Retrieving Field Base Maps from LiDAR point clouds

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Summary : LiDAR point clouds facilitate the production of field base maps providing pre-information from the running layer to the mapper. We define the running layer as the most crucial layer to orienteering from ground up to 2.3m above ground. We introduce field base maps representing the vegetation height as the vegetation density in the running layer. Working with LiDAR point clouds with up to 1 billion points, highly efficient computing workflows are indispensable. We present workflows based on OL Laser, LAStools and QGIS.

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1. Situation

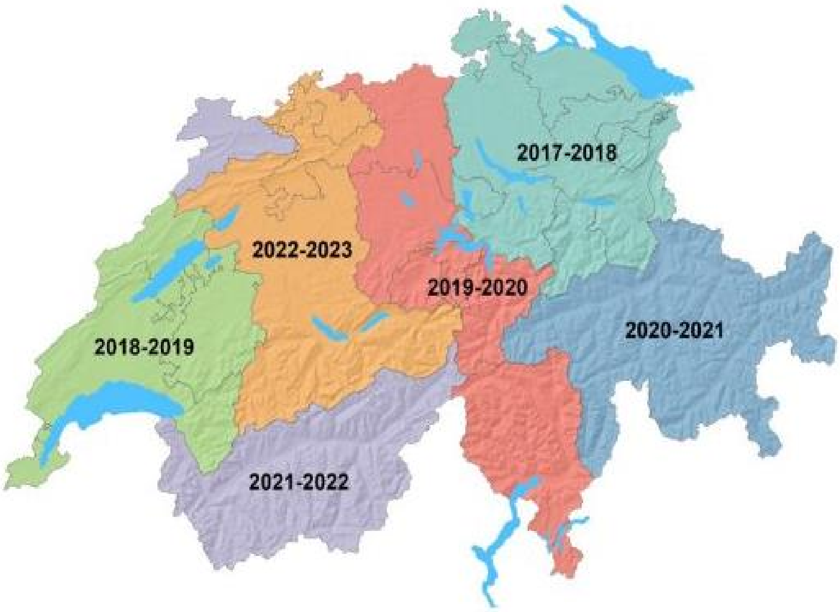

fig.1. Time schedule of the swisstopo LiDAR campaign.

The availability of LiDAR data in Switzerland is characterized by the high degree of autonomy of its cantons. While some provide regularly up-to-date LiDAR data as open geo-data (e.g. BE, TG, ZH, BL, AG) other cantons still provide nothing but the soon twenty years old DTM and DSM. The later are 1m grids, filtered and partly incomplete. Thus the federal agency started a campaign in 2017 to update and level the surface information nationwide (fig.1.). The first products of the campaign, LiDAR point clouds from the Cantons of SH, ZH, ZG, SZ, GL, SG, TG, AI and AR will be available in spring 2019. The campaign ends in 2024 with the publication of the data from the Cantons of BE, SO, BS and BL. The data is provided to the cantons for free. The cost to the end-user will depend on the respective cantons policies. The LiDAR point clouds will be restricted to an altitude below 2400 m above sea level which in general the areas below the tree line.

Above tree-line an enhanced SwissAlti3D based on aerials with 10cm resolution will be provided.

No updates are planed though. So after the swisstopo campaign it is back to the cantons policies.

https://www.swisstopo.admin.ch/de/wissen-fakten/geoinformation/lidar-daten.html

2. Adlisberg Project

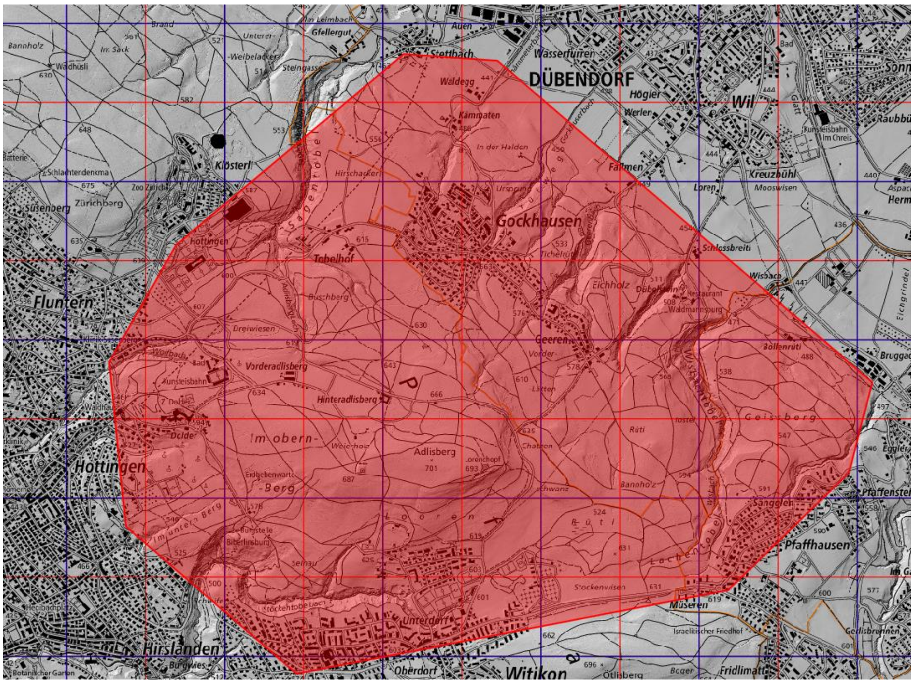

fig.2. Location of the Adlisberg map; red mesh represents the LiDAR tiles provided as open geo-data by the Canton of Zürich.

The Adlisberg is a terrain bounding east to Zürich. The area is about 10km². About 66 LiDAR tiles are to be included. Each tile consists in a quarter square kilometer LiDAR point cloud. The point density is up to 100 points per square meter and about a billion points over the entire area.

Such high amount of data makes highly efficient computing workflows indispensable.

3. Computing workflows

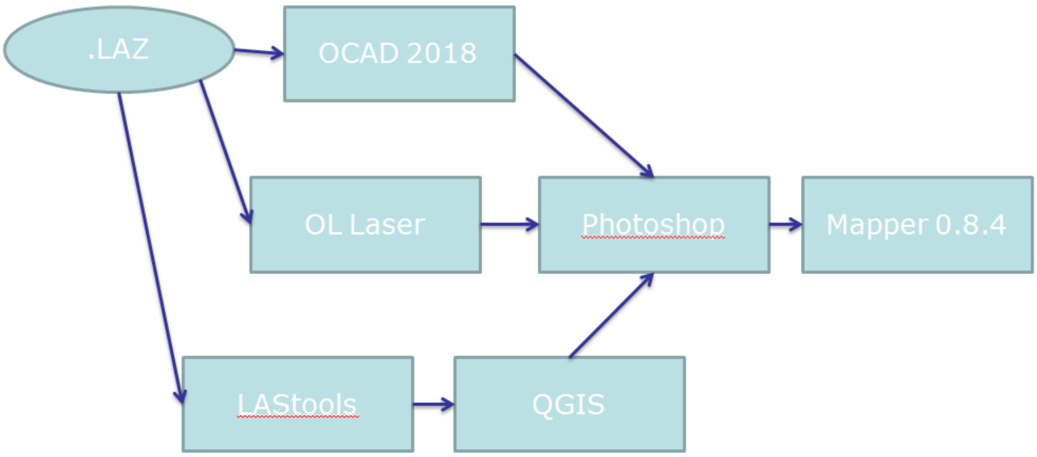

fig.3. Workflows of field base map production

At the moment OCAD does not provide the efficiency needed to master big data. Therefore we choose different tracks.

OL Laser is a swedish product, tailored to field base map production of LiDAR data. The basic advantage of OL Laser is the possibility to run tile by tile processing.

http://www.oapp.se

The end-products of OL Laser are geo-referenced images and contours. Thus to fine-tune multiple recalculations of the underlying data would be necessary. For aspects with a lot of fine-tuning necessary we therefore choose a second workflow. There-in we store some aspects as grids to just fine tune the symbolization.

LAStools is a suite of high-efficient, batch-scriptable command-line tools and the lone-standing expertise in LiDAR handling. LAStools are used to classify, filter, tile, rasterize, triangulate, generate contours, vectorize a.s.o. We use LAStools to pre-process and rasterize the LiDAR point clouds.

https://rapidlasso.com/lastools/

QGIS is a powerful open source geographic information system. On field base map generation we mostly use it to fine tune symbolization as to execute raster calculations.

https://www.qgis.org/

4. Field base maps

The basic purpose of field base maps is to provide the fast and precise localization for cartographic features. The data must be as unprocessed as possible. We do not advocate pre-generated content. It is in the forest the (cartographic) magic happens.

Field base maps provide the background of the field notes. Thus field base maps must :

- → Not rival the field notes. They shall be discrete but still depict all relevant information in a appropriate resolution.
- → Be distinctable from all other field base maps. That is secured by a good variation of undertones.
- → Be combinable. This is made by a color harmonization between different field base maps and a transparency of all NO DATA areas.

5. Layers

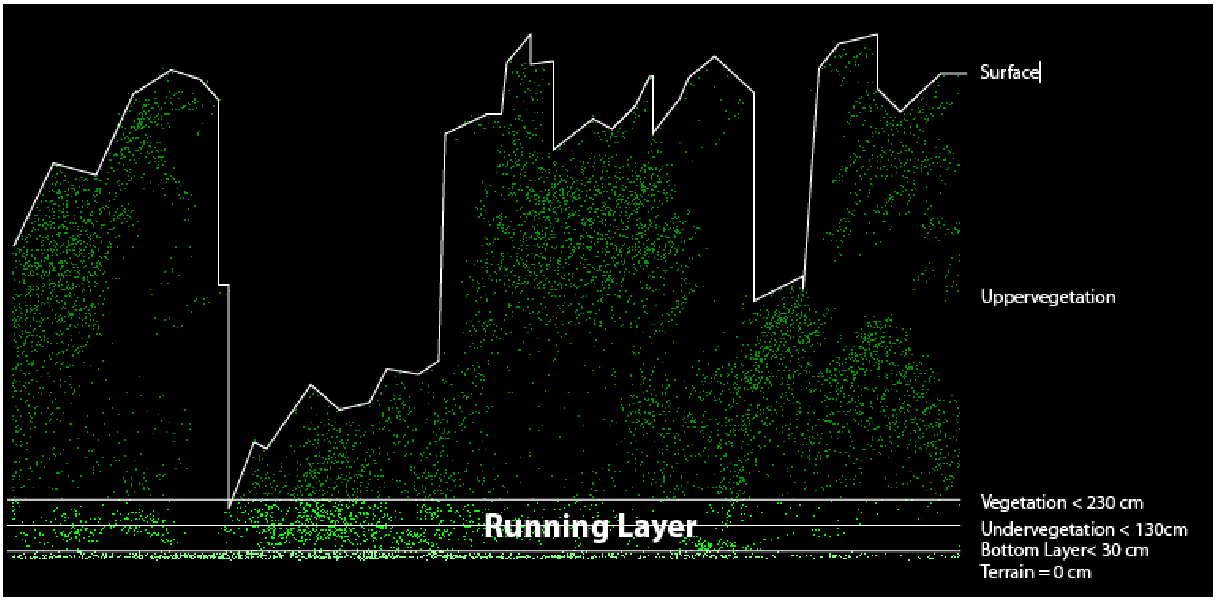

fig.4. Layer definitions

Different layers of the vegetation have different significance to the orienteering runner. The most important information is provided by the terrain (T) and the running layer (RL). The surface (S) significance is more local, while the upper vegetation is of minor interest most of the time.

We divide the running layer into three sub-layers according to the significance of the points inside these sub-layers. The bottom layer is defined as from the ground up to 30cm and a level of vegetation that does not influence the runability of the terrain to much. The undervegetation layer is situated from above the bottom layer up to 1.3m. Points measured inside this layer indicate vegetation reducing runability. The uppermost sub-layer of the running layer fills the gap from 1.3m up to 2.3m and is called the vegetation layer. Points detected inside this layer indicate vegetation reducing both runability and sight.

6. Field base maps

6.1. Tree top height

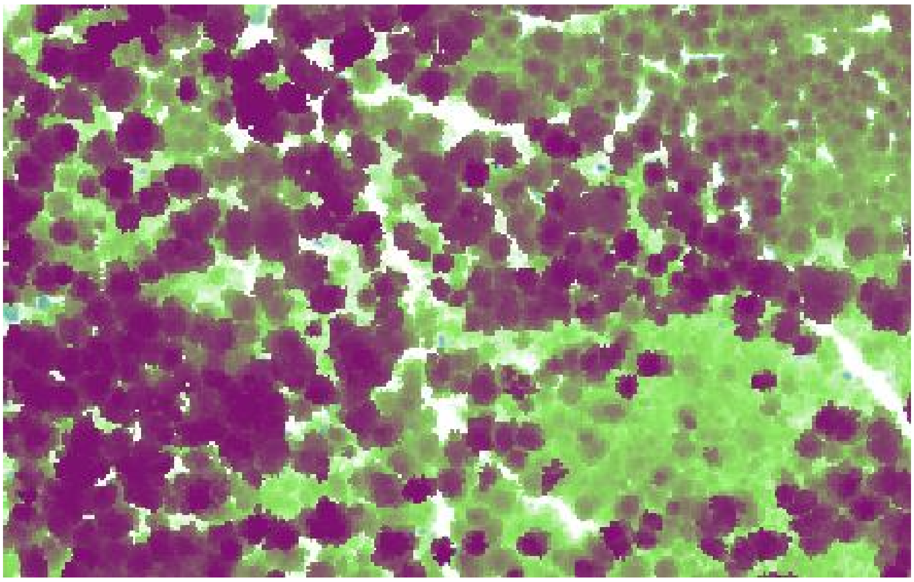

fig.5. Tree top height; trees more than 5m high. Light green low trees 5-10m; dark purple up to 40m.

The tree top height for is a field base map to localize map features in stocks with varying tree heights. One can localize prominent trees and groves.

6.1.1. Workflow Tree top height

LAStools

```
lasheight -i ./Tiles/*_100.laz -replace_z -odix _height –olaz
lasgrid -i ./Tiles/*_height.laz -odir Raster -odix _CRheight -step 1 -
elevation_highest
```

QGIS

→ Symbolisation

Photoshop

→ Set white to transparent

6.2. Tree top intensity

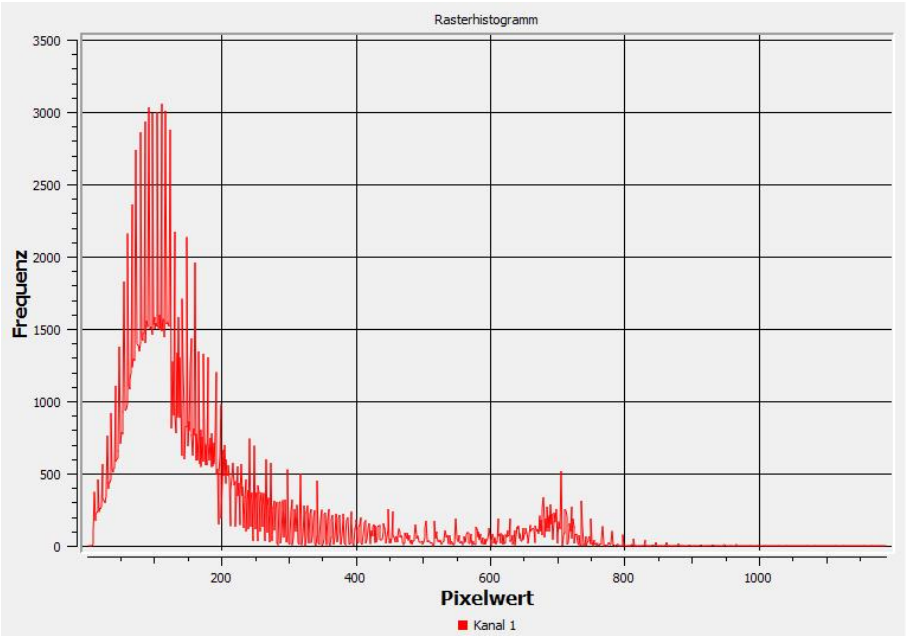

fig.6. Raster histogram of the intensity of the tree top layer. Values between 50 and 200 correspond to deciduous trees (mostly beech and oak), while values between 600 and 800 represent Norway spruce.

Our second field base map pictures the intensity of the tree tops. LiDAR detect not only an objects position but also the intensity of the reflected beam. The better an object reflects the laser beam the higher the intensity. Thus in mixed forest it is possible to distinct different tree species by intensity.

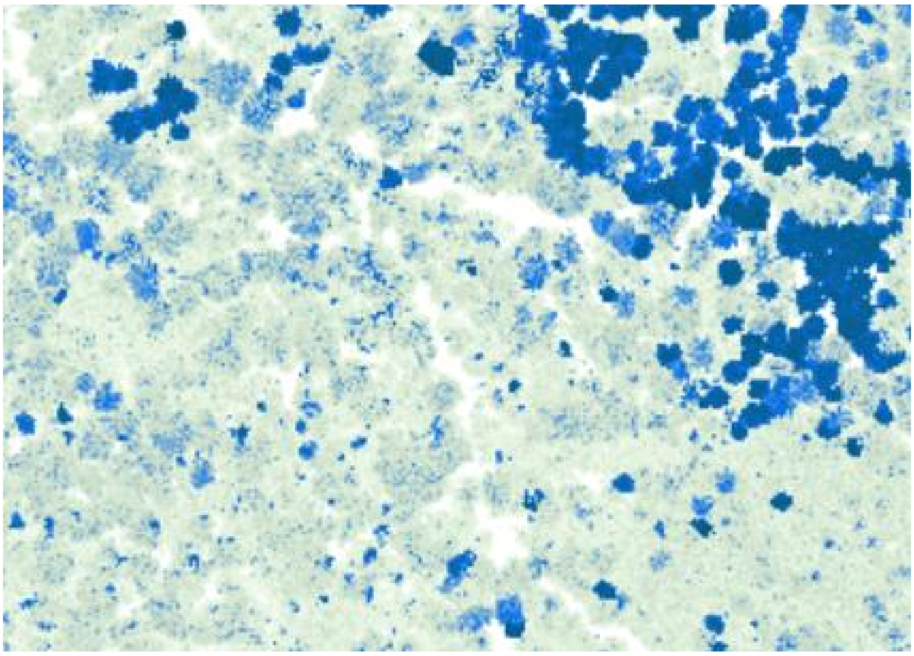

fig.7. Field base map tree top intensity. Dark blue represent high intensity linked to spruce. Light green is linked to (leafless) beech and oak.

6.2.1. Workflow tree top intensity

LAStools

```
lasheight -i ./Tiles/*_100.laz -replace_z -odix _height –olaz
lasgrid -i ./Tiles/*_height.laz -odir Raster -odix _CRintensity -step 1 -intensity_highest -keep_first -drop_z_below 2.3
```

QGIS

→ Symbolisation

6.2.2. Field perspective

fig.8. Field perspective combined with the tree top intensity field base map view. Dark blue trees correspond with the spruce trees on the photo.

6.3. Running Layer Vegetation Height

With the third field base map we focus on the running layer, while all information above the running layer is cut off. We use the vegetation height inside the running layer to identifiy areas with very sparse to zero vegetation and thus very good runability.

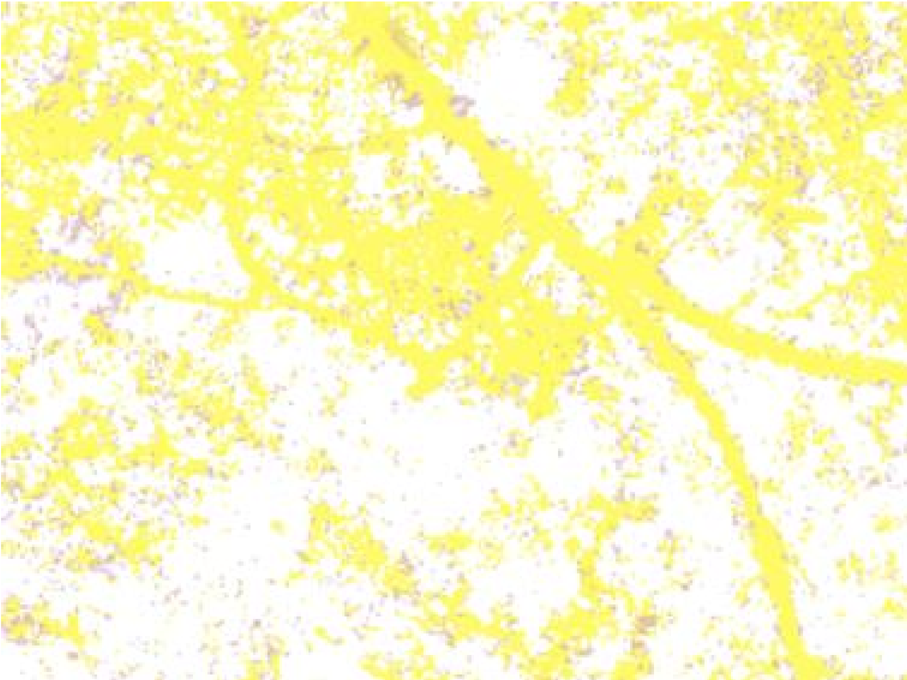

fig. 9. Running Layer Vegetation Height. Vegetation height up to 30 cm is represented in yellow. Higher vegetation is masked in white.

6.3.1. Workflow

LASTools

```
lasheight -i ./Tiles/*_100.laz -replace_z -odix _height –olaz
lasgrid -i ./Tiles/*_height.laz -odir Raster -odix _RLheight -step 1 -
elevation_highest -drop_z_above 2.3
```

QGIS

→ Symbolisation

Photoshop

→ Set white to transparent

6.3.2. Field perspectives

fig.10. Sample photo from the terrain and field base map. Yellow representing areas with no vegetation inside the running layer.

fig.11. Sample photo from the terrain. Straight ahead you can guess a ride (distinct in the terrain) combined with the field base map of the running layer vegetation height.

6.4. Running layer vegetation density

The most useful and most often used base map for this kind of Swiss terrain and mixed forest with a lot and varying undergrowth ist the running layer vegetation density. This field base map represents the relative amount of points detected inside the UV and V layers relative to the total amount of measurements inside the running layer RL.

$$\frac{UV + V}{BV + V + UV}$$

As a result high values point to relatively high degrees of vegetation inside the running layer, while low values indicate low opposition by vegetation.

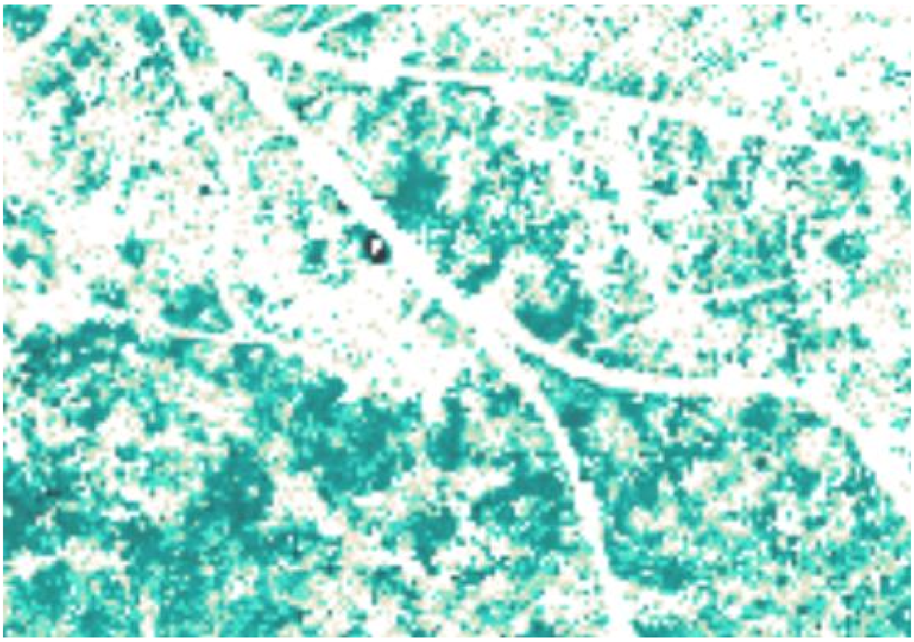

fig.12. Running Layer Vegetation Density. The darker the turquoise, the denser the vegetation.

Due to the mixed forest characteristics of the forest also the vegetation in the running layer is mixed. Depending on the kind of vegetation the values may vary depending on the season the LiDAR measurements were made. As in our case the LiDAR data was retrieved in March, small beech undergrowth was still leafless, while spruce undergrowth was not. To make it even more complicated some parts of the beech undergrowth does not loose its leaves… This complexity makes it impossible to establish a direct relation between running layer vegetation density and later on classification in regard of ISOM vegetation runnability. Maybe that would be possible for areas with more even vegetation characteristics.

6.4.1. Workflow

LASTools

```
lasheight -i ./Tiles/*_100.laz -replace_z -odix _height –olaz
lasgrid -i ./Tiles/*_height.laz -odir Raster -odix _VDens  -step 2 -point_density -drop_z_below 1.3 -drop_z_above 2.3
lasgrid -i ./Tiles/*_height.laz -odir Raster -odix _UVDens  -step 2 -point_density -drop_z_below 0.3 -drop_z_above 1.3
lasgrid -i ./Tiles/*_height.laz -odir Raster -odix _GDens  -step 2 -point_density  -drop_z_above 0.3
```

QGIS

- → rastercalculation (UV + V)/(BV+ UV+V)
- → Symbolisation

Photoshop

→ Set white to transparent

6.4.2. Field perspectives

fig.13. Running layer vegetation density. Sample photo from the terrain with the respective map excerpt. Clean runnable forest in front. Augmenting but mild vegetation density further back.

fig.14. Running layer vegetation density. Sample photo from the terrain with the respective map excerpt. Clean runnable forest in at the right-hand-side. Dense vegetation from the center to the left.

6.5. Terrain

Last field base map in our suite is focussing on the terrain, and thus builds the base for all terrain features as landforms, point features, cliffs etc. It consists in the 1.25m contours to be combined with either the slope or the relief image.

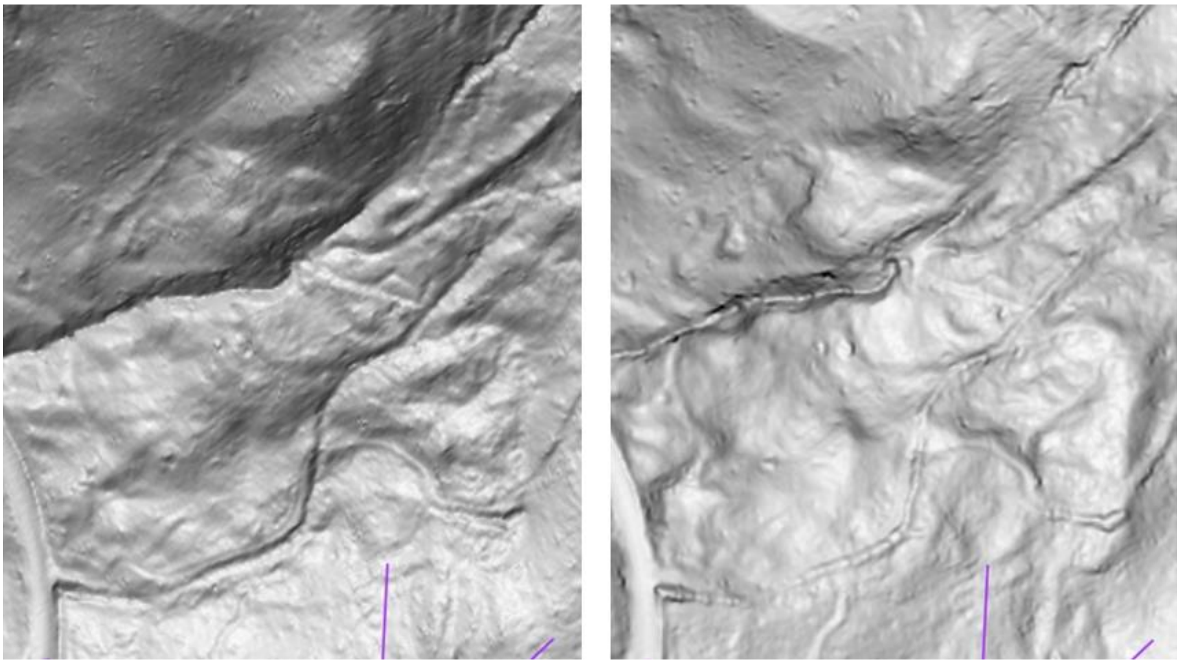

fig.15. Comparison of hillshading on the left and slope image on the right.

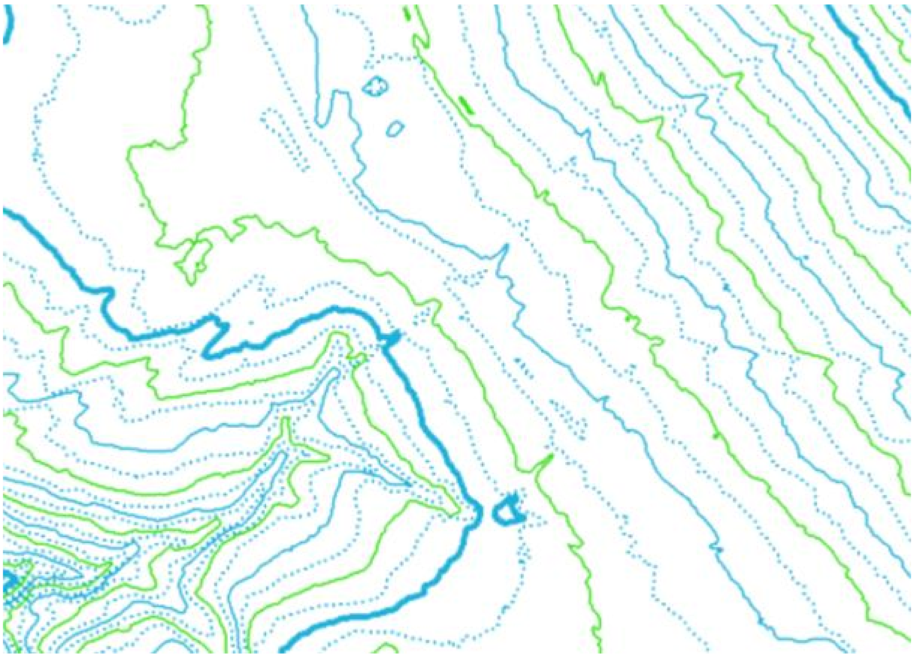

fig.16. Contours 1.25m equidistance. Blue lines represent the raw regular 5m contour, green the raw form line. Dotted blue lines mark the edges of the bands within the regular contours can be exaggerated to emphasize prominent landforms.

6.5.1. Workflow Terrain

OL Laser

→ Create contours 1.25m, slope and hillshading in batch-mode

OCAD

→ Georeference OL Lasers OCAD files ; merge all; symbolize; export as .png

Photoshop

→ Set white areas transparent

6.5.2. Field perspectives

fig.17. Slope image revealing the exact position of small landforms as the re-entrant in the center of the photo, the earth bank in front or the two lobes on both sides of the reentrant.

fig.18. The location and direction of this forestry extraction track is obvious on the hillshade field base map.

6.6. Additional field map layer

To complete the set of field base maps, also non-LiDAR based ones are added here.

6.6.1. Cadrastral plan

Fig. 19. The cadrastral plan provided by the Canton of Zurich ; filtered ; in blue.

6.6.1.1. workflow

Open Orienteering Mapper

→ Import GeoBau .dxf provided by the Canton of Zurich
→ Find>[Query editor] : (Select key by value)>assign symbol
→ Alternatively use Symbol conversion by CRT

CRT file syntax

Empty lines are ignored. Lines starting with a # character are considered comments, i.e. they are ignored, too. Every other line is a replacement rule and consists of two parts.

The first part of the rule is the target symbol number. It determines which symbol will be assigned to matching objects.

The second part of the rule, separated from the first part by white space, determines the objects this rule applies to. This can be given either as a symbol number or as a object query. When using object queries, more specific rules need to follow more general rules.

Example from OSM-ISOM2017.crt:

- 406 natural = wood
- 408 natural = wood AND (wood:age = young OR wood:age = very_young)
- 404 natural = wood AND wood:density = sparce
- 408 natural = wood AND wood:density = dense

Fig.20. Excerpt from the open orienteering manual

6.6.2. Exisiting orienteering map

fig.21. Orienteering map from 2012. Colors modified for reduced interference with the field notes.

7. Conclusion

The main advantage with the LiDAR Point Clouds it to provide the mapper with more and more detailed pre-information about the situation inside the Running Layer. At the same time, the undamped growth of data makes the need for efficiant processing eminent. While the orienteering mapping standard software OCAD doesn't provide such efficiancy in regard of big data for instant, working with OL Laser, LAStools and QGIS are valueable alternatives.

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