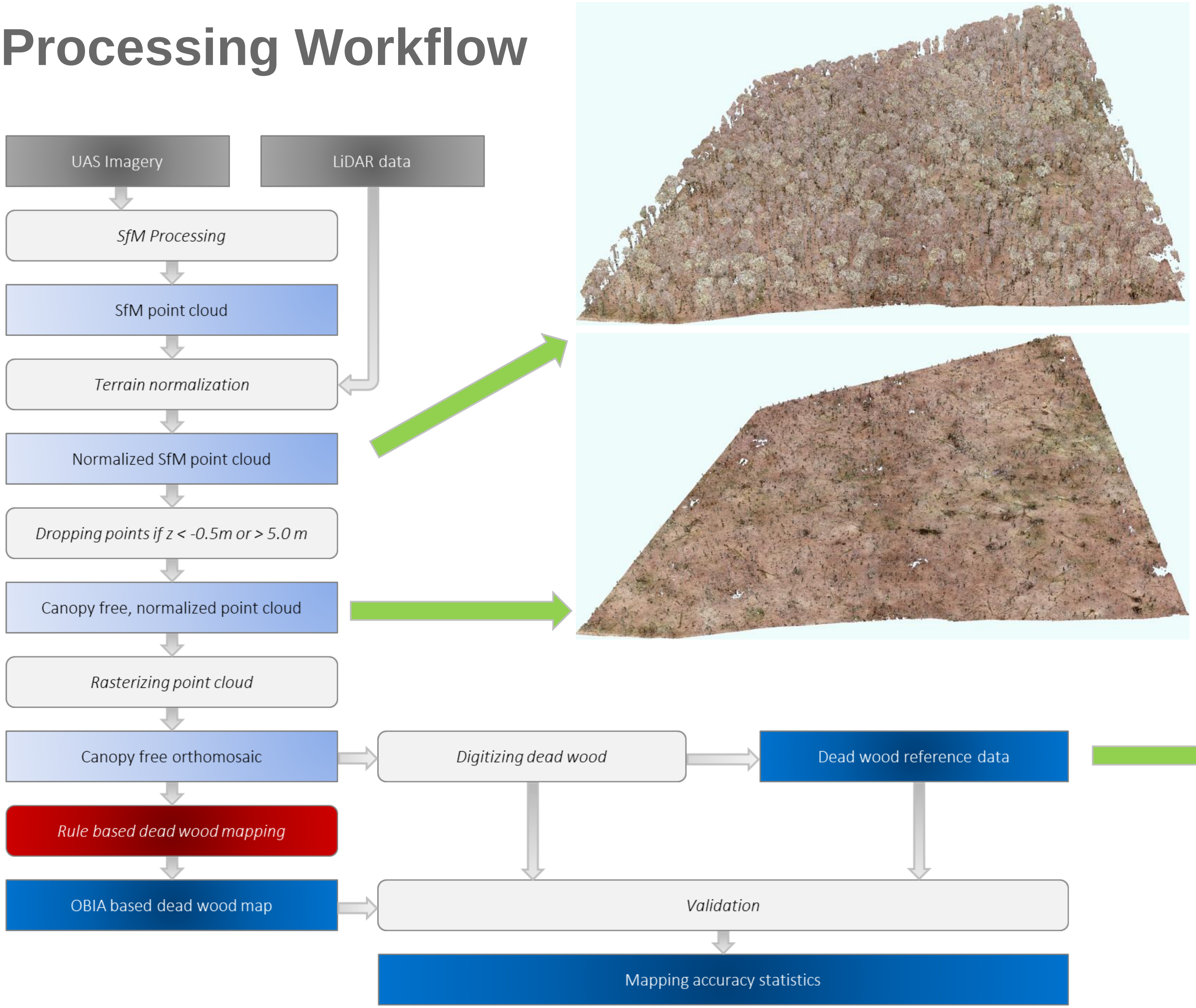
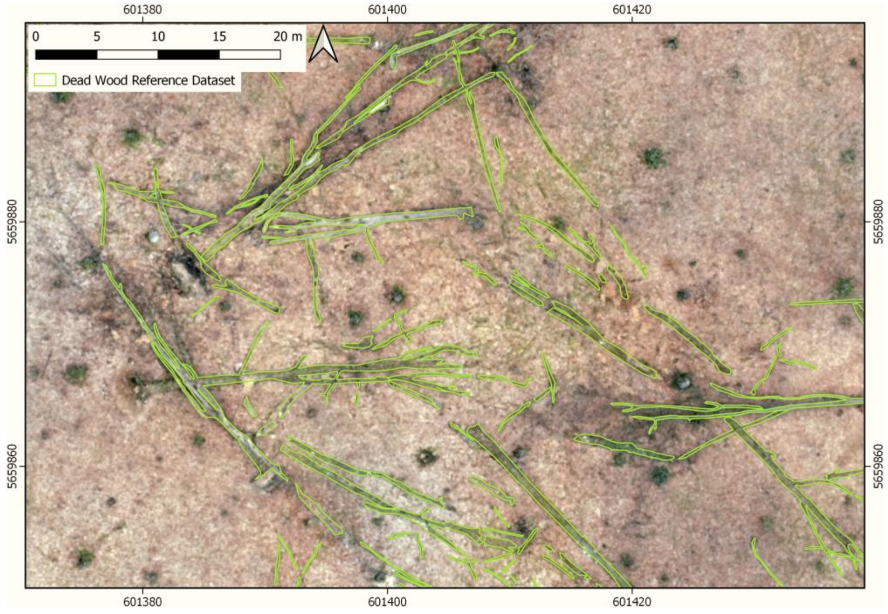
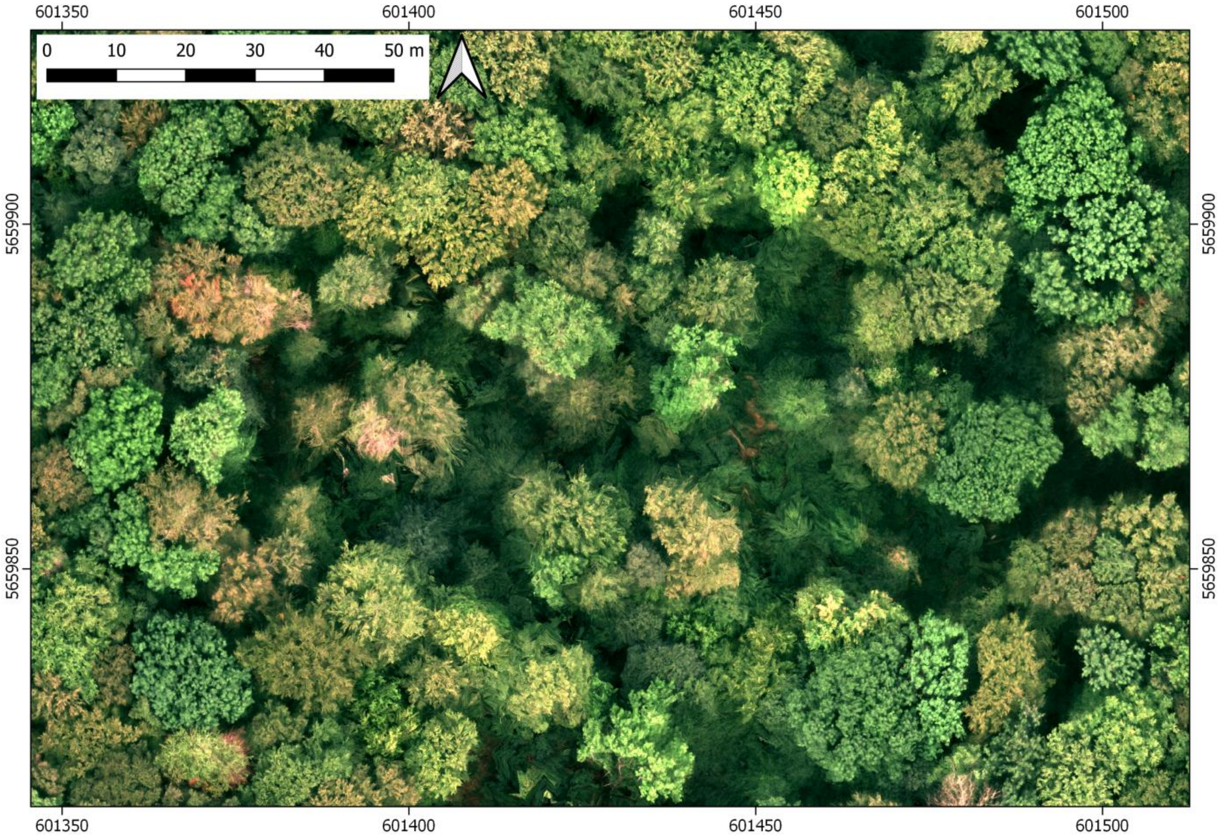
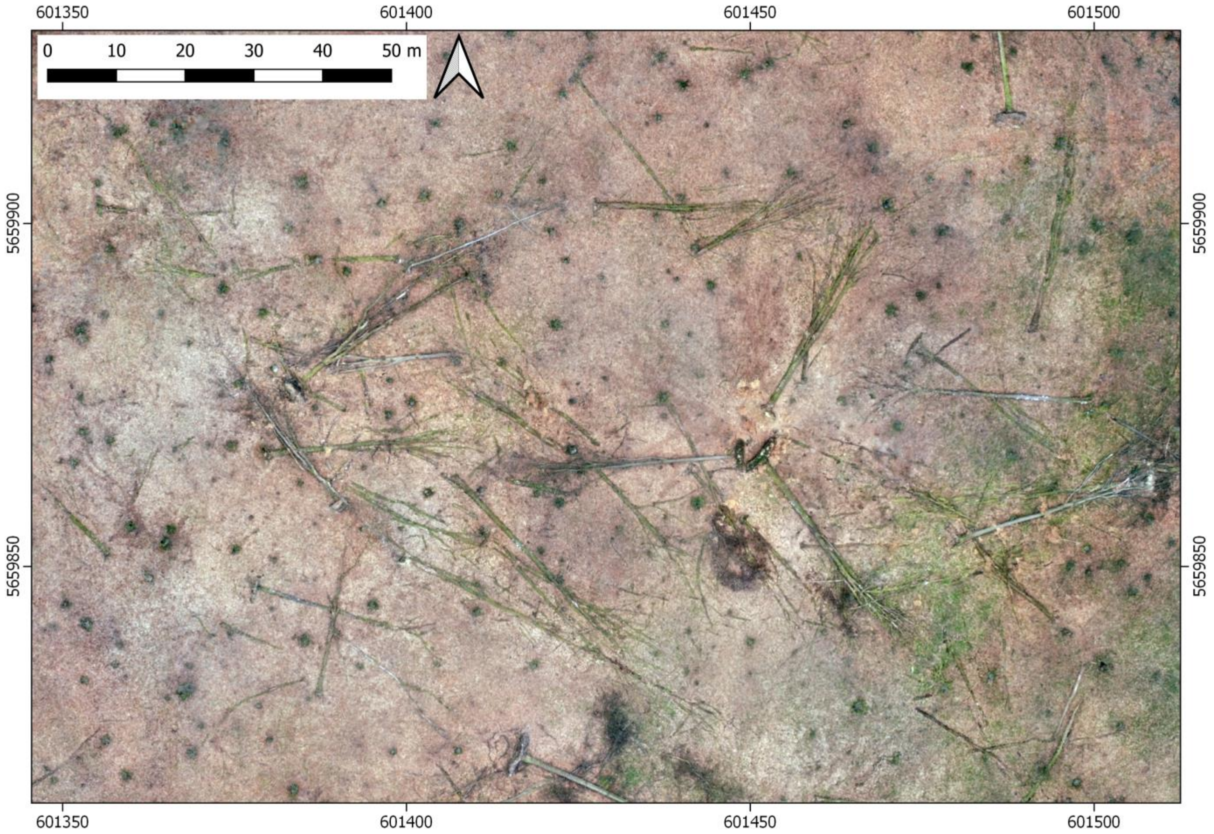




Comparison with UAS Dataset acquired in Summer



Subset of a UAS imagery-based orthomosaic (acquisition date 2019/09/19) of the Huss-site (data not used in this study).



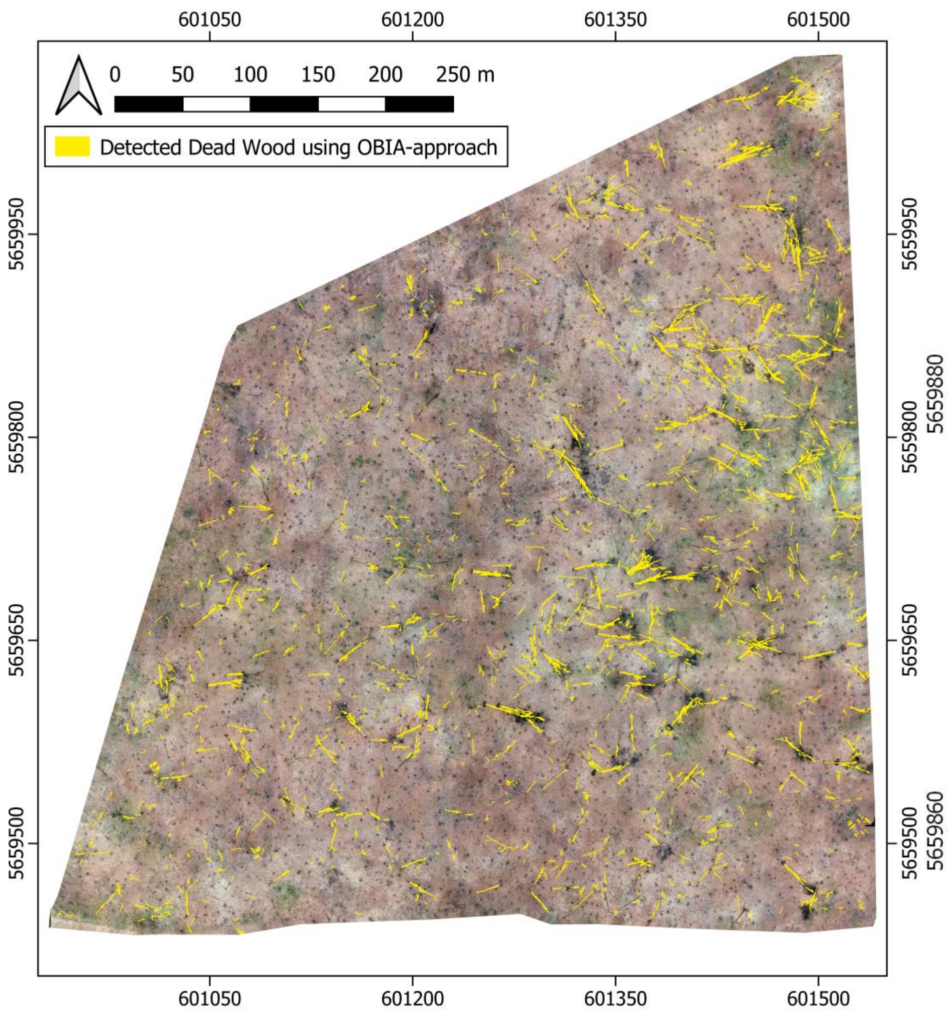
Same subset of site. The UAS imagery (used in this study) was acquired during leaf-off conditions (2019/03/20). Processing according to previous slide. Raster features forest floor.

Dead wood detection using a raster data-based OBIA approach

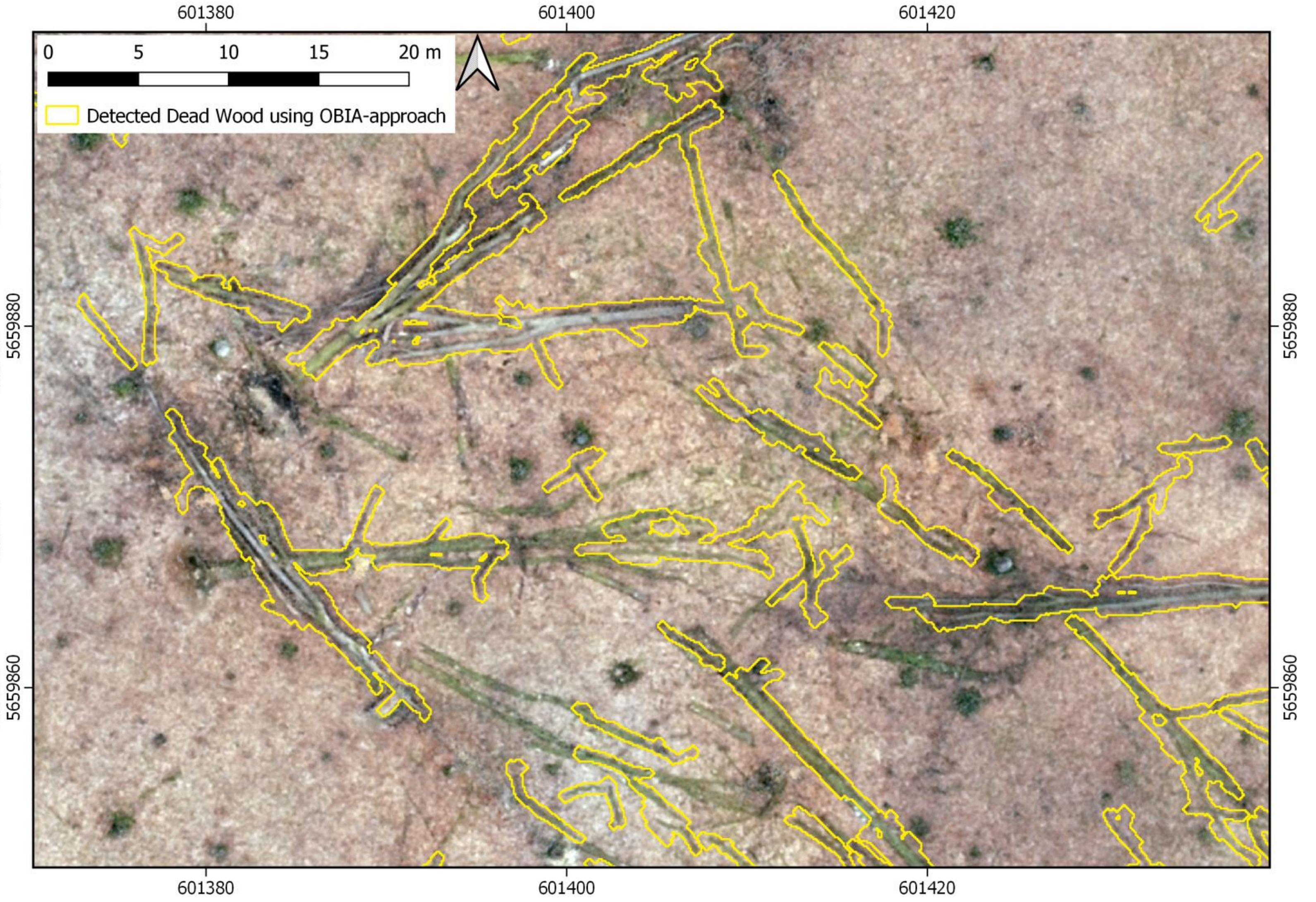
1. For each of the image layers (RGB) a line extraction algorithm was applied (variables: line length, line width, border width, line direction)
2. Line extraction algorithm was embedded in a loop covering all angles from 0 to 179 degrees
3. Threshold-based segmentation and classification
4. Resulting classification was adapted to meet certain object criteria and to eliminate misclassifications
5. Remove small objects (minimum mapping unit 30 pixels)
6. Connecting objects belonging to the same dead wood cluster: growing classified segments

These steps were implemented in eCognition.

Results: Dead Wood Detection

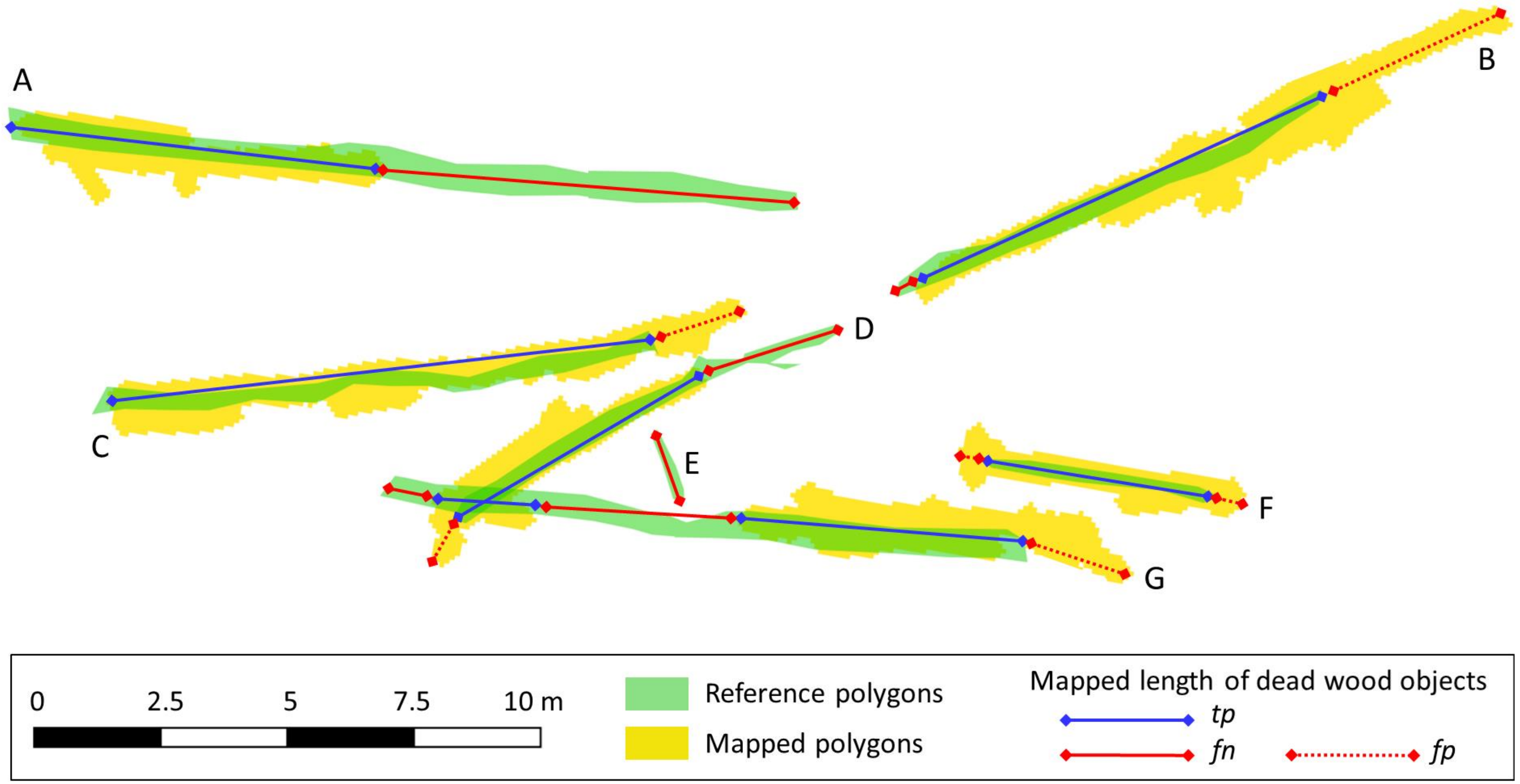


Entire Huss-Site



Subset of Huss-Site

Accuracy Assessment



Small subset of Huss-site to illustrate the two accuracy analysis approaches

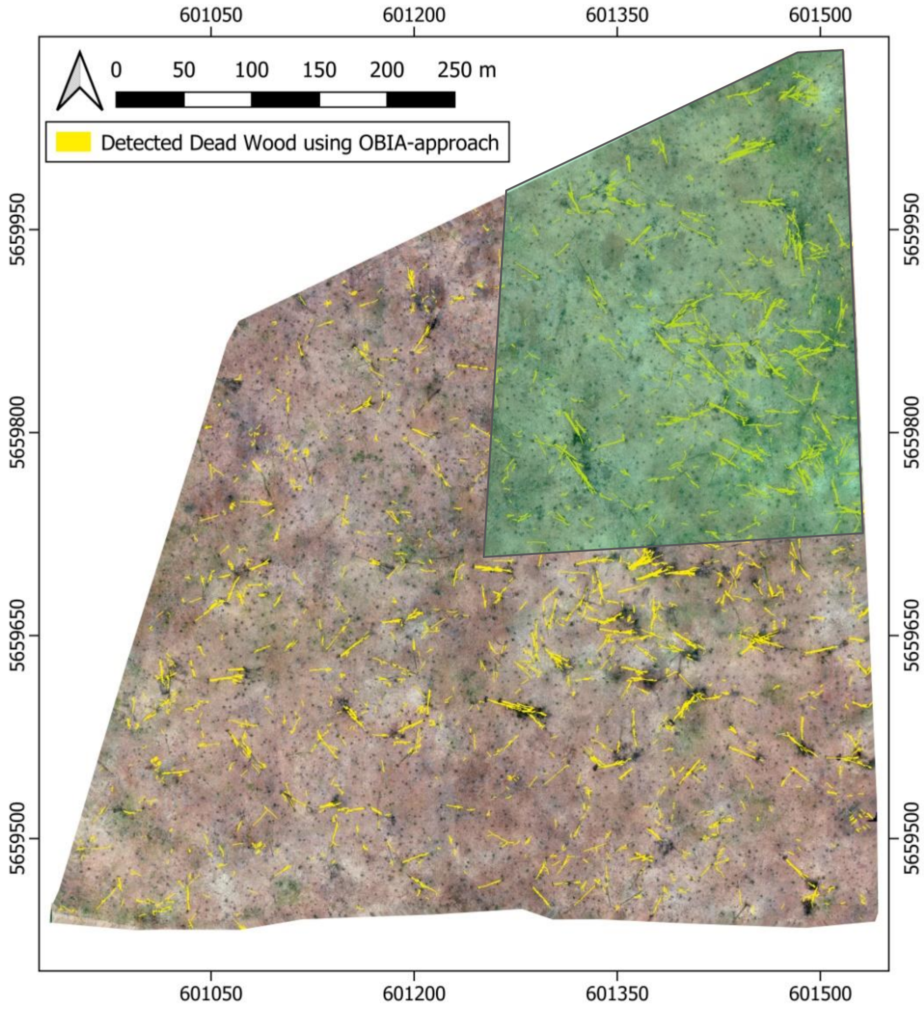
<u>Length based approach</u>

- Length of overlap area of reference polygons and mapped polygons corresponding to the same dead wood object (solid blue lines) defined as correctly detected (*tp* length)
- Missed out parts of the dead wood objects (solid red lines): *fn* length
- Dotted red lines: overestimation (*fp* length)
- Length measurements were summed up for the entire validation area (1/4 of Huss-site)

<u>Object number based approach</u>

- Object based validation approach considers dead wood objects as entities (one overturned tree or one dismantled major branch represents one entity)
- Dead wood object was tagged as correctly identified (*tp*) if > 50% of its length was correctly detected
- E.g. for object A, the length of the correctly recognized (*tp*) partition of the object is less than 50% of the total length of this object. Consequently, this dead wood object was tagged as missed out (*fn*).

Accuracy Assessment



Entire Huss-Site and validation area in the Northeast

	tp	*fn*	*fp*	Precision	Recall
Total length	4.473	1.995	887	83.5	69.2
No. of objects	180	45	76	70.3	80.0

For the validation area:

- 4,473 m of dead wood were correctly identified
- 180 deadwood objects were correctly identified

Conclusions and Outlook

- UAS imagery covers area of ca. 50 ha → reasonable area covered in approx. 25 minutes
- Stereoscopic image data allows creation of orthomosaics featuring forest floor
- UAS imagery enables extraction of coarse dead wood debris with an accuracy > 70%
- High geolocation accuracy of RTK UAS enables the measurement of the absolute positions of the dead wood and also allows for the development of monitoring concepts (i.e. regular data acquisition)

Conclusions and Outlook

- UAS imagery covers area of ca. 50 ha → reasonable area covered in approx. 30 minutes
- Stereoscopic image data allows creation of orthomosaics featuring forest floor
- UAS imagery enables extraction of coarse dead wood debris with an accuracy > 70%
- High geolocation accuracy of RTK UAS enables the measurement of the absolute positions of the dead wood and also allows for the development of monitoring concepts (i.e. regular data acquisition)
- In this study we only used spectral information: due to high degree of decay a considerable number of dead wood objects feature almost the same elevation levels as surrounding ground
- Outlook: Monitoring approach will be developed integrating spectral and structural information (based on change detection: recognition of new dead wood)

Dead wood detection using a raster data-based OBIA approach (Parameters)

Method	Function	Subfunction/Value
Extract lines for RGB layers	update line parameters	sv_line_length = 20 sv_line_width = 3 sv_border_width = 3 sv_angle = 0
	loop: if sv_angle <= 179 then (red channel) sv_angle = 0	line extraction (A: sv_angle, W: sv_line_widthpx, L: sv_line_lengthpx, B: sv_border_widthpx) ‘lv_red’ => ‘Rlines’
	loop: if sv_angle <= 179 then (green channel) sv_angle = 0	line extraction (A: sv_angle, W: sv_line_widthpx, L: sv_line_lengthpx, B: sv_border_widthpx) ‘lv_green’ => ‘Glines’
	loop: if sv_angle <= 179 then (blue channel) sv_angle = 0	line extraction (A: sv_angle, W: sv_line_widthpx, L: sv_line_lengthpx, B: sv_border_widthpx) ‘lv_blue’ => ‘Blines’
	layer arithmetics	(val “Blines+Glines+Rlines”, layer lines[32Bit float])
Segment and classify lines	creating ‘lvl’:	unclassified <=30 < lines on lines
Reshaping	lines with Area <= 30 Pxl at lvl1: loop: lines at lvl1: lines at lvl1:	unclassified grow into classified where lines > 0 merge region
Pixel-based growing	sv_number_pixels_growth = ‘sv_number_pixels_growth’ cycles: lines at lvl1:	2 grow into all merge region