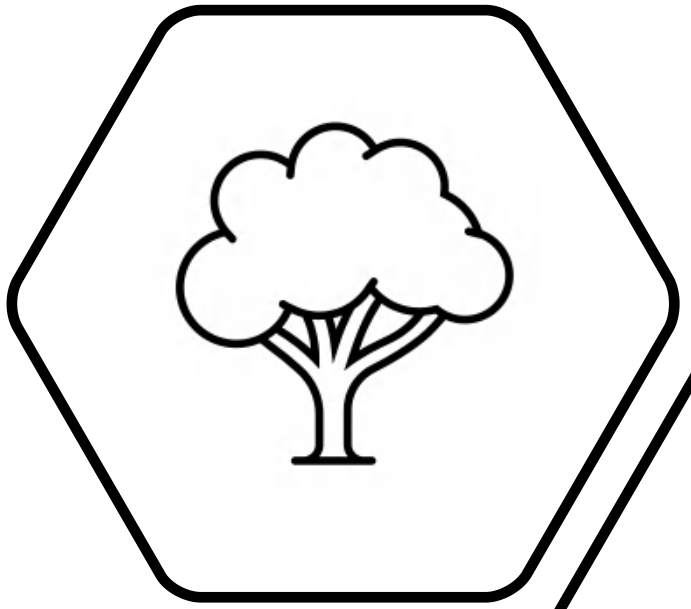
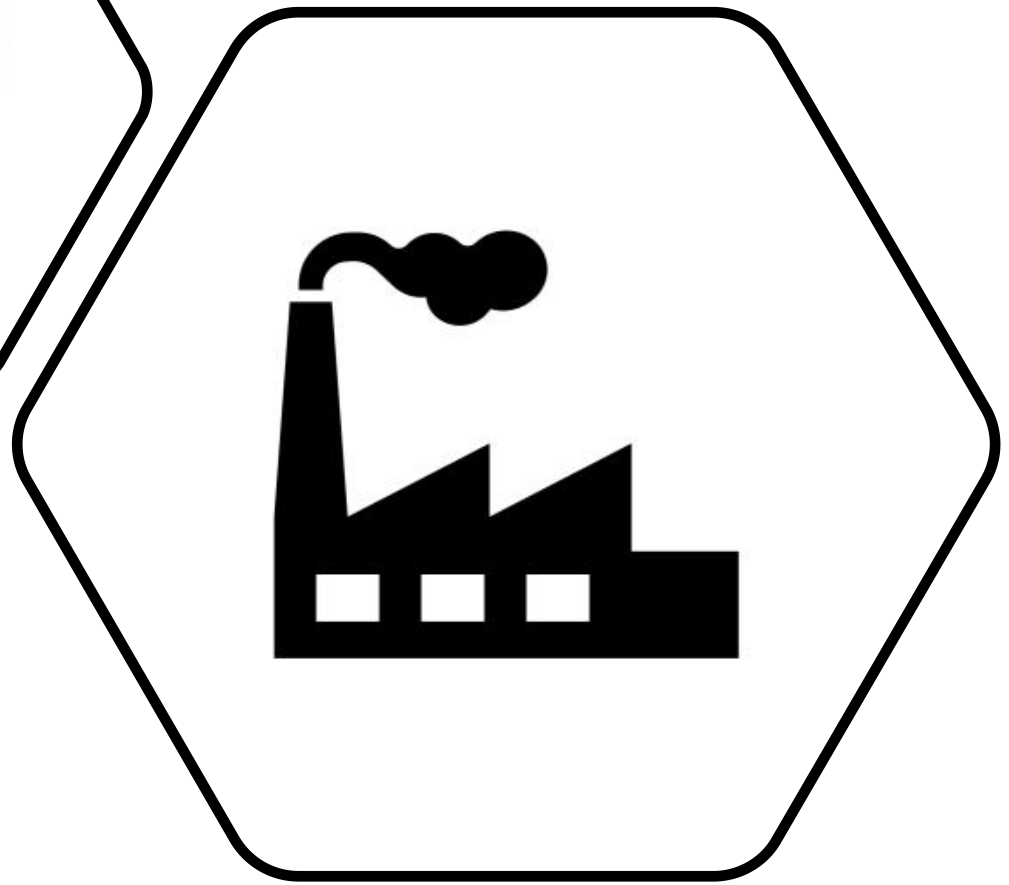
Plants versus CO_2

Does the vegetation of a specific region suffice to compensate the CO_2 emissions of this exact region?

Seminar: GIS Analyses using FOSSGIS
Lecturer: Christina Ludwig
Presented by: Niko Kolaxidis & Tobias Romes
University of Heidelberg

Introduction





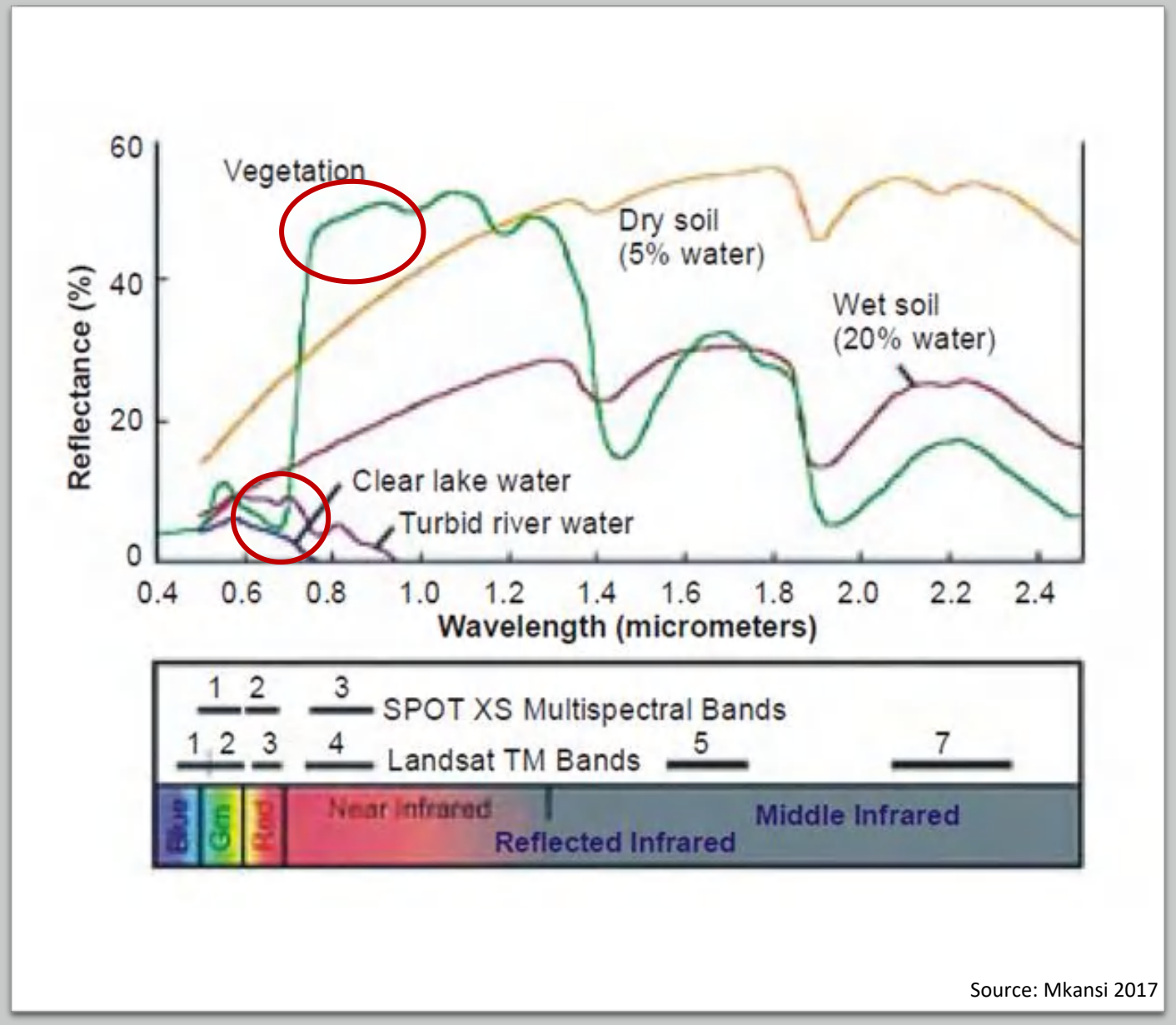
Does the vegetation of a specific region suffice to compensate the CO_2 emissions of this exact region?

1. Classification of the region: vegetated areas vs. non-vegetated areas
2. Calculation of CO_2 sequestration ability in considered area
3. Comparison of CO_2 emissions and sequestration ability

NDVI

- **N**ormalized **D**ifference **V**egetation **I**ndex
- Unique spectral reflection of vegetation
- Calculate photosynthetic activity, vitality and density through formula:

$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{Red})}{(\mathrm{NIR} + \mathrm{Red})}$$

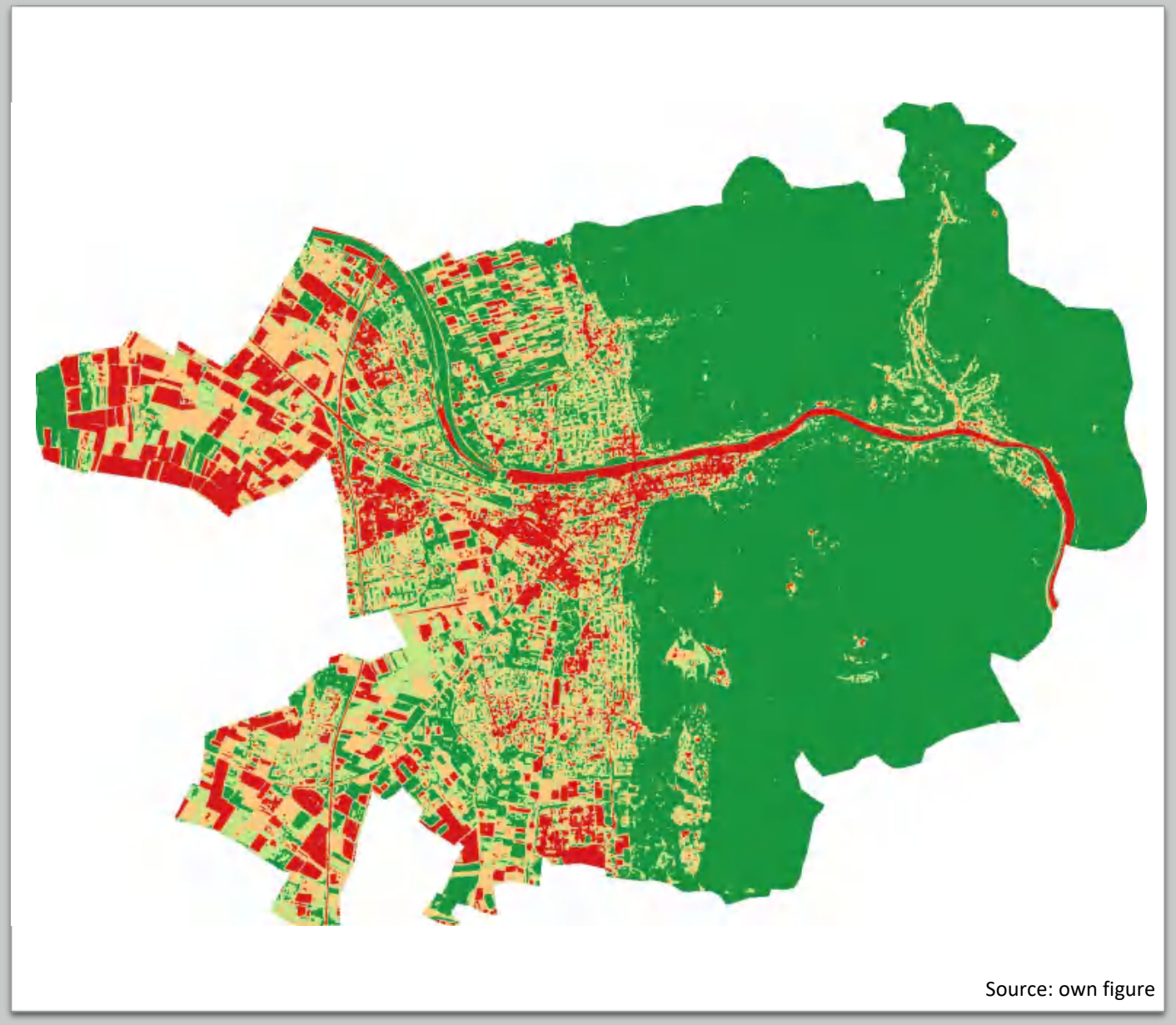


Source: Mkansi 2017

NDVI

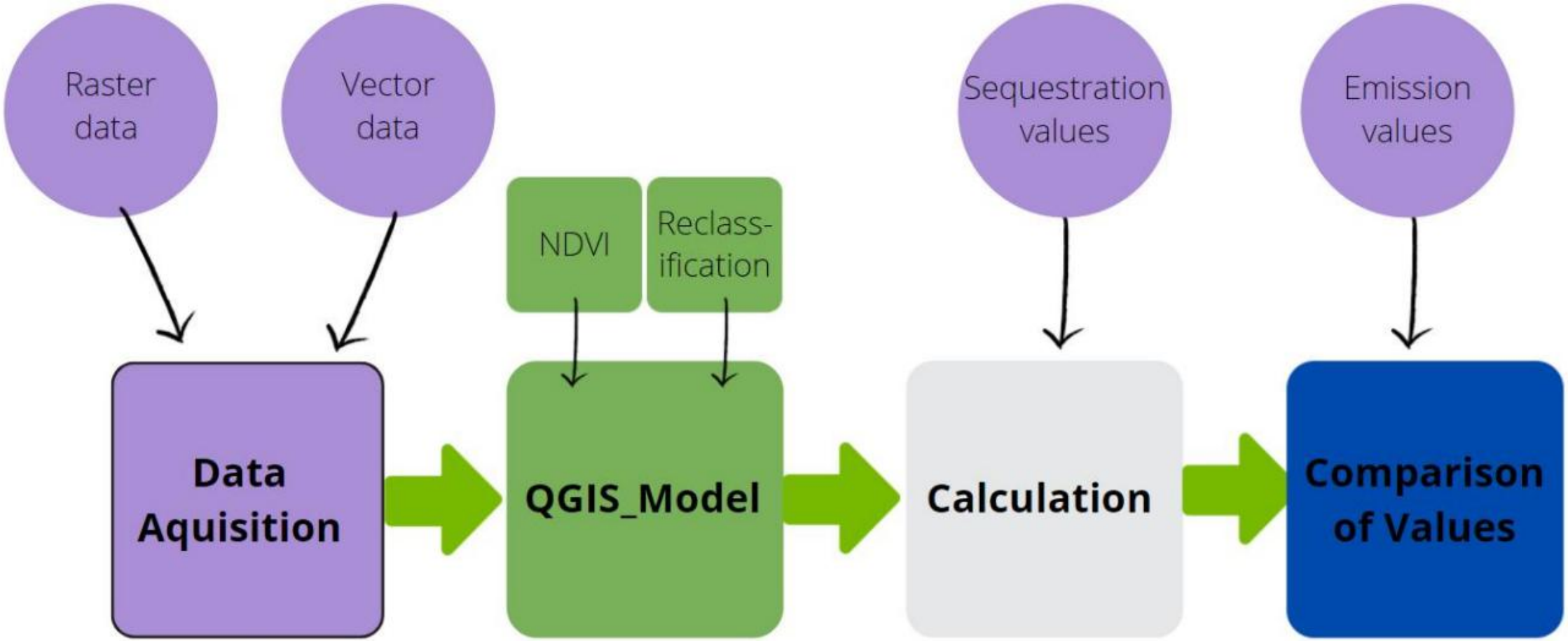
$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{Red})}{(\mathrm{NIR} + \mathrm{Red})}$$

Areas	Value
No Vegetation	-1 – 0.2
Low level of vegetation (shrub/grass)	0.2 - 0.4
Medium level of vegetation (crops)	0.4 - 0.6
High level of vegetation (forest)	0.6 - 1



Source: own figure

Workflow


Raster data
Vector data
NDVI
Reclass-ification
Sequestration values
Emission values
Data Aquisition
QGIS_Model
Calculation
Comparison of Values

Requirements

Data:

- Multispectral raster data
- Vector data (city outlines)
- CO_2 emission data
- Annual amount of CO_2 fixed by vegetation

Software:

- NDVI calculation tool
- Classification tool
- Spreadsheet (Excel)

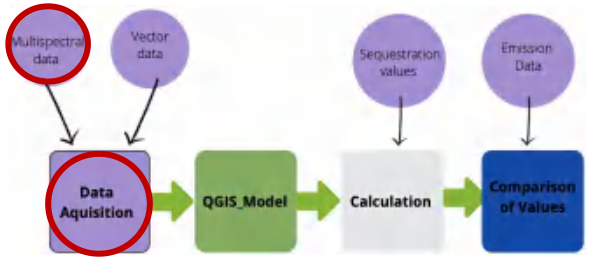
$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

Raster data from Sentinel 2

Source: Copernicus.eu

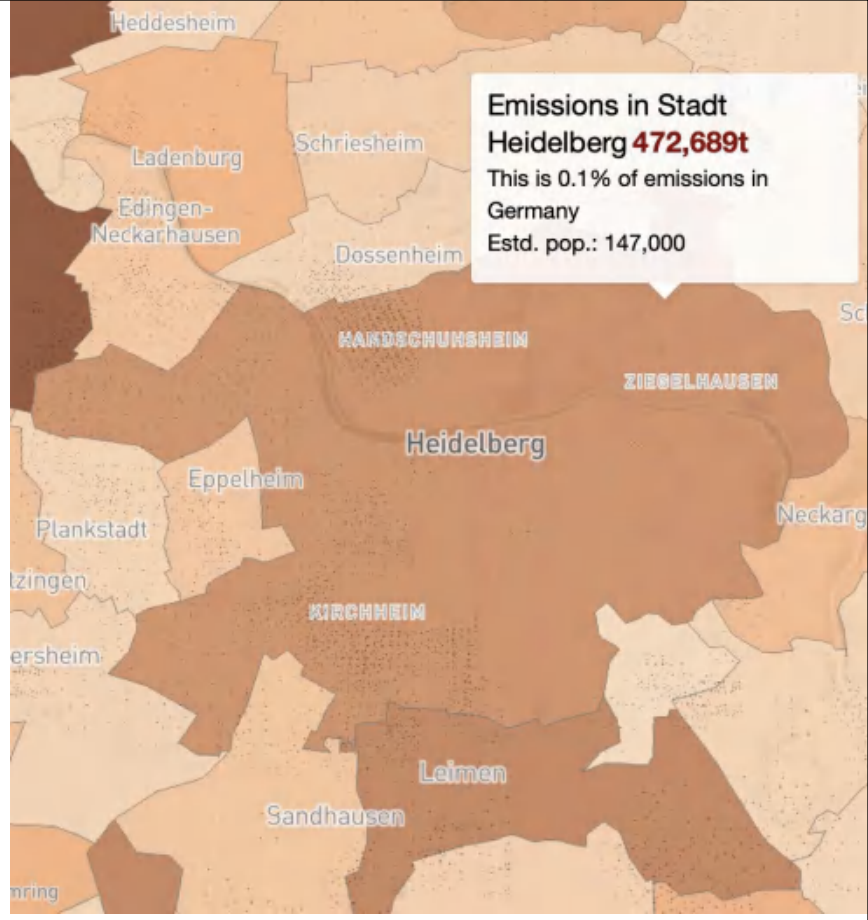
	Spectral Band	Centre Wavelength (nm)	Band Width (nm)	Spatial Resolution (nm)
B1	Coastal aerosol	443	20	60
B2	Blue (B)	490	65	10
B3	Green (G) [1]	560	35	10
B4	Red (R) [1]	665	30	10
B5	Red-edge 1 (Re1) [1]	705	15	20
B6	Red-edge 2 (Re2) [1]	740	15	20
B7	Red-edge 3 (Re3) [1]	783	20	20
B8	Near infrared (NIR) [1]	842	115	10
B8a	Near infrared narrow (NIRn) [1]	865	20	20
B9	Water vapor	945	20	60
B10	Shortwave infrared/Cirrus	1380	30	60
B11	Shortwave infrared 1 (SWIR1)	1910	90	20
B12	Shortwave infrared 2 (SWIR2)	2190	180	20

Source: Zheng et. al (2018)



CO_2 emission data

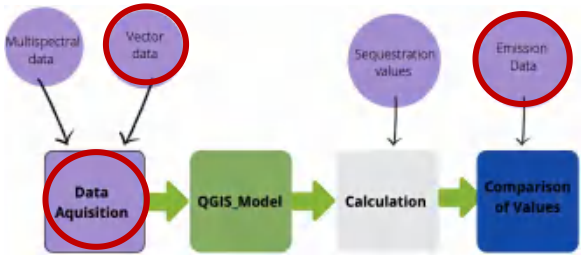
- OpenGHGmap.net
- Available free for Europe
- Output: one value (e.g. Heidelberg: **472,689 t CO_2/year**)
- Administrative level up to small towns
- Con: Data only for year 2018



Source: OpenGHGMap.net

Vector data

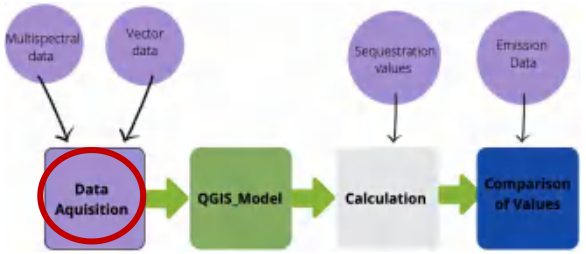
- gadm.org
- Vector data available for whole world
- Administrative level up to small towns
- Current data
- Output: Geopackage or shapefile



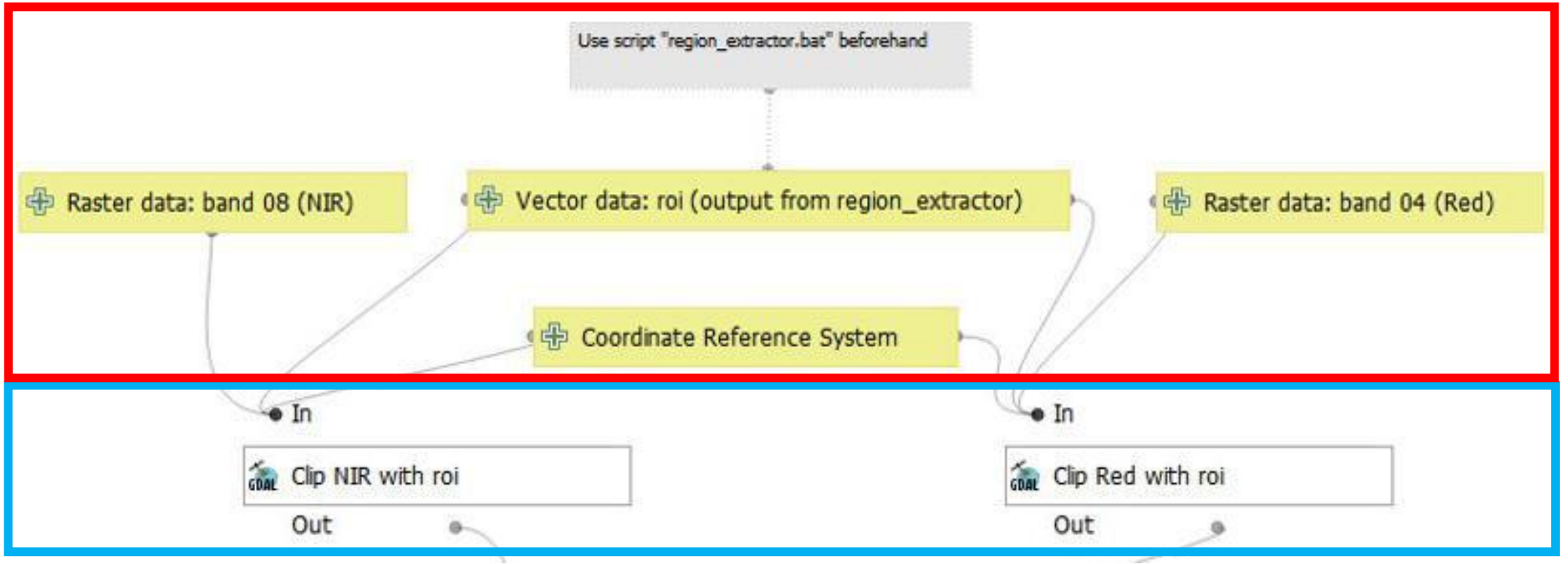
Extracting the region of interest (roi)

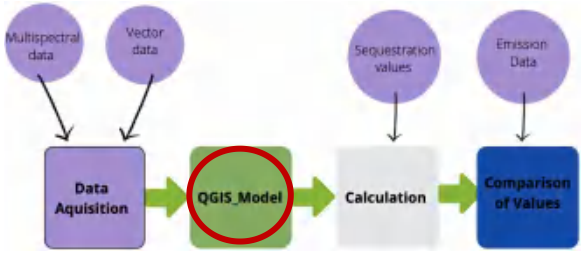

```
echo Enter the region of interest (roi):
set /p roi= e.g. Heidelberg
```

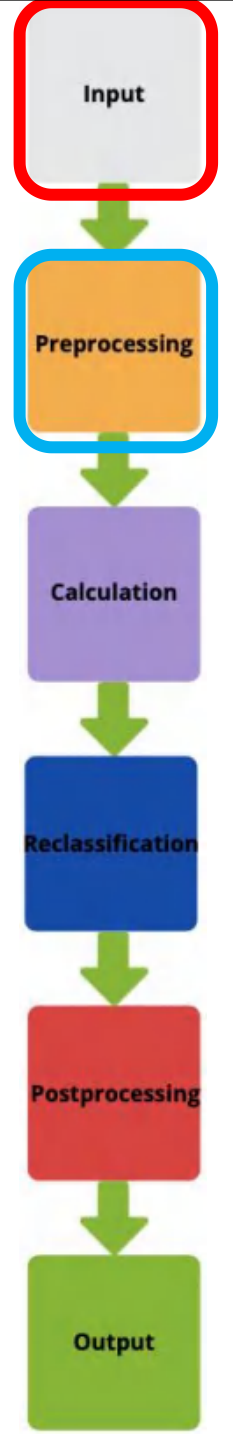
```
ogr2ogr -f "ESRI Shapefile"  ./data/Heidelberg.shp  -lco ENCODING=UTF-8 -t_srs EPSG:25832
-sql "SELECT * FROM gadm36_DEU_3 WHERE NAME_3= 'Heidelberg' " ./data/gadm36_DEU.gpkg
```



Automation: QGIS model







Comparison: Raster Calculator

Raster Calculator: QGIS

\+ fast (2 sec for Heidelberg)

\+ easy to use

-- needs to output into a file, therefore difficult to implement into Graphic Modeler

O slightly less values (pixels) → ?

Raster Calculator: SAGA

\- slow (40 sec for Heidelberg)

\+ easy to use

++ easy to implement into Graphic Modeler

O slightly more values (pixels) → different values

Comparison: Raster Calculator

Calculated with values from QGIS

Total area of specified classes of your roi	
HERE (m²)	ha (m² / 10.000)
2400,234122	0,240
14610025,08	1.461,00
15451907,2	1.545,19
13378804,98	1.337,88
65599798,68	6.559,98

Emission value (t CO2 / year)		
472.689		
Total sequestation ability of roi (t CO2 / year)		
min	mean	max
52.933,98	100.202,64	147.471,30
Balance (emission ↔ sequestation)		
419.755,02	372.486,36	325.217,70

Total: 10.904,29 ha

Source: own figure

Calculated with values from SAGA

Total area of specified classes of your roi	
HERE (m²)	ha (m² / 10.000)
2498,660627	0,250
13313463,5	1.331,35
16442386,28	1.644,24
15054130,44	1.505,41
65215542,08	6.521,55

Emission value (t CO2 / year)		
472.689		
Total sequestation ability of roi (t CO2 / year)		
min	mean	max
53.616,05	102.291,46	150.966,87
Balance (emission ↔ sequestation)		
419.072,95	370.397,54	321.722,13

Total: 11.002,29 ha

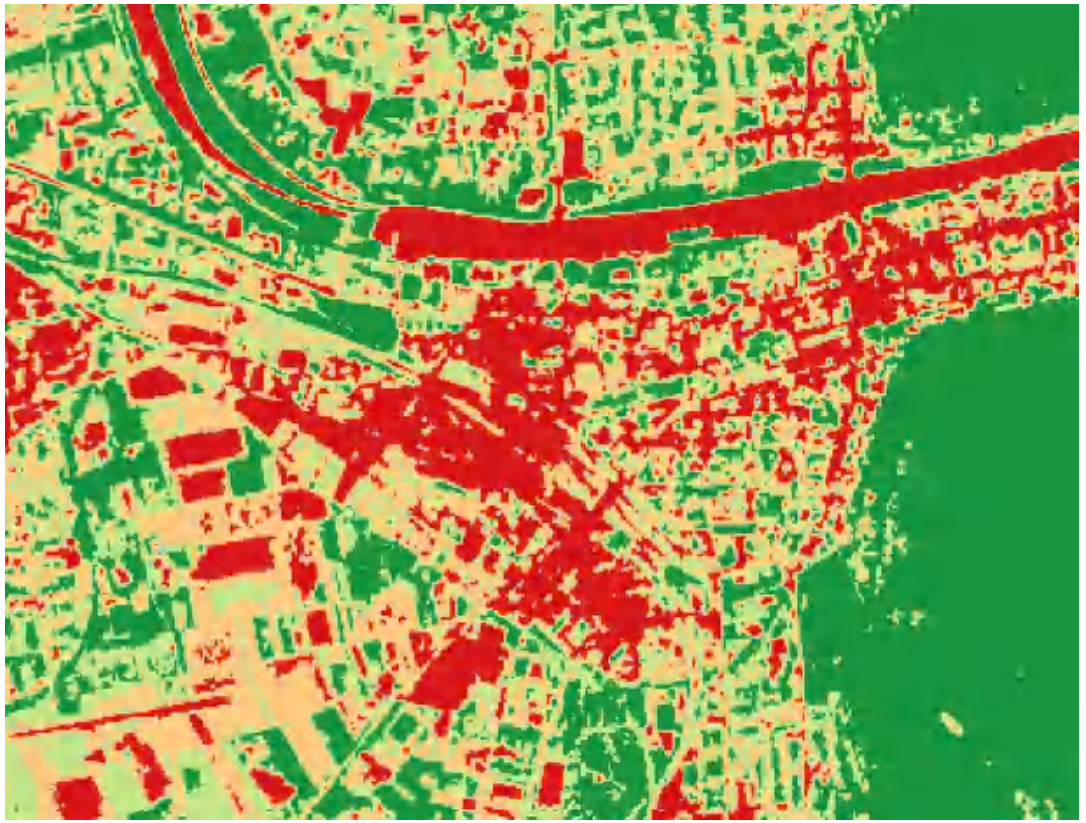
Source: own figure

Comparison: Raster Calculator

NDVI calculated with QGIS

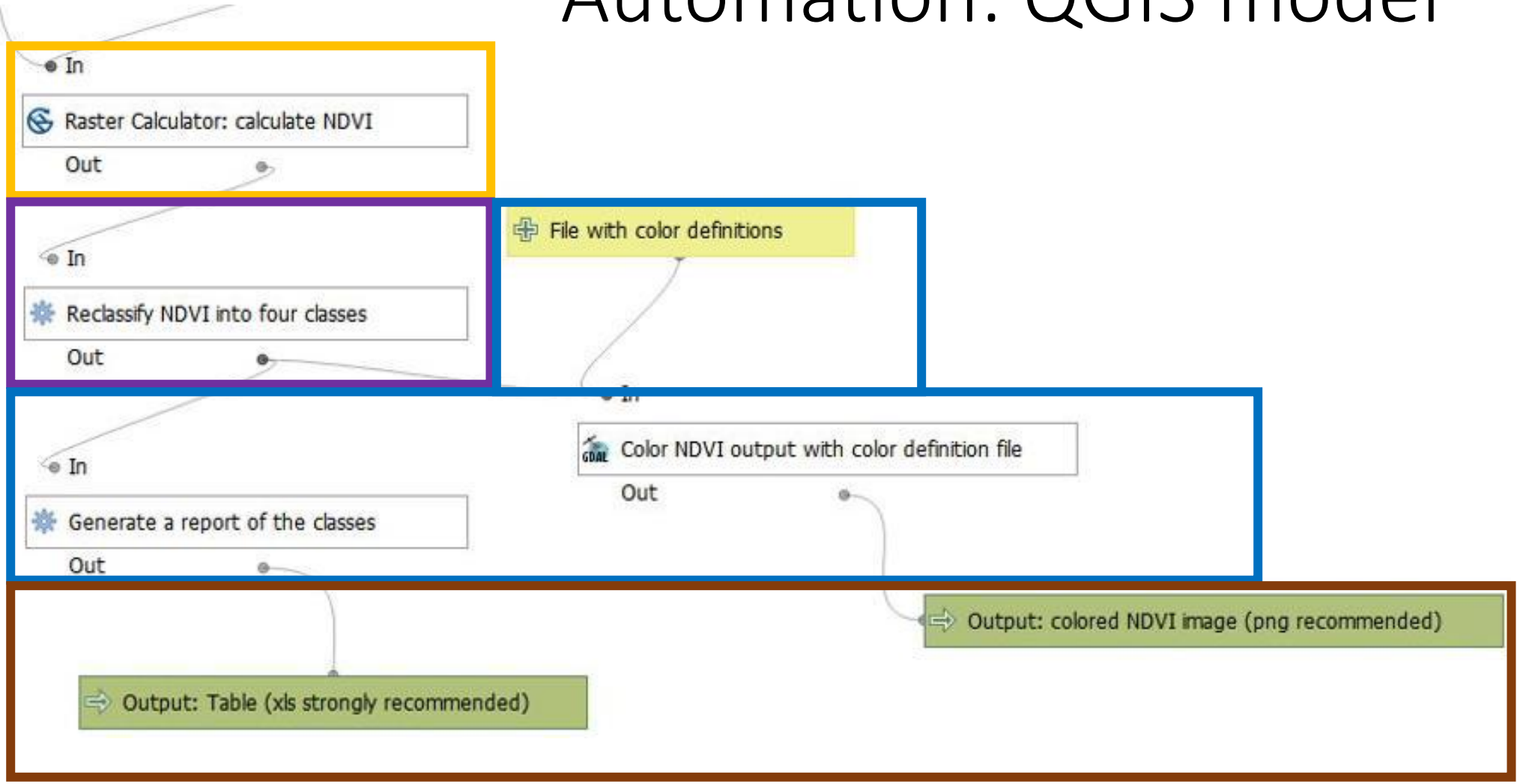
Source: own figure

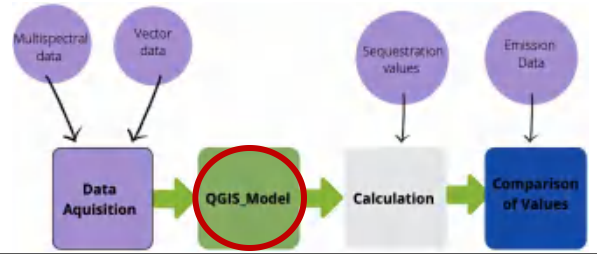
NDVI calculated with SAGA

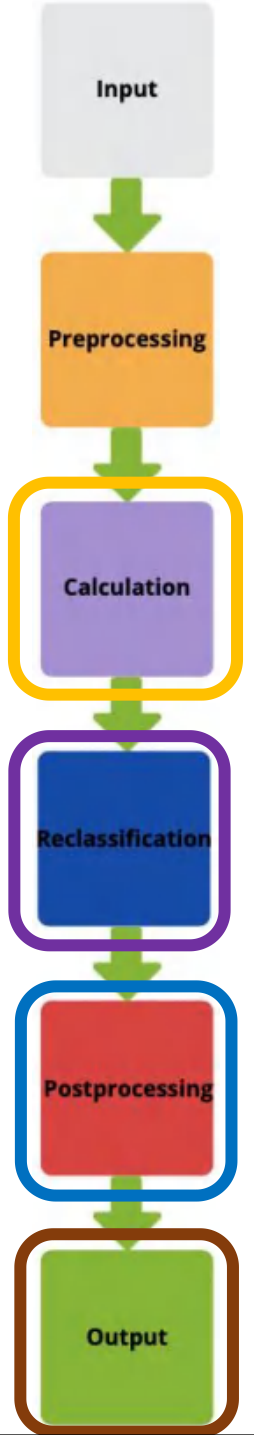


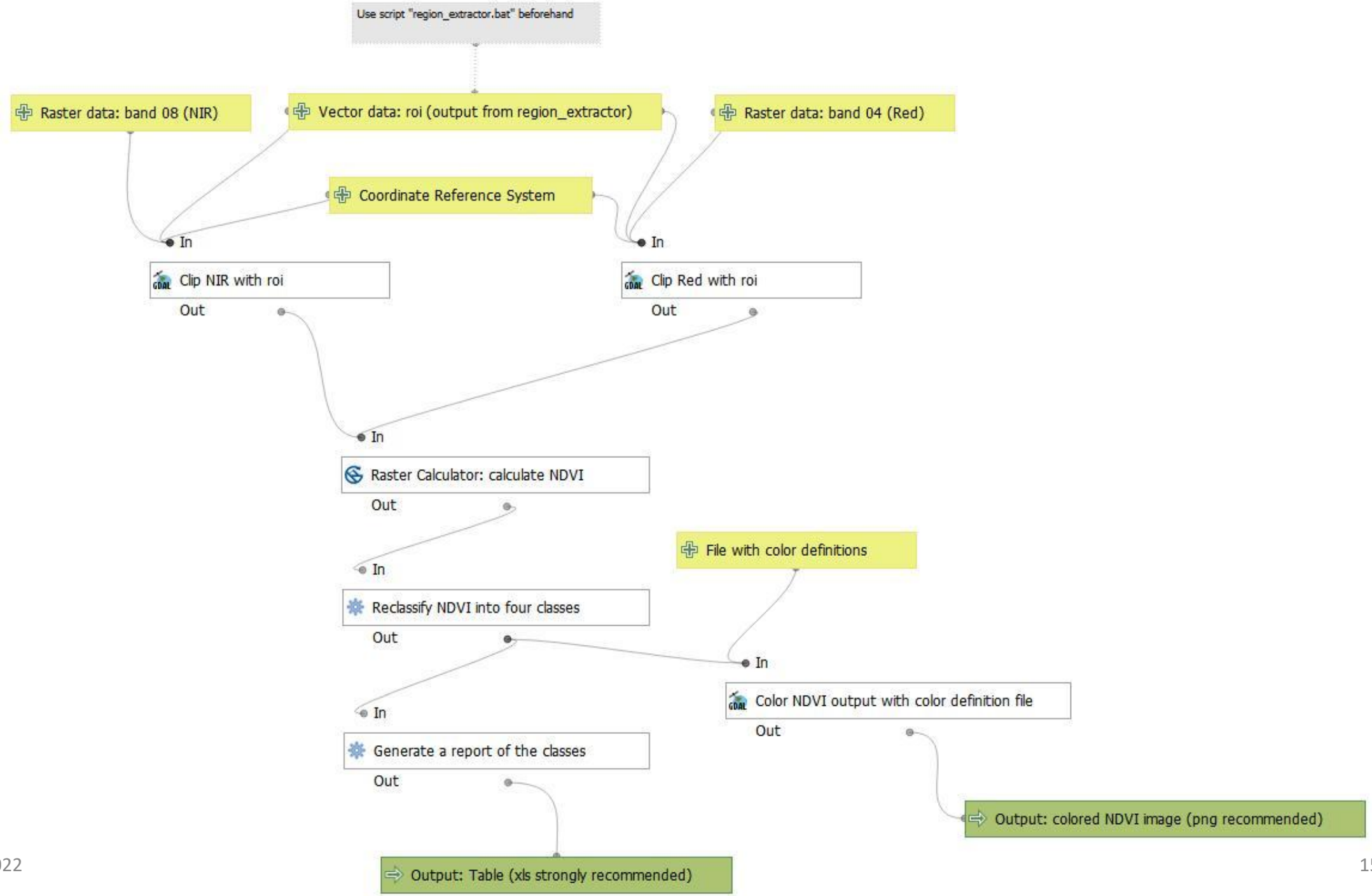
Source: own figure

Automation: QGIS model








Use script "region_extractor.bat" beforehand
Raster data: band 08 (NIR)
Vector data: roi (output from region_extractor)
Raster data: band 04 (Red)
Coordinate Reference System
In
In
Clip NIR with roi
Clip Red with roi
Out
Out
In
Raster Calculator: calculate NDVI
Out
In
File with color definitions
Reclassify NDVI into four classes
Out
In
Color NDVI output with color definition file
Out
In
Generate a report of the classes
Out
Output: colored NDVI image (png recommended)
Output: Table (xls strongly recommended)

Calculations in Excel

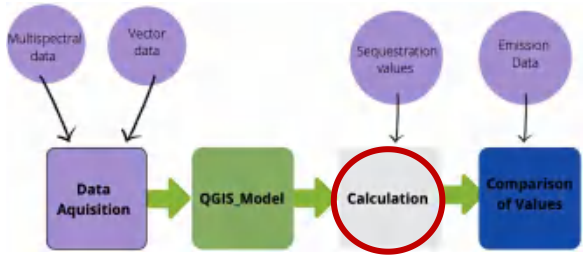
		Total area of specified classes of your roi		Sequestration ability (t CO2 / ha / year)			Total sequestration ability (t CO2 / year)		
Class	Level of vegetation	HERE (m²)	ha (m² / 10.000)	min	mean	max	min	mean	max
-1	No data value (ignore)		0,000	/	/	/	/	/	/
1	no vegetation (-1 - 0.2)		0,00	0,00	1,00	2,00	0,00	0,00	0,00
2	shrub/grass (0.2 - 0.4)		0,00	3,50	6,00	8,50	0,00	0,00	0,00
3	crops (0.4 - 0.6)		0,00	3,50	12,25	21,00	0,00	0,00	0,00
4	forest (0.6 - 1)		0,00	6,53	11,14	15,75	0,00	0,00	0,00

Emission value (t CO2 / year)		
Total sequestration ability of roi (t CO2 / year)		
min	mean	max
0,00	0,00	0,00
Balance (emission ↔ sequestration)		
0,00	0,00	0,00

*Green means the vegetation **is able to compensate** all CO2 emissions of your roi.*

*Red means the vegetation **does not compensate** all CO2 emissions of your roi.*

Source: own figure



Results

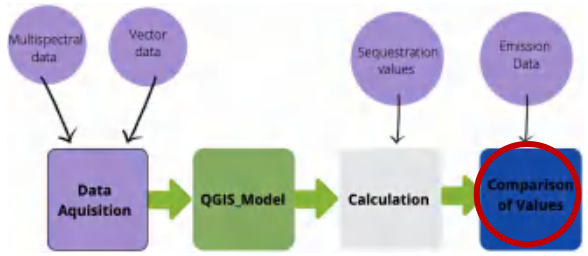
Class	Level of vegetation	Total area of specified classes of your roi		Sequestration ability (t CO2 / ha / year)			Total sequestration ability (t CO2 / year)		
		HERE (m^2)	ha (m^2 / 10.000)	min	mean	max	min	mean	max
-1	No data value (ignore)	2498,660627	0,250	/	/	/	/	/	/
1	no vegetation (-1 - 0.2)	13313463,5	1.331,35	0,00	1,00	2,00	0,00	1.331,35	2.662,69
2	shrub/grass (0.2 - 0.4)	16442386,28	1.644,24	3,50	6,00	8,50	5.754,84	9.865,43	13.976,03
3	crops (0.4 - 0.6)	15054130,44	1.505,41	3,50	12,25	21,00	5.268,95	18.441,3	26.913,7
4	forest (0.6 - 1)	65215542,08	6.521,55	6,53	11,14	15,75	42.592,27	72.653,3	102.714,48

Emission value (t CO2 / year)		
472.689		
Total sequestration ability of roi (t CO2 / year)		
min	mean	max
53.616,05	102.291,46	150.966,87
Balance (emission ↔ sequestration)		
419.072,95	370.397,54	321.722,13

Green means the vegetation ***is able to compensate*** *all CO2 emissions of your roi.*

Red means the vegetation ***does not compensate*** *all CO2 emissions of your roi.*

Source: own figure



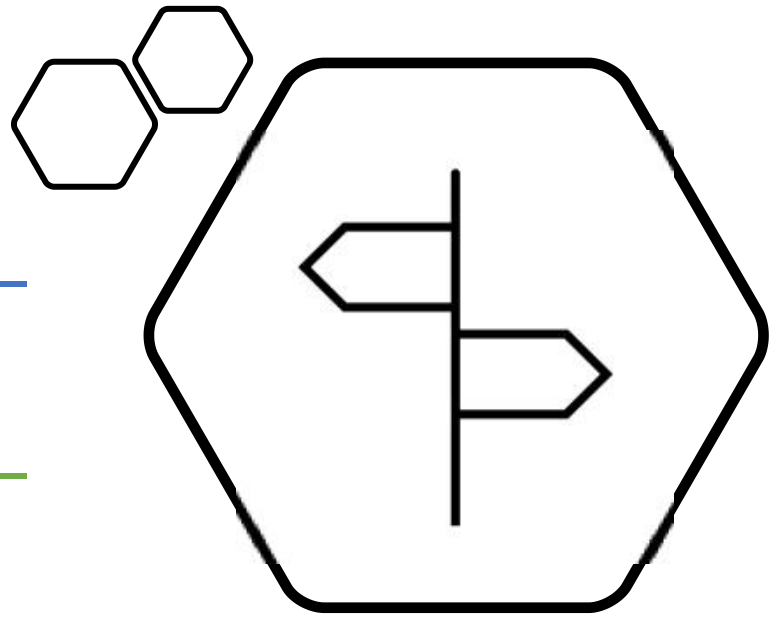
Discussion: problems/limitations

- All values are estimated and not to be taken as scientifically proven
- Data for sequestration not adequate for empirical statements – difficult to aquire data in the first place
- No up-to-date data for CO_2 emissions (other sources needed)

BUT:

- Model is applicable with other data → more accurate data leads to better results
- Good tool for getting a first impression of the imbalance between emission and sequestration in a city's extent

Outlook



- Further compare the Raster Calculators (other GIS?)
- Look for better data sources for sequestration and emission
- Implement of roi_extractor.bat into the QGIS model
- Automatically import results from model into the Excelsheet
- Repository is finished, just needs updating if new implementations work

List of sources

- Candiago, S. & Remondino, F. & De Giglio, M. & Dubbini. M. & Gattelli, M. (2015): Evaluating Multispectral Images and Vegetation Indices for Precision Farming Applications from UAV Images. - In: Remote Sensing, 7, pp. 4026 - 4047.
- Deutsches Zentrum für Luft- und Raumfahrt e.V. (2022): Die Sentinel-Satellitenfamilie. - URL: https://www.d-copernicus.de/daten/satelliten/daten-sentinels/ [as of: 30.01.2022].
- Matese, A. & Di Gennaro, S.F. (2018): Practical Applications of a Multisensor UAV Platform Based on Multispectral, Thermal and RGB High Resolution Images in Precision Viticulture. - In: Agriculture, 8(7):166.
- Mkansi, R. (2017): Spectral reflectance of soil, vegetation and water. - URL https://mkansireminder.wordpress.com/2017/04/24/spectral-reflectance-of-soil-vegetation-water/ [as of: 30.01.2022].
- Norwegian University of Science and Technology (2018): OpenGHGmap. - URL: https://openghgmap.net/#Heidelberg,%20Baden-Württemberg,%20Deutschland [as of: 30.01.2022].
- Zheng, Q. & Huang, W. & Cui, X. & Shi, Y. & Liu, L. (2018): New Spectral Index for Detecting Wheat Yellow Rust Using Sentinel-2 Multispectral Imagery. - In: Sensors, 18, p. 868.

Thank you very much for your attention!