Automatic derivation of large scale topographic maps from ALS and possible applications for orienteering maps

Austrian example

Georg Gartner
Vienna University of Technology
georg.gartner@tuwien.ac.at

László Zentai
Eötvös University,Budapest
laszlo.zentai@elte.hu

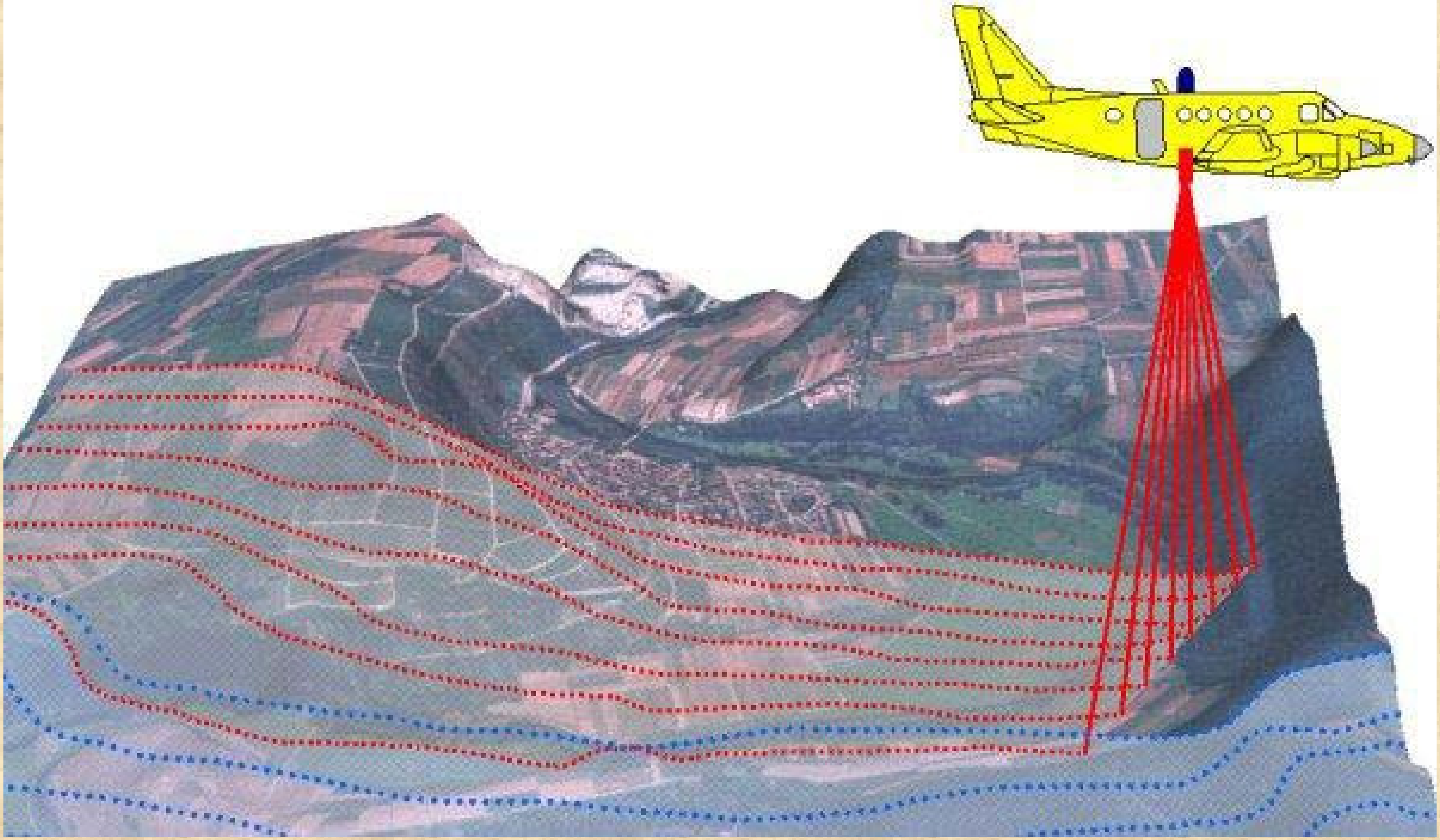
Background of the authors 1

- We are both professor of cartography (Vienna and Budapest). Both of us are teaching cartography, but laser scanning is not our research topic. We can not say that we are experts, but our knowledge is mostly theoretical than practical.
- We are both hobby orienteers (although I am working in the IOF since 1996 – MC and Council).
- We are both very active in the International Cartographic Association, where we promote orienteering (which practically not treated very seriously or not known at all by professional cartographers).

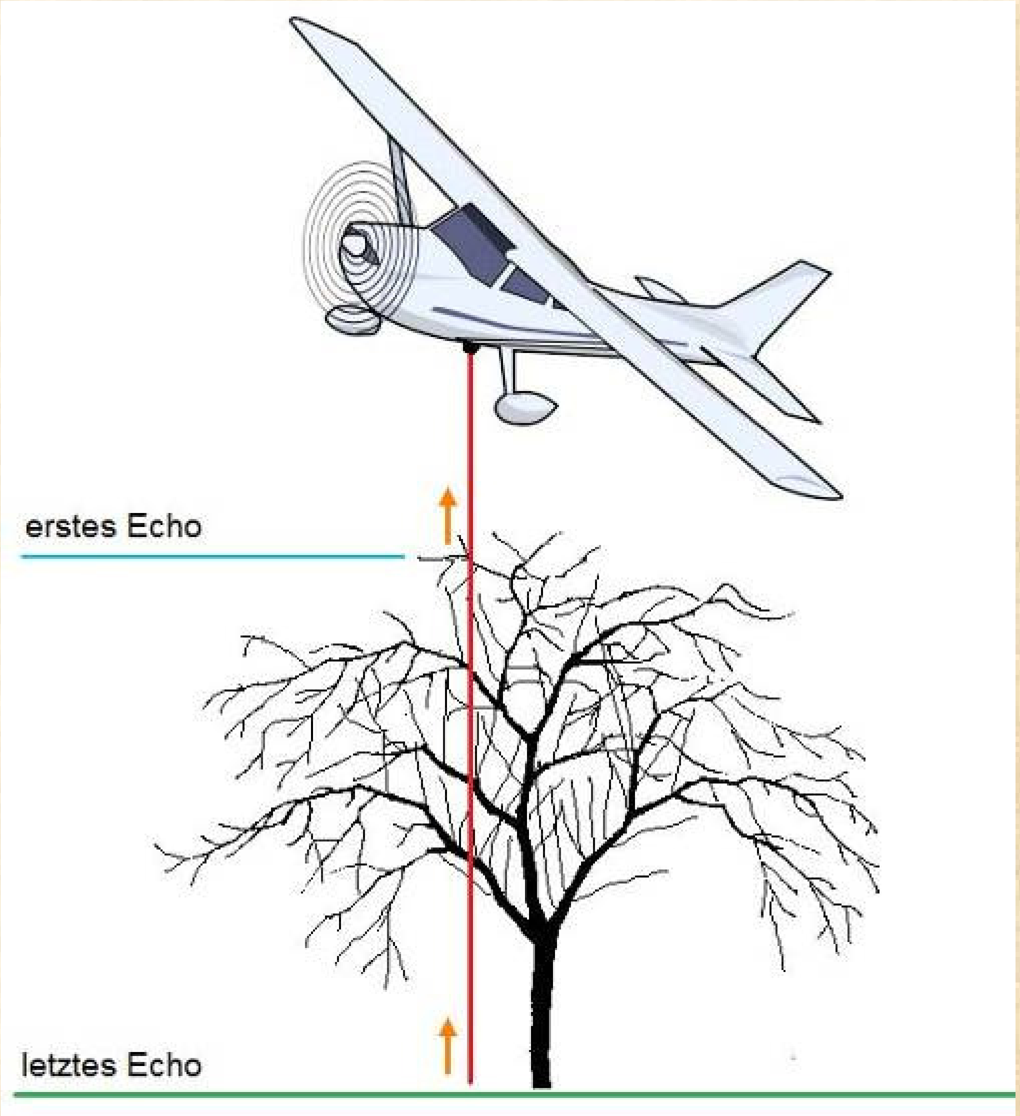
Background of the authors 2

- AUT and HUN are both continental countries, our terrains are not so complex, we don´t have so many details on the terrain.
- The level of national orienteering is not very high compared to top countries, but not very low.
- The laser scanning data is very expensive or simply not available for orienteering at the moment.
- The base map access is different. Hungary 1:10000, Austria 1:15000 state topographic maps.
- So our approach is rather scientific, but the main aim was to present the development of orienteering maps for cartographer who are not familiar with our sport (2007-).

Airborne Laser Scanning



Airborne Laser Scanning

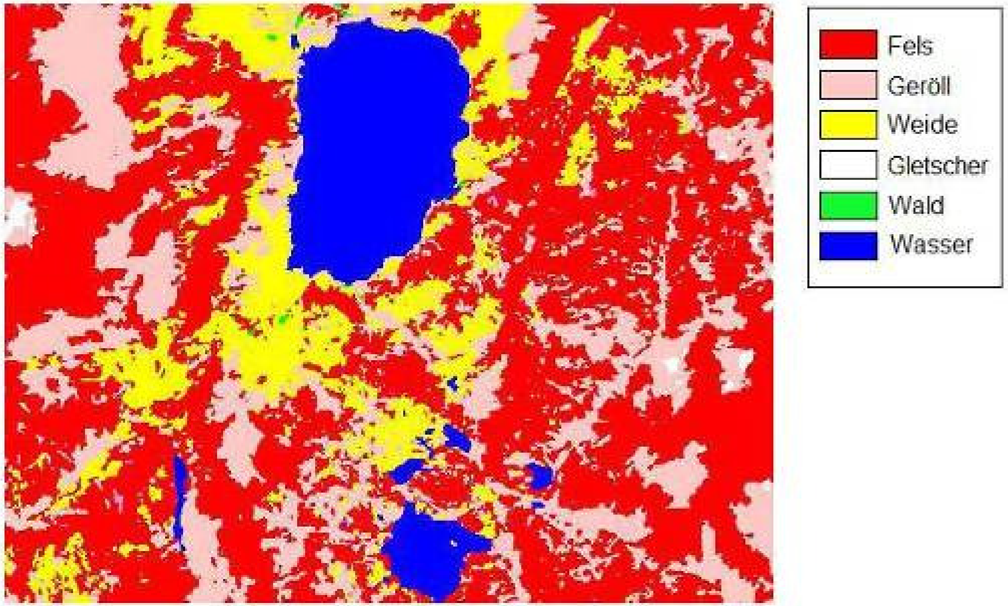


The technology of Airborne Laser Scanning data is becoming increasingly interesting for the production of orienteering maps. This is based on the fact that laserscanning data are available more easily and to lower costs and also that the quality of these data is permanently increasing.

Airborne Laser Scanning

Usually airborne laser scanning campaigns try to cover a particular area with laser pulses and thus result in related point clouds.
An important measure in that context is the point density on ground, which varies according to the used device and the flying height. In the meantime point densities of up to 16 points per sqm can be reached, which enable the method of airborne laser scanning as a suitable method for detecting and modeling even small topographic features.
This is true also in forested areas, as at least some of the pulses are typically able to penetrate trough the canopy and provide information about the ground altitude.
Based on the point clouds sophisticated algorithms apply to model the topography and/or specific features. This is usually based on reflections from the ground and has to be often cross-checked by manual editing and filtering of the data.

Airborne Laser Scanning



Deriving Topographic Map Features in Mountainous Areas

Hypothesis

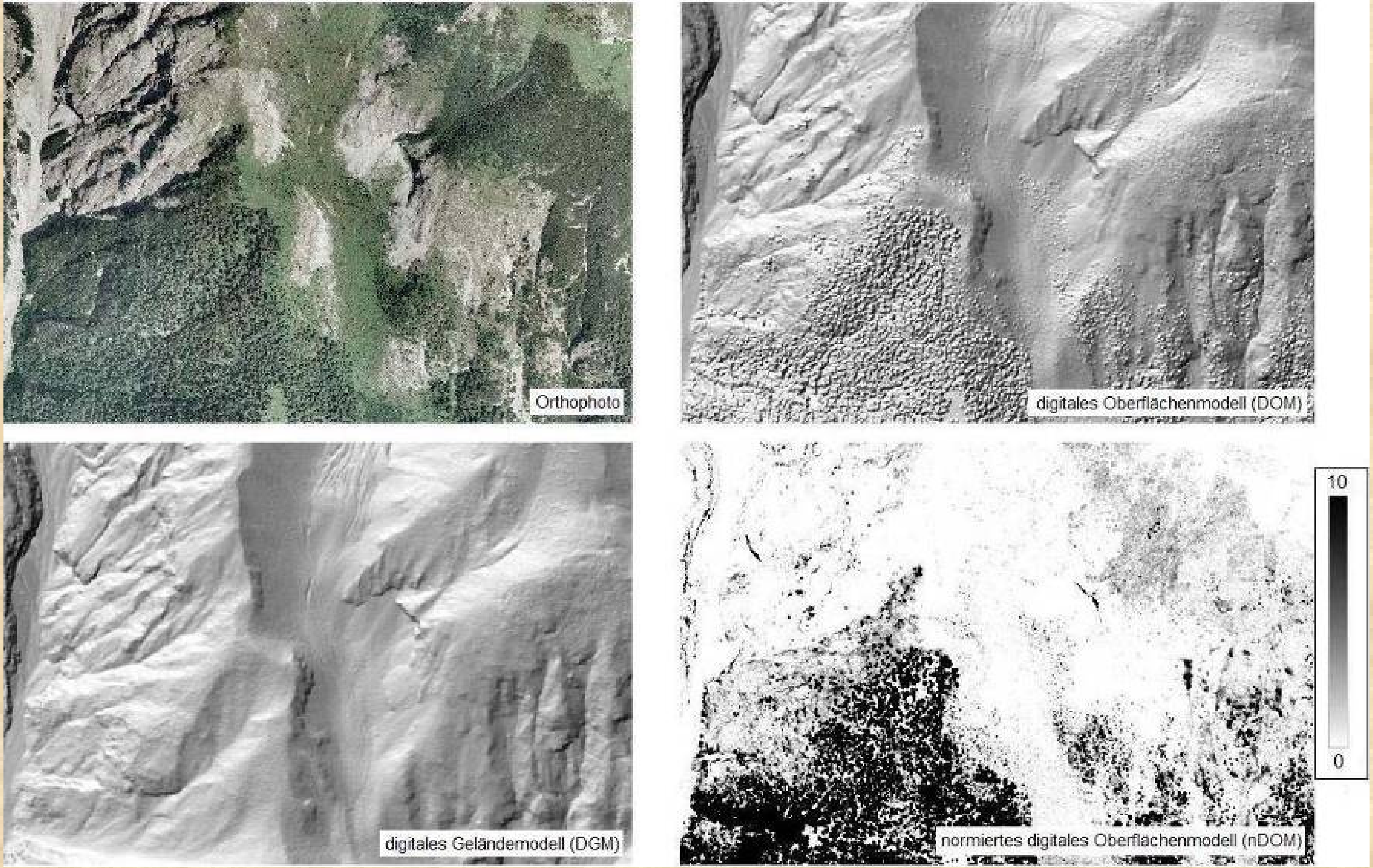
A semi-automated derivation of selected map features of large scale topographic maps is possible.

The usual applied procedure includes the geometrical modeling, the semantic classification and finally the cartographic modeling, consisting of generalization and symbolization aspects.
So far, all of these steps are independently processed and no direct work-flow has been achieved yet.

Test Area

The test area Mannersdorf is located southeast of Vienna in the Leitha mountains (near the Hungarian border).
A RIEGL Airborne Laser Scanner LMS-Q560 was used to collect the full-waveform Airborne Laser Scanning (ALS) data. The scan was performed in 2007, where the trees were still leafless. The flight altitude was about 600 m above ground, which resulted in a laser footprint size of 30 cm on ground. A preliminary georeferencing was done by the data provider, the final georeferencing was performed by the Institute of Photogrammetry and Remote Sensing at the Vienna University of Technology applying the method of simultaneous fitting of aerial Laser Scanner strips.
These ALS data were originally used for archaeological prospection of forested areas.

Test Area


Orthophoto
digitales Oberflächenmodell (DOM)
digitales Geländemodell (DGM)
normiertes digitales Oberflächenmodell (nDOM)
10
0

Method

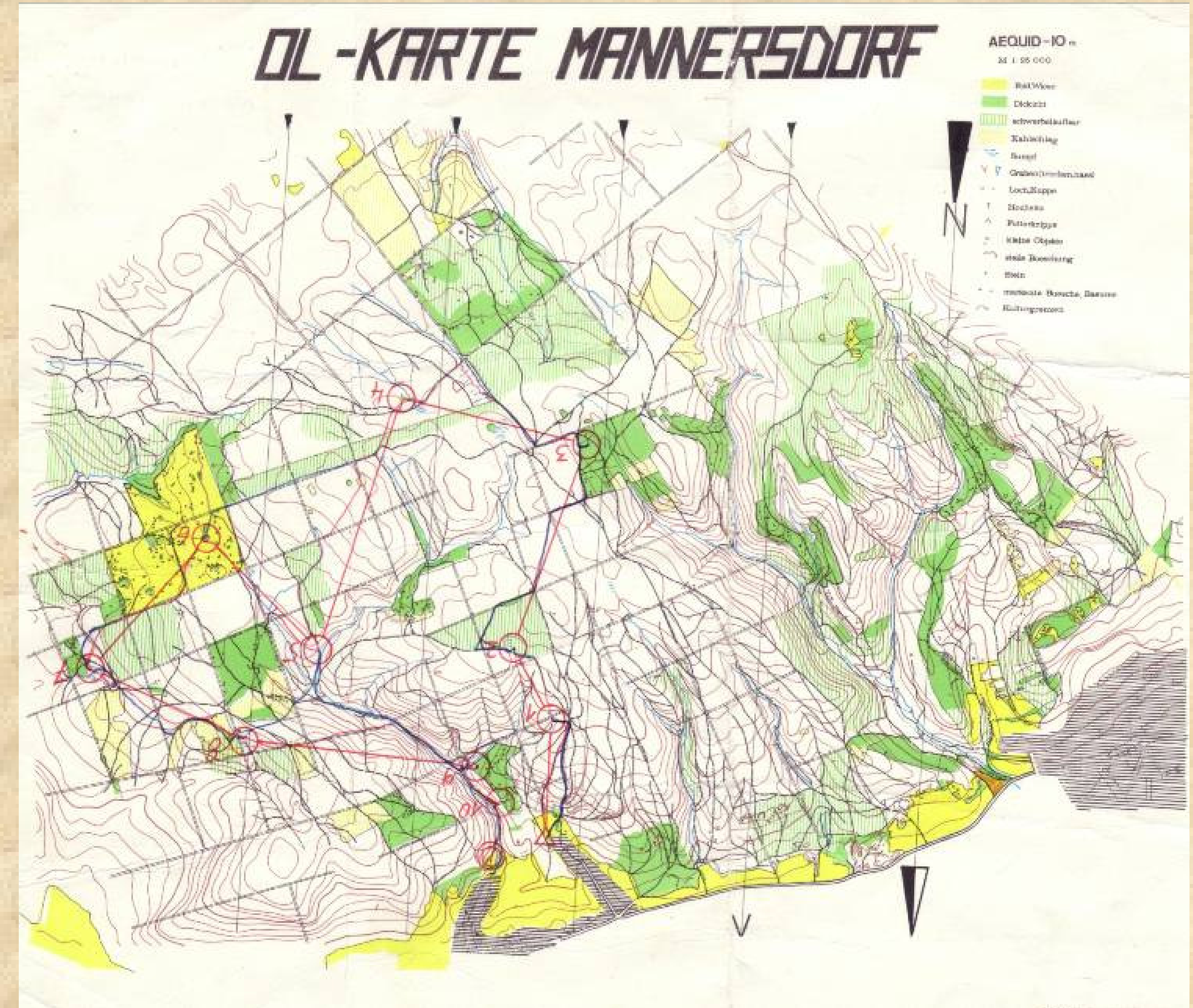
The processing of the full-waveform ALS data was executed with the program SCOP++ (Kraus et al, 2005; Inpho, 2009).
Additional information of the received echoes allows the determination of first, last and further intermediate echoes. This is necessary for deriving a Digital Terrain Model (DTM) and a Digital Situation Model (DSM). To derive an enhanced DTM, the last echoes have to be classified in ground points and off-terrain points. In addition, the off-terrain points can be distinguished in houses and low-, medium- and high vegetation which can be used for further analysis as shown later.

Method

The actual orienteering map "Mannersdorf" (2007) at the scale of 1: 10 000 was created by applying GPS as primary data acquisition method.

The editorial work was done by a member of the Viennese Orienteering Club "Naturfreunde Wien".

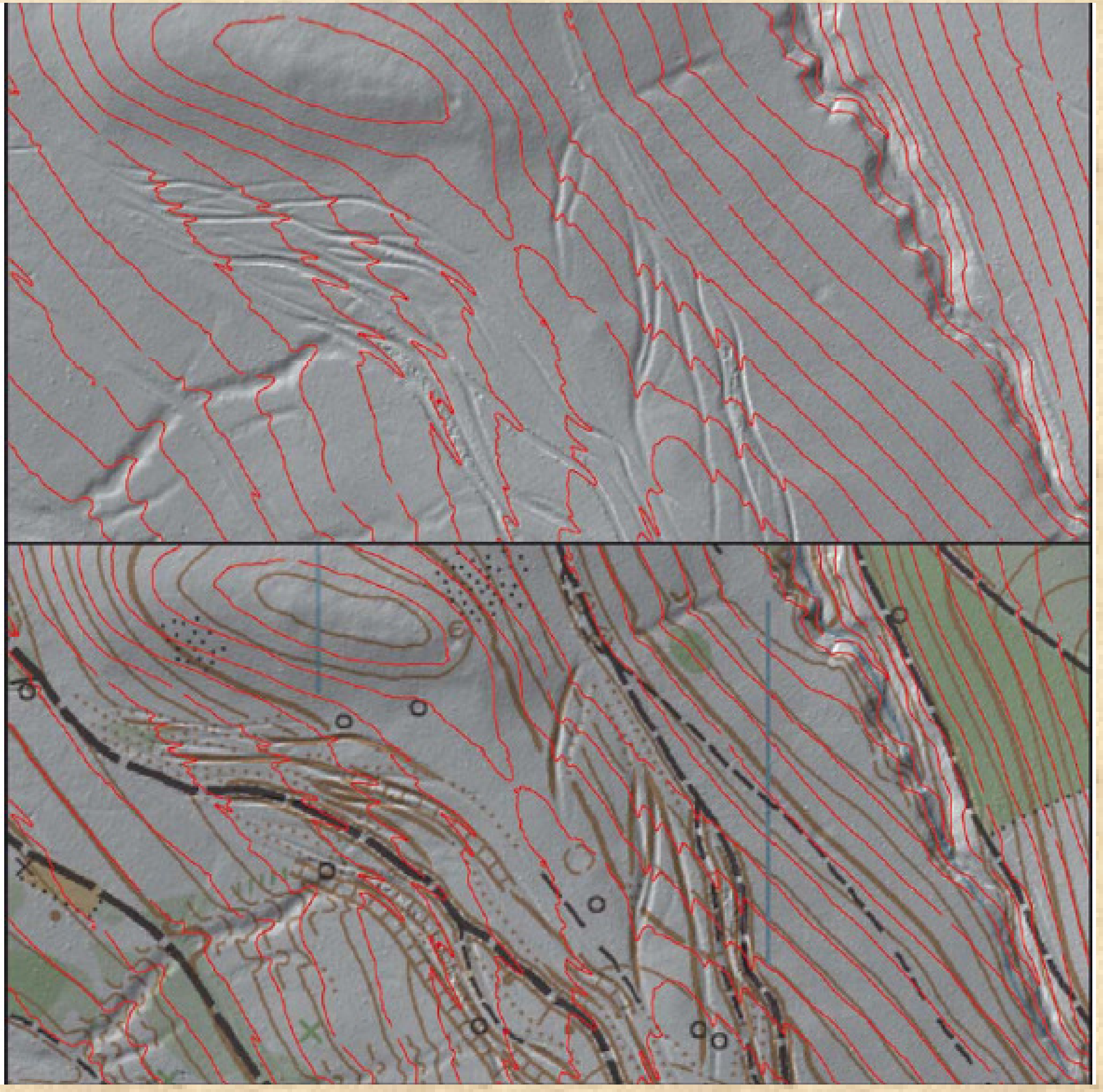
For a higher geometric accuracy, the orienteering map was geo-referenced in a GIS by referencing the road and the path network onto an orthophoto. The geo-referenced map is than compared with the filtered and classified ALS data.


OL-KARTE MANNERSDORF
AEQUID - 10 m
N

Linear features

As already demonstrated in Gartner et al (2007), linear features like paths and erosion gullies can easily be detected. The figure shows at the upper part a DTM derived form ALS data with a grid width of 0,5 m and contour lines derived from the DTM.
At the bottom, this DTM is combined with the orienteering map and the contour lines. The figure illustrates, supporting the findings of Gartner et al (2007), the high geometrical quality of the contour lines derived from DTM in the context of orienteering maps.

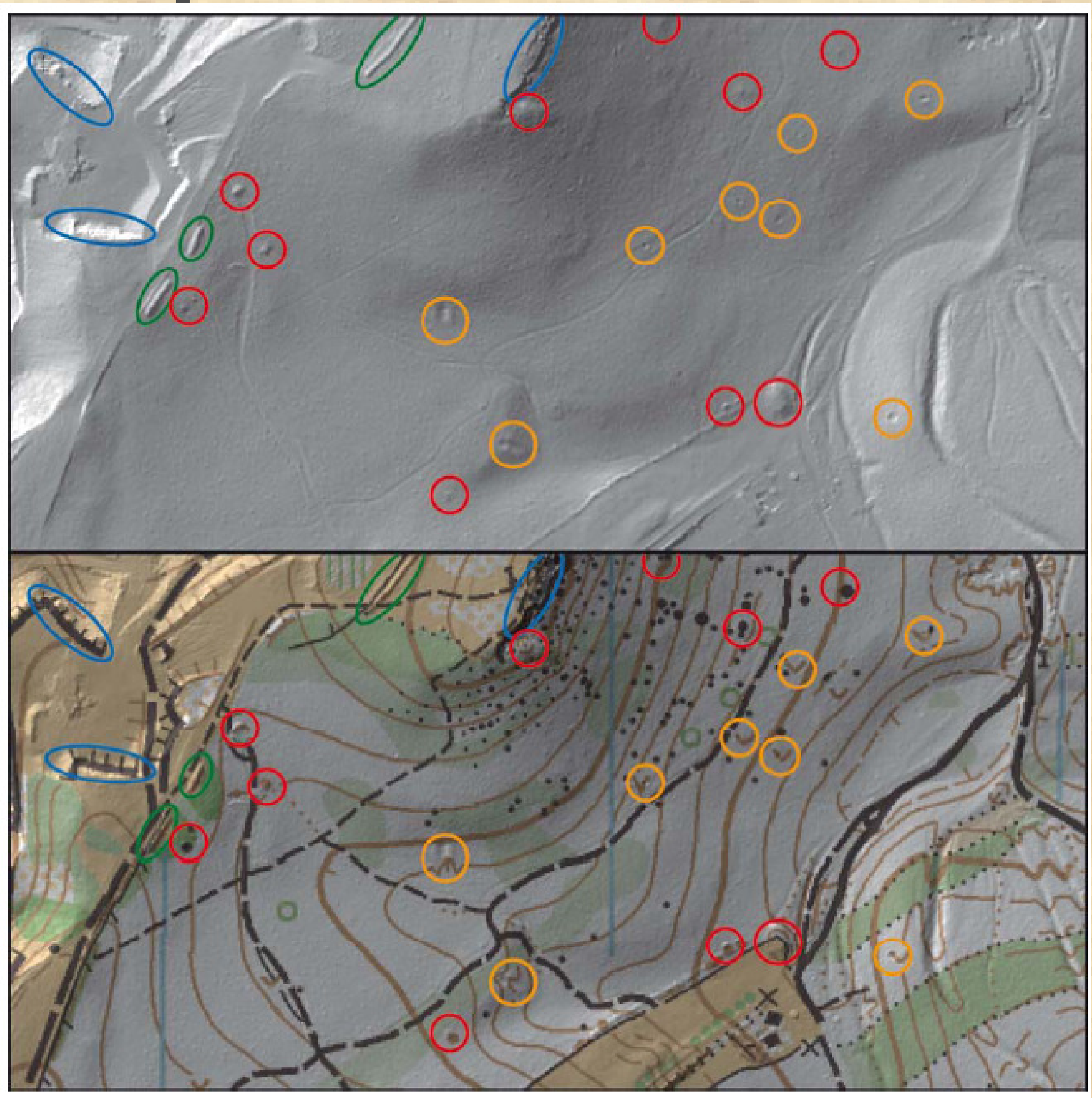
Linear features



Linear features

The next figure shows that further linear features like rock faces and earth walls and not only erosion gullies or paths can be detected from the DTM. The upper part of figure represents the DTM, while at the lower part of figure the DTM is again combined with the orienteering map. The green markings display earth walls that are too small to be visualized with contour lines. This feature can be depicted with a high geometric accuracy and probability, as the comparison with the orienteering map shows.

Linear and point features



Linear features

Rock faces can be detected easily as well in terms of the geometrical definition, as highlighted with blue markings. A semantic classification as rock face remains insecure and therefore uncertain.
In summary the geometry of linear features can be detected with sufficient reliability while a semantic classification of the feature type is hard to define. An additional validation is necessary, either by using additional data such as orthophoto or by executing a topographic field work campaign.

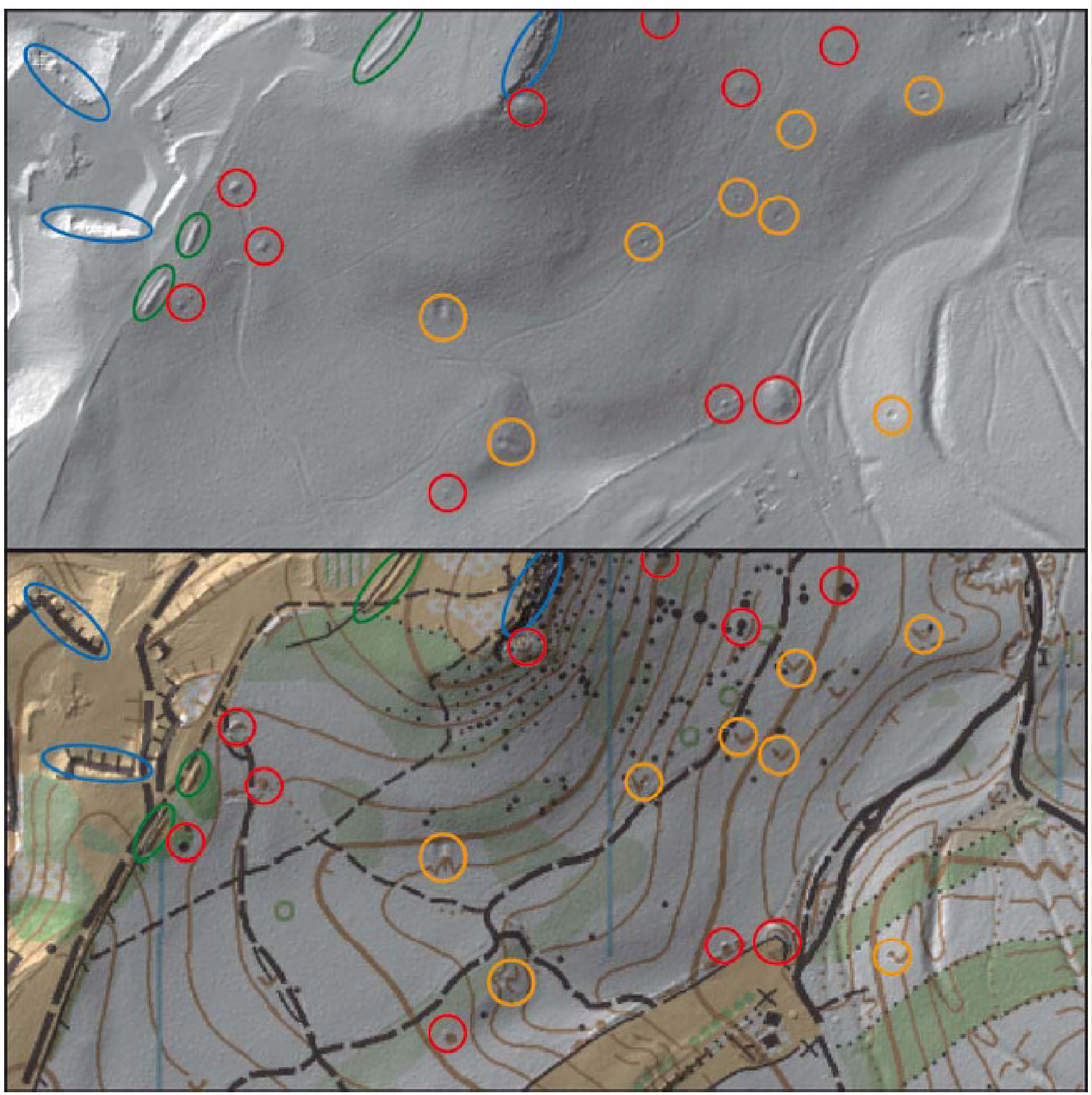
Point features

Point features can be detected with different grades of quality, using a high resolution DTM. Land forms like *pits, holes or depressions* can be depicted with a high geometric accuracy and probability, as shown in figure, marked with orange circles. The size of the feature is an important attribute to be used for the identification of the feature type.

Features like *small knolls and boulders*, marked with red circles, can be depicted with a sufficient geometric accuracy but remain uncertain in their semantic plausibility, except those knolls that are large enough in size to be visualized with contour lines.

The classification has to be done again at the field work.

Linear and point features

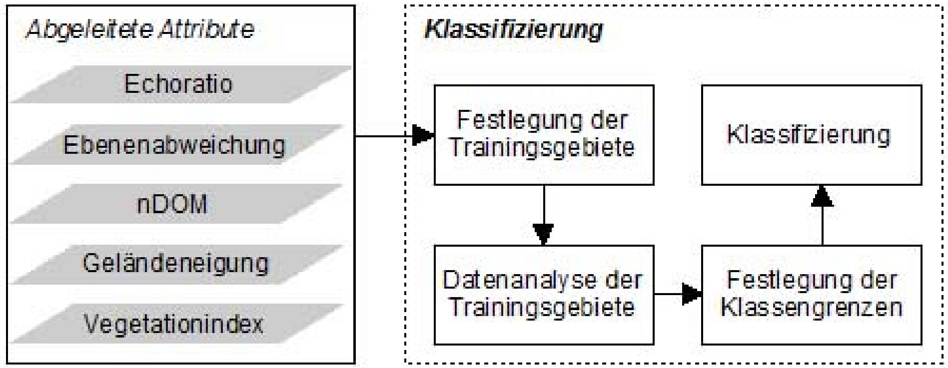


Point features

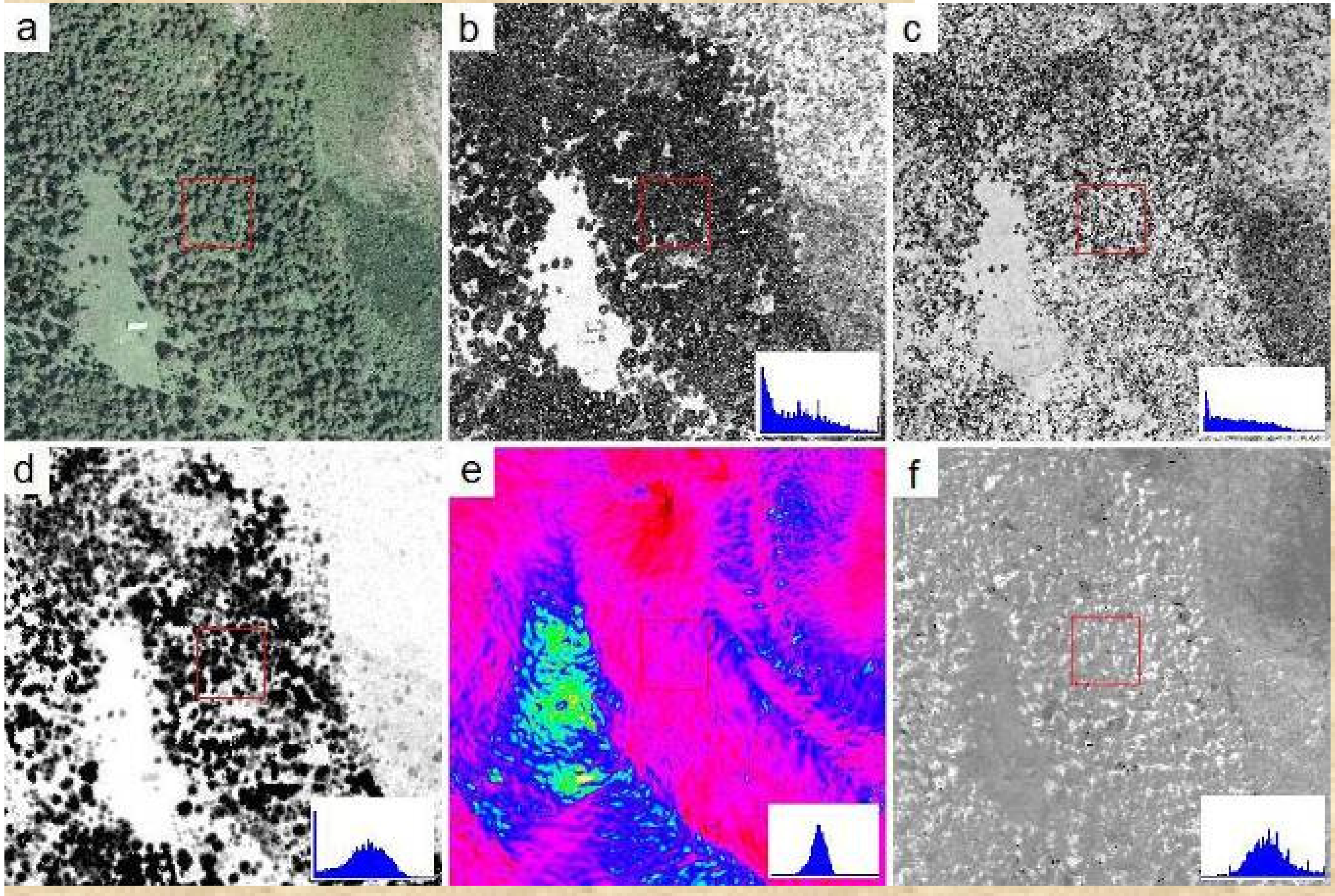
There are not many experiences reported on detecting point features in the context of orienteering maps. The results shown above are promising, but currently not operational.

The numbers of possible point features that can be depicted is still negligible in terms of what would be needed for deriving all relevant point features of common orienteering maps. The achieved geometric accuracy is definitively sufficient for the purpose of an orienteering map, but the semantic plausibility of some features has to be improved to guarantee a significant fundament for the necessary field work and to minimize time and effort of classification of not identified features.

Derivation

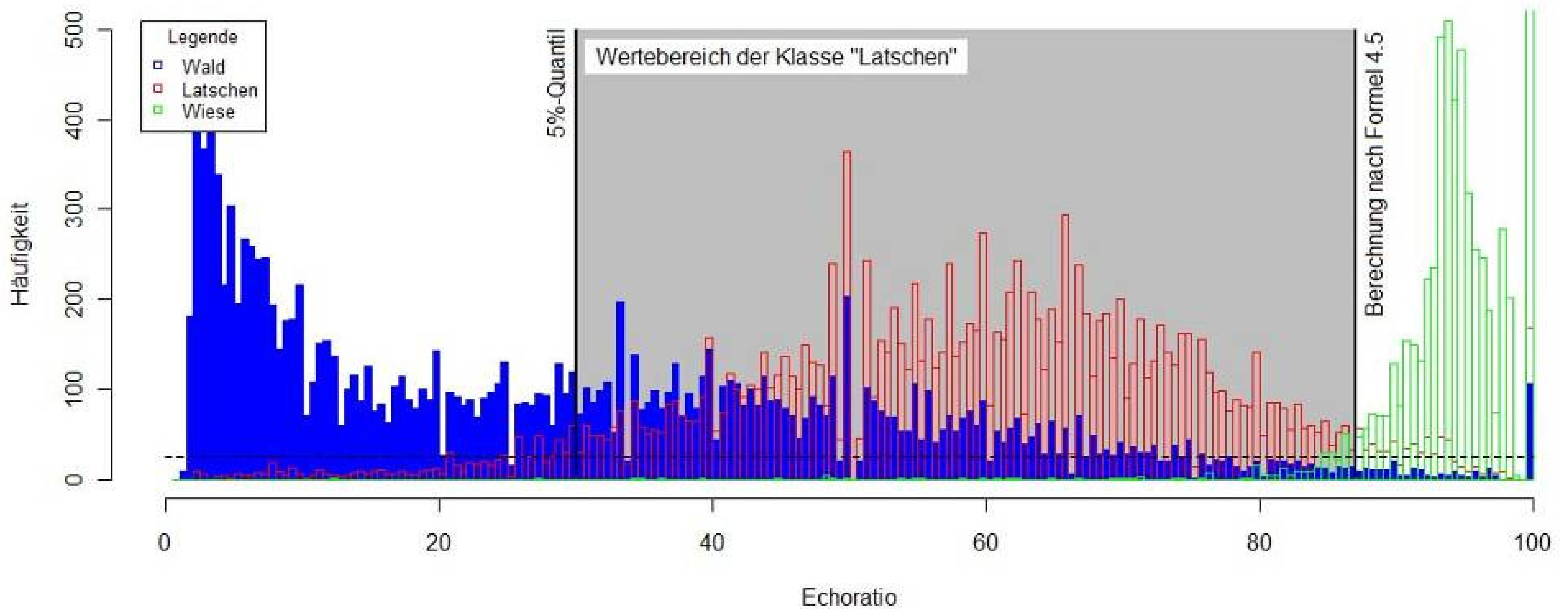


Abgeleitete Attribute
Echoratio
Ebenenabweichung
nDOM
Geländeneigung
Vegetationindex
Klassifizierung
Festlegung der Trainingsgebiete
Klassifizierung
Datenanalyse der Trainingsgebiete
Festlegung der Klassengrenzen

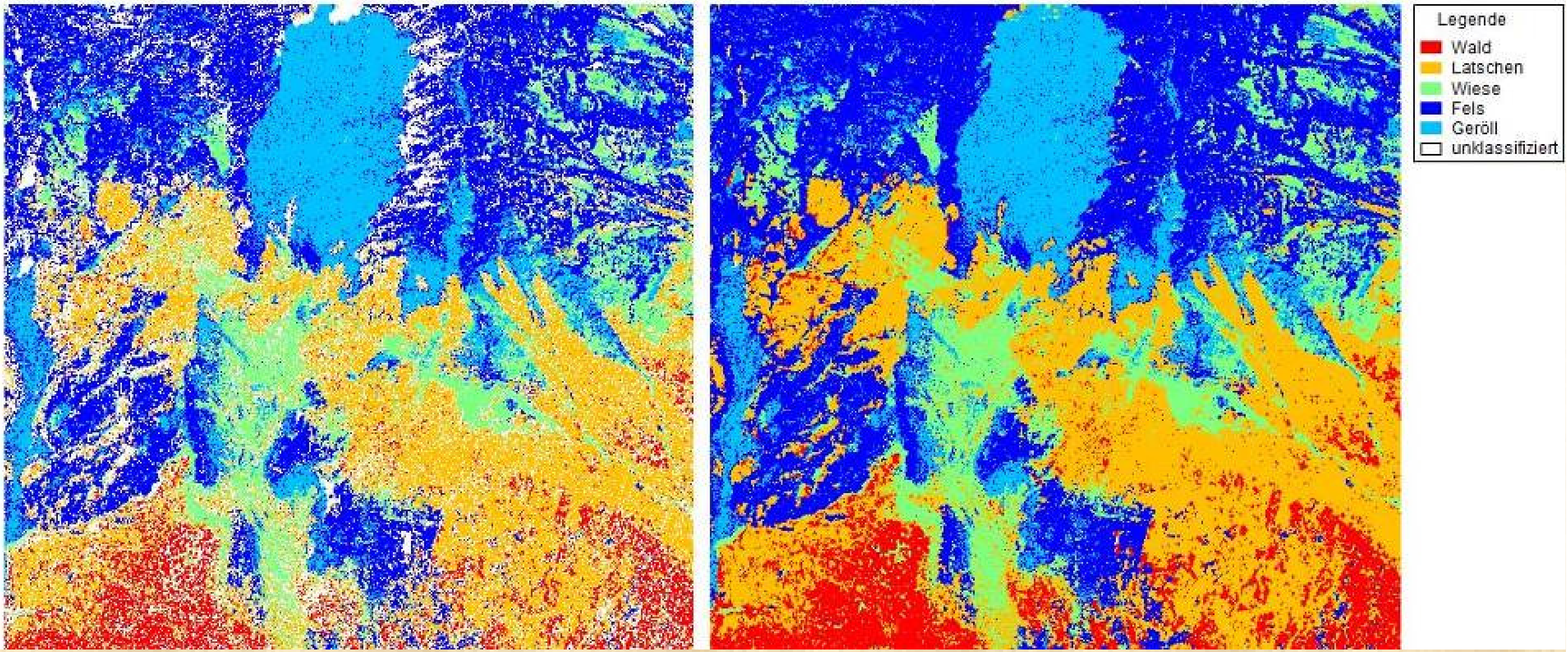


a
b
c
d
e
f

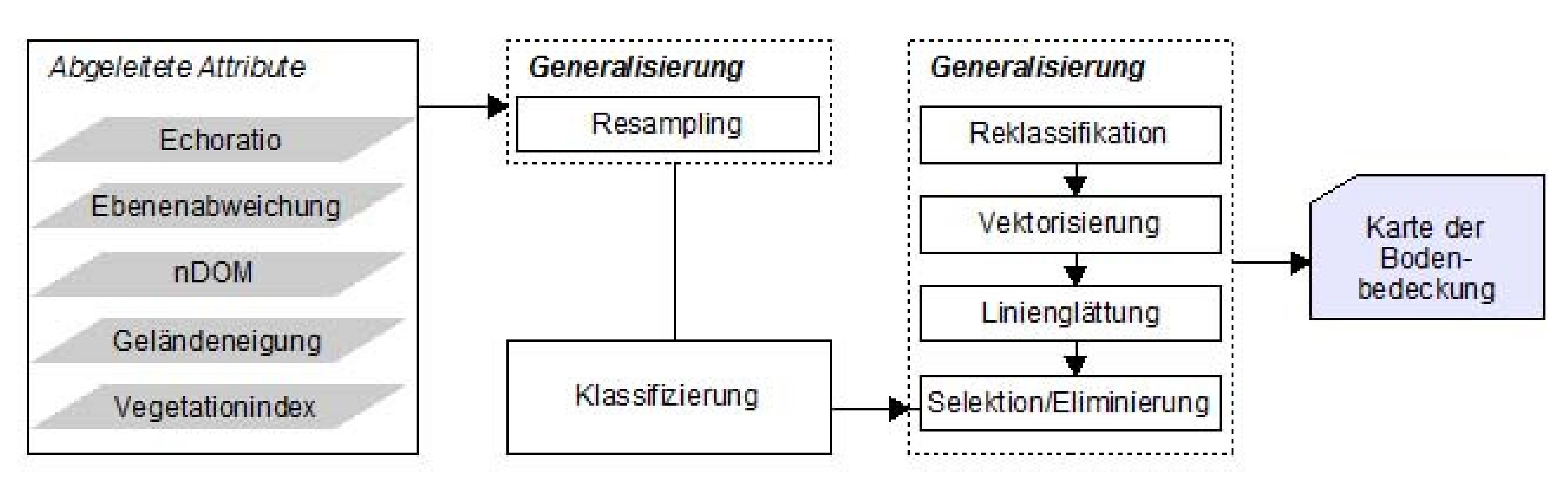
Derivation


Legende
Wald
Latschen
Wiese
5%-Quantil
Wertebereich der Klasse "Latschen"
Berechnung nach Formel 4.5
Häufigkeit
0
100
200
300
400
500
0
20
40
60
80
100
Echoratio

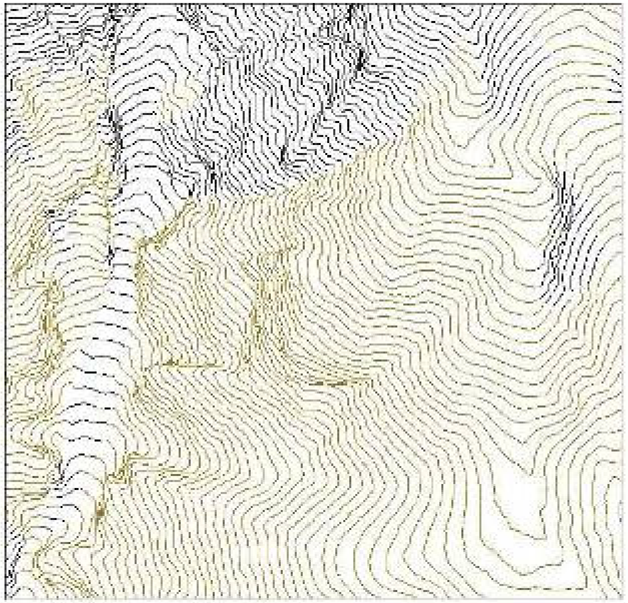
Derivation

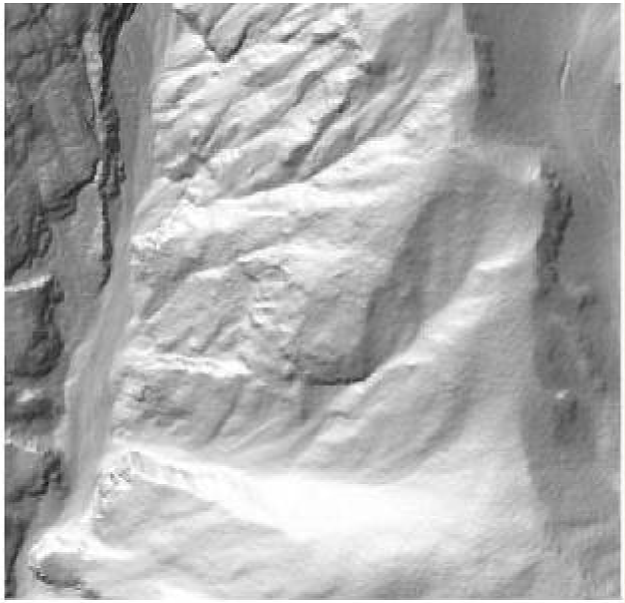


Derivation



Abgeleitete Attribute
Echoratio
Ebenenabweichung
nDOM
Geländeneigung
Vegetationindex
Generalisierung
Resampling
Klassifizierung
Generalisierung
Reklassifikation
Vektorisierung
Linienglättung
Selektion/Eliminierung
Karte der Boden-bedeckung



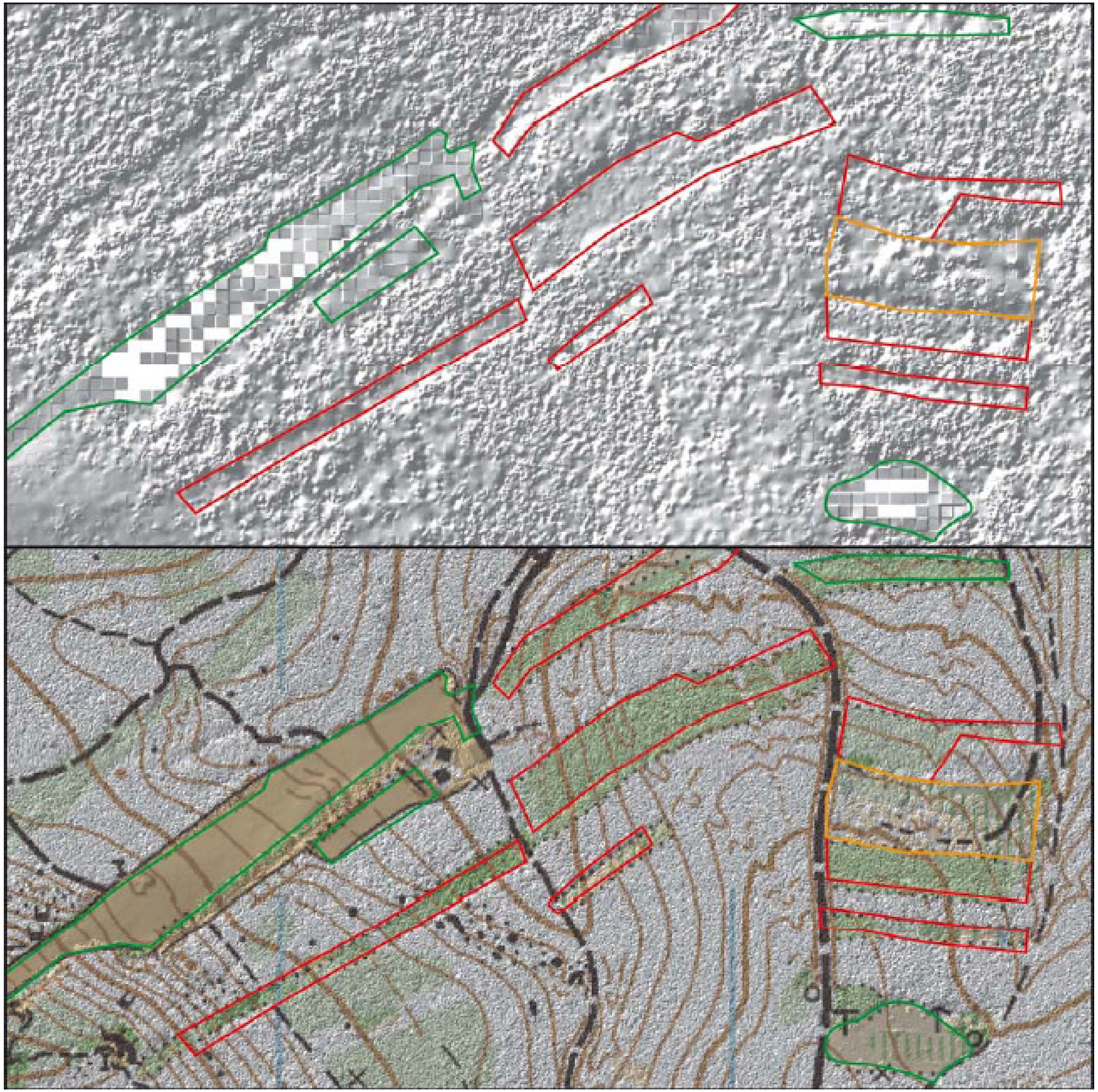


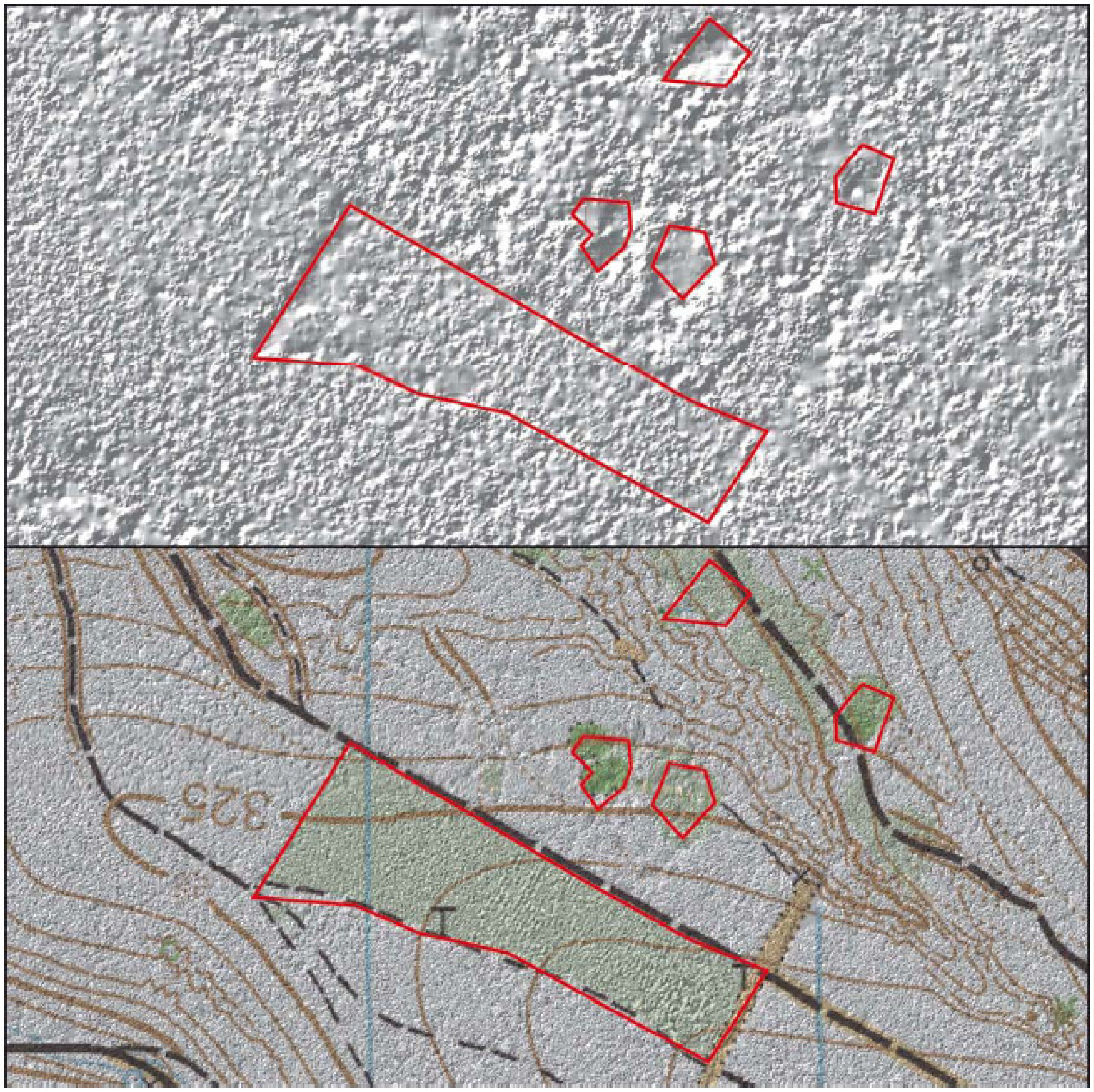
Area features

For the detection of areal features, especially vegetation, a DSM has to be used. At the lower part of the next two figures, the DSM is shown in combination with the orienteering map. The filtered point cloud of the first pulse data could be applied to depict open land, as illustrated in the next figure at the upper part with the green lines. The orange lines of the figure shows areas of rough open land that could not depicted from the DSM, but that are slightly represented with a different surface structure compared to the ground structure of the surrounding forest. These areas can also be recognized in classified model of high vegetation, due to different structures. The model of high vegetation is shown at the lower parts of figures.

Area features

For the detection of areas of limited runnability, the classified model of high vegetation, created during the process of generating the DTM, has to be used. The figure illustrates an example of this model, were relatively sharp edges of these areas of limited runnability could be discovered. One possible explanation for this phenomenon could be a different height of the vegetation in the areas with constricted runnability compared to the height of trees in open forest.
This example demonstrates as well the constraints that have to be estimated at present state of research. The edges of those areas of high vegetation in the classified model are not significant certain to achieve a sufficient geometric accuracy and it could not be guaranteed that all areas with constricted runnability could be recognized

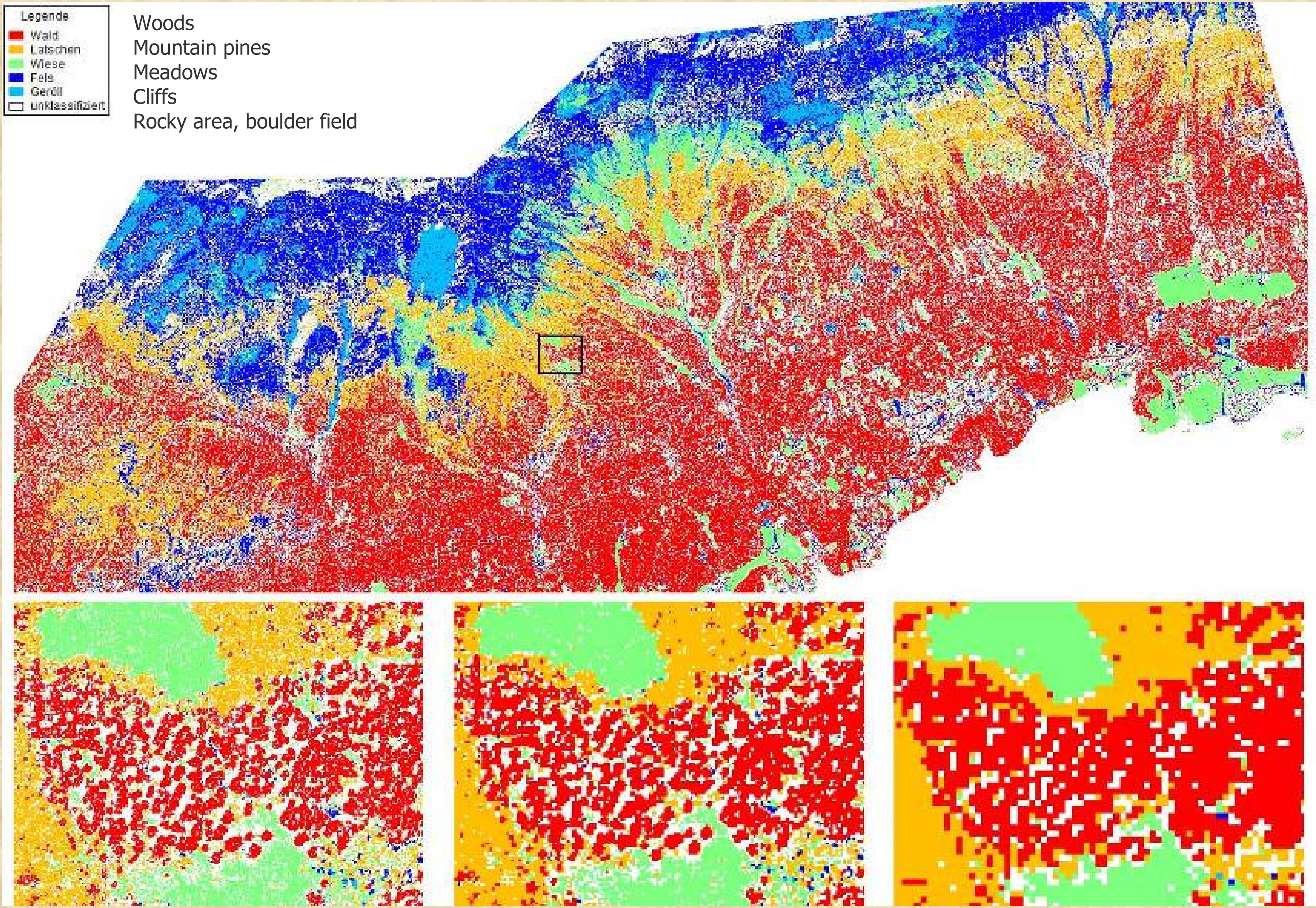



325

Area features

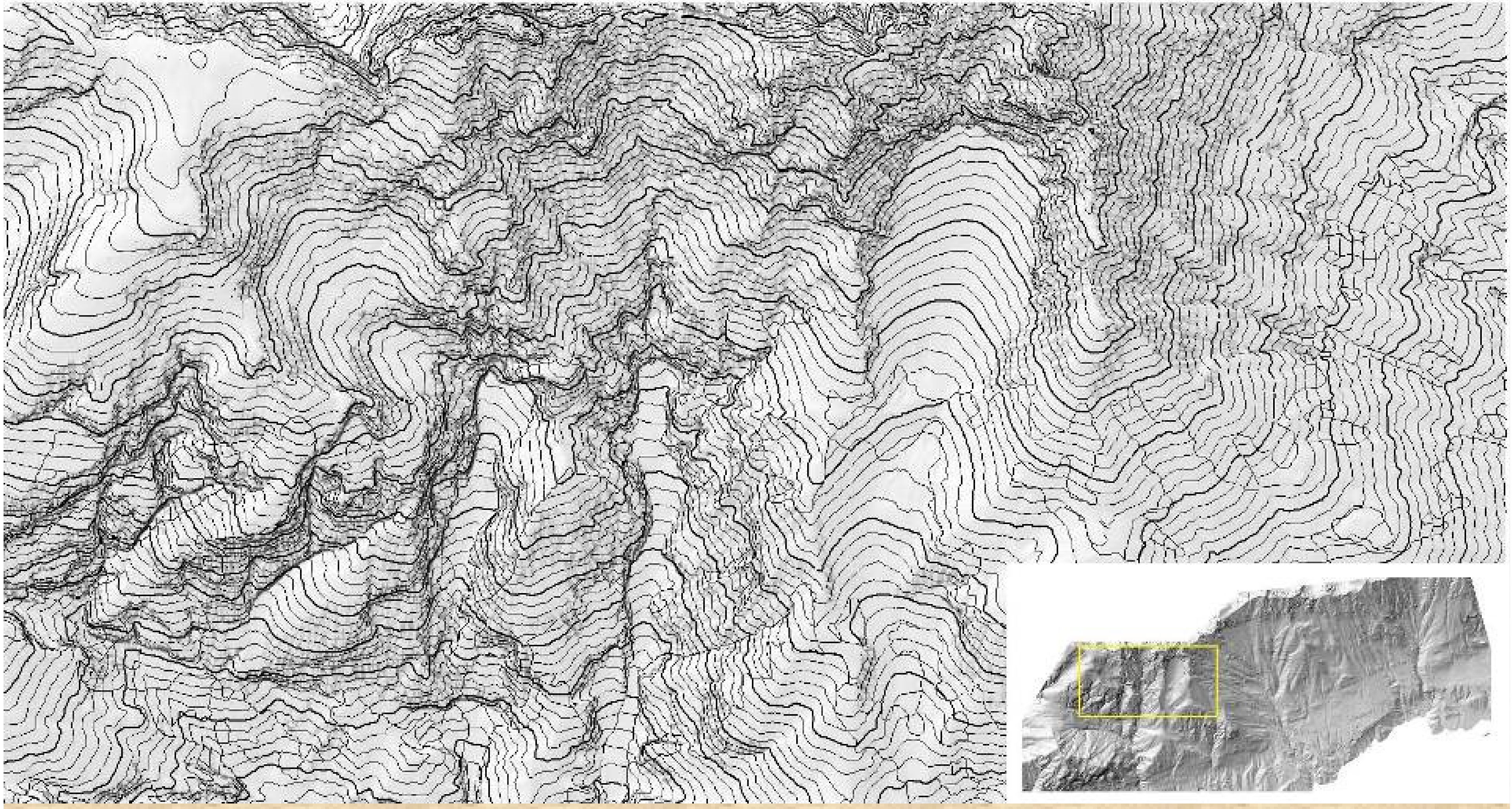
To summarize, the potential of laser scanning data as a fundament for deriving areal features of orienteering maps is still in an immature status. The problem of defining certain and sharp geometrical definitions has to be seen in a close context with the semantic definition of the features. However, it can be assumed, that as shown in the comparison above, particular characteristics of orienteering maps as e.g. the “runnabiliy of forests” might be derivable in the future.

Derivation: Vegetation



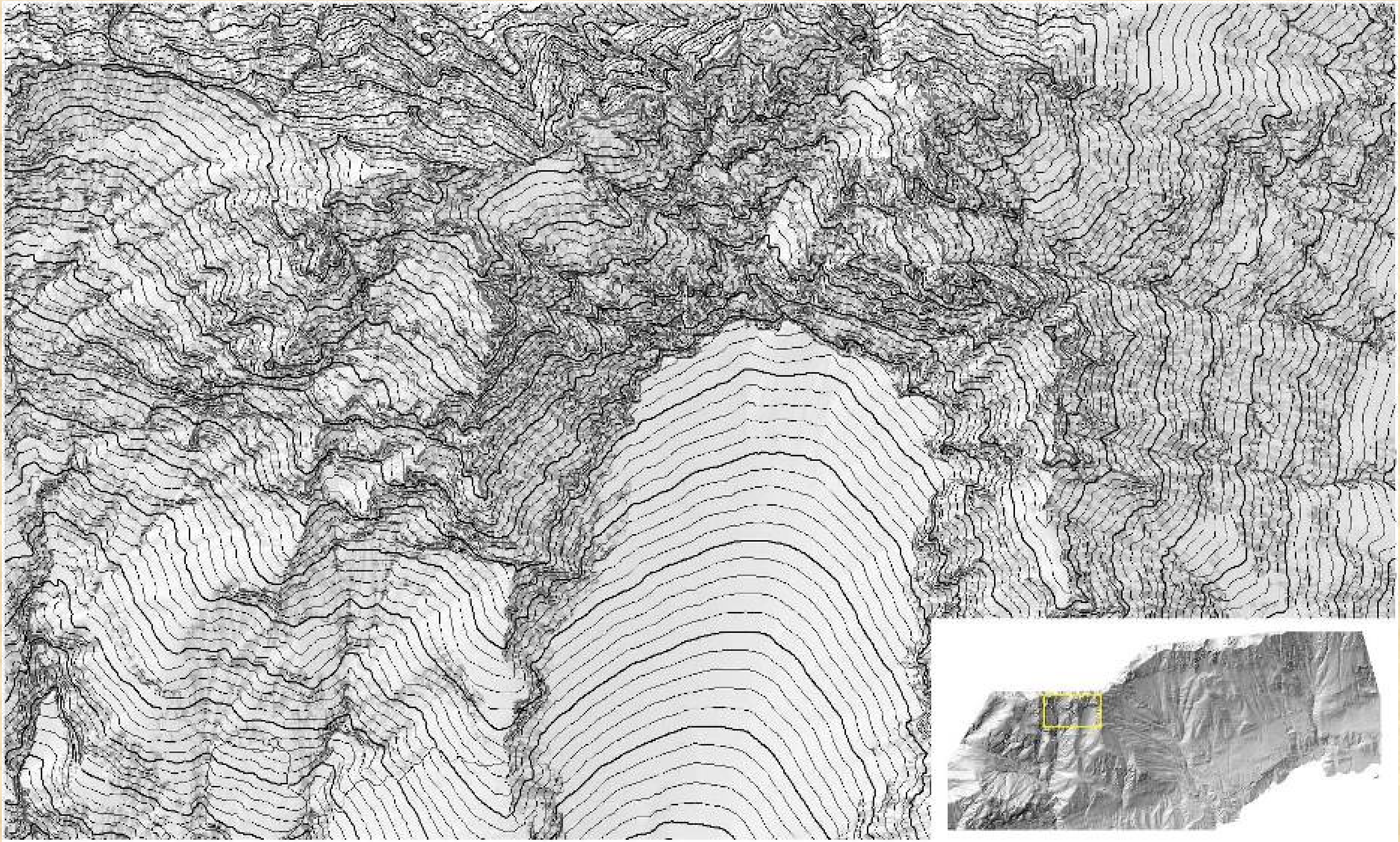
Derivation

Rock depiction

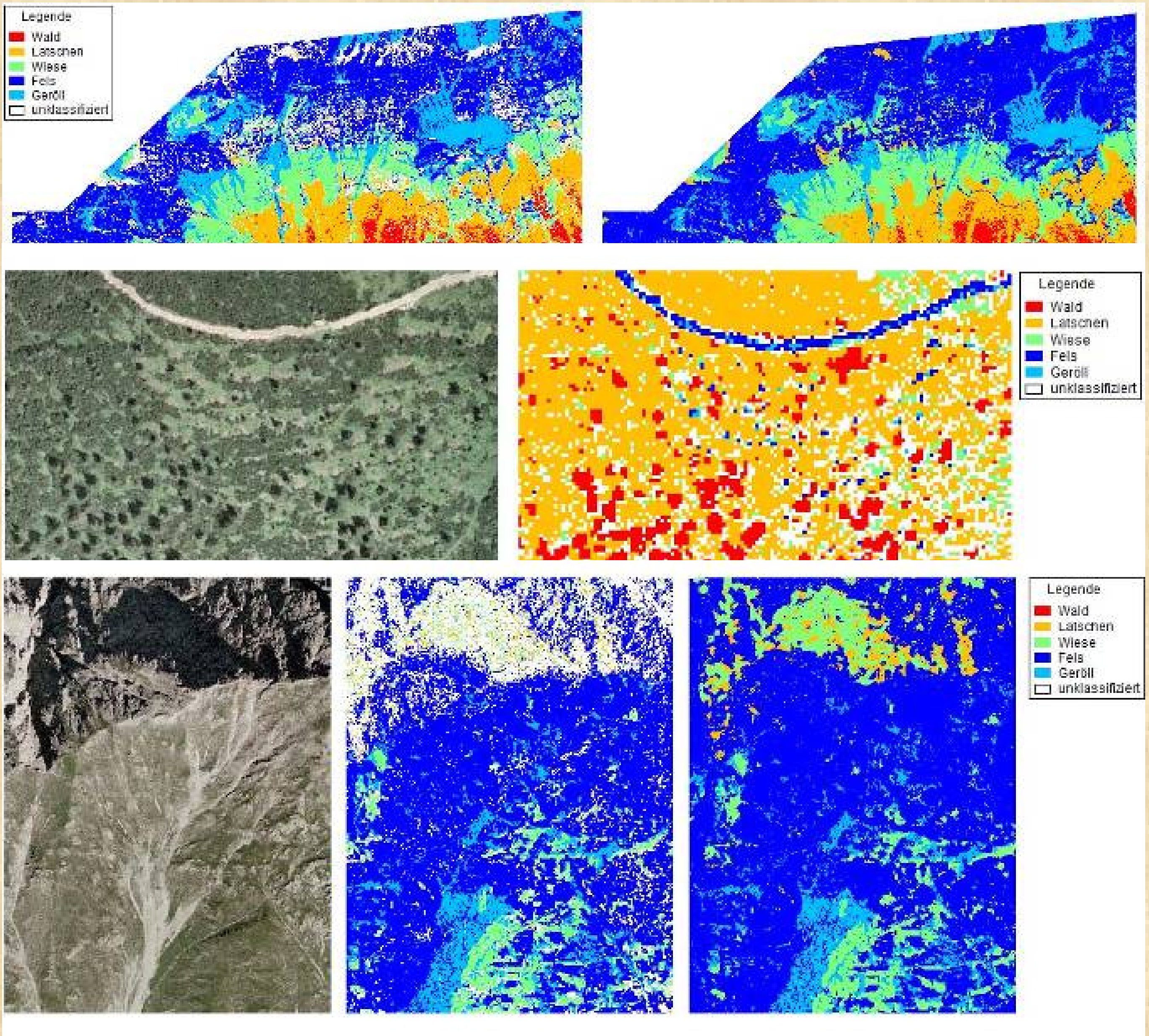


Derivation

Rock depiction

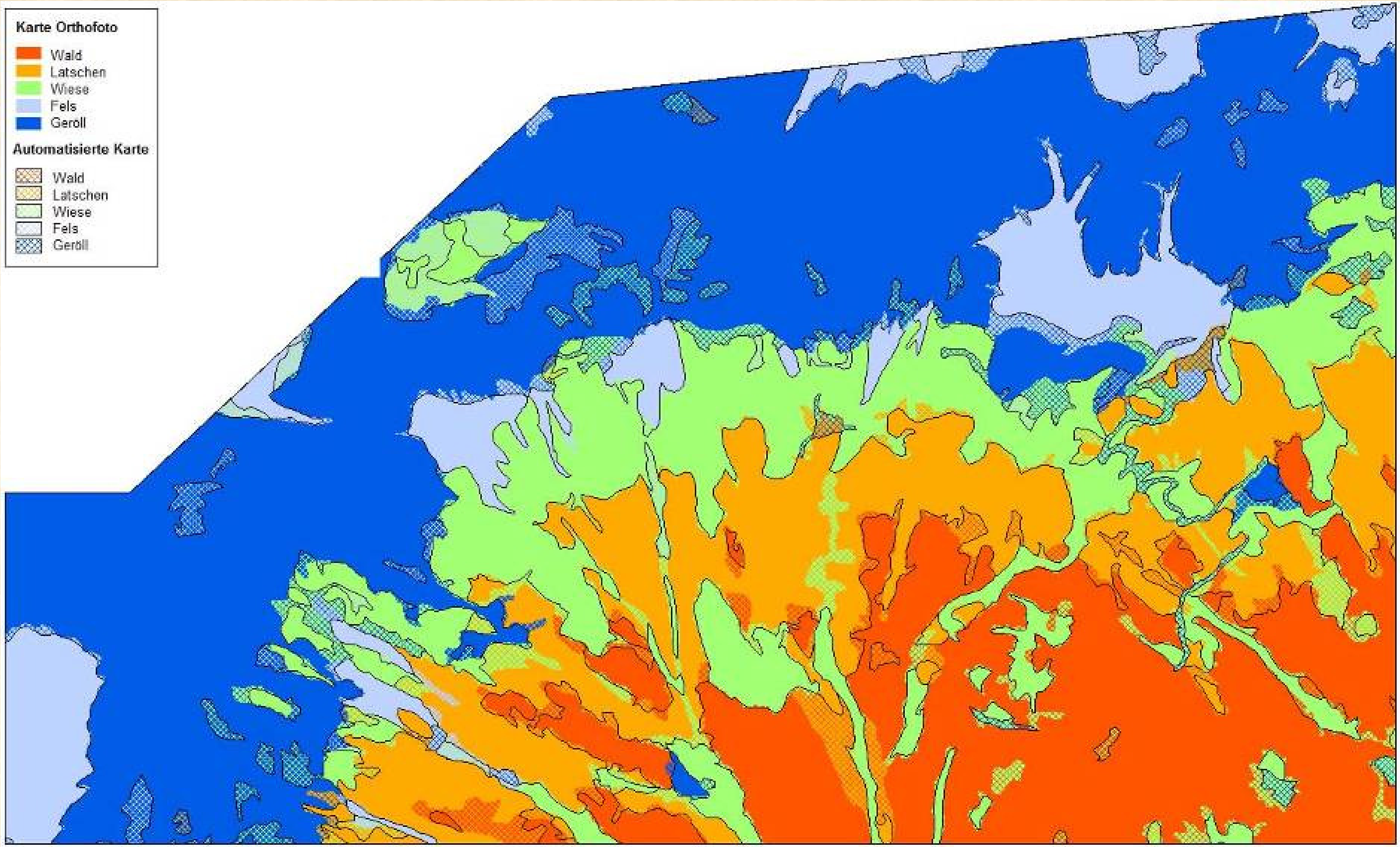


Validation



Cross Check
with orthophoto

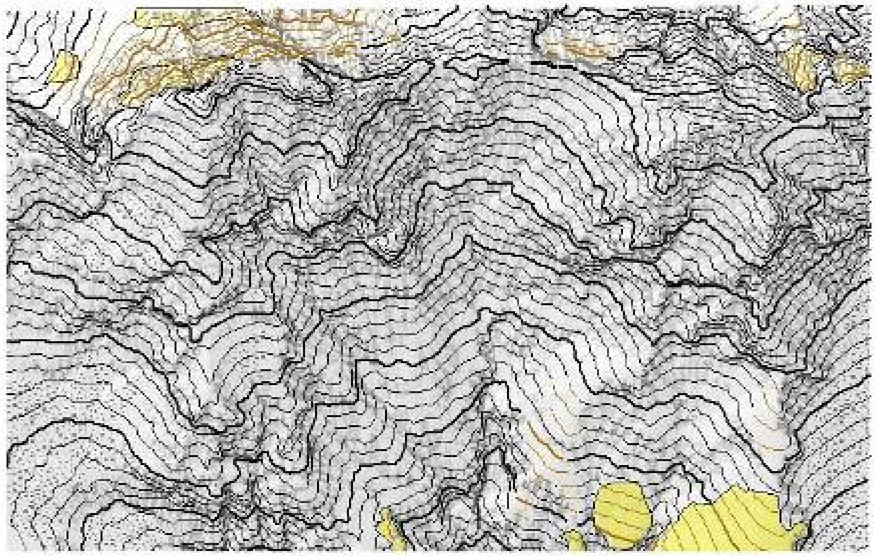
Validation

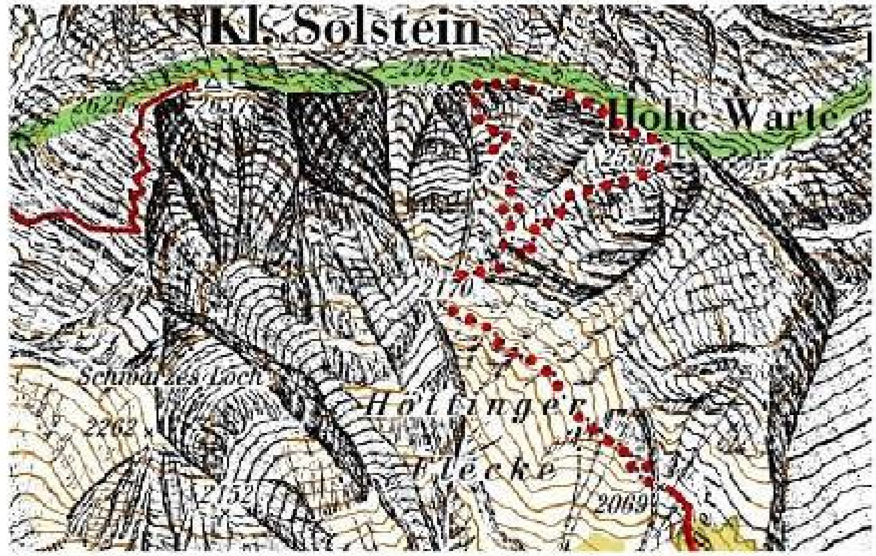


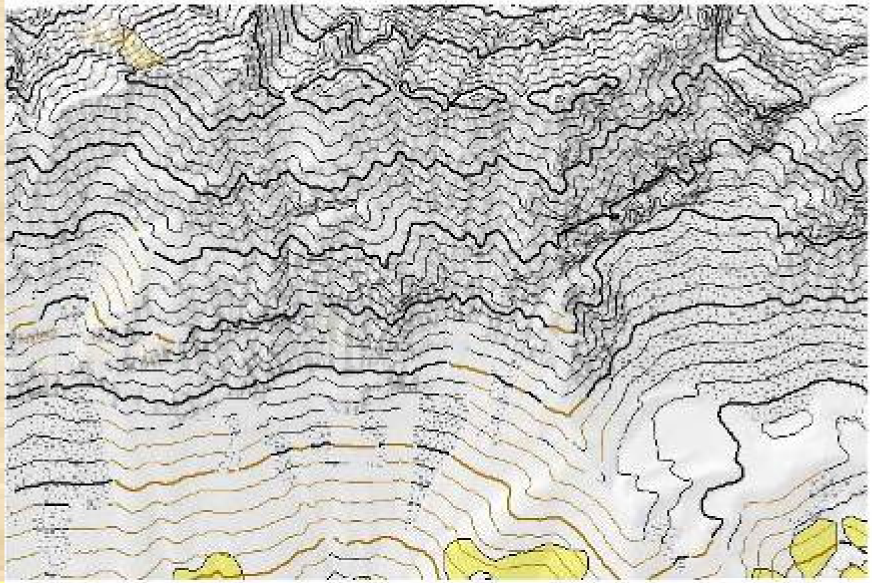
Karte Orthofoto
Wald
Latschen
Wiese
Fels
Geröll
Automatisierte Karte
Wald
Latschen
Wiese
Fels
Geröll

Validation

Comparison with topomaps

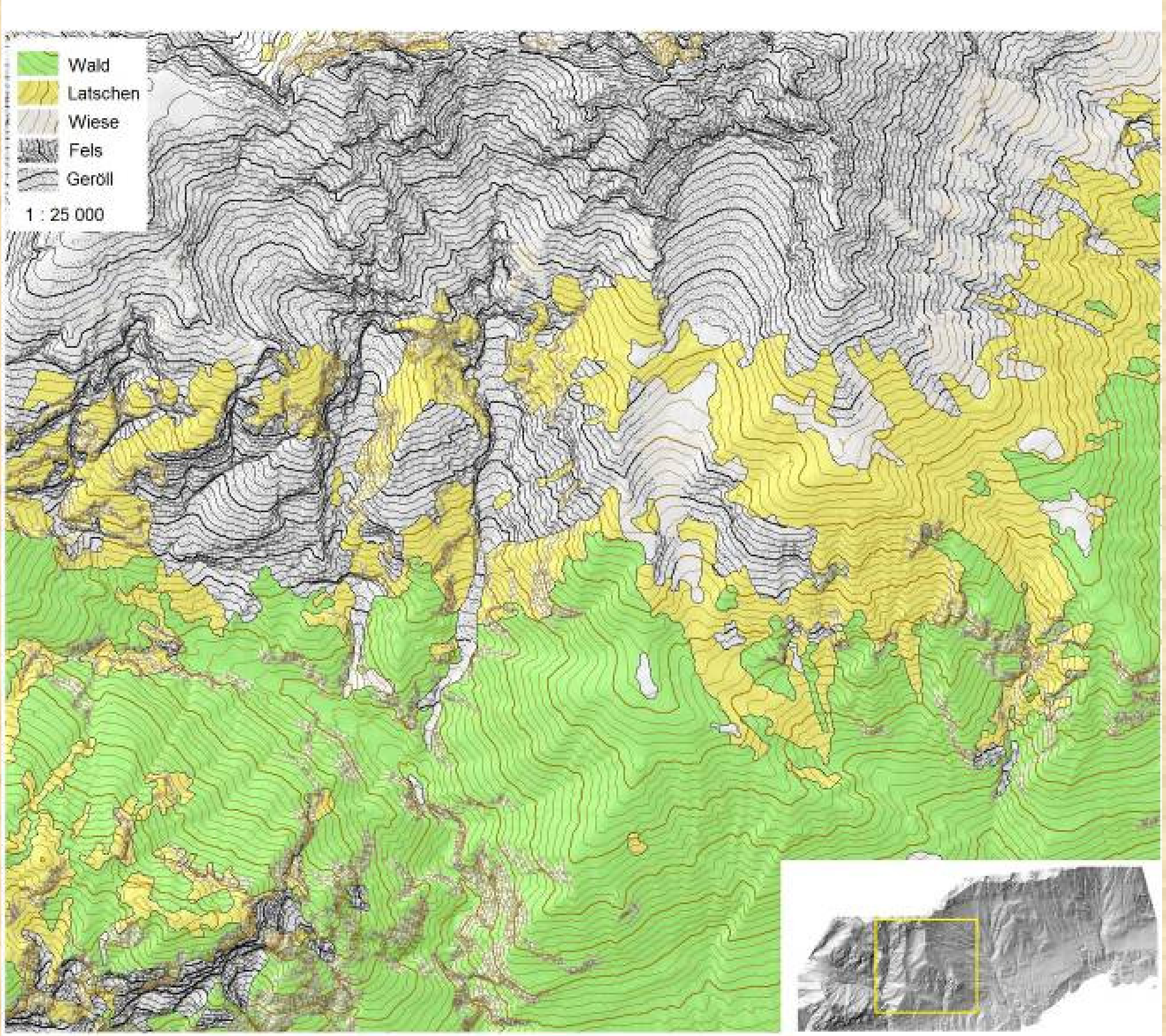






Derivation

Final map



Derivation

A comparison of the automated map with reference maps resulted in an area-wise correctness of 86% and 93% respectively, depending on the reference map. On the other hand, the automated representation of rocks was only partly convincing.

Conclusions

- This was the theoretical overview based on 2-3 years old development.
- In countries where the access of laser scanning data is (relatively) easy it´s a common technique now.
- The implementation of this new technology was as fast (or faster) than the implementation of computer drawing technologies around 1990.