Dataset	EPSG	Source
MOD17A3_Science_NPP_2015.tif	4326	https://www.ntsg.umt.edu/project/modis/mod17.php under Key Datasets → The MOD17 dataset
2500_NUTS1.shp	31467 (GK3), but can also be one of the other EPSG	https://gdz.bkg.bund.de/index.php/default/nuts-gebiete-1-2-500-000-stand-01-01-nuts2500.html
VG250_GEM.shp	25832 (UTM32s)	https://gdz.bkg.bund.de/index.php/default/verwaltungsgebiete-1-250-000-ebenen-stand-01-01-vg250-ebenen-01-01.html

A. Reduce raw data to Schleswig-Holstein:

1 Prepare raw data

1.1 New QGIS project with EPSG 4326

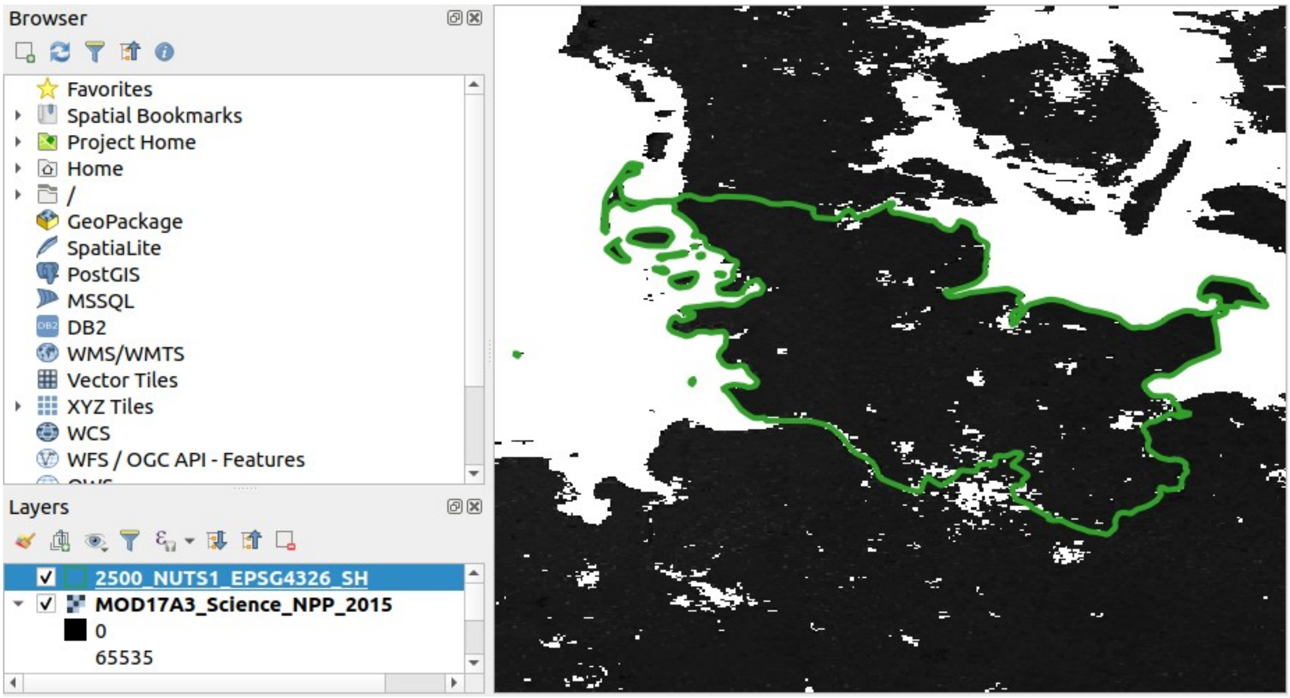
1.2 Load *MOD17A3_Science_NPP_2015*.tif

1.3 Load *2500_NUTS1*.shp

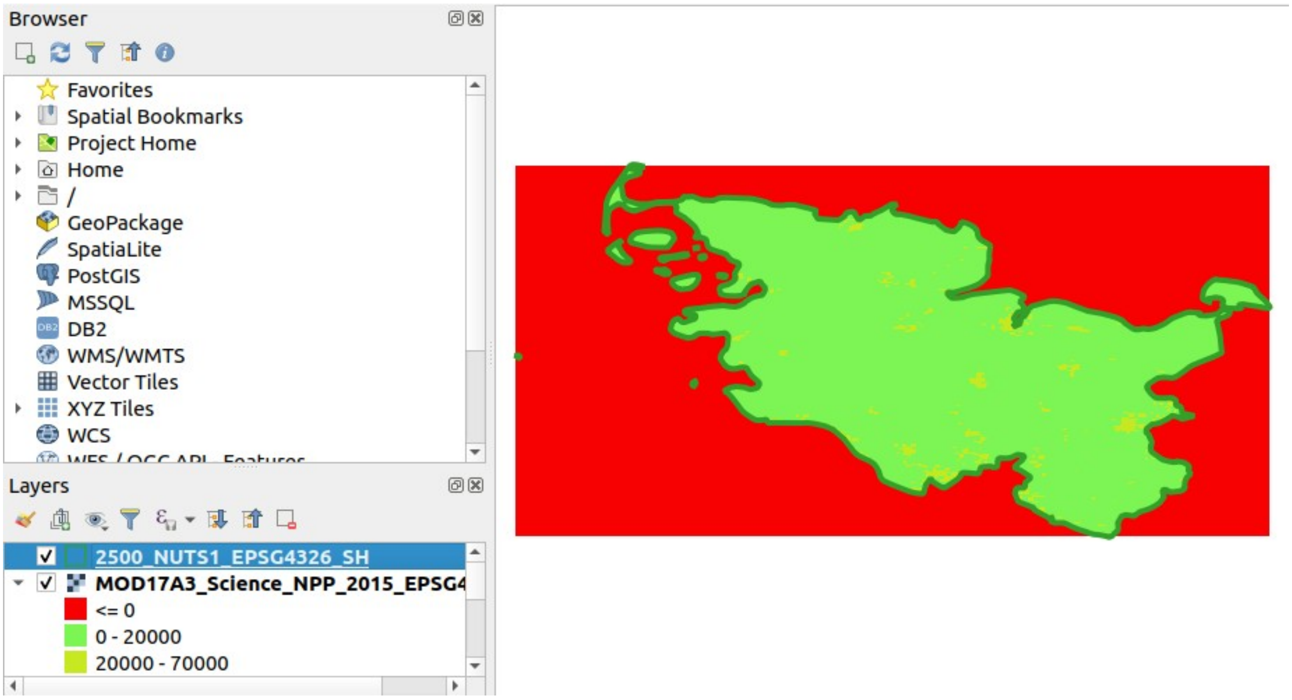
1.4 Vector general → Reproject *2500_NUTS1* to project EPSG. Output: *2500_NUTS1_EPSG4326*.shp

2. Clip out Schleswig-Holstein

2.1 Open attribute table of *2500_NUTS1_EPSG4326*. Select Schleswig-Holstein. Vector general → Extract selected features. Output: *2500_NUTS1_EPSG4326_SH*.shp



2.2 GDAL → Clip Raster by mask layer. Input layer: *MOD17A3_Science_NPP_2015*, mask layer: *2500_NUTS1_EPSG4326_SH*. Output: *MOD17A3_Science_NPP_2015_EPSG4326_SH*

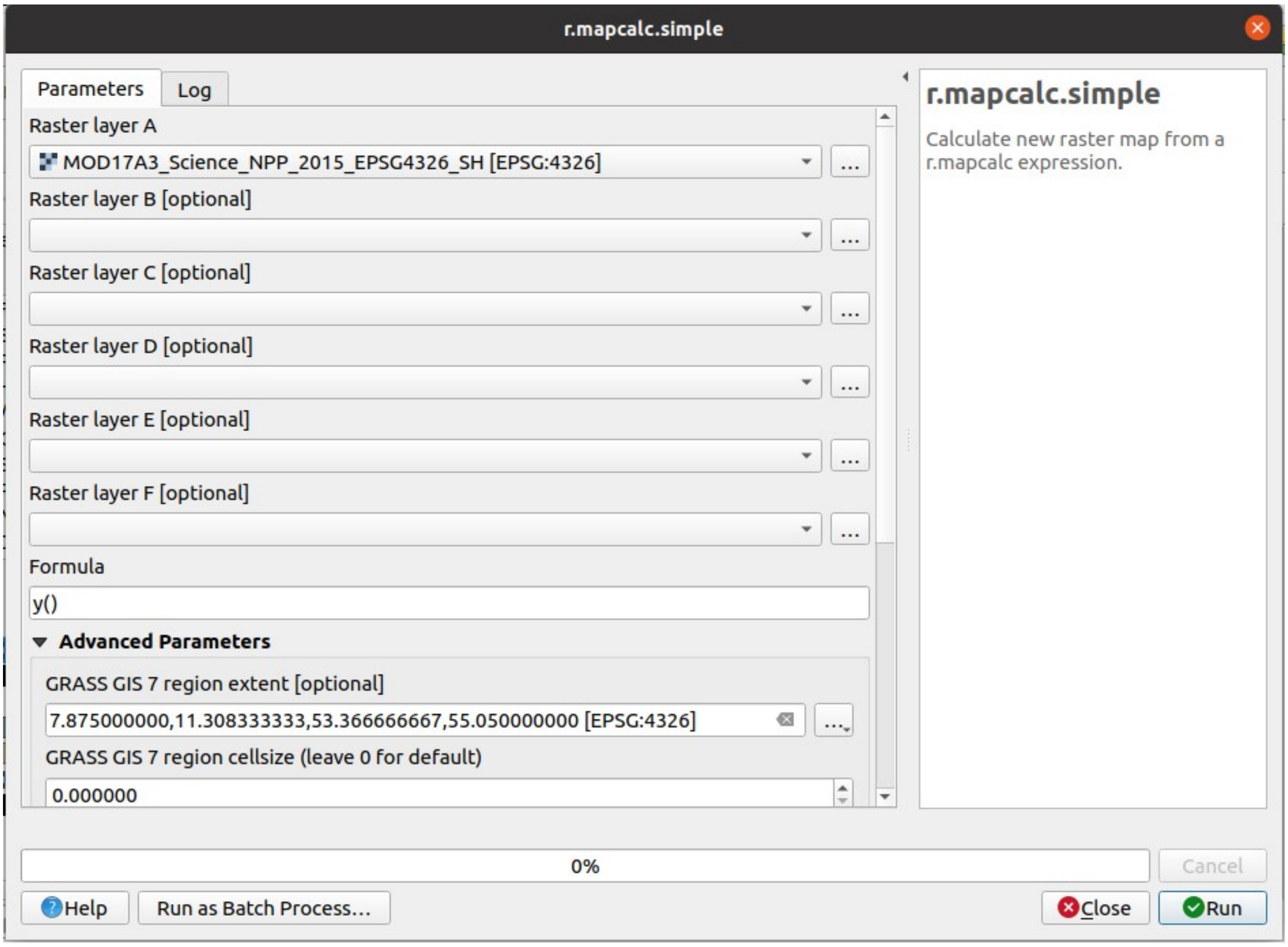


3. Calculate the size of each raster tile

Although it is stated that MOD17A3_Science_NPP_2015.tif consists of 1km^2 large pixels, the pixels are not uniform in size. The size of the pixels varies with latitude. We found the formula to calculate the size of a pixel in https://gis.stackexchange.com/questions/107395/multiplying-raster-value-with-pixel-size-using-qgis

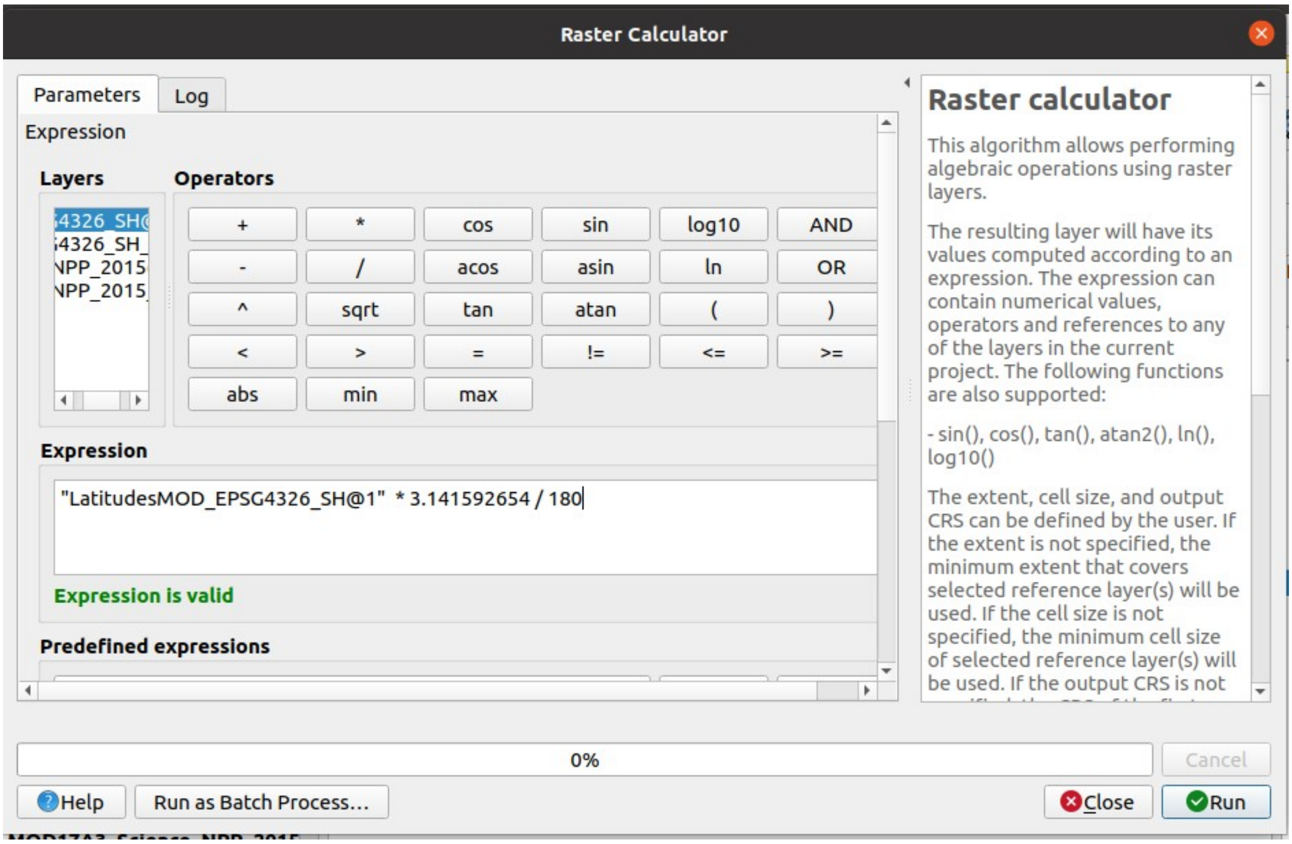
> To an excellent approximation, the area of each cell is 0.8534 * cos(latitude) square kilometers. (0.8534 = (0.0083 * 111.300)^2.) This formula leads to a fast, efficient, direct solution. For details, see our thread about converting back from square meters to square degrees. For a slightly more accurate formula see gis.stackexchange.com/a/29743/664 -- which answers essentially the same question as this. – whuber Jul 17 '14 at 15:08

3.1 We create a raster layer where each pixels value is its latitude. GRASS → Raster → r.mapcalc.simple, see Screenshot, y() gives the latitude, region extent is the Input layer. Output: LatitudesMOD_EPSG4326_SH

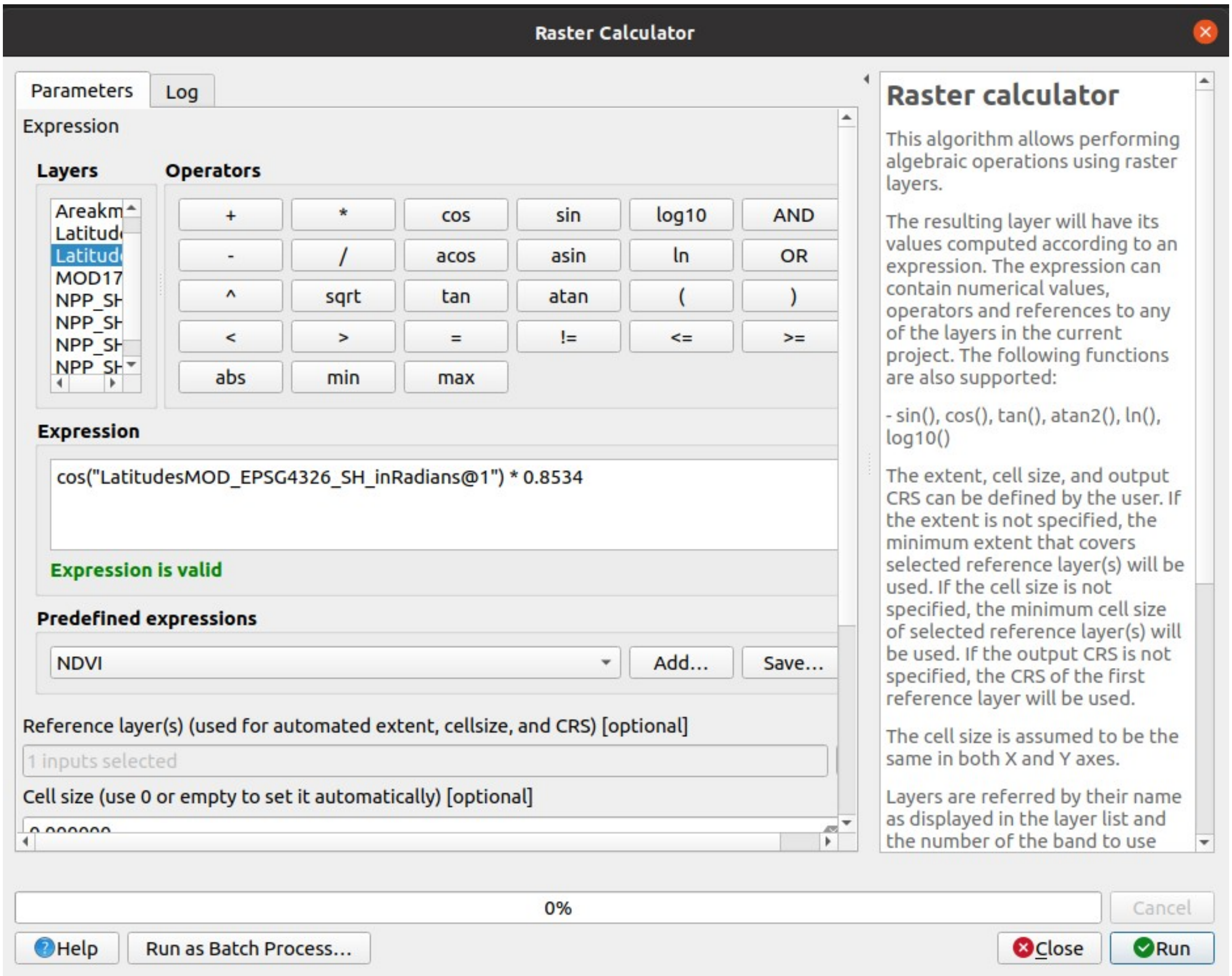


The latitude in QGIS is measured in degrees, we need to convert it to radiens as shown here: https://www.schlauerlernen.de/radiant-grad-winkel/

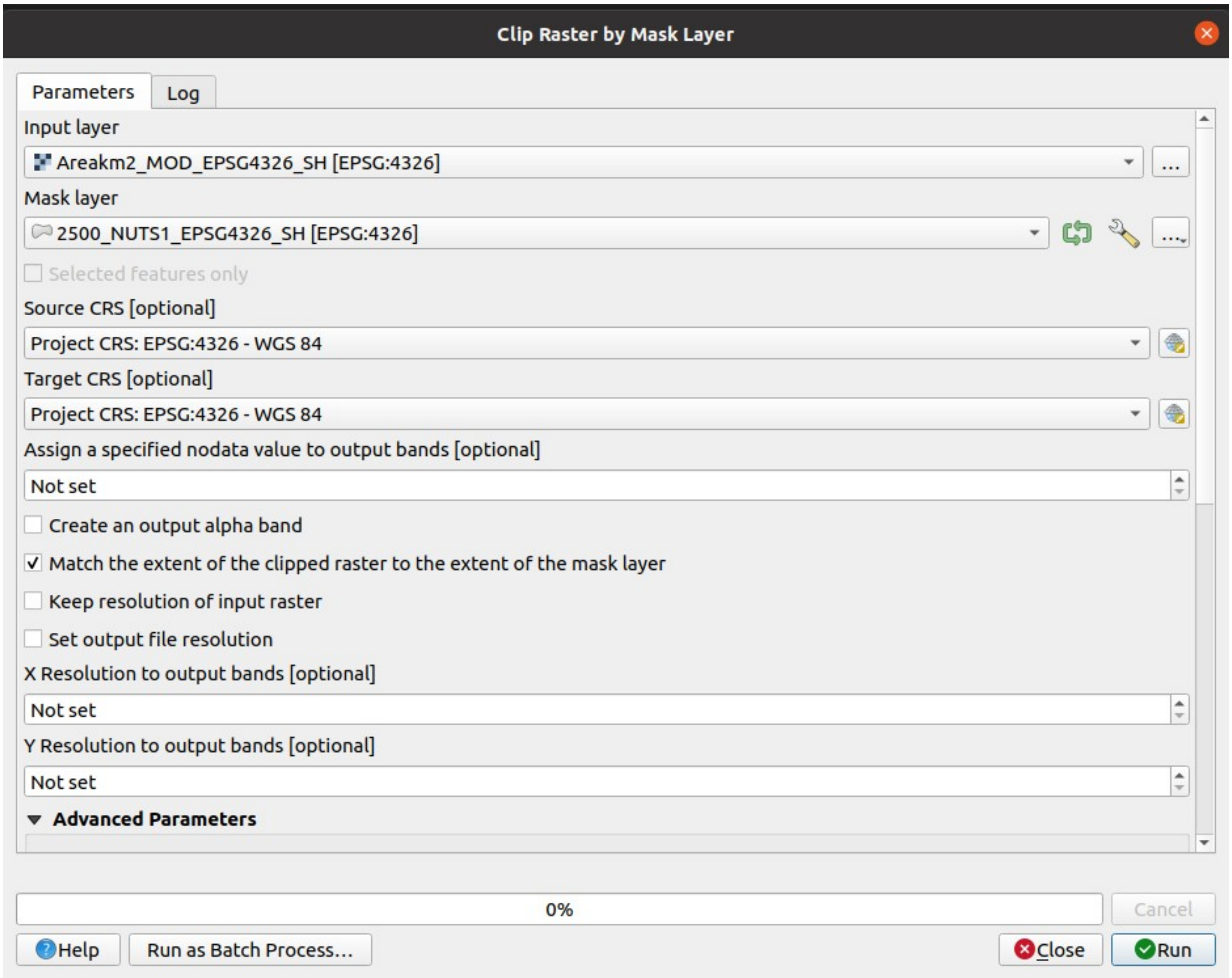
3.2 Raster analysis → Raster calculator, see Screenshot, set *LatitudesMOD_EPSG4326_SH* as reference layer. Output: *LatitudesMOD_EPSG4326_SH_inRadians*



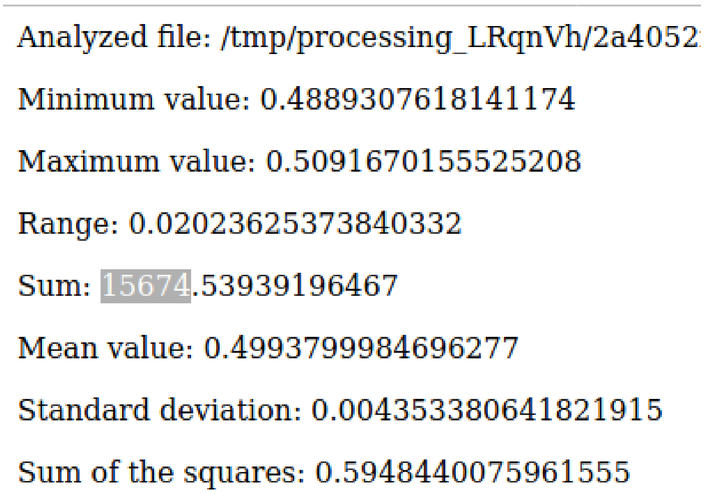
3.3 Use the formula 0.8534 * cos(latitude) m^2. See screenshot. Input: *LatitudesMOD_EPSG4326_SH_inRadians* Output: *Areakm2_MOD_EPSG4326_SH*



3.4 Check whether *Areakm2_MOD_EPSG4326_SH* represents the exact area for Schleswig-Holstein. GDAL→ Clip Raster by Mask Layer, Input: Layer *Areakm2_MOD_EPSG4326_SH*, Mask layer: *2500_NUTS1_EPSG4326_SH*, Output: *Areakm2_MOD_EPSG4326_SH_Clipped*



3.5 Raster analysis → Raster layer statistics, Input: *Areakm2_MOD_EPSG4326_SH_Clipped*, Sum: 15674.5 km², area of Schleswig-Holstein from vector layer *2500_NUTS1_EPSG4326_SH* is 15843 km² (Field calculator → geometry → $area). So the raster is ca. 1 % smaller than the actual size of Schleswig-Holstein.



Analyzed file: /tmp/processing_LRqnVh/2a4052

Minimum value: 0.4889307618141174

Maximum value: 0.5091670155525208

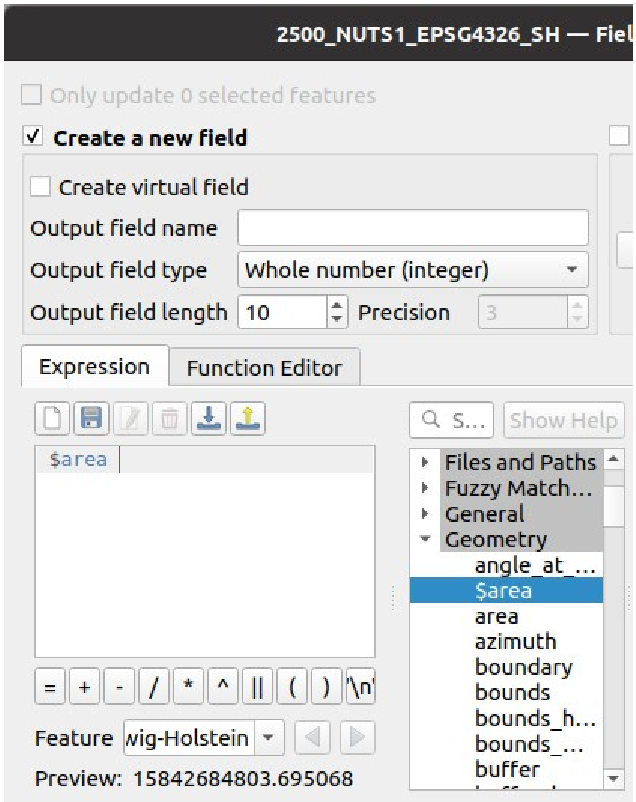
Range: 0.020236253738403320

Sum: 15674.53939196467

Mean value: 0.4993799984696277

Standard deviation: 0.004353380641821915

Sum of the squares: 0.5948440075961555



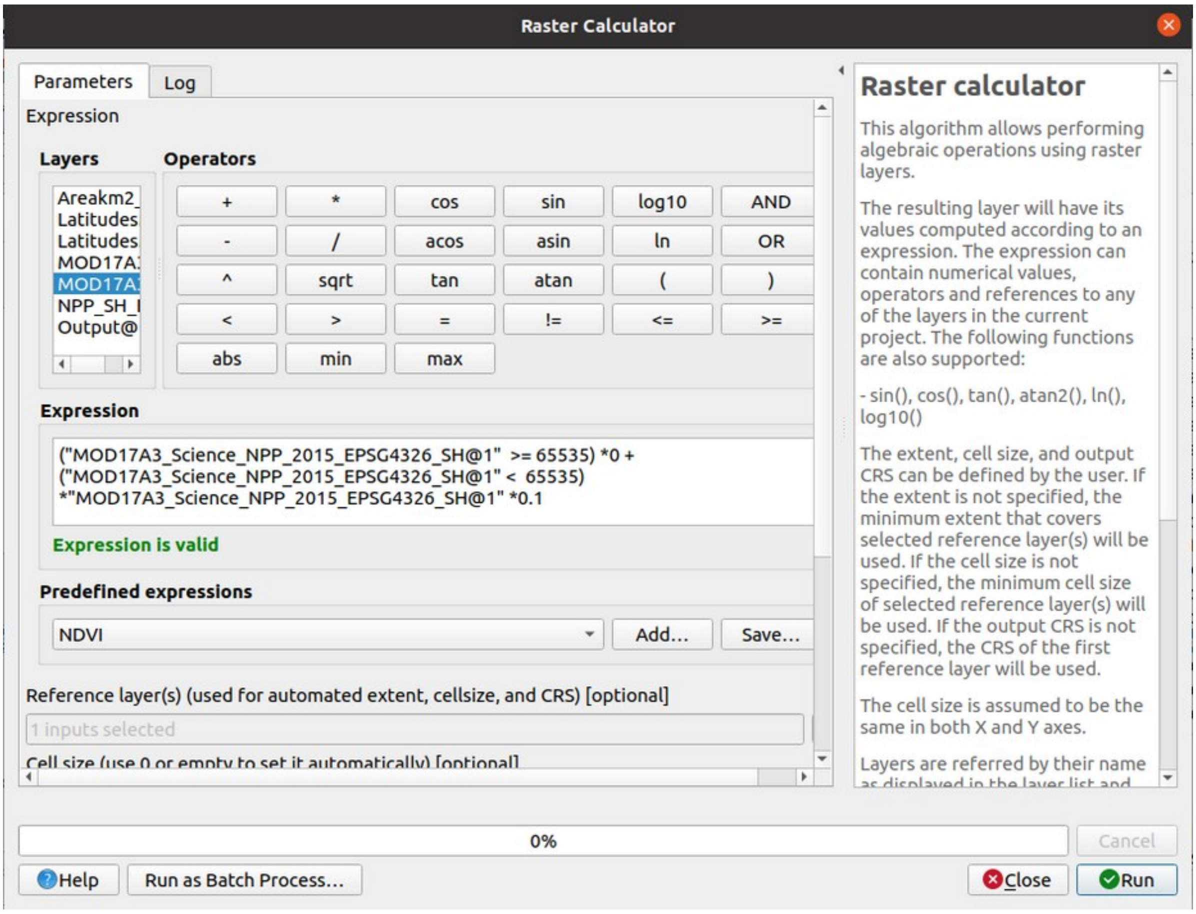
4. Adjust values of ***MOD17A3_Science_NPP_2015_EPSG4326_SH***

NA values in *MOD17A3_Science_NPP_2015_EPSG4326_SH* are coded as 65535 (see MOD17A3_data_info.txt). We set them to 0.

All other values >0 in *MOD17A3_Science_NPP_2015_EPSG4326_SH* have to be multiplied by 0.1 to get it in g C m^{-2} (see Readme.txt).

```
field name: Npp
data type: uint16
scale_factor:    0.000100
valid_range:    0  65500
_FillValue:    65535
long_name:  MOD17A3 NPP--MODIS Gridded 1KM Annual Net Primary Productivity (NPP)
units:  kg_C/m^2
```

```
NAME: NPP
DESCRIPTION: Annual Net Primary Production
SCALE FACTOR: 0.1 (i.e.--multiply Npp_1km by 0.1 to get actual value)
UNITS: g carbon m-2
```



4.1 Raster analysis → Raster calculator (see Screenshot. Important: Set *MOD17A3_Science_NPP_2015_EPSG4326_SH* as Reference Layer). Output: *NPP_SH_EPSG4326_gCm2*

We first wanted and also did:

~~**5. Reproject our final layers in section A to EPSG 2583**~~

~~5.1 Reproject (Warp) NPP_SH_EPSG4326_gCm2 to NPP_SH_EPSG25832_gCm2 and Areakm2_MOD_EPSG4326_SH to Areakm2_MOD_EPSG25832_SH~~

But, warping to EPSG 25832 leads to different values in g C !

Analyzed file: /media/GemeinsamerSpeicher/Studiur	Analyzed file: /media/GemeinsamerSpeicher/Stuc
Minimum value: 0	Minimum value: 0
Maximum value: 638443200	Maximum value: 638443200
Range: 638443200	Range: 638443200
Sum: 9695634224820	Sum: 12091672629544
Mean value: 116500459.3004422	Mean value: 116672191.9522183
Standard deviation: 156901618.7771997	Standard deviation: 156974933.7023705
Sum of the squares: 2.048793632225578e+21	Sum of the squares: 2.553732770208472e+21

→ Skip 5. and continue all steps in EPSG 4326

B Calculate the NPP balance of Schleswig-Holstein

1. Prepare layers

~~1.1 New project with EPSG 25832~~

~~1.2 Load Areakm2_MOD_EPSG25832_SH.tif~~

~~1.3 Load NPP_SH_EPSG25832_gCm2.tif~~

1.4 Load VG250_GEM.shp

1.5 Clip VG250_GEM to Schleswig-Holstein. Attribute table → select features: Select variable SN_L = 01, Output: *VG250_GEM_SH*

~~1.6 Reproject *VG250_GEM_SH* to EPSG 4326. Output: *VG250_GEM_SH_EPSG4326*~~

Making a raster from the reprojected *VG250_GEM_SH_EPSG4326* fails for some reason. Therefore we continue with the EPSG 25832 version *VG250_GEM_SH*, although the supply side layers are in EPSG 4326!!!! We know that this is against the standards of working with geographic data, but the maps visually appear to be in the same place. This will hopefully not change the results too much.

2. Create a carbon demand layer in C m^{-2}

Multiply inhabitants of *VG250_GEM_SH* with the per capita biomass flow to the EU taken from Kastner et al. 2015. The per capita biomass flow in dry mass (dm) is 1.2 t dm c^{-1} y^{-1}. Multiply this by 0.5, the carbon content of dry biomass (see FAO: http://www.fao.org/forestry/17111/en/). Per capita biomass flow to EU in carbon is then 0.6 * 10^6 g C c^{-1} y^{-1}. This value is multiplied by the inhabitants to get the demand of biomass. It is important to note that the biomass included in this number is only biomass from agriculture, not forestry. The number seems to represent the net consumption (imports – exports) of biomass: “Table 2 displays the EU’s trade in agricultural products in physical (eHANPP and biomass flows) […] the numbers reveal that the EU is a net importing (physical trade balance = imports minus exports) region, both in terms of primary biomass flows and eHANPP.” (Kastner 2015, p. 831).

Table 1 Biomass flows[a] and eHANPP of the EU (EU-27) in 2007 compared to other world regions for both consumption-based accounts (CBA) and production-based accounts (PBA) accounts

	Biomass flows[a] (t dm/cap/yr)		*eHANPP flows (t dm/cap/yr)*		*eHANPP intensity (t HANPP/t biomass)*	
	CBA	PBA	CBA	PBA	CBA	PBA
North America	1.9	2.4	7.7	9.4	4.1	3.9
EU-27	**1.2**	**1.0**	**5.3**	**4.5**	**4.5**	**4.3**
Oceania	1.1	1.9	11.3	22.3	9.9	12.0
South America	1.0	1.4	9.3	11.1	9.4	8.0
FSU and other Europe	0.9	1.0	6.6	6.7	7.5	6.7
Central America and Caribbean	0.7	0.5	5.9	4.5	8.4	9.9
Southeast Asia	0.7	0.8	4.7	4.5	7.0	5.9
Northern Africa and Western Asia	0.6	0.3	2.7	2.1	4.9	6.7
Eastern Asia	0.5	0.4	2.1	1.7	3.9	3.9
Sub-Saharan Africa	0.4	0.3	6.0	6.0	15.9	17.4
Southern Asia	0.4	0.4	1.8	1.9	4.9	5.3
World	0.7	0.7	4.0	4.0	6.1	6.1

Note: The last two columns show the HANPP intensity expressed as tonnes of eHANPP per tonne of primary equivalent biomass flow. Region definitions other than the EU-27 follow Kastner and colleagues (2014)

[a]biomass expressed in primary crop and wood equivalents, details see text.

eHANPP = embodied human appropriation of net primary production; HANPP = human appropriation of net primary production; EU = European Union; FSU = Former Soviet Union; t = metric tonnes; dm = dry matter; cap = capita; yr = year.

5.1 Carbon Content of Vegetation

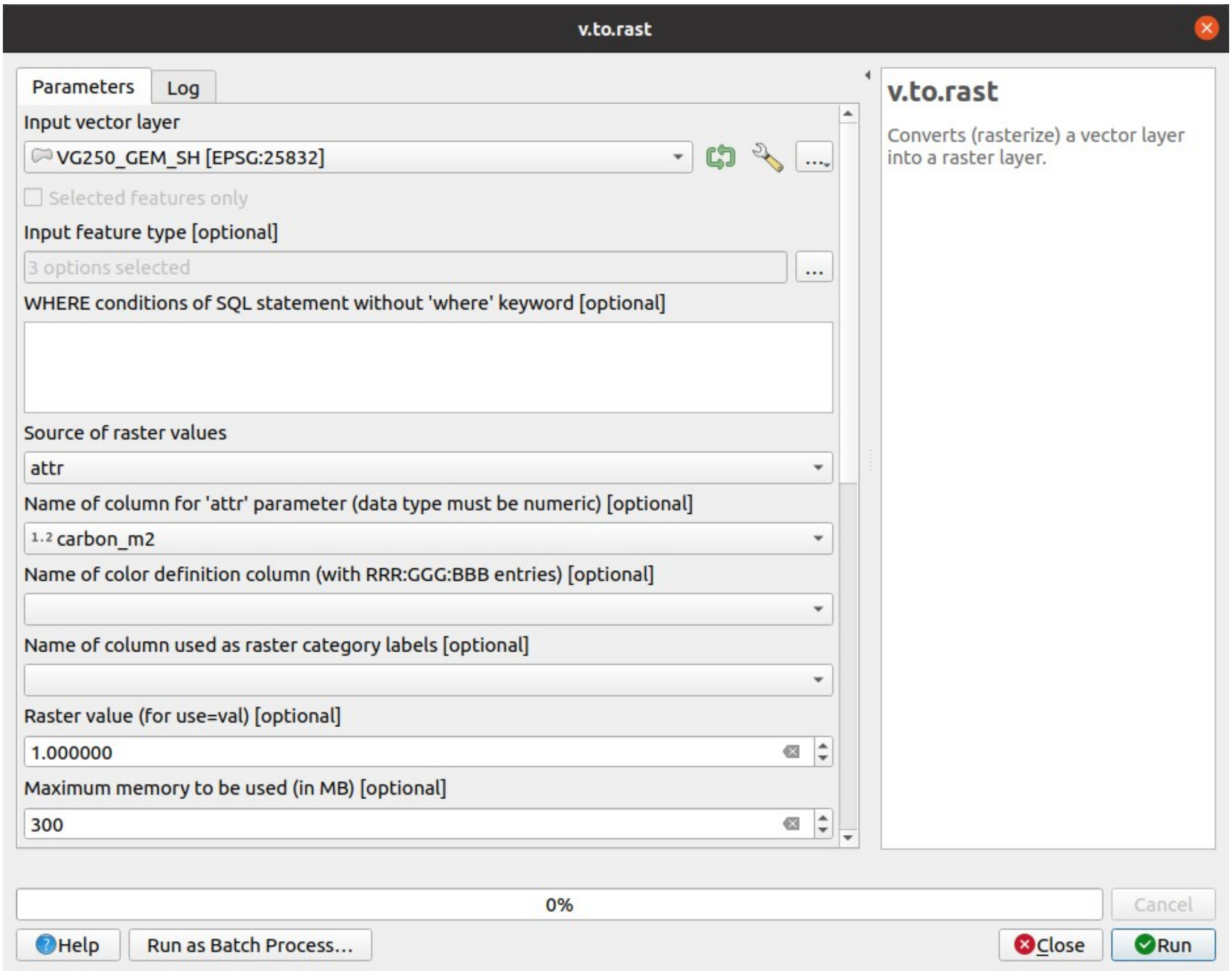
The carbon content of vegetation is surprisingly constant across a wide variety of tissue types and species. Schlesinger (1991) noted that C content of biomass is almost always found to be between 45 and 50% (by oven-dry mass).

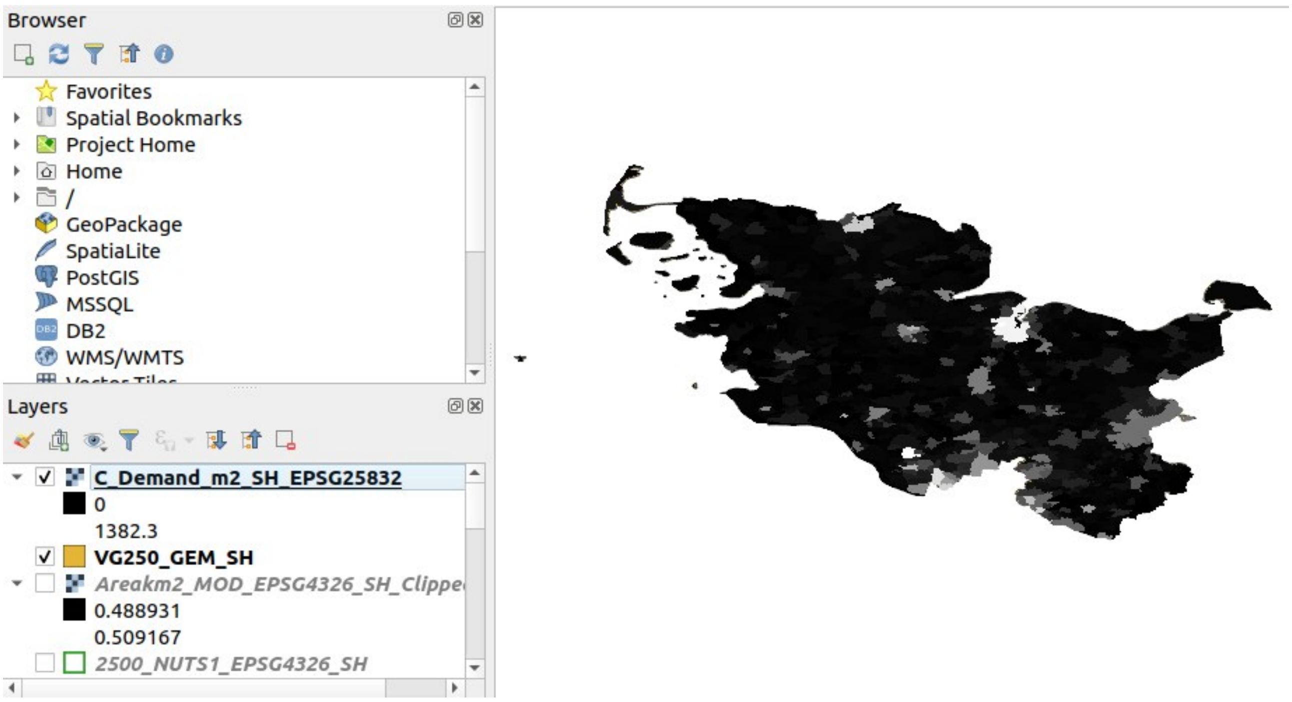
In many applications, the carbon content of vegetation may be estimated by simply taking a fraction of the biomass, say
$C \;=\; 0.475 * B$ where C is carbon content by mass, and B is oven-dry biomass.

2.1 *VG250_GEM_SH* → Attribute table → Field calculator: "EWZ" * 0.6 * 10^6, new field is carbondem

2.2 Calculate carbondem per m² (Field calculator: carbondem / $area, new variable carbon_m2)

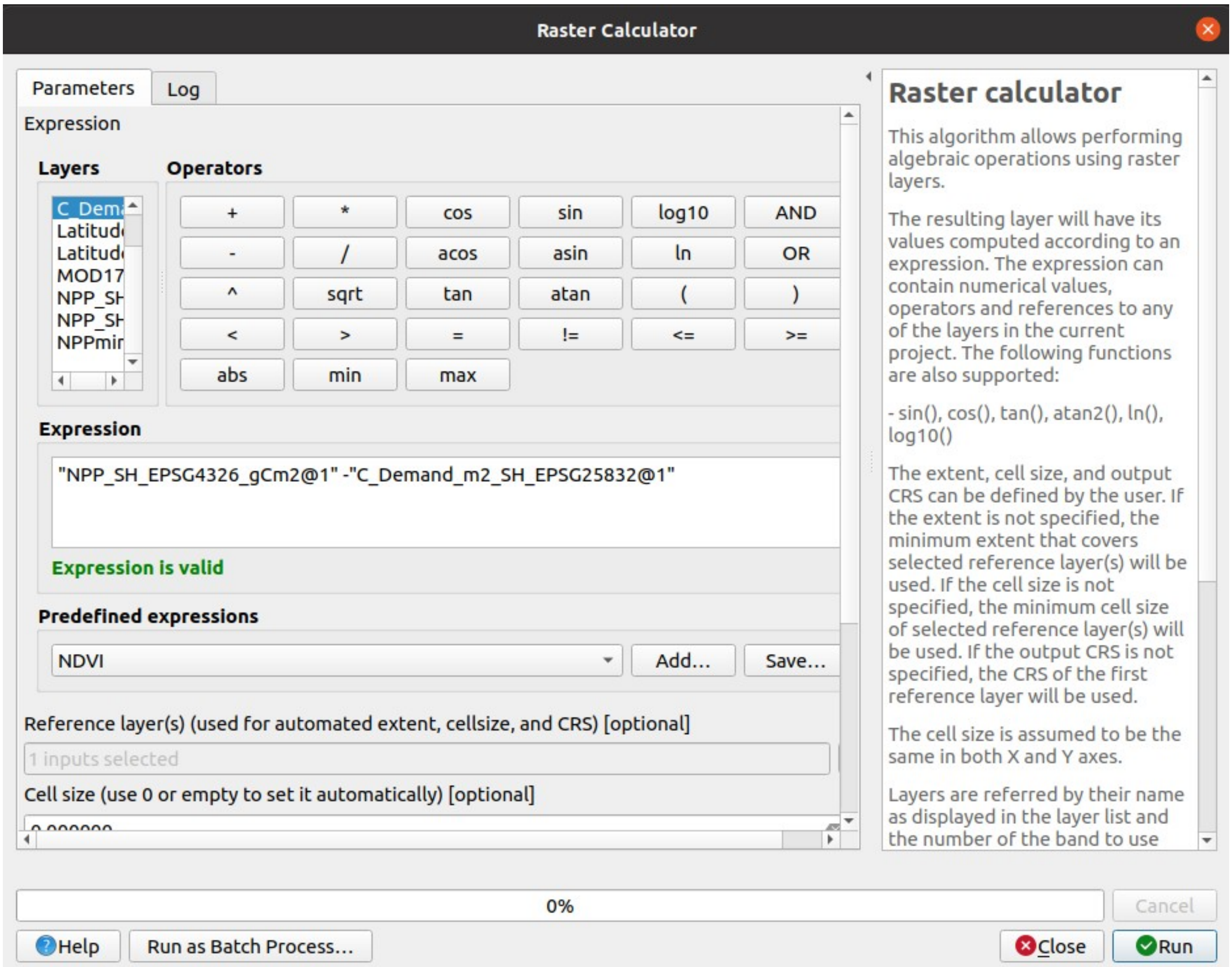
2.3 Make a raster from *VG250_GEM_SH* with GRASS → v.to.rast, see Screenshot. We don't choose a region extent here, otherwise it will not work. Output: *C_Demand_m2_SH_EPSG25832.tif*


v.to.rast
Parameters
Log
Input vector layer
VG250_GEM_SH [EPSG:25832]
Selected features only
Input feature type [optional]
3 options selected
WHERE conditions of SQL statement without 'where' keyword [optional]
Source of raster values
attr
Name of column for 'attr' parameter (data type must be numeric) [optional]
carbon_m2
Name of color definition column (with RRR:GGG:BBB entries) [optional]
Name of column used as raster category labels [optional]
Raster value (for use=val) [optional]
1.000000
Maximum memory to be used (in MB) [optional]
300
v.to.rast
Converts (rasterize) a vector layer into a raster layer.
0%
Cancel
Help
Run as Batch Process…
Close
Run


Browser
Favorites
Spatial Bookmarks
Project Home
Home
/
GeoPackage
SpatiaLite
PostGIS
MSSQL
DB2
WMS/WMTS
Layers
C_Demand_m2_SH_EPSG25832
0
1382.3
VG250_GEM_SH
Areakm2_MOD_EPSG4326_SH_Clippe
0.488931
0.509167
2500_NUTS1_EPSG4326_SH

3. Create a carbon balance layer in C m^{-2}

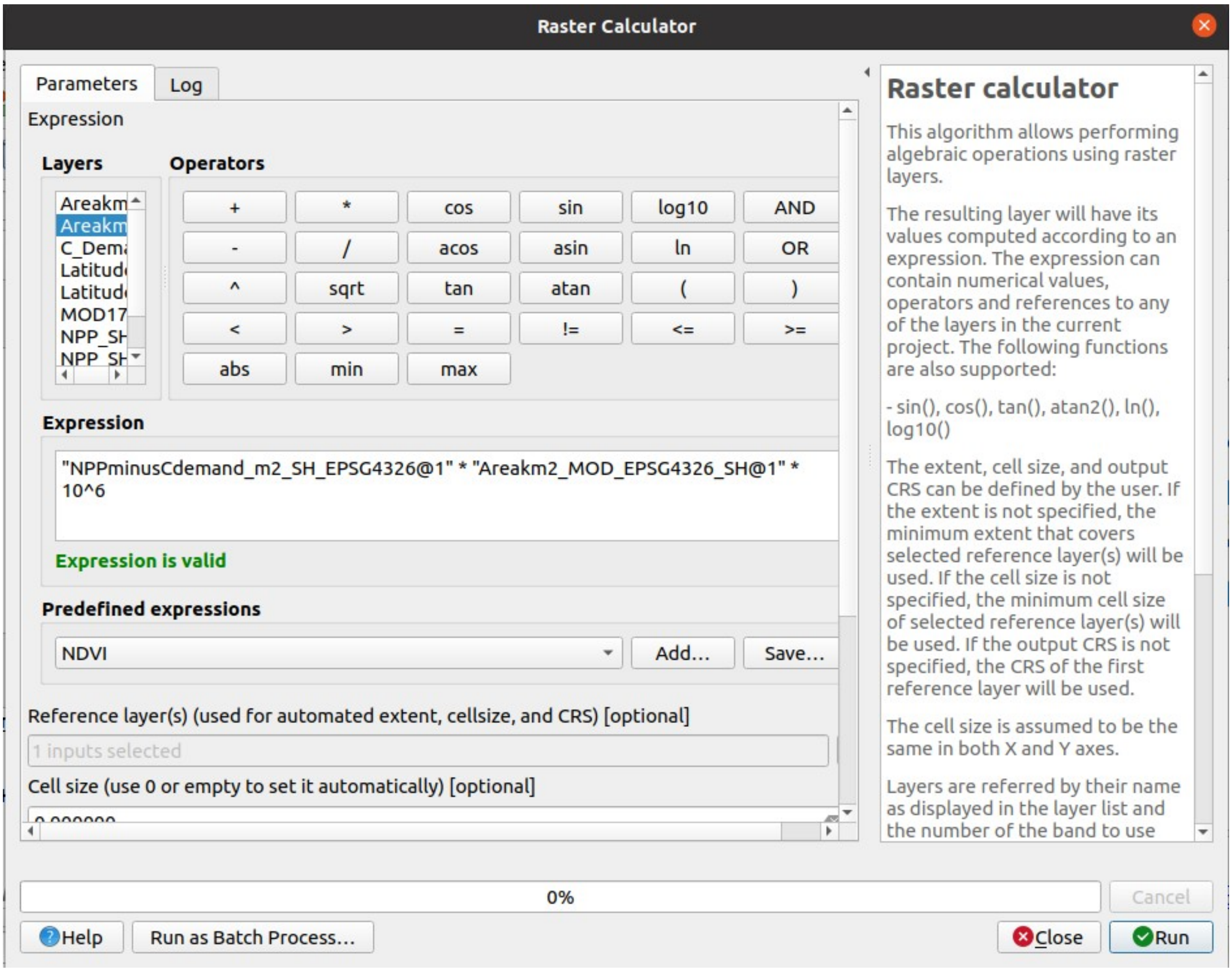
3.1 Subtract carbon demand per m² from NPP per m² with Raster calculator, see Screenshot. Output: *NPPminusCdemand_m2_SH_EPSG4326*



4. Make a carbon balance layer in total carbon per pixel

Multiply *NPPminusCdemand_m2_SH_EPSG4326* with *Areakm2_MOD_EPSG4326_SH* (times 10^6 for km^2 in m^2) to get absolute values of NPP balance for each raster tile.

4.1 → Raster calculator, see Screenshot. Output *NPPminusCdemand_absolute_SH_EPSG4326*



6. Calculate the total NPP of Schleswig-Holstein

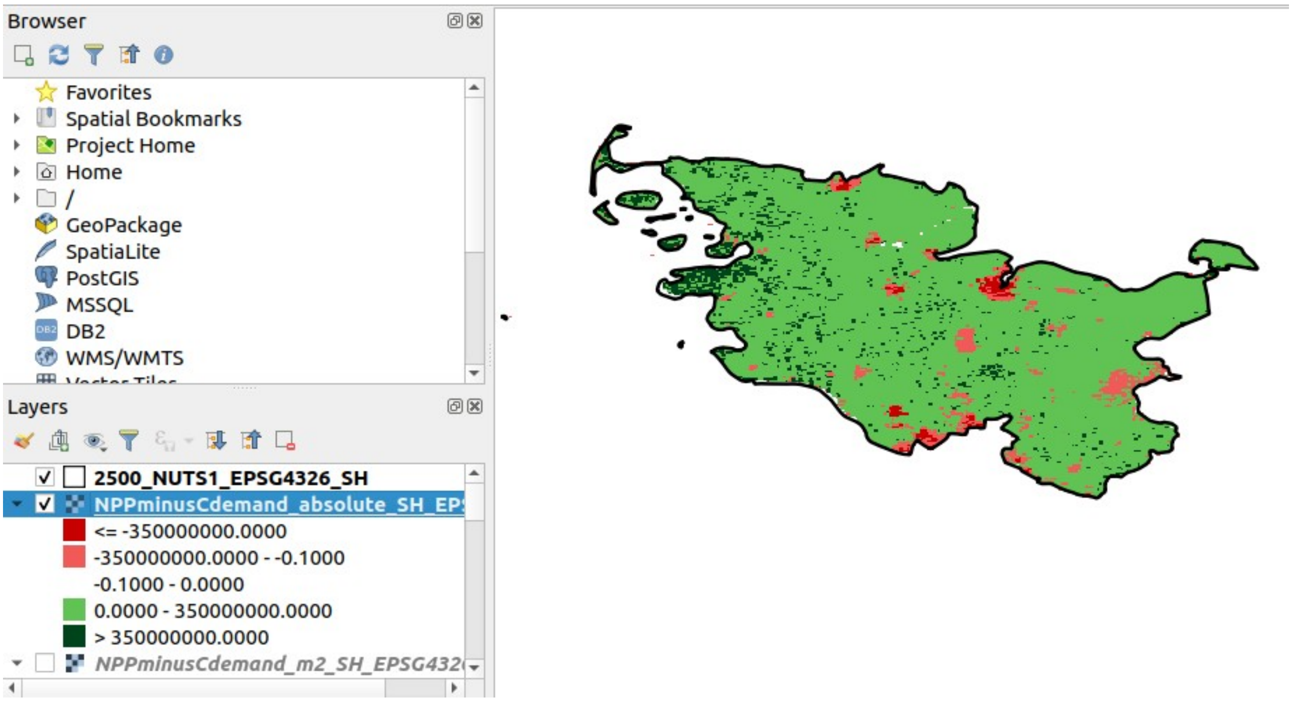
6.1 → Raster calculator, Multiply *NPP_SH_EPSG4326_gCm2* with *Areakm2_MOD_EPSG4326_SH* (times 10^6 for km^2 in m^2) to get absolute values of NPP for each raster tile (see Screenshot in 4.), Output: *NPP_SH_EPSG4326_gC*

6.2 Raster analysis → Raster layer statistics, Input: *NPP_SH_EPSG4326_gCm2*. Is the sum 9.7 * 10^{12} ?

Final results

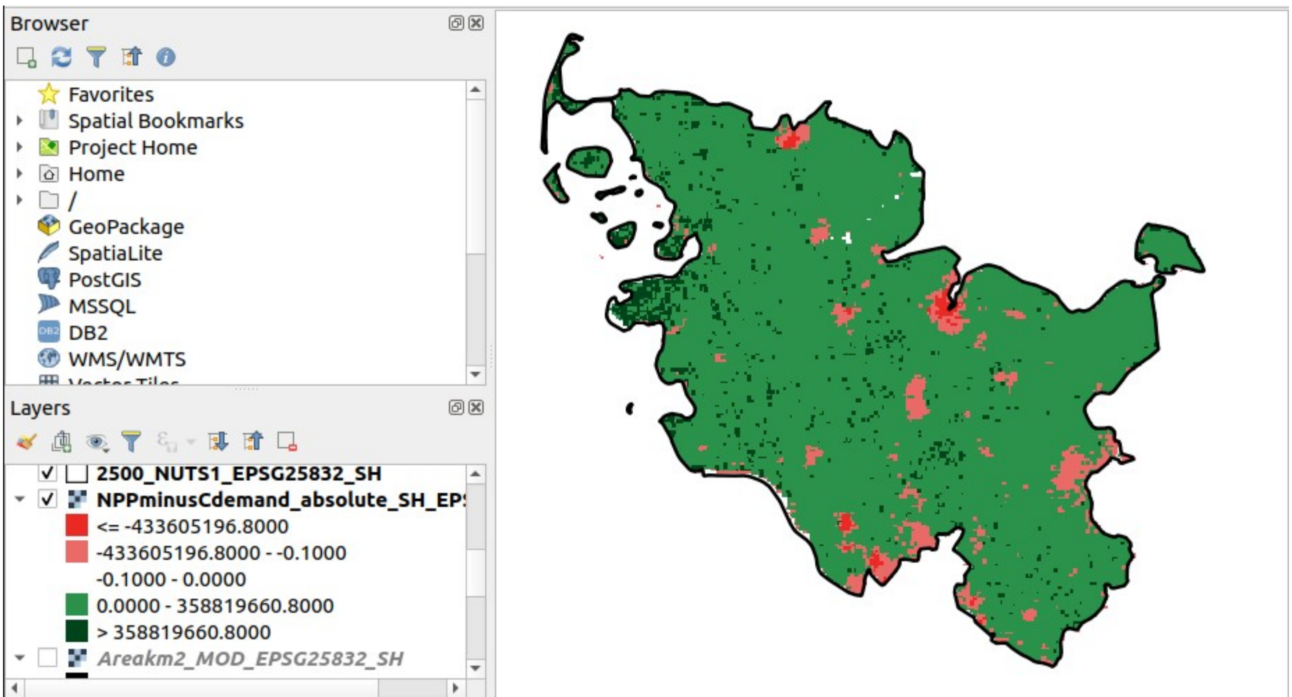
The sum of the area of all raster pixels is …. There is a difference, of unknown origin, of … to the actual size of Schleswig-Holstein of ... as computed from the NUTS layer. This results in a total NPP of 9.7 * 10^6 t C y^{-1} for Schleswig-Holstein (see R code). O'Neill et al. 2007 calculate 14.40 * 10^6 t C y^{-1} for Nova Scotia. Nova Scotia has an area of 55.284 km² (Wikipedia). This is 3.5 times the size of Schleswig-Holstein (15.800 km²). At the same time the mean NPP of roadless areas in Nova Scotia is 294 g C m^{-2} $year^{-1}$ (O'Neill et al. 2007, p.), while for Schleswig-Holstein the calculated overall mean NPP from our data set (see figure 1) is 646 g C m^{-2} $year^{-1}$ (see R code and Histogram on last page) which is 2.2 times higher.

The final map in EPSG 4326 looks like this. Here the the total carbon balance for Schleswig-Holstein is 7.9 * 10^{12} g C y^{-1}. Calculated with Raster analysis → Raster layer statistics, the value is the Sum.



We actually wanted to produce the map in EPSG 25832, where the proportions would look more natural. But here the total carbon balance is 9.8 *10^{12} g C y^{-1}. So there is a difference of 1.9 * 10^{12} g C y^{-1} between both maps.

An interesting future project might be to produce a real HANPP-like map, which shows the percentage of NPP consumed by the people in Schleswig-Holstein in a spatial extent. For this the consumption of biomass which is now located in the cities would have to be distributed across the productive land. Calculating a “virtual” aggregate appropriation of NPP in Schleswig-Holstein, see R code yields 18%. The interpretation would be that if the people of Schleswig-Holstein had to consume all their imported biomass locally in Schleswig-Holstein, this means that they would consume 18% of the total biomass production in Schleswig-Holstein. This doesn’t sound very much, but we are missing time to put this number in a context. Only the remark that in our biomass consumption we took from Kastner (2015) only agricultural biomass is included. So to the 18% also biomass consumption from forestry would have to be added to present the total biomass consumption. It should be pointed out that actually HANPP is a comparison of human use of



biomass with natural ecosystem NPP. Our measure differs in this point as we compare human consumption only with actual NPP. For a short – 3 page long – teaser on how this spatial footprint concept could be an important tool for assessing local shortages of biomass for human consumption and overuse of ecosystems especially in more unstable regions than Schleswig-Holstein with respect to population/consumption dynamics and NPP dynamics, we refer to Running (2014).

C Making the histogram and the aggregated NPP for SH in R

1. Export the NPP maps as csv file

1.1 The per squaremeter NPP map. Vector creation –> Raster pixels to points. Input: *NPP_SH_EPSG4326_gCm2*

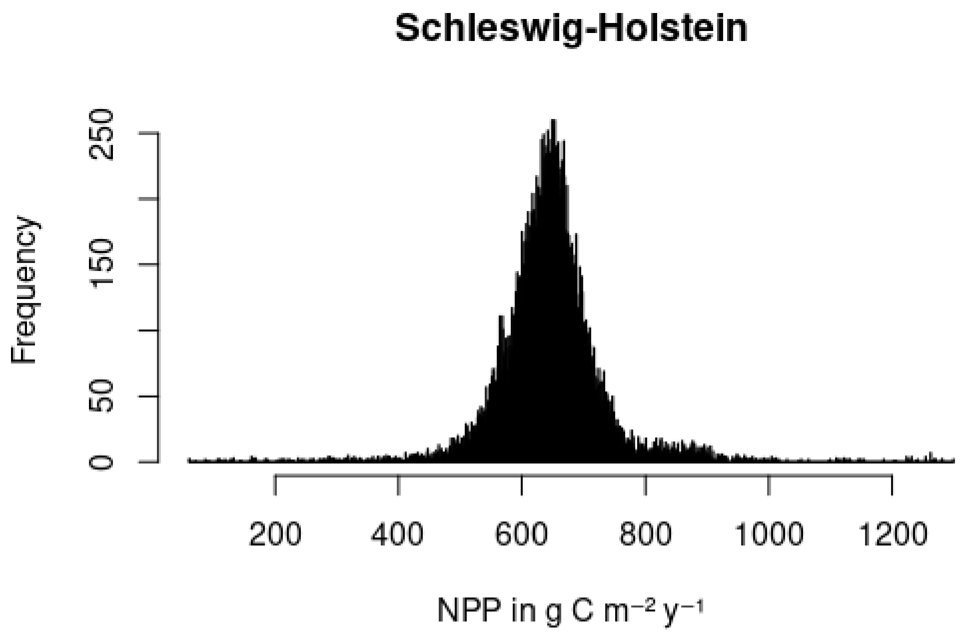
1.2 The total NPP map. Vector creation –> Raster pixels to points. Input: *NPP_SH_EPSG4326_gC*

1.3 Export the new point layers as .csv

2. Load into R and run code

2.1 import .csv files into R

2.2 Run the R code attached as FinalProject_2020-03-25.R



Literature

Kastner, Erb, Haberl (2015) : Global Human Appropriation of Net Primary Production for Biomass Consumption in the European Union, 1986–2007. In: Journal of Industrial Ecology. Vol 19. Nr 5. https://doi.org/10.1111/jiec.12238

O’Neill, Tyedmers, Beazly (2007). Human appropriation of net primary production (HANPP) in Nova Scotia, Canada. In: Regional Environmental Change. Vol 7. Nr 1-14. https://doi.org/10.1007/s10113-006-0021-1

Running (2014). A regional look at HANPP: human consumption is increasing, NPP is not. In: Environmental Research Letters. Vol 9. Nr 11. http://dx.doi.org/10.1088/1748-9326/9/11/111003