USING SPATIAL INFORMATION TO SUPPORT DECISIONS ON SAFEGUARDS AND MULTIPLE BENEFITS FOR REDD+

STEP-BY-STEP TUTORIAL: VERSION 1.0

MAPPING AREAS OF IMPORTANCE FOR MULTIPLE BENEFITS OF REDD + USING QGIS 2.18

UN-REDD PROGRAMME

Food and Agriculture Organization of the United Nations

UNDP Empowered lives. Resilient nations.

UN environment

The UN-REDD Programme is the United Nations Collaborative initiative on Reducing Emissions from Deforestation and forest Degradation (REDD) in developing countries. The Programme was launched in September 2008 to assist developing countries prepare and implement national REDD+ strategies, and builds on the convening power and expertise of the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP) and UN Environment.

The UN Environment World Conservation Monitoring Centre (UNEP-WCMC) is the specialist biodiversity assessment centre of UN Environment, the world's foremost intergovernmental environmental organisation. The Centre has been in operation for over 35 years, combining scientific research with practical policy advice.

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We welcome comments on any errors or issues. Should readers wish to comment on this document, they are encouraged to get in touch via: ccb@unep-wcmc.org.

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Contents

1. Introduction

REDD+ is a voluntary climate change mitigation approach that has been developed by Parties to the UNFCCC. It aims to incentivize developing countries to reduce emissions from deforestation and forest degradation, conserve forest carbon stocks, sustainably manage forests and enhance forest carbon stocks. This may involve changing the ways in which forests are used and managed, and may require many different actions, such as protecting forests from fire or illegal logging, or rehabilitating (degraded) forest areas.

REDD+ has the potential to deliver multiple benefits beyond carbon. For example, it can promote biodiversity conservation and secure ecosystem services from forests such as water regulation, erosion control and non-timber forest products. Some of the potential benefits from REDD+, such as biodiversity conservation, can be enhanced through targeting areas where actions can have the greatest impact. Spatial analysis can be used to help identify such areas.

The purpose of this tutorial series is to help participants in technical working sessions, who are already skilled in QGIS, an open source software to develop GIS analysis, to undertake analyses that are relevant to REDD+. The tutorials have been used to build capacity in a number of countries to produce datasets and maps relevant to their spatial planning for REDD+, and to develop such map products. Maps developed using these approaches appear in a number of publications whose aim is to support planning of strategy options that enhance biodiversity and ecosystem services as well as delivering climate change mitigation (see http://bit.ly/mbs-redd for country materials). There is of course no requirement for countries to use the approaches described in these tutorials.

Open Source software can be used to undertake spatial analysis of datasets in the context of REDD+. Open-source software is released under a license that allow software to be freely used, modified, and shared (http://opensource.org/licenses). Therefore, using open source software has great potential in building sustainable capacity and critical mass of experts with limited financial resources.

When REDD+ actions prevent the loss or degradation of forest, this might result in multiple benefits in addition to protecting or enhancing carbon stocks. These include "ecosystem-based benefits", such as conservation of forest biodiversity, water regulation, soil conservation, timber, forest foods and other non-timber forest products.

Where countries have identified biodiversity conservation as a goal for REDD+, and to be consistent with the Cancun safeguards for REDD+ on protecting biodiversity, it is useful to identify areas where specific REDD+ actions are feasible and can protect threatened species. It may also be useful to identify areas outside forest where threatened species may be vulnerable to the displacement of land-use change pressures or to afforestation. Many countries have identified that it is a priority for their REDD+ actions to maintain or enhance freshwater provisioning and/or soil erosion control.

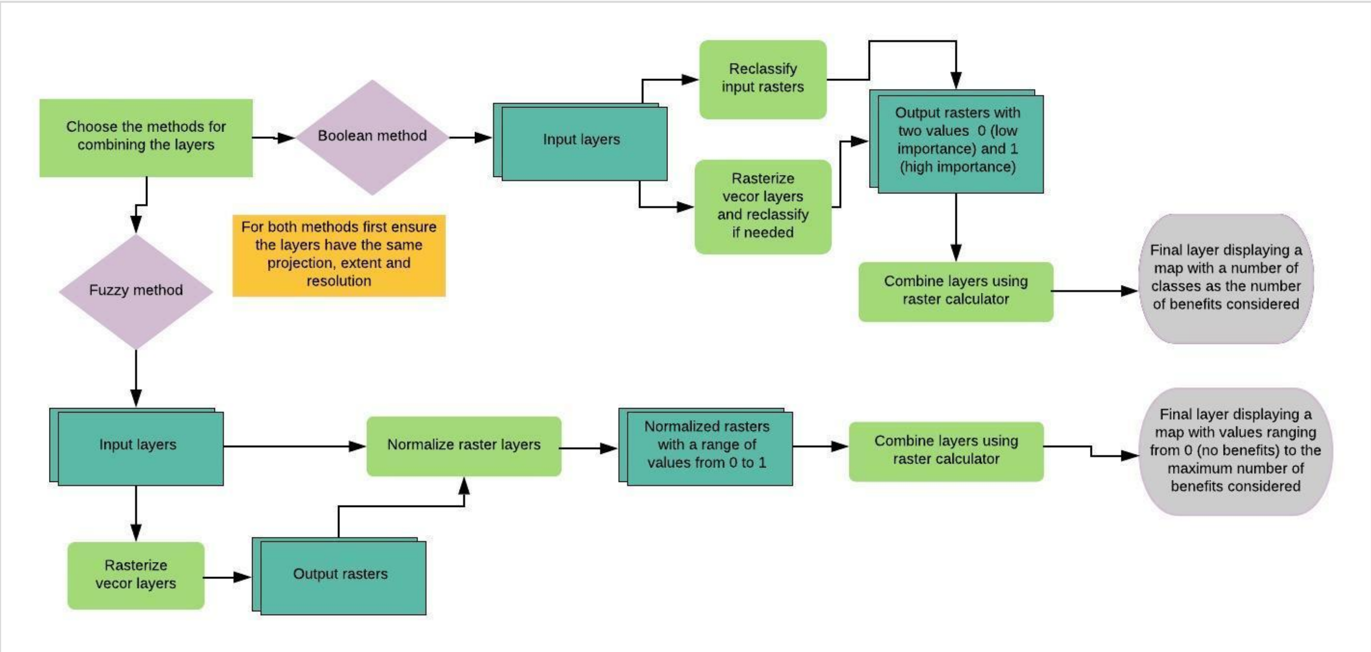
The greatest priority for REDD+ might be to focus on areas where action to retain or restore forests can potentially provide multiple benefits. In order to gain an idea of the potential location of these areas, the results from separate analyses can be combined to identify forest areas of potential importance for a larger number of benefits from REDD+. A combined map of benefits can provide a more effective communication to decision-makers, presenting sometimes complex information more simply and making it more accessible to them.

This Tutorial uses data from the Liberia country experience to show an example analysis drawing on four separate analyses layers to determine areas of high value for the various combinations of potential benefits. The data layers are combined in a single composite map, which makes it possible to easily identify the areas that are most likely to generate the highest amount of benefits.

Two methods are presented in this tutorial, a **Boolean approach**, which uses Boolean statements, where the spatial data have just two states (0 and 1), which differentiates areas of high importance and low importance; and a **Fuzzy method** where the variables are continuous, so there a degree of importance is shown. In both cases the original data have to be manipulated and threshold chosen.

Both methods have pros and cons and their limitations need to be understood. It is important that the output maps clearly indicate the technique and the thresholds used for the map production to simplify the data. Below an image showing the workflow to carry out this analysis using the two methods.

The analysis runs entirely in the QGIS version 2.18 (www.qgis.org).



1. Mapping areas of importance for multiple benefits

1.1. What data are important for mapping areas of importance for multiple benefits

The first step for this analysis is to choose the environmental and/or social benefits to be included in the combined map. Select the benefits that are important to be considered in your country (for example national priorities), and for which spatial data is available. These benefits may include:

- Mitigation of greenhouse gases.
- Scenic natural beauty for tourist purposes.
- Conservation of biodiversity.
- Support to communities vulnerable to water stress.
- Potential for socioeconomic improvement.
- Control of soil loss due to water erosion.
- Potential for improving governance.

Benefits can be interpreted based on the information available at the national level and spatial data layers with relevant information identified for analysis. The objective of the analysis is to identify areas where said benefits converge.
For the purpose of this tutorial, the following raster layers from Liberia will be used:

- Species Richness
- Key Biodiversity Areas (KBAs)
- Forest Carbon
- Freshwater provision
- Sediment Regulation

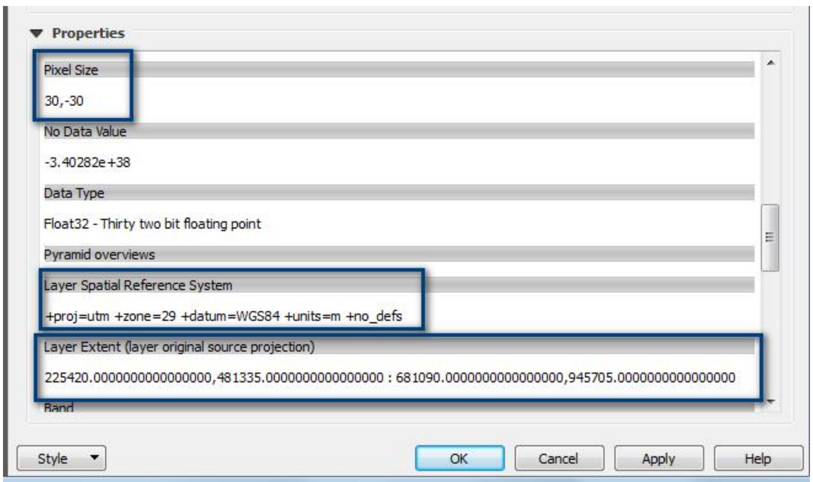
1.2. Ensure that raster layers have the same extension, projection and resolution

Before starting the image analysis of the raster data, the raster analysis steps in QGIS, is important to check the input raster layers to ensure they have the same extent, projection and resolution. This is because QGIS uses tools from multiple data providers and it can sometime cause a tool not to function if there are inconsistencies in these parameters. To change extent, projection and resolution in QGIS, you have to use the **Saves as** function.

a. First, **Right-click** on the raster dataset you wish to match to.

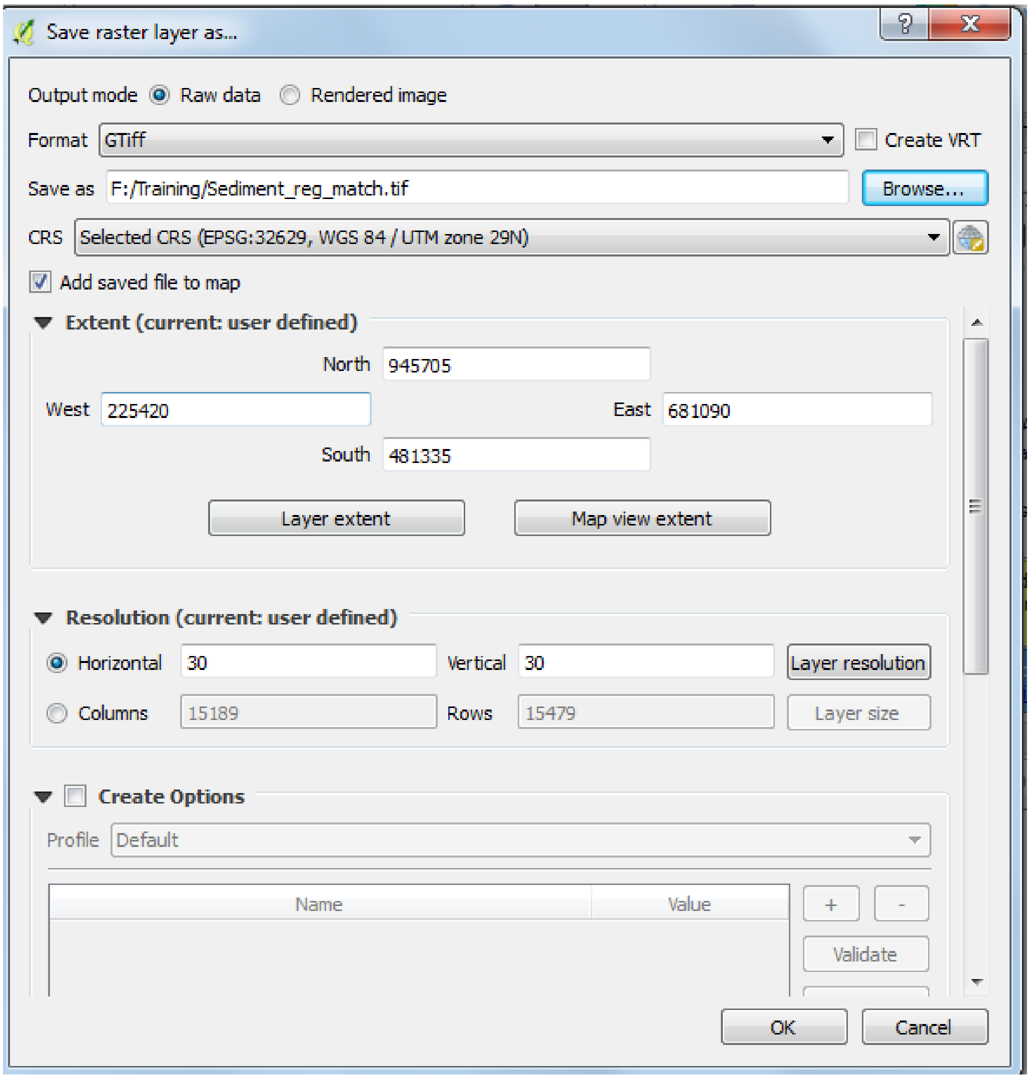
b. In the layer properties window click on the **Metadata** tab.

c. At the bottom of this window is a **Properties** box, Scroll down to find the extent, projection and resolution details



d. Copy these information into a text document as you will need them to set the extent of any non-matching dataset.
e. Click **OK** to close the layer properties window.
f. Check the properties of the other raster datasets to check that they match.
g. For any non-matching dataset right-click on the dataset and click **Save as.**

You will be able to save the raster dataset to a new name and change the extent, resolution and projection details.

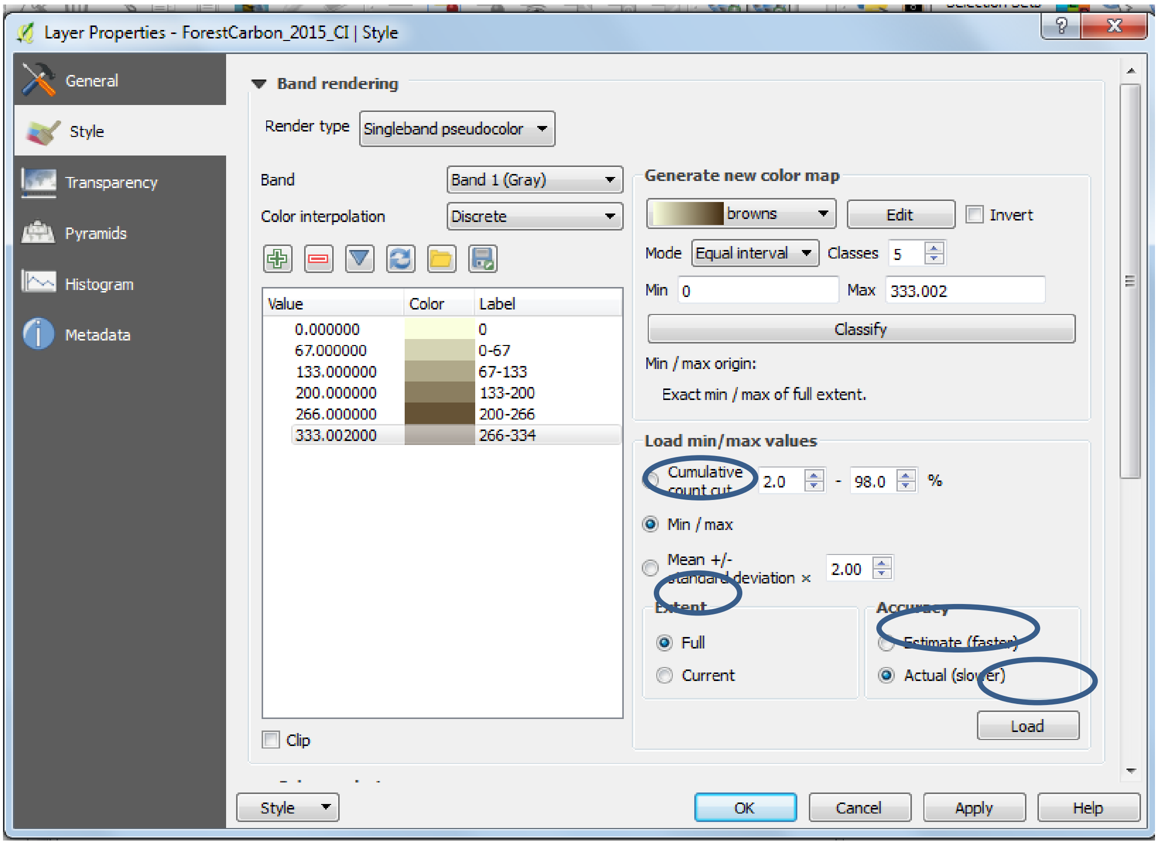


2. Combine the benefit layers using a Boolean method

In order to combine the benefits layers into a single layer showing areas with maximum convergence of benefits, it is necessary to simplify the information. For each layer, it is important to consider what high importance means. For example, for those layers where the thematic data cover the whole map (e.g. biomass carbon) decide upon the threshold level that will determine the areas of highest importance. Symbolising the data into class-breaks by quantiles or other methods can help determine these thresholds. For other layers, presence or absence may determine importance, where all areas are of equal importance (i.e. if an area has been defined as a Key biodiversity Area or not). Once importance has been determined, each layer will need to be reclassified accordingly to "0" for not important and "1" for important (see example processes below). This is the basis to perform a Boolean analysis and is generally undertaken using a Raster method so any data not already in a raster format will need to be converted.
If any of the input layers have any areas of "no data" these should be assigned a value of "0" unless these areas are to be excluded from the whole analysis. ***The tool used to undertake the final overlay analysis will otherwise exclude any pixel with no data value in the analyses, regardless of whether data are present in those no-data area in some of the other datasets.***

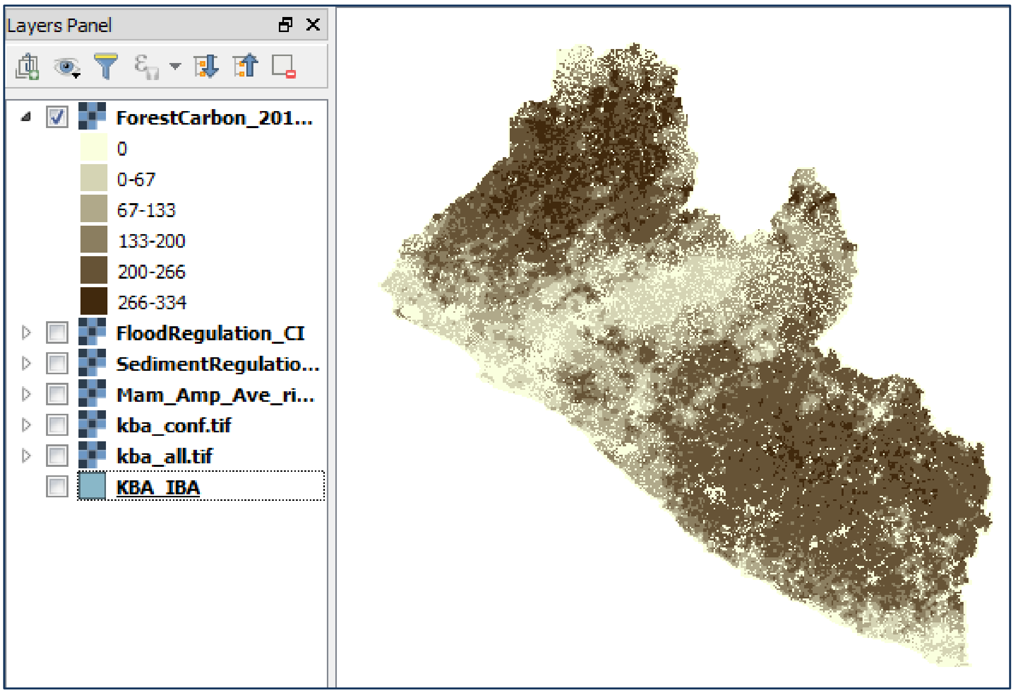
2.1. Symbolize input rasters into discrete class breaks and reclassify

a. Symbolise any continuous raster benefit layers into **discrete** class breaks. In the example below we have used **6 discrete Equal interval** classes. Make sure you **Load** the actual min and max values to ensure it takes into account all the values in the dataset when classifying. Choose a **color ramp**. (To access the layer properties right click the layer and select Properties)



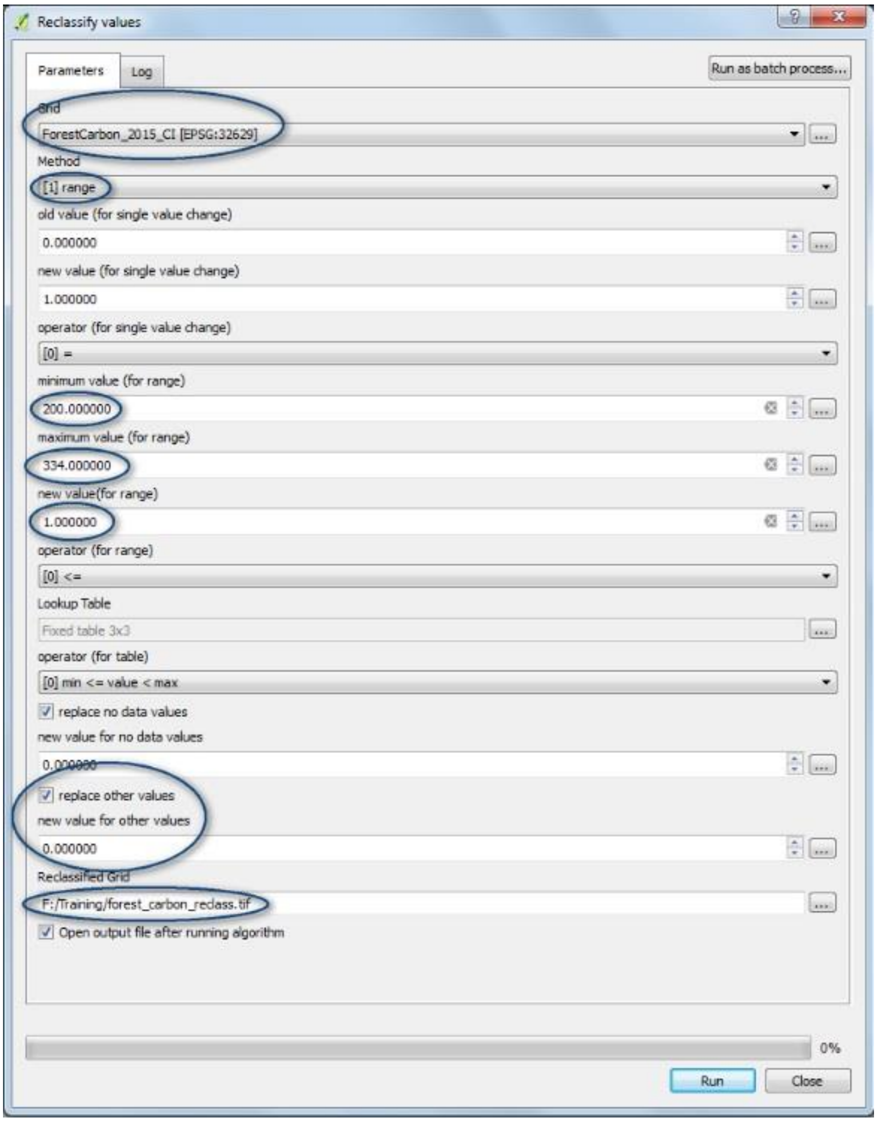
b. Click **Classify** to show the class breaks (you can now manually change these if you have specific class breaks you wish to apply e.g. you may wish to make the class breaks whole numbers and change the Labels).
c. Click **Apply** to close the layer properties window and apply the symbology.

The example below shows the forest carbon map for Liberia:



The next step is to decide a threshold value to prioritize areas important for the provision of this benefit. In this example, we will choose the top two classes: 200 -266 and 266-334.
To reclassify the raster use SAGA's Reclassify tool. In the search box of the processing toolbox write, "reclassify" and select the tool by double clicking.

d. Execute ***SAGA's Reclassify values*** tool using as an input the raster layer you have symbolised. This tool allows classifying pixels above the threshold value as **"1"** and pixels below threshold value as **"0".**
e. Select as Method "Range" since you are reclassifying a range of values.
f. Select as **Minimum value**, the lower value of the range you want to reclassify as 1 and as **Maximum value** the upper one. In this example, the lower value is 200 and the upper value 334.
g. Select as new value for range **1**, new value for **no data values** as **0** and new value for other values as **0**.
h. Select a folder where to save the reclassified raster and give a name. Then click Run.
i. Repeat steps **a-h** for the other raster benefits layers. In this example: **freshwater provision, sediment regulation** and **species richness.**



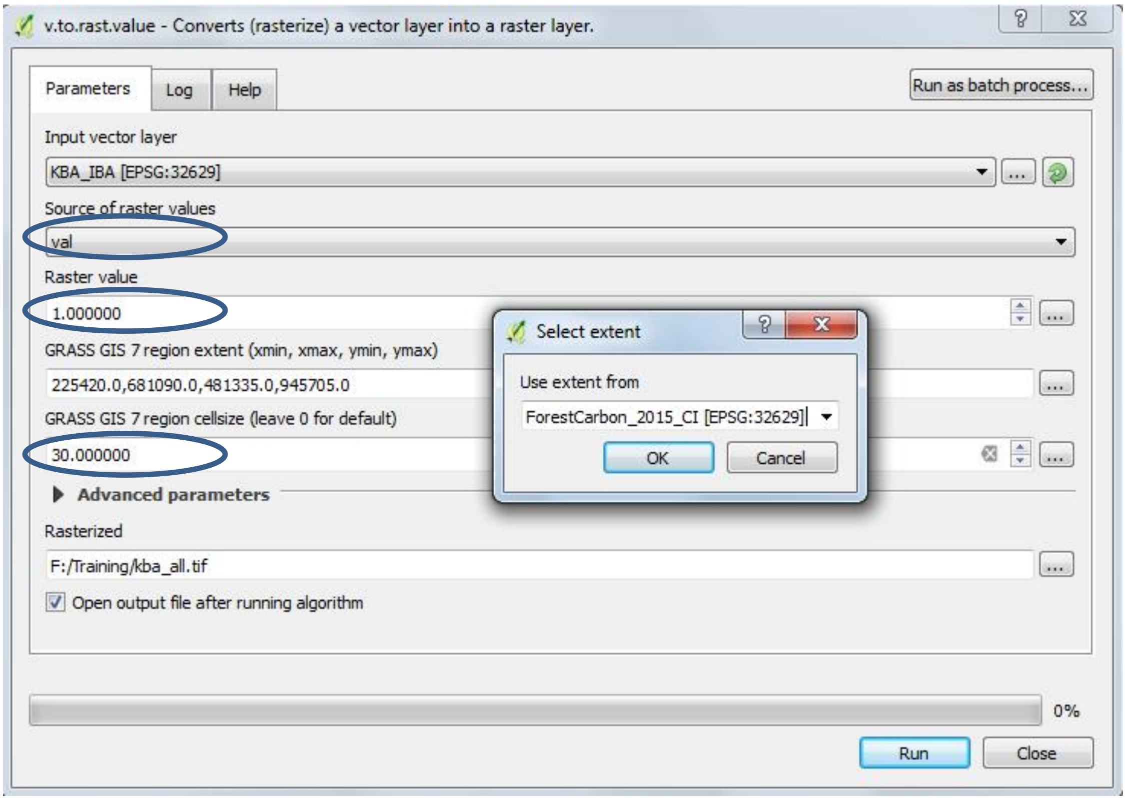
2.2. Rasterise and reclassify input vector benefit layers

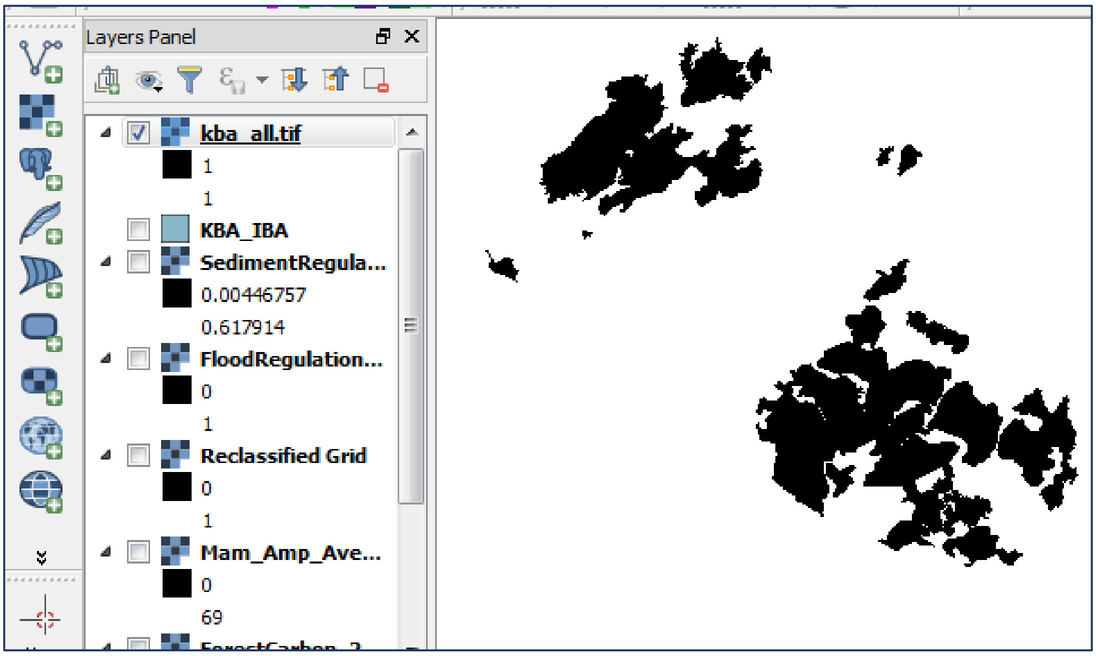
2.2.1. Convert to Raster using a single value

If you have any vector benefit layers, you can rasterize them using the ***GRASS v.to.rast.attribute or GRASS v.to.rast.value tools.*** *In this instance, we chose the* ***GRASS*** *tools rather than the* ***GDAL rasterize*** *because it gives the option to set the extent of the output to be the same as an existing raster. To access these tools write in the search box of the processing toolbox "rasterize" and select the indicated GRASS tool.*

- **a.** If you want all the features in the vector layer to have the same value in the converted raster, you can use the **v.to.rast.value** tool and set all features to have a value of 1 in the output raster. In this example, we convert the shapefile "ALL KBAs" to a raster, where the value 1 represents the KBAs.
- **b.** Select as source of raster values "val", as Raster value 1, use the extent from one of the layers with the right extent and the correct cell size.
- **c.** Select the folder where to save the output raster, give a name and click Run.

Check that the resulting layers has the same geographic projection, resolution and extent as the raster layers you have previously reclassified.



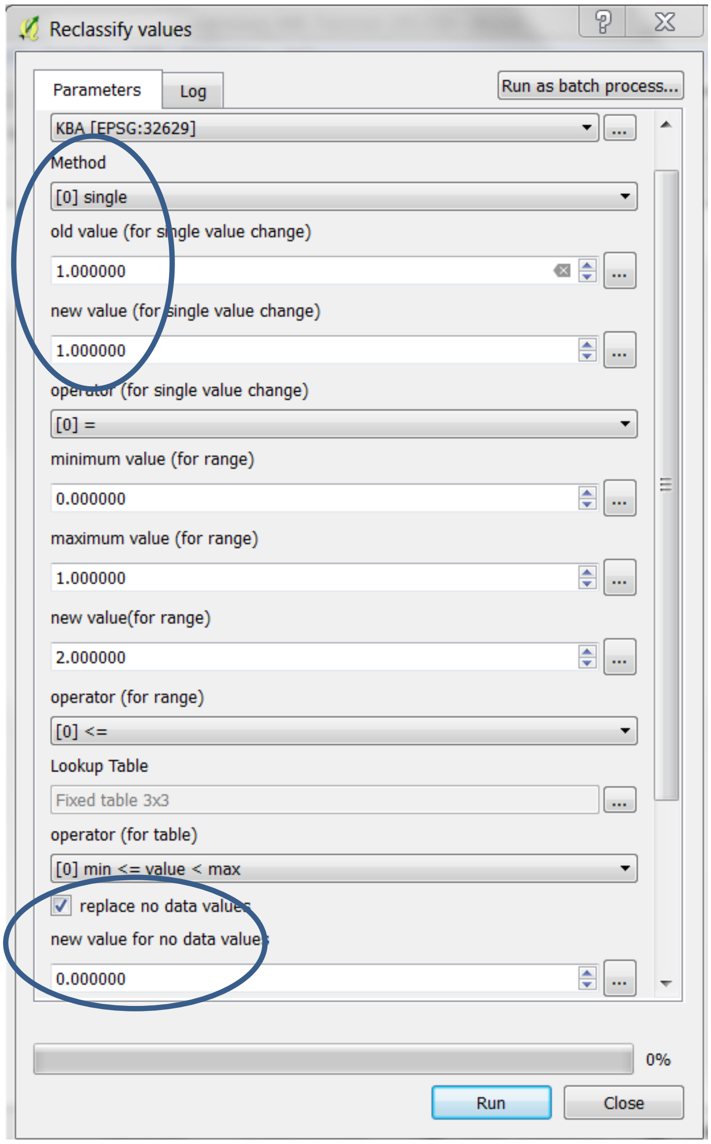


d. The output raster has just one value (1) for the areas where there are confirmed KBAs and no data for the rest of the extent. As mentioned before, the areas with no data need to be replaced with the value 0, to avoid these areas to be completely excluded during the last step of the analyses. To assign the value 0 to no data areas use the "Reclassify" tool in SAGA, as shown in previous steps.

e. In the Method box select "single". As old value 1 and as new value 1 again, since we don't want to change the value of the areas occupied by the confirmed KBAs.

f. Keep ticked the "replace no data values" option and insert the value 0.

g. Select a folder where to save the output raster, give a name and click Run.

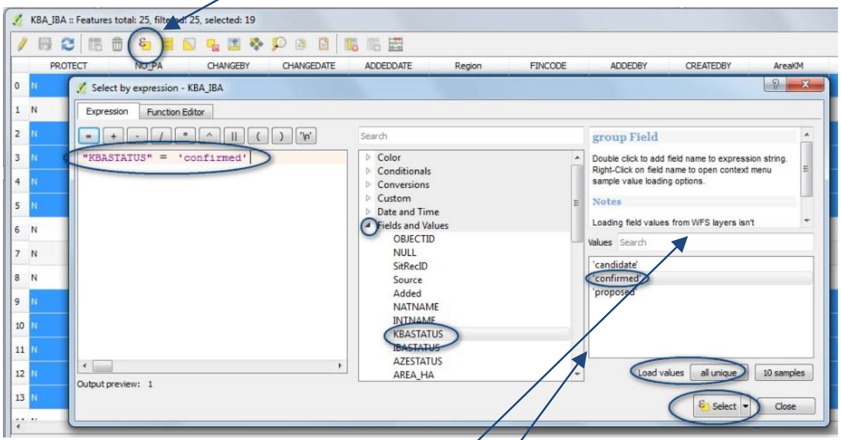


The result will look like the image above showing 1 where a KBA polygon is present, ***however it does not distinguish between status of different KBAs.*** *If you want to distinguish between status or any other attribute follow the steps described below.*

2.2.2.Convert to Raster using an attribute

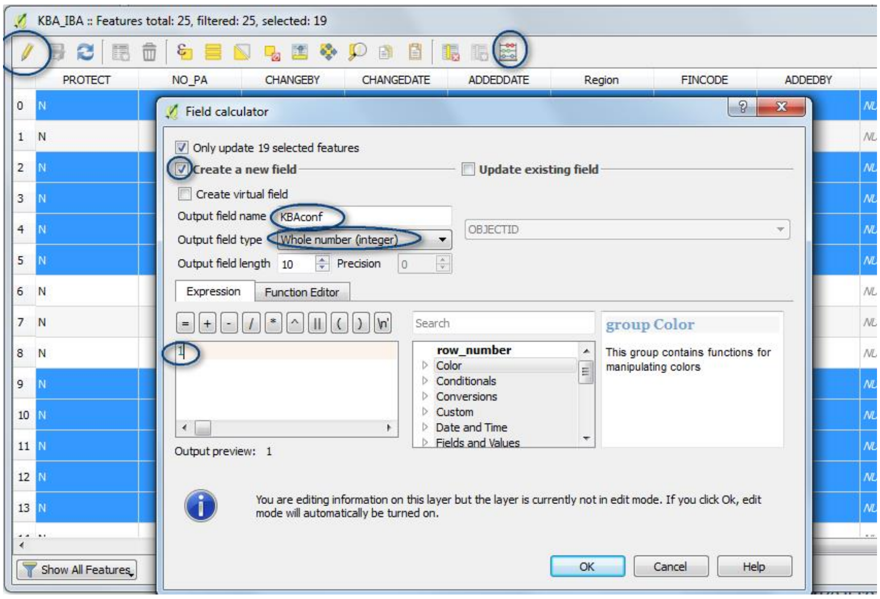
If you want to convert a vector dataset to raster based on a value in the attribute table you can use the **v.to.rast.attribute** tool. This tool requires you to pick a numeric field, which is used to assign the correct value to the output raster. You can add and calculate a new attribute field if there is no appropriate field in the vector dataset.
In this example, we only want to convert KBAs with a 'confirmed' status.

a. Right-Click on the KBA layer to open the attribute table and see that there is a field called "KBASTATUS". This is a text field, which cannot be used to rasterise the layer. Therefore, we will first used this field to select just the confirmed KBAs and then create a new numeric field to be used for rasterizing the vector.
b. Click the select features using an expression button.
c. In the expression builder select KBAs where status is 'confirmed'.
d. Click **Select,** then click **Close.** The selected features are now highlighted in blue.



Sometimes the third panel on the right showing the values of the field of interest is hidden because collapsed/minimised. In order to open it pull to the right the edge of the second panel.

e. Select the **Toggle editing mode** and click the **Open field calculator** button.
f. **Create a new field** called **KBAconf** and calculate the values to be **1.** Ensure that the box **"Only update selected features"** is ticked**.**
g. Click OK to add and populate the field.

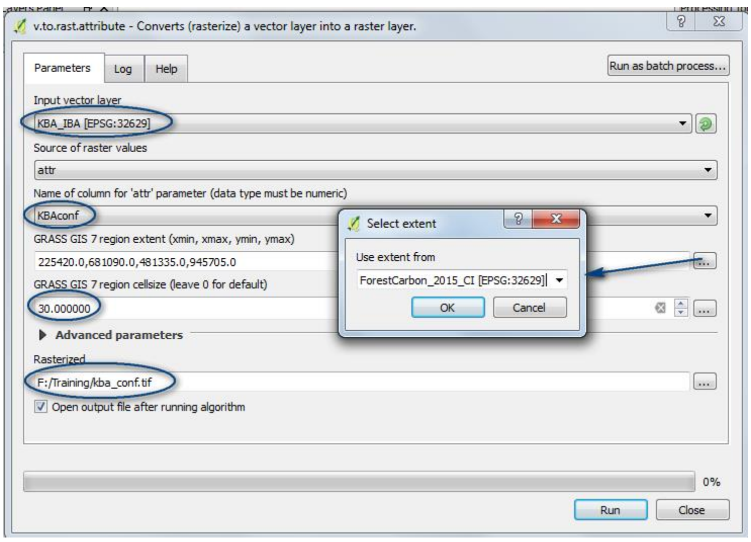


h. Click the **stop editing button (the pencil)** on the top left hand corner of the attribute table to save the table.

i. Now, rasterize this vector layer using **v.to.rast.attribute tool**. In the "Name of column for 'attr' parameter" use the field value (**KBAconf)** you have just created.

j. Select as extent one of the previous layers created and the correct cellsize.

k. Repeat steps d-g of previous section to ensure that the resulting layer doesn't have areas with no data, but just 0 and 1.



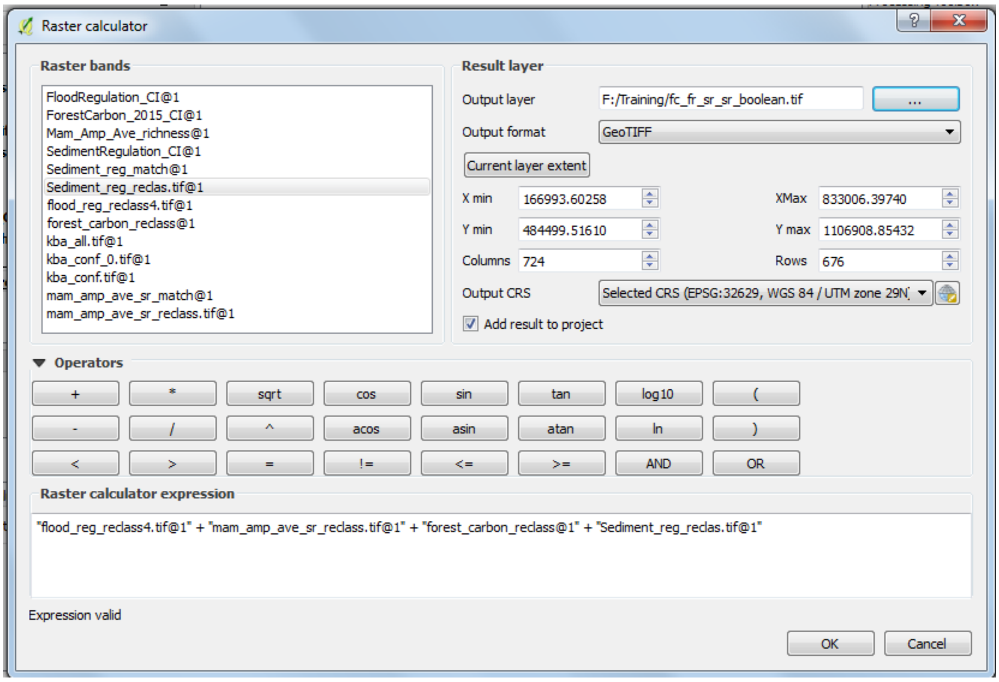
Again, after processing check to ensure that the extent, projection and resolution are the same as in the other raster layers.

2.3. Add Boolean rasters to generate the composite multiple benefits layer

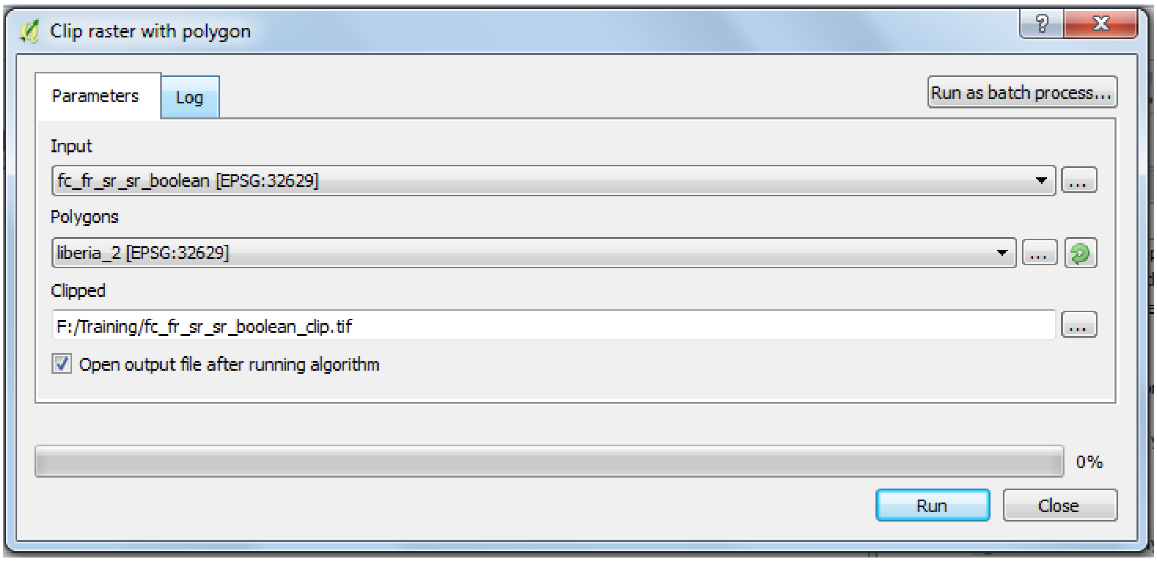
a. Once you have all your layers in Boolean format, you are ready to add them to obtain the composite multiple benefits layer. To do this use **Raster Calculator** tool, in the main raster menu.

b. Add the datasets to the raster calculator expression box and use the Operator '+' to sum them, as shown in the picture below. Select the folder and name to the output layer and click OK.

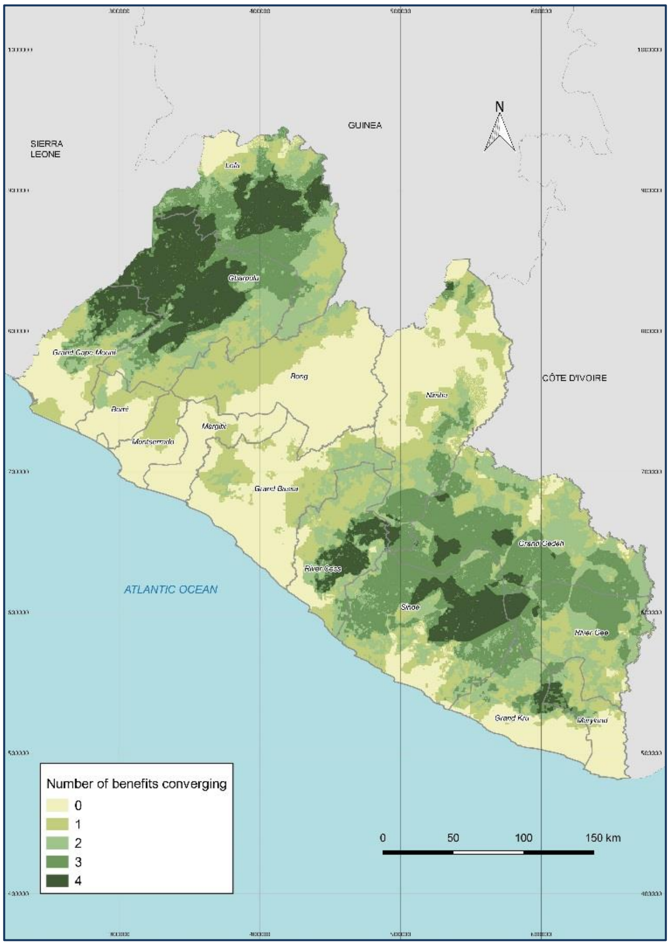
Note: - we have two data layers representing biodiversity value (the KBAs and the species richness); you should use just one of the two datasets to avoid biodiversity to have a higher weight than the other variables.



c. Clip the final combined Boolean benefits data to the Liberia coastline using the SAGA Clip raster with polygon tool.



The final Boolean map should display with 4 classes where 1 represents 1 benefit and 4 indicates 4 benefits.



3. Combine the benefit layers using a Fuzzy overlay method

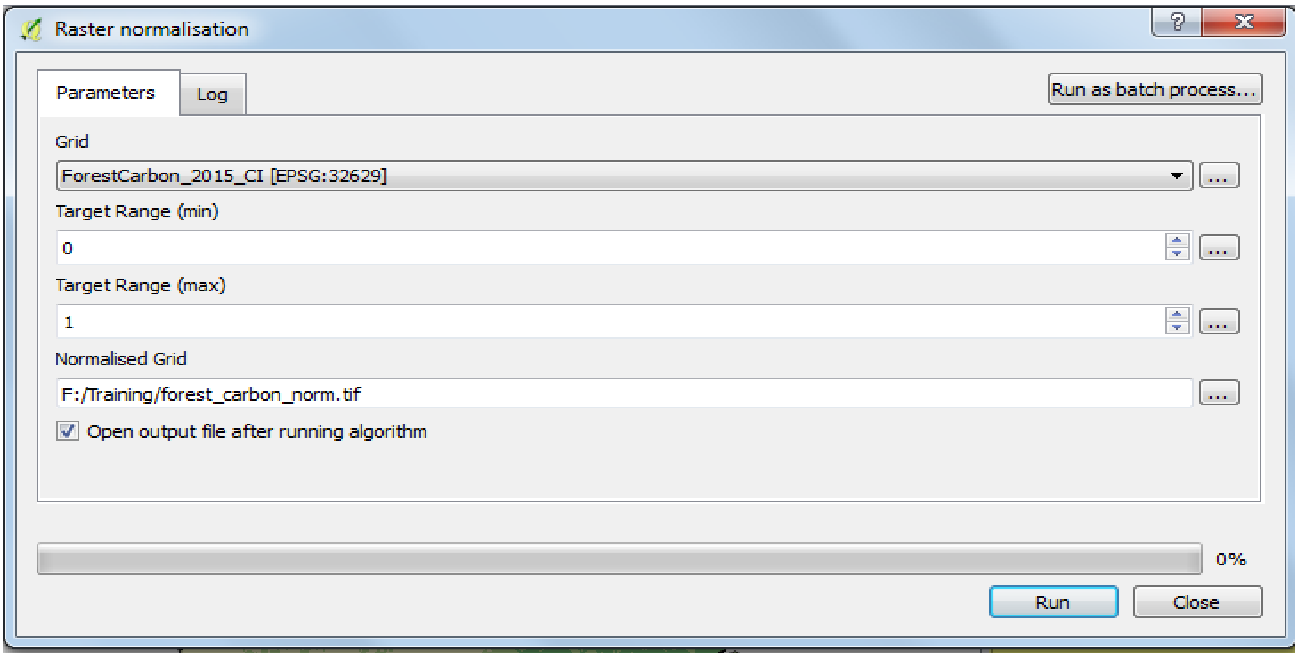
An alternative way to combine benefits into a single map is to use a Fuzzy overlay method. In this approach, quantitative criteria are evaluated as fully continuous variables rather than collapsing them to Boolean (1-0) constraints. This method reclassifies or transforms the data values to a common scale. The data are normalised to a scale - most commonly ranging from 0 – 1 or 0 - 100.
The process of converting data to such numeric scales is more commonly called ‘standardisation’ or ‘normalisation’.

In this tutorial we will demonstrate fuzzy overlay using a linear scaling. This is the most commonly used (but not necessarily recommended) technique. The new raster values are calculated using the expression below, where $\boldsymbol{x_i}$ is the value to be normalized, $\mathbf{min}_i$ is the lowest value in your data and $\mathbf{max}_i$ is the highest value.

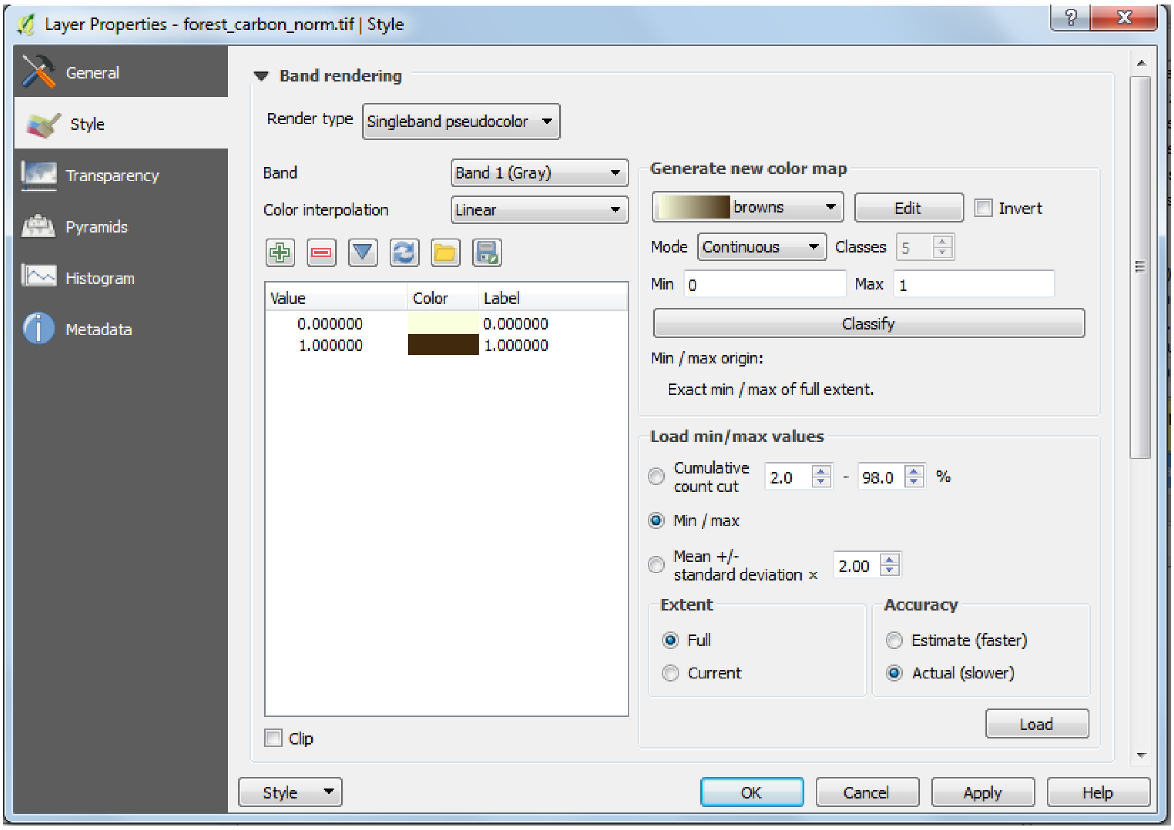
$$X_i = (x_i - \min_i) / (\max_i - \min_i)$$

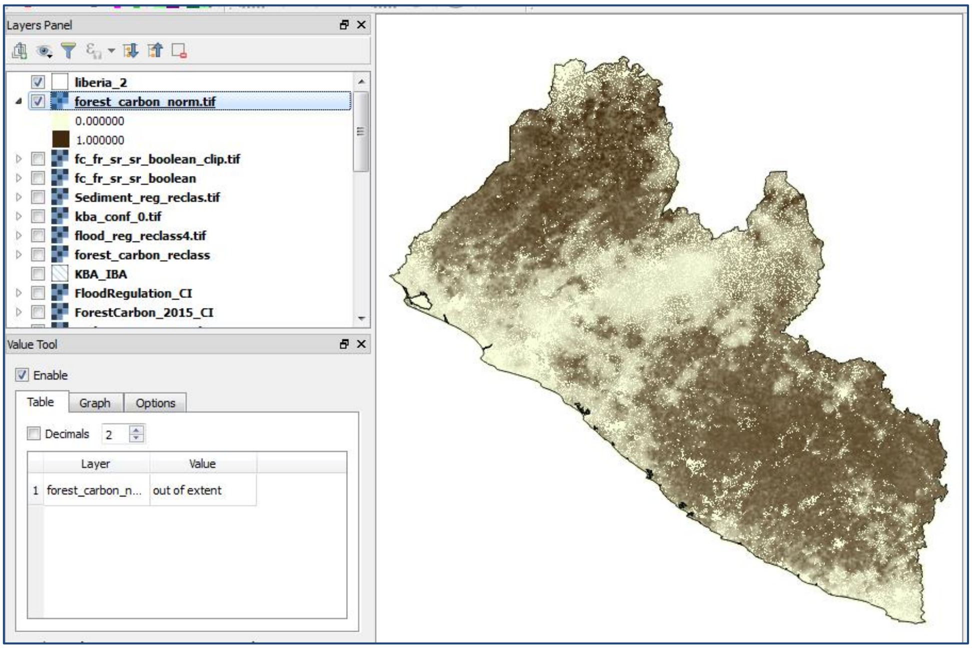
3.1. Normalize raster layers

a. Search for the **SAGA Raster normalization** using the search box in the processing toolbox.
b. In the grid box select one of your rasters. In the example below Forest carbon and as target range 0-1
c. Select the folder where to save the output and give a name. Click Run.



d. Once you have obtained your output raster, you can symbolize the data and see that it is now on a scale of 0-1, with 0 representing low and 1 representing high, and a range of values in between.





e. Repeat steps **a-c** for the other rasters. In this example, **flood regulation**, **sediment regulation** and **KBA** datasets.

Note: - The KBA dataset for example does not have a linear scale – it is either there or not. Therefore, the Boolean 1-0 dataset will be the same as the normalized dataset for this layer.

f. Once you have all your layers in the normalised format, you are ready to add them to obtain the composite multiple benefits layer. To do this use **Raster Calculator** tool, in the main raster menu as you did in the Boolean method.

The final map will still have a minimum value of 0 and maximum value of 4 but there will be a wide range of values in between. In case, as in this example, there are no pixels where all the 4 benefits have value 1 you won't get the maximum value 4.

g. Clip the final combined normalized benefits data to the Liberia coastline using the **SAGA Clip raster with polygon tool.**