




PRODUCING URBAN HOT SPOT MAPS

**STEP BY STEP GUIDE ON
THE USE OF QGIS**

Producing urban hot spot maps

Step by step guide on the use of QGIS



The designations employed and the presentation of material on maps included in the guide do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

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Scope and purpose

This guide shows you step-by-step how to create urban hot spot maps.

Urban hot spots are in the context of the present guide understood as locations with rapid increase of artificial surfaces/built-up areas. The guide shows how to identify and visualize such locations on maps.

The guide explains the use of open-source software, namely Quantum Geographic Information System (QGIS) to construct a map displaying the rate of increase of artificial surfaces in a geographical area over time. Maps are generated in accordance with the land cover category ***built-up area*** of the European Space Agency (ESA) land cover classification, which corresponds to the land cover category ***artificial surfaces*** (which includes urban and associated areas) of the System of Environmental-Economic Accounting (SEEA).

Note the guide shows how to illustrate *gross increases* in artificial surfaces; it does not take into account decreases in artificial surfaces. As decreases in artificial surfaces, i.e. conversions of artificial surfaces to natural surfaces are rare, this should have minor to no impact on the resulting illustrations.

The guide takes you through 3 steps:

Step 1: Download the data you want to work with from available open sources – **Data downloading**

Step 2: Strip and clean the data downloaded to filter the layers relevant to your chosen geographical area – **Data pre-processing**

Step 3: Produce the urban hot spot map – **Data processing**

These steps should take approximately 4 hours to complete from start to finish.

Before starting step 1, make sure you have QGIS installed on your computer. First time users can refer to the **Appendix** for help.

For illustrative purposes, the guide uses select open-source data for a specific geographical area, the Ganga Brahmaputra River Basin in India. The resulting map is shown on the page below together with explanations of the involved calculations.

You can generate your own maps, choose other data which suit your purpose and the geographical area of your interest, and adjust the thresholds for what categorizes an “urban hot spot”; the guide advises how to do so.

The **Appendix** to this guide provides a list of open-source datasets that may be useful for your own purposes.

So, let's get started!

Calculations and Maps

To calculate the expansion of artificial surfaces, we used data downloaded from the European Space Agency (ESA).

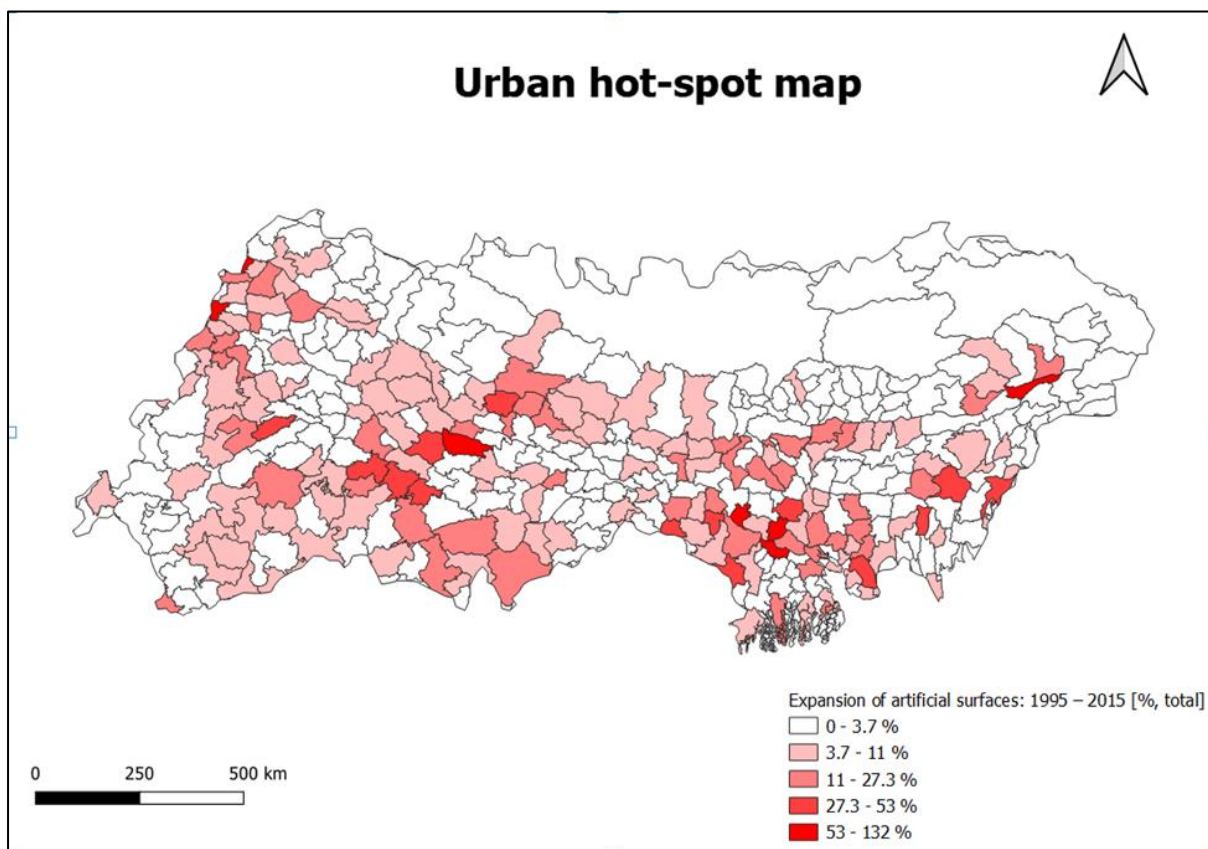
The data contains shape files consisting of land cover pixels, each pixel representing an area of land. The ESA land cover classification distinguishes 31 classes of land cover pixels, and it ranges from “No Data” to “Permanent Snow and Ice”, represented by a discrete number between 0 to 220, and a distinct color as seen in the chart below:

Value	Label	Color
0	No Data	
10	Cropland, rainfed	
11	Herbaceous cover	
12	Tree or shrub cover	
20	Cropland, irrigated or post-flooding	
30	Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)	
40	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%)	
50	Tree cover, broadleaved, evergreen, closed to open (>15%)	
60	Tree cover, broadleaved, deciduous, closed to open (>15%)	
61	Tree cover, broadleaved, deciduous, closed (>40%)	
62	Tree cover, broadleaved, deciduous, open (15-40%)	
70	Tree cover, needleleaved, evergreen, closed to open (>15%)	
71	Tree cover, needleleaved, evergreen, closed (>40%)	
72	Tree cover, needleleaved, evergreen, open (15-40%)	
80	Tree cover, needleleaved, deciduous, closed to open (>15%)	
81	Tree cover, needleleaved, deciduous, closed (>40%)	
82	Tree cover, needleleaved, deciduous, open (15-40%)	
90	Tree cover, mixed leaf type (broadleaved and needleleaved)	
100	Mosaic tree and shrub (>50%) / herbaceous cover (<50%)	
110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)	
120	Shrubland	
121	Evergreen shrubland	
122	Deciduous shrubland	
130	Grassland	
140	Lichens and mosses	
150	Sparse vegetation (tree, shrub, herbaceous cover) (<15%)	
151	Sparse tree (<15%)	
152	Sparse shrub (<15%)	
153	Sparse herbaceous cover (<15%)	
160	Tree cover, flooded, fresh or brakish water	
170	Tree cover, flooded, saline water	
180	Shrub or herbaceous cover, flooded, fresh/saline/brakish water	
190	Urban areas	
200	Bare areas	
201	Consolidated bare areas	
202	Unconsolidated bare areas	
210	Water bodies	
220	Permanent snow and ice	

Class 190 represents pixels for built-up areas (urban areas, artificial surfaces) and all other classes represent pixels for non-built-up areas. For this exercise, the 31 classes are grouped into 2 classes – built-up and non-built-up areas.

The methodology used in this guide to determine the expansion of artificial surfaces compares the number of built-up pixels at the beginning and end of a time period; in this example we compare 1995 with 2015. The rate of expansion is the change in the number of built-up pixels during the period divided by the number of built-up pixels at the beginning of the period.

The map below illustrates the expansion of artificial surfaces along the Ganga-Brahmaputra River Basin during 1995 to 2015. Different levels of expansion are indicated by differences in colour. The darker the colour, the greater the relative expansion of artificial surfaces during the period covered. The threshold expansion for an “urban hot spot” can be determined by the user.



The expansion intervals of the legend on the map was generated using the [Natural Breaks \(Jenks\) Mode](#) in QGIS. This mode is pre-programmed in QGIS and arranges the rate of expansion of natural surfaces into natural classes by minimizing the statistical variance of the rate within classes and maximize the statistical variance of the rate between classes.

QGIS offers other pre-programmed modes which the user may wish to explore, such as *Equal Interval*¹, *Geometric Interval*², *Quantile*³ and *Standard Deviation*⁴.

¹ The Equal Interval classification method divides the range of values into equal sized ranges.

² The Geometric Interval classification method divides the range of values based on a geometric progression, and the class breaks are based on class intervals that have a geometrical series.

³ The Quantile classification method divides the range of values into groups that contain an equal number of values.

⁴ The Standard Deviation classification method divides the range of values into class breaks with equal value ranges that are a proportion of the standard deviation – usually at intervals of one, one-half, one-third or one-fourth – using mean values and standard deviations from the mean

Step 1 – Data downloading

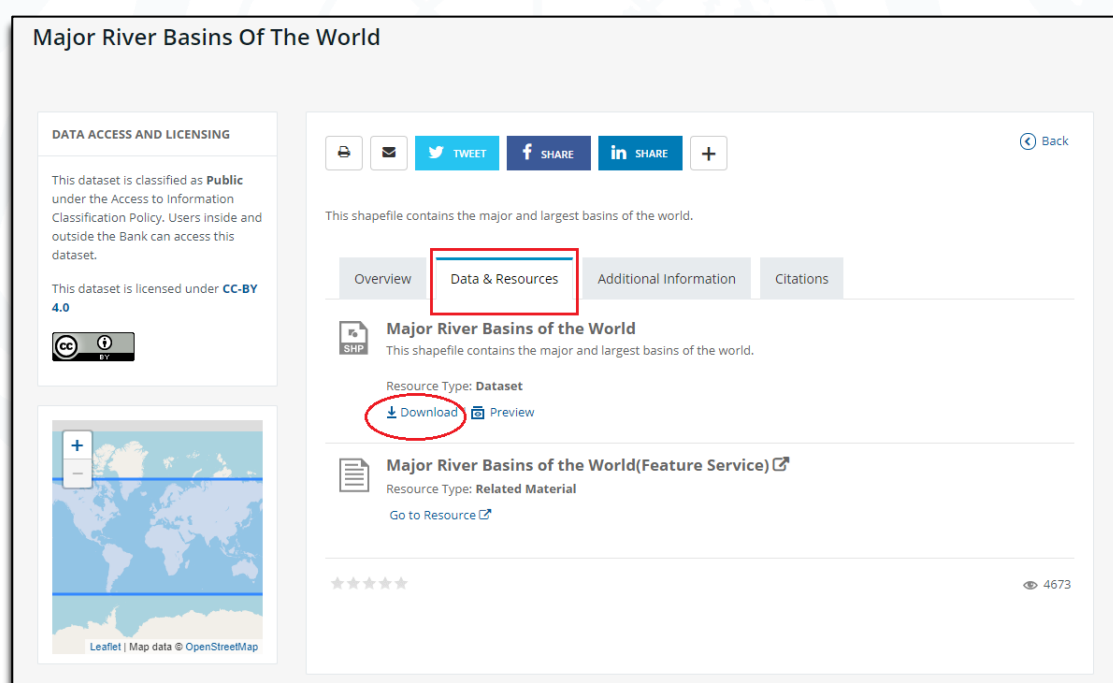
In this section, we will show how to download both raster datasets and vector datasets for use in developing the urban hot spot maps.

1.1 Downloading vector data

We start with downloading the [Major River Basins of the World](#) from World Bank, which provides shape file⁵ boundaries for all major river basins in the world. Please note that the **Appendix** outlines examples of the most frequently used vector data and we encourage you to investigate these examples.

To download the shape files used in this exercise:

1. Click this [link](https://datacatalog.worldbank.org/dataset/major-river-basins-world) (<https://datacatalog.worldbank.org/dataset/major-river-basins-world>)
2. Click on the tab “Data & Resources” and click on the “Download” link
3. Save the downloaded data in a folder named “Downloaded Data” or a name of your choosing in a convenient location on your system



1.2 Downloading administrative boundaries data

Now we are going to Download [Administrative Boundaries data](#) from Diva GIS. Please note that the **Appendix** outlines examples of the most frequently used earth observation data and we encourage you to investigate these examples.

⁵ The **shapefile** format is a geospatial vector data format for geographic information system (GIS) software. It is developed and regulated by Esri as a mostly open specification for data interoperability among Esri and other GIS software products. The shapefile format can spatially describe vector features: points, lines, and polygons, representing, for example, water wells, rivers, and lakes. Each item usually has attributes that describe it, such as *name* or *temperature*.

Step 1 – Data downloading

To download the administrative boundaries data used in this exercise:

1. Click on the [link](https://www.diva-gis.org/gdata) (<https://www.diva-gis.org/gdata>)
2. When the landing page emerges as in the picture below, take the following steps as seen in the picture below:
click on the [Country](#) drop down button and select “India”
click on the [Subject](#) drop down button and select “Administrative areas”
click “OK” and save the downloaded file as “IND_adm2.shp” in the folder named “Downloaded Data” (or the name chosen)

The screenshot shows the DIVA-GIS website interface. At the top, there is a blue header with the text 'DIVA-GIS free, simple & effective'. Below the header, there are three navigation tabs: 'Download program', 'Documentation', and 'Free Spatial Data'. The main content area has a 'Home' link and a heading 'Download data by country'. Below the heading, there is a sub-heading 'Select and download free geographic (GIS) data for any country in the world'. The form contains two dropdown menus: 'Country' with 'India' selected and 'Subject' with 'Administrative areas' selected. An 'OK' button is located below the dropdowns. Red arrows and circles highlight the dropdown arrows and the 'OK' button.

3. Refresh the landing page, and when the page emerges, repeat the above step with the change as follows:
click on the [Country](#) drop down button and select “Nepal”
click on the [Subject](#) drop down button and select “Administrative areas”
click “OK” and save the downloaded file as “NPL_adm2.shp” in the folder named “Downloaded Data” (or the name chosen)
4. Refresh the landing page, and when the page emerges, repeat the above step with the change as follows:
click on the [Country](#) drop down button and select “Bangladesh”
click on the [Subject](#) drop down button and select “Administrative areas”
click “OK” and save the downloaded file as “BGD_adm2.shp” in the folder named “Downloaded Data” (or the name chosen)
5. Refresh the landing page, and when the page emerges, repeat the above step with the change as follows:
click on the [Country](#) drop down button and select “China”
click on the [Subject](#) drop down button and select “Administrative areas”
click “OK” and save the downloaded file as “CHN_adm2.shp” in the folder named “Downloaded Data” (or the name chosen)
6. Refresh the landing page, and when the page emerges, repeat the above step with the change as follows:

Step 1 – Data downloading

click on the [Country](#) drop down button and select “Bhutan”
click on the [Subject](#) drop down button and select “Administrative areas”
click “OK” and save the downloaded file as “BTN_adm1.shp” in the folder named “Downloaded Data” (or the name chosen)

7. Refresh the landing page, and when the page emerges, repeat the above step with the change as follows:
click on the [Country](#) drop down button and select “Myanmar”
click on the [Subject](#) drop down button and select “Administrative areas”
click “OK” and save the downloaded file as “MMR_adm2.shp” in the folder named “Downloaded Data” (or the name chosen)

1.3 Downloading land cover data

Now we are going to Download [Global land cover data](#) from the European Space Agency (ESA) with 300-meter resolution, for years 1995 and 2015. Please note that the **Appendix** outlines examples of the most frequently used earth observation data and we encourage you to investigate these examples.

To download the land cover data used in this exercise:

8. Click on the [link \(http://maps.elie.ucl.ac.be/CCI/viewer/download.php\)](http://maps.elie.ucl.ac.be/CCI/viewer/download.php)
9. When the landing page of “The Land Cover CCI Climate Research Data Package (CRDP)” emerges, you will be prompted to complete the section circled below to register and download the [Global land cover data](#). Provide **Name**, **Organisation** and a **Valid e-mail** as these are required fields.
10. After filling the required fields, read the “[Terms, conditions and privacy policy](#)” and check
“[I have read and agree...](#)”
11. Click “[Validate](#)”

Step 1 – Data downloading

climate change initiative
Land Cover

Data access

Please enter a few details about yourself, before downloading the requested product.

Name:

Organisation:

e-mail:

I have read and agree to the [Terms, conditions and privacy policy.](#)

After clicking “[Validate](#)”, a new page will appear from which you download the relevant data

12. Go to [Land Cover Maps-v2.0.7](#) Section

13. Click the link “[by_year: 24 tif files, 1 band](#)”

Land Cover Maps - v2.0.7

[Download product user guide](#) [Download quick user guide](#)



24 consistent global land cover maps at 300 m spatial resolution, on an annual basis from 1992 to 2015.

The annual LC maps v2.0.7 for years 2000, 2005 and 2010 replace completely the “v1.6.1 epoch-based” dataset as the annual LC maps v2.0.7 have been improved both in the representation of the areas stable over time and in the characterization of change.

Each pixel value corresponds to the label of a land cover class defined based on the UN Land Cover Classification System (LCCS). LCCS classifiers support the further conversion into Plant Functional Types distribution required by the Earth System Models. The typology counts 22 classes.

The 24 LC maps series is delivered along with 4 quality flags which document the products:

- *qualityflag1* pixel has been processed or not,
- *qualityflag2* pixel status as defined by the pre-processing,
- *qualityflag3* number of valid observations available to derive the classification,
- *qualityflag4* number of land cover changes detected over the 24 years.

These 4 quality flags document the full time series and are not year specific.

These maps are derived from a unique baseline LC map which is generated thanks to a classification chain applied on the entire MERIS FR and RR archive from 2003 to 2012.

Independently from this baseline, LC changes are detected at 1 km based on a time series of annual global classifications generated from AVHRR HRPT (1992 - 1999), SPOT-Vegetation (1999 - 2012) and PROBA-V (2013 - 2015). Systematic analysis of the temporal trajectory of each pixel allowed depicting the major changes for a simplified land cover typology matching the IPCC classes. These classes are: cropland, forest, grassland, wetlands, settlements and other lands; the latter class being further split into shrubland, sparse vegetation, bare area and water.

LC map 2015

- [1.tif file, zip_compression](#) - 258Mo
- [1.netcdf file, zip_compression](#) - 2.33Go

LC maps full 1992-2015 serie

- [1.tif file, 24_bands, zip_compression](#) - 846Mo
- [1.netcdf file, 24_bands, zip_compression](#) - 55.8Go
- [by_year: 24.tif files, 1_band](#) - approx. 300Mo/tif

ESACCI-LC for Sen2Cor data package

- [54.tif files, zip_compression](#) - 5.1Go

Rem: includes LC maps, water bodies v4 and snow products

Quality flags

- [1.tif file, 4_bands, zip_compression](#) - 2.13Go

Rem: already included in the 24-bands netcdf file

Legend

- [Legend \(.csv\)](#)
- [Symbology for ENVI \(.dsr\)](#)
- [Symbology for ArcGis \(.lyr\)](#)
- [Symbology for QGIS \(.qml\)](#)

14. After clicking the link, this window will appear:

Step 1 – Data downloading

Name	Size	Date Modified
CCILC-UW1_20170831_01_Armo-ESA_ESA_Contribution-to-GEO-LC.pdf	12.9 MB	9/25/17, 7:00:00 AM
CCILC-UW1_20170831_02_Defourny-UCLouvain_Global-annual-LC-time-series-from-1992-to-2015.pdf	6.4 MB	9/25/17, 7:00:00 AM
CCILC-UW1_20170831_03_Brockmann-BC_CCI-LC-Multi-mission-pre-processing-overview.pdf	7.0 MB	9/25/17, 7:00:00 AM
CCILC-UW1_20170831_04_Lamarche-UCLouvain_LC-change-and-seasonal-dynamics-within-the-CCI-LC-products.pdf	6.8 MB	5/15/18, 7:00:00 AM
CCILC-UW1_20170831_05_Achard-JRC_Quality-assessment-of-the-CCI-LC-maps.pdf	18.7 MB	9/25/17, 7:00:00 AM
CCILC-UW1_20170831_06_Kirches-BC_The-CCI-LC-user-tool.pdf	840 kB	9/25/17, 7:00:00 AM
CCILC-UW1_20170831_07_Santoro-GammaRS_The-CCI-water-body-products.pdf	1.8 MB	9/25/17, 7:00:00 AM
CCILC-UW1_20170831_08_MOHCUK-LSC-MPIM_Uncertainty-aspects-in-satellite-derived-LC-information.pdf	4.5 MB	9/25/17, 7:00:00 AM
CCILC-UW1_20170831_09_MOHCUK-LSC-MPIM_Impacts-of-consistent-global-annual-LC-maps-on-land-surface-models.pdf	4.2 MB	9/25/17, 7:00:00 AM
CCILC-UW1_20170831_10_Lamarche-UCLouvain_Lessons-learn-from-mapping-Africa-at-20-m-with-Sentinel-2A.pdf	9.5 MB	10/4/17, 7:00:00 AM
CCILC-UW1_20170831_11_Conchedde-FAO_CCI-LC-in-support-of-FAOSTAT-land-statistics.pdf	1.5 MB	9/25/17, 7:00:00 AM
CCILC-UW1_20170831_12_Curran-UNCCD_Contribution-of-the-CCI-LC-maps-to-UNCCD.pdf	2.3 MB	9/25/17, 7:00:00 AM
CCILC-UW1_20170831_13_Doeleman-PBL_Implementing-CCI-LC-in-the-HYDE-database-and-IMAGE.pdf	2.0 MB	9/25/17, 7:00:00 AM
CCILC-UW1_20170831_14_Durvilleir-JRC_Potential-changes-in-the-surface-energy-balance-due-to-changes-in-LC.pdf	3.8 MB	9/25/17, 7:00:00 AM
CCILC-UW1_20170831_Broadcast.mp4	7.6 GB	9/25/17, 7:00:00 AM
CCILC-UW1_20170831_extra_Mackie-OECD_Use-of-CCI-LC-for-per-pixel-change-assessment.pdf	185 kB	9/25/17, 7:00:00 AM
CCILC-UW1_20170831_extra_Wessis-GFW_Use-of-CCI-LC-in-Global-Forest-Watch.pdf	730 kB	9/25/17, 7:00:00 AM
ESACCI-LC-L4-ALL-FOR-SENCCOR.zip	5.1 GB	2/8/18, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1992-v2.0.7.tif	298 MB	3/9/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1992-v2.0.7b.nc	2.4 GB	7/3/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1992-2015-v2.0.7.zip	846 MB	3/13/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1992-2015-v2.0.7b.nc.zip	55.8 GB	10/8/18, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1993-v2.0.7.tif	298 MB	3/9/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1993-v2.0.7b.nc	2.4 GB	7/3/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1994-v2.0.7.tif	298 MB	3/9/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1994-v2.0.7b.nc	2.4 GB	7/3/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1995-v2.0.7.tif	298 MB	3/9/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1995-v2.0.7b.nc	2.4 GB	7/3/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1996-v2.0.7.tif	297 MB	3/9/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1996-v2.0.7b.nc	2.4 GB	7/3/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1997-v2.0.7.tif	297 MB	3/9/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1997-v2.0.7b.nc	2.4 GB	7/3/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1998-v2.0.7.tif	298 MB	3/9/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1998-v2.0.7b.nc	2.4 GB	7/3/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1999-v2.0.7.tif	298 MB	3/9/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-1999-v2.0.7b.nc	2.4 GB	7/3/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-2000-v2.0.7.tif	298 MB	3/9/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-2000-v2.0.7b.nc	2.4 GB	7/3/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-2001-v2.0.7.tif	297 MB	3/9/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-2001-v2.0.7b.nc	2.4 GB	7/3/17, 7:00:00 AM
ESACCI-LC-L4-LCCS-Map-300m-P1Y-2002-v2.0.7.tif	297 MB	3/9/17, 7:00:00 AM

15. In the window, look for the “.tif”⁶ files with the general title of “ESACCI-LC-L4-LCCS-Map-300m-P1Y” and the years of your choosing. For the exercise done in this guide, we looked for years 1995 and 2015 as we are comparing expansion of artificial surface for the 20-year period along the Ganga Bhrmaputra River Basin for a 20-year period. These are: [ESACCI-LC-L4-LCCS-Map-300m-P1Y-1995-v2.0.7.tif](#)
[ESACCI-LC-L4-LCCS-Map-300m-P1Y-2015-v2.0.7.tif](#)

16. Download these files and save them in a convenient folder of your choosing. For this exercise, we saved the files in a folder named “Downloaded Data”.

You have completed Step 1 – Data downloading! Well done so far!

⁶ Tagged Image File Format, abbreviated TIFF or TIF, is a computer file format for storing raster graphics images.

Step 2 – Data pre-processing

After we have downloaded the data, the next action is Data pre-processing done using QGIS. QGIS is a geographic information system that supports viewing, editing and analysis of geospatial data.

More information on how to download and install and use QGIS is provided in the **Appendix** to this guide.

The steps in this section can be described as trimming the data downloaded and extracting the data relevant to mapping land cover change.

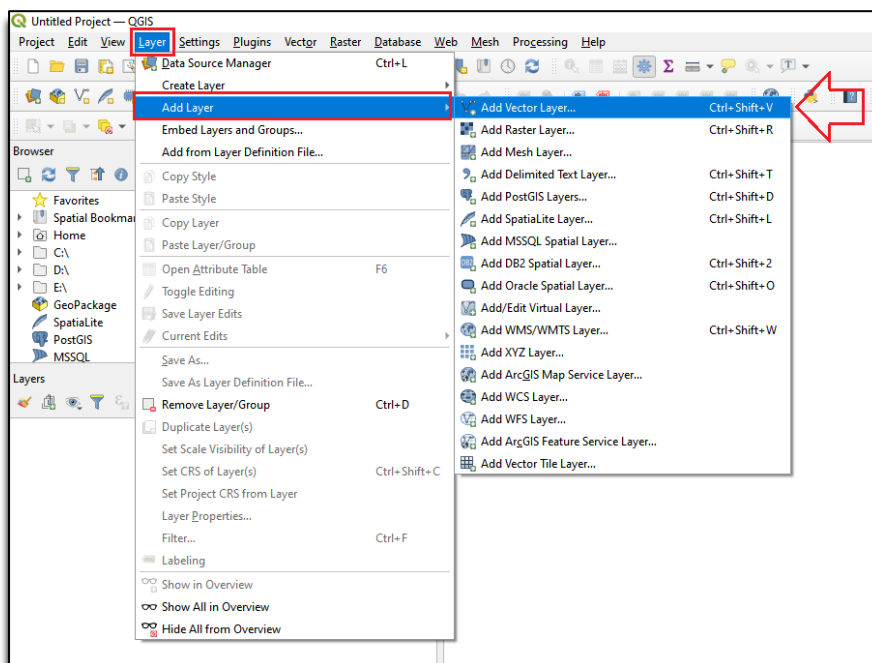
2.1 Extract Ganges-Brahmaputra River Basin

For this exercise, we created a new folder and named it “Data Pre-Processing”. We encourage that the user does the same or choose a folder name and location that is convenient.

Open [QGIS Desktop with GRASS](#), and do the following:


1. Click on “Layer”
2. Go to “Add Layer”
3. Select “Add Vector Layer”⁷

These steps are indicated in the picture shown below:

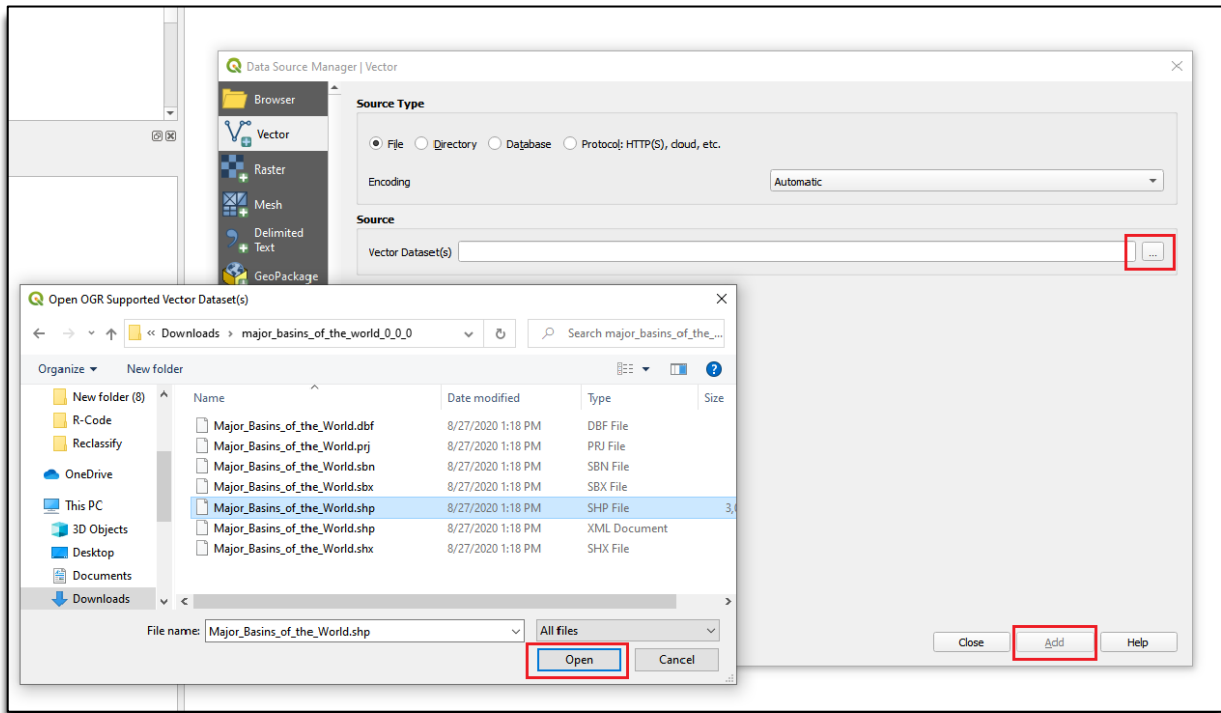


⁷ **Vector layers** are, along with raster **layers**, one of the two basic types of data structures that store data. **Vector layers** use the three basic GIS features – lines, points, and polygons – to represent real-world features in digital format.

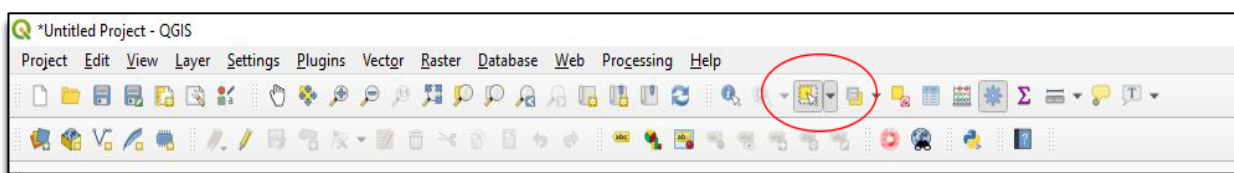
Step 2 – Data pre-processing

- Next, Click the **Browse** button  and select the file “Major River Basins in the World” in **.shp** file format
- Click “**Open**”
- Click “**Add**” and close the window

These steps are shown in the picture below:

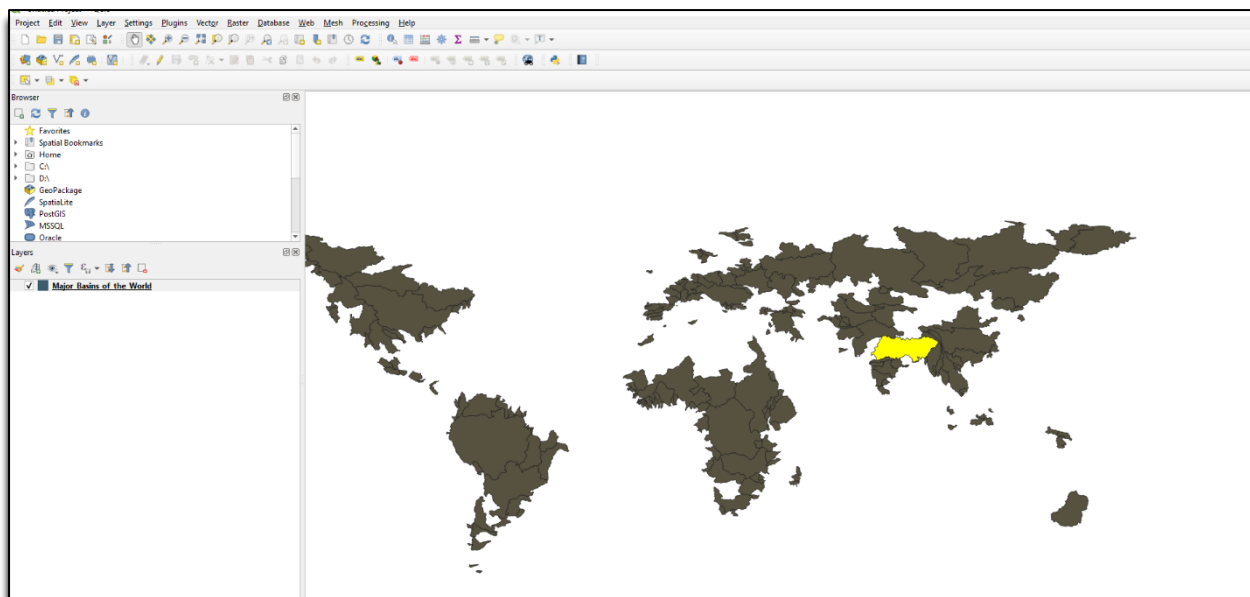


- On the toolbar, click the button “**Select**”, as outlined in the picture below:



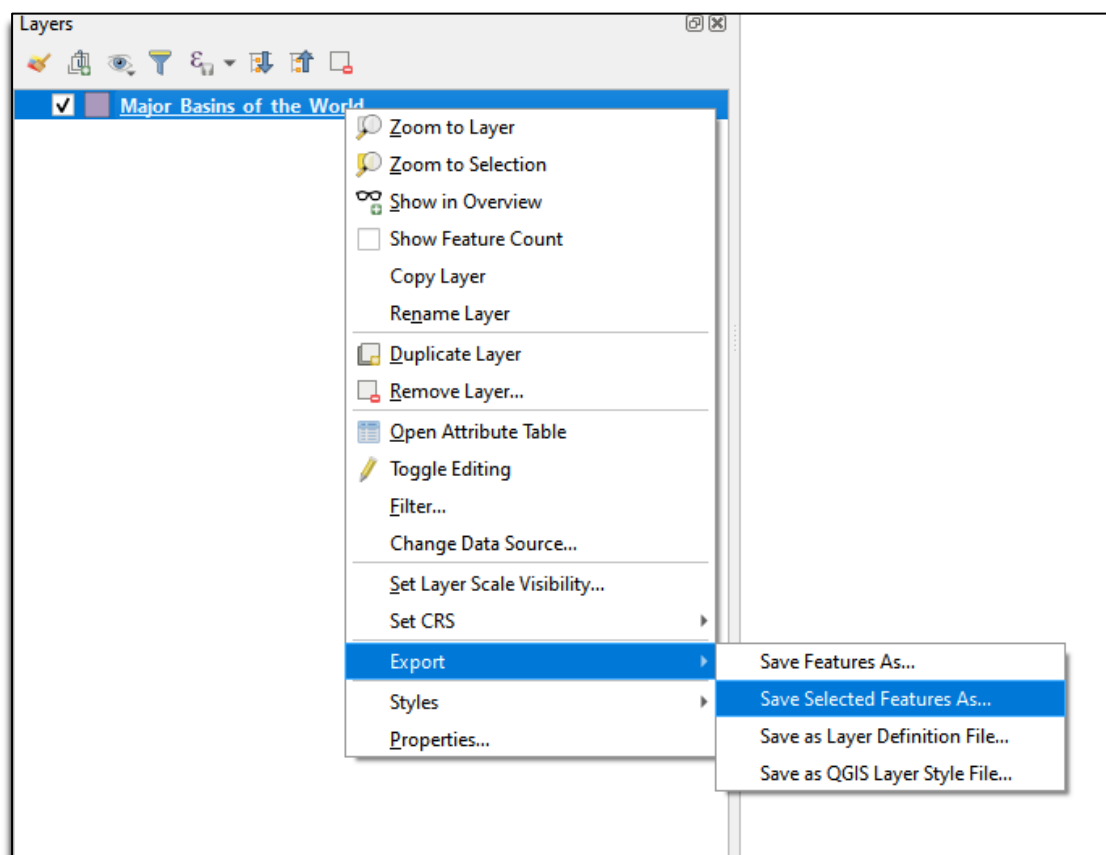
- In the map that appears on the Map Panel of the QGIS Interface, click on your chosen region to highlight it. In this exercise, we clicked to highlight the Ganga Bhramaputra Basin Admin in Shape File Form (**.shp**) and an image like the one below appears:

Step 2 – Data pre-processing



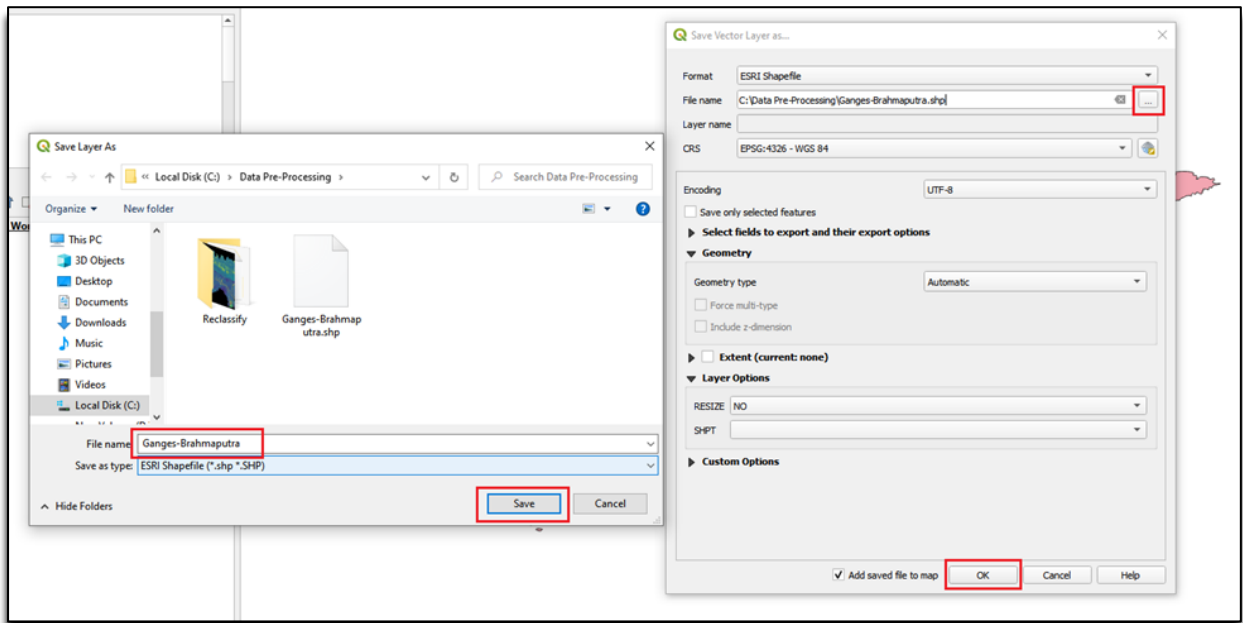
9. In the left bottom panel (called the layer panel) of the QGIS interface, right click on the file
“Major River Basins in the World”
10. Select “Export”
11. Select “Save Selected Features As”

These steps are highlighted in the picture below:



Step 2 – Data pre-processing

- Next, select “Browse” and open the folder “Data Pre-Processing” (or the folder that you chose)
- Name the File with a name of your choosing. For this exercise, we name it **Ganges-Brahmaputra.shp**
As noted in the picture below, please ensure that the “Format” is “ESRI Shapefile”. For some users, the default is .csv.
- Click “Save”
- Click “OK”



- In the Layer Panel, right click on “Major River Basins of the World”
- Click “Remove Layer”

This step has extracted the relevant Ganges-Brahmaputra from the river basin data and has removed data that is not relevant.

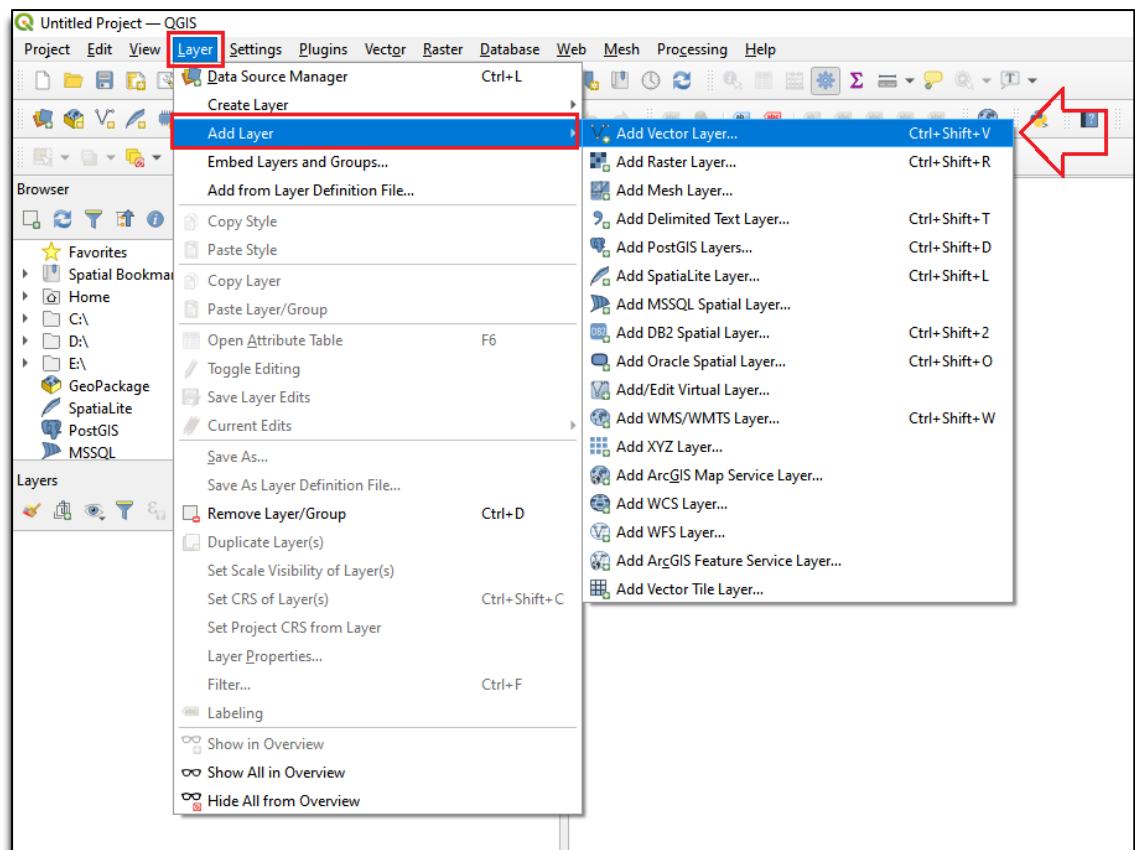
2.2 Extract Admin Boundaries of Ganges-Brahmaputra River Basin

These next steps extract the relevant respective boundaries of the Ganges-Brahmautra River Basin

- Click on “Layer”
- Go to “Add Layer”
- Select “Add Vector Layer”⁸

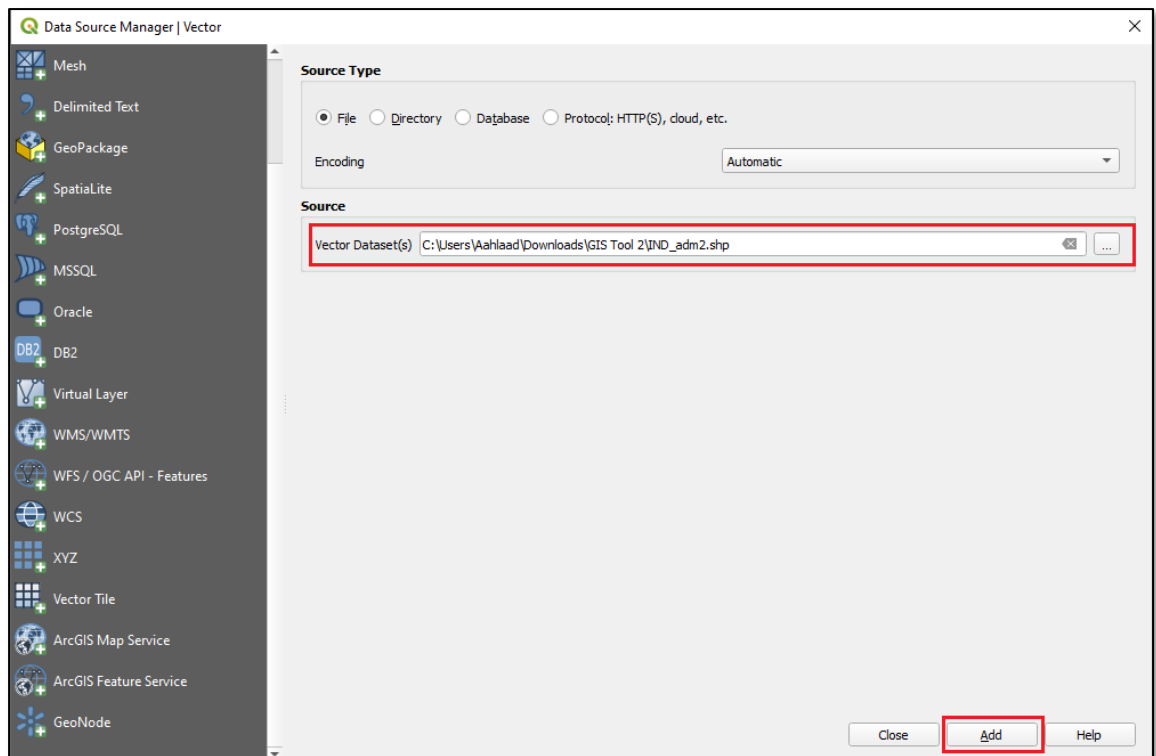
⁸ **Vector layers** are, along with raster **layers**, one of the two basic types of data structures that store data. **Vector layers** use the three basic GIS features – lines, points, and polygons – to represent real-world features in digital format.


Step 2 – Data pre-processing




4. Next, Click the Browse button and select the file "IND_adm2" in .shp file format
5. Again, Click on "Layer"
6. Go to "Add Layer"
7. Select "Add Vector Layer"

Step 2 – Data pre-processing





8. Next, Click the **Browse button**  and select the file “NPL_adm2” in .shp file format
9. Click “Open”
10. Click “Add” and close the window

11. Again, Click on “Layer”
12. Go to “Add Layer”
13. Select “Add Vector Layer”


14. Next, Click the **Browse button**  and select the file “BGD_adm2” in .shp file format
15. Click “Open”
16. Click “Add” and close the window

17. Again, Click on “Layer”
18. Go to “Add Layer”
19. Select “Add Vector Layer”

20. Next, Click the **Browse button**  and select the file “CHN_adm2” in .shp file format
21. Click “Open”
22. Click “Add” and close the window
23. Again, Click on “Layer”
24. Go to “Add Layer”
25. Select “Add Vector Layer”


26. Next, Click the **Browse button**  and select the file “BTN_adm1” in .shp file format
27. Click “Open”
28. Click “Add” and close the window

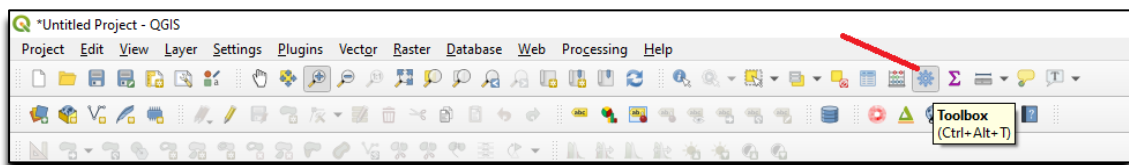
Step 2 – Data pre-processing

29. Again, Click on “Layer”
30. Go to “Add Layer”
31. Select “Add Vector Layer”
32. Next, Click the [Browse button](#)  and select the file “MMR_adm2” in .shp file format
33. Click “Open”
34. Click “Add” and close the window

2.3 Merging vector layers in QGIS

In this step, we merge into QGIS the vector files downloaded in the steps above.

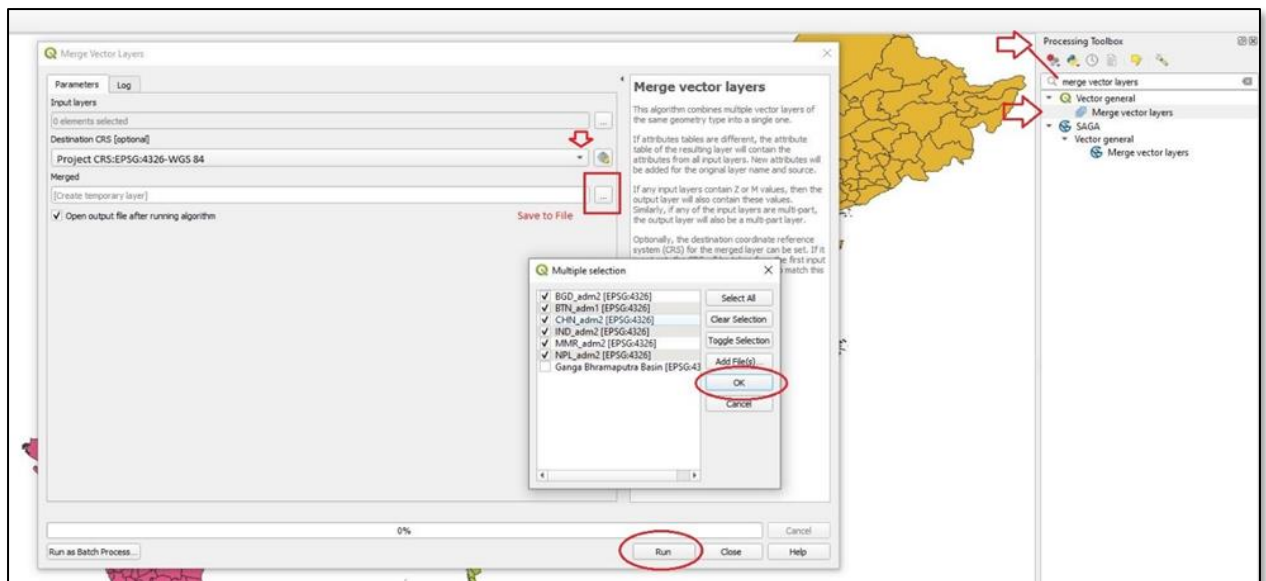
1. For first-time QGIS downloads, click the button highlighted in the  picture below, as the [Processing Toolbox](#) may not appear automatically



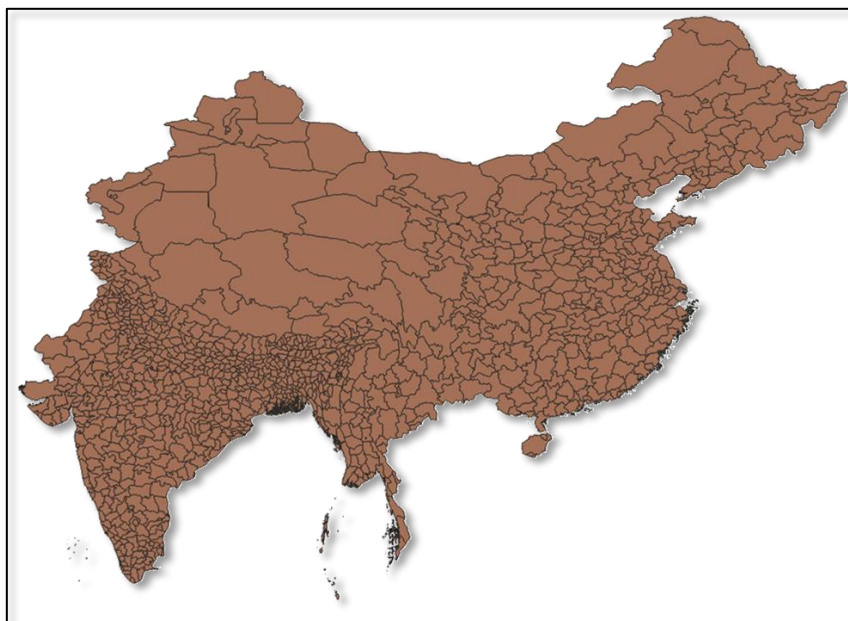
2. When the [Processing Toolbox](#) appears, search for “Merge Vector Layers”
3. In the window that appears, complete the Parameters as follows:
 - a. Input Layer = Select all the Vector Layers saved; as shown in the picture below
“IND_adm2”
“NPL_adm2”
“BGD_adm2”
“CHN_adm2”
“BTN_adm1”
“MMR_adm2”
Click on “OK”
 - b. Destination CRS [optional] = “Project CRS: EPSG: 4326.WGS84”
 - c. Merged = Select “Browse” and click “Save to File” and save the file as “Merged.shp” or a name of your choosing
 - d. Click “Run”
 - e. Click “Close” after the Program runs

These steps are shown in the picture shown below:

Step 2 – Data pre-processing

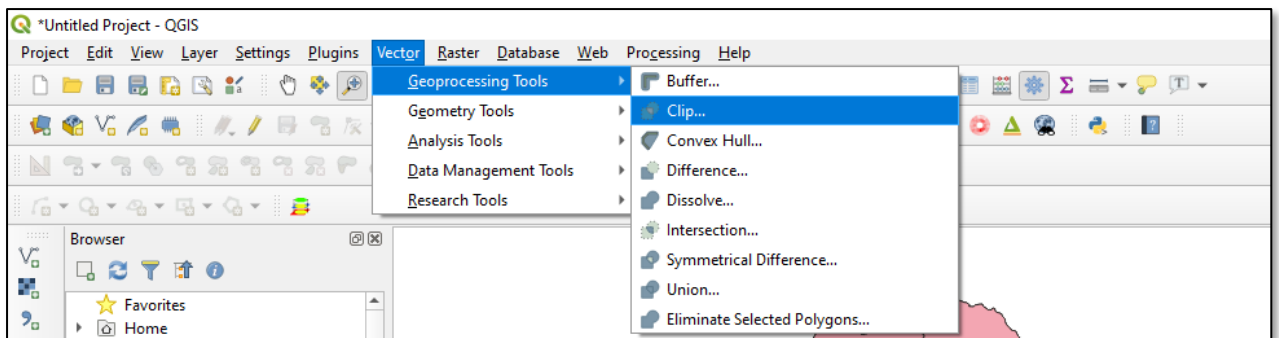


After running these steps, a picture like the one below should appear:



4. Next, Click on “Vector”
5. Go to “Geoprocessing Tools”
6. Select “Clip”

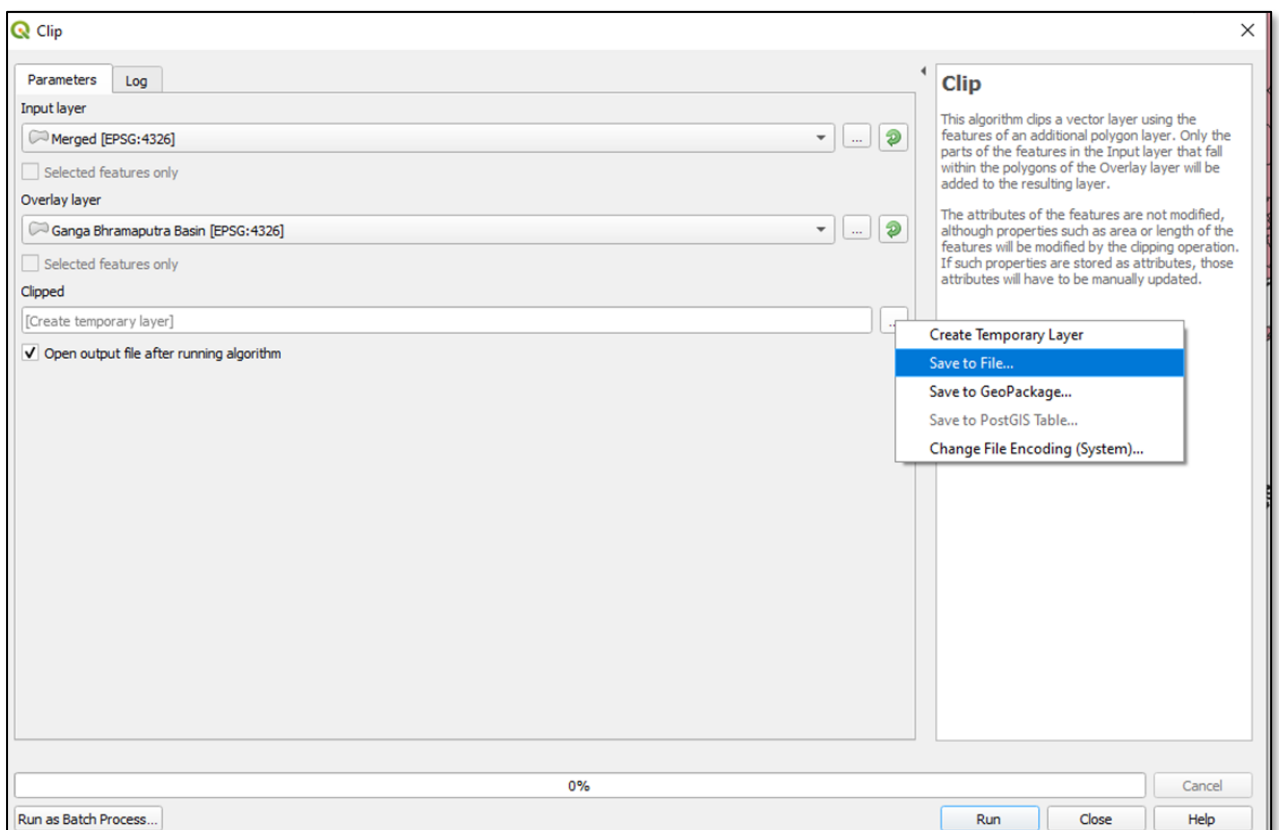
Step 2 – Data pre-processing



7. In the window that appears, complete the Parameters as follows:

- a. Input layer = "Merged [EPSG:4326]"
- b. Overlay layer = "Ganga Brahmaputra Basin [EPSG:4326]"
- c. Clipped = Select "Browse" and click "Save to File"
- d. Save File as "Ganga Brahmaputra Basin Admin" (or a name of your choosing)
- e. Click "Run"
- f. Click "Close" after the Program runs

These steps are shown in the picture shown below:

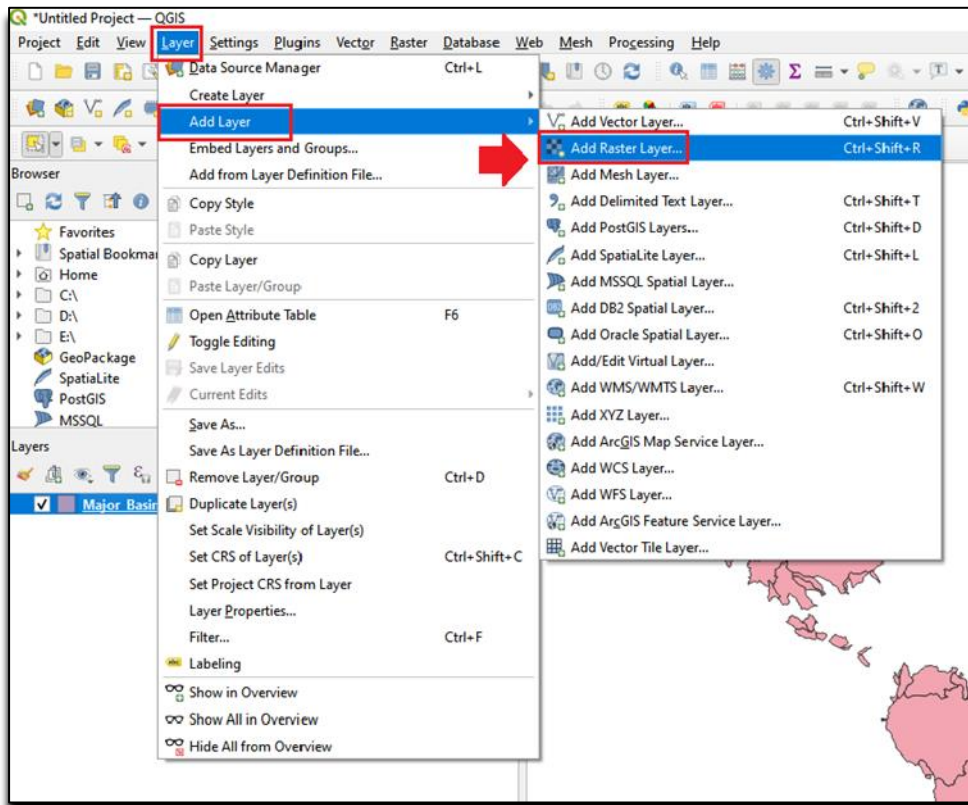



2.4 Adding ESA land cover data to QGIS

The next steps add the ESA Global land cover datasets to QGIS:

Step 2 – Data pre-processing

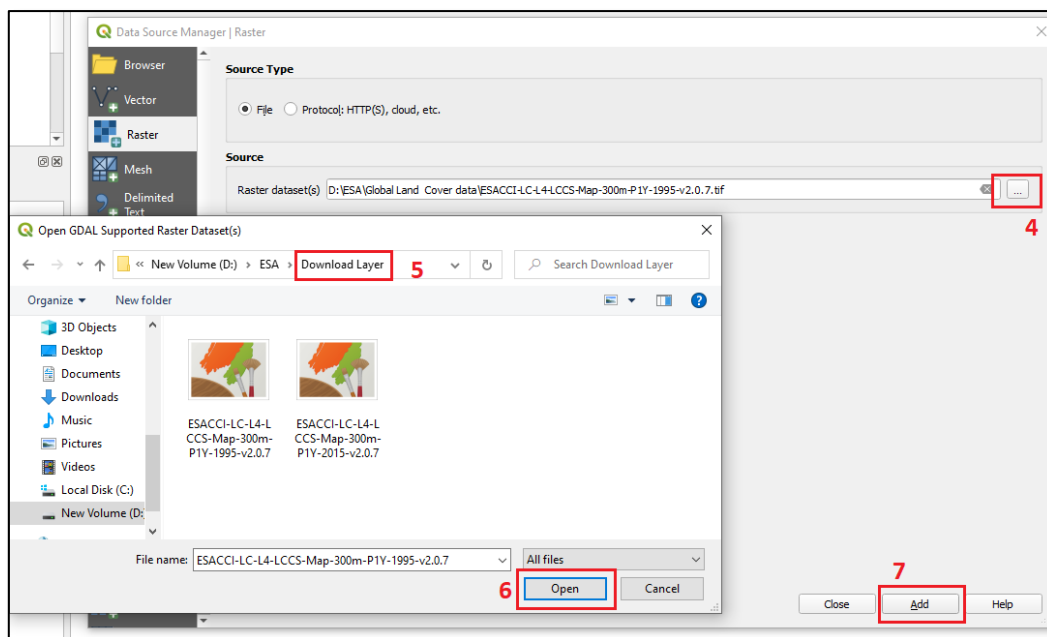
1. On the QGIS toolbar, click on “Layer”
2. Click on “Add Layer”
3. Select “Add Raster Layer”⁹




4. A new window will appear; click on  as illustrated in the picture below
5. Select “Download Layer”
6. Open “ESACCI-LC-L4-LCCS-Map-300m-P1Y-1995-v2.0.7.tif”
7. Click “Add”

⁹ A **raster** consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information. **Rasters** are digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps.

Step 2 – Data pre-processing



8. Again, click on  as illustrated in the picture above
9. Select “Download Layer”
10. Open “ESACCI-LC-L4-LCCS-Map-300m-P1Y-2015-v2.0.7.tif”
11. Click “Add”

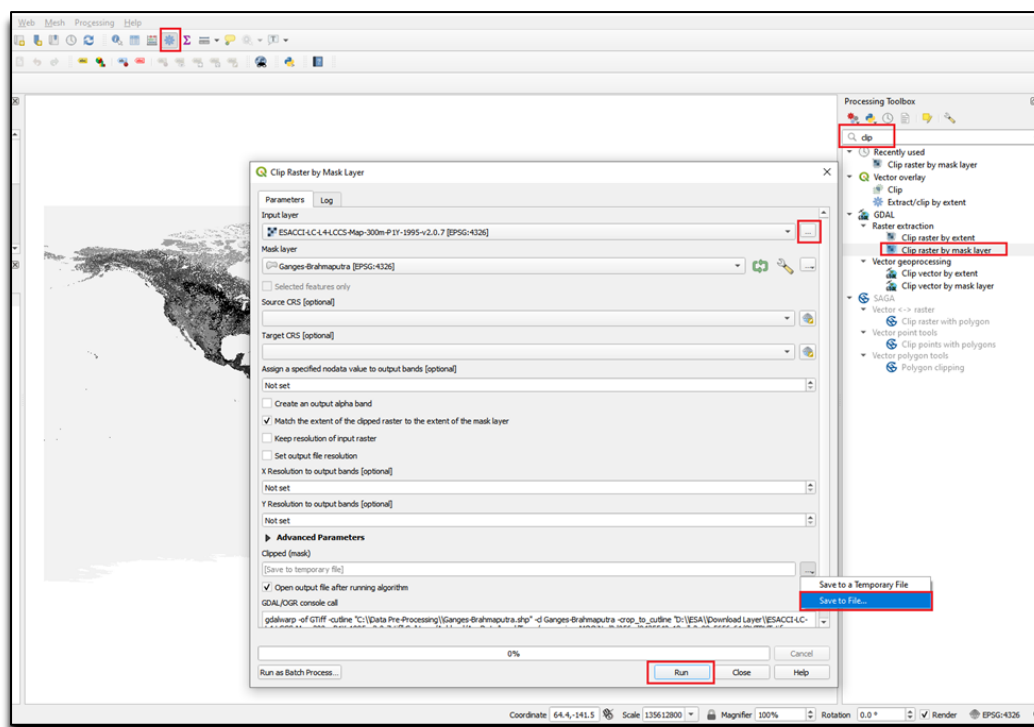
2.5 Clipping ESA Global land cover datasets

The next steps add the ESA Global land cover datasets to QGIS, and layers each respective file with the extracted [Ganges-Brahmaputra.shp](#) file

1. Go to the [Processing Toolbox](#), search for “Clip”
2. Select “Clip Raster by Mask Layer”
3. In the window that appears, complete the Parameters as follows:
 - a. Input Layer = “ESACCI-LC-L4-LCCS-Map-300m-P1Y-1995-v2.07.tif” by clicking the drop-down button
 - b. Mask Layer = “Ganges-Brahmaputra.shp”
 - c. Assign a specified no data value to output bands [optional] = “Not set”
 - d. Select “Match the extent of the clipped raster to the extent of the mask layer”
 - e. Under “Advanced Parameters” Heading, by Clipped (mask), click [Browse](#) button
 - f. Select “Save To File” and name it “Year 1995 Land Cover”
 - g. Click “Run”
 - h. Click “Close” after the Program runs

These steps are outlined in the picture below:

Step 2 – Data pre-processing



The 1995 Ganges- Brahmaputra River Basin Mask Layer should now appear in the window.

4. In the **Processing Toolbox**, search for “Clip”
5. Select “Clip Raster by Mask Layer”
6. In the window that appears, complete the Parameters as follows:
 - a. Input Layer = “ESACCI-LC-L4-LCCS-Map-300m-P1Y-2015-v2.07.tif” by clicking the drop-down button
 - b. Mask Layer = “Ganges-Brahmaputra.shp”
 - c. Assign a specified nodata value to output bands [optional] = Set as default
 - d. Select “Match the extent of the clipped raster to the extent of the mask layer”
 - e. Under “Advanced Parameters” Heading, by Clipped (mask), click **Browse** button
 - f. Select “Save To File” and name it “Year 2015 Land Cover”
 - g. Click “Run”
 - h. Click “Close” after the Program runs

The 2015 Ganges- Brahmaputra River Basin Mask Layer should now appear in the window.

7. In Layer Panel, right click on “ESACCI-LC-L4-LCCS-Map-300m-P1Y-1995-v2.07.tif”
8. Click “Remove Layers”
9. In Layer Panel, right click on “ESACCI-LC-L4-LCCS-Map-300m-P1Y-2015-v2.07.tif”
10. Click “Remove Layers”

You have completed Step 2 – Data pre-processing! Let’s keep going!

Step 3 – Data processing and visualization

In this section, we will show how to present the findings of the land cover change analysis via the following sections:

1. Reclassifying the ESA global land cover data into two types – urban (built-up) and non-urban (non built-up). Please note that **built-up** under the ESA land cover classification is equivalent to **artificial surfaces** under the SEEA land cover classification.
2. Visualize the urban hot spots and the rate of the expansion of artificial surfaces for the respective 5-year intervals using maps developed in QGIS

3.1 Converting ESA to urban (built-up) and non-urban (non built-up)

For the purposes of our urban hot-spot mapping, the 31 ESA Classifications are reclassified into built-up and non-built-up. The resulting conversion is used to illustrate the expansion of artificial surfaces along the Ganga Brahmaputra River Basin in this guide.

According to the ESA, land cover classification is distinguished into 31 classifications as shown in the figure below and discrete numbers are assigned to each category, with values ranging from 0 (“No Data”) to 220 (“Permanent Snow and Ice”).

Value	Label	Color
0	No Data	
10	Cropland, rainfed	
11	Herbaceous cover	
12	Tree or shrub cover	
20	Cropland, irrigated or post-flooding	
30	Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)	
40	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%)	
50	Tree cover, broadleaved, evergreen, closed to open (>15%)	
60	Tree cover, broadleaved, deciduous, closed to open (>15%)	
61	Tree cover, broadleaved, deciduous, closed (>40%)	
62	Tree cover, broadleaved, deciduous, open (15-40%)	
70	Tree cover, needleleaved, evergreen, closed to open (>15%)	
71	Tree cover, needleleaved, evergreen, closed (>40%)	
72	Tree cover, needleleaved, evergreen, open (15-40%)	
80	Tree cover, needleleaved, deciduous, closed to open (>15%)	
81	Tree cover, needleleaved, deciduous, closed (>40%)	
82	Tree cover, needleleaved, deciduous, open (15-40%)	
90	Tree cover, mixed leaf type (broadleaved and needleleaved)	
100	Mosaic tree and shrub (>50%) / herbaceous cover (<50%)	
110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)	
120	Shrubland	
121	Evergreen shrubland	
122	Deciduous shrubland	
130	Grassland	
140	Lichens and mosses	
150	Sparse vegetation (tree, shrub, herbaceous cover) (<15%)	
151	Sparse tree (<15%)	
152	Sparse shrub (<15%)	
153	Sparse herbaceous cover (<15%)	
160	Tree cover, flooded, fresh or brakish water	
170	Tree cover, flooded, saline water	
180	Shrub or herbaceous cover, flooded, fresh/saline/brakish water	
190	Urban areas	
200	Bare areas	
201	Consolidated bare areas	
202	Unconsolidated bare areas	
210	Water bodies	
220	Permanent snow and ice	

There are individual colors assigned to each of the 31 Classifications. Class 190 represents built-up areas; all other classes represent non-built-up areas.

Step 3 – Data processing and visualization

The steps in this section show how to simplify the ESA land cover classifications into built-up and non-built-up to show the rate of expansion of artificial surfaces.

The reclassification is done for all the land cover data downloaded, namely the [Year 1995 Land](#) and the [Year 2015 Land Cover](#) files.

1. Open “Notepad” (for Windows)
2. Copy Text as follows
0 thru 180 = 0
190 = 1
191 thru 220 = 0
3. Save as “[Built up and non built up](#)” and Close
4. In the Processing toolbox, search for “[reclass](#)” in the Search bar
5. Select “[r.reclass](#)” and a new window appears
6. In the window that appears, complete the Parameters as follows:
 - a. Input Raster Layer = “[Year 1995 Land Cover](#)” by clicking the drop-down button
 - b. For file containing reclass rules = click the [Browse button](#) and look for the Notepad entitled “[Built up and non built up](#)”, as previously saved
 - c. Under the “[Advanced Parameters](#)” heading, and then under the “[Reclassified](#)” heading, click the [Browse button](#)
 - d. Select “[Save To File](#)” and name it “[Year 1995 Reclass](#)” in a new folder entitled “[Reclassify](#)”
 - e. Click “[Run](#)”
 - f. Click “[Close](#)” after the Program runs

Now, for the reclassification for the [Year 2015 Land Cover Layer](#):

7. In the Processing toolbox, search for “[reclass](#)” in the Search bar
8. Select “[r.reclass](#)” and a new window appears
9. In the window that appears, complete the Parameters as follows:
 - a. Input Raster Layer = “[Year 2015 Land Cover](#)” by clicking the drop-down button
 - b. For file containing reclass rules = click the [Browse button](#) and look for the Notepad entitled “[Built up and non built up](#)”, as previously saved
 - c. Under the “[Advanced Parameters](#)” heading, and then under the “[Reclassified](#)” heading, click the [Browse button](#)
 - d. Select “[Save To File](#)” and name it “[Year 2015 Reclass](#)” in a new folder entitled “[Reclassify](#)”
 - e. Click “[Run](#)”
 - f. Click “[Close](#)” after the Program runs

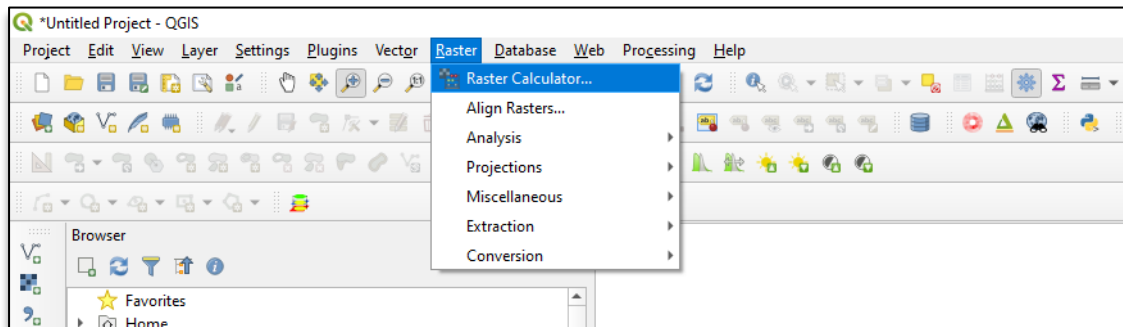
These steps remove the layers that have now become irrelevant and keep only the “[Year 1995 Reclass](#),” “[Year 2015 Reclass](#)” and “[Ganga Brahmaputra Basin Admin](#)” Layers:

10. In the Layers Panel, right click on all other layers (except the “[Year 1995 Reclass](#),” “[Year 2015 Reclass](#)” and “[Ganga Brahmaputra Basin Admin](#)” layers)
11. Click “[Remove Layers](#)”

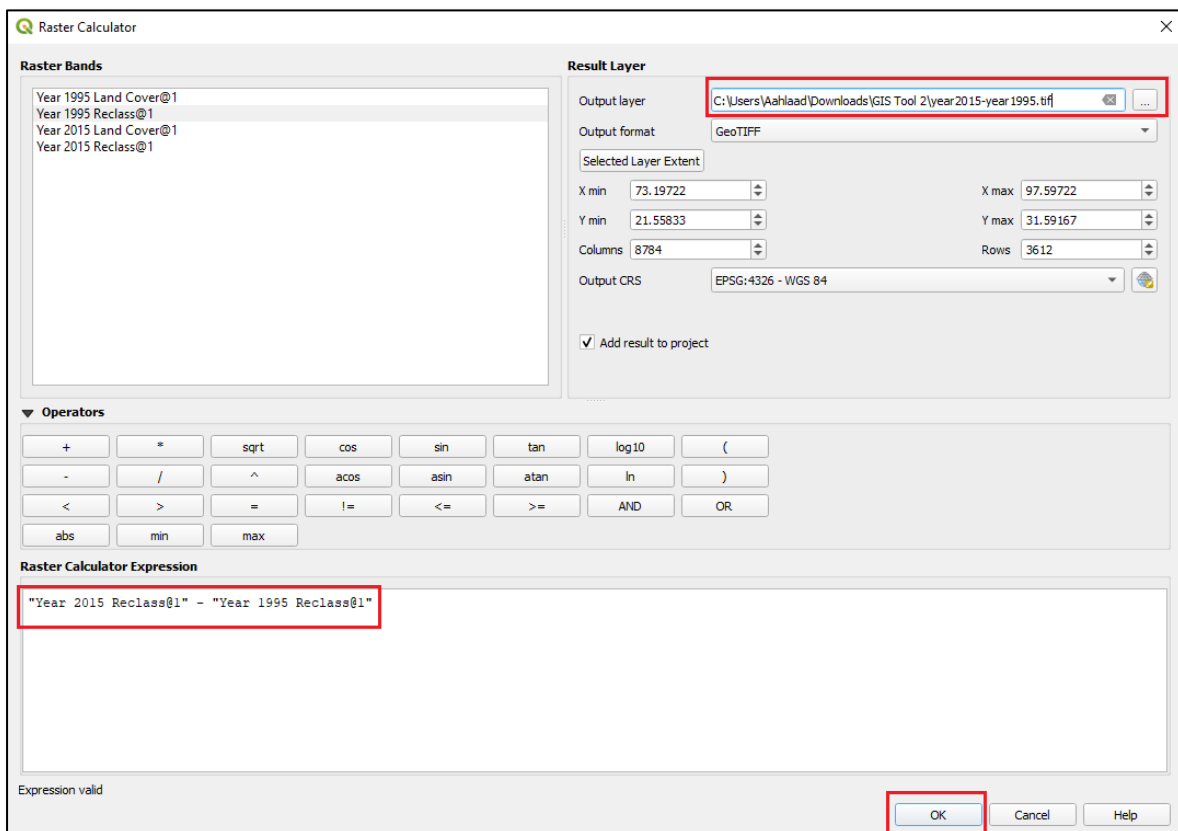
3.2 Raster Calculator

The next steps show how to make the raster calculation to show the difference in expansion of artificial surfaces for the time periods being analysed.

1. In the Processing toolbox, select “Raster”
2. Select “Raster Calculator”



3. In the window that appears, complete the parameters as follows:
 - a. Raster Calculator Expression = “Year 2015 Reclass@1” – “Year 1995 Reclass@1”
 - b. Result Layer = click “Browse” and save the layer in a location of your choosing and assign the name “year2015-year1995.tif”
 - c. Output format = “GeoTiff”
 - d. All other parameters are kept as default
 - e. Click “OK” to see the output difference result

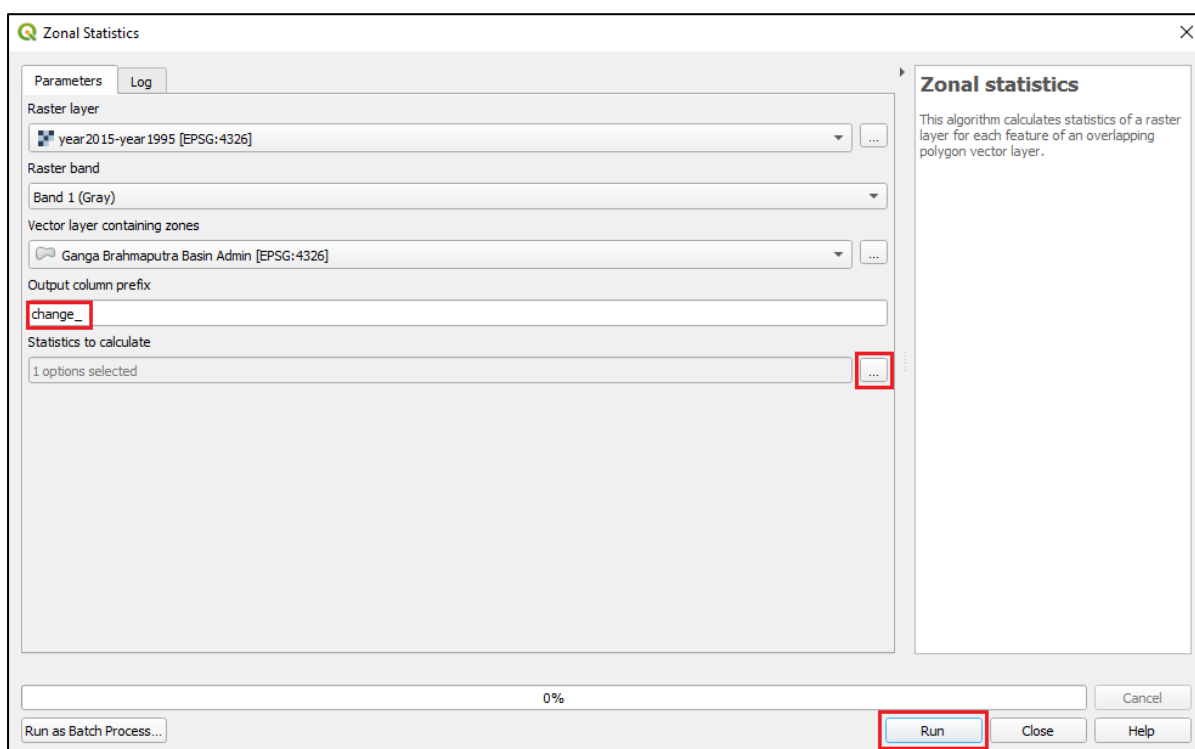


3.3 Summing urban land change pixels

The next steps show how to sum the land cover change pixels to visualize the difference in expansion of artificial surfaces for the time periods being analysed.

1. In the Processing Toolbox, search for “zonal statistics”
2. In the window that appears, complete the parameters as follows:
 - a. Raster layer = “year2015-year1995 [EPSG: 4326]”
 - b. Raster band = default
 - c. Vector Layer containing areas = “Ganga Brahmaputra Basin Admin [EPSG: 4326]”
 - d. Output column prefix = “change_”
 - e. Statistics to calculate = click “Browse” and in the window that appears, select “Sum” and click “OK”
 - f. Click “Run”
 - g. Click “Close” after the Program runs

These steps are shown in the picture below:

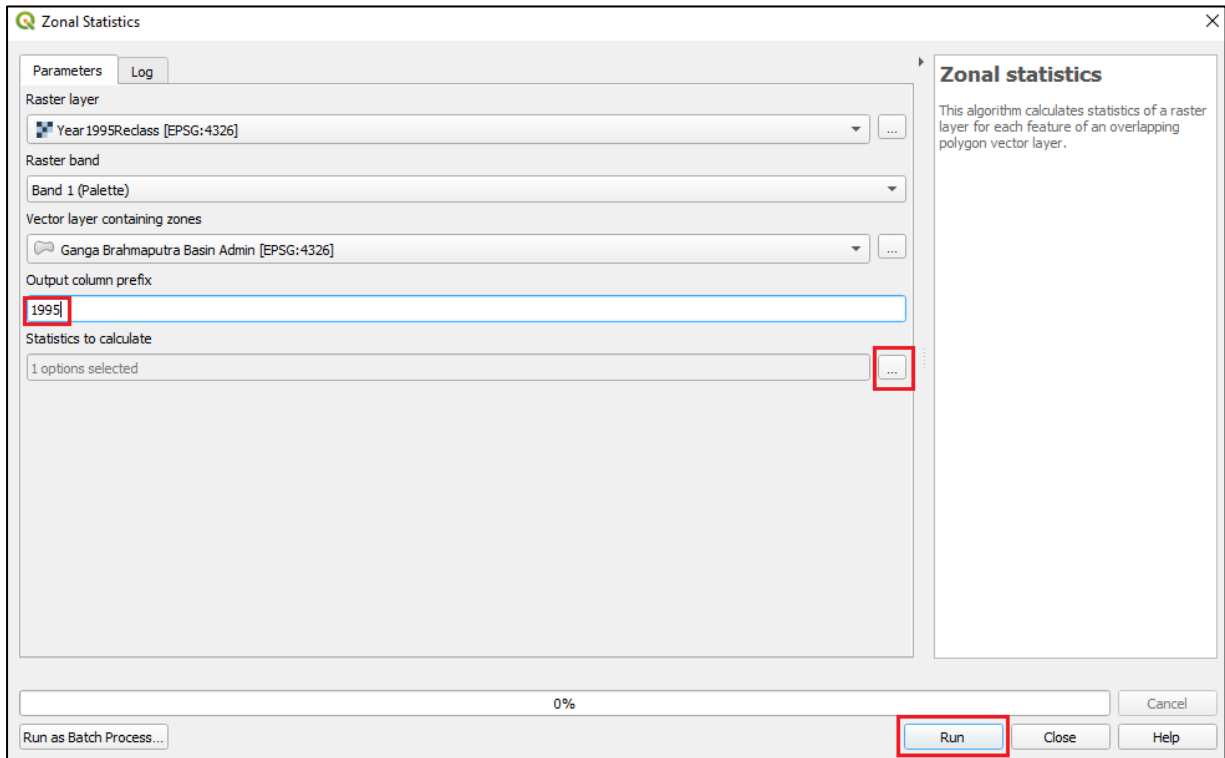


3. In the Processing Toolbox, search for “zonal statistics”
4. In the window that appears, complete the parameters as follows:
 - a. Raster layer = “Year 1995 Land Cover [EPSG: 4326]”
 - b. Raster band = default
 - c. Vector Layer containing areas = “Ganga Brahmaputra Basin Admin [EPSG: 4326]”
 - d. Output column prefix = “1995”

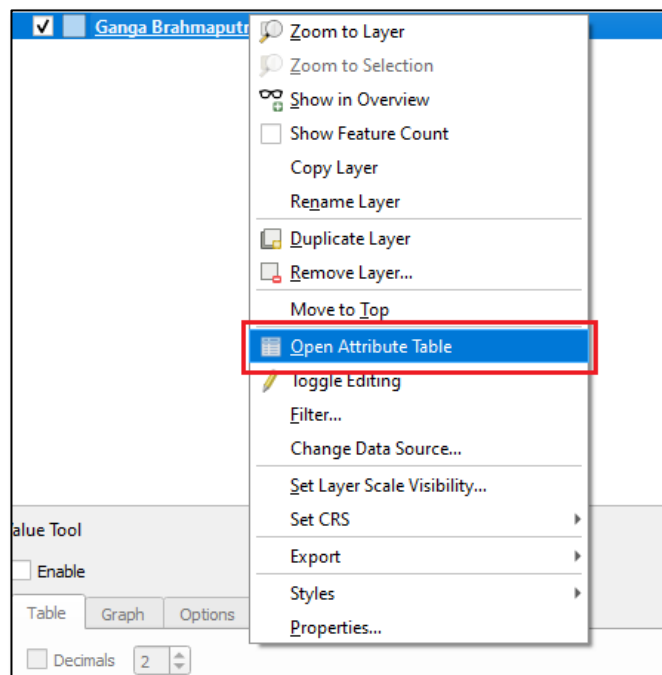
Step 3 – Data processing and visualization

- e. Statistics to calculate = click “Browse” and in the window that appears, select “Sum” and click “OK”
- f. Click “Run”
- g. Click “Close” after the Program runs


These steps are shown in the picture below:

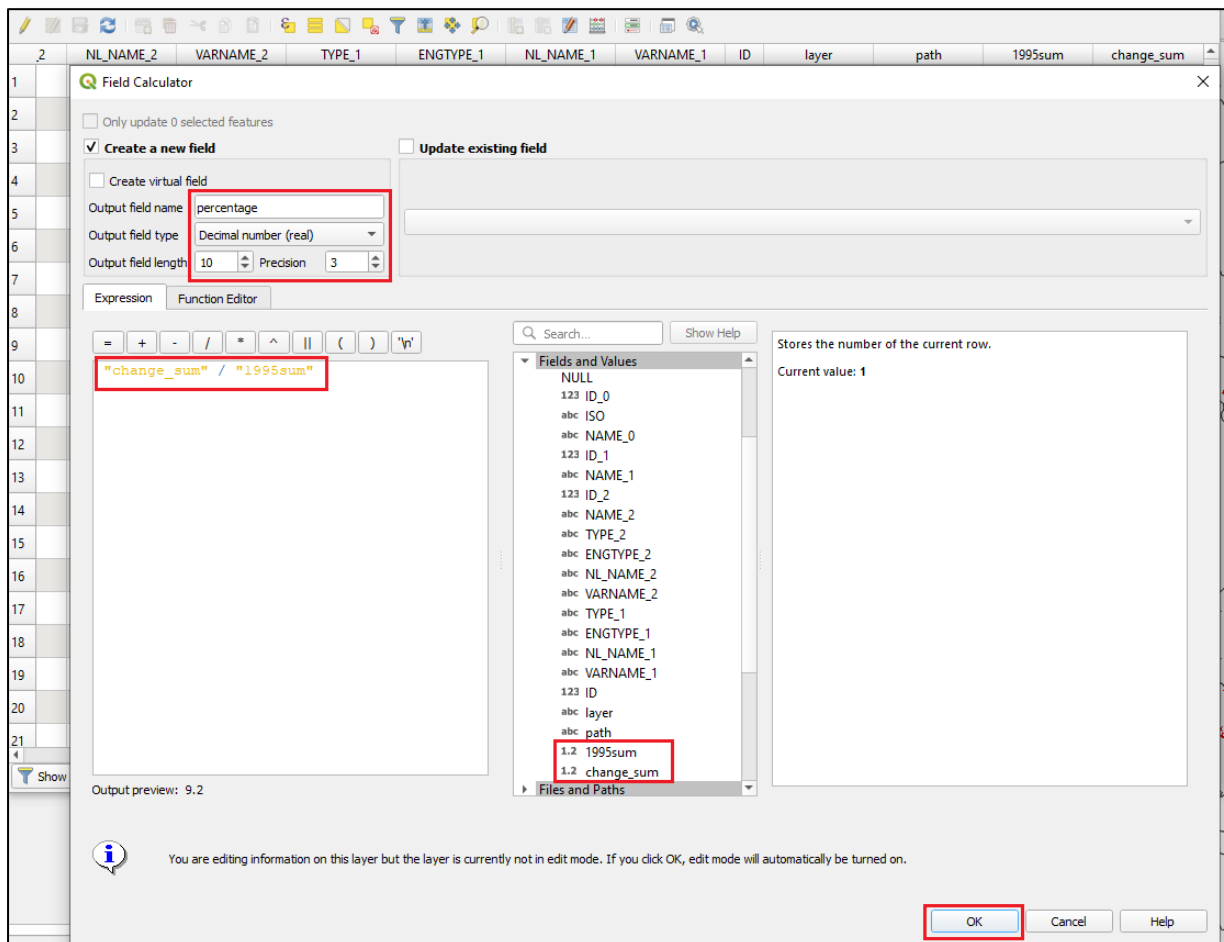



5. In the Layer Panel, right click on = “Ganga Brahmaputra Basin Admin” and click “Open Attribute Table” as in the picture below:



Step 3 – Data processing and visualization

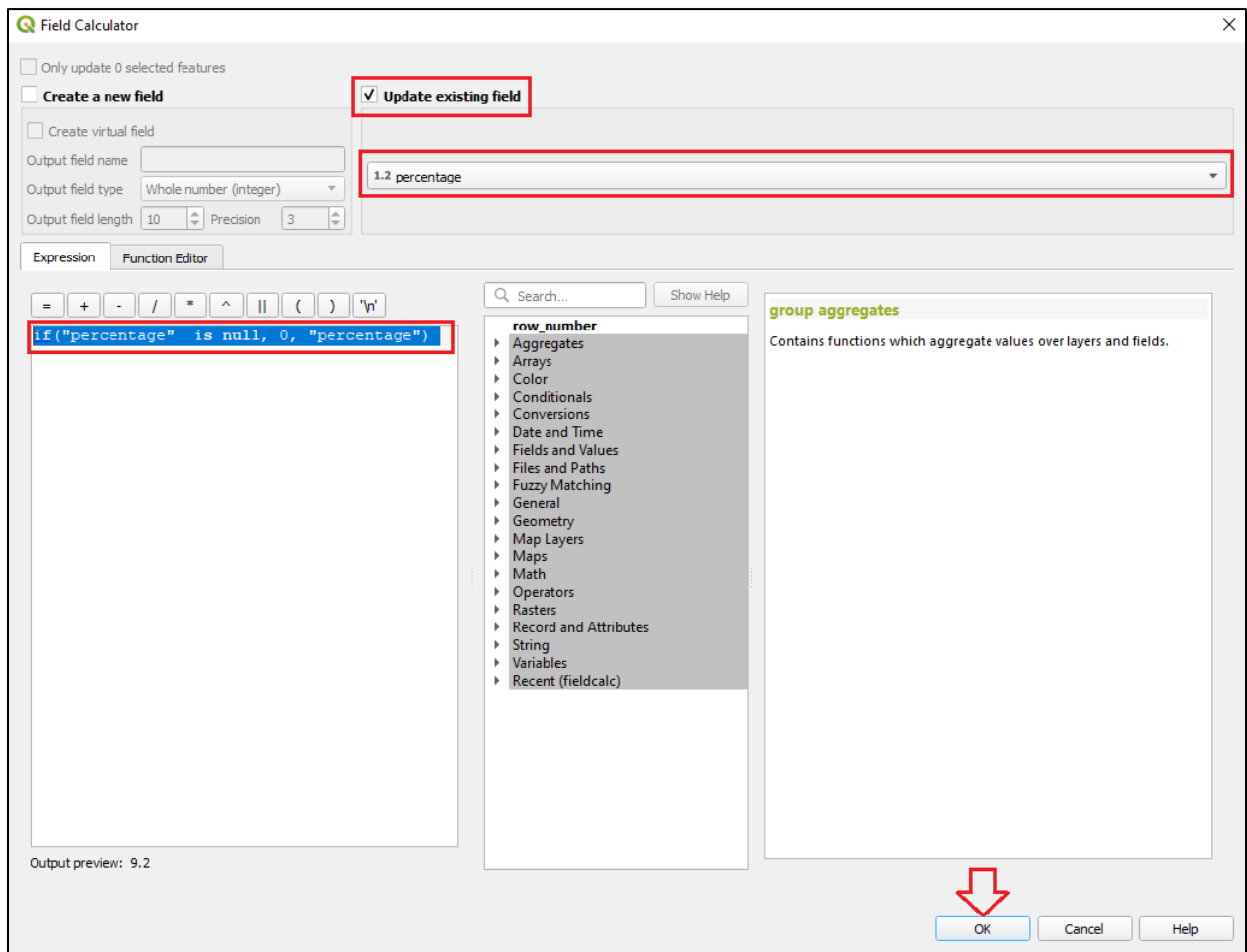
6. In the new window that appears, click on “Field Calculator” .
7. In the new window that appears, complete the parameters as follows:
 - a. Output field name = “percentage”
 - b. Output field type = “Decimal number (real)”
 - c. Output field length = “10”
 - d. Precision = “3”



- e. In the description panel to the left, type the formula “change_sum” / “1995sum” as shown above
 - f. Click “OK”
8. Again, click on “Field Calculator” .
 9. Select “Update existing field”
 10. Click the dropdown button and select “percentage”
 11. In the description panel to the left, type the condition “if(“percentage” is null, 0, “percentage”)”
 12. Click “OK”

These steps are seen in the picture below.

Step 3 – Data processing and visualization



Expansion of artificial surfaces – Colors and Labels

We continue with categorizing the rate of expansion of artificial surfaces for the period 1995 – 2015.

The methodology compares the number of built-up pixels (i.e. pixels indicating a built-up area) at the beginning and end of a time period; in this example we compare 1995 with 2015. The rate of expansion is then calculated using the change in the number of built-up pixels during the period and divides it by the number of built-up pixels at the end of the period.

The legend on the map was generated using the Natural Breaks (Jenks) Mode in QGIS. This method is pre-programmed in QGIS, and arranges the rate of expansion of natural surfaces into natural classes by minimizing the variance of the rate of increase within classes and maximizing the statistical variance of increase between classes.

The table below gives the details of the levels of expansion of artificial surfaces according to the Natural Breaks (Jenks) Mode as seen on the map:

Rate of increase of built-up pixels between 1995 and 2015 (%)	Level of expansion of artificial surfaces (according to Natural Breaks (Jenks) Mode)
0.00 – 3.70	1
3.70 – 11.00	2
11.00 – 27.30	3
27.30 – 53.00	4
53.00 – 132.00	5

The threshold for what constitutes an “urban hot spot” can be determined by the user.

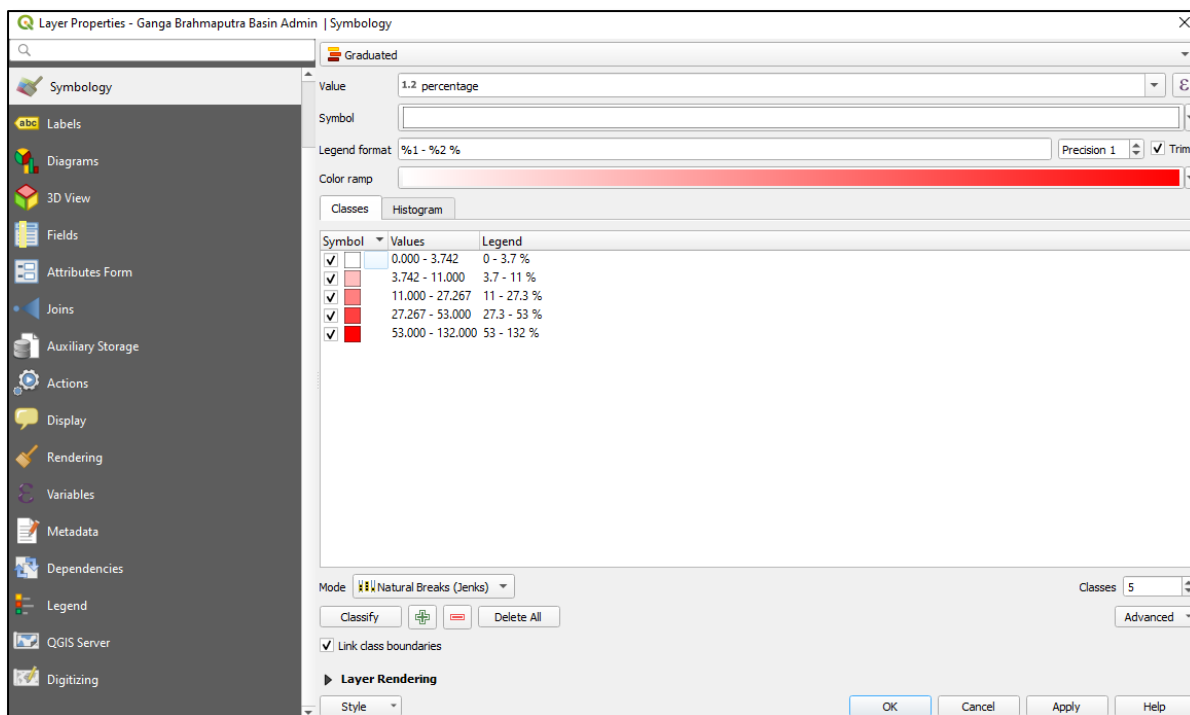
This section of steps shows how to make the labels and colors to show the expansion of artificial surfaces.

The Steps to change the colors and labels are as follows:

1. In Layer Panel, right click on “Ganga Brahmaputra Basin Admin”
2. Click “Properties”
3. Click “Symbology”
4. Click the drop-down button at the top and choose “Graduated”
5. Under “Value,” click the drop-down button and choose “percentage”
6. Under “Legend format,” choose “%1 - %2”
7. Under “Method,” choose “Color ramp”
8. Under “Mode,” look for “Natural Breaks (Jenks)” in the dropdown box
9. Under “Classes,” select 5
10. Click “OK”

These steps are outlined in the picture below:

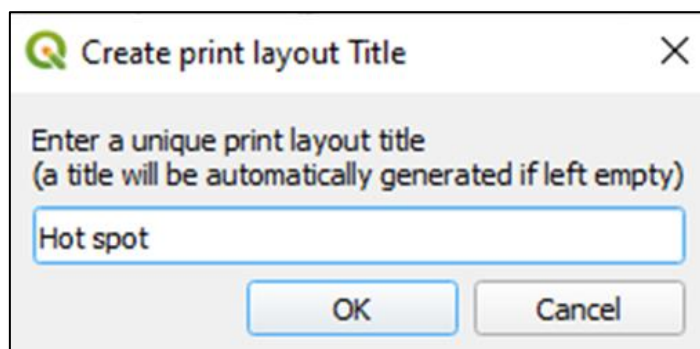
Step 3 – Data processing and visualization




3.4 Mapping expansion of artificial surfaces along the river basin

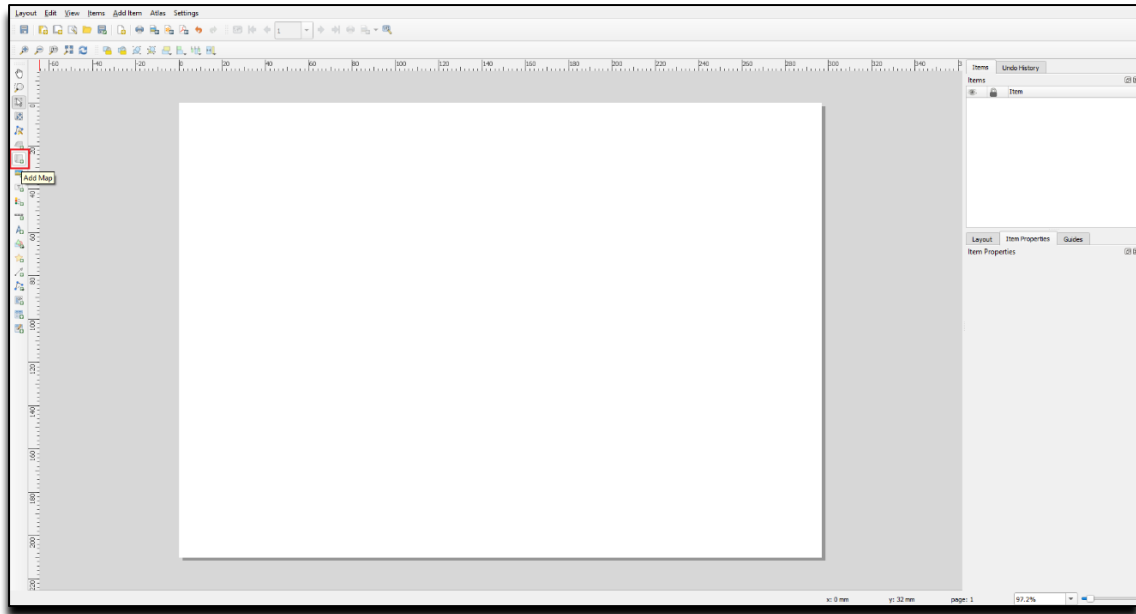
This set of steps produces the visualization of the urban land cover change using maps:

1. In the Toolbar at the top of the page, Click on “Project”
2. Click on “New Print Layout” and the following window will appear

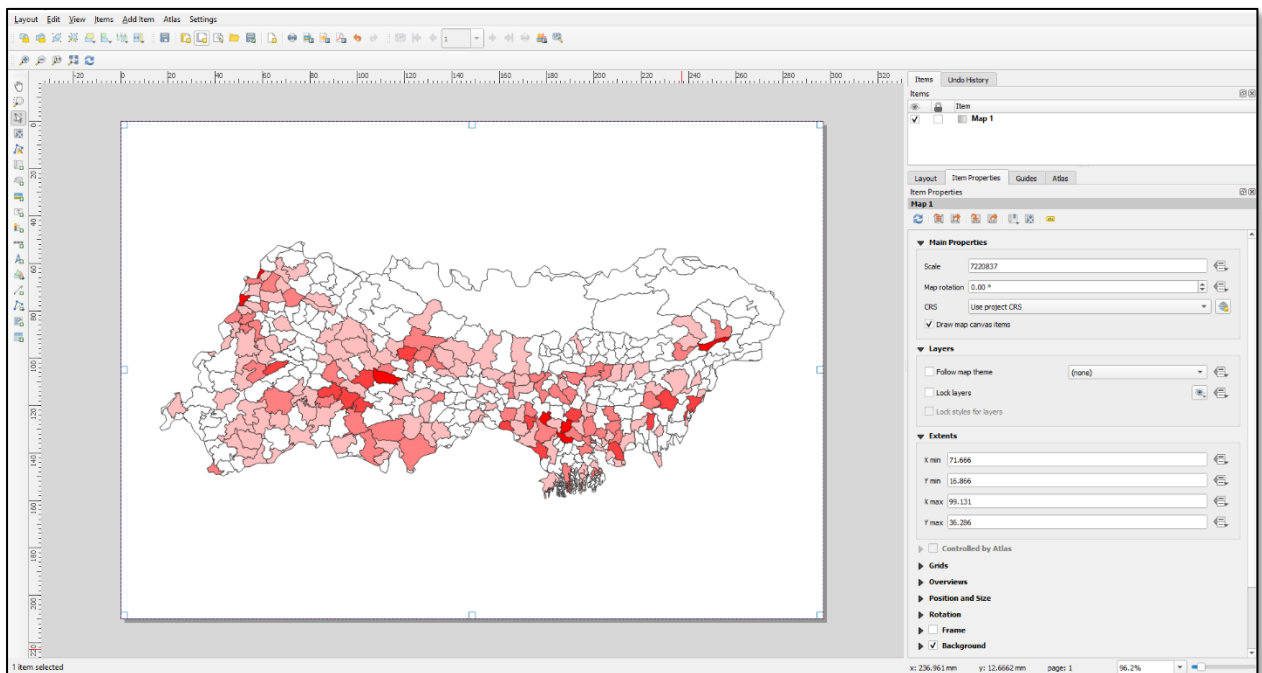


3. Define print Layout Title as “Hot spot” and click “OK”
4. On the new window that appears, on the toolbar to the left, click on “Adds a new Map to the layout”  as highlighted in the picture below:

Step 3 – Data processing and visualization



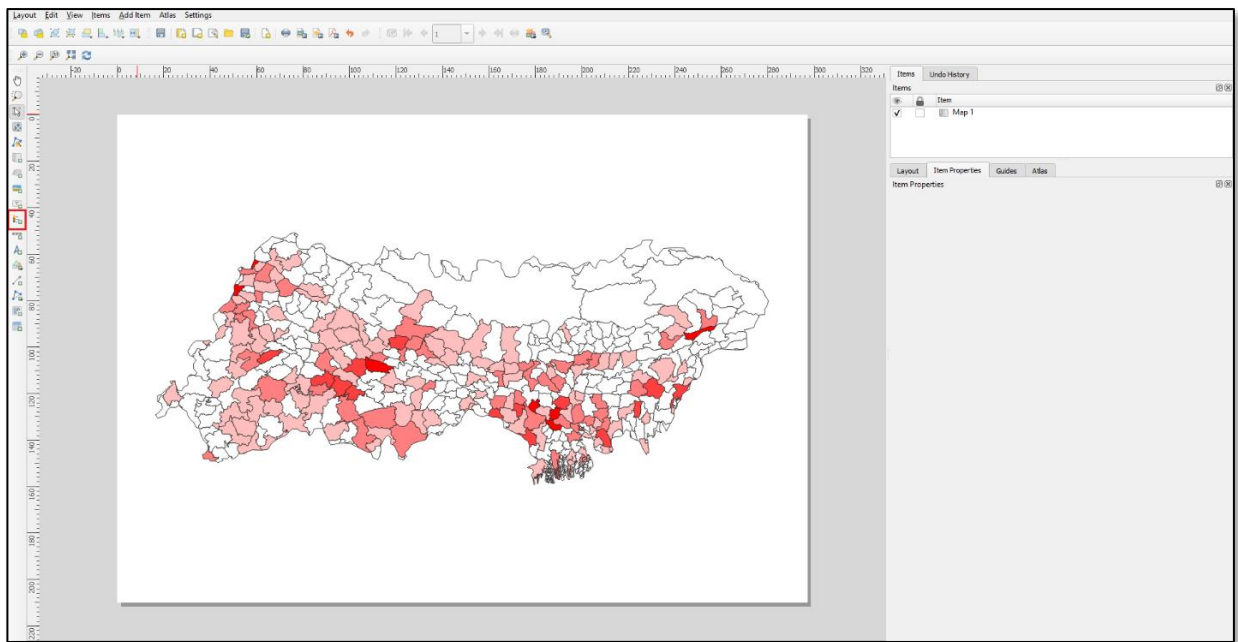
5. For the map to appear on the white screen, click on the white screen and draw a rectangle with the cursor. This image below reflects the selection as was made in this exercise, and yours may appear differently:



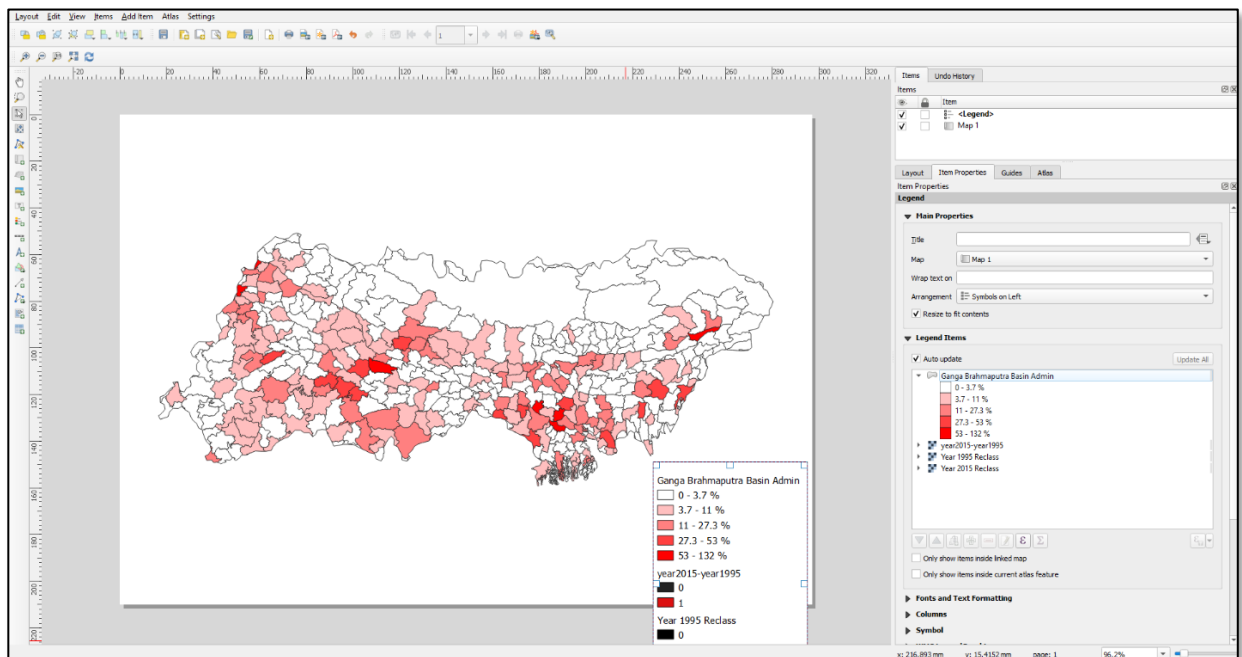
6. On the toolbar at the left, click on **Adds a new Legend to the layout** as highlighted in the picture below:



Step 3 – Data processing and visualization



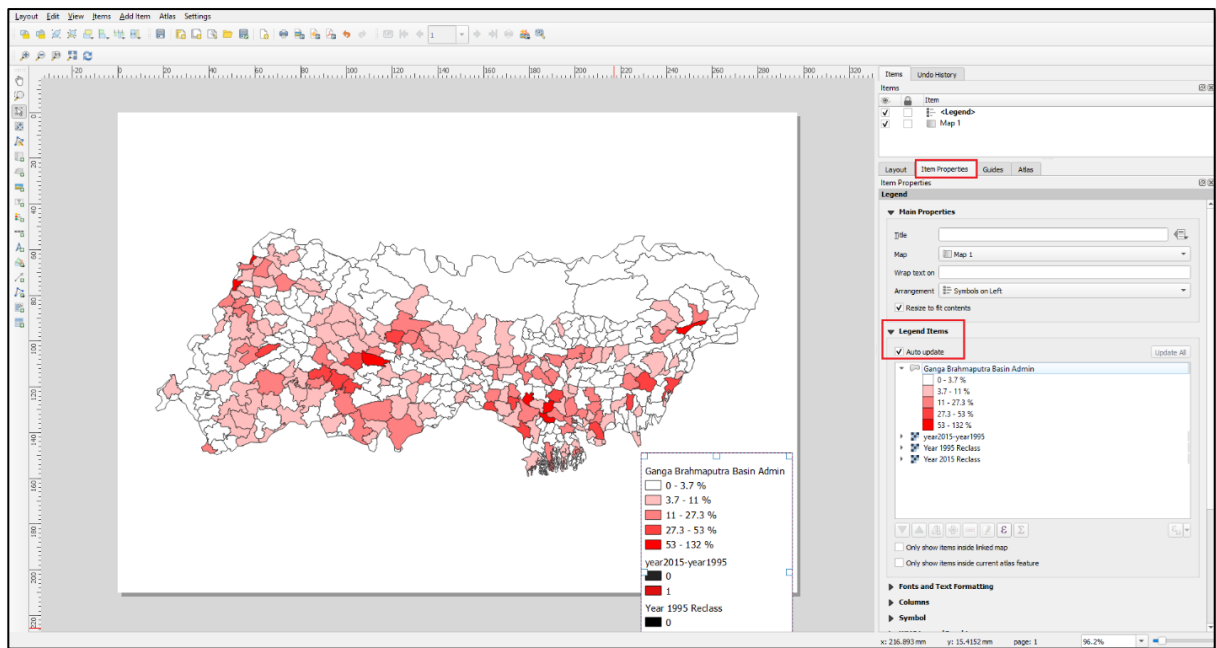
7. For the legend to appear on the map, click on the map and draw a rectangle with the cursor, and the following image will appear.



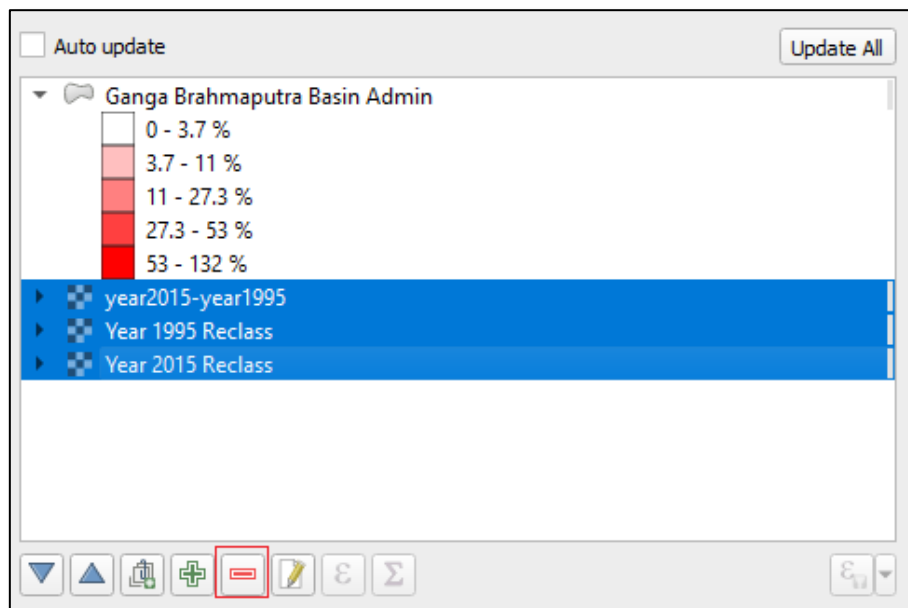
Multiple legends will appear on the screen, because of the numerous layers listed under “Legend Items”. Following the next steps will remove the extra layers, which will then remove the extra legends:

8. On the Taskbar to the right of the picture below, click on the tab “Item Properties” and click off “Auto update” as highlighted the picture below:

Step 3 – Data processing and visualization



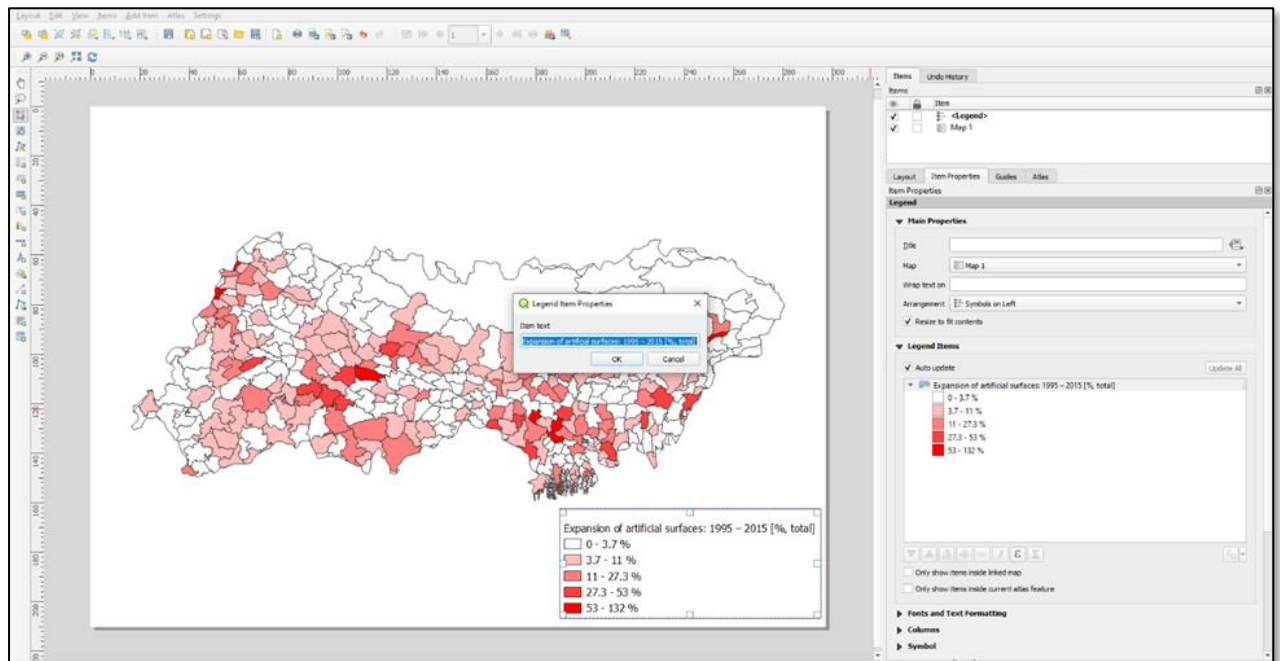
9. Highlight all the layers except for the first layer and click the **minus** button as shown in the picture below:



This should result in one legend remaining, which now requires formatting to fit on the screen.

10. To change the title of the legend, under "**Legend Items**," double-click on the title "**Ganga Brahmaputra Basin Admin**"
11. In the window that appears, change the title from "**Ganga Brahmaputra Basin Admin**" to "**Expansion of artificial surfaces: 1995 – 2015 [%, total]**" as shown in the picture below:

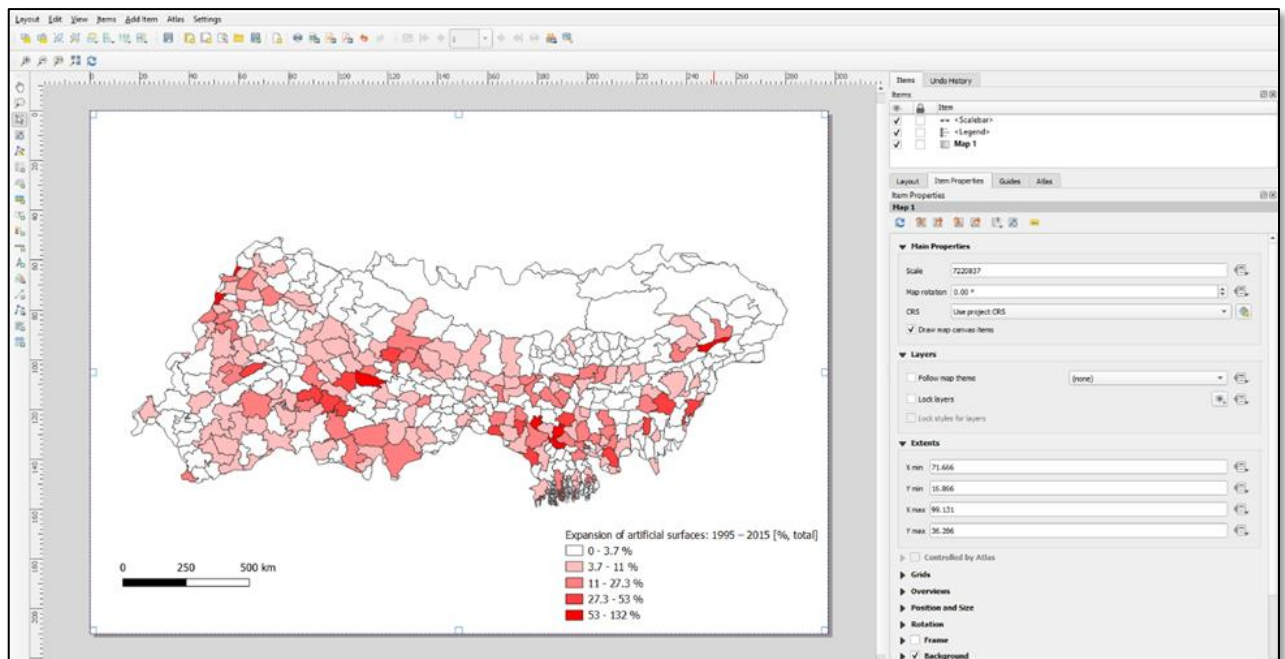
Step 3 – Data processing and visualization



12. On the toolbar at the left of the interface, click “Adds a new Scale Bar to the layout”



13. For the scale to appear on the map, click on the map and draw a rectangle with the cursor, and the following image will appear:

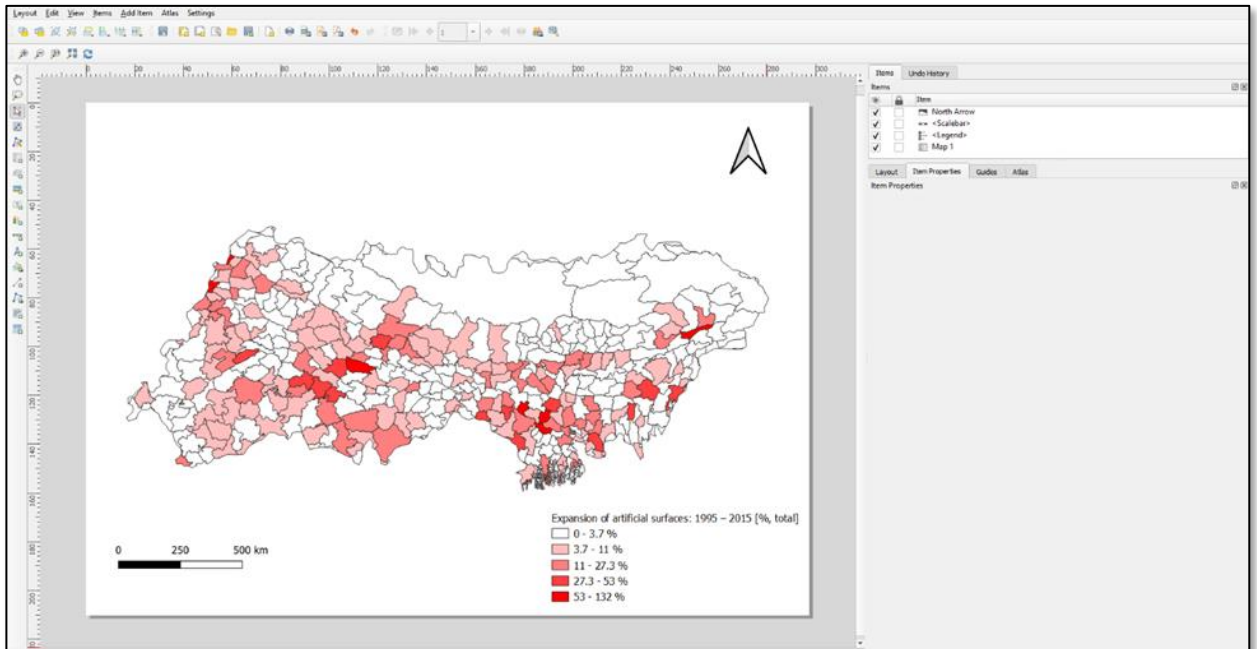


Step 3 – Data processing and visualization

14. On the toolbar at the left of the interface, click “Adds a new North Arrow to the layout”

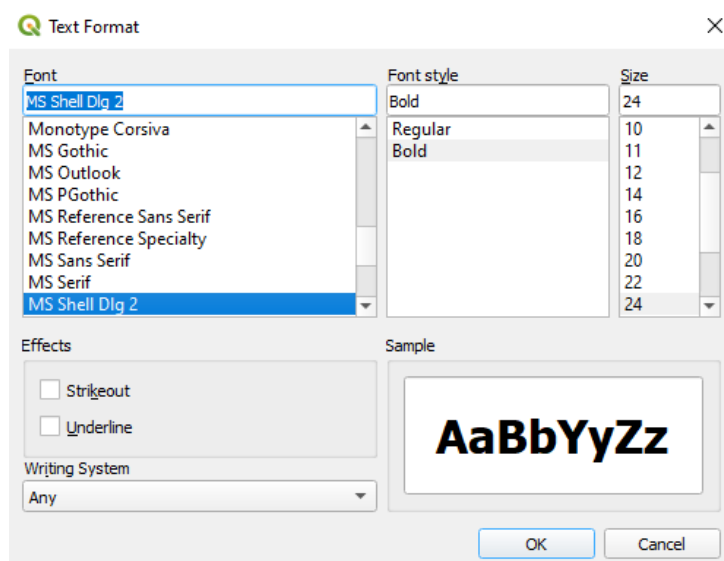


15. Click on the top right-hand corner of the map and draw a rectangle with the cursor, and the north arrow will show on the map similarly to the picture below:



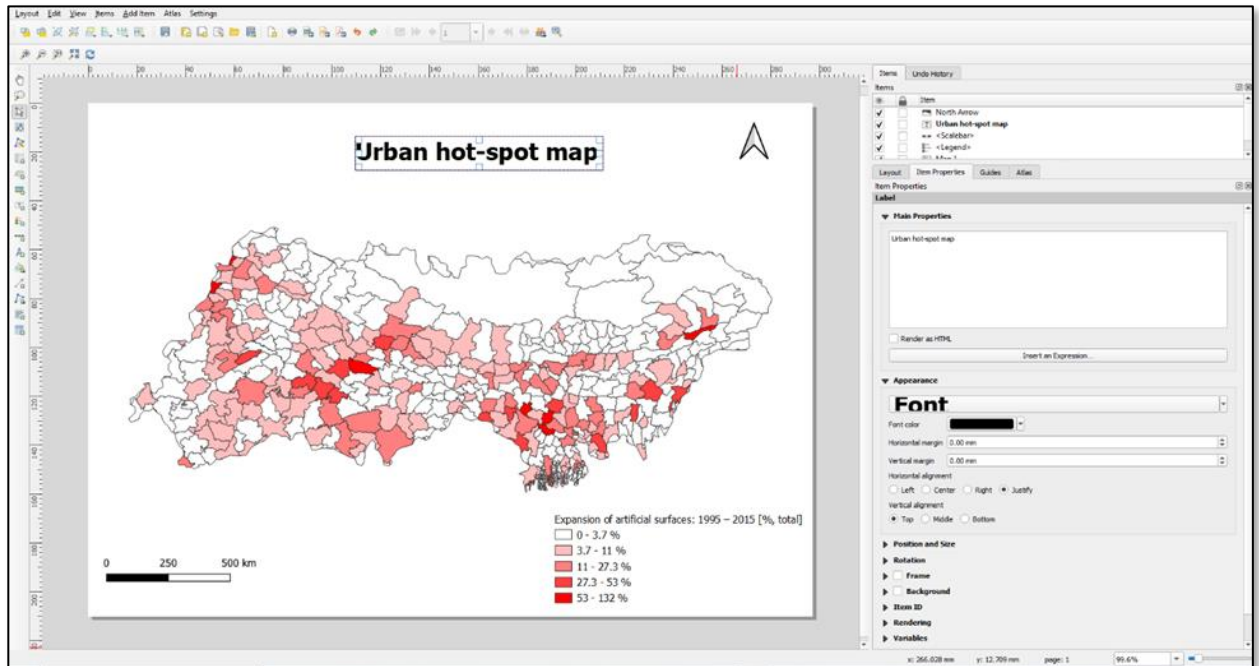
16. On the toolbar at the left of the interface, click “Adds a new Title to the layout”
17. Click on the top left-hand corner of the map and draw a rectangle with the cursor
18. On the toolbar at the right of the interface, click on “Item Properties”
19. Complete “Label” under “Item Properties” as “Urban hot-spot map”

Under “Appearance”, edit “Font” and other characteristics as outlined in the picture below:

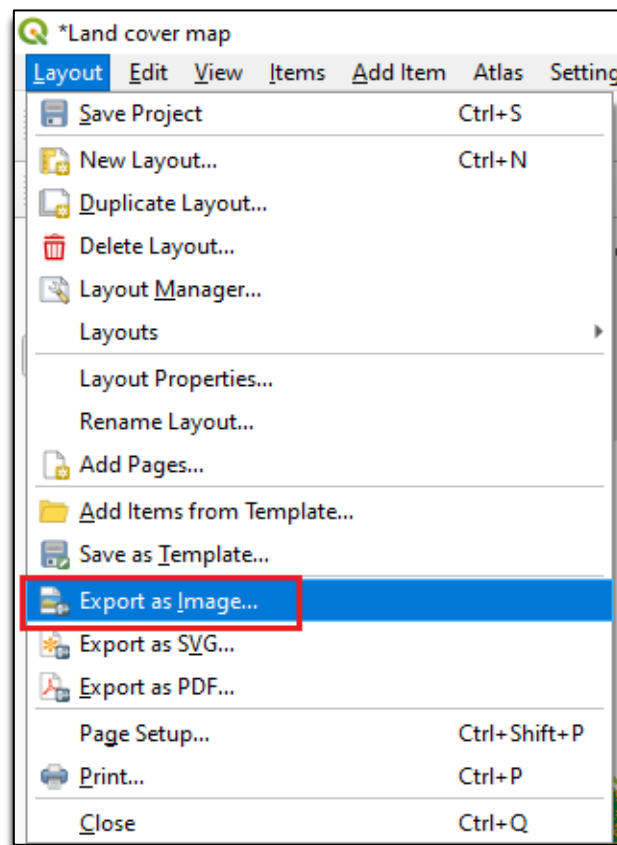


Step 3 – Data processing and visualization

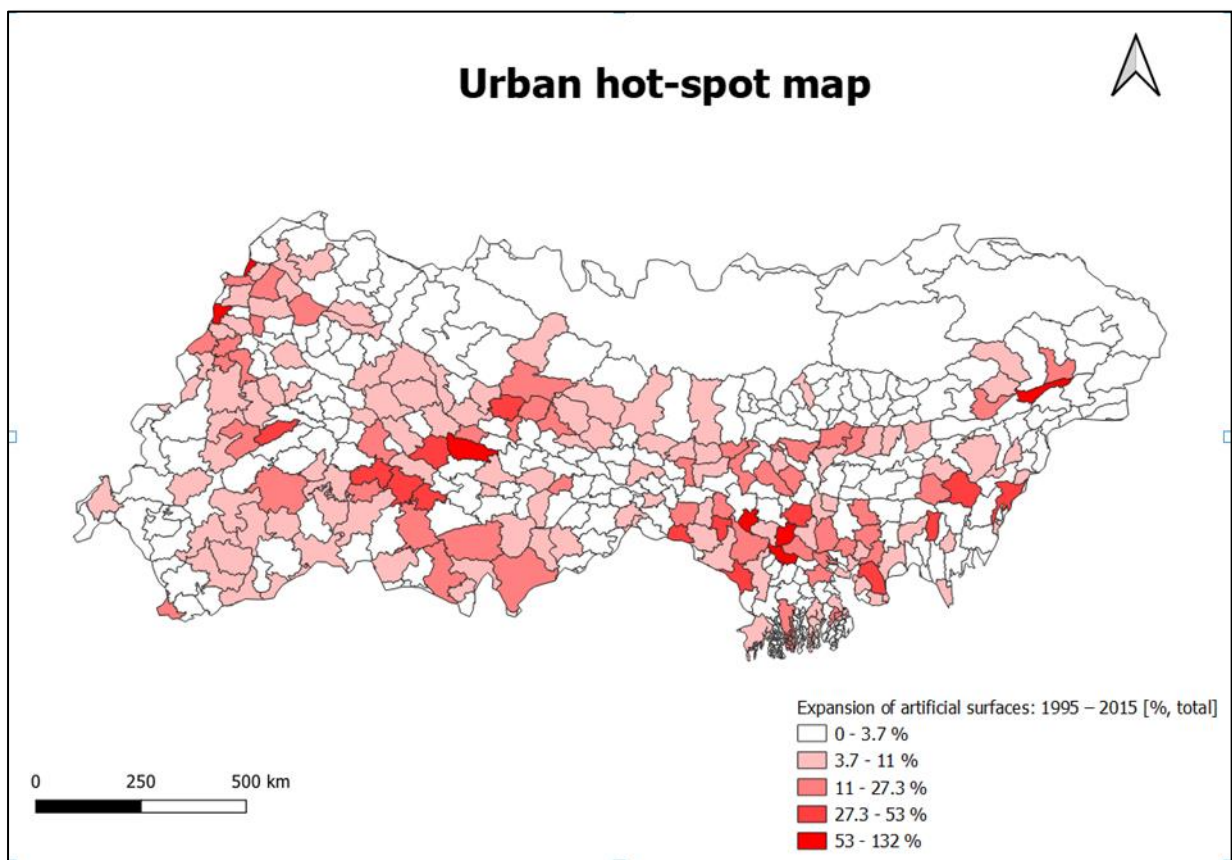
We see the “Urban hot-spot map” as shown in the picture below:



20. On the taskbar at the top of the interface, click “Layout” button and Select on the “Export as Image” as shown in the picture below:



21. Save under proposed name and proposed format



This map shows the rate of change of expansion of artificial surfaces along the Ganga-Brahmaputra River Basin from 1995 to 2015.

You have completed Step 3 of 3! Well done on producing your visualizations! We wish you good luck as you continue the journey ahead.

Appendix

The Appendix gives a brief overview of QGIS, which is the open source program used in the exercise outlined in this guide; and shows how to download and install these programs for use.

A. QGIS

QGIS is a cross-platform desktop geographic information system that supports viewing, editing and analysis of geospatial data.

We used the most recent version of QGIS available, and we advise that you do the same. However, while most versions of QGIS will work, we recommend that you use QGIS version 3.10 and above, with the following plugins:

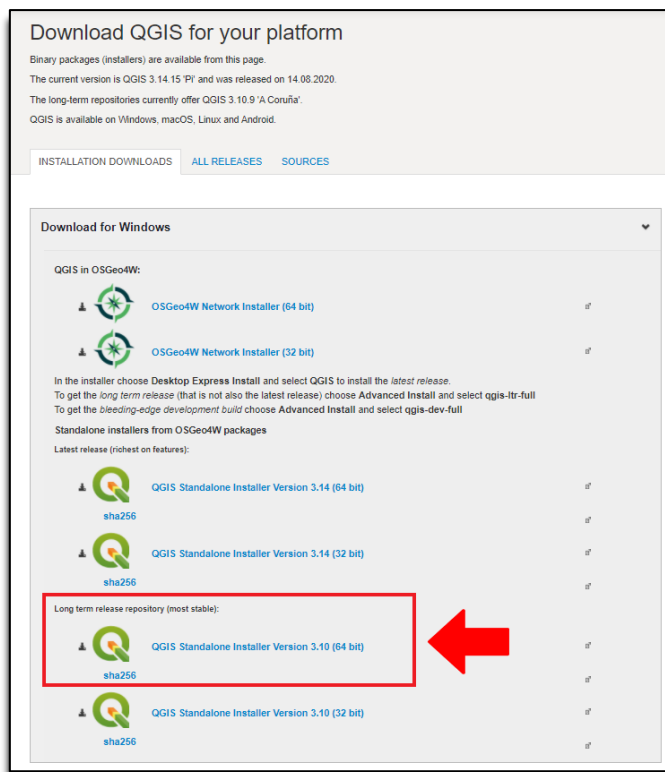
- GRASS – Geographic Resource Analysis Support System
- SAGA – System of Automated Geoscientific Analysis
- GDAL – Geographic Data Abstraction Library

Downloading and Installing QGIS

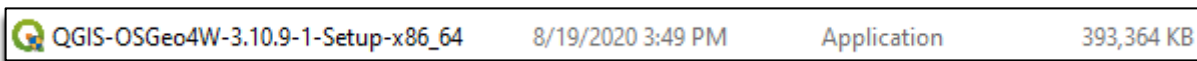
1. Go to the QGIS [website](https://qgis.org/en/site/forusers/download.html) (<https://qgis.org/en/site/forusers/download.html>)

We used the most recent version of QGIS available and we advise that you do the same. However, while most versions of QGIS will work, we recommend that you use QGIS version 3.10 and above, with the following plugins:

- GRASS – Geographic Resource Analysis Support System
 - SAGA – System of Automated Geoscientific Analysis
 - GDAL – Geographic Data Abstraction Library
2. Download the QGIS Standalone Installer Version 3.10, and choose either the 32-bit or 64-bit based on the configuration of your individual system as suggested in the picture below:



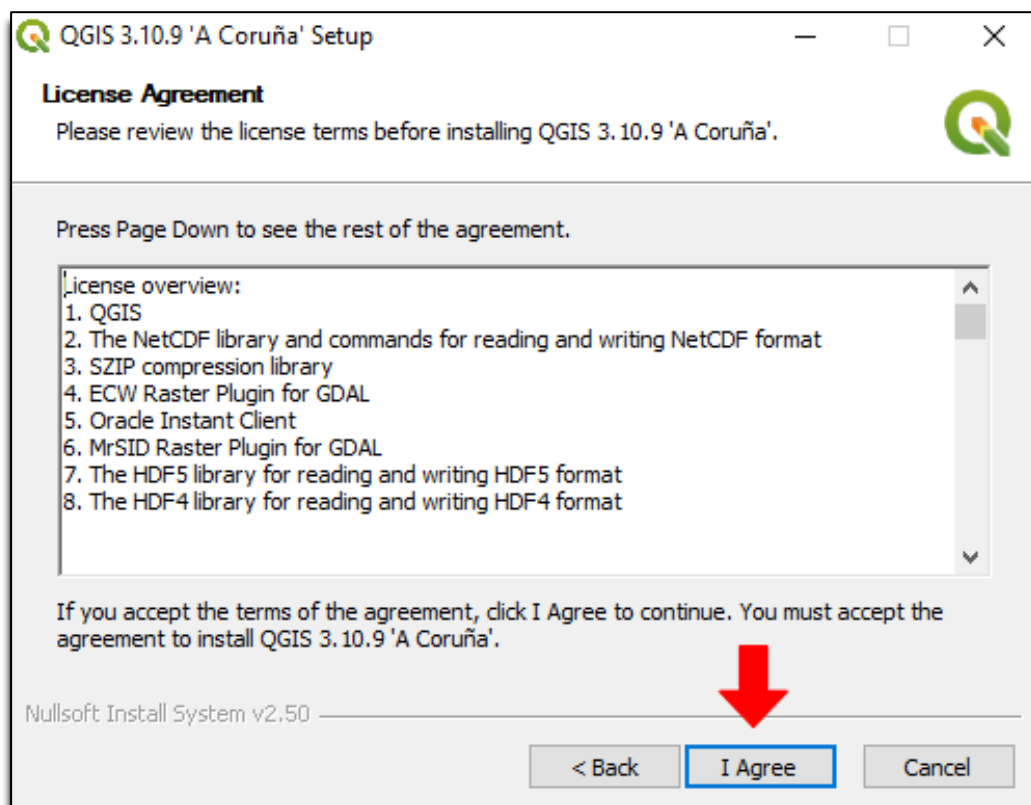
For the exercise in this guide, we used the 64-bit version, and downloaded and installed QGIS-OSGeo4W-3.10.9-1-Setup-x86_64 as shown in the picture below:



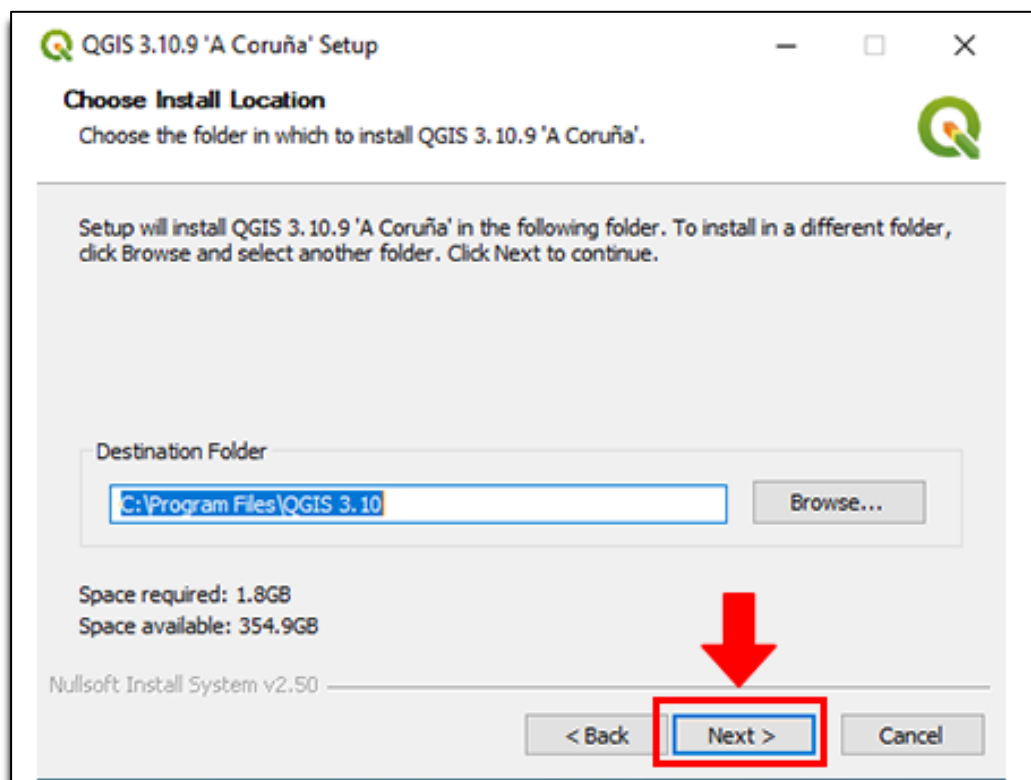
3. On the Welcome to QGIS-OSGeo4W-3.10 page, click on [Next](#) button as seen below:



4. Click on **I Agree** for license agreement as seen below:



5. Click on **Next** in Choose Install Location, as seen in picture below:

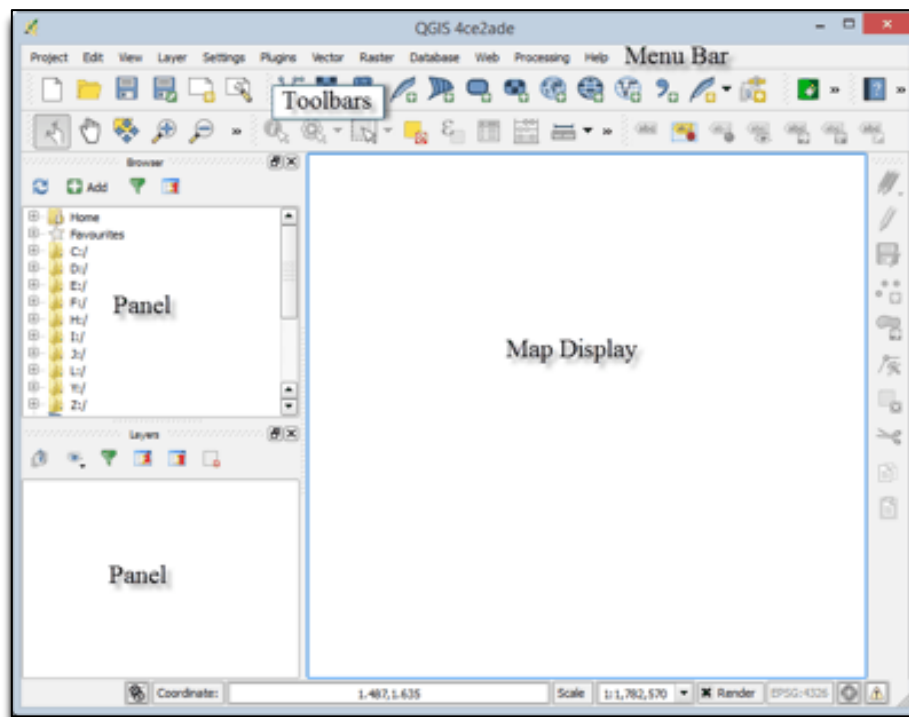


6. Once the installation process is complete, click on **Finish**, as seen in the picture below. The software is now installed on your computer and ready to use.



More Characteristics of QGIS

The QGIS interface has four areas:



Appendix

- Menu bar - provides access to the majority of QGIS Desktop's functionality.
- Toolbars - provide quick access to QGIS Desktop functionality; they can be arranged to either float independently or dock along the sides of the application's window.
- Panels, such as Browser, and Layers - provide a variety of functionality and can be arranged to either float independently or dock above, below, right, or left of the map display.
- Map display - shows the styled data added to the QGIS project.

The following toolbars are particularly useful, and they should be enabled:

- File - provides quick access to creating, opening, saving QGIS projects, and creating and managing print composers.
- Manage Layers - contains tools to add vector, raster, database, web service, text layers, or create new layers.
- Map Navigation - contains tools useful for panning, zooming, and refreshing the map display.
- Attributes - provides access to information, selection, field calculator, measuring, bookmarking, and annotation tools.

If you want to customize, you can:

- toggle the visibility of toolbars:
 - by clicking View | Toolbars, or by right clicking the menu bar or enable toolbar button, which will open a context menu allowing you to toggle toolbar and panel visibility.
- assign shortcut to actions by clicking Settings | Configure shortcuts.
- change application options, such as interface language and rendering options by clicking Settings | Options.

B. Available datasets

In this guide, the open-source data used are (1) the shape file data for the Major River Basins in the World which was downloaded from the World Bank, and (2) Tagged Image File Format Files for the Global Land Cover Data which is downloaded from the European Space Agency. The guide shows the steps to download the data, and then filter the data to process and show the rate of expansion of artificial surfaces on the chosen area.

For illustration, this guide shows how to map expansion of artificial surfaces along the Ganga Brahmaputra River Basin in India, as it is one of the largest river basin in the Asia-Pacific region; but the user may download similar data from the World Bank and from the European Space Agency to map land cover changes in a chosen area.

In the tables below, some of the most frequently used and most popular datasets are outlined. We encourage the user to investigate and determine which datasets are most suitable for their own uses.

Administrative Boundaries

This table outlines sources for the administrative boundaries data that are most frequently used.

Name	Data Source
GADM – Database of Global Administrative Areas	https://gadm.org/data.html
DIVA-GIS Data	https://www.diva-gis.org/
HDX Data	https://data.humdata.org/dataset
Natural Earth Data	https://www.naturalearthdata.com/

Earth Observation Data

This table outlines earth observation data that are most frequently used. Earth Observation data outlines land cover areas and ocean and marine areas, and the data presented in the table below vary by resolution and the years available.

Sensor	Available From	Resolution	Data Source
Landsat 1 to 3	1972-1989	30M	https://earthexplorer.usgs.gov
Landsat 4-5TM	1982-2012	30M	https://earthexplorer.usgs.gov
Landsat 7	1999-Present	30M	https://earthexplorer.usgs.gov
Landsat 8	2013	30M	https://earthexplorer.usgs.gov
Aster	1999	30M	https://earthexplorer.usgs.gov
Sentinel	2015	10M	https://earthexplorer.usgs.gov
Modis	2003-Present	250M, 500M, 1km, 5Km	https://search.earthdata.nasa.gov
ESA	1992-2018	300M	ftp://geo10.elie.ucl.ac.be/v207/