POLITECNICO MILANO 1863

FOSS4G - IT 2018

La correzione atmosferica delle immagini Sentinel-2: tecniche e software a confronto

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Starting point

The *identification of plant species* from the integration of Earth Observation (EO) data from different data sources paying special attention to Sentinel 2 mission of the ESA Copernicus Program

→ **AIM**: a continuous, widespread, and updated mapping of the distribution of tree species

In this regard, the research focus has moved from the integration of different EO data to the study of Sentinel 2A images, their limits and potential applications with respect to the identification of plant species.

→ **AIM:** investigate all the possible issues that affect the classification of optical images from Sentinel 2A mission especially in terms of plant species identification.

Data approach

Two main issues have been identified:

1 *Data characteristics* → *the limited number of image bands (low spectral resolution)* is insufficient to discriminate the spectral signatures of single species due to the lack of spectral differences. Furthermore, due to *the limited geometric resolution* the problem of mixed pixels occur, i.e. an image pixel covers various objects, reducing the ability to identify single species.

2 *Data quality* → the intrinsic characteristics of Sentinel 2 images such as errors in reflectance values due to *atmospheric "noise"*, topographic features, the presence of cloud and their shadows on ground

Atmospheric correction

Sentinel 2A images (Level-1C) are provided by ESA in Top of Atmosphere (TOA) reflectance. Obviously the effects of atmosphere have to be considered to obtain the Bottom of Atmosphere (BOA) reflectance that is the reflectance value at ground level.

Two main approaches to compute surface reflectance:

- *image based techniques*
- *physically based techniques*

Both approaches have been tested using respectively:

- *Dark Object Subtraction (DOS) model*
- *Second Simulation of Satellite Signal in the Solar Spectrum (6S) model*

Both models have been tested using respectively:

- *QGIS v. 2.18.15 (DOS)*
- *GRASS GIS v. 7.4.0 (6S)*
- *Arcsi v. 1.4.2 (6S)*

DOS - atmospheric correction

Dark Object Subtraction (DOS)

- Based on the lower reflectance value (darker objects) of the image
- It is assumed that the radiance received at sensor from this pixel is almost entirely composed of atmospheric scattering
- The radiance value of this pixel is then subtracted from all pixels
- Being an image-based model, no other input data than bands is required

DOS → QGIS → Semi-Automatic Classification Plugin v. 5.3.11

- The only data input are the image bands and the metadata file
- Applies a DOS1 model (the simplest one)
- It returns corrected .tif file (one for each band) converted in physical value (range 0-1)
- Outliers (reflectance > 1) are set to 1

6S - atmospheric correction

Second Simulation of Satellite Signal in the Solar Spectrum (6S)
is a Radiative Transfer Model which simulates the effect of the atmosphere on light passing through it.

Being a physically based model, it requires several inputs:

- Geometric configuration of the scene and lighting
  - sensor altitude and geometry,
  - sensing date and bounding box of the image
  - solar irradiance
  - sun position (zenith and azimuth)
- atmospheric measurements
  - atmospheric profile
  - aerosol profile
  - others like Aerosol Optical Thickness (AOT) and Vertical Water Content
- Ground altitude
- Radiance values of the bands scene

6S - atmospheric correction

6S → GRASS GIS → i.atcorr

It requires lots of input parameters in addition to image band:

- range = the min/max theoretical values the input data can reach (1,10000 – outliers are set to 10000)
- elevation map = DEM of the whole area (EU-DEM v1.1 resampled to 10m resolution)
- input values in radiance or reflectance (TOA reflectance)
- rescale = output data range (0,1)
- parameters = text file with 6S parameters

```
25 --geometrical conditions Sentinel-2A
8 2 10.17 10.29253204 46.04626546 -- month day hh.ddd lon lat ("hh.ddd" is in decimal hours GMT)
2 --atmospheric model=midlatitude summer
1 --aerosols model=continental
0 --visibility [km]
0.470299 --AOT at 550nm
-0.459 --mean target elevation above sea level [km]
-1000 --sensor height (here, sensor on board a satellite)
167 --band number processed (es. 167 blue band Sentinel-2A)
```

All the parameters have to be manually retrieved and inserted in the txt file!

6S - atmospheric correction

6S → GRASS GIS → i.atcorr

```
25 --geometrical conditions Sentinel-2A
8 2 10.17 10.29253204 46.04626546 -- month day hh.ddd lon lat ("hh.ddd" is in decimal hours GMT)
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```

- Month, day, hh.ddd, lon and lat → metadata files
- Atmospheric and aerosol model → Arcsi
- Mean elevation → from input DEM map
- AOT at 550nm → AERONET (Aerosol Robotic Network) data at different wavelengths thus interpolated to obtain AOT at 550nm using Py6S, a python interface to 6S

!! AOT value must be related to the investigated area and to sensing date/time of the images → not always available !!

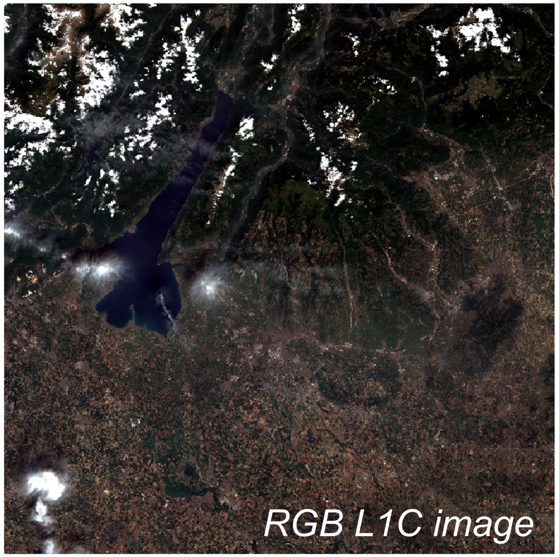
6S - *atmospheric correction*

6S → ARCSI

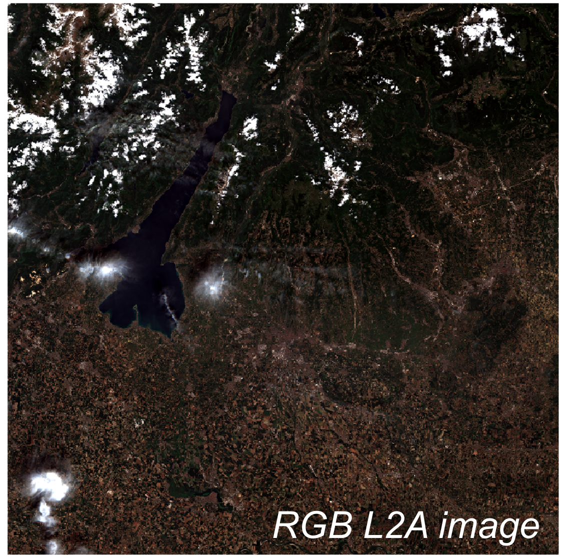
- It requires only the metadata file and a DEM (EU-DEM v1.1) as input data
- Atmospheric and aerosol model are automatically retrieved
- It allows to *estimate automatically the AOT* value from the image:
  - It estimates the surface reflectance in the blue channel by using a simple DOS model;
  - Taking this estimated reflectance as input, 6S is then numerically inverted to identify the AOT value, which provides a surface reflectance value as close to that estimated from DOS as possible;
  - Once the AOT value has been estimated it has been used to parameterise and run 6S to build a Lookup Table (LUT) at elevation steps of 100 m and apply this to produce surface reflectance.

Arcsi doesn’t normalize the outliers thus reflectance values > 1 can occur!!

Results – RGB composites

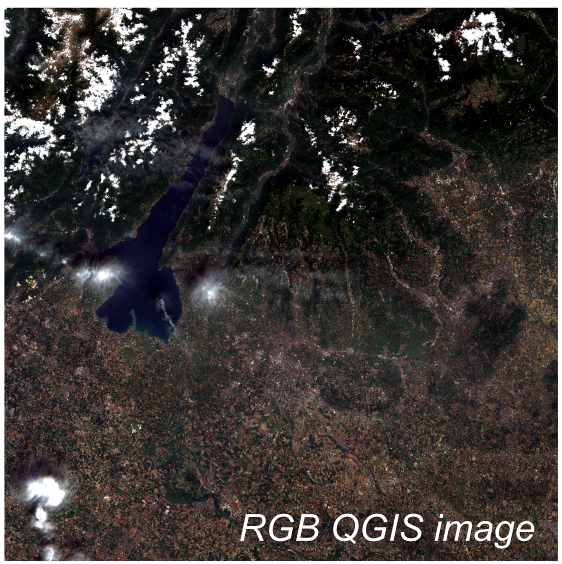


RGB L1C image

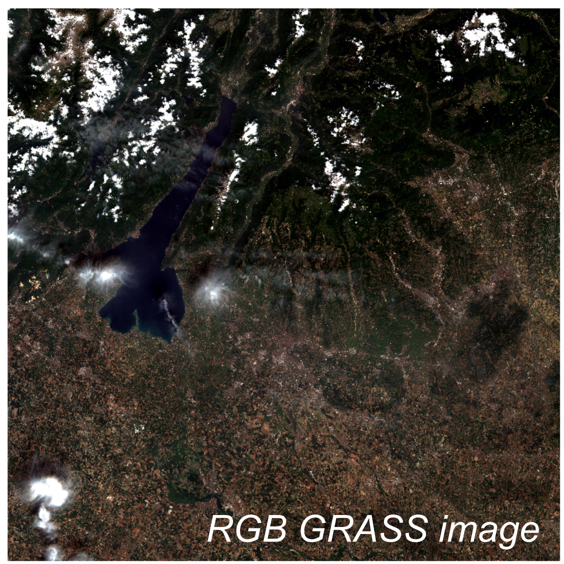


RGB L2A image

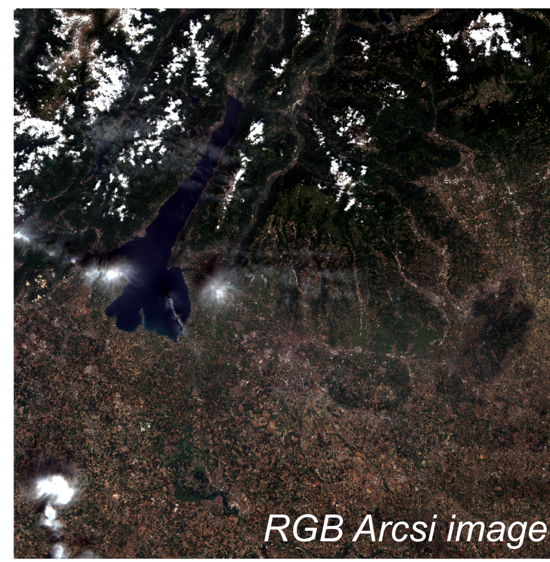
Since May 2017 Sentinel 2 images are also provided by ESA in BOA reflectance (Level-2A). ***Obviously these images have been considered*** but from the related metadata file emerged that *the final surface reflectance is computed using the same model parameters for each hemisphere*. This lead to a rough simplification of the final reflectance results for all analysed images.



RGB QGIS image

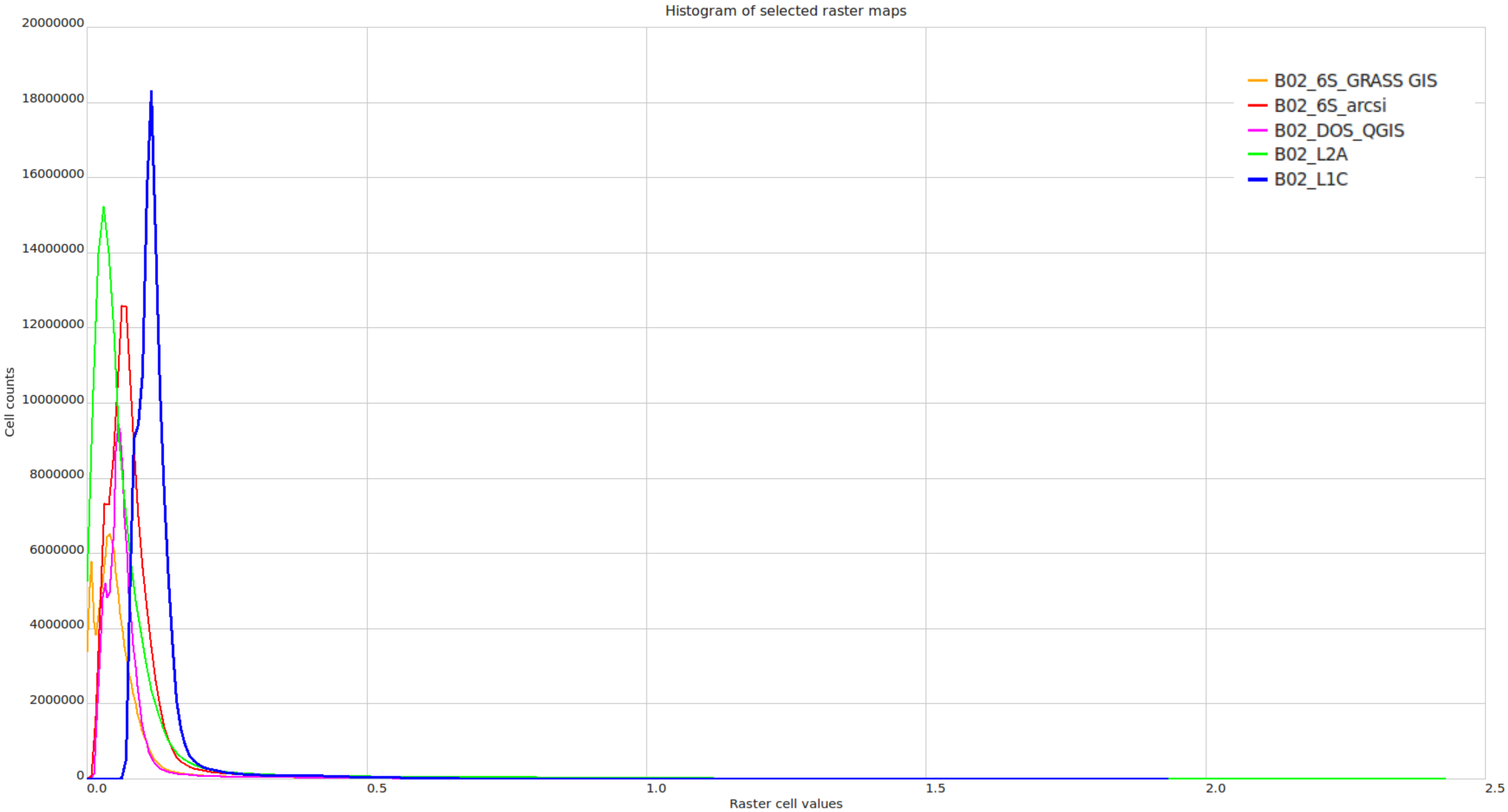


RGB GRASS image



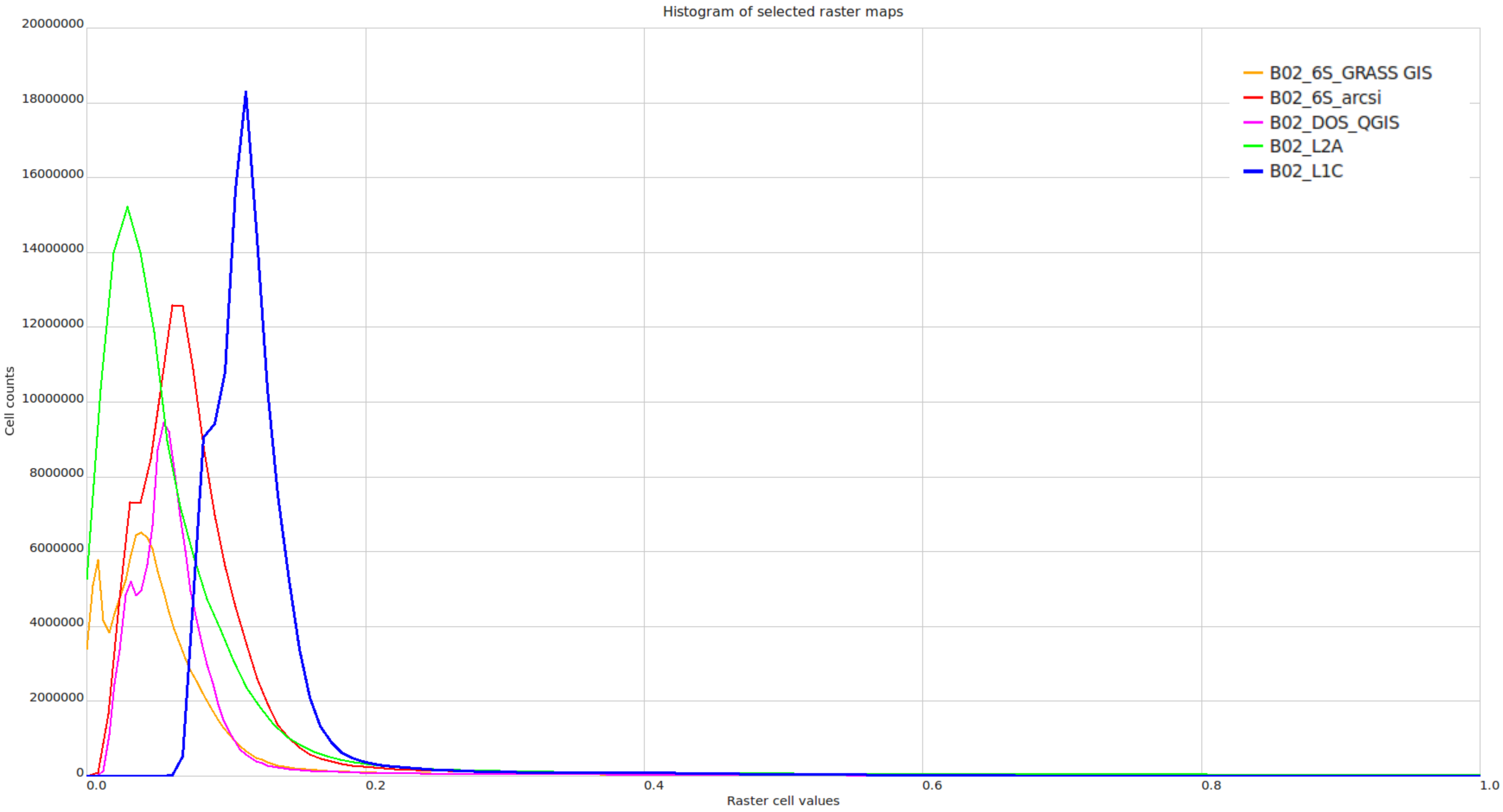
RGB Arcsi image

Results and comparisons



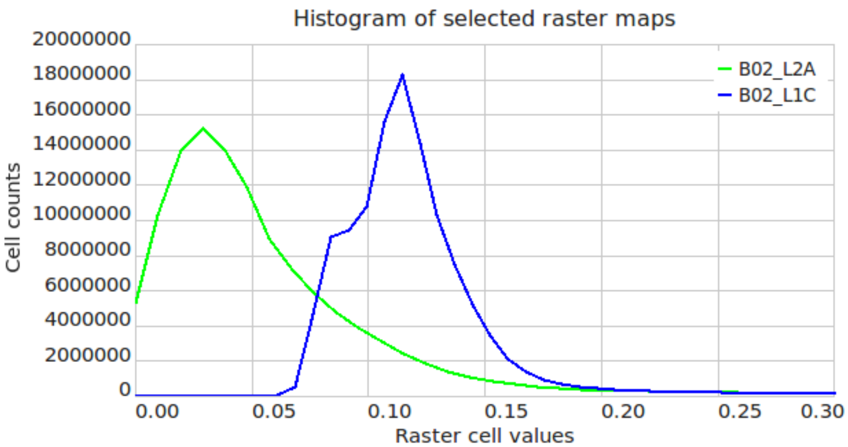
Histogram of blue bands (reflectance value > 1)

Results and comparisons

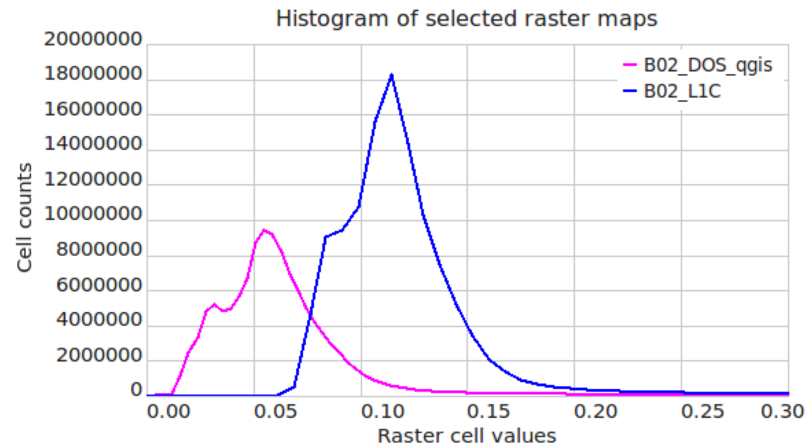


Histogram of blue bands

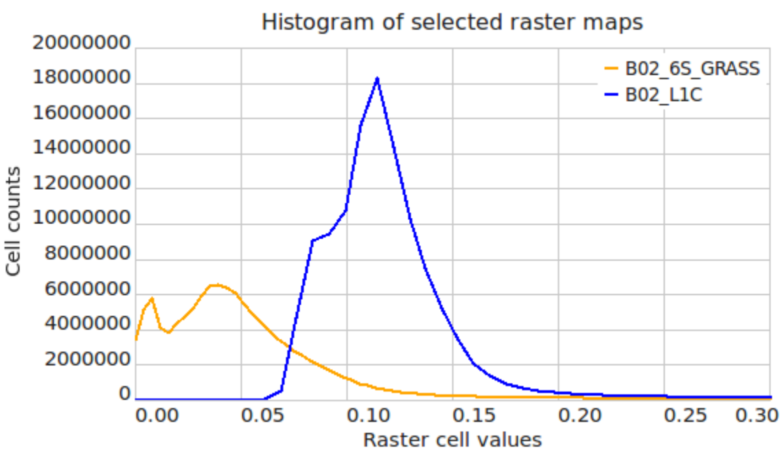
Results and comparisons



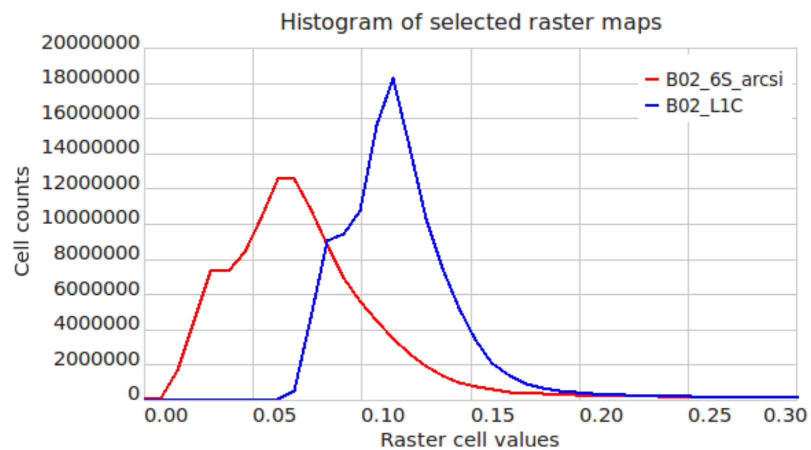
Histogram of blue bands (L1C and L2A)



Histogram of blue bands (L1C and QGIS)



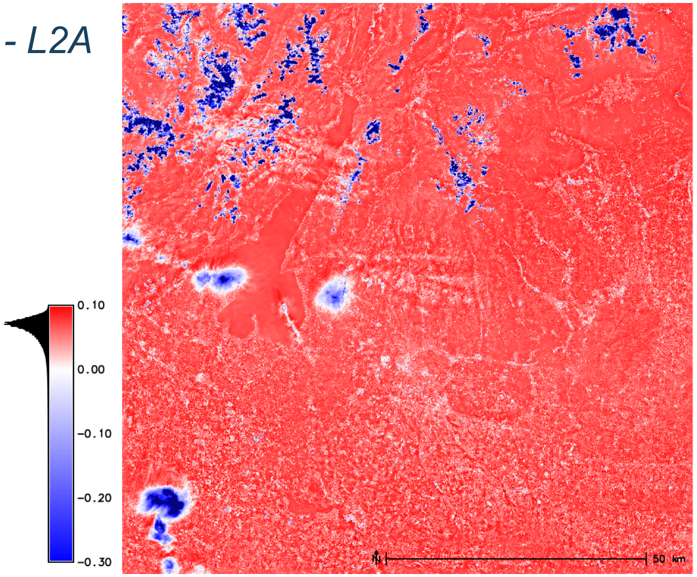
Histogram of blue bands (L1C and GRASS)



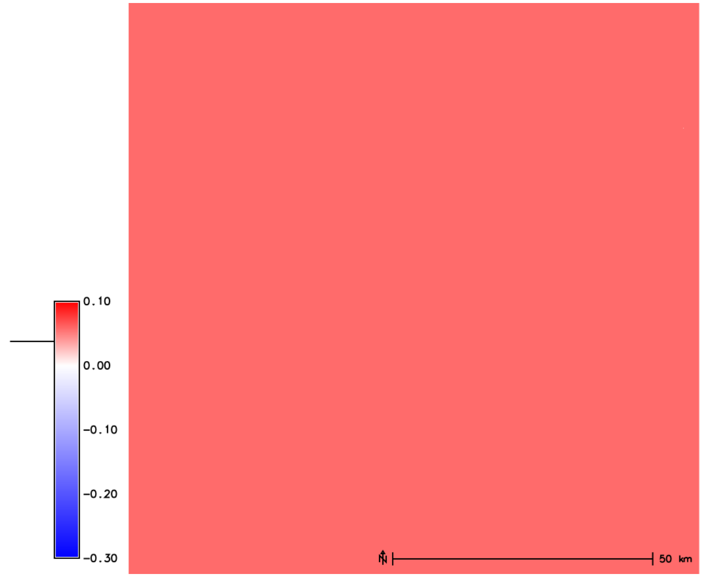
Histogram of blue bands (L1C and Arcsi)

Results – Correction differences for Blue bands

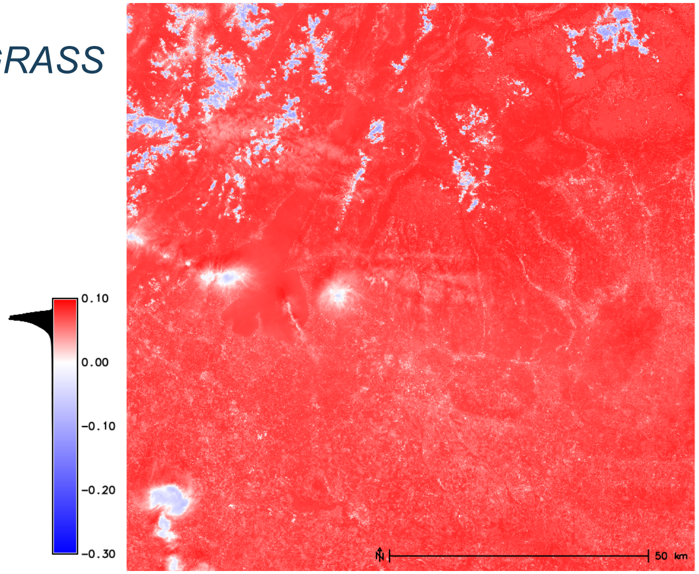
L1C - L2A



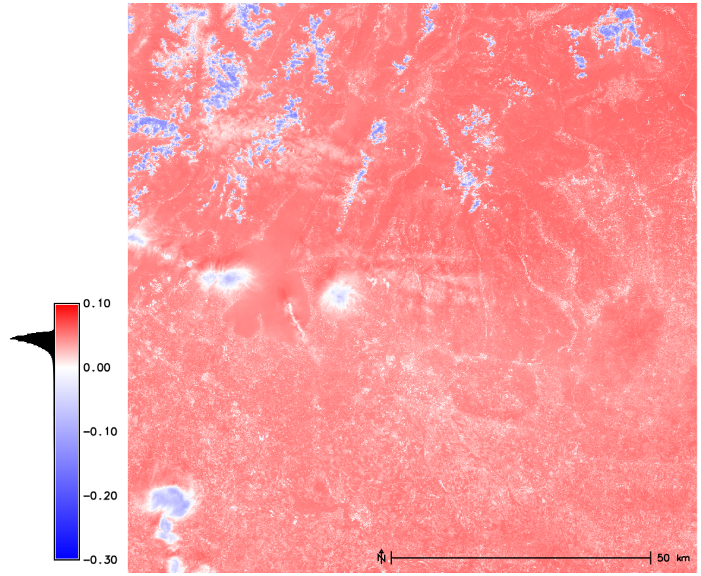
L1C - QGIS



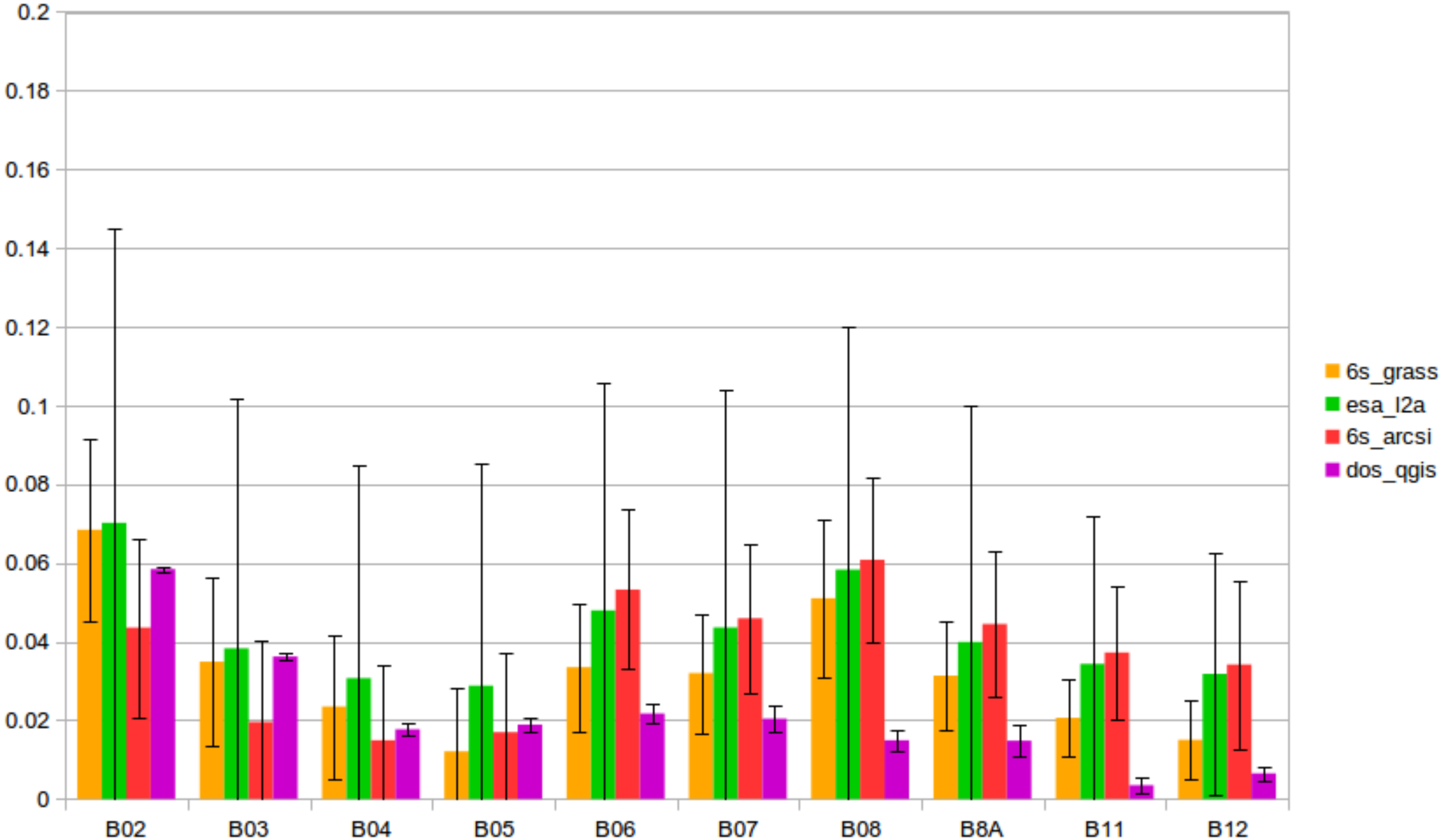
L1C - GRASS



L1C - Arcsi

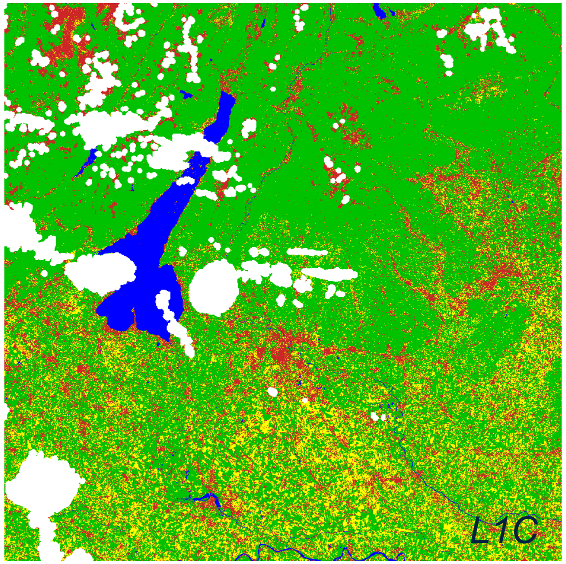


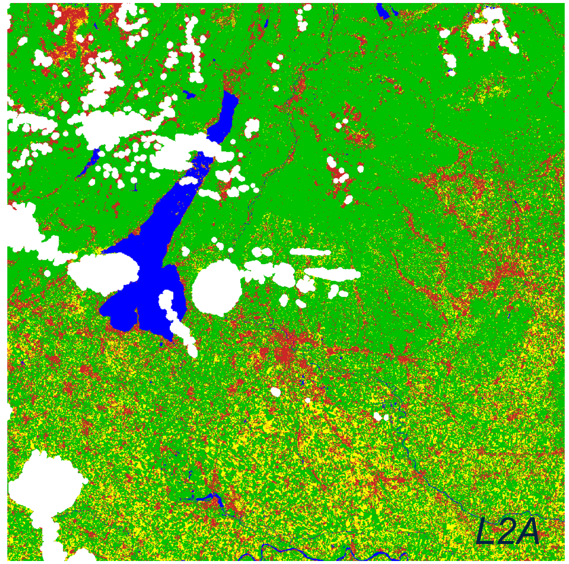
Results – Correction difference statistics for all bands



Mean and standard deviations of the correction with respect to all bands

Results – Classification Approach

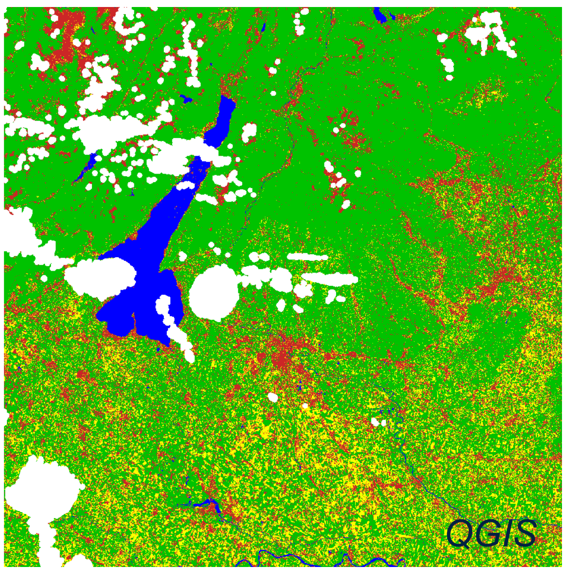


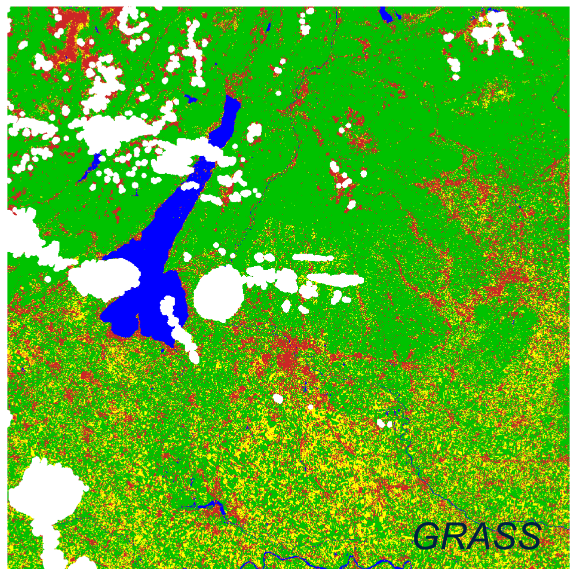


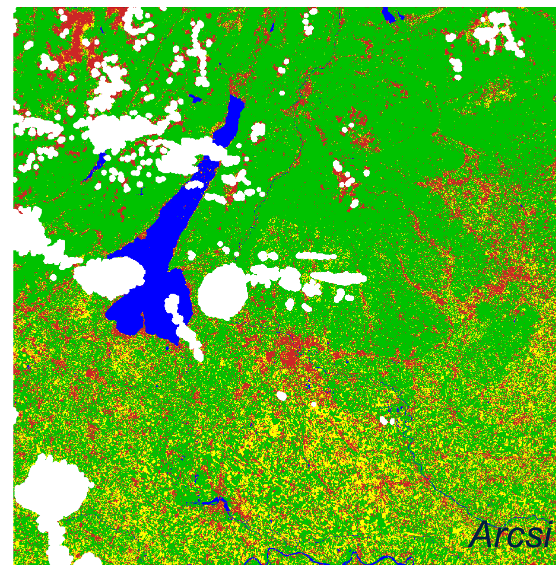
- 10 bands used (10-20 m res)
- Supervised classification
- Maximum Likelihood
- Same training areas (10 for each class)

1 water
2 vegetation
3 built-up
4 bare soil

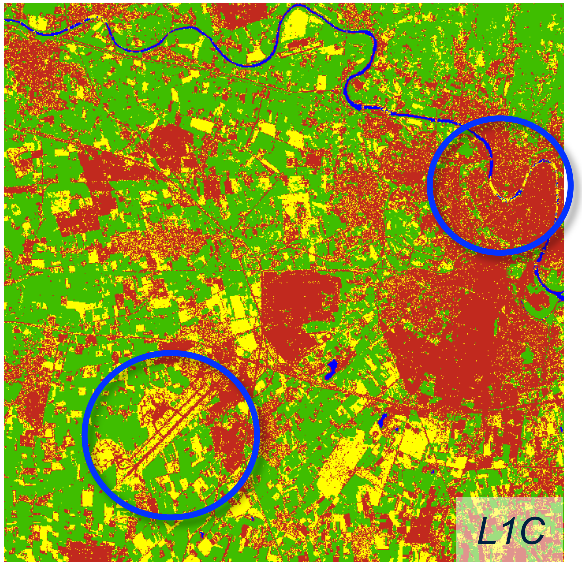
- Cloud masked using mask from L2A

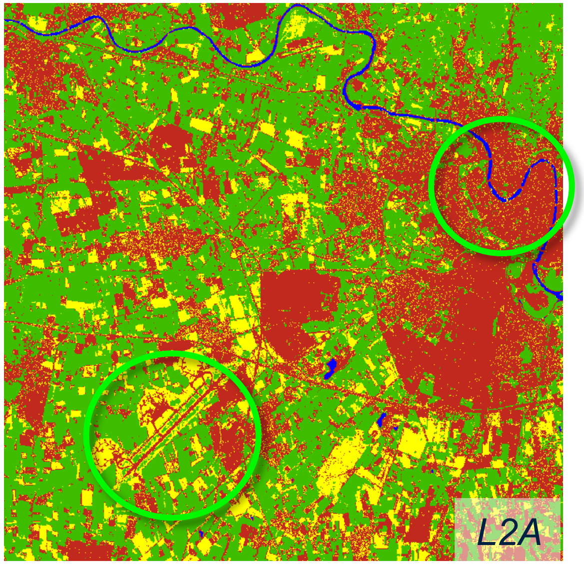






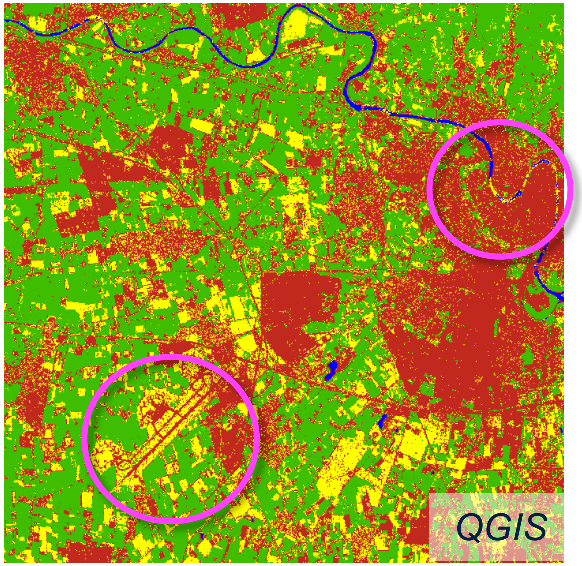
Results – Classification Approach

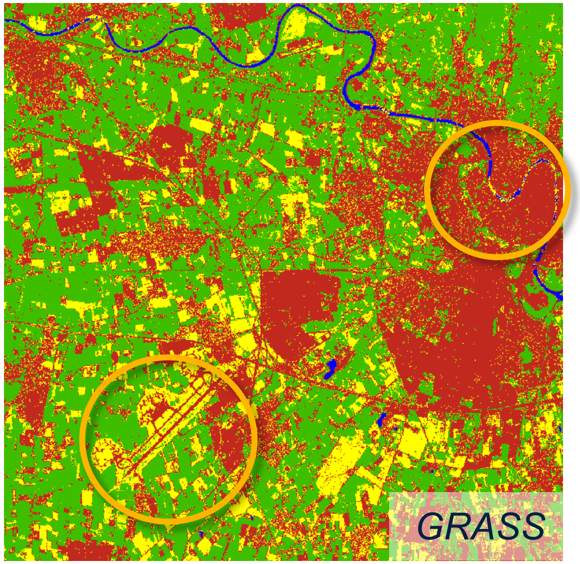


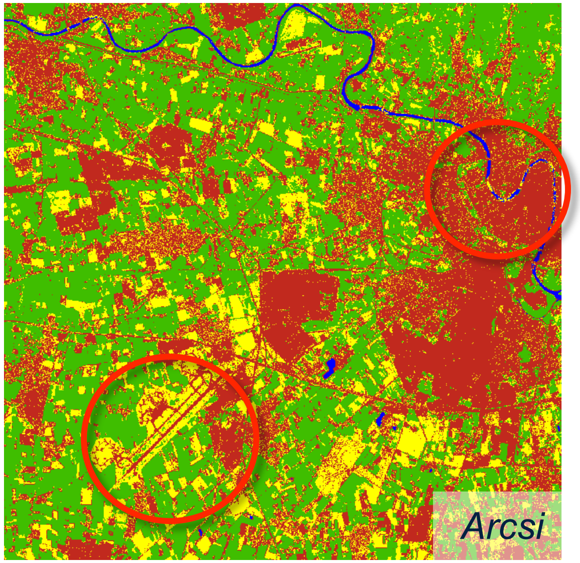


- Accuracy assessment using Kappa Analysis
- Same validation areas (10 for each class)

Both classification and accuracy assessment have been performed using GRASS GIS







Results – Classification Approach

Cats	% Commission	% Ommission	Estimated K
1	0.147080	1.543596	0.997820
2	3.101044	0.701516	0.948338
3	13.467598	21.051200	0.838454
4	24.478054	18.066702	0.725371

Kappa	Kappa Variance
0.909964	0.000001

Obs Correct	Total Obs	% Observed Correct
145097	154766	93.752504

K analysis L1C

Cats	% Commission	% Ommission	Estimated K
1	0.165523	1.746230	0.997547
2	3.519844	0.665955	0.941361
3	15.569049	15.733043	0.813247
4	17.249653	22.085488	0.806469

Kappa	Kappa Variance
0.915520	0.000001

Obs Correct	Total Obs	% Observed Correct
145710	154766	94.148586

K analysis L2A

Cats	% Commission	% Ommission	Estimated K
1	0.147094	1.553529	0.997820
2	3.017003	0.704749	0.949738
3	13.767087	17.415119	0.834862
4	20.596127	19.071399	0.768924

Kappa	Kappa Variance
0.917003	0.000001

Obs Correct	Total Obs	% Observed Correct
145857	154766	94.243568

K analysis QGIS

Cats	% Commission	% Ommission	Estimated K
1	0.146988	1.482011	0.997822
2	3.045845	0.696667	0.949258
3	14.466525	15.729159	0.826472
4	18.687023	20.842994	0.790343

Kappa	Kappa Variance
0.918610	0.000001

Obs Correct	Total Obs	% Observed Correct
146034	154766	94.357934

K analysis GRASS

Cats	% Commission	% Ommission	Estimated K
1	0.170985	1.410493	0.997466
2	3.297188	0.682119	0.945071
3	13.871257	17.772512	0.833612
4	20.892615	20.337673	0.765597

Kappa	Kappa Variance
0.914906	0.000001

Obs Correct	Total Obs	% Observed Correct
145638	154766	94.102064

K analysis Arcsi

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for your attention!