|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Attribute** | **General** | **Class** | | | | | | |
| **buildings** | **Paved roads** | **ground** | **Low vegetation** | **Medium vegetation** | **High vegetation** | **Others (cars, water, ...)** |
|  |  |  |  |  | Most important attributes for distinguishing between vegetation and non-vegetation are:   1. Amplitude 2. Density Ratio 3. Echo ratio   (Rutzinger el al. 2008)  To distiguish between high and low vegetation:   1. Z 2. Reflectance? 3. Nr of Echos? | | |  |
|  |  | Most important attributes for each land cover type (Qin 2022):     * A\_first = Amplitude * Omega\_first = width of the first echo * nH\_Eavg = ratio of the energy weighted average height and the height of the waveform * R\_AOmega = ratio of amplitude and width of the first echo * Omega\_R\_f\_fl = ratio of the first echo width and the sum of the first and last echo widths of the waveform * H\_Eavg = energy weighted average height * SYM\_s = ratio of S\_rise (sum of the amplitudes during the rise time of the first peak) and S\_fall (…) | | | | | | |
| *GPSTime* |  |  |  |  |  |  |  |  |
| *Amplitude* | Has been found to be useful in the classification of land cover but is dependent on range and incidence angle (Alexander et al. 2010)  In practice, the echo amplitude is most commonly regarded as the intensity (Wagner 2008) | 40 – 250 (pitched roof) (Alexander 2010) | 5 – 60  (Alexander 2010) | Rutzinger et al. 2008:  Ampl\_mean <43.64  &  Echoratio\_mean  < 0.391   * Non-vegetation   Ampl\_mean <43.64  & densratio\_mean < 0.9195  & echoratio\_mean >= 0.056   * Non-vegetation | Rutzinger et al. 2008:  ampl\_mean <43.64  &  Echoratio\_mean >= 0.391   * Vegetation   Ampl\_mean >=43.64  & densratio\_mean >= 0.9195   * Vegetation   Ampl\_mean >= 43.64  & densratio\_mean <0.9195  & echoratio\_mean < 0.056   * vegetation   Alexander et al. 2010:  Amp = 50 – 300 (grass) |  | 0 – 200 (trees) (Alexander 2010) |  |
| *EchoWidth* | Can, together with the range, be used to derive backscatter cross section (Alexander et al. 2010)  Echo width can significantly distinguish the vegetation (especially trees) from paved areas or built-up features (Mallet et al. 2008)  Qin 2022: |  | Sharp and narrow peak echo (Yan 2014) |  |  |  | Trees: large echo width (Yan 2014) |  |
| *CrossSection* | = backscatter cross section; Can be derived from echo width and range à from this a backscatter coefficient can be computed that has a better performance in classification than the amplitude. The coefficient is especially useful for separating road and grass.  Usually represented by the Greek letter sigma (Alexander et al. 2010) | 0 – 0,8 (pitched roof) (Alexander 2010) | 0 – 0,3 (road) (Alexander 2010) |  | 0 – 0,7 (grass) (Alexander 2010) |  | 0 – 0,5 (trees) (Alexander 2010) |  |
| *EchoNumber* |  |  |  |  |  |  |  |  |
| *NrOfEchos* |  |  |  |  |  |  |  |  |
| *RGIndex* |  |  |  |  |  |  |  |  |
| *Reflectance* | (Yan 2014)ALS wavelength usually 0.8-1.55[µ](https://de.wiktionary.org/wiki/%C2%B5)m (Wagner et. Al TU Wien | Bricks: 0.17-0.19 | 0.12-0.18 |  | Dry grass: 0.2-0.58 |  |  |  |
| *BeamVectorX* |  |  |  |  |  |  |  |  |
| *BeamVectorY* |  |  |  |  |  |  |  |  |
| *BeamVectorZ* |  |  |  |  |  |  |  |  |
| *Range* | Can, together with the echo width, be used to derive backscatter cross section (Alexander et al. 2010) |  |  |  |  |  |  |  |
| *ScanAngle* |  |  |  |  |  |  |  |  |
| *NormalX* |  |  |  |  |  |  |  |  |
| *NormalY* |  |  |  |  |  |  |  |  |
| *NormalZ* |  |  |  |  |  |  |  |  |
| *NormalSigma0* |  |  |  |  |  |  |  |  |
| *NormalizedZ* | Qin 2022: |  |  |  |  |  |  |  |
| *DensityRatio* |  |  |  | Rutzinger et al. 2008:  Densratio\_mean < 0.761  &  Echoratio\_mean >=0.078   * non-vegetation | Rutzinger et al. 2008:  Densratio\_mean >=0.761   * vegetation   densratio\_mean<0.761  &  Echoratio\_mean < 0.078   * vegetation |  |  |  |
| *Backscatter Coefficient* | Can be derived from the backscatter cross section (derived from echo amplitude, width and range)  Performs better as a classification feature than amplitude or cross section because the amplitude is dependent on so many things (flying height, incidence angle, weather conditions, …)  Backscatter coefficients are used to radiometrically calibrate the amplitude data  (Alexander et al. 2010) | 1 – 4 (pitched roof) (Alexander 2010) | 0 – 2 (road) (Alexander 2010) |  | 1 – 4 (grass) (Alexander 2010) |  | 0 – 4 (trees) (Alexander 2010) |  |
| *Symmetry related features (Qin 2022)* | Symmetry-related features can describe the symmetric of echoes, which are closely related to the spatial distribution and scattering characteristics of objects. […] Vegetation and rough ground always have obvious asymmetries, whereas flat building, water and impervious ground often have apparent symmetry. (Qin 2022) |  |  |  |  |  |  |  |

Literature that has already been read:

* Alexander et al. 2010 (Max)
* Rutzinger et al. 2008 (Max)
* Bakula 2016 (Theresa)
* Yan 2014 (Theresa)
* Chen 2022 (Max)
* Lin 2016 (Max)
* Qin 2022 (Max)
* Zhou 2017 (Theresa): distance (z), intensity (amplitude), echowidth
* Zorzi 2019