World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

Using Farmer Field Schools Approaches to Overcome Land Degradation in Agro-Pastoral Areas of Kenya

Land degradation assessment – Baseline survey on spatial analysis of land cover / degradation trends and Toolkit Development.

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LESSON 6 – MODERATE RESOLUTION SATELLITE IMAGES AND RAIN USE EFFICIENCY

Lesson overview

In this lesson you will learn about moderate resolution satellite images; how to disentangle rainfall driven vegetation changes from other factors affecting vegetation changes using the concept of Rain Use Efficiency (RUE); spatial filtering and other more advanced grid calculation are introduced; you will also learn about using multiple criteria for evaluating land degradation.

MODIS Enhanced Vegetation Index (EVI)

The MODIS (Moderate Resolution Image Spectrometer) sensor carried on board the TERRA and AQUA satellites was developed for better estimation of vegetation compared to the AVHRR sensor (see lesson 5). Supported by other on board sensors the MODIS vegetation data can be calculated using a more advanced algorithm – the Enhanced Vegetation Index (EVI). For this project EVI with 16day intervals (23 datasets per year) was downloaded for the period March 2000 to December 2006. The MODIS EVI data used in this study is version 4 (MOD13q1v004) in 250 m resolution.

Rain Use Efficiency (RUE)

To overcome the shortcomings of using annual vegetation indices for tracking land degradation (as in lesson 5), the concept of Rain Use Efficiency (RUE), which combines rainfall and vegetation information, was developed for arid and semi-arid regions. It is an attractive index in regions where growth is limited by rainfall, and where there is a linear relation between rainfall and vegetation. As RUE is calculated using seasonal or annual time-steps it is also hypothesized to bridge short-term fluctuations in vegetation dynamics. In parts of Kenya (including parts of the district of Narok) rainfall is most likely not limiting vegetation growth, and RUE will not be less ideal to use for identifying land degradation. In this project RUE was calculated using MODIS EVI data (see below) and rainfall data resampled to fit the EVI data spatial and temporal resolution. RUE was calculated with annual time steps going from October to September the following year.

District level datasets

The project CD contains more detailed data for the districts included in the study. A complete list of the data available for each district can be found in the web-catalog for each district. The more detailed data include sub-district boundaries; rivers, streams and water bodies, a detailed digital elevation models (DEM) and population census data for sub-districts going back to the 1970s. For the districts of Mwingi and Narok animal counts, both livestock and wildlife, going back to the 1970s are also available.

Start DIVA-GIS, create a new project (e.g. Project6) and save it (e.g. create a new folder under the district folder and call it my diva). Choose a district to work with (Mbeere, Mwingi or Narok) and add the following vector datasets to the Data View (replace "xx" with the district name):

Data layer	Folder	File
Sub-districts	\data_spatial\xx\mapdata\politic	xx-district-boundary
Rivers	\data_spatial\xx\mapdata\hydro	xx_rivers
Water bodies	\data_spatial\xx\mapdata\hydro	xx_waterbodies
Land cover	\data_spatial\xx\mapdata\landcover	xx_landcover

The landcover data is a simplified version of the vector landcover dataset available for the whole of Kenya (\data_spatial\ke\rs\landcover\ke-spatial-agg). These landcover datasets are produced by FAO (Africover) from satellite images taken by the Enhanced Thematic Mapper (15 – 30 m resolution) around the year 2000. To get the documentation for the original dataset click here; to get the legend entries for the full dataset click here. To get the legend of the simplified landcover datasets for each district, open the attribute table for the district landcover data in DIVA-GIS, make the simplified landcover dataset the active theme by clicking it in the Legend, and then click the Table tool, 🔳. The simplified landcover classification is in the last column (field) "LC". Use the LC field to symbolize the landcover (look at the symbolization you did in Lesson 2 for hints). Then also symbolize the other data layers in the table above.
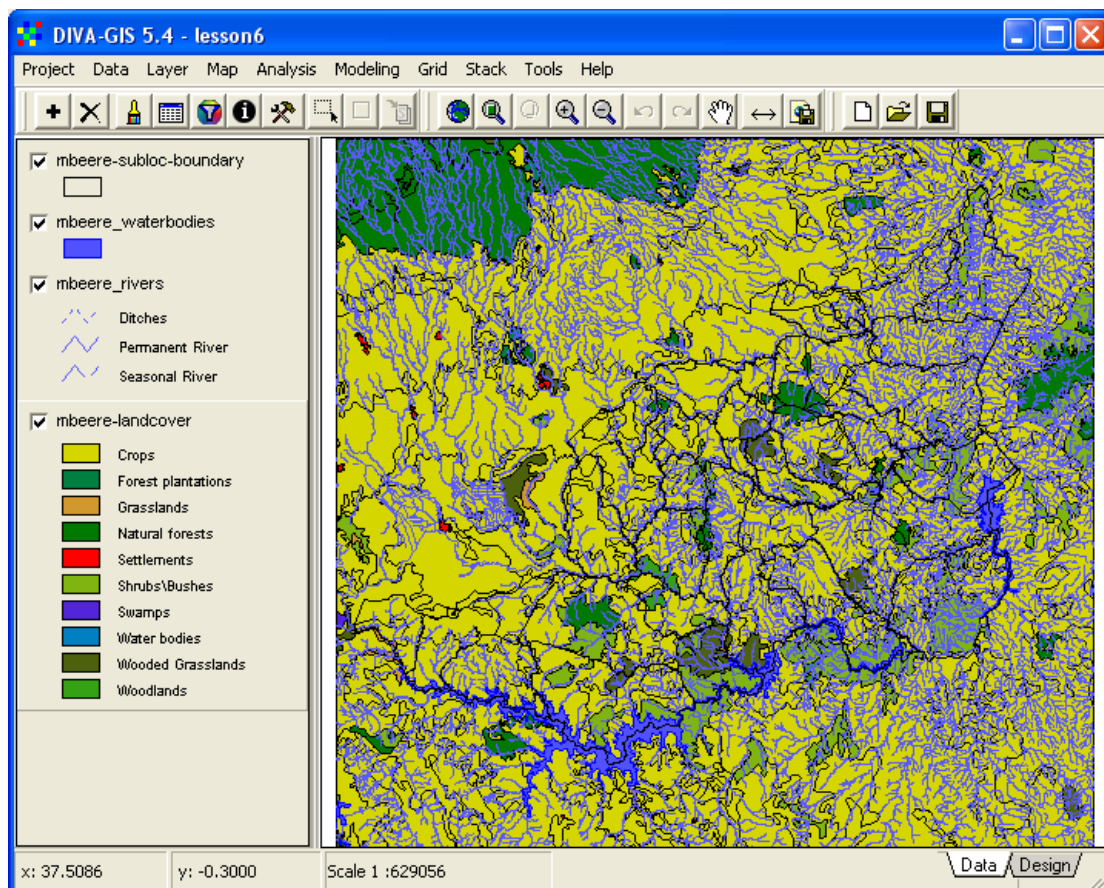
As all the spatial data on the project CD is in Geographic coordinates (longitude and latitude), you can also add any of the data from the dataset covering the whole of Kenya. Add the vector line layer showing the border of Kenya (\data_spatial\ke\mapdata\politic\ke_keadmin1_line_adds.shp) and then click the

Zoom to Full Extent tool, . Symbolize the line vector with the country border (you have more options symbolizing a line compared to the outline of a polygon, hence it is better to add the line for country border in this case).
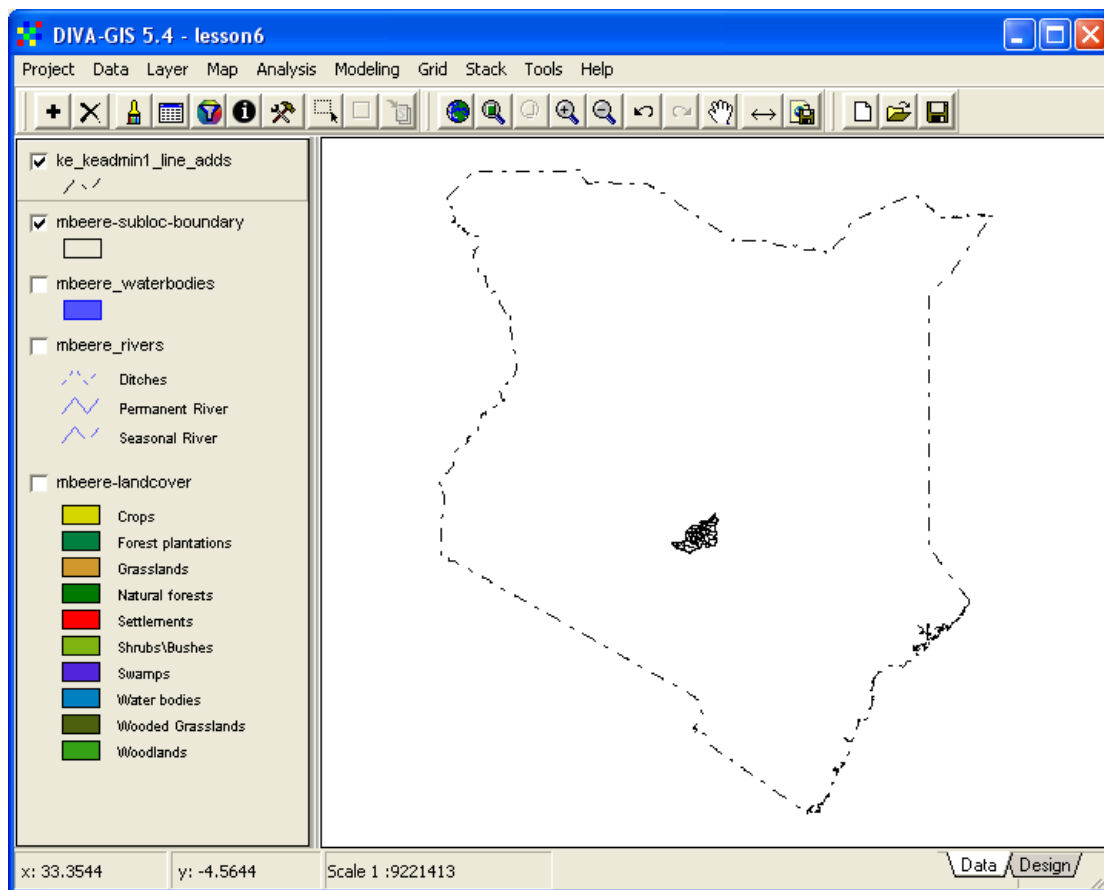
To return to the zoom only showing your district, make one of the district datasets the active theme by clicking it in the Legend, then click the Zoom to Theme tool, 🔍.

MODIS vegetation data

For the more detailed level district analysis of vegetation and rainfall changes, vegetation data from MODIS (Moderate Resolution Imaging Spectroradiometer) was used (see the project report for details). MODIS records data at 250m –1000m resolution covering the whole earth every second day. The data is then composed into 8day and 16day composites of cloud free images, and standard vegetation indexes are produced and made freely available over the internet. For this project the 16day composites were downloaded and the Enhanced Vegetation Index (EVI) vegetation data extracted. EVI is a better index than NDVI (see lesson 5), and is not disturbed by soil and water conditions. From the 16day EVI composites three annual indexes of vegetation were calculated; annual average vegetation, annual maximum vegetation and annual increments in vegetation – these indexes are explained in detail in the project report and in lesson 5. The annual vegetation indexes for the districts were calculated using 12 months starting in October and ending in September. This was done to better depict the annual growing cycle, which has its minimum in September-October in East Africa. Start by adding the indexes for annual average EVI in the folder \data_spatial\xx\rs\evi-mod13q1v004\year_oct-sep\average; where xx is the district name. If you are going to add several grid files at the same time, it is better to uncheck the option for Layer is visible when added in the Option window (found via the menu: Tools – Options; see lesson 3 to set the Options).

Only add the grid (*,grd) files, do not load any image (*.jpg) file. You do not need them, as the symbolization of the grid files is identical to the image files.

Put the added vegetation images at the bottom of the Legend, and turn on the layer showing the sub-districts, then sequentially turn on each vegetation image.
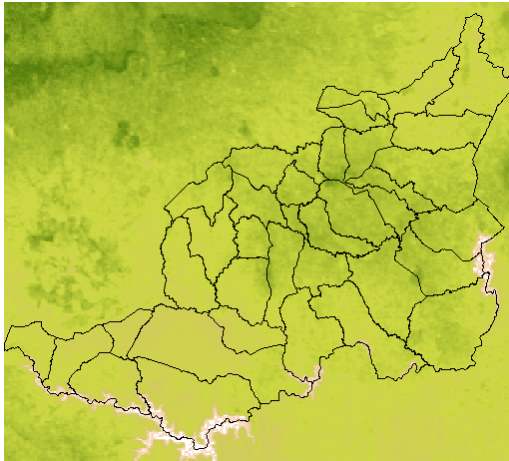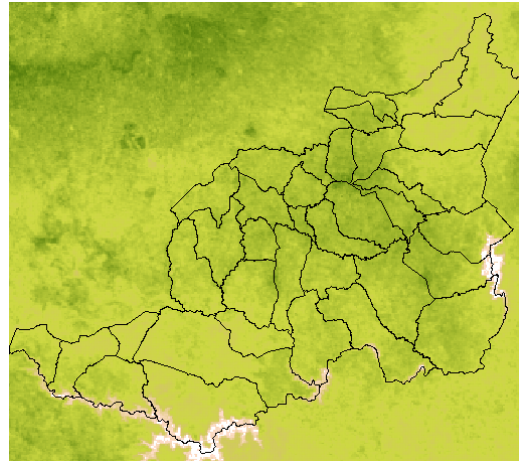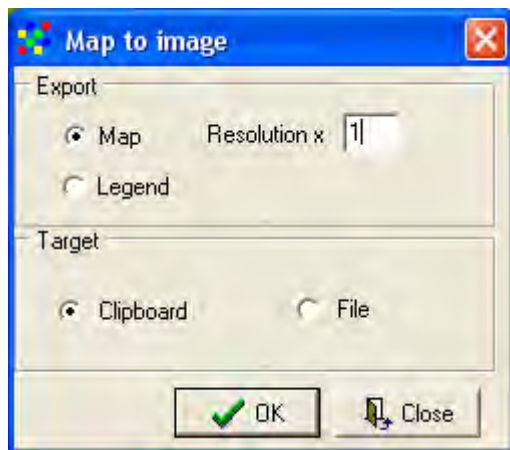

| 2000/01 | 2002/03 |

The two small map-images above were generated by clicking the Map to Image tool, in DIVA-GIS, using the Clipboard as Target, and then pasted into this document (by clicking Ctrl-v), without being saved to any intermediate image file.


MODIS EVI versus AVHRR NDVIg

To compare the MODIS EVI data with the AVHRR NDVIg data, add NDVI data for the same years as the MODIS EVI you just added – the average NDVI data is in the folder \data_spatial\ke\rs\ndvig\year_oct-sep\average. Compare the resolution of NDVI and EVI – the EVI has a resolution of 250 m, and the NDVI of 8000 m. As we are looking at 2-dimensional (2D) data, the difference in resolution is in fact three orders of magnitude - the MODIS data being a thousand (1000!) times more detailed.
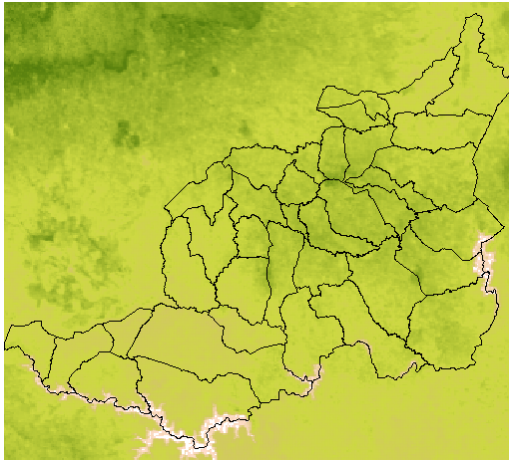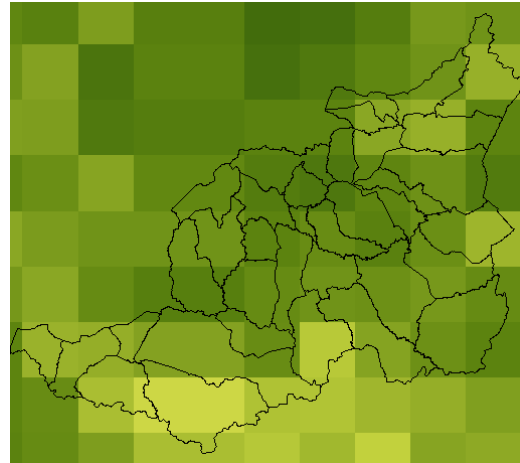
| EVI 2000/01 | NDVI 2000/01 |

If you look in the Legend of EVI and NDVI you can also see that the data range is quite different – NDVI ranges 0-250, while EVI ranges approximately 0-10000. EVI is derived from the MODIS sensor and are of much higher quality than NDVI derived from the older AVHRR sensor.

Visual exploration of MODIS vegetation data

In lesson 5 you explored the regional vegetation (NDVI) data from NOAA-AVHRR (8 km resolution) for the whole of Kenya. You can now use the MODIS EVI to explore the local vegetation changes in your district by following the steps described in lesson 5.

Time series analysis

Vegetation trends

For mapping out land degradation it is more interesting to analyze the trends in vegetation than the vegetation cover a particular year. In lesson 4 you learnt to build a stack and plot data from a selected position including values from all layers in the Stack. In lesson 5 you used a stack to study the long-term vegetation trend (1981-2006) from NDVI data. Now you can use the stacks for EVI data to study the more local, but shorter term (2000-2006) vegetation trends in your district. You just need to open the stack for plotting via the menu: Stack – Plot. The stack for annual average EVI is in the same folder as the grid data, click the Stack button and navigate to open it (the folder only contains one stack). You can make the Stack Plot window larger by grabbing the blue border with the left mouse button, and dragging the mouse. Click the Click on Map button, , and then just click in the map and you will get the vegetation development for each 250m x 250m cell over the last 6 years
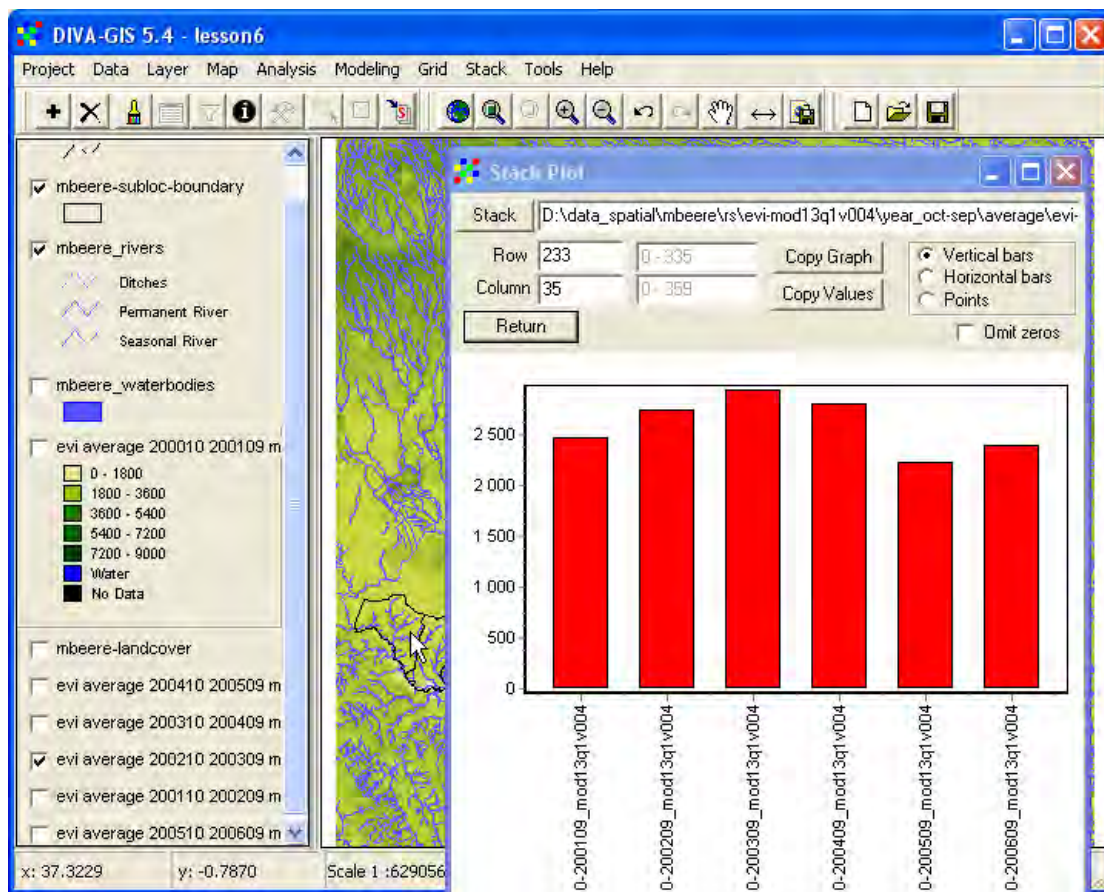
Stack regression

Annual average EVI

In <u>lesson 5</u> you used a stack for doing ordinary least square (OLS) trend analysis. Look at <u>lesson 5</u> and calculate the trend for average vegetation change 2000-2006 using MODIS EVI data instead. Compare the trend you generated with the trend derived from normalized (standardized) EVI data (see <u>lesson 5</u> to repeat normalization of data). The normalized trend, based on z-score data from the normalization, is already available on the dataset of your district (\data_spatial\xx\rs\evi-mod13q1v004\year_oct-sep\average\xx-evi-average-z-slope_200010-200609_mod13q1v004.grd; where xx is the district name).
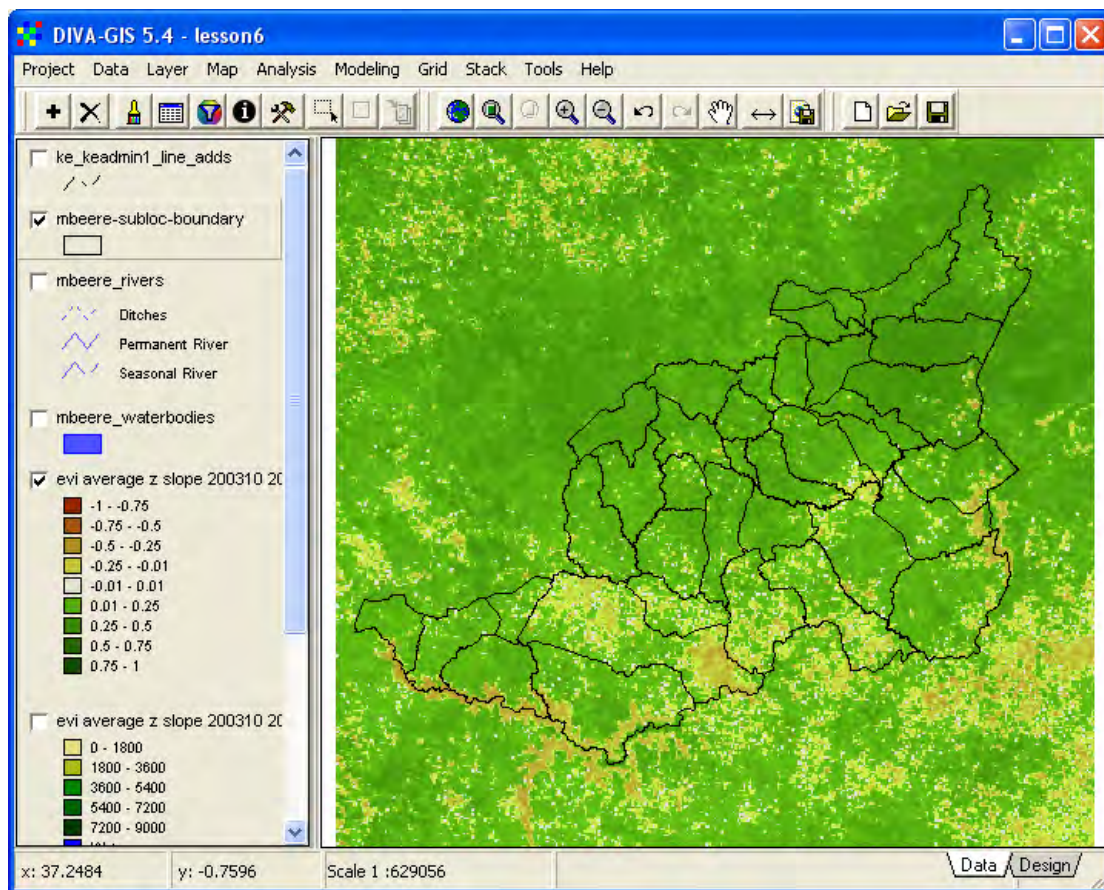
Annual maximum and increment EVI

Now you can repeat the steps done using the annual average EVI with the annual maximum and annual increment EVI indexes, The difference between these indexes are discussed at the beginning of lesson 5. There are already stacks available for both indexes, and also the normalized ("z-score') trends are included.

Rainfall grid data

Rainfall grid maps at 8 by 8 km resolution, representing 10day rainfall from June 1995 until December 2006, are included in the dataset, and can be viewed via the Kenya dataset web-catalog. The rainfall data were taken from the Famine Early Warning System (FEWS) web site. This rainfall dataset is created from a combination of ground station data and satellite images measuring the cloud temperature which falls when precipitation is generated from the cloud. For the detailed studies of the districts of Mbeere, Mwingi and Narok the rainfall data was resampled to 250 m resolution and then an average filter was applied to smooth the derived rainfall surfaces. This was done to avoid having artificially abrupt changes in the analysis of Rain Use Efficiency.

The rainfall data for the whole of Kenya is in the folder \data_spatial\ke\grid\precip\year_oct-sept\sum. Add one or two of the annual rainfall layers, and then use the Stack tool to get the stack containing all the rainfall data going back to 1995. Use the Stack Plot tool to look at the rainfall variation in your district (the stack is in the same folder as the rainfall grid data). The stack plot below shows a large variation in rainfall, and a quite negative trend. It is obvious that the variation in rainfall will influence the vegetation growth.
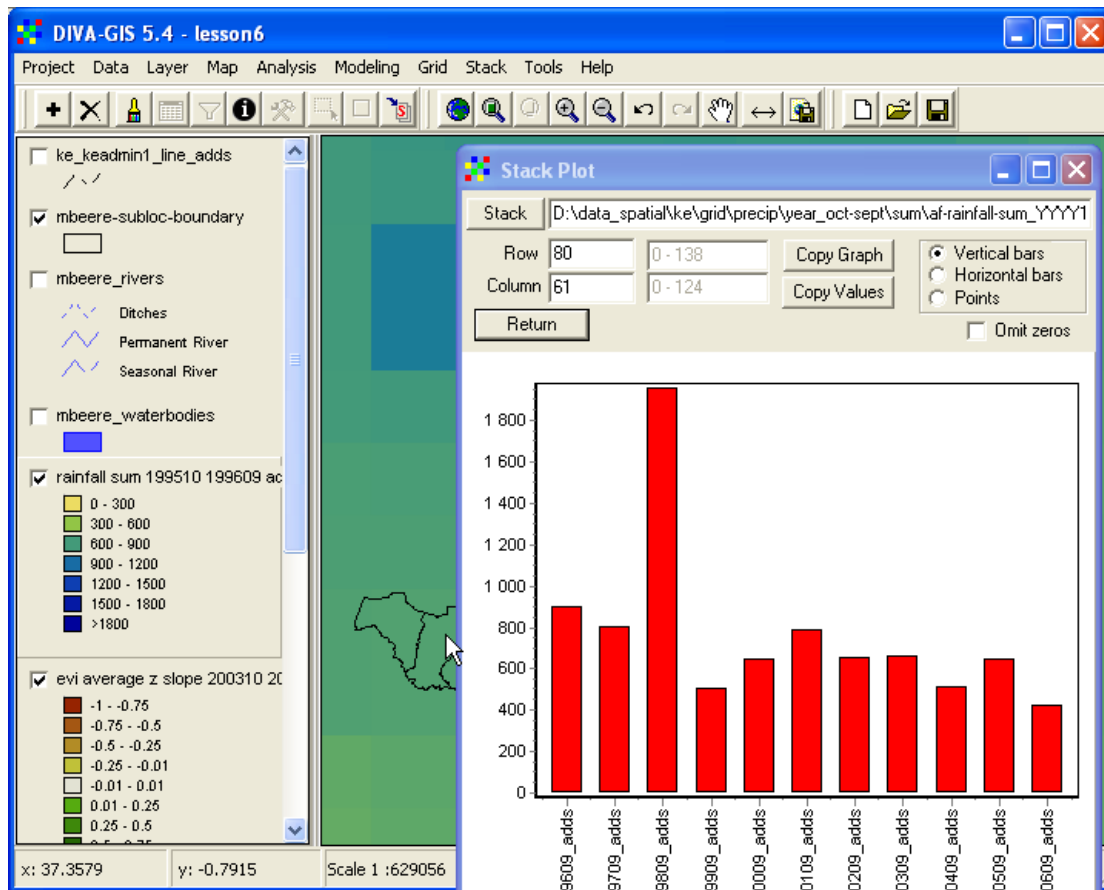
For the districts, the 8km x 8km rainfall data was changed to 250 x 250 m resolution and then filtered. Filtering a grid file is the process where the central pixel (cell) in a window (kernel in GIS-jargon) gets a new value derived from all the cells in the window. The kernel (window) can be 3x3, 5x5, 7x7 etc pixels in size, and the derived value can be the average, the median, the mode, the standard deviation, the minimum, the maximum etc. These steps can in principle be done in DIVA-GIS, and will be the topic of the next sections.

Grid cutting, aggregating and filtering

<u>Cut grid</u>

First you must cut the original grid file (the rainfall grid at 8km x 8km in this case), which is done under the menu: Grid – Cut. The cutting can be set to either rows and columns in the original file, using coordinates, or using an existing grid file as template. The latter was used in the example below.
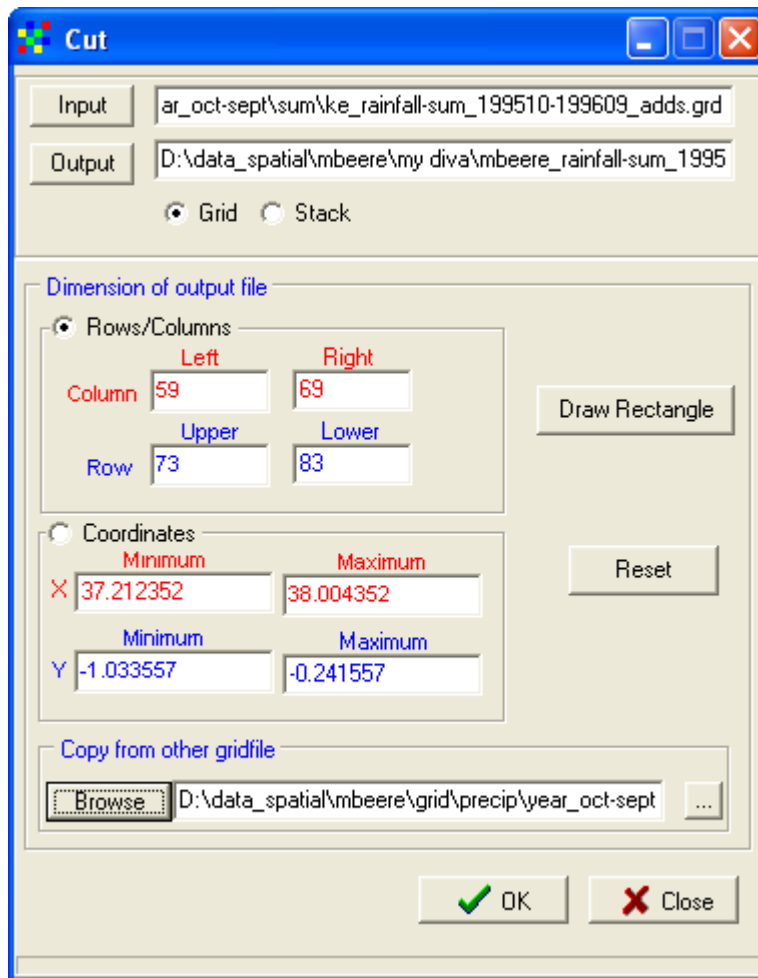
Aggregate / disaggregate grid

The next step is to expand (disaggregate in DIVA-GIS terminology) the cut grid file, also done from the grid menu: Grid – Disaggregate:
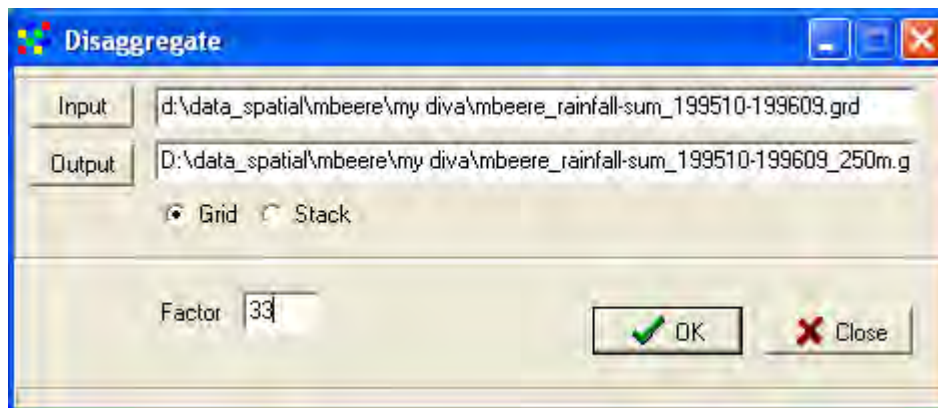
The disaggregated file contains many more cells (above the expansion factor was set to 33).

Filtering a grid by analyzing cell neighborhoods

The last step is to filter the disaggregated grid, which is also done from under the grid menu: Grid – Neighborhood. In the Neighborhood window you can set the size of the filter (3x3 in the example below) and you can also set the Method (mean in the example below).
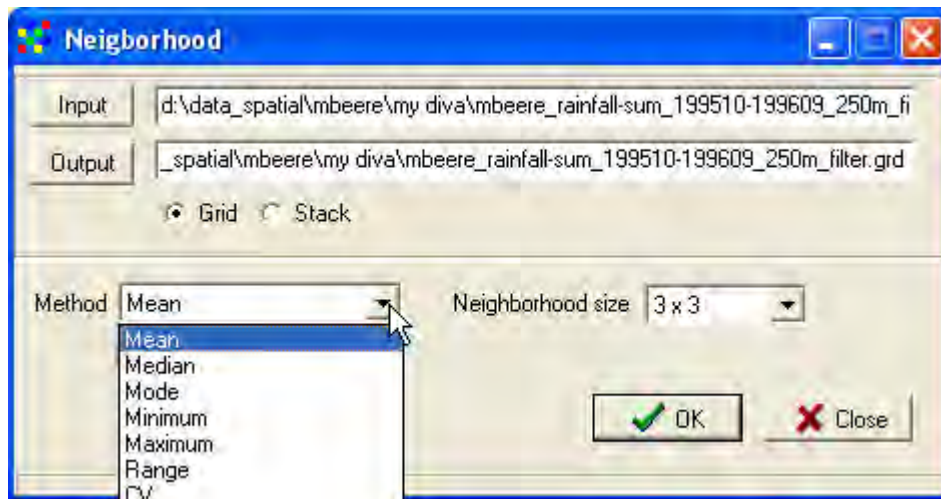
In principle the rainfall grids from the included districts were created in this way. Some more tricks were however needed to get them to fit properly to the EVI datasets, and a very large filter had to be applied. Hence the creation of the 250 m resolution rainfall grids where done with a purpose written software, and can not be exactly recreated using DIVA-GIS.

The ready made rainfall grids for the districts are under the folder \data_spatial\xx\grid\precip\year_oct-sept\sum; where xx is the district name. Add one of the expanded and filtered rainfall grids, and you can see the smoothness in the spatial rainfall gradients.
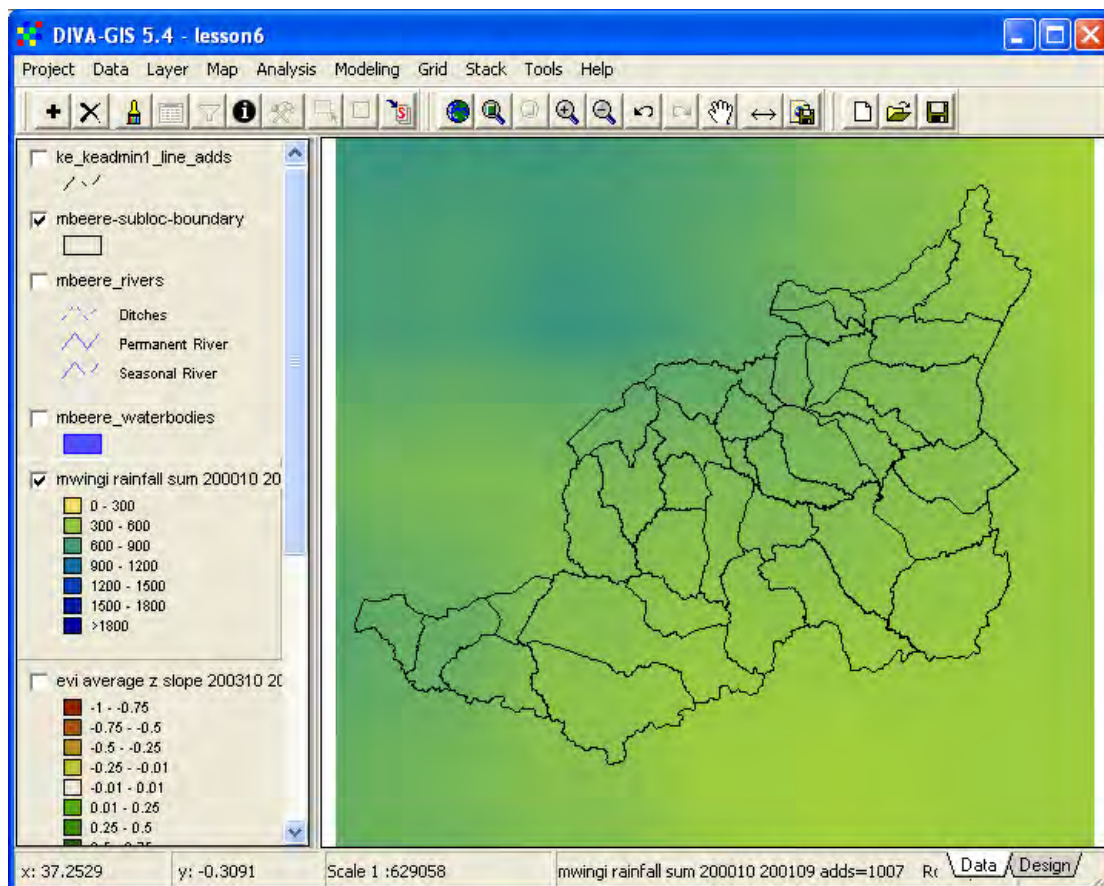

The 250m x 250m rainfall data is artificially accurate, and should not be used for any detailed analysis. It was created to overcome the difficulty in using rainfall data at 8km and compare it with vegetation data in 250m resolution.

Calculating Rain Use Efficiency

Rain Use Efficiency (RUE) is a method to disentangle the rainfall driven variation in vegetation from other factors governing changes in vegetation (see above). RUE is simply calculated as the ratio between an annual vegetation index and annual rainfall (some studies use growing season instead of annual indexes, but in this project the annual indexes have been used).

You can calculate RUE using DIVA-GIS, by using grid overlay to divide vegetation growth (EVI annual index) with rainfall (annual rainfall sum). From the DIVA-GIS menu choose Grid – Overlay, and select the vegetation index as the First grid, and the rainfall as the Second grid, as show below. Choose Divide as the Operation, and give a logical Output file name by clicking Result (put the result in your district my diva folder). Click Apply to run the operation and create a RUE grid.
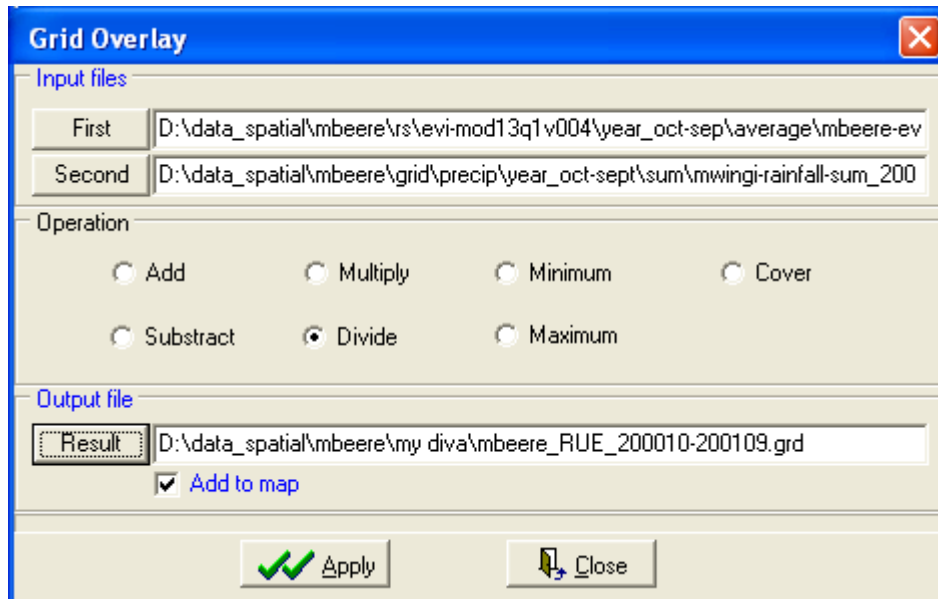

The value of the resulting RUE grid will vary dependent on the data ranges and units in your input files, and for some areas you might get a negative RUE (e.g. water areas). In the example below the symbolizing was changed in the resulting RUE grid, and the water bodies layer was put on top of the RUE as RUE is not a valid concept for water areas.
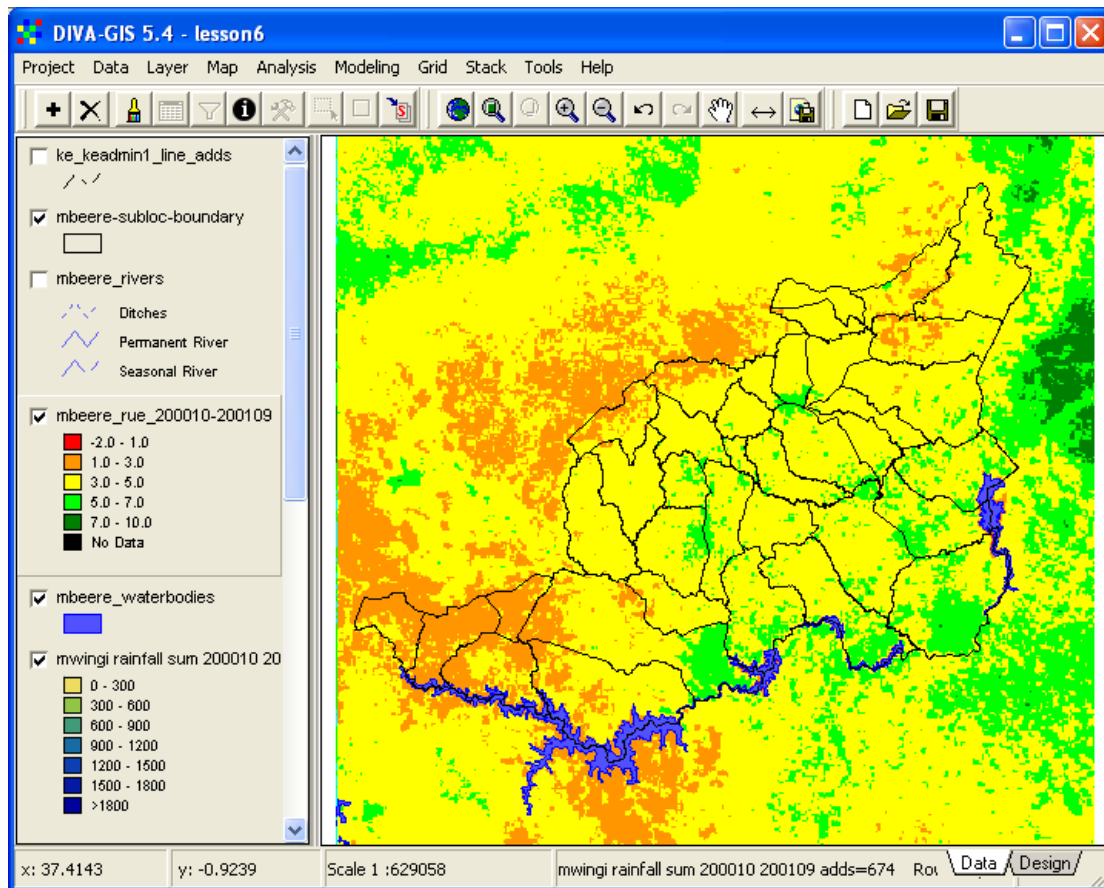
The RUE layer shows the variation in vegetation growth with the influence of rainfall taken away. If the vegetation data had been in units of biomass production per area (e.g. g/m^2), RUE would have shown the absolute growth per mm of rainfall. There are documented methods to convert EVI (or NDVI) to absolute biomass growth, but detailed ground surveys are needed to adopt those methods. And in this study we are mostly interested in finding areas that have relatively higher and lower RUE and areas where RUE has changed over time, hence the indexed RUE that you just calculated will be sufficient.

The RUE for the included districts is already calculated for each year 2000 to 2006, but only for the vegetation index derived from the annual increments in EVI (see lesson 5 to learn about the increment index). You find the RUE grid layers calculated using annual vegetation increments in the folder \data_spatial\mbeere\rs\rue-evi\year_oct-sep\increment. Apart from the annual RUE grid layers, there is also a trend grid calculated using normalized z-score values (see lesson 5 to repeat normalization and z-scores). You can calculate the trend based on the original data by using the stack included in the folder with the RUE data.
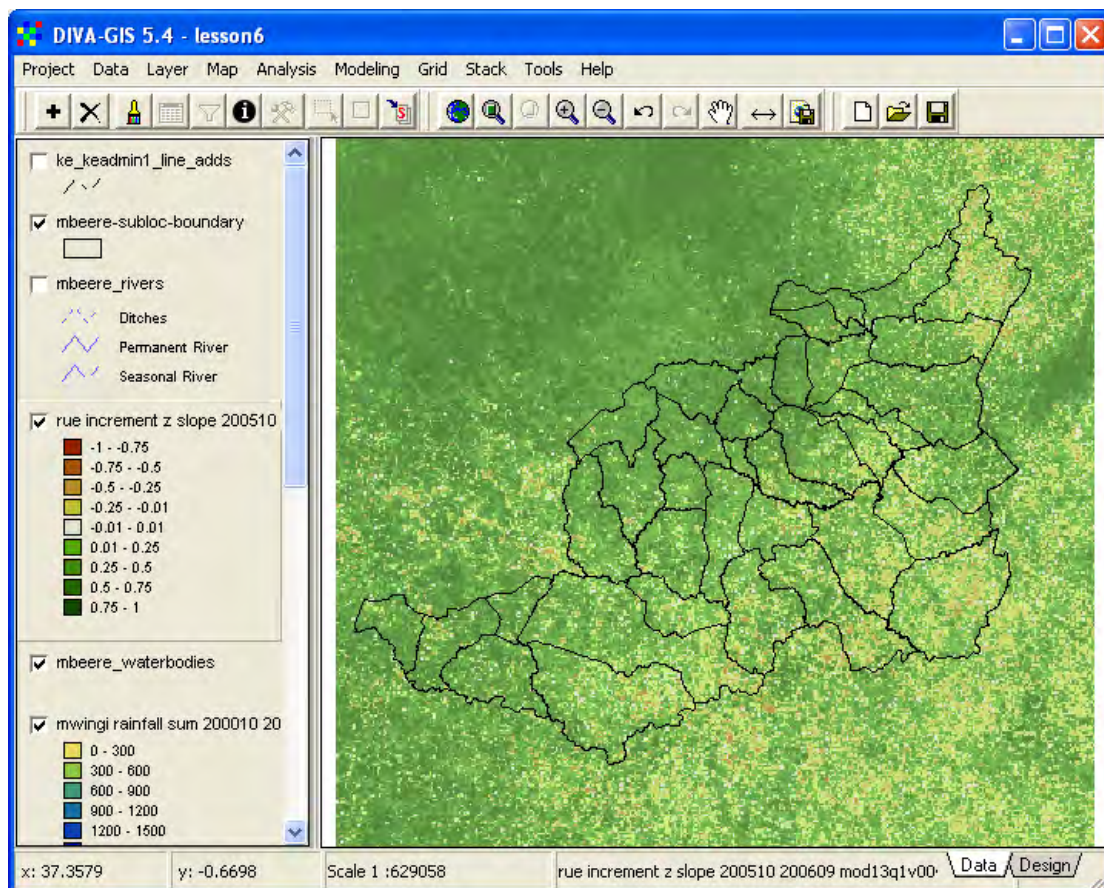
The z-score trend in Rain Use Efficiency shown above is probably one of the best estimates we can get for identifying degradation hotspots and improvement coolspots from the datasets available. As the time series is rather short (6 years), and the rainfall data is artificially accurate (see above) you should however combine the RUE trend with the vegetation trends (all three vegetation indexes – annual average, annual maximum and annual increments) to derive a final hotspot / coolspot map.

Multi Criteria Evaluation (MCE) for identifying hotspots and coolspots

To evaluate which cells that are most likely affected by land degradation you should combine multiple criteria – an analysis called Multi Criteria Evaluation (MCE). You already did an MCE in lesson 5 (albeit the terminology was not introduced), when you identified degradation hotspots using a combination of the trends of the three vegetation indexes that you have used also in this lesson. Try to repeat the steps undertaken in lesson 5 to identify local degradation hotspots / coolspots in your district.

Under the folder \data_spatial\xx\grid\land_degrade, where xx is the district, you will find ready made indexes of both hotspots and coolspots, as well as an MCE-index of land degradation. The land degradation images where created by combining the four normalized (z-score) trends for: 1) RUE, 2) annual average vegetation, 3) annual maximum vegetation, and 4) annual vegetation increment, and dividing the result with the number of input layer (4 in this case):

Lmce_index = (RUE_z-trend+EVI-average_z-trend+EVI-max_z-trend+EVI-increment_z-trend)/4

This MCE-formula can be easily implemented in DIVA-GIS by using the Grid Calculator (under the menu: Grid – Calculate, see lesson 5).

The final hotspot / coolspot grid layers were then created by extracting areas where at least 16 cells (1 km^2) formed a joined cluster (this step is not possible to do with DIVA-GIS). The hotspot / coolspot classes were set by thresholding the identified hotspots / coolspots cells into classes using equal ranges. The MCE degradation map was changed from having values in the range –1 to 1, to have values in the range –255 (hotspots) to 255 (coolspots). (The last step was only done for saving disk space and fit the dataset on CDs, it is not needed.) Below is the final hotspot / coolspot map for Mbeere district, which should be a good starting point for field work and closer analysis of background factors contributing to land degradation in Kenya.