User's guide to GIS GRASS 7.0 for Watershed Morphology

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Abstract

This is a GRASS GIS 7.0 based manual which documents some of the most important and helpful tools to handle with watershed morphology data. The reader will find in this manual a description about how to execute important watershed morphology analysis such as river network extraction, watershed delineation, mean watershed slope and main channel longitudinal profile. This manual gathers necessary steps to achieve important results in watershed morphology studies, showing that those ones are feasible in a realistic analysis. The approach made here is unconventional, in the sense that it aimed to raise numerical results to the watershed morphology only from elevation GIS data, which allowed to find both: an effective way to get those results and a deep technical discussion about the maturity of GIS tools to watershed morphology analysis.

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1 Introduction

The field of watershed studies covered herein is part of the content of the Watershed Hydrology, which is an important knowledge for the society as a whole and especially for engineering students, since they can get started to morphology concepts, like watershed and river longitudinal profile, and at same time, to manage GIS data. The way engineers manage watershed information has been improved since engineering started to plan water facilities.

Recently, a lot of different tools has aided civil engineers and cartographic engineers to do both get data updated and get improved project data for water related studies. The GRASS GIS Software has been developed for 30 years, since its first release from NASA in the 80's, which has included all the most promising geospatial data storage and management technics and geostatistical technics as well.

The objectives of this report are to:

Use GRASS as a procedure to accomplish basic tasks at GIS softwares.

Document a procedure to accomplish simple watershed morphology analysis such as extracting river networks, obtaining watershed delineations, evaluating the mean watershed slope and plotting main channel longitudinal profiles.

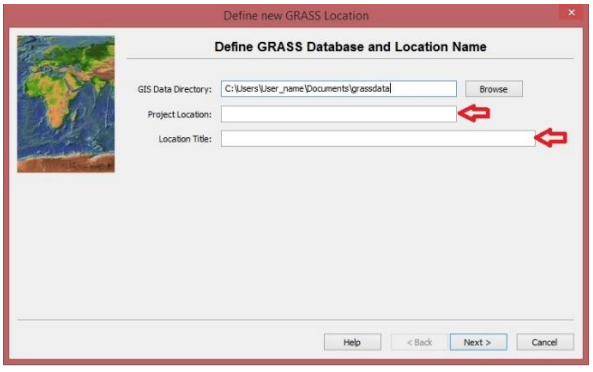
The reader will find in this manual all the content organized in such a way that procedures are showed by sequels of tasks. Basic geoprocessing concepts are treated when convenient. Also, explanations about the processes themselves are provided and why their steps are needed, as well as alternative ways to solve the problems.

2 Basic Functions in GIS GRASS 7.0

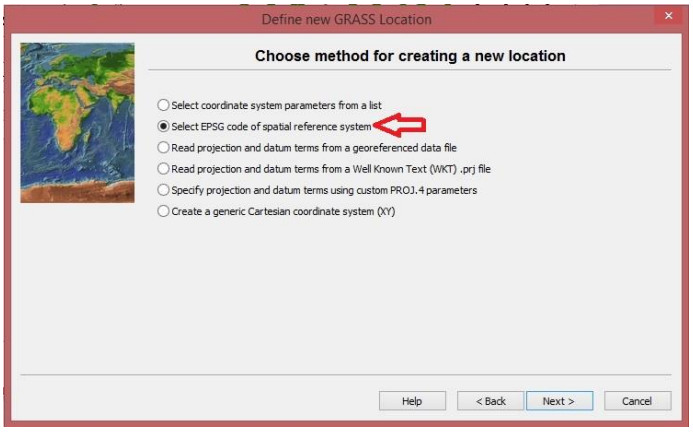
2.1 Set a Region

1. Open the Grass. In the initial layout you will click on “New”.

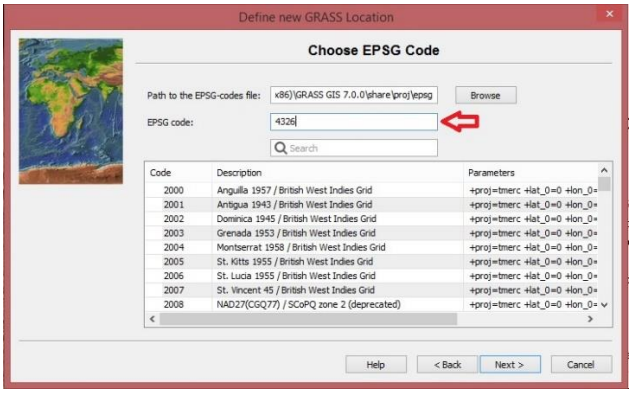
2. Fill the blanks “Project Location” and “Location Title”, after you will click on “Next”.



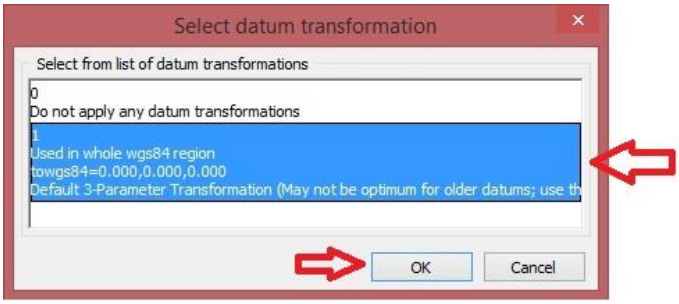
3. Select the option EPSG and click on “Next”.



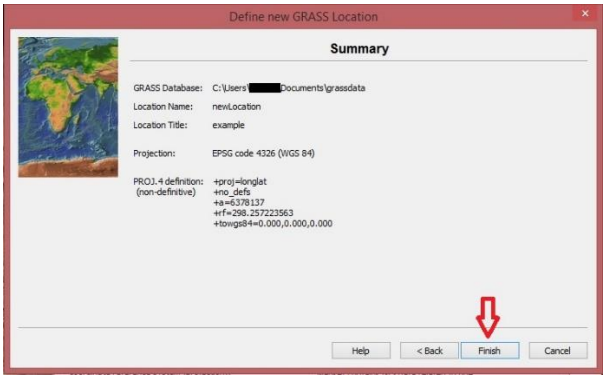
4. Insert the code “4326” at the blank EPSG Code and click on “Next”.



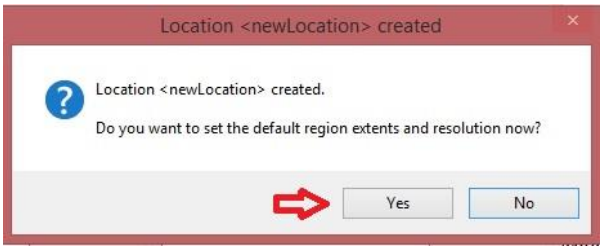
5. Confirm your selection just clicking on “OK”.



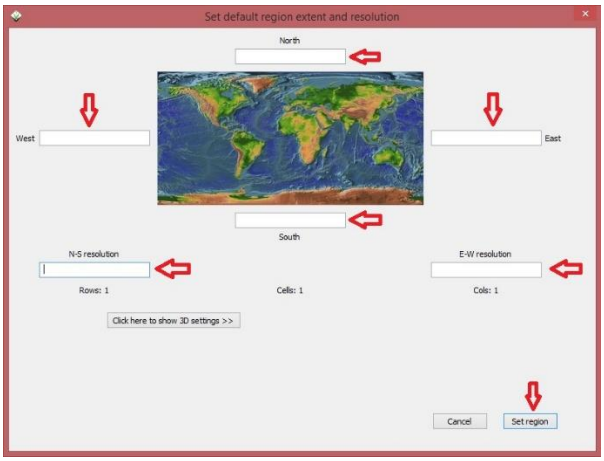
6. Check out your Summary and move on clicking on “Finish”.



7. You will see a message asking you to set the default region, click on “Yes”.

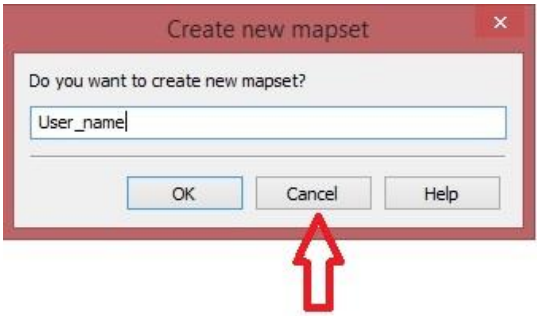


8. Set the limits and resolution of your region filling the indicated blanks at the picture below, then click on “Set region”.



Note: You can just accept the default values and set it after.

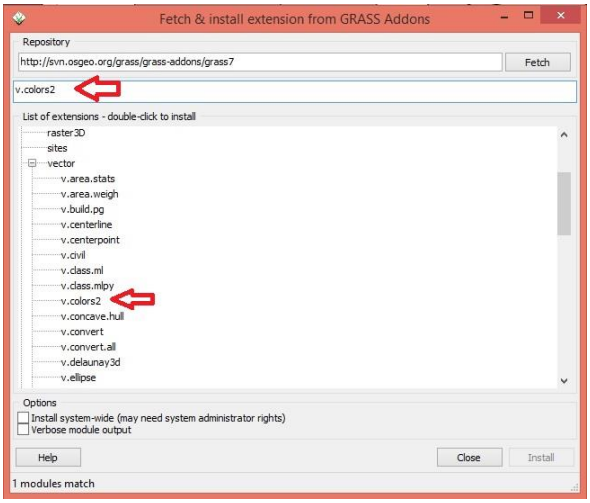
9. You will see a message asking you to create a new mapset, you must click on “Cancel”.



2.2 Installing Extensions

You will click on the main menu “Settings” >> “Addons extensions” >> “Install extension from addons”.

1. As a result you will see”Fetch & install etension from GRASS Addons” window, you can search your wished addon (or extension) into the menu or type its name in the blank space below the “Repository” (e.g. v.colors2). Then, you will click on “Install”.



2.3 The Map Display Window

1. The window Map display shows you the content of the Vector or Raster that you imported in your “Layer Manager” display.

2. There are a lot different tool available at Map display that are important you understand, as:

3.  Query raster/vector map(s): With this tool selected and the raster/vector that you are projecting to be market you are able to access the “Query results” information about each single point in your raster/vector map.

4. Note: At “Layer Manager” when you check the box referent a vector/raster you are going to project it at “Map display” and if you “mark” it clicking on the name of the raster/vector doing this to be gray colored you will be able to see the “Query results” about this raster/vector.

5.  Zoom in and zoom out: Using this tool you are able to do a zoom in/out in your map just clicking on the interesting point, but you can to draw a square at the interesting area to obtain a zoom in/out too.

6.  Zoom to selected map layer(s): This tool is going to show you your entire layer area at “Map display” window

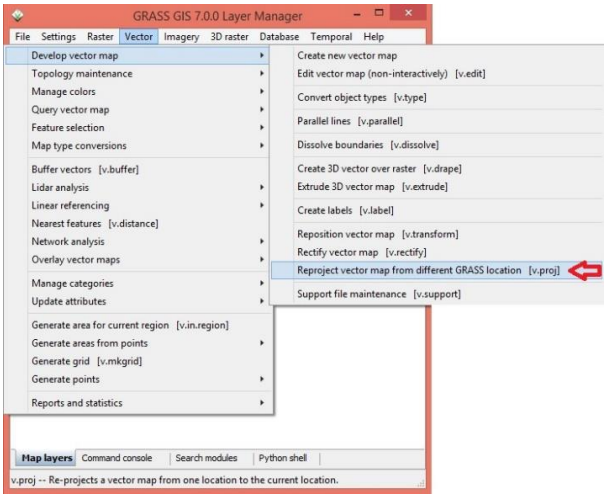
7.  Zoom to computational region extent: This tool is going to show you your entire computational region. To see what your computational region is you can set the dropdown box at the bottom of the “Map display” as “Show comp. extend”.

8.  Analyze map: Clicking on this tool you will see some extra features which are very helpful measure some aspects and parameters as distance and area. All these tool are easy to use, you can check it out to see their usability.

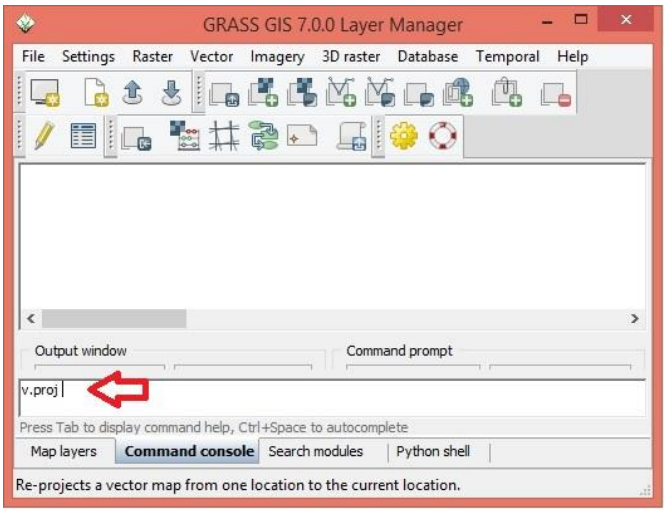
2.4 Change Coordinate Projection (lat/lon to UTM)

Note: If you are interesting to covert from lat/lon to UTM it is important you are in your destiny location, in this case in a UTM location.

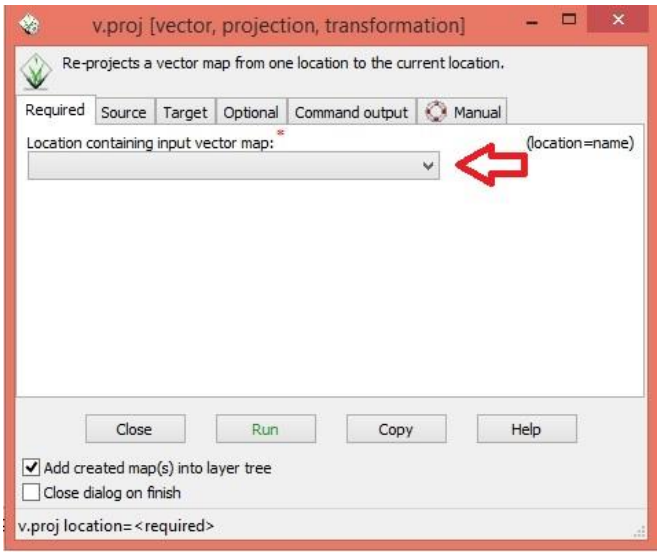
1. You will click on “Vector” >> “Develop vector map” >> “Reproject vector map from different GRASS location [v.proj]” as showed below.



Also, you can just type “v.proj” in your “Command console”. You will have the same result as showed in the next chart.

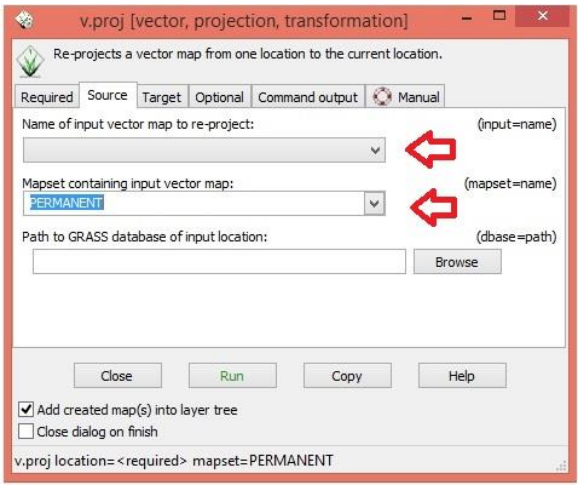


2. At “Required” tab you will set the parameter “Location containing vector map” as the location name of the vector you want to convert into an UTM projection.

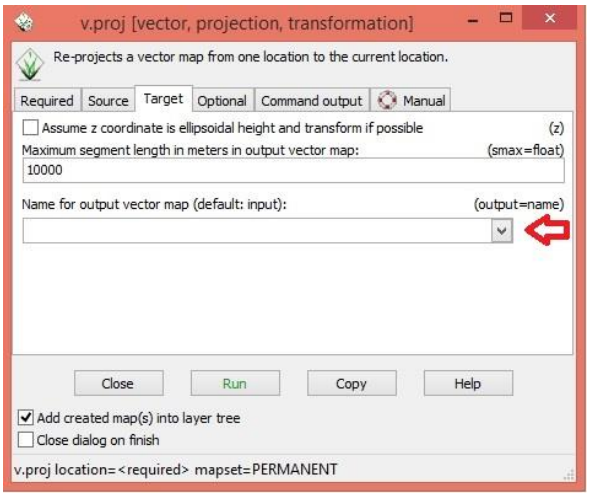


3. At “Source” tab you will set the parameter “Name of input vector map to re-project” as the name of the vector you want to convert into an UTM projection. Also you will set the parameter “Mapset containing input vector map” as PERMANENT if you’ve been using default

settings or with the mapset name that you saved the vector map.



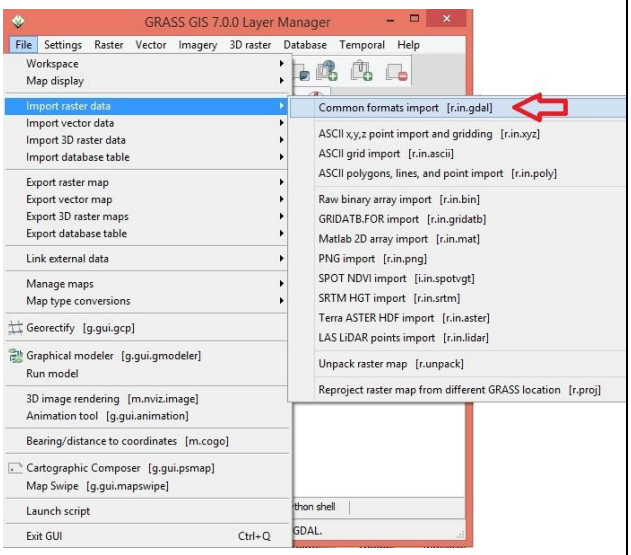
4. At "Target" tab you will set the parameter "Name for output vector map (default: input)" as the name you want to the new map after converted. Then you will click on "Run".



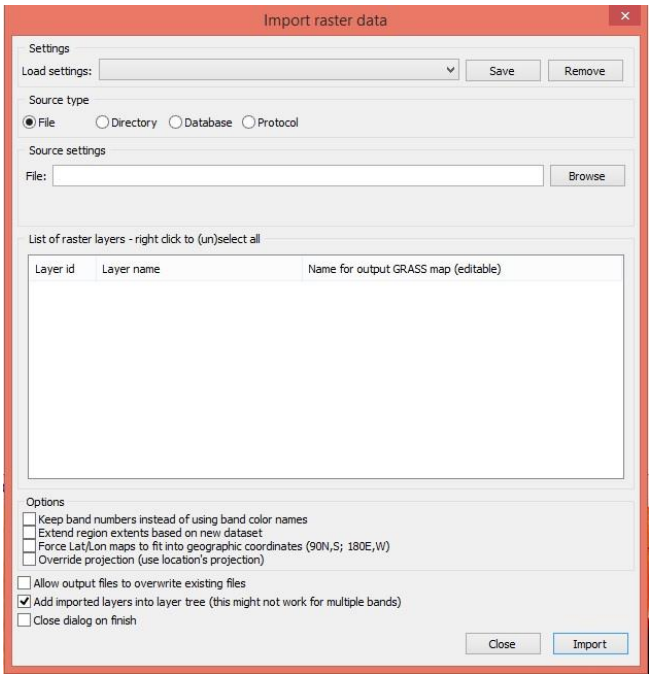
2.5 Add a raster map by importing/exporting

2.5.1 Import a raster map

1. In your "Layer Manager"" you will click on "File" >> "Import raster data" >> "Common formats import".

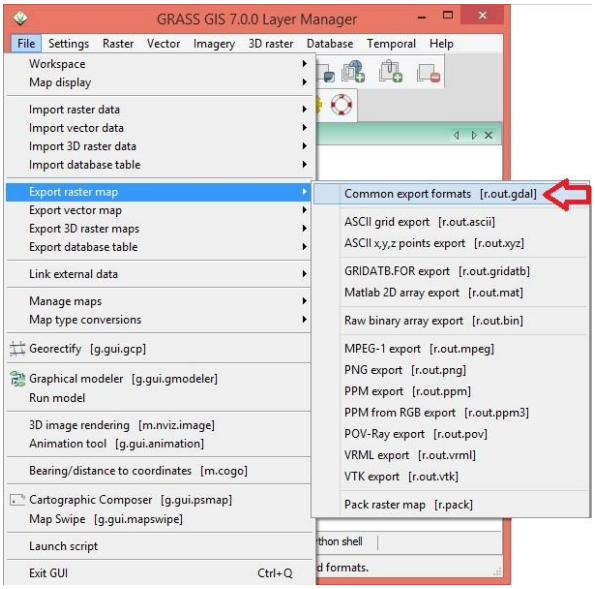


2. At "Import raster data" window you will set your preferences to import as well as "Source Type" and "Source settings", then you will click on "Import".

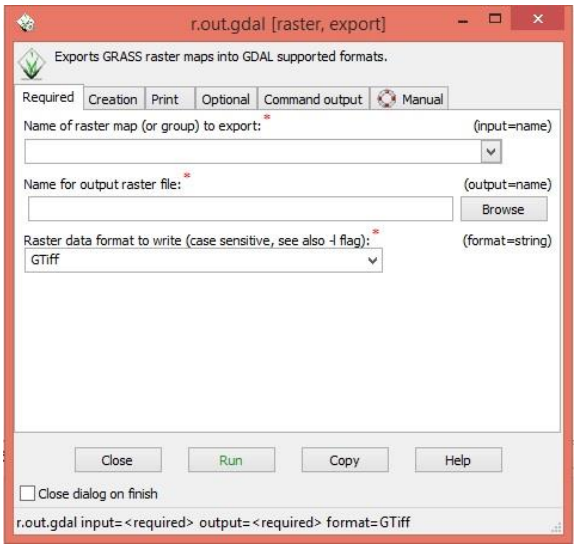


2.5.2 Export a raster map:

3. In your "Layer Manager" you will click on "File" >> "Export raster map" >> "Common export formats".

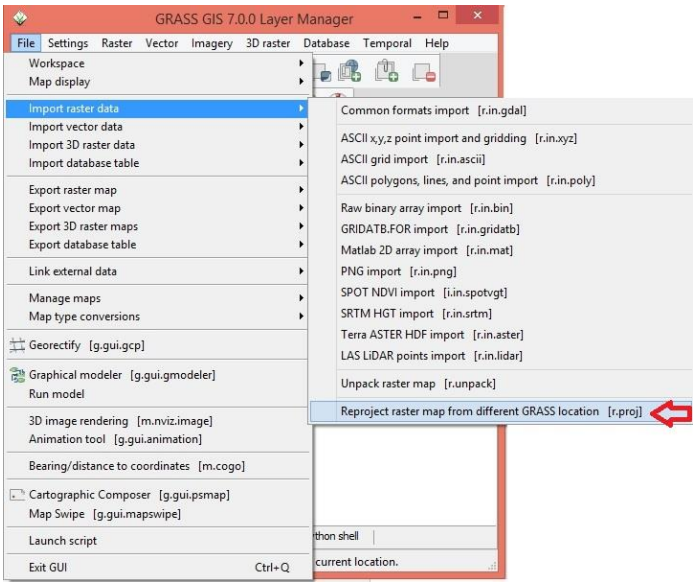


4. At “r.out.gdal” window you will set your preferences to export as well as “Name of raster map”, “Name for output raster map” and “file extension”, then you will click on “Run”.



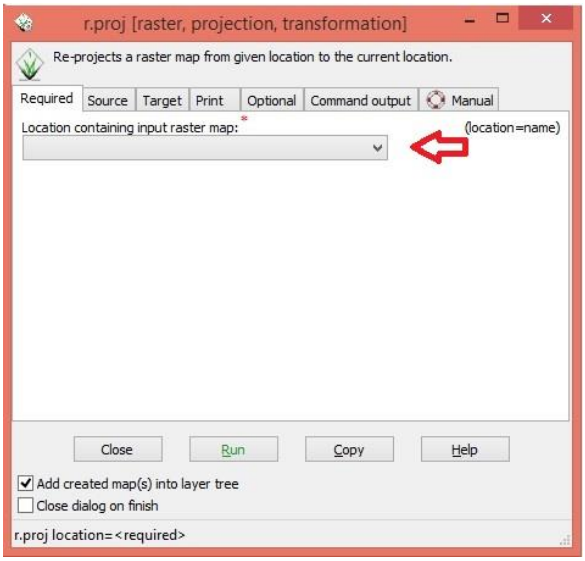
2.6 Add a raster map by re-projecting

1. You will click on “File” >> “Import raster data” >> “Reproject raster map [r.proj]”. Also, you can have the same result typing “r.proj” in your “Command console” line.

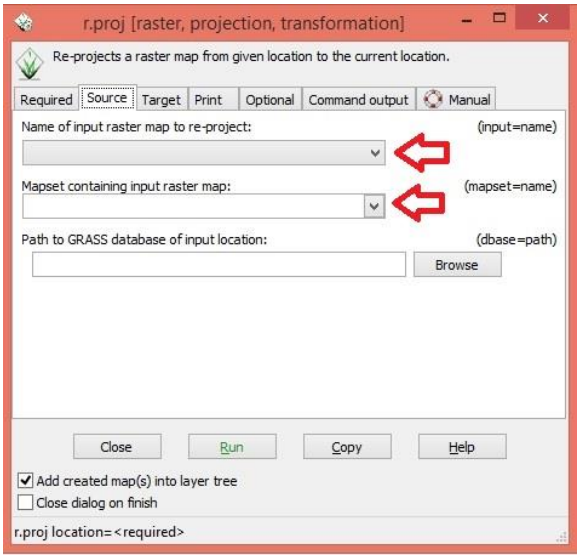


Note 1: You can also click on “Raster” >> “Develop raster map” >> “Reproject raster map”.

2. As a result, a new window will be showed for you, then you will set the parameter “Location containing input raster map” at tab “Required”.



3. At tab “Source” you will set the parameters “Name of input” and “Mapset containing input raster map”.



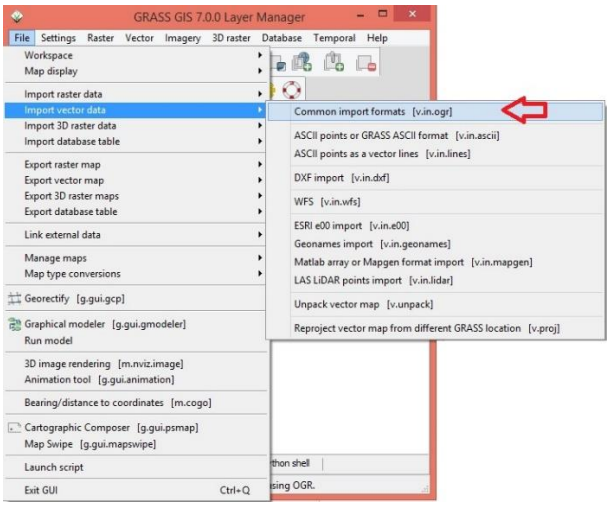
4. As a result you will see the layer that you are re-projecting showed in your “Map display”.

Note 2: If you are re-projecting a layer from LAT-LON system to UTM you must be with a location opened corresponding to your output, in this case an UTM location.

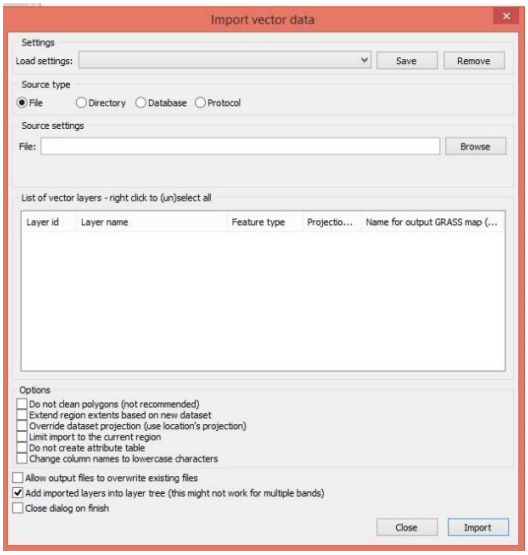
2.7 Add a vector map by importing/exporting

2.7.1 Import a vector map:

1. In your “Layer Manager”” you will click on “File” >> “Import vector data” >> “Common formats import”.

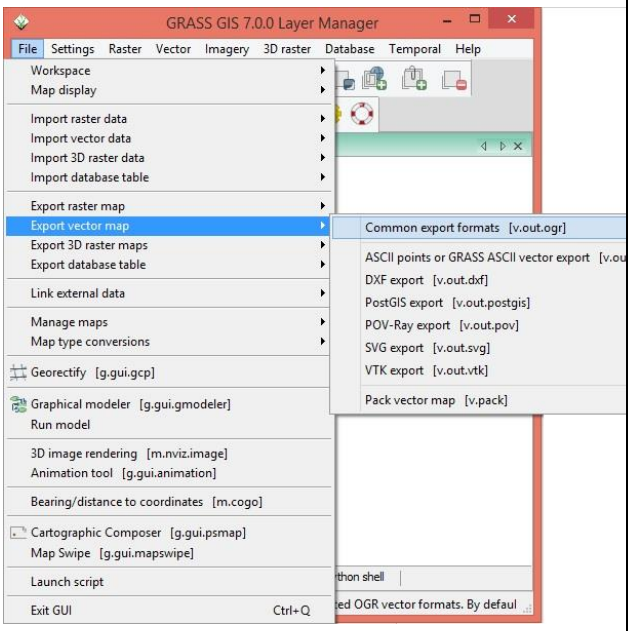


2. At “Import vector data” window you will set your preferences to import as well as “Source Type” and “Source settings”, then you will click on “Import”.

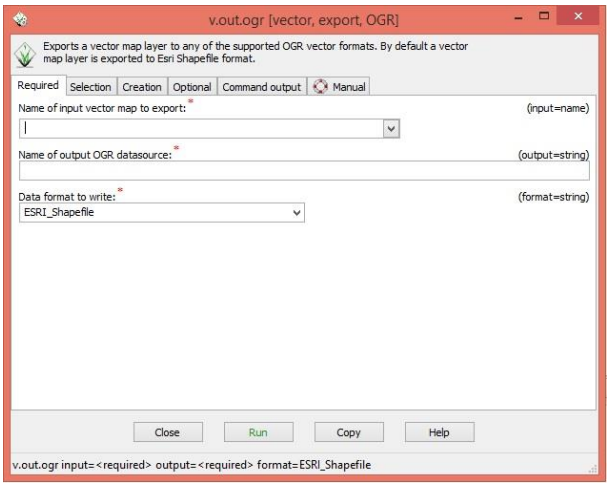


2.7.2 Export a vector map:

1. In your “Layer Manager” you will click on “File” >> “Export vector map” >> “Common export formats”.

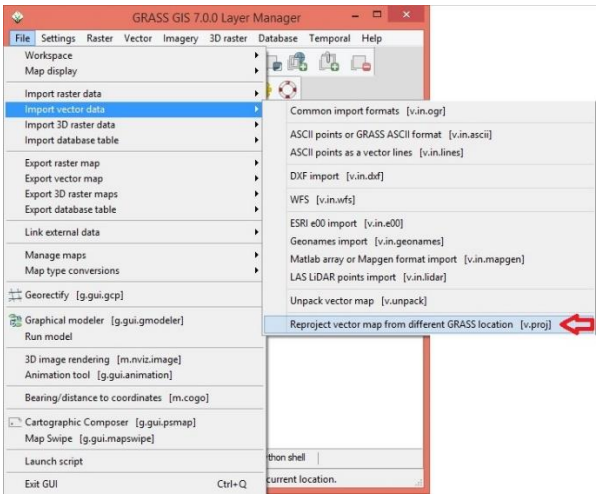


2. At “v.out.ogr” window you will set your preferences to export as well as “Name of vector map”, “Name for output OGR datasource” and “Data format to write”, then you will click on “Run”.



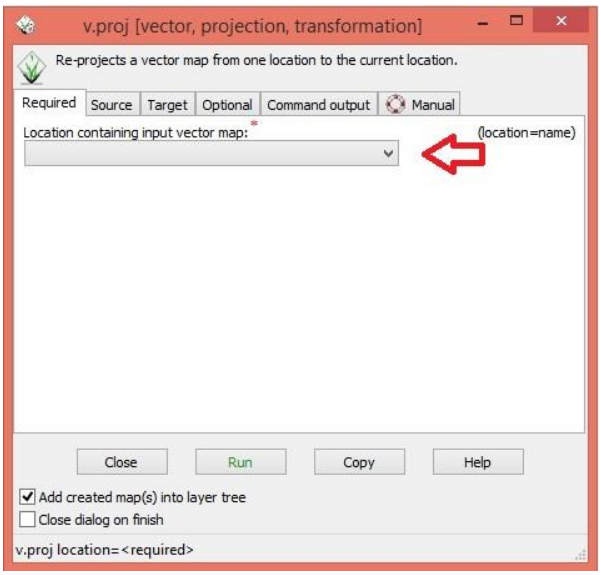
2.8 Add a vector map by re-projecting

1. You will click on “File” >> “Import vector data” >> “Reproject raster map [v.proj]”. Also, you can have the same result typing “v.proj” in your “Command console” line.

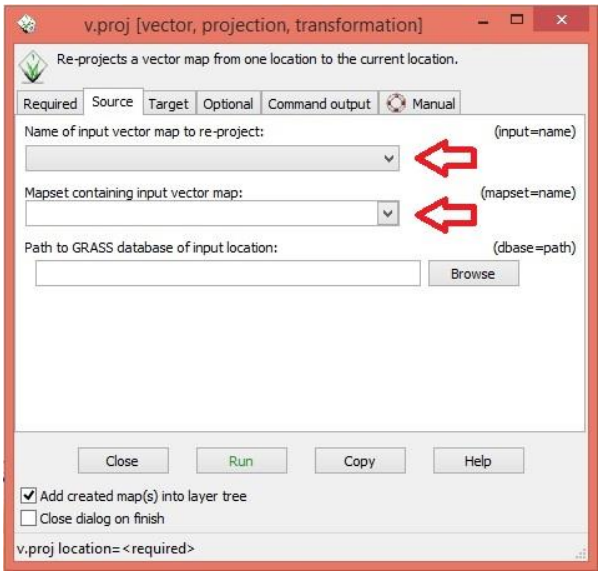


Note 1: You can also click on “Vector” >> “Develop vector map” >> “Reproject vector map”.

2. As a result, a new window will be showed for you, then you will set the parameter “Location containing input vector map” at tab “Required”.



3. At tab "Source" you will set the parameters "Name of input" and "Mapset containing input vector map".



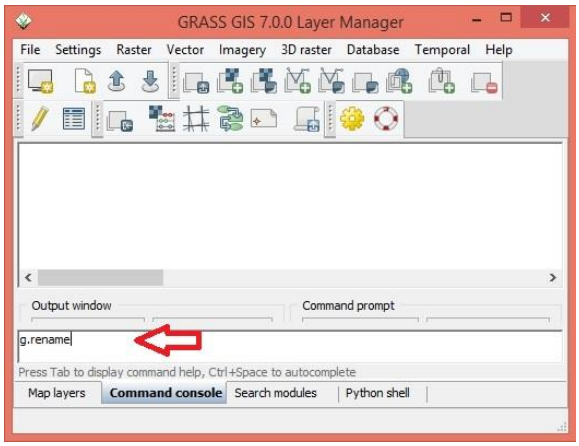
4. As a result you will see the layer that you are re-projecting showed in your "Map display".

Note 2: If you are re-projecting a layer from UTM system to LAT-LON you must be with a location opened corresponding to your output, in this case a LAT-LON location.

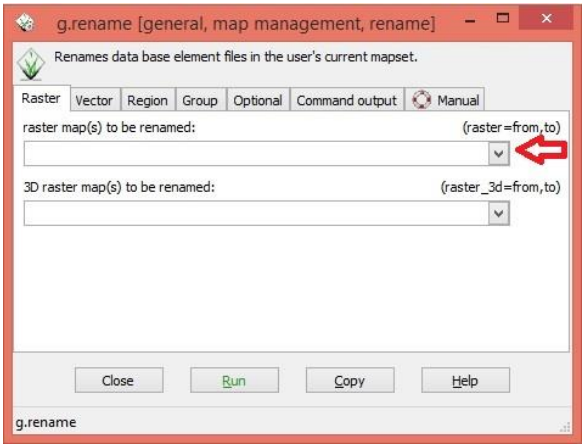
2.9 Rename a map

2.9.1 Raster Map:

1. The first step you will type “g.rename” at your “Command console”.

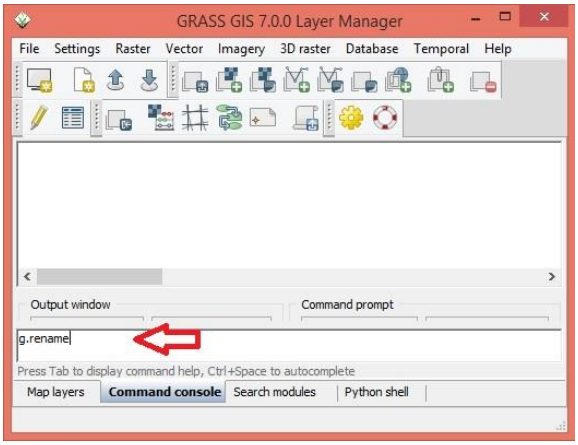


2. At”g.rename” window you will select the raster map you want to rename at the dropdown box called “raster map(s) to be renamed”. Also, you will type at the same window the new name for this same raster separated by comma (i.e. old_raster@PERMANENT,new_raster). Then you will click on “Run”.

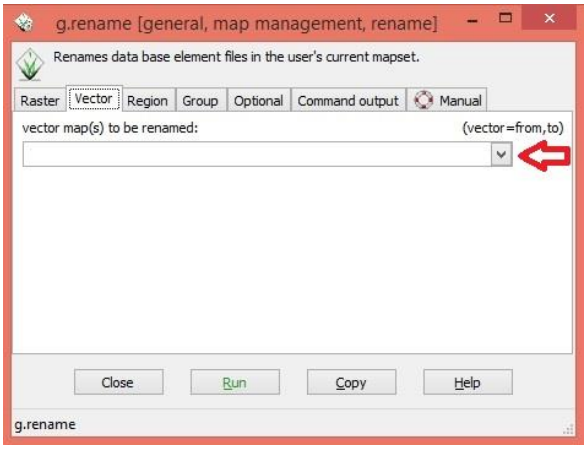


2.9.2 Vector map:

1. The first step you will type “g.rename” at your “Command console”.



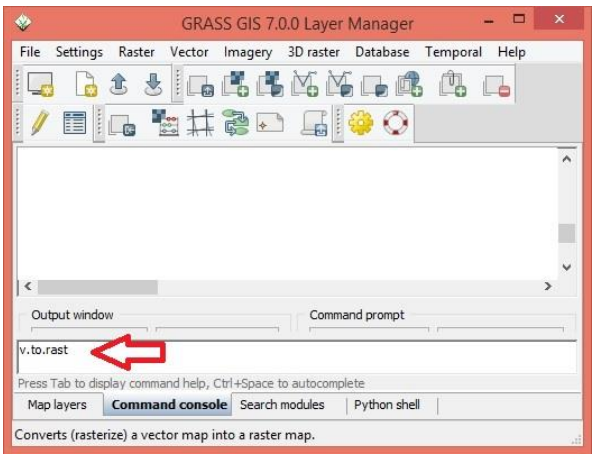
2. At “g.rename” window you will select the vector map you want to rename at the dropdown box called “vector map(s) to be renamed” at tab “Vector”. Also, you will type at the same window the new name for this same raster separated by comma (i.e. old_vector@PERMANENT,new_vector). Then you will click on “Run”.



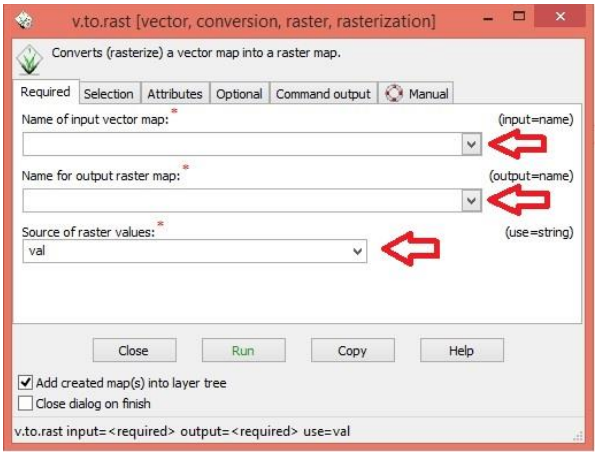
2.10 Convert between vector and raster types

2.10.1 From vector to a raster:

1. Type the command “v.to.rast” in the command line at “Layer Manager”.



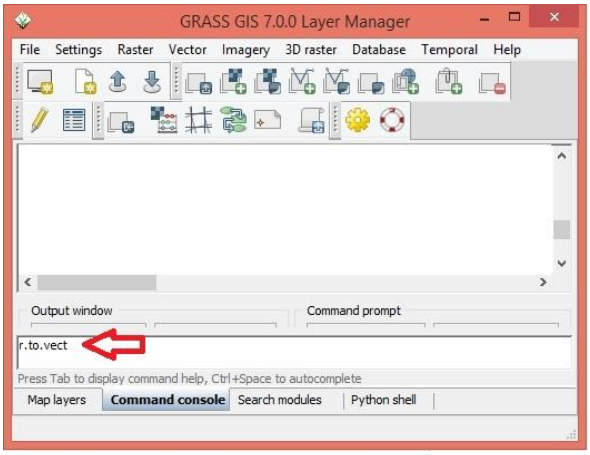
2. Fill the blank “input” with the map’s name you want to convert, and fill the blank “output” with the map’s name you want to generate. Also, set the dropdown box as “val”, then click on “Run”.



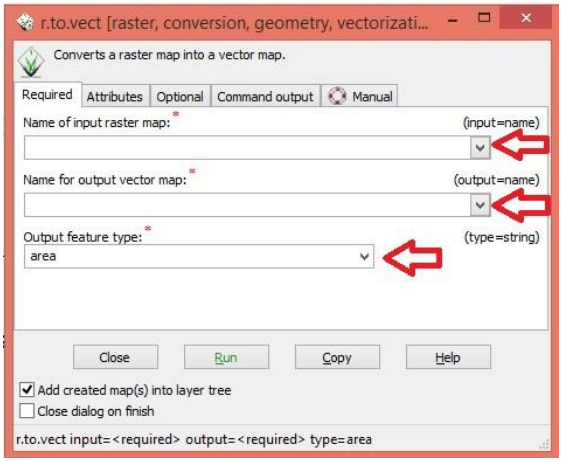
3. As a result, you will see the converted map in your “Layer Manager”.

2.10.2 From raster to vector:

1. Type the command “r.to.vect” in the command line at “Layer Manager”.



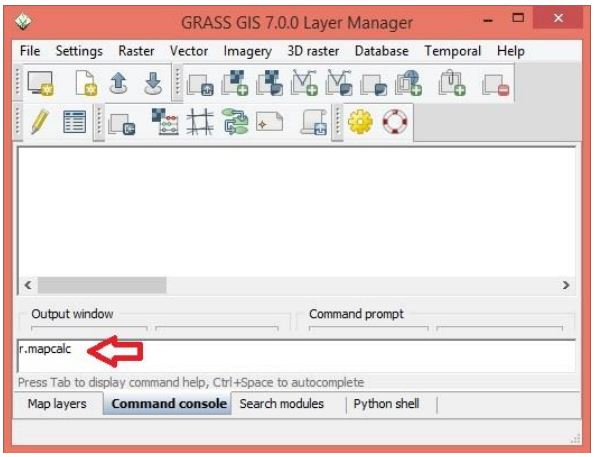
2. Fill the blank “input” with the map’s name you want to convert, and fill the blank “output” with the map’s name you want to generate. Also, set the dropdown box as “area”, then click on “Run”.



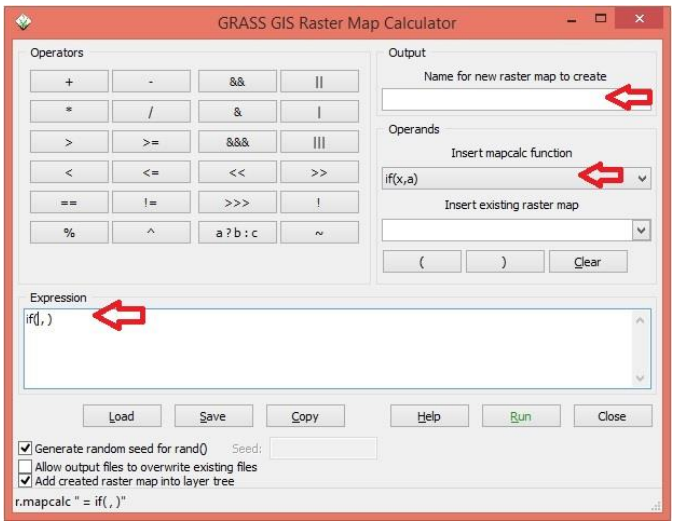
3. As a result, you will see the converted map in your “Layer Manager”.

2.11 Clip a Raster

1. You will type “r.mapcalc” in your “command console”. As a result you will see the “GRASS GIS Raster Map Calculator” window.



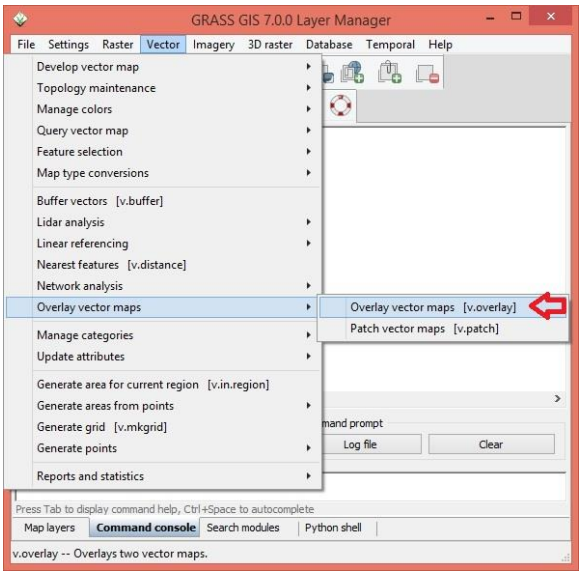
2. At “GRASS GIS Raster Map Calculator” window you will fill the attributes “Output” with the name of your new map and “Operands” with the function “if(x,a)”. In the dropdown box you will select the layer that has your crop format and the layer that you will crop as well as they must be separated per comma (i.e. if(raster_format_I_want,raster_I_have)). Then you will click on “Run”.



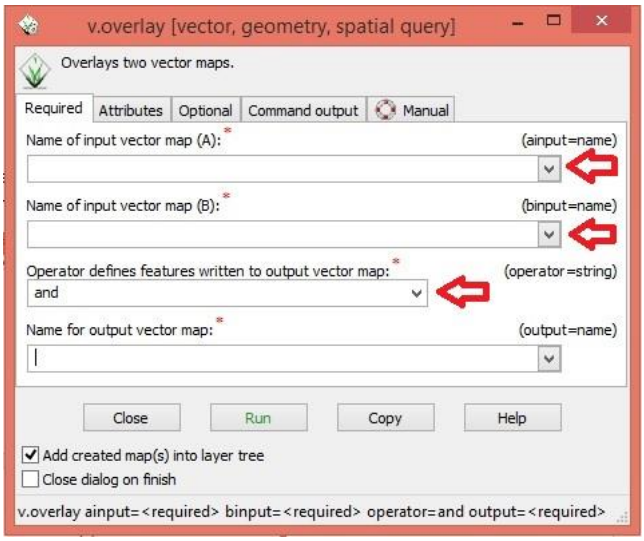
Note: To understand better what expect from a crop you can see an example given at “Main canal longitudinal profile” topic of this document.

2.12 Clip a vector

1. You will click on “Vector” >> “Overlay vector maps” >> “Overlay vector maps [v.overlay]”. Then you will see the “v.overlay” window.



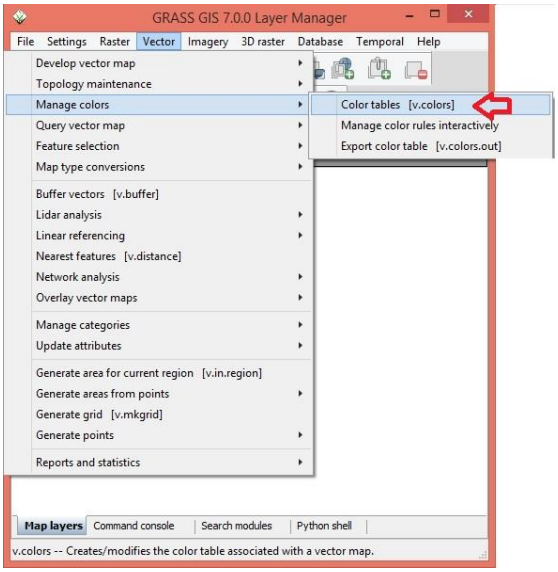
2. At “v.overlay” window you will set parameter as “Name of input vector map (A):” with the vector map you want to crop, “Name of input vector map (B):” with the vector that has the area of interest which will be the cut, “Operator defines features written to output vector map:” with “and”, and you will fill the blank “Name for output vector map” with the name of the vector you want to generate. Then, click on “Run”.



Note: To understand better what expect from a crop you can see an example given at “Main canal longitudinal profile” topic of this document.

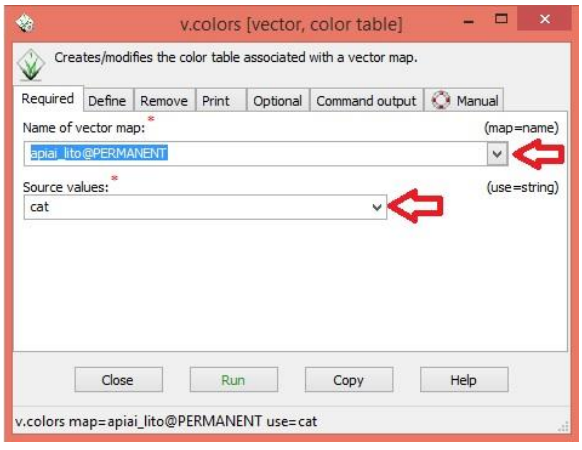
2.13 Set a vector color table

1. You will click on “Vector” >> “Manage colors” >> “Color tables”.

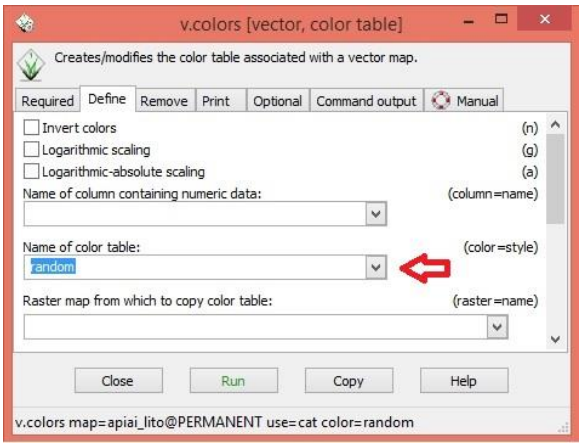


2. Note 1: Also, you can have the same result typing “v.colors” in your “Command console”.

3. As a result, a new window will be showed to you, then you will set the parameter “Name of vector map” at tab “Required”.



4. At tab “Define” you will set the parameter “Name of color table” as the color table that you need. After this, just click on “Run”. Figure 1 depicts the result of the color table called *random* to a lithology vector map,



Note 2: An important tool is the dropdown box called “Vector map from which to copy color table” that can help you when you need to compare two or more different layers using them color scale.

Note 3: the colors of the color table will be applied to every categorized feature in the map; closed regions. Eventually, more than one map feature will belong to one thematic information from the map theme. For example, one geological formation might appear splitted in two or more regions, which in this case will show with two or more color and is not desirable. To apply the color table to a specific map information, one is referred to the topic *Add a RGB_column to the vector map table* of this document.

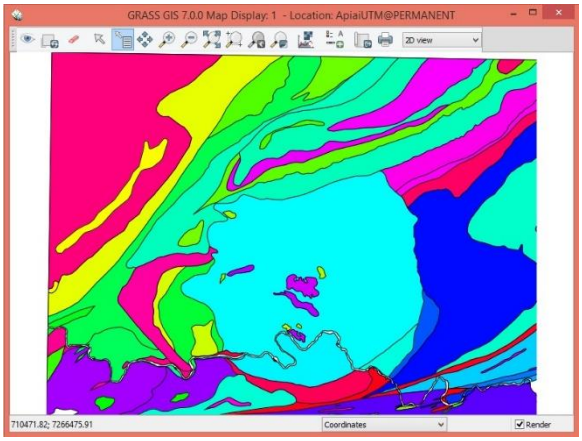
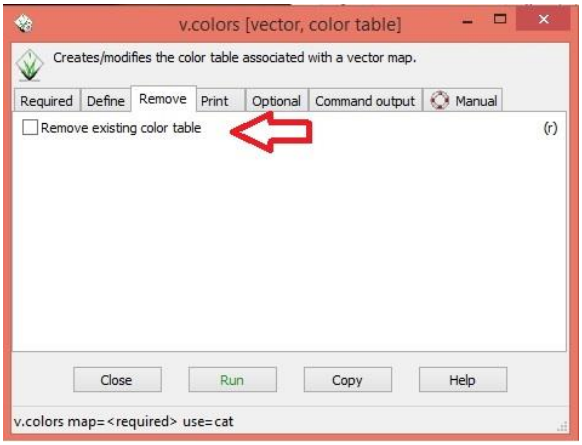


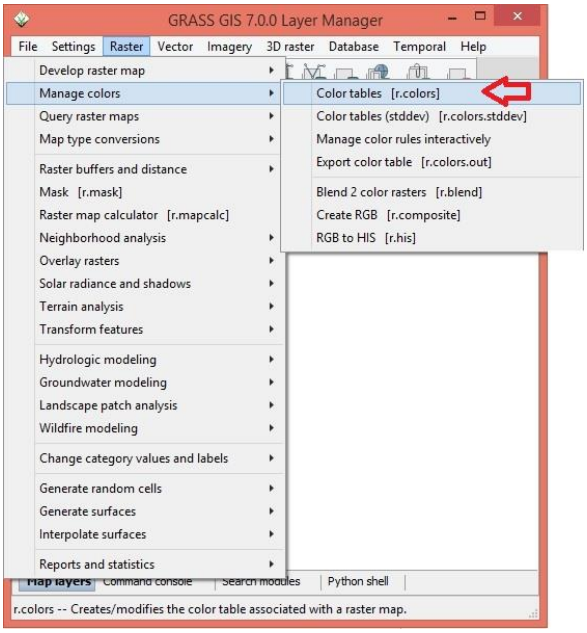
Figure 1: Result from using the *random* as the name of color table.

Note 4: If you want to remove the new color table included you should go back to the command "v.colors" and at tab "Remove" you can just check the box and click on "Run".

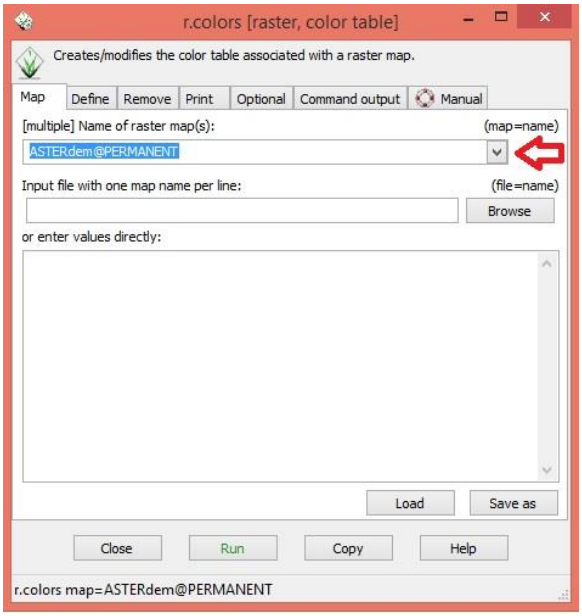


2.14 Set a raster color table

1. You will click on "Raster" >> "Manage colors" >> "Color tables".

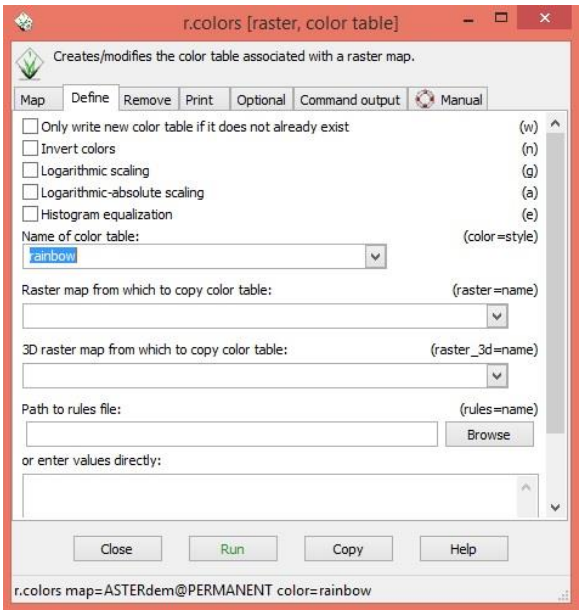


2. As a result, a new window will be showed for you, then you will set the parameter "Name of raster map" at tab "Map",



Note 1: Also, you can have the same result typing "r.colors" in your "Command console" line.

3. At tab "Define" you will set the parameter "Name of color table" as the color table that you need. After this, just click on "Run". Figure 2 depicts the result of the color table called *rainbow* to an elevation raster map,



Note 2: An important tool is the dropdown box called "Raster map from which to copy color table" that can help you when you need to compare two or more different layers using them color scale.

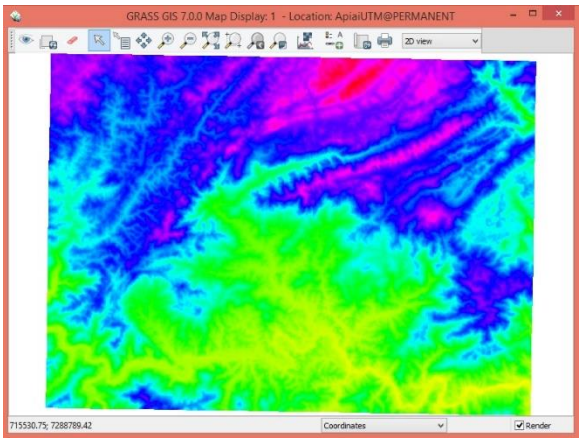
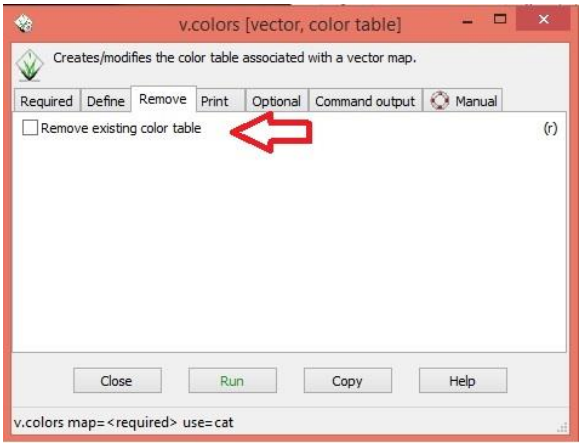


Figure 2: Result from using the *rainbow* as the name of color table.

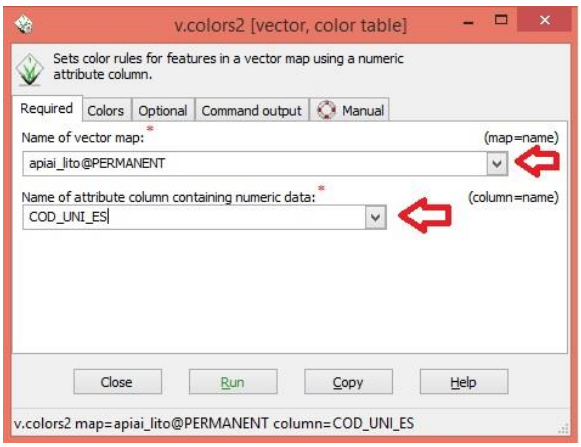
Note 3: If you want to remove the new color table included you should go back to the command "r.colors" and at tab "Remove" you can just check the box and click on "Run".



2.15 Add a RGB_column to the vector map table

First, you have to install the command "v.colors2" at first time you will use it. To install it you are referred to the topic "Installing add-ons" of this document.

1. With your command installed you will type "v.colors2" in your "command console". As a result you will see the "v.colors2" window

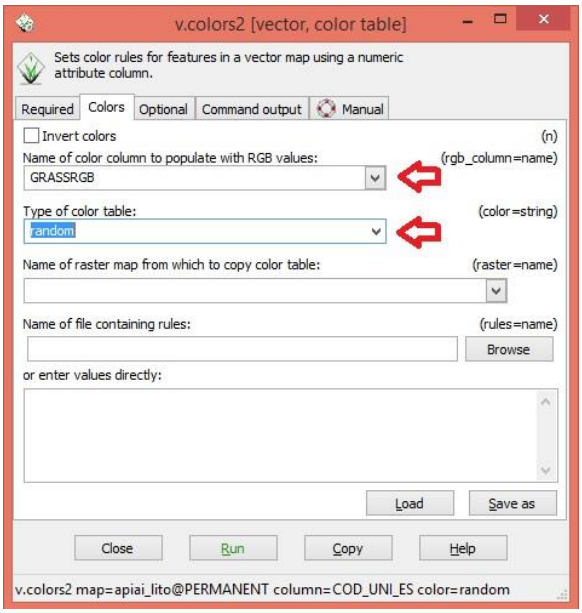


2. At tab "Required" you will fill the parameters "Name of vector map" and "Name of attribute column containing numeric data".

Note 1: The parameter "Name of attribute column containing numeric data" will be the value's column in your "attribute data" relative your map. If you need to see your "attribute data" at "Layer Manager" you will click on with the right button upon the layer of interest, then you will click on "Show attribute data".

3. Still in "v.colors2" window, at tab "colors" you will fill the attributes "Name of color column to populate with RGB values" and "Type of color table" then click on "Run".

Note 2: If you do not fill the attribute "Name of color column to populate with RGB values" it will be filled automatically as "GRASSRGB"



4. To apply the results in your map you will click on with the right button in the layer that you created the new column RGB and click on "Properties". As a result you will see "d.vect" window, then you will change the attribute "Colorize features according color definition column" at table "colors" to the column name that you already created in those pre steps, then click on "OK". Now you can see the results in your map. Figure 3 depicts the result of the color table called *random* to the attribute column called *COD_UNI_ES* in the attribute table of a lithology vector map,

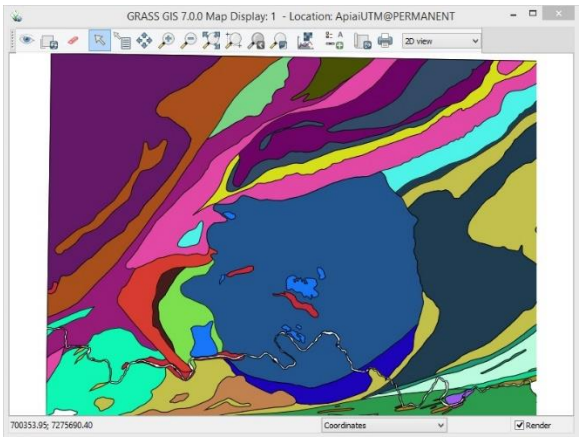
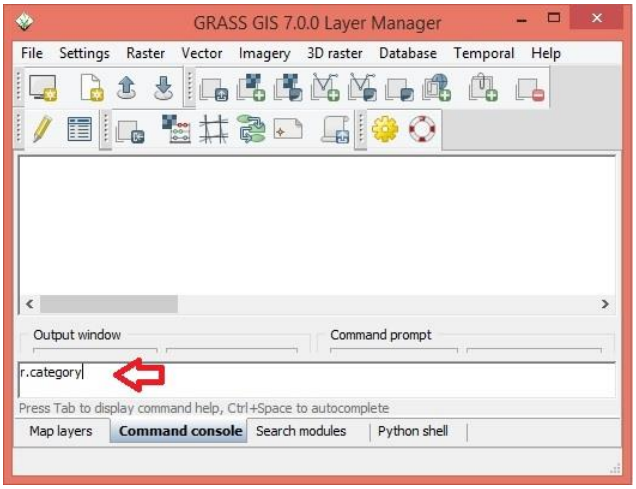


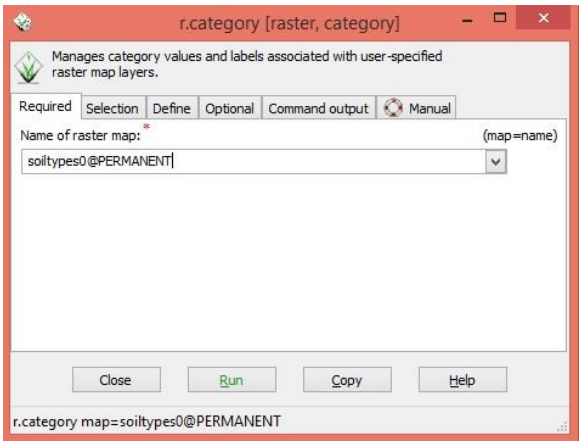
Figure 3: Result from using the *random* as the name of color table.

2.16 Add (set) category labels to a raster map

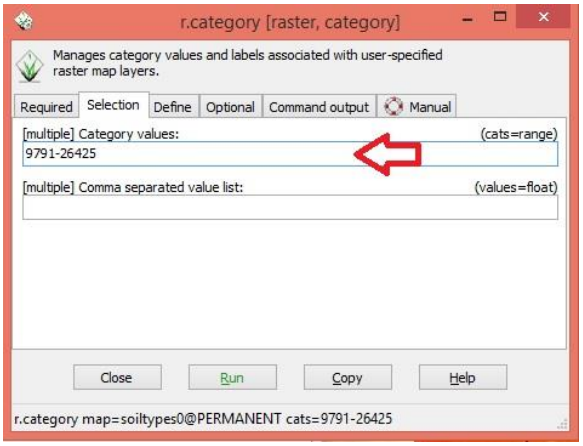
1. First of all you are going to type "r.category" in your "Command console". As a result you will see the "r.category" window.



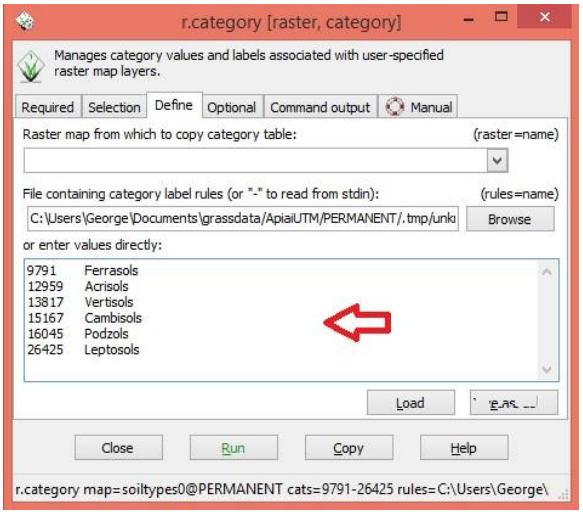
2. At tab "Required" you will set the parameter "Name of raster map" as the name of the map you want to add/set to the categories labels.



3. At tab “Selection” you will set the parameter “Category values:” as the values which your categories will content or the range they are (i.e. I have a raster map showing me soils code that go from 9791 to 26425, I will fill the blank “Category values” as well as my interval: 9791-26425).



4. At tab “Define” you will fill the blank “or enter values directly:” as a relationship between your categories that you set at tab “Selection” and the labels that you want to have for each category.



Note 1: you will enter the values as:

“The value in your range” “Field separator” “Label name”

Using the same range at step #3 we could have this, for example:

9791 Ferrasols

12959 Acrisols

13817 Vertisols

15167 Cambisols

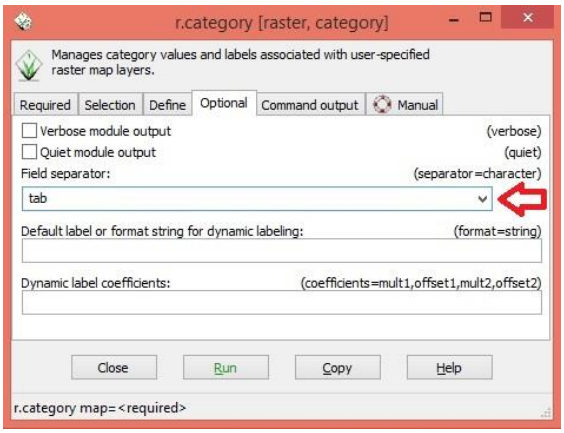
16045 Podzols

26425 Leptosols

Note 2: In this example the “Field separator” is the default choice (tab).

Note 3: The blank “File containing category label rules” will be different for each one according your GIS GRASS installation.

5. At tab “Optional” you can change the “Field separator” mentioned before. After all parameter filled you must click on “Run”.



6. As a result now you can see the new category in your map. For example, the next picture show you an soils distribution map which was added a category label contenting the range of all the different type of soils and classifying them as Ferrasols, Acrisols, Vertisols, Cambisols, Podzols and Leptosols. As you can see, this is a result from the "Cartographic Composer" according the range. Figure 4 depicts the result of the category label rules to the raster values in a soil types raster map, The legend was added with the aid of the Cartographic Composer GRASS module, which is addressed by this document at the topic The Cartographic Composer.

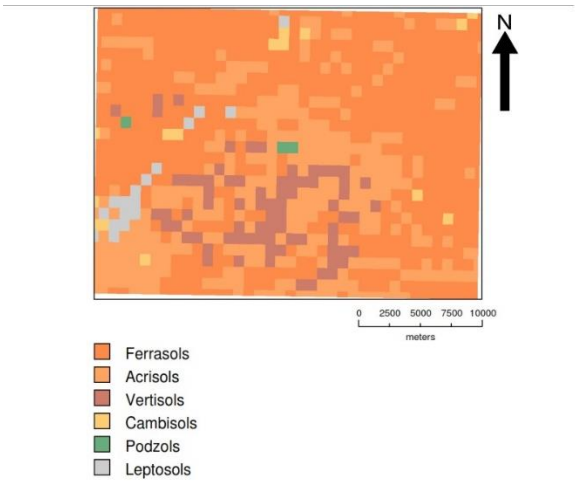
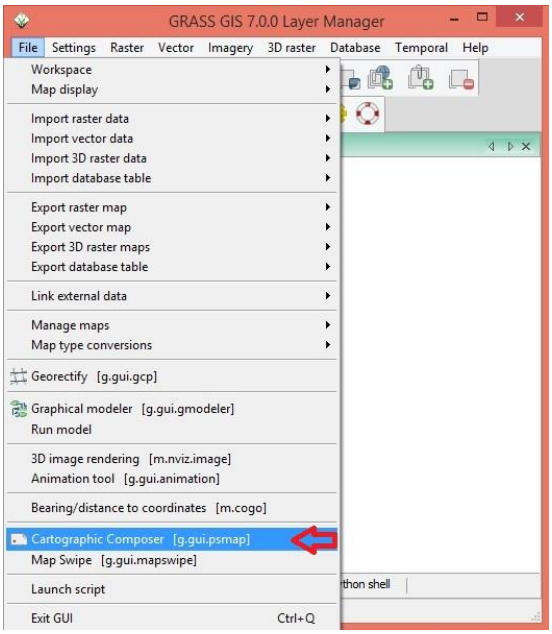


Figure 4: Result from add category label to a soil's map.

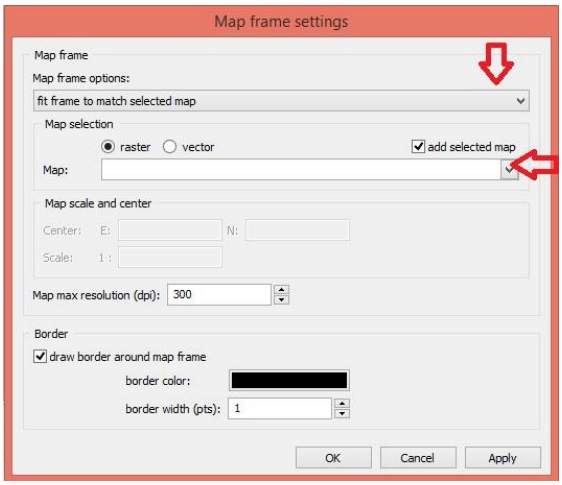
2.17 The cartographic composer

1. To access the Cartographic mode you will click on “File” >> “Cartographic Compose”. As a result you will see the “GRASS GIS Cartographic Composer” window.



2. First of all, at “GRASS GIS Cartographic Composer” window you will click on  “Map frame”.

3. At the box “Map frame settings” you will set the parameters “Map frame options” and “Map selection”.



4. Clicking on  you will see a range of options as “Legend”, “Map info”, “Scale bar”, “Text”, “Image” and “North Arrow”. Every those are simple to use, but there is a little trick to use the tool “Legend”.

When you click on “legend” you are going to see the “Legend settings” window asking you about “Raster legend” and “Vector legend”, but you are not able to add for example a vector in that window. However, if you want to include Raster and Vectors to use in your legends you have to click on twice on your “MAP FRAME” area. Then you will see options to do it, and after you can go back to the tool legend and manipulate the legends as you like.

5. After the entire process you should save your project and to do the Cartographic composer has a useful tool based on Encapsulated PostScript handled by clicking on the button  (so called Generate text file with mapping instructions). Saved project is loaded by clicking on the button <add button icon>.

The map can be exported to publishing formats like Portable Document File (PDF) by clicking on  .

6. As an example you can see a result from a map created with the cartographic composer mode (Figure 5). Two layer maps were used in this example: one vector map showing a watershed area and another raster map elevations map showing the terrain elevation. The raster legend was added as depicted. Also you can see a text labeling the legend and an arrow showing the North.

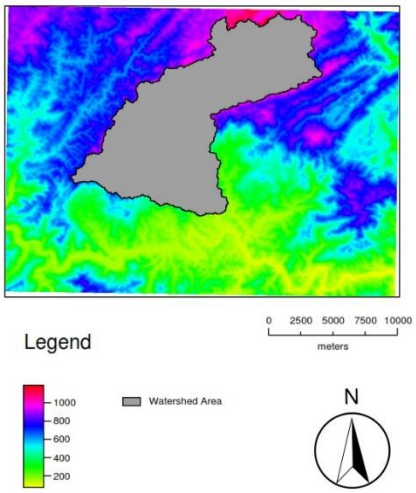


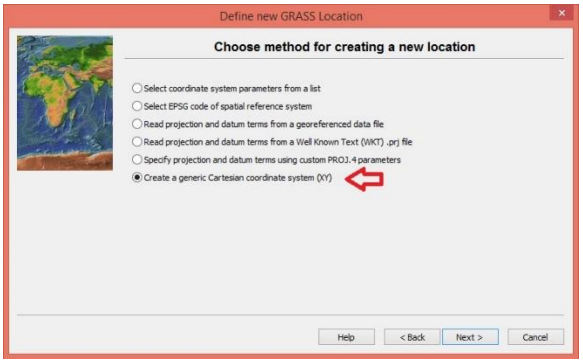
Figure 5: Result from using a raster and a vector map together at cartographic composer mode.

2.18 Georeferencing images/group

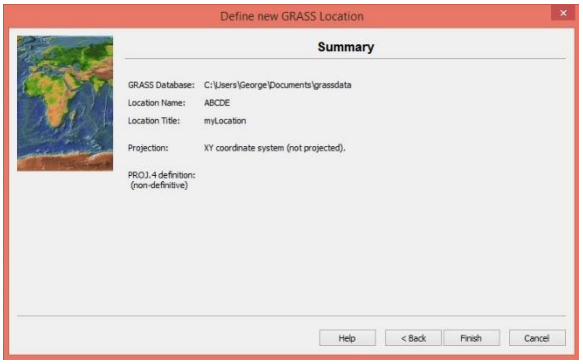
1. Open the Grass. In the initial layout you will click on “New”.

2. Fill the blanks “Project Location” and “Location Title”, after you will click on “Next”.

3. You will select the option “Create a generic Cartesian coordinate system (XY)”.



4. You will check twice your choices and click on “Finish”.



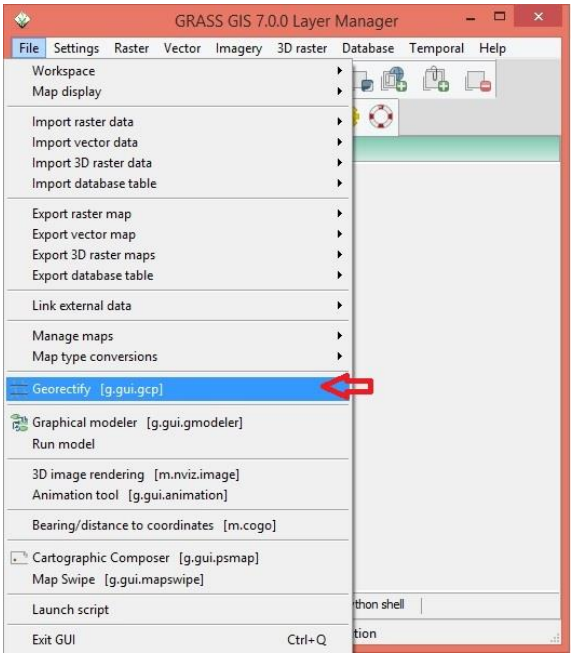
5. At “Location <Name Location> created” window you will click on “No”.

6. At “Create a new mapset” window you will click on “Cancel”.

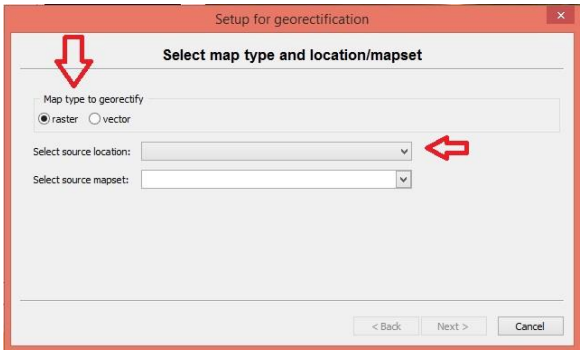
7. Now you will select your just new location created and click on “Start Grass Session”.

8. Use the command “r.in.gdal” (addressed by the topic “Add a raster map by importing/exporting”) to import the map figure you want to georectify into the location you just created.

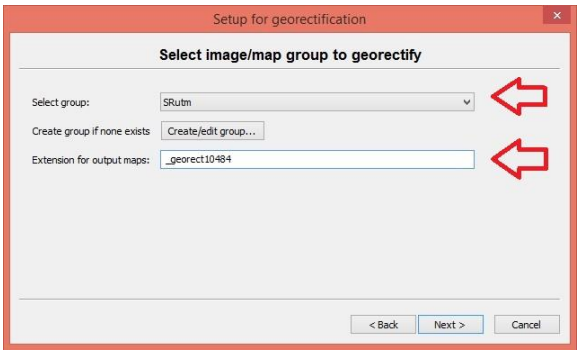
9. You will go to “File” >> “Georectify [g.gui.gcp]”.



10. At”Setup for georectification” window you will select between “Raster” and “Vector” then you will set the parameter “Select source location”. The dropdown menu “Select source mapset” will be filled automatically.

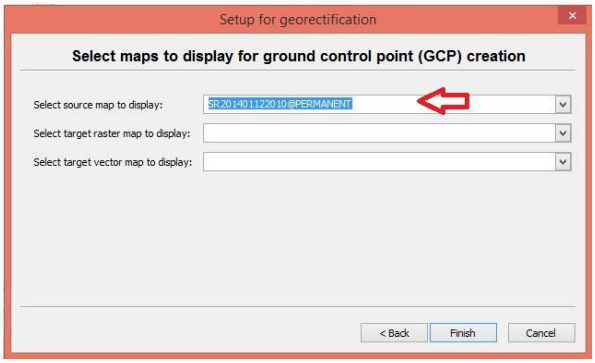


11. Either, type an extension at "Extension for output maps:" or accept the default.



Note 1: The dropdown box "Select group" will be automatically the group from the location that you're working with. If you want to georeference an image from another location, you should open such location before, then repeat these steps.

12. Now you will select the map you want to georeference at "Select source map display" set as well you will select the same map at "Select target raster map to display" set.



13. At "Manage Ground Control Points" (Manage GCP) you click on  to add new GCP points.

Note 2: You must include at least 3 points and they cannot be aligned or it is going to cause an error. See example below (Figure 19).

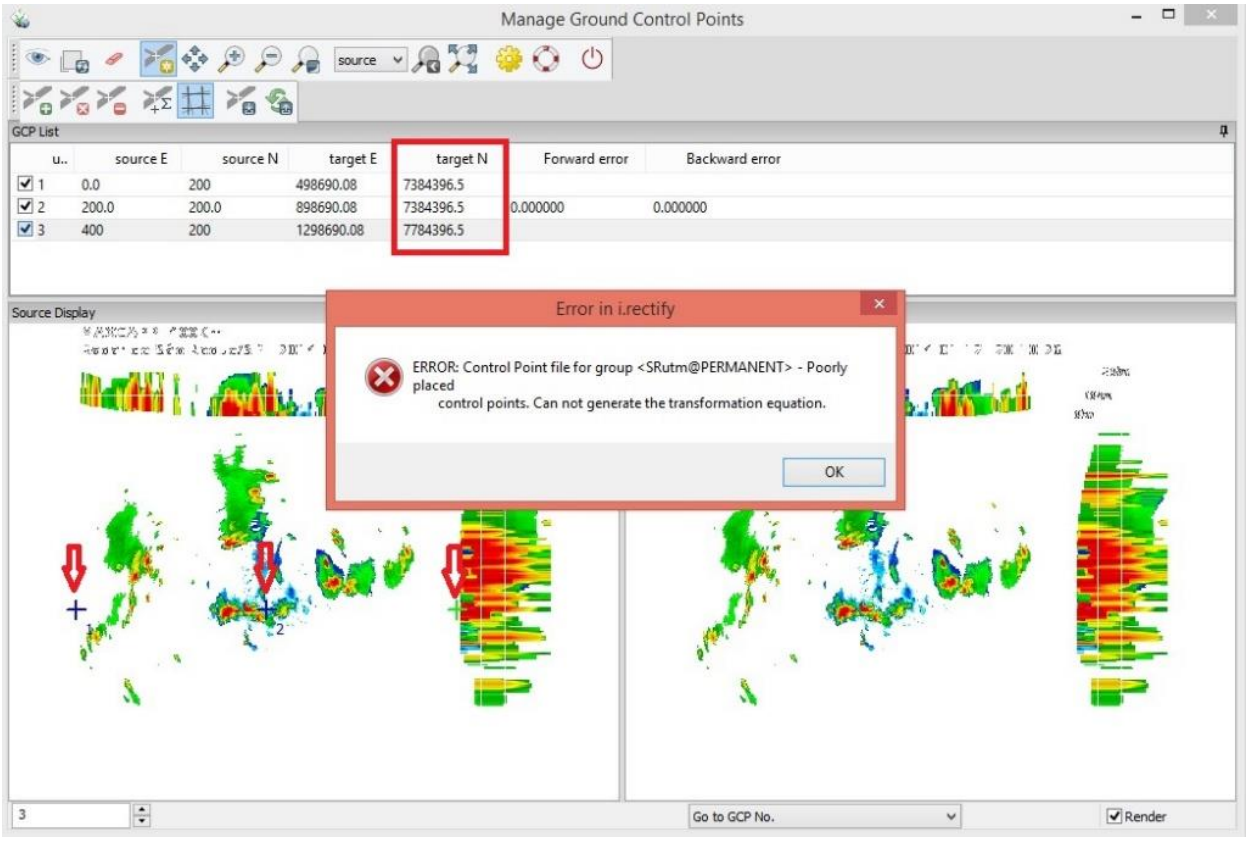
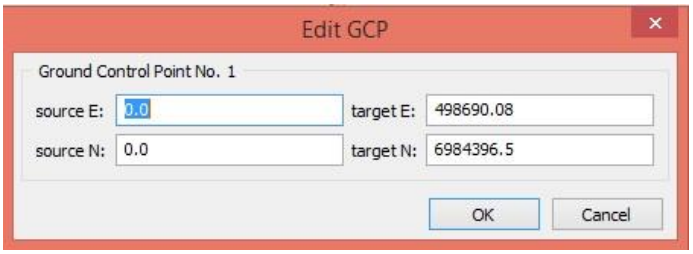


Figure 19: Result from setting three align points to georeference a map.

14. The next step is to fill in correctly the ground points. To do so you must click on twice upon each record of the GDP list and fill in the pixel's coordinates and fill the



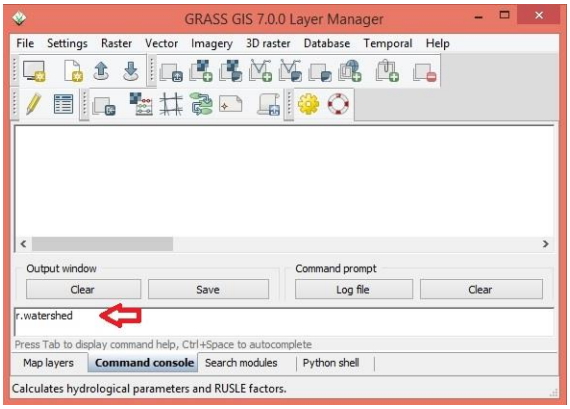
UTM coordinates.

15. Now you will just finish the process of georeferencing clicking on at  .

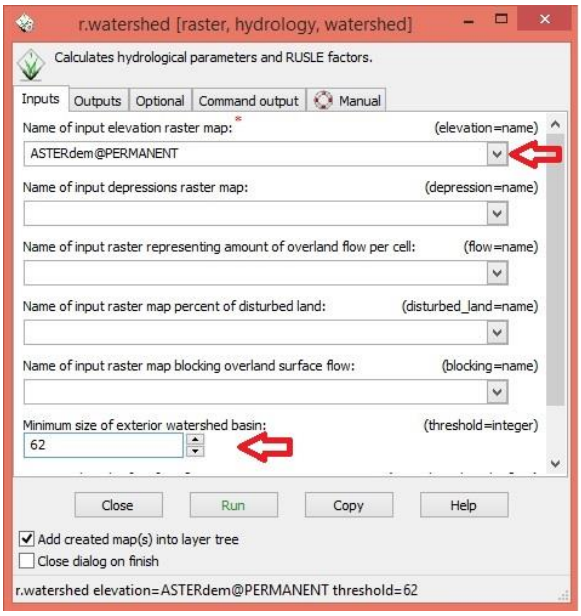
3 Main Watershed Applications

3.1 River network extraction

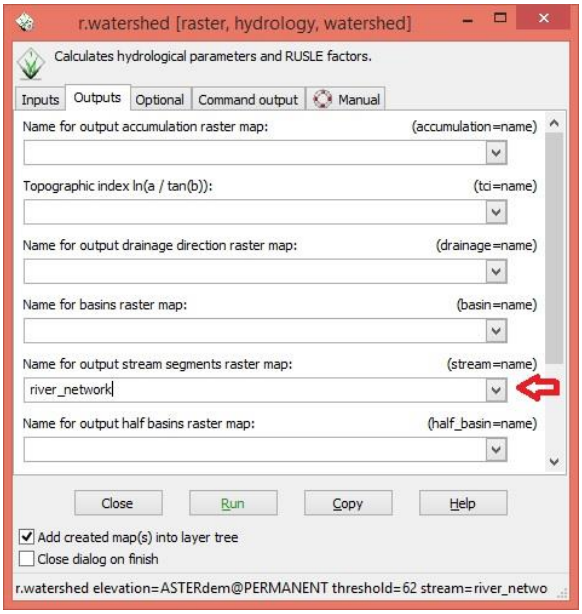
1. First step you will type the command "r.watershed" at your "Command console".



2. At "r.watershed" window you will set the parameters "(elevation=name)" with the raster layer that you have containing terrain elevations. Also, you will fill the blank "(threshold=integer)" with the value of the minimum watershed area that you expect, then you must dived it per your resolution's layer (i.e. 62 = 500000m²/(90x90m²)).



3. Next you will change to the tab "Outputs", then you will fill the blank "stream". Then you will click on "Run".



4. The expected result in going to be as the picture below (Figure 6).

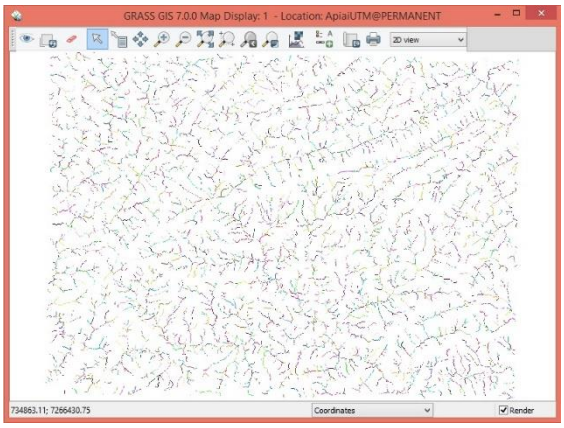
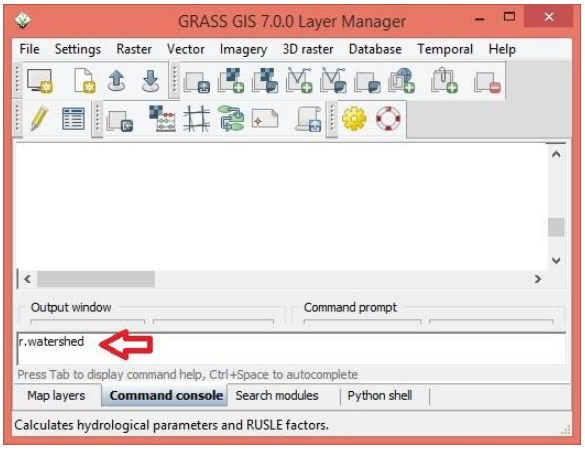


Figure 6: Obtained result from the topic "River network extraction" using a raster map with the ground elevations.

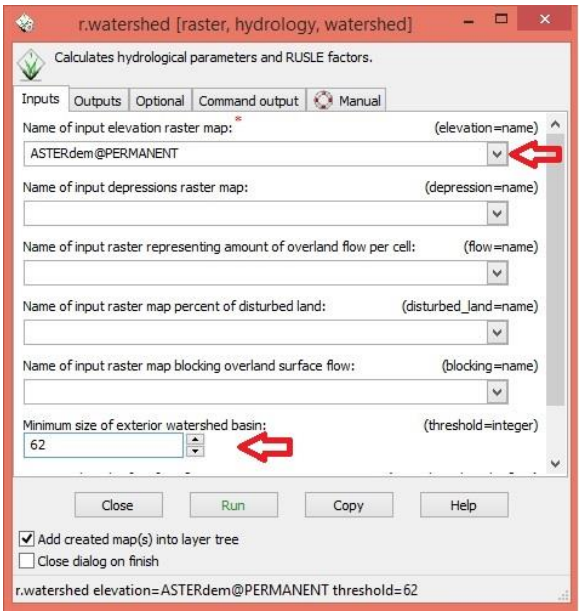
3.2 Watershed delineation

1. First of all, you should know that exist a third part (add on) module to accomplish this task so called “r.basin”, which is accessed only from the “command console”. The module “r.basin”it is a simple command and you can try it before these steps, if the result is not the wanted you can try the next steps.

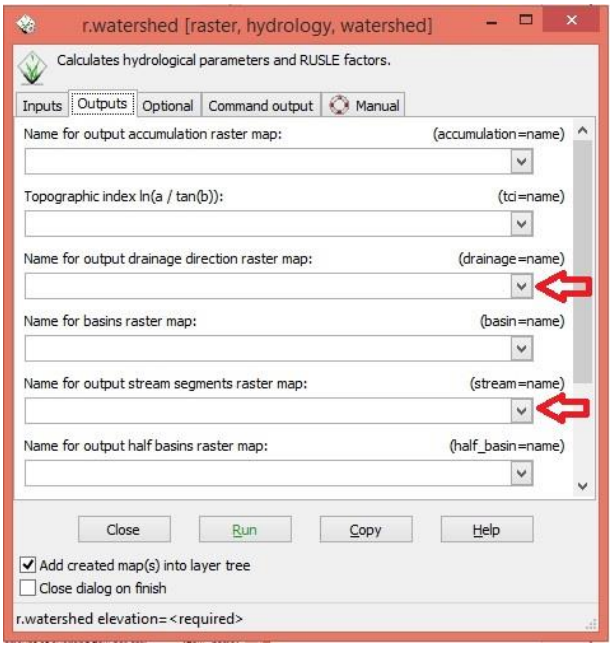
2. You will type “r.watershed” at “Command console”.



3. You will fill the blank “elevation” with the raster layer name that you have elevations included. Also, you will fill the blank “threshold” with the value of the minimum watershed area that you expect, then you must dived it per your resolution’s layer (i.e. 62 = 500000m²/(90x90m²)).



4. Now, change to the tab “Outputs”, then you will fill the blanks “drainage” and “stream”. After on “Run”.



5. The expected result to the output “stream” we already know from the step “River network extraction”, and the expected result to the “drainage” output is going to be as the picture below (Figure 7).

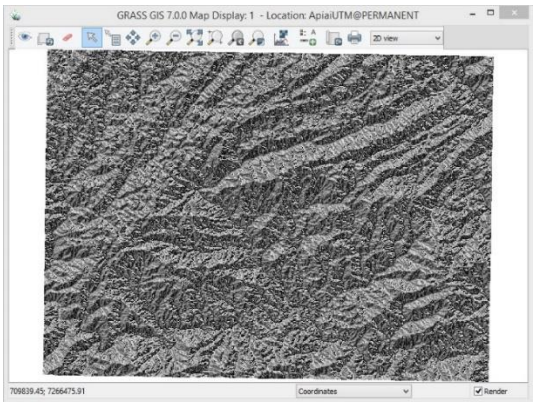
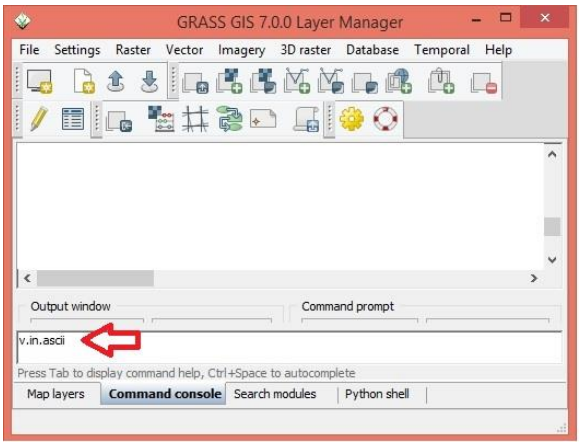


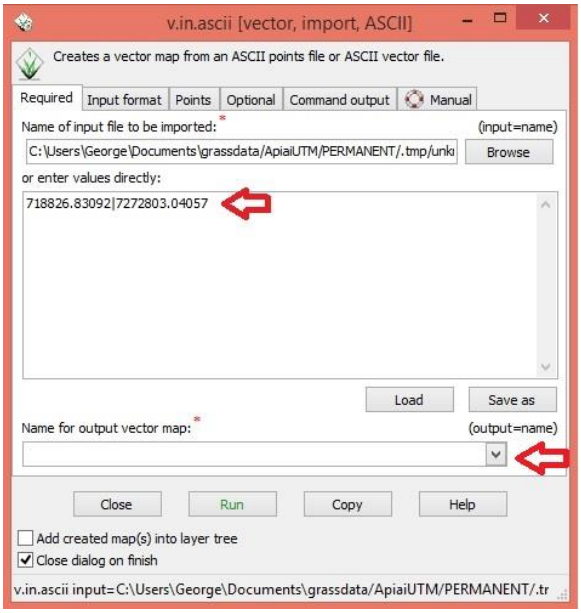
Figure 7: Result from using a raster map with the ground elevations to create a drainage map.

6. The next step is to verify the outlet position in your raster stream map (note: the coordinates to your outlet should be upon whatever pixel to the raster stream).

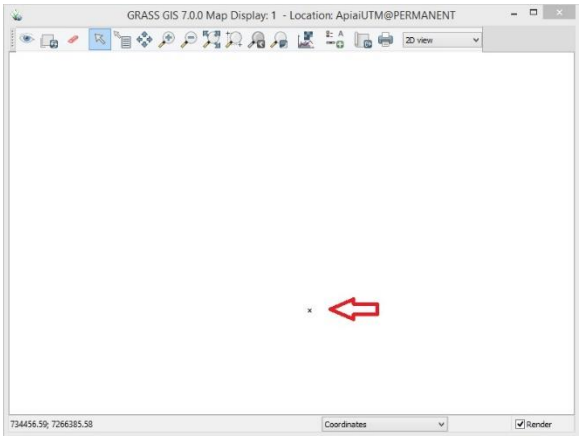
7. To do it, you will type the command "v.in.ascii" at "console command".



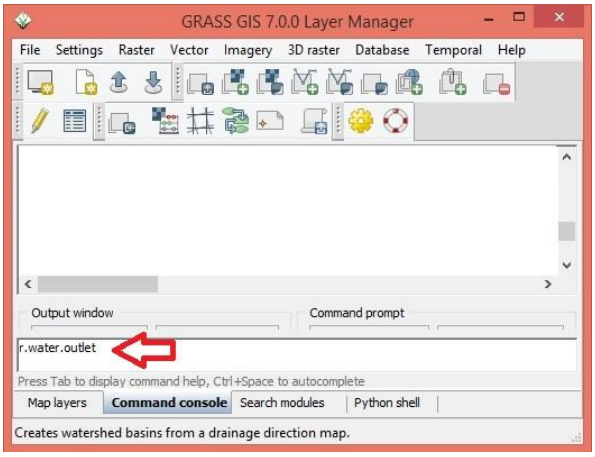
8. You will type the outlet's coordinates in the blank "enter values directly" as well as 718826.83092|7272803.04057. Then, give a name to the output map at blank "output". After, click on "Run".



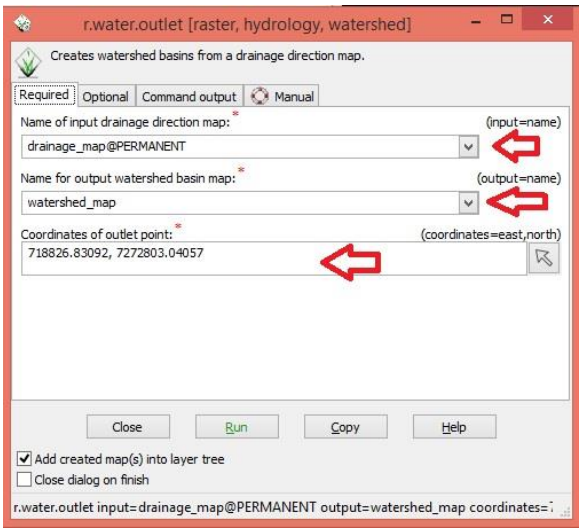
9. The expected result to the "v.in.asc" command is going to be as the picture below.



10. Now, you will type “r.water.outlet” at command console.



11. You will add the coordinate of your outlet in the blank “coordinates”. Also, you will fill the blanks “input” and “output”. After, you will click on “Run”.



12. As a result you will have a new layer with the area of the watershed (Figure 8).

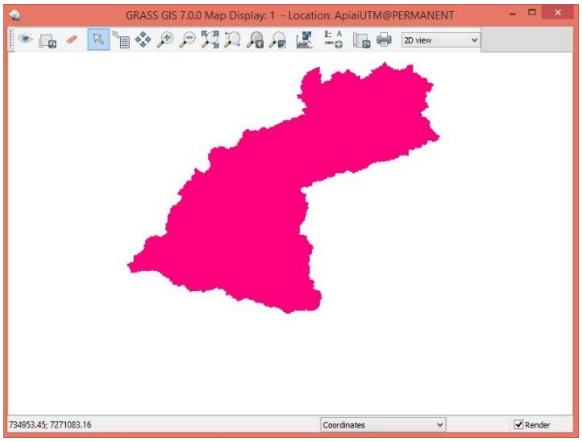
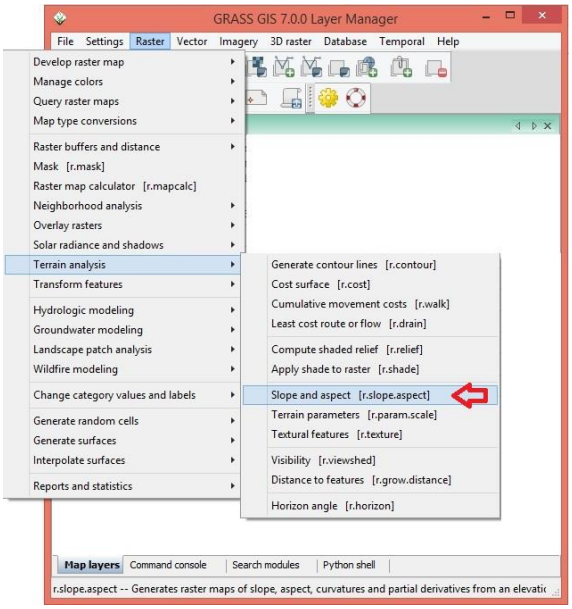


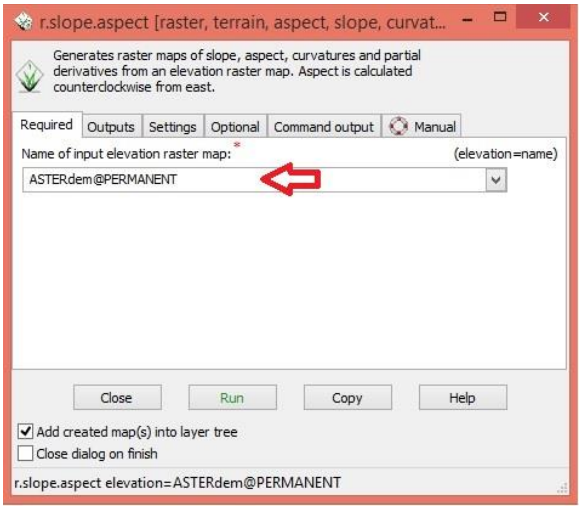
Figure 8: Result from delineating a watershed area a raster map.

3.3 Mean watershed slope

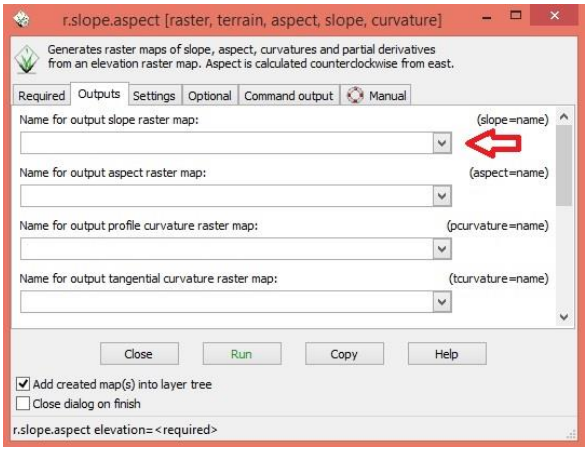
1. You will click on “Raster” >> “Terrain Analysis” >> “Slope and aspects”.



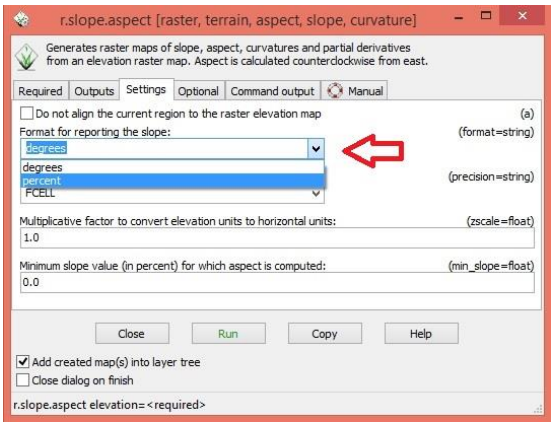
2. At tab “Required” in the ”r.slope.aspect” you will set the parameter “Name of input elevation raster map” as a name’s map that you have containing the elevations value.



3. At tab “Outputs” you will set the parameter “Name for output slope raster map” as the name the map you want get it.



4. At tab “Settings” you will set the dropdown box “Format for reporting the slope” as you prefer. Then you will click on “Run”.



5. The next pictures (Figure 9 and 10) show you the elevation map and the terrain slope map resulting from these steps.

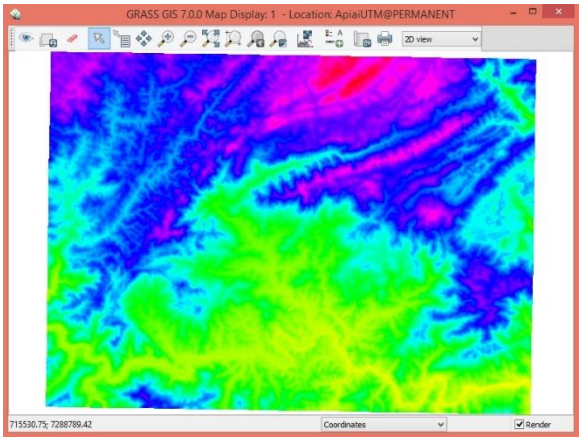


Figure 9: Shows the original elevations map which is going to origin the "Terrain Slope map".

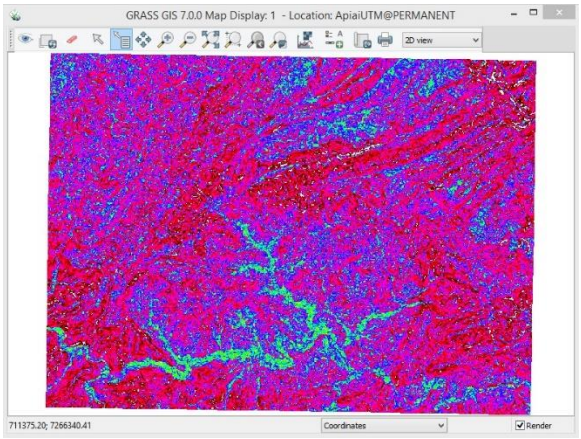
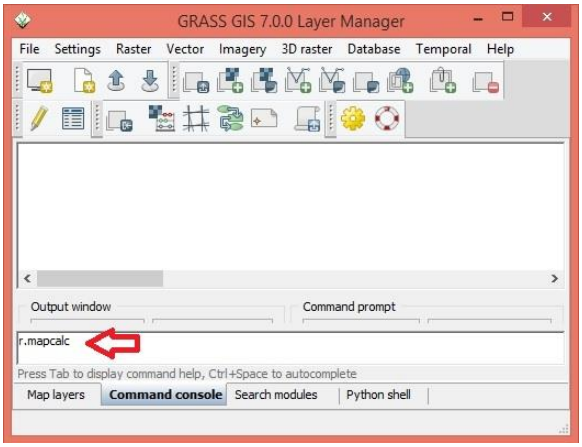
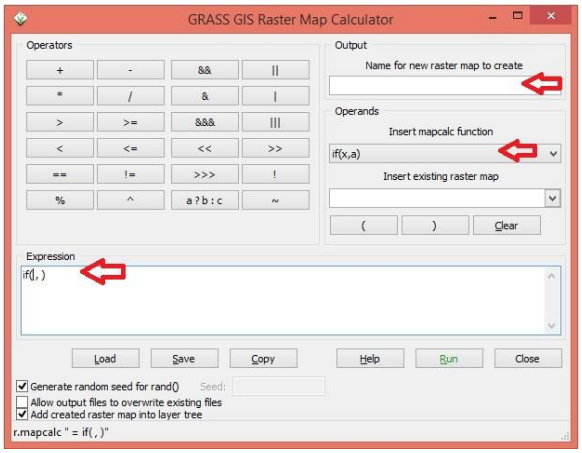


Figure 10: Result from using an elevations map to create a slope map.

6. The next step will make a crop between the Watershed area and the Slope map. To do it you will type "r.mapcalc" at your "command console".



7. In the new open window you will fill the attributes "Output" with the name of your new map and "Operands" with the function "if(x,a)". In the dropdown box you will select the layer that has the watershed shape and the map which has the slope data set as well as they must be separated per comma (i.e. if(raster_format_I_want,raster_I_have)) Then you will click on "Run".



8. The next picture (Figure 11) show you the watershed area with the ground slope as a result from these steps

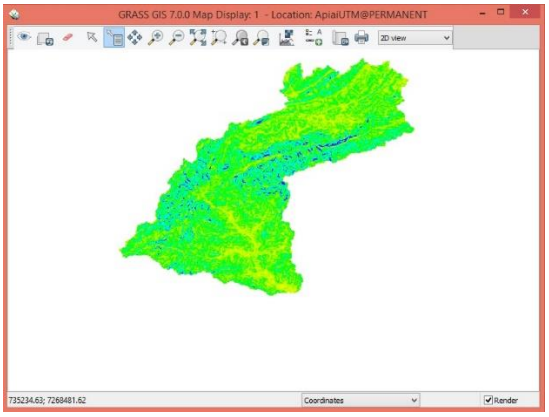


Figure 11: Result of cropping the slope map to the watershed shape.

9. Now, you will check and select the layer resulted from the crop, and at your "Map display" window you will click on  (Analyze map) and select the tool "Create a histogram of raster map".

10. At "Histogramming Tool" window you will click on  (Plot statistics).

11. At "Statistics" window you will see some different information and the average slope at the watershed will be the "mean of absolute values:".

12. At Figure 12 you can see the results from these steps as well as the average slope resulted from a test.

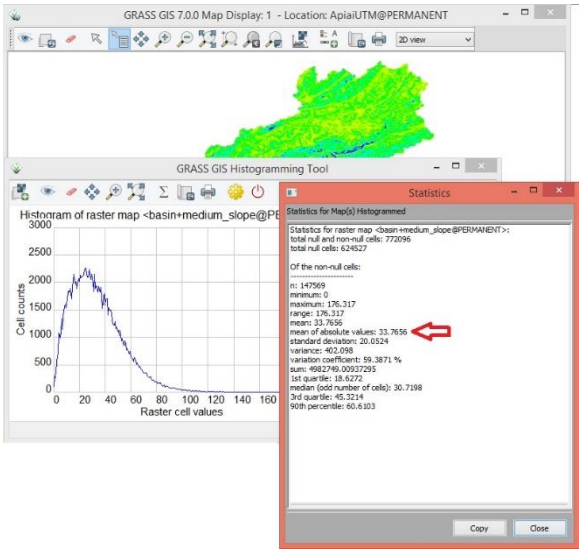


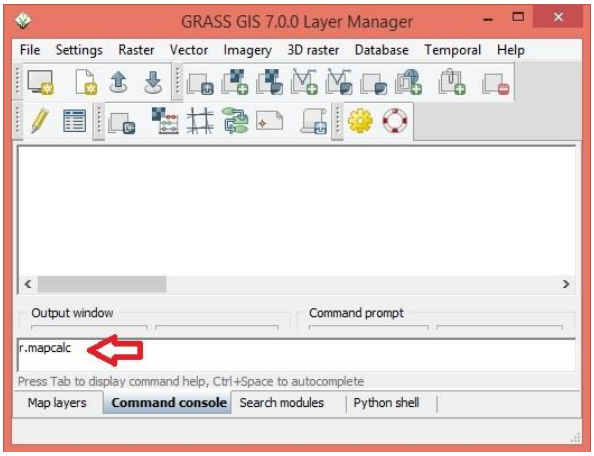
Figure 12: Result of the mean slope at the watershed area.

3.4 Main channel longitudinal profile

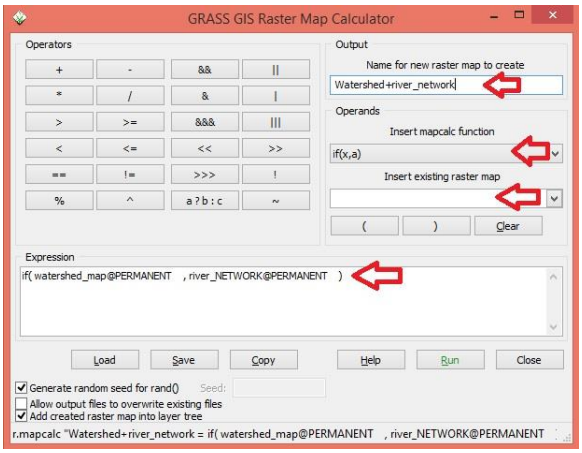
First of all, you should know that exist a third part (add on) module to accomplish this task so called “r.basin”, which is accessed only from the “command console” However, sometimes this command can give you back the longest canal and not the deepest one, as a main canal is supposed to be. The command “r.basin” it is a simple command and you can try it before these steps, if the result is not the wanted you can try the next steps.

1. At the first step you will need to obtain the stream network map. This map is obtained from the terrain elevation raster map.

2. The stream network is addressed by the River network extraction topic of this document. Now you will type “r.mapcalc” in your “command console”.



3. In the Raster Map Calculator Window you will fill in the attributes “Output” with the name of your new map and choose “Operands” dropdown menu to the function “if(x,a)”. In the Insert existing raster map dropdown menu you will select one layer to your crop boundary (in this case, your watershed map) first. Then, another raster map to crop (in this case, your stream network map). The names of the existing maps you pick shows in the Expression text box. You need to edit the text box in order the raster names show separated by a comma (i.e. if(raster_boundary_I_want, existing_raster_I_have)). Then you will click on “Run”.



4. Since the checkbox “Add the generated raster map into layer tree” is checked, the resulting stream network will be shown with its name in the layer tree as well as into the Map Display window with the watershed shape as depicted in the Figure 13.

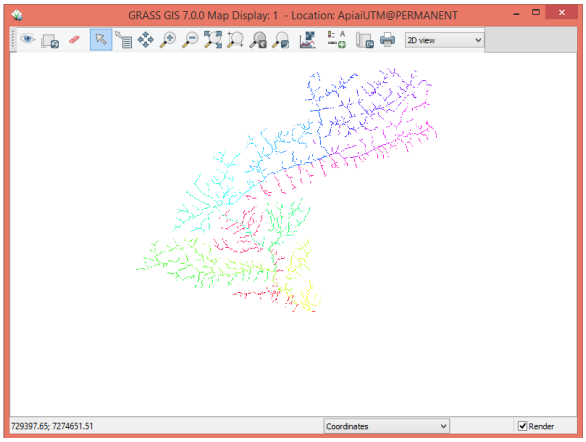


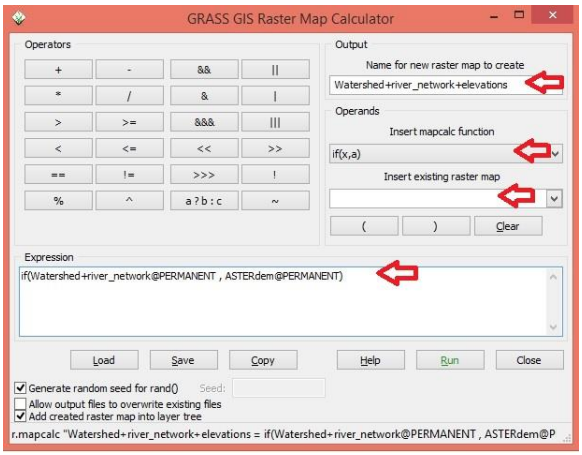
Figure 13: Result from making a crop between the watershed area and the river network.

5. Now you will take note of the codes within the main channel. To do so you will select the stream network watershed clip raster (clicking on it at the layer tree; it will be marked as gray). At the "Map display" click on at  button to query ID code values in the watershed stream network raster. Find every single code represent only the pixels which belongs to the main channel. Write down each code either in a piece of paper or a simple text editor (e.g. notepad).

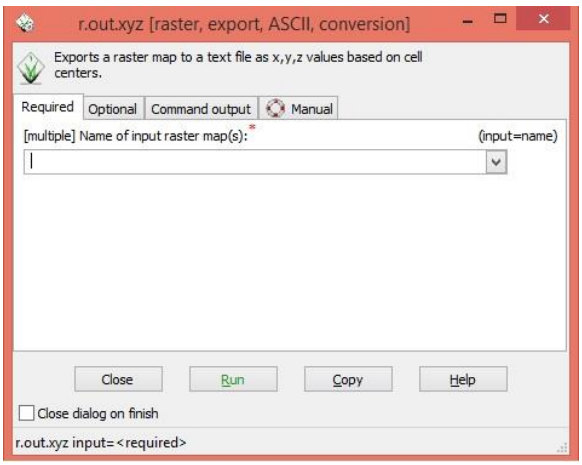
6. Make another crop, now to the elevation heights with the watershed stream network shape.

7. You will again type "r.mapcalc" at your "Command console".

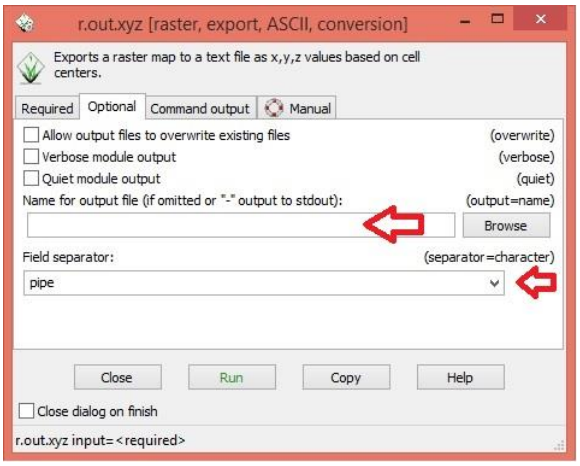
8. Fill in the blank "Output" with the name of your at watershed stream elevation clip map and "Operands" with the function "if(x,a)". In the dropdown menu you will select the layer that has your crop shape (in this case, the stream network map as the watershed shape). Scroll the dropdown menu again to the layer that you will crop (in this case, your elevation map). At the text box, the two maps must be shown separated by a comma (i.e. if(raster_shape, raster_map_to_crop)). Then you will click on "Run". The generated map is going to be shown both in the layer tree and in the Map Display window. It looks like the previous clip except by the values attributed to each pixel, which are no longer ID codes, they are elevation heights.



9. Then you will export the raster map into a (ASCII) text file and import it into a spreadsheet editor. To do it you will click on "File" >> "Export raster map" >> "[r.out.zyx]". At "r.out.xyz" you will fill the blank "Name of input raster map(s)" by typing the two raster crops just made separated by comma.



10. At tab "Optional" you will set the parameter "Name for output file" as the file path you want to be saved (including the map's name with the extension you wish, e.g. txt). Also you will set the parameter "Field separator" as you prefer.



11. The XYZ text file exported from GRASS has no header. At a spreadsheet editor import such XYZ file. Your XYZ file should have 4 columns (UTM E, UTM N, ID and elevations). Now add headers to each column. Use the names we described such columns just above if you want. Then select all the filled cells and add an automatic filter. With the aid of the code list you wrote/typed down on step 5, open the column ID's filter and keep selected just the codes which belongs to your main channel As depicted in the snapshot (Figure 14).

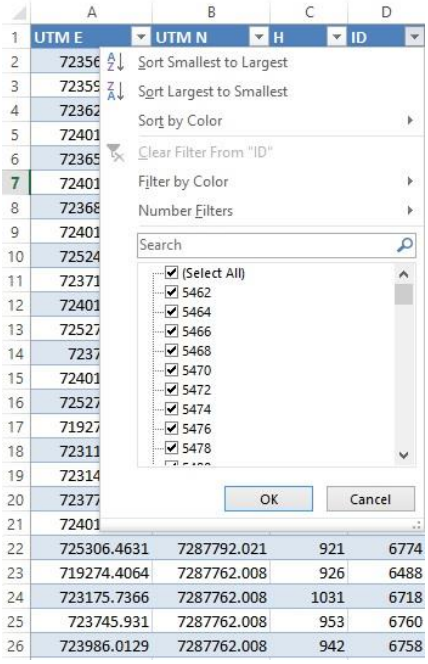


Figure 14: Result from to export a data set to a spreadsheet editor.

Note 1: From this point is already possible to plot the main channel chart. However, the values comes in disorder making noise at the chart as the next picture (Figure 15).

Note 2: To avoid this problem we should either follow the next steps or manually sort the table according to the coordinate sort describes the main channel geometry. To manually resort the coordinates, resort all coordinates according to either east coordinates or north coordinates with respect to the channel longitudinal geometry. Select small ranges of coordinate pairs still with inconsistency and apply the sort trying to lead them aligned to the expected meandering. If this is your choice

skip to the step 20 after manually re-sorting.

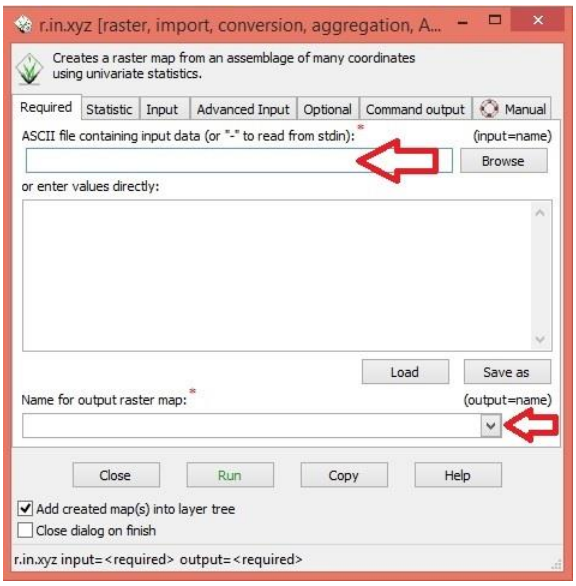
Figure 15: Result from plotting a chart with the data set as exported.

12. After you identify and select all the main channel codes the next step is to export the spreadsheet file. To do it you will copy and paste the entire table in a new spreadsheet tab or file, because you cannot export a dynamic table (if you do this you will export the entire data set and not only the filter). So, after you copy and paste you will click on "File" >> "Export" >> "Text (Tab delimited)".

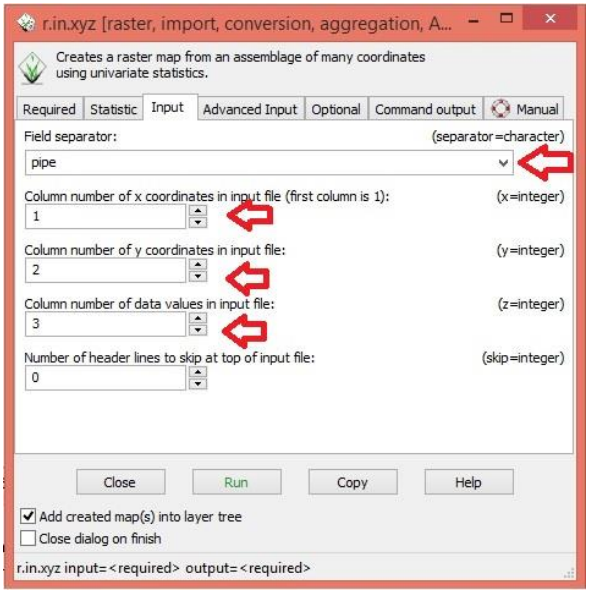
13. After you export the data set from a spreadsheet editor you will import back the file into the GRASS. To do it you will click on "File" >> "Import raster data" >> "[r.in.xyz]".

14. In the next open box you will set the directory of your exported spreadsheet file (.txt). Also you have to type an output name to the file at tab "Required" in "(output=name)".

15. Browse to the text file you just created in the spreadsheet editor. Also you have to type an output name to the map at tab "Required" in "(output=name)".



16. Set the parameter "Field separator" as the character used to separate the columns when you exported the text file from the spreadsheet editor. Also you might set the parameters "(x=integer)" as the UTM E coordinates, "(y=integer)" as the UTM N coordinates and "(z=integer)" as the height coordinates. Then you will click on "Run".



17. The expected result from this importation is going to be shown as the picture below (Figure 16).

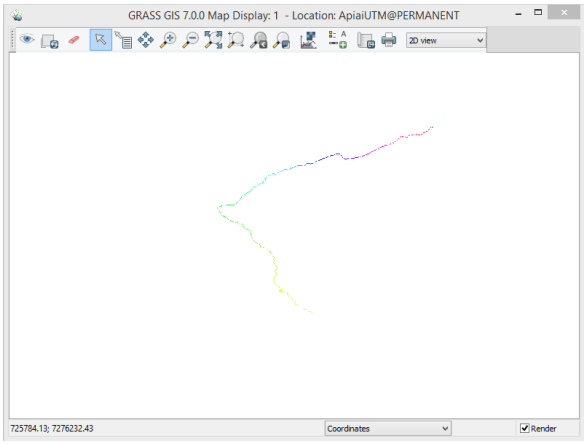
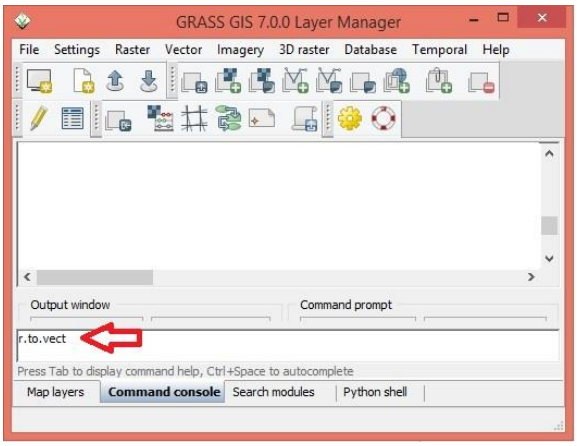
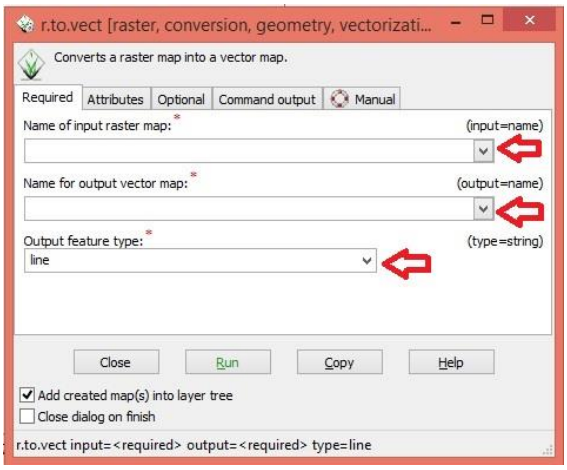


Figure 16: Result from importing the data set already filtered in a spreadsheet editor.

18. The next step is to convert the raster map into a vector map in order to obtain the canal coordinates sorted accordingly to the canal's longitudinal geometry. However, the raster value will not be attributed to the vector map in each node and we will have to import such sorted coordinates back to the spreadsheet editor to link them to the elevations. To do so you will type the command "r.to.vect" in the command console.



19. Fill the blank “input” with the map’s name you want to convert, and fill the blank “output” with the map’s name you want to get. Also, set the dropdown box as “area”, then click on “Run”.



20. As a result, you will see the converted map in your “Layer Manager” (Figure 17).

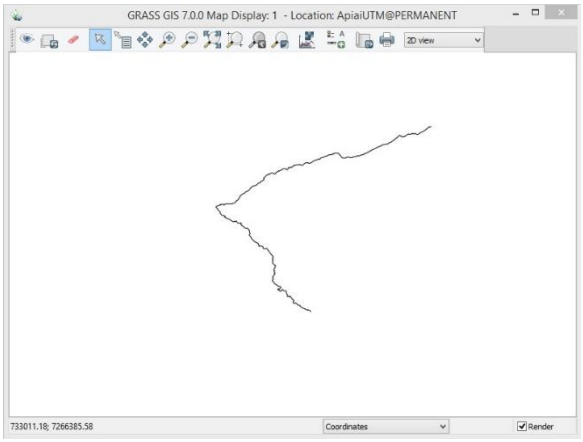
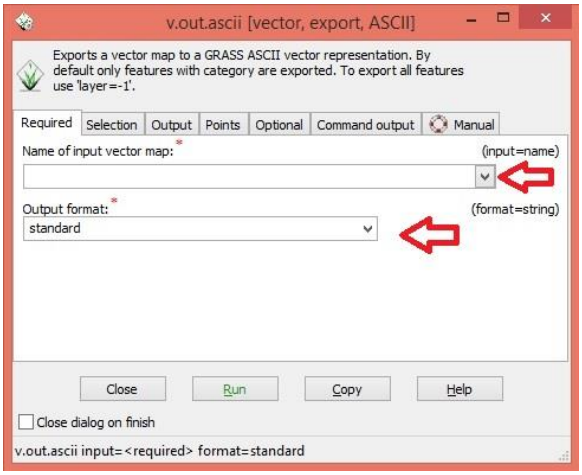


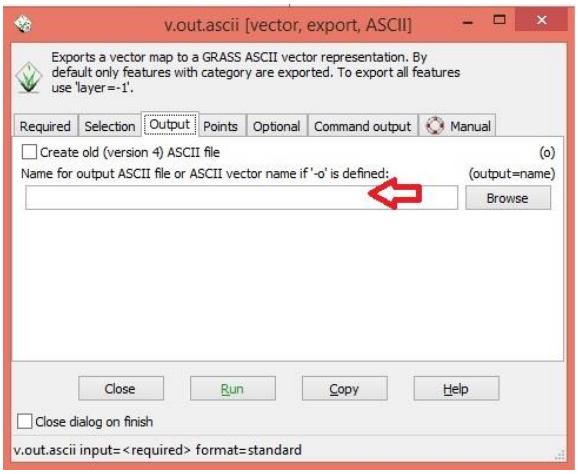
Figure 17: Result from converting the mainchannel raster file to a vector.

21. Now you will export the vector map and open it in a spreadsheet editor. To do so you will click on “File” >> “Export vector map” >> “[v.out.ascII]”.

22. At tab “Required” you will set the parameter “(input=name)” and the parameter “(format=string)” as “standard”.



23. At tab “Output” you will fill the blank “(output=name)” with the path to your new file.



24. The file comes organized by values into categories. You should to re-sort only such categories now. The result will be the correct main channel geometry.

25. Note that the XYZ file you just imported does not have the elevations informed and we have to attach them to the sorted coordinates now. To plot the canal longitudinal profile you will make some extra columns in your table. One will be the difference between values of X (UTM E), another will be the difference between values of Y (UTM N). Also, a column with the result of a hypotenuse from these two differences (X and Y). Then, a column content the cumulative sum of the hypotenuse that will represent the distance.

Note: The cumulative sum should be equal the total length of the main channel. The Canal longitudinal profile chart is going to be the chart between the distance and the height in each point.

Note: You must attach the elevation (available at the XYZ text file exported from the watershed stream network elevation clip) to the coordinate sort found. Remember, every pair of coordinates are unique, then you should link a pair of coordinates that have an elevation value with an equal pair of coordinates. To do so, you will need to create a unique key to every pair of coordinates, for example, by using the function Concatenate at a spreadsheet editor (i.e.=CONCATENATE(TEXT(B3," 0"),TEXT(C3," 0"))) where B represents UTM E and C represents UTM N. This function will create a unique phrase or key with these two coordinates in UTM E and UTM N. You will make the same in both tables. After, you can use the spreadsheet function Vertical Lookup (i.e =VLOOKUP(B2,C2:D1568,2,FALSE)) where B2 represents the key value, C2:F1568 represents the column to search such key value, 2 (two) represents how many columns aside (right side) you will look up and FALSE says whether the search column is sorted or not.

Now you are able to plot the canal longitudinal profile. Do it using the chart tool of your spreadsheet editor. You could notice that the chart will present a lot of ups. It happens sometimes because the pixel of the used radar is sometimes smaller than the channel width (the water surface width). Hence, the pixel will storage an averaged elevation, which is a wrong elevation between the river overbank and the water surface elevation in these cases.

To handle problems like that, one can make a correction at the longitudinal profile using the function IF in a spreadsheet editor. If the profile is oriented downstream to the right, use this “=IF(K2>E3,E3,K2)”, where K2 is the height corrected and E2 is the original height value. The formula says if some K elevation is bigger than the previous one, use the previous one

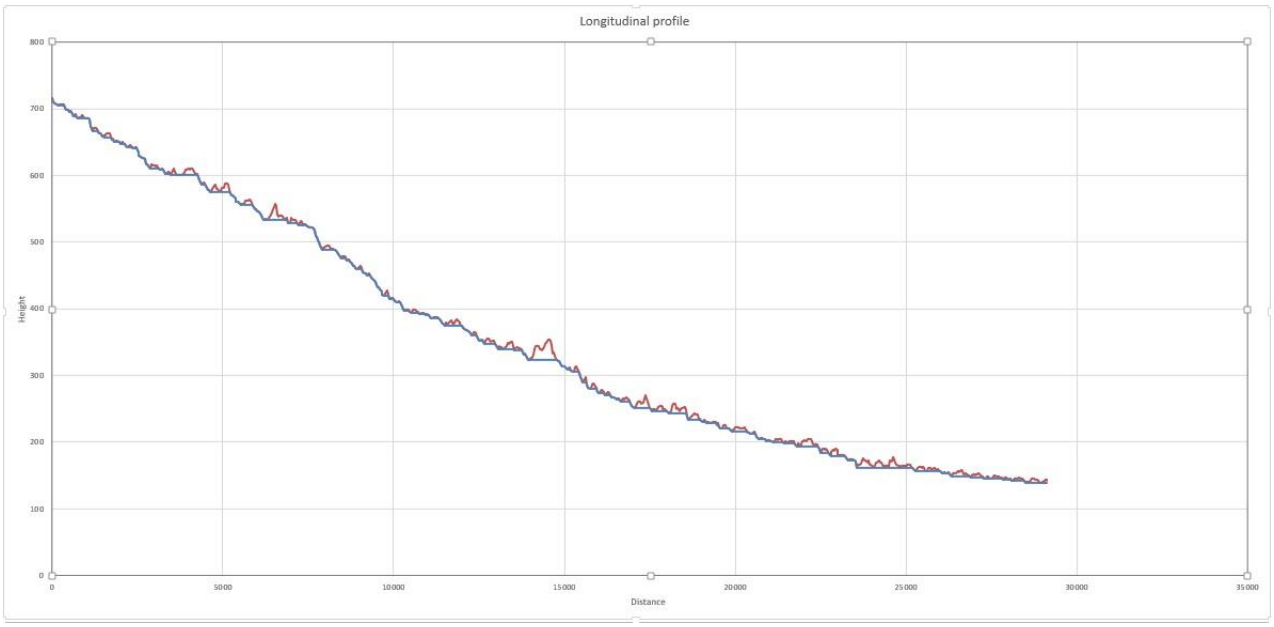


Figure 18: Result from plotting the original and the corrected data set of the mainchannel.

4 Conclusion

This manual gathers necessary steps to achieve important results in watershed morphology studies, showing that those ones are feasible in a realistic analysis.

The main channel longitudinal profile analysis allowed one to notice that an additional software (spreadsheet editor) is needed to complement the GIS GRASS tools in doing so.

Since the river longitudinal profiles are supposed to be downhill, the results obtained with 1-sec resolution elevation data showing jumps up are inconsistent. That occurs because 1-sec resolution is not high enough to accurate river longitudinal profiles in small watersheds.

Finally, the software GIS GRASS 7.0 shows a very useful tool to help one to develop a watershed morphology analysis. In some sense, it makes easier to students, engineers and researches to accomplish watershed morphology studies because of the worldwide availability of digital data and their treatability.

5 Acknowledgments

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6 References

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