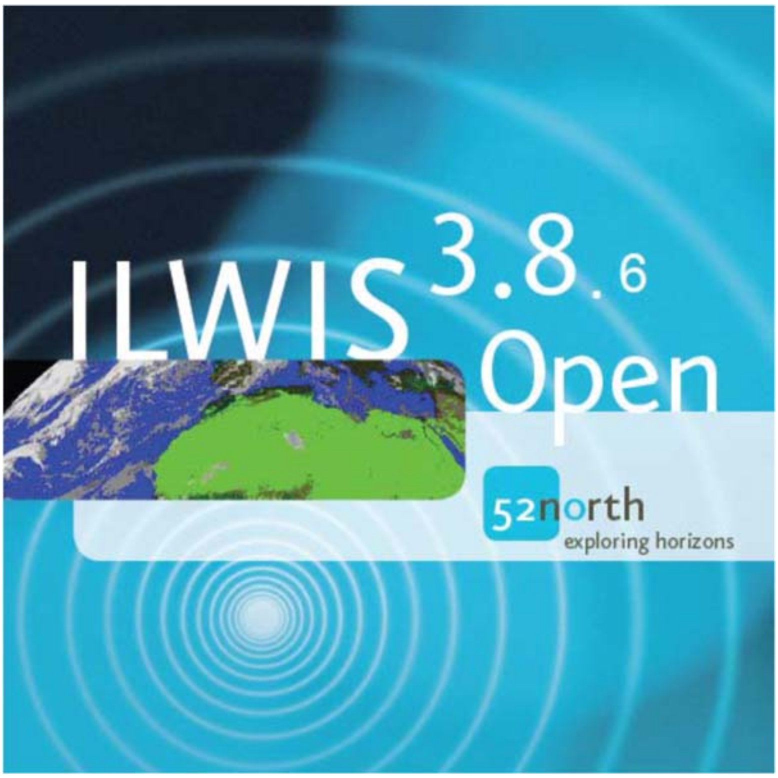
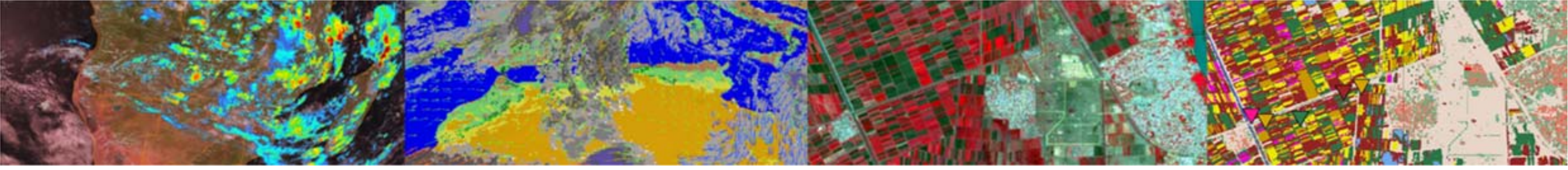


ILWIS 386 - Exercises

Ben Maathuis and Bas Retsios, 20-11-2019



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1 Introduction

This document will introduce you some of the new functionality implemented in ILWIS 386 but also on the existing routines in order to conduct various GIS processing capabilities offered by the software. A number of issues will be discussed like data import, scaling, creating sub-maps and clipping raster maps using a (country) mask, re-projecting and resampling of raster data, computing statistics, creating output maps for reporting purposes, conducting analysis using elevation models like slope maps and derive contributing areas, work with time series data and conduct calculations on time series, creating animations and display of synchronized animations, perform calculations from the command line, as well as from a script.

1.1 Overall learning objectives

After review of the document and conducting the exercises described you will be able to:

- Use basic GIS functionality provided by ILWIS 386
- Understand linkage between raster maps and tables, re-projection / resampling of maps, combine information from various maps
- Retrieve information and create appropriate visualization
- Convert data from point or polygon to raster format
- Import of data from different sources
- Perform a multitude of computations to create value added information

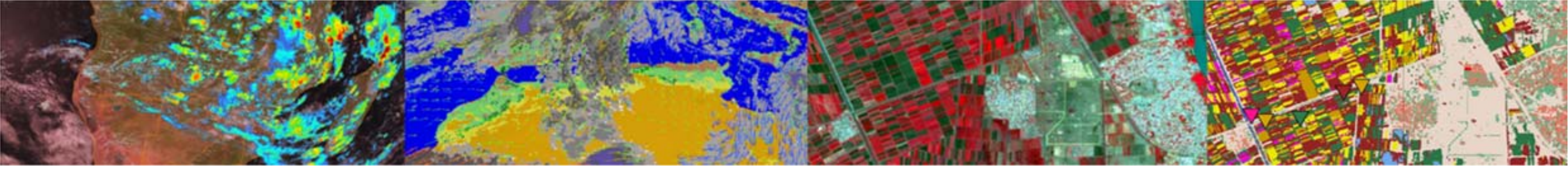
2 Prerequisites

This manual reflects the capability of ILWIS 386. To download the latest software version, please check the following address: https://filetransfer.itc.nl/pub/52n/ILWIS386/Software/. Also check the corresponding *.txt file for the latest bug reports. The ilwis*setup.exe file can be downloaded and transferred to your local system and the file can be executed. Navigate to the ILWIS386 installation folder, double click ilwis.exe and the software should start and is ready to use. Eventually a shortcut can be made to the desktop. Also a shortcut is available from within the Windows Start menu (under ILWIS).

Instructions provided within the manual should be carefully studied. Certain data created in one of the exercises will be used at a later stage, therefore the structure of the guide should be followed from the start. Within ILWIS, using the help functionality a lot of additional information is provided. In case of questions, don't hesitate to consult this utility.

Furthermore the exercises described over here assume that you have some basic background using ILWIS386, as provided through the "*Introduction tutorial*", this document and sample data required can be obtained from https://filetransfer.itc.nl/pub/52n/ILWIS386/Tutorial/, check the document "Lesson 3 ILWIS Tutorial" and for the tutorial data retrieved from https://filetransfer.itc.nl/pub/52n/ILWIS386/Data/ the file "*Tutorial_data.zip*".

Before you start, copy the exercise data file ("*ILWIS386_exercises.zip*"), which is also made available at https://filetransfer.itc.nl/pub/52n/ILWIS386/Data/ to your local hard-disk, and unzip the file. After unzipping, move the resulting folder 'ILWIS386_exercises' to the root of your hard-disk. Then start ILWIS, navigate to the exercise data folder and close ILWIS, so that the folder is remembered as the most recent working folder. From now on, starting ILWIS should automatically start in the appropriate folder.

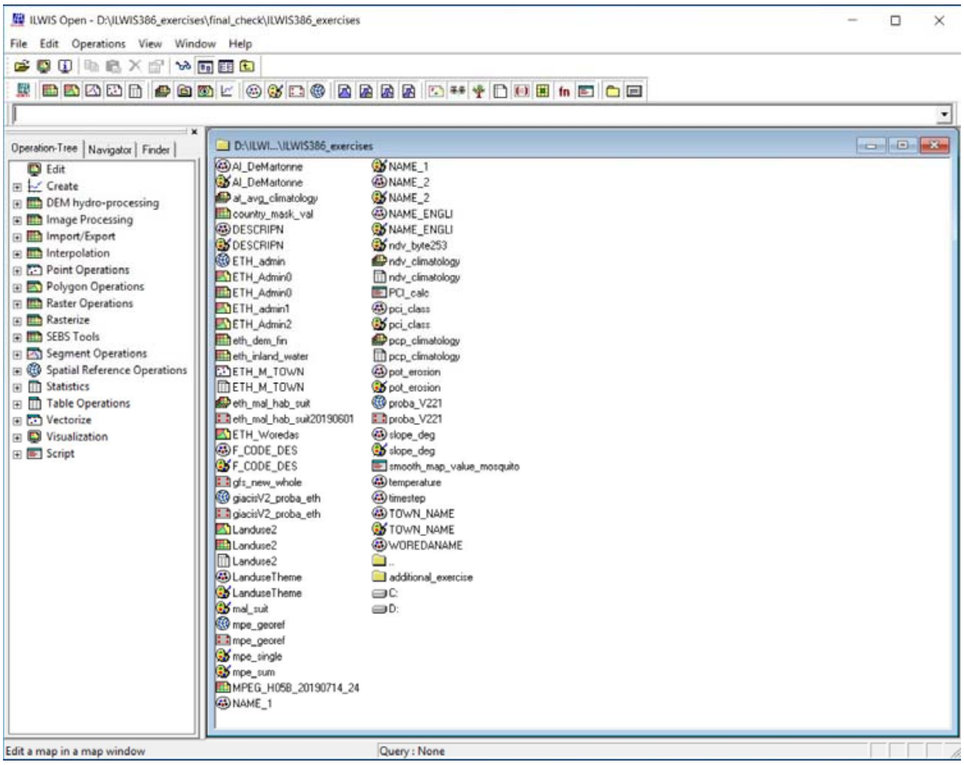


3 ILWIS 386 exercises

3.1 Introduction

Once you have downloaded and installed ILWIS 386 and installed the exercise data the following information and files should be available on your ILWIS catalog. See the figure below and compare it with your settings. Check from the main menu the option “Help” > “About ILWIS”. Here ILWIS Open version 3.8.6.0 is used. Note the various icons used for the different objects in ILWIS!

Figure 1: Opening ILWIS and initial catalog display



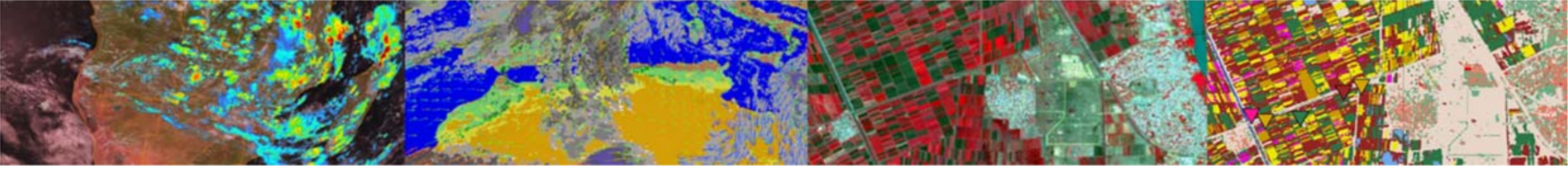
3.2 Import, scaling and clipping a PROBA Vegetation NDVI map

Every 10 days, data from multiple overpasses are mosaicked and a NDVI map is created over the African continent. This procedure started with the launch of the SPOT Vegetation instrument in 1998 and continues till this day, now with PROBA Vegetation and Sentinel 3 (OLCI instrument). Here a sample map of PROBA Vegetation is used. For more information see Wolters et. al. (2018) . Here a NDVI map of 20190321, containing the information for the last dekad[1] of March 2019 is provided, as a maximum value composite. The data format is a “tif” file and before it can be used in ILWIS the data needs to be imported. In such a case, next to the file format a number of issues have to be considered, like:

- The values, value range and data precision
- The projection details
- Eventual scaling and offset used

Start ILWIS and navigate to the appropriate directory. Here the folder “C:\ILWIS386_exercises” is assumed. From the main ILWIS menu select the options “File” > “Import” > “Geospatial Data Abstraction Library (GDAL)” > “Raster” > “GeoTIFF”. As Input Map select “proba_ndv” and press

[1] Dekad is a period of 10 days. For NDVI, each month has 3 dekads. The last NDVI dekad in a month may not have 10 days, depending on the number of days of that month.



“Open” and “OK”. After the import routine is completed a new item named “proba_ndv” appears in the ILWIS Catalog. Double-click it to display the newly imported map “proba_ndv”. Change the Representation (under Display Tools > Portrayal) to “ndv_byte253”.

Now check the map values by pressing the left mouse button on the map. Navigate with the left mouse button pressed over the ocean, inland water, the yellow to green areas and note the values. Also check the white areas. What is the value format and the range? Note that the values for the cursor location are also given in the pixel information window at the lower left corner.

Furthermore note the missing coordinate information as given in the lower right corner of the map display window. The appropriate coordinate and projection information was not available within the tif file. Therefore, based on additional information provided for the Proba Vegetation African window, a georeference and coordinate system was created and included in the dataset. Open the georeference and coordinate system “proba_V221” and check their details. Note that a Plate Carree projection is used and the pixel size is 993.924 meters. Close all open map windows. In the ILWIS main window, right-click with the mouse on the imported map “proba_ndv”, and from the context sensitive menu select the option “Properties”. Change the Georeference from “none” to “proba_V221” and press “Apply” and “OK”. Display the map again using as Representation “ndv_bye253”and check the coordinates once more. From the map window select the icon “Add Layer”. In the “Add Data Layer” form change the “Filter” to “Base Maps” by selecting it in the drop down menu, then select “country_boundaries” and press “OK”. From the layer manager on the left of the map display, for the map “country_boundaries”, select the options “Display Tools” > “Portrayal” > “Fixed Colors” > “Single Color” and select black as Draw Color, press “Apply” and “Close”.

Now zoom in over Ethiopia, check the NDVI map values over the country. It can be noted that a few pixels are assigned to 252 (missing information e.g. due to persistent cloud cover) and 254, which is representing water bodies. Mostly the NDVI is scaled from 0 to 1. In case of the raw PROBA Vegetation, the data is in byte format, and values over 250 do not contain relevant NDVI values. To transform the map to the appropriate NDVI range a scaling and offset have to be applied. This information is normally presented in the metadata information of the product. Here the scaling is 0.004 and the offset is -0.08.

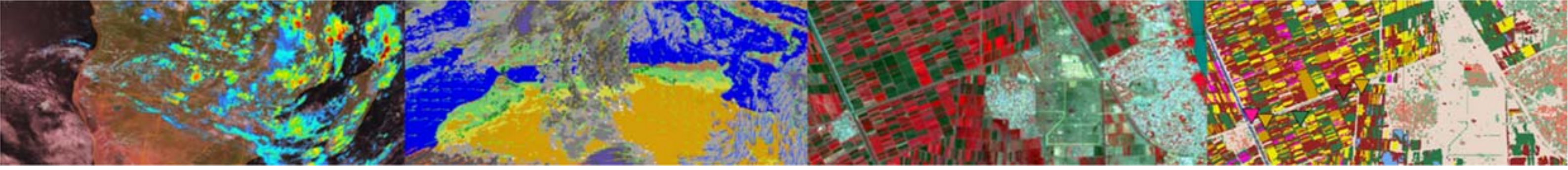
To transform the ndvi map from the initial byte range to the appropriate ndvi range the following computation can be performed:

Proba_ndv_cor:=0.004*proba_ndv-0.008

Type this expression in the command line in the main ILWIS window and press <enter>, in the “Raster Map Definition” window, select as value range 0 to 1 and press “OK” to execute the calculation. Display the map “Proba_ndv_cor”, now using as Representation “NDVI1”. Zoom in to Ethiopia (display also the country_boundaries vector map) and once more check the values. Note that the water bodies now have been assigned “not a number”, defined by ILWIS as ‘?’. Why?

As we are not interested in the whole map over Africa, but want to use a certain portion of the map, a so-called sub-map can be created. Open the georeference “giacisV2_proba_eth”. This Georeference is defining the corner coordinates and projection (note Plate Carree is an equal area projection) which are used for Ethiopia for the remainder of all further exercises.

To create a submap, right-click the map “proba_dnv_cor”, from the context sensitive menu, select the option “Spatial Reference Operations” > “Resample”. In the Resample Map menu, select the option Nearest Neighbour Resampling Method, as Output map specify “Proba_ndv_Eth” and as Georeference “GiacisV2_proba_Eth” and press “Show”.



In the display map window, change the Representation to “NDVI1”, add the polygon map “ETH_Admin0”[2], under the Display Tool uncheck the option “Areas”, now only the country boundary is displayed.

In a new map window display the raster map “ETH_Admin0”, also check the properties and check the map value, here it is a string with the name of the country. Which georeference is used?

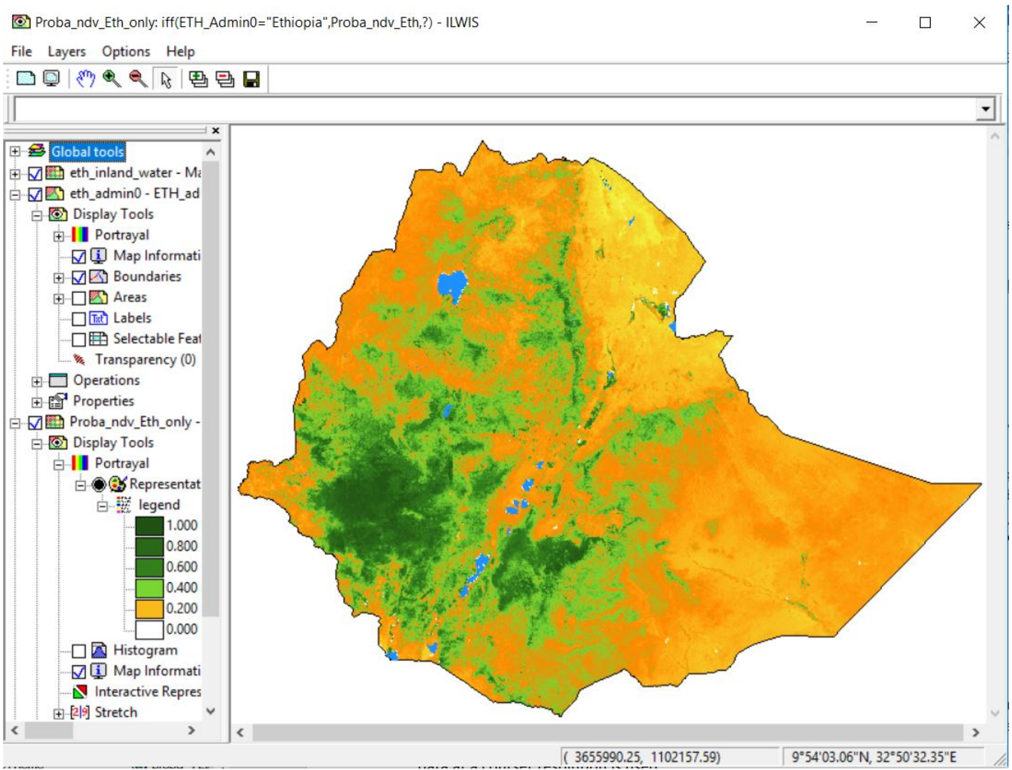
The equation before was using values, now we are going to apply a string in a calculation. Note that both the raster map “ETH_Admin0” and “Proba_ndv_Eth” use as Georeference “GiacisV2_proba_Eth” and therefore have the same size and map dimensions. These maps match pixel-by-pixel, and can therefore be combined in pixel-based computations. To extract only the NDVI values for the country, type the following equation in the command line of the main ILWIS menu and press <enter> to execute the expression:

Proba_ndv_Eth_only:=iff(ETH_Admin0=”Ethiopia”,Proba_ndv_Eth,?)

Display the result, using the appropriate representation, here “NDVI1”. Try to explain the equation used in your own words!

Add the polygon map “ETH_Admin0”, boundaries only and the raster map “eth_inland_water”. Your results should resemble those in the figure provided below. Note that the inland water mask is slightly different from the mask used for the Proba-Vegetation map.

Figure 2: Creating an NDVI map over Ethiopia



[2] Note that the ILWIS Catalog contains two objects named “ETH_Admin0”. One is a polygon map, the other is a raster map. Based on the icon in the catalog you can distinguish which is which.

3.3 Daily precipitation from Meteosat Second Generation – HSAF H05B

Ethiopia is a country which is very dependent on rainfall, especially for its agricultural production, as most agriculture is rain fed. Based on frequent precipitation measurements as retrieved by blending Low Earth Observing MicroWave-derived precipitation rate measurements and GEO-Stationary InfraRed images, daily maps of rainfall over Africa can be obtained. An example is the H05B which is produced by the Satellite Application Facility on Hydrology.

For further information you can consult the Product User Manual, see HSAF (2017). The data is preprocessed at ITC and made available to the users (in ILWIS format) on a daily basis (for the previous day) at: http://filetransfer.itc.nl/pub/mpe/HSAF_H05B/.

Display the map "MPEG_H05B_20190714_24", note the file name convention used, the suffix indicates that the data is integrated over 24 hours! The map therefore represents the 24 hour accumulated precipitation (in mm) for 20190714. Use as Representation "mpe_sum". Display also the base map "country_boundaries", boundaries in a black color. Check the map values. As can be seen from the map, due to the earth curvature with respect the location of the MSG satellite (at 0 degrees, the Prime or Greenwich Meridian, over the equator) Ethiopia looks quite distorted.

To correct this issue, again a resampling procedure is going to be applied. Right-click the map "MPEG_H05B_20190714_24", from the context sensitive menu select the option "Spatial Reference Operations" > "Resample". In the Resample Map menu, select the option "Nearest Neighbour" Resampling Method, as Output map specify "MPEG_Eth" and as Georeference "GiacisV2_proba_Eth" and press "Show". Explain why here a 'nearest neighbour' resampling is the most appropriate!

Display the map "MPEG_Eth", using as Representation "mpe_sum", also display the polygon file "ETH_Woredas", only the boundaries therefore uncheck the display option "Areas". Check the precipitation values and the names of the woredas.

Now we are going to calculate the average precipitation for the given day per woreda as well as the difference in precipitation over each of the woredas, like minimum, maximum and standard deviation.

Close all open maps before you continue. First the woreda map needs to be transformed from a polygon map into a raster map. Right-click with the mouse on the polygon map "ETH_Woredas", select the option "Polygon to Raster" from the context sensitive menu and from the Rasterize Polygon Map window, select as georeference "GiacisV2_proba_Eth" and press "Show". Once the routine is completed the newly created raster map is shown. Inspect the map values. Note that each woreda is shown by its respective name. In the ILWIS main window, right-click on the newly created raster map "ETH_Woredas" and inspect the properties. Check the domain of the map. Open the domain "WOREDANAME" and check the content. Note that the rainfall map has a value domain!

Now we are going to cross two maps, the ETH_Woredas map with the precipitation map. From the main ILWIS menu, select the options "Operations" > "Raster Operations" > "Cross". As first map select "ETH_Woredas" and as second map "MPEG_Eth", as output cross table specify "woreda_mpeg" and press "Show". Check the content of the table and explain the organization of the table, especially each record name. Now we are going to perform a number of table aggregation calculations. From the table menu, select the option "Columns" > "Aggregation" and specify the other settings as given in the figure below and subsequently press "OK".

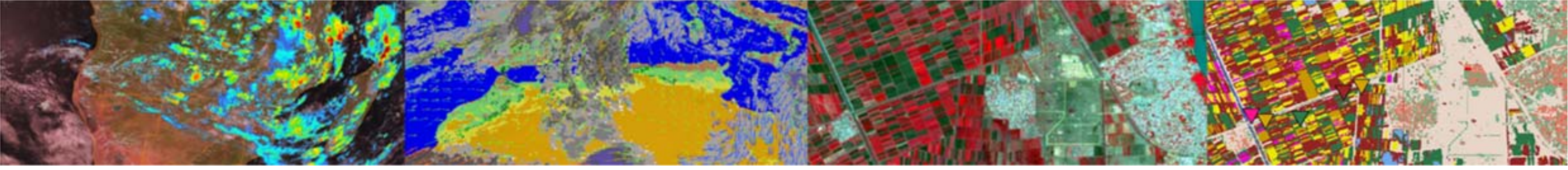
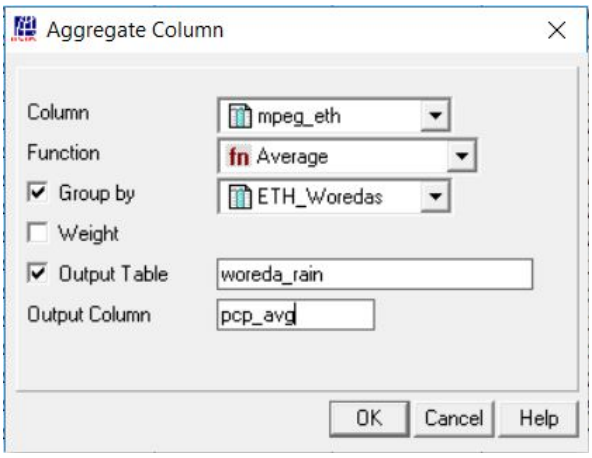


Figure 3: Aggregate column settings



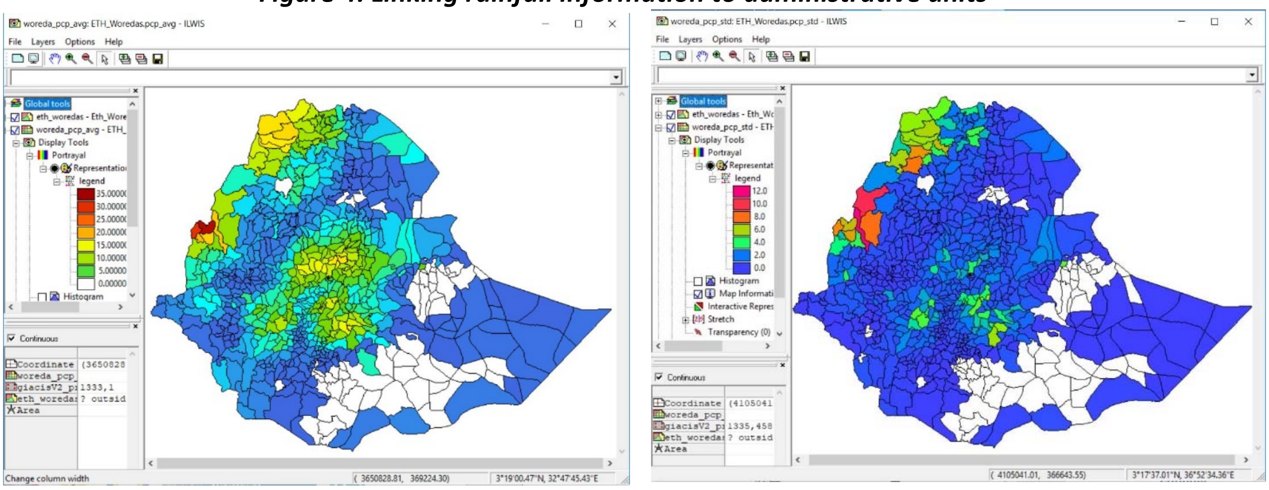
For each woreda the average precipitation is calculated and stored in a new table “woreda_rain” and in there in a column named “pcp_avg”. Open the new table “woreda_rain” and check the content. Why did we group by ‘ETH_Woredas’? Close the table “woreda_rain” before you continue.

Now also calculate other statistics from table “woreda_mpeg”, like sum, minimum, maximum and standard deviation. Every time use as output table “woreda_rain” and call the new Output Columns “pcp_sum”, “pcp_min”, “pcp_max” and “pcp_std” respectively.

Close the table “woreda_mpeg” and open the table “woreda_rain”. Check the content and then close the table. Right-click with the mouse on the raster map “ETH_Woredas”, select the “Properties” and activate the check box “Attribute Table” and from the drop down list select “woreda_rain” and press “OK”. Once more display the raster map “ETH_Woredas” and now check the map / table values in the lower left hand pixel information window. Close the map.

Now we can also create raster attribute maps using the data from the attribute table. Right-click with the mouse on the raster map “ETH_Woredas”, from the context sensitive menu select the option “Raster Operations” > “Attribute Map”, from the Attribute Map of Raster Map window, use as Attribute “pcp_avg” and as output map specify “woreda_pcp_avg”, press Show. Once the map is displayed, select as Representation “mpe_single”, add the layer ETH_Woredas (only the boundaries). Repeat the procedure and calculate a new map “woreda_pcp_std”, using as attribute the standard deviation (pcp_std). Also display the map and add the woreda boundaries (only). Your results should resemble those in the figure below, rain_avg on the left and rain_std on the right hand side. What can be concluded when both maps are compared?

Figure 4: Linking rainfall information to administrative units



More advanced processing of rainfall data and presentation of the results, e.g. create appropriate map layout and visualization, will be conducted at a later stage.

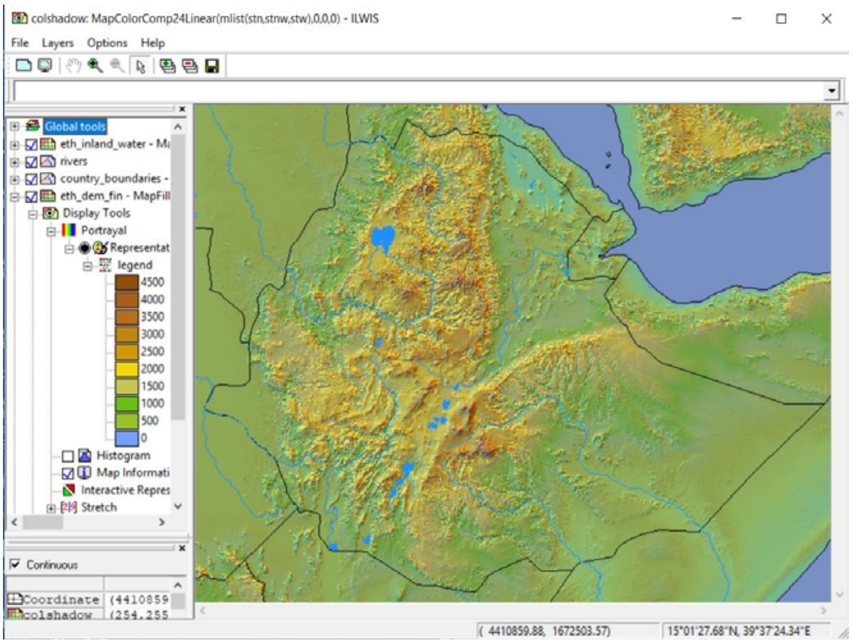
3.4 DEM processing and compute the Sediment Transport Index

Based on the data acquired from the Space Shuttle an enhanced Shuttle Land Surface model was released, having a spatial resolution of 1 arc-second, approximately 30 meters with elevation intervals of 1 meter. Additional details on this SRTM mission and product are described in Farr et. al. (2007).

For this exercise the data at a coarser spatial resolution is used, again resampled to the same georeference as used in the previous exercises. Note that a Plate Carree projection is used, having a metric coordinate system and is equidistant, therefore distances in X and Y directions are equal. Note that this is not the case when using maps with geographic coordinates as the Y distance changes over latitude! Furthermore this elevation model is corrected for sinks representing internal depression which create problems when trying to conduct hydrologic flow functions.

Display the elevation model “eth_dem_fin”, use as Representation “ElevationMeter”, check the map values and then close the map. From the main ILWIS menu select the option “Operations” > “Dem Hydro-processing” > “DEM Visualization”, use “eth_dem_fin” as DEM, leave the output name as default and press “OK”. The operation conducted creates from the DEM illumination directions using linear filters from west, north-west and north directions. Subsequently these are merged in an output map. Once the map is calculated the results are displayed in a new map window. Add the DEM “eth_dem_fin”, using as representation “ElevationMeter”. Under the Display Tools options for this map, click on transparency and set the transparency to 45 %, eventually add the base map “country boundaries”, but change the boundary color to black. Also add the base map “rivers”, and select “Dodgerblue” as the single color. Also add the map “Eth_inland_water”. See also the figure below.

Figure 5: Visualization of elevation map over Ethiopia



Next is the calculation of slope steepness. In order to do this, first check from the main menu, the Option “Help” > “Index” and select “Slope map” and read / study carefully how the slope is derived from an elevation data set.

As we already have a DEM, we can directly start the filtering procedure. Select from the main ILWIS menu the option “Operation” > “Image Processing” > “Filtering”, as Raster Map “eth_demfin”, as filter name select “DFDX” from the drop down menu, as output map specify “DX” and press “Show”. Repeat the procedure and now select the filter “DFDY” and as output map specify “DY”.

Now having obtained the elevation differences in X and Y direction the slope can be derived as the pixel size is constant in both X and Y direction. The slope in percentage is derived using the following command, which can be typed on the command line within the main ILWIS menu:

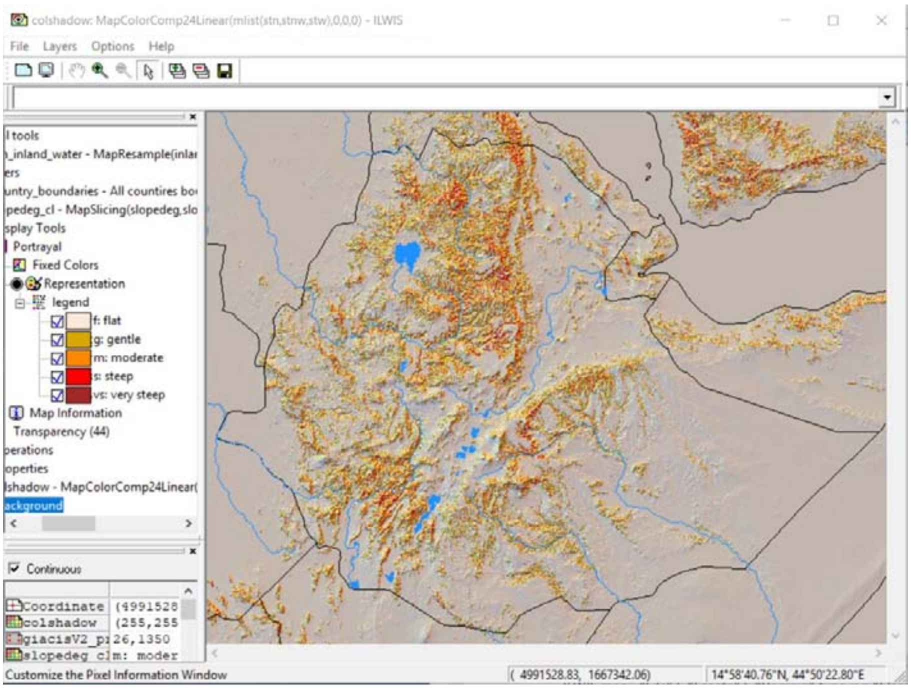
slopepct:=100*HYP(DX,DY)/ PIXSIZE(eth_dem_fin)

press "OK" to start the computation. Display the map "slopepct" and check the values. Now calculate the slope in degrees, type the following expression in the ILWIS main menu command line and press "OK":

slopedeg:=RADDEG(ATAN(slopepct/100))

Display the map "slopedeg" and check the values. Note that a domain called "slope_deg" is provided in the dataset. Open this domain and check the class intervals. This domain can be applied to classify the slopedeg map into several classes. In order to do this, from the main ILWIS menu, select the option "Operations" > "Image Processing" > "Slicing", as Raster map select "slopedeg", as domain "slope_deg" and as output raster map specify "slopedeg_cl" and press "Show". Add the map "colshadow", in the layer manager on the left, drag the layer "colshadow" below the layer "slopedeg_cl", then set for layer "slopedeg_cl" the transparency to 45 %. Zoom in on some of the steep areas and check the results obtained. See also the figure below.

Figure 6: Classified slope map over Ethiopia



You can also classify the slope map in percentages. To do so, create a new domain, using the menu option "File" > "Create" > "Domain" from the ILWIS main window. Enter a name for this domain, e.g. "slope_pct", ensure the type is "Class", and also enable the option "Group". The classes 0-10%, 10-25%, 25-50%, 50-100%, >100% for the slope map in percentages can be defined, by inserting several domain items in the "Domain Class" editor. The last class should have as upper limit the highest possible map value! Note that also a Representation with the same name is created. Double clicking the Representation shows the colours, these can be modified according to your requirements. When the domain is ready, it can be used to classify the "slopepct" map.

Now we will determine the upstream contributing area per pixel. In order to do this, first check from the main menu, the Option “Help” > “Index” and select “Flow Accumulation” and read / study carefully how the upstream area is derived from an elevation data set.

From the main ILWIS menu select the option “Operations” > “Dem Hydro-processing” > “Flow Determination” > “Flow Direction”, as input DEM use “eth_dem_fin”, activate the option for “parallel drainage correction” and as output map specify “eth_dem_fd”. What do the values in the map represent?

From the main ILWIS menu select the option “Operations” > “Dem Hydro-processing” > “Flow Determination” > “Flow Accumulation”, as input flow direction map use “eth_dem_fd” and as output map specify “eth_dem_fa”. Check the result obtained. To improve the visualization of the map, under “Display Tools”, double click the option “Stretch”, activate the ‘Logarithmic stretching’ option. What do the map values represent?

Having obtained the slope and the contributing area the Sediment Transport Index (STI) can be derived. This index accounts for the effect of topography on erosion. The two-dimensional catchment area is used instead of the one-dimensional slope length factor as in the Universal Soil Loss Equation. The equation for the index applied is derived from Burrough and McDonnell (1998):

$$STI = \left(A_s / 22.13\right)^{0.6} * \left(\sin \beta / 0.0896\right)^{1.3}$$

Where: As is the unit contributing area (in m2/m)and β is the slope angle (in degrees) at a given pixel. Type the following expression on the command line in the main ILWIS menu and press <enter> to execute the calculation:

```
STI:=POW(((eth_dem_fa*PIXSIZE(eth_dem_fin)*PIXSIZE(eth_dem_fin))/(22.13)),0.6) *
POW(SIN(DEGRAD(slopedeg))/0.0896, 1.3)
```

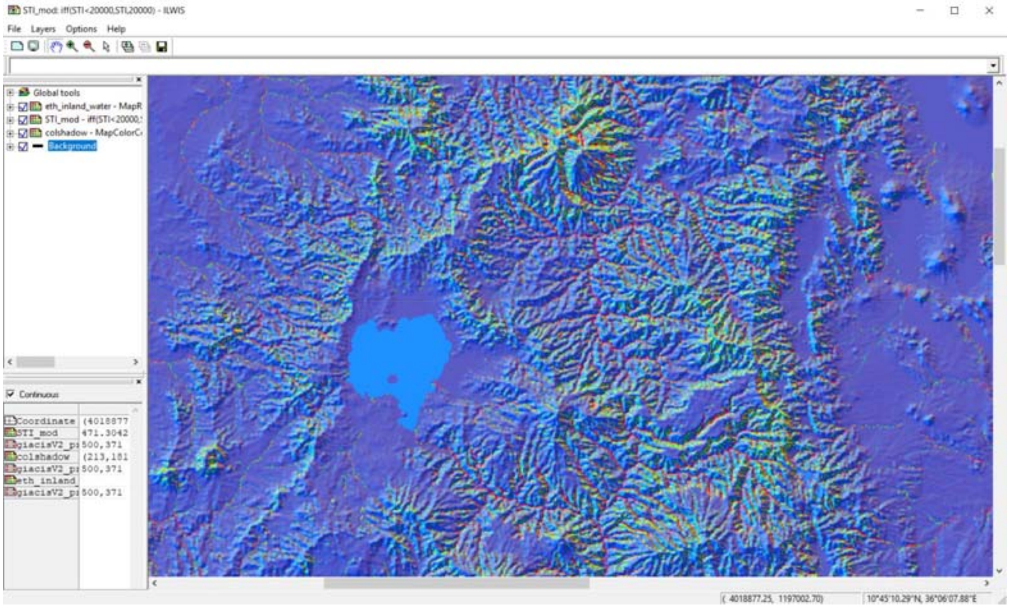
Check the result obtained. To improve the visualization of the map, under “Display Tools”, double click the option “Stretch”, activate the ‘Logarithmic stretching’ option. What do the map values represent?

As the stream network has received very high values, the map is going to be slightly modified using the following expression, to set the maximum to an STI value of 20.000:

```
STI_mod:=iff(STI<20000,STI,20000)
```

Display the map “STI_mod” and add the color shaded elevation model “colshadow” as a layer under “STI_mod”. For the STI_mod map use a transparency of 45 %, zoom in on the Ethiopian highlands and check the results. Note the remarkable differences between the (steep) valleys and the (flat) plateau’s as well as the reddish toned stream network. If you also add layer “eth_inland_water”, your results should resemble those provided in the figure below. Note Lake Tana and the Simien Mountains, situated towards the north-east of the lake.

Figure 7: Sediment Transport Index over the Central Highlands in Ethiopia



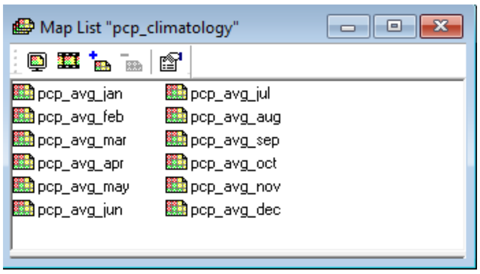
Finally open the map “eth_dem_fin” once again in a new Map Window. Use as Representation “ElevationMeter”. Right-click the “Display Tools” and from the context sensitive menu activate the option “Track Profile”. In the map legend check the box in front of the “Track Profile” option. On the elevation map a line can be drawn, by clicking the left mouse button and displacing the mouse to the destination location and clicking the left mouse button again.

In the Track Profile Graph window the track profile is shown. By clicking on a location along the graph, the corresponding location can be seen as a circle on the map. Eventually the track can be shown as a table, using the option “Open track as Table” and can be saved. Close all maps before you continue.

3.5 Working with Time Series, using NDVI and Precipitation Climatology

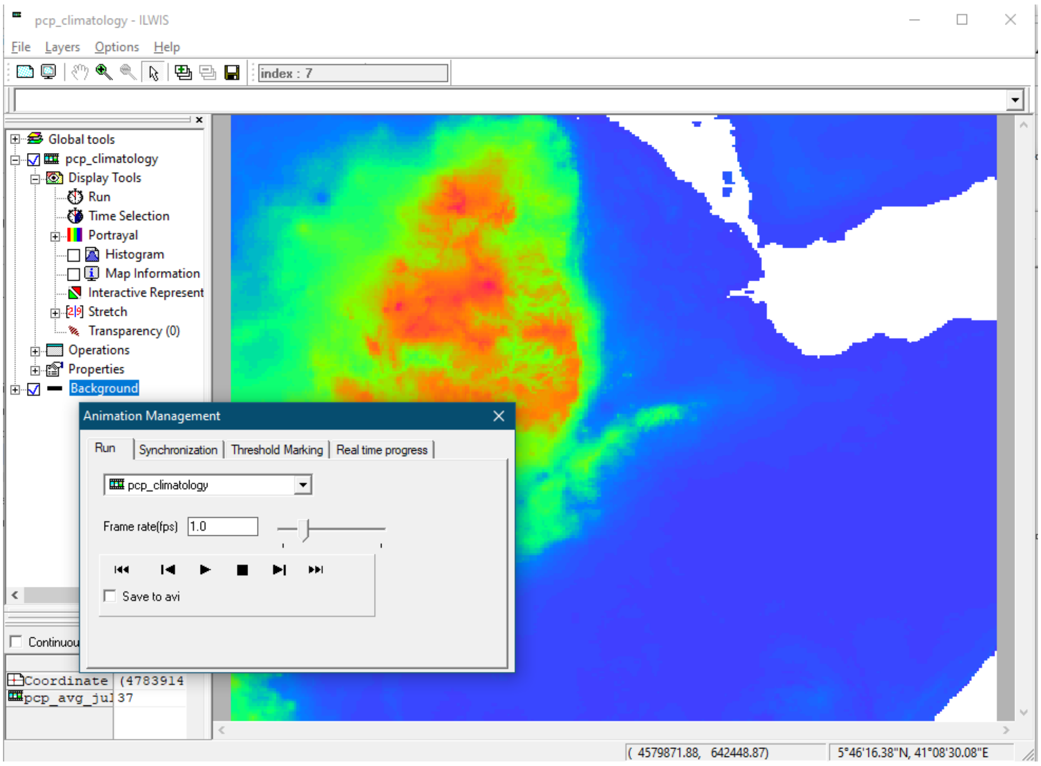
A number of time series have been prepared showing the climatology of the precipitation (in mm) on a monthly basis (map list: pcp_climatology) and the changes in greenness of the country, expressed by the NDVI (as byte map, ndvi values from 0-255) on a dekad basis (map list: ndv_climatology). Double click the map list “pcp_climatology”. Check the content (12 raster maps, one for each month of the year).

Figure 8: Map list and map list content



In the map list menu, click the button “Open As Animation” (the second button from the left with the filmstrip icon), to display the map list in a new Map Window, in “animation” mode. Under the option “Display Tools”, select the option “Run” and in the Animation Management window that appears, press the “Play” button, see also the figure below.

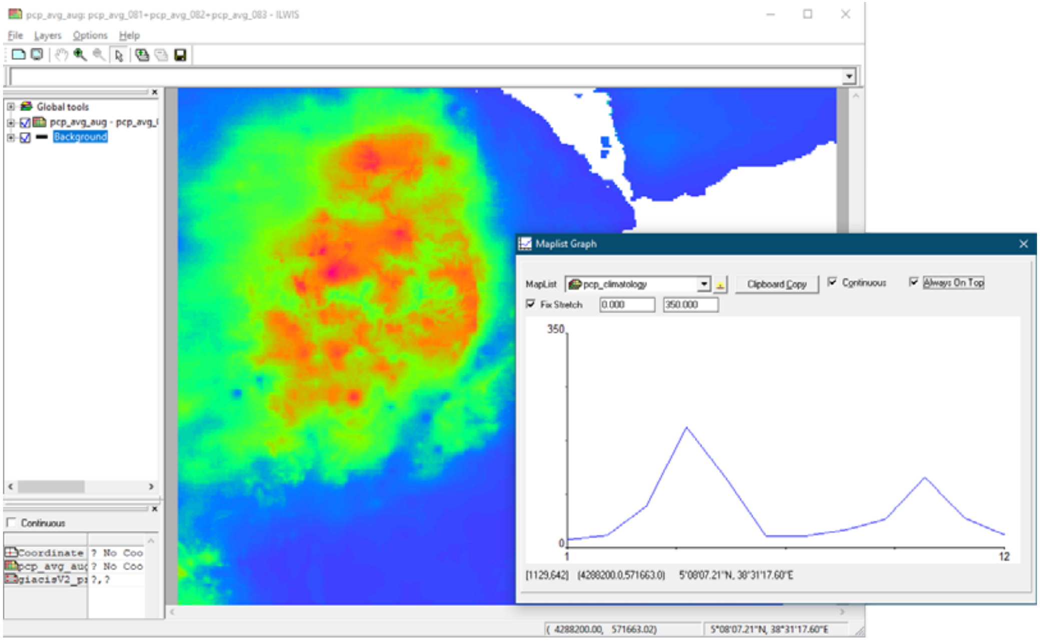
Figure 9: Map List visualization as animation



Review carefully the mean monthly changes of precipitation over the year. Close the animation map window.

Open again the map list “pcp_climatology” and display the map “pcp_avg_aug”. From the main ILWIS menu select the option “Operations” > “Statistics” > “MapList” > “MapList Graph”. As MapList select “pcp_climatology”, activate the options “Fix Stretch”, “Continuous” and “Always on Top”. Now move the cursor over the map and check the monthly mean rainfall distribution over various parts of the country.

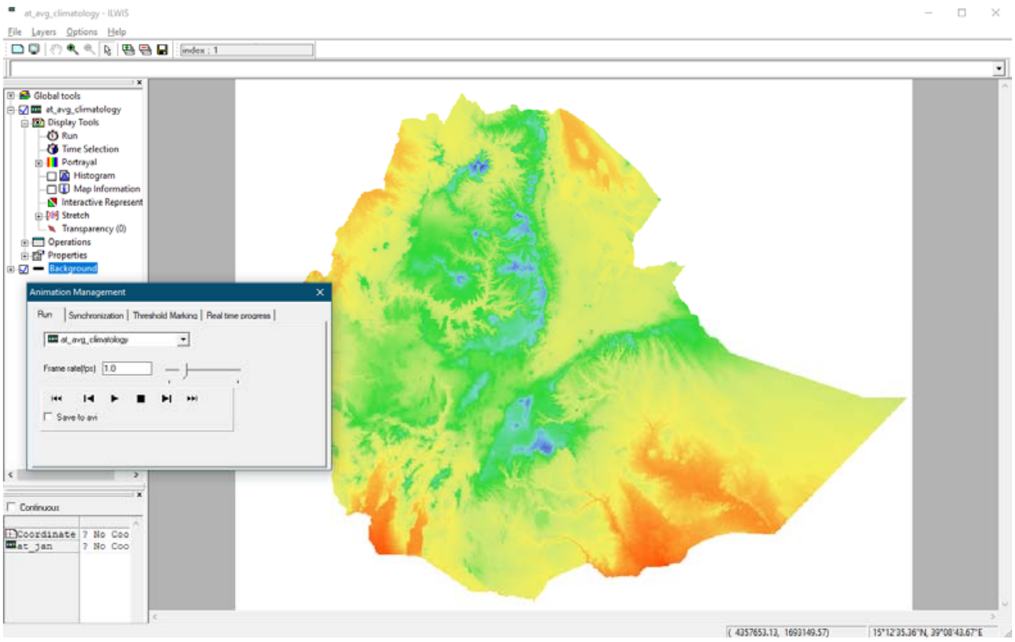
Figure 10: Map List visualization as a graph



Note that there are remarkable changes, unimodal – bimodal distributions together with low – high precipitation volumes. Close the MapList Graph window and also close the map “pcp_avg_aug”.

Now display as animation the map list “at_avg_climatology”. Here the average monthly air temperature is shown. Note the differences between the low lands, e.g. Afar – Rift region and the highlands. Close the animation map window when done.

Figure 11: Map List visualization of average air temperature as animation



Finally display the map list “ndv_climatology” as animation. Under “Display Tools” change the default representation to “ndv_byte253”. Again note the change in greenness of the country over the year. Do not close the animation, keep it open and running for the next step.

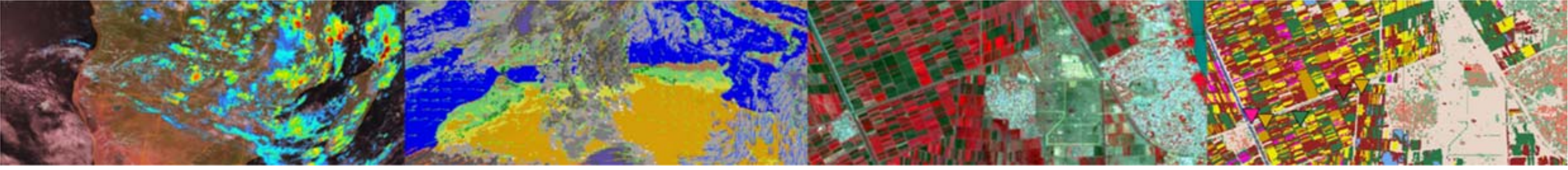
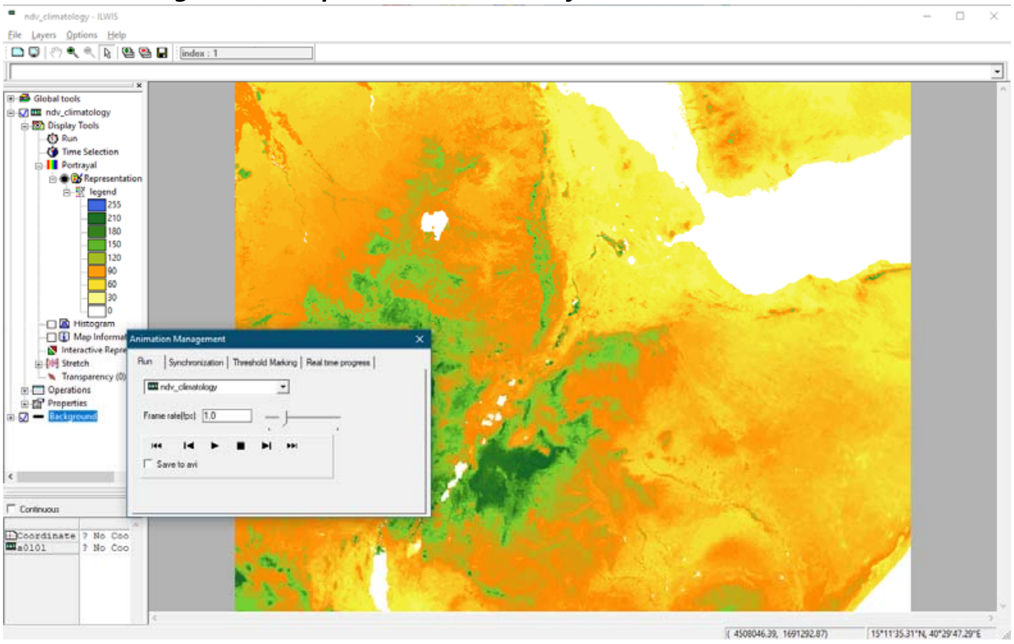
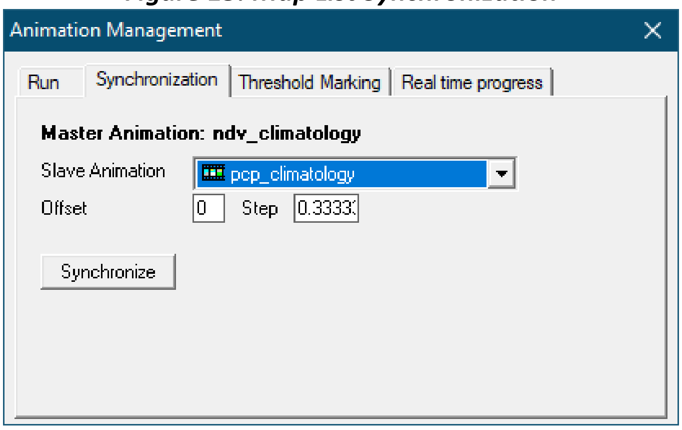


Figure 12: Map List visualization of the NDVI as animation



As there are clear relations between rainfall and vegetation, it is interesting to synchronize the animations “pcp_climatology” and “ndv_climatology”. Keeping “ndv_climatology” from the previous step open, open as well the map list “pcp_climatology” as an animation in a new map window, but do not click the Play button to start it. In the Animation Management window, ensure that the animation that is selected in the “Run” tab is “ndv_climatology” (if it is not, change the selection), and then switch to the tab named “Synchronization”. In “Slave Animation”, select “pcp_climatology”. The “Step” is auto-computed to 0.3333, because ndv_climatology has 36 frames and pcp_climatology 12, so every 3 frames of ndv are equivalent to 1 frame of pcp. Click the button “Synchronize”.

Figure 13: Map List Synchronization



Now you will see that the “pcp_climatology” runs perfectly in-sync with “ndv_climatology”. You can move and shrink the two windows, to fit them side-by-side on the screen. In the Animation Management window, you can switch back to tab “Run”, and (as long as “ndv_climatology” is selected) the play/stop/pause/rewind/frame-step buttons will have effect on both animations, keeping them in-sync at all times.

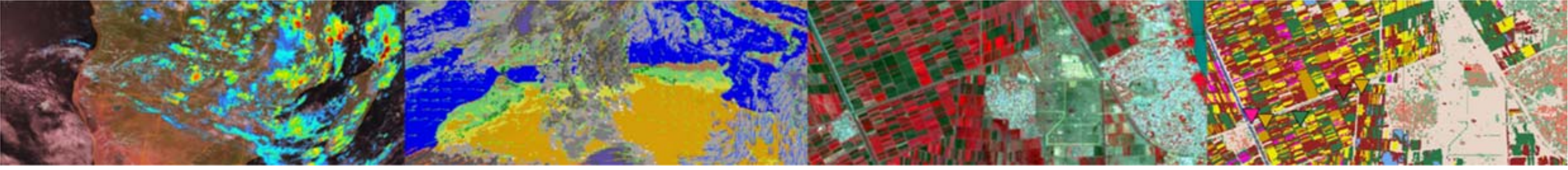
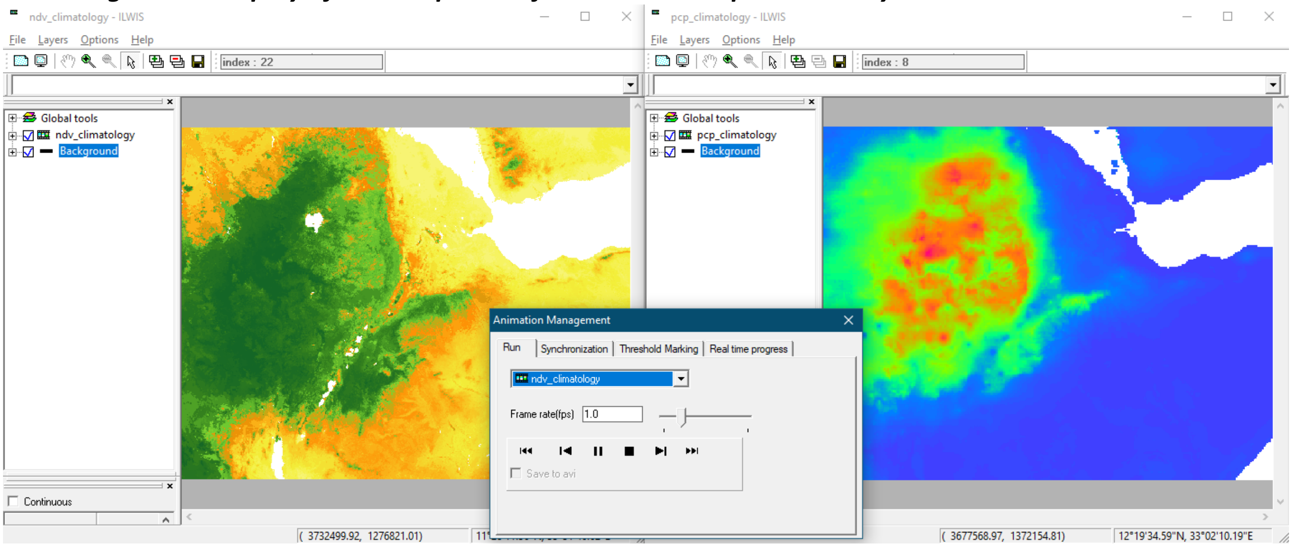


Figure 14: Display of two Map Lists of NDVI and Precipitation as synchronized animation



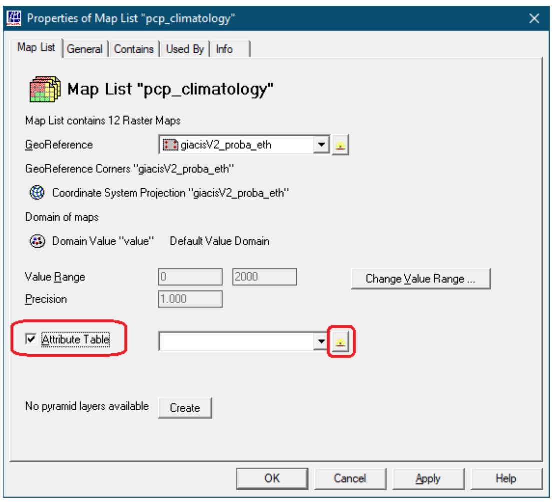
To “break” the synchronization, in the “Run” tab of the Animation Management window, select “pcp_climatology”, and click the stop button. Now the animations are no longer linked. Note that “ndv_climatology” keeps playing, but “pcp_climatology” returns to frame 1. Close the animations.

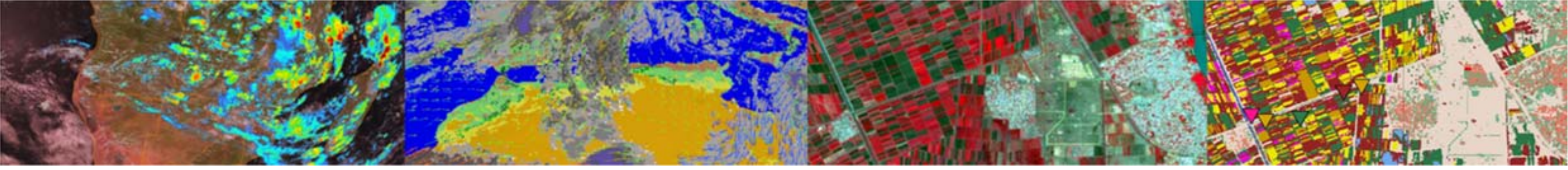
Note that this synchronization was based on frame-number. The map lists provided were constructed so that their lengths (timewise) are the same (1 year), and the time between frames is more or less constant (one has monthly frames, the other 3x per month), so it is possible to compute a “Step” between them for the synchronization. Strictly spoken, this is not correct, because the months of the year have a varying number of days, and also the last dekad in the month is of varying length. You may, however, have animations that have much more irregular timesteps, or their durations do not coincide. To solve this, synchronization can also be done based on real-time timestamps.

First we will add timestamps to both “pcp_climatology” and “ndv_climatology”. Close all ILWIS windows except the ILWIS Main Window (e.g. close the map windows and the Animation Management window). In the ILWIS Main Window, observe the opened catalogs. Close all Map List catalogs if they are open. Ensure only the catalog to the exercise data is open.

Click with the right-mouse-button on “pcp_climatology”, and select “Properties”. In the “Properties of Map List” window that appears, enable the option “Attribute Table”. Then click the yellow button that appears on the right, to create a new table.

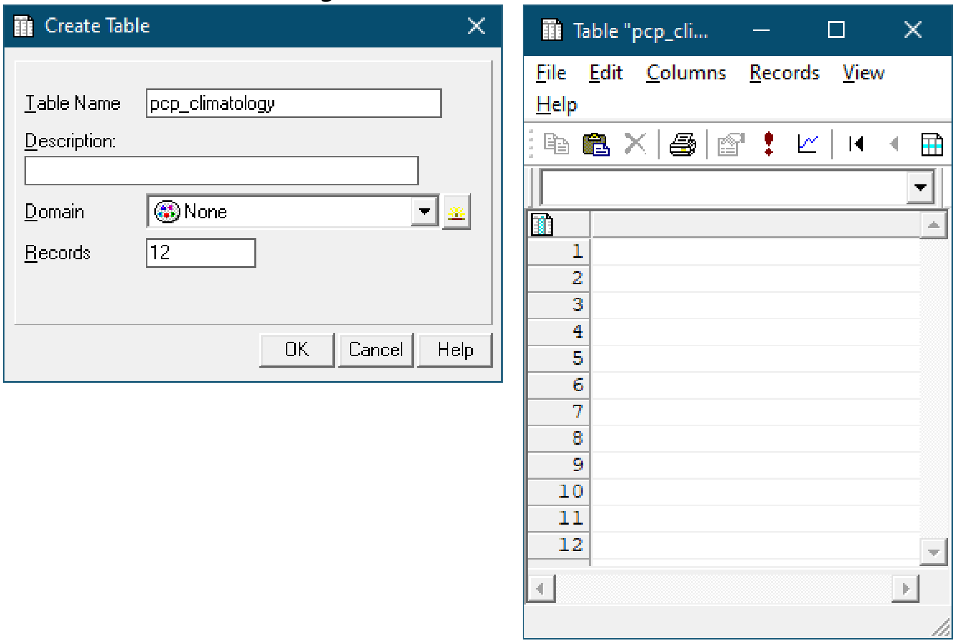
Figure 15: Link a table to a Map List





In table name type “pcp_climatology”, change the Records to 12, and click OK. A new table appears, with 12 rows (we dedicate one row to each band in map list “pcp_climatology”).

Figure 16: Create a new table

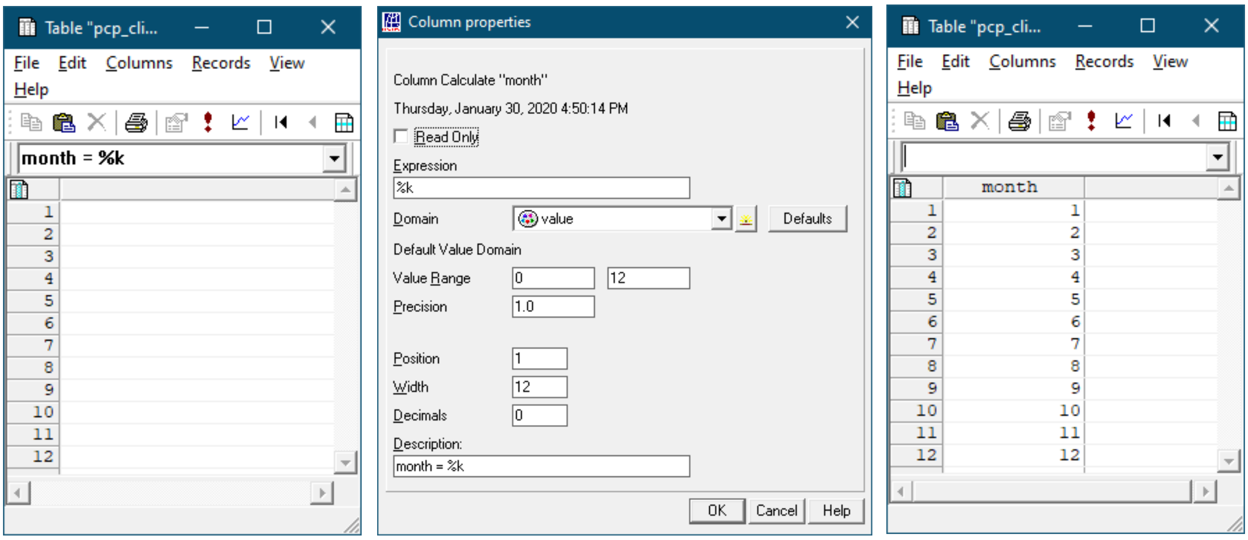


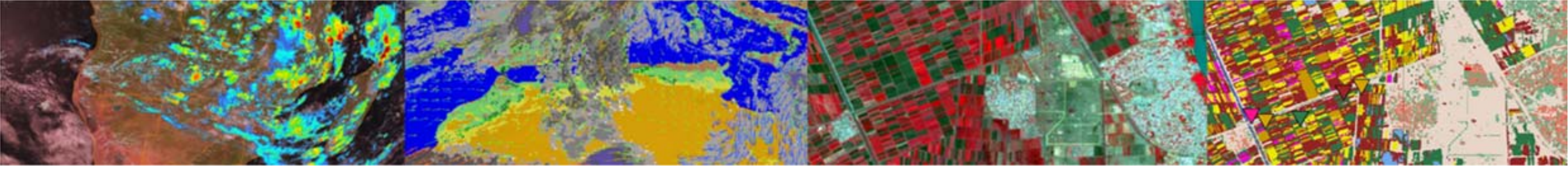
The Table window has a command-line. This is the horizontal white space below the buttons. In the command line type the following formula:

Month = %k

and press <enter>, see also the figure below (left). Note ‘%k’ is a predefined parameter and stands for “Key Column”. Click “OK” in the Column properties form that appears (centre). A new column named “month” is created, with the numbers 1 to 12 (right).

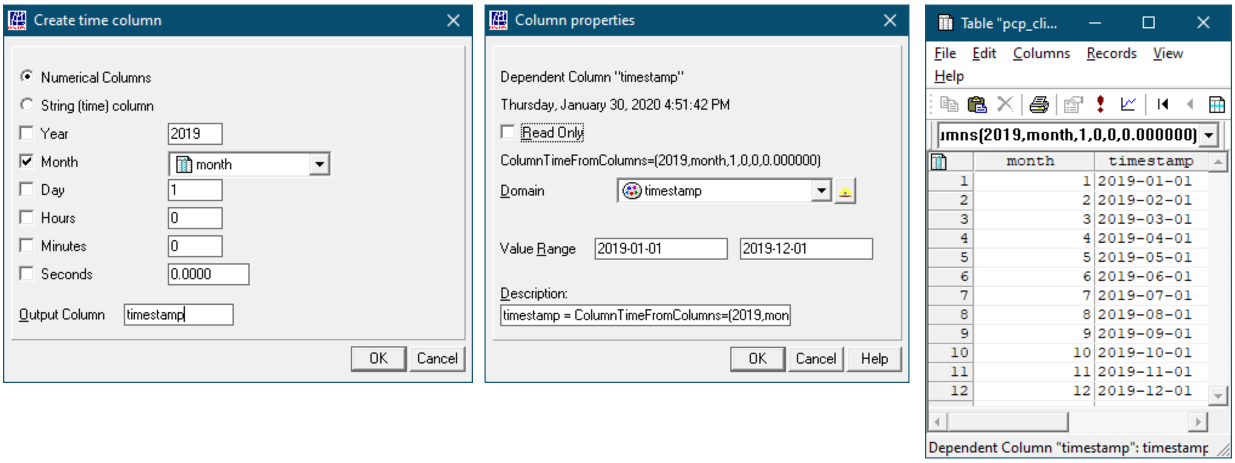
Figure 17: Creating a new column using an expression





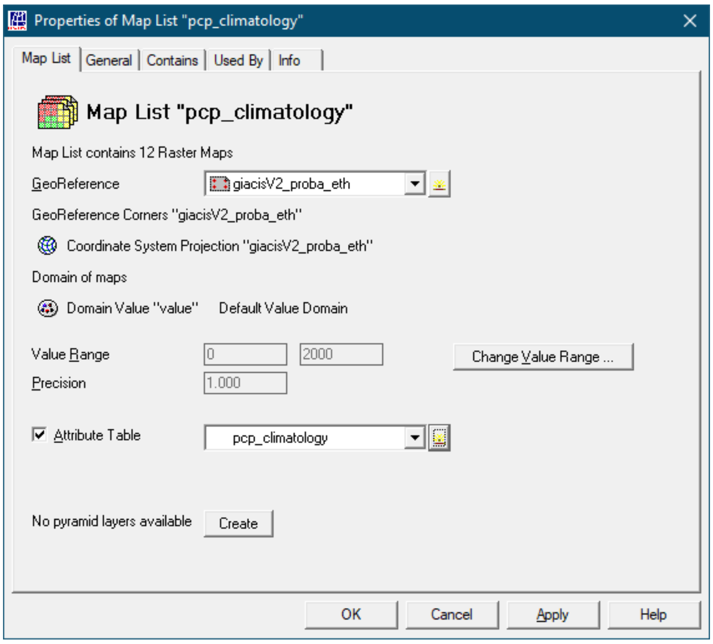
In the menu of the Table window, navigate to “Columns”> “Columns to Time Column”. Put a checkmark at “Month”, and choose column “month”. In Year type 2019, Day = 1, Hours = 0, Minutes = 0, Seconds = 0. Output column = “timestamp”. Click “OK” to execute the operation. Also click “OK” in the Column properties form that appears. A new column is added, with the intended dates of the map list bands. Confirm that the dates are “OK”.

Figure 18: Create time column



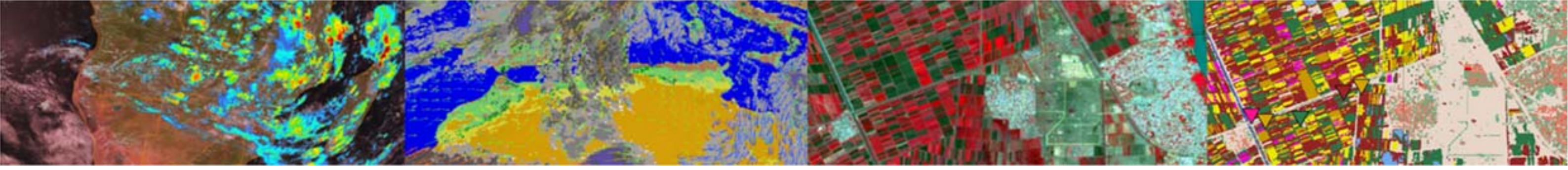
Close the table. Click OK in the “Properties of Map List” window to finalize the association of the table to the map list.

Figure 19: Properties listing of the Map List pcp_climatology



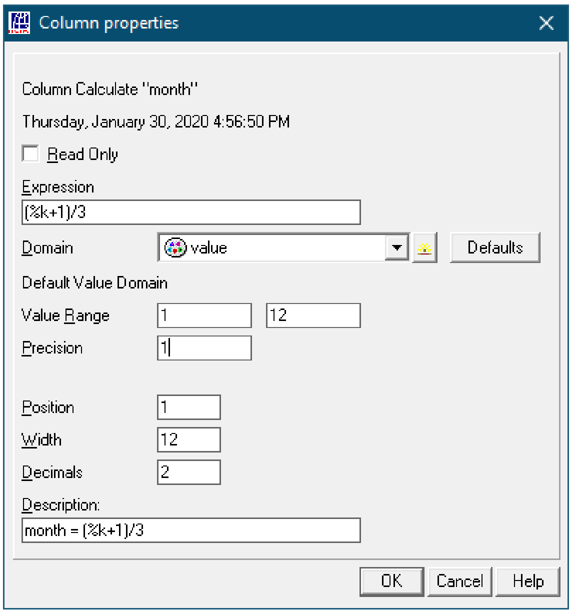
The procedure for “ndv_climatology” is similar. Select the “Properties” of “ndv_climatology”, enable Attribute Table, and click the yellow button to create a new one. Give as table name “ndv_climatology”, change the Records to 36, and click “OK”. Type the following formulas in the Table command-line to create columns month and daynr, representing all dekad moments in a year, and press <enter> to execute the expression:

Month = (%k+1)/3



In the ‘Column properties’ form that appears, change ‘value range’ from “1” to “12”, and precision to “1”, to get integer month numbers.

Figure 20: Column properties of the new column ‘month’ created

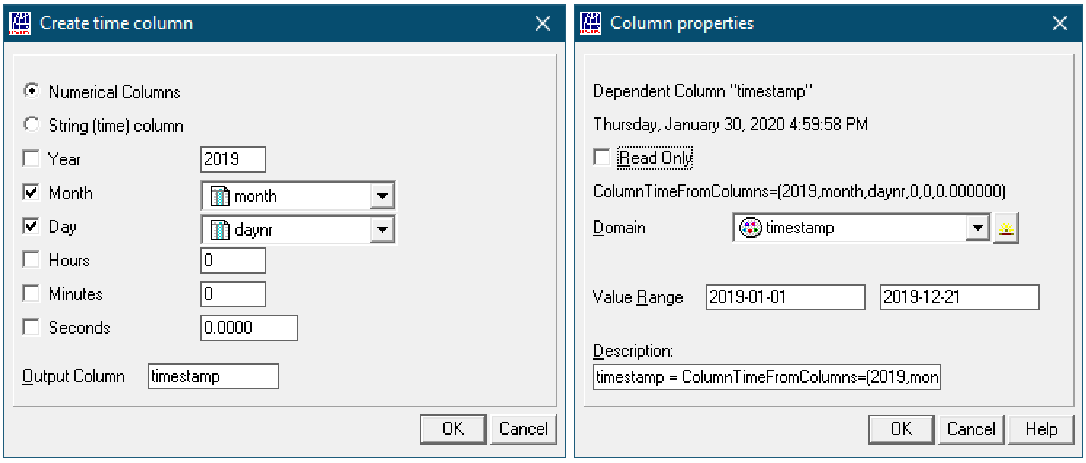


Also execute the formula for daynr:

daynr = 1 + 10 * ((%k - 1) mod 3)

In Columns to Time Column, put a checkmark at “Month” and “Day”, and choose the columns “month” and “daynr”. In Year type 2019, Hours = 0, Minutes = 0, Seconds = 0. Output column is “timestamp”. Click “OK” to execute. Also click “OK” in the Column properties form that appears.

Figure 21: New time Column and properties windows



Finally the “timestamp” column is added to the table.

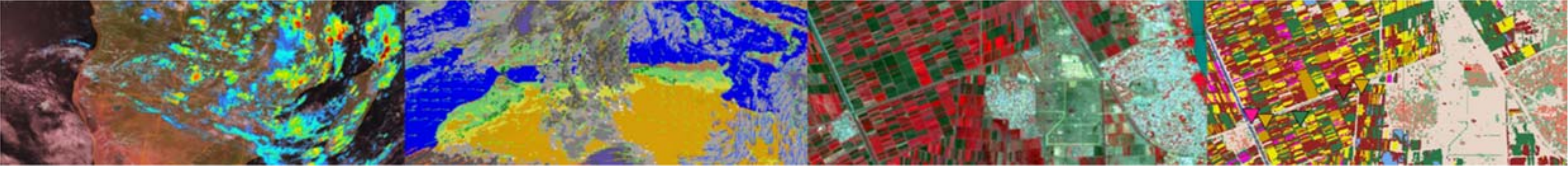
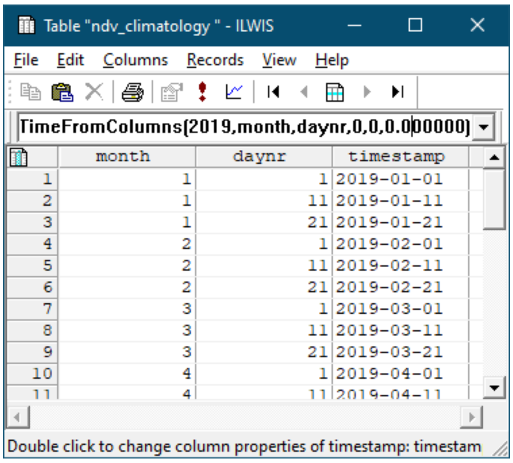


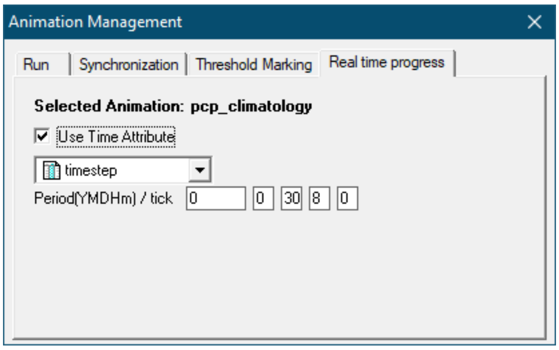
Figure 22: New timestamp column in the table



Confirm that the dates are ok. Close the table, and click "OK" in the "Properties of Map List" window to finalize the association of the table to the map list. Now open both map lists as animation, but do not yet click the "Play" button to start them. For "ndv_climatology" change the representation to "ndv_byte253".

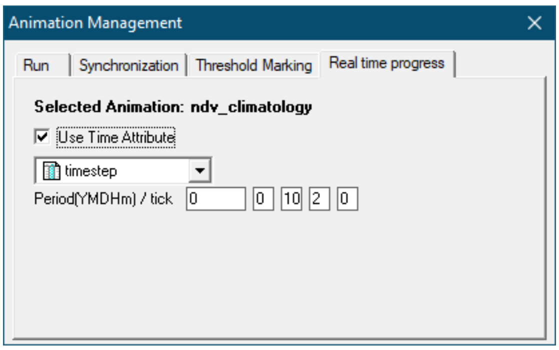
In the Animation Management window, select the animation "pcp_climatology" in the "Run" tab, then go to the "Real time progress" tab to enable "Use Time Attribute". The earlier created "timestamp" column is automatically selected.

Figure 23: Animation management for the precipitation time series



Go back to the "Run" tab, and select "ndv_climatology". Then go to the "Real time progress" tab to enable "Use Time Attribute" as well for this animation.

Figure 24: Animation management for the ndvi time series



Now go back to the "Run" tab, and click the "Play" button. The animations will run in-sync. On top of each map window, the current map index number and also the timestamp is displayed.

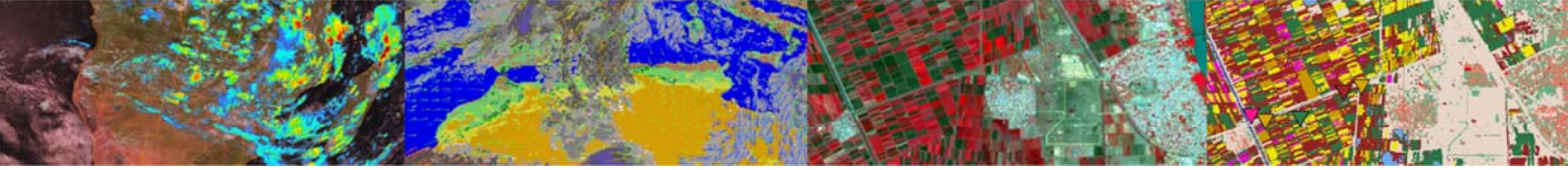
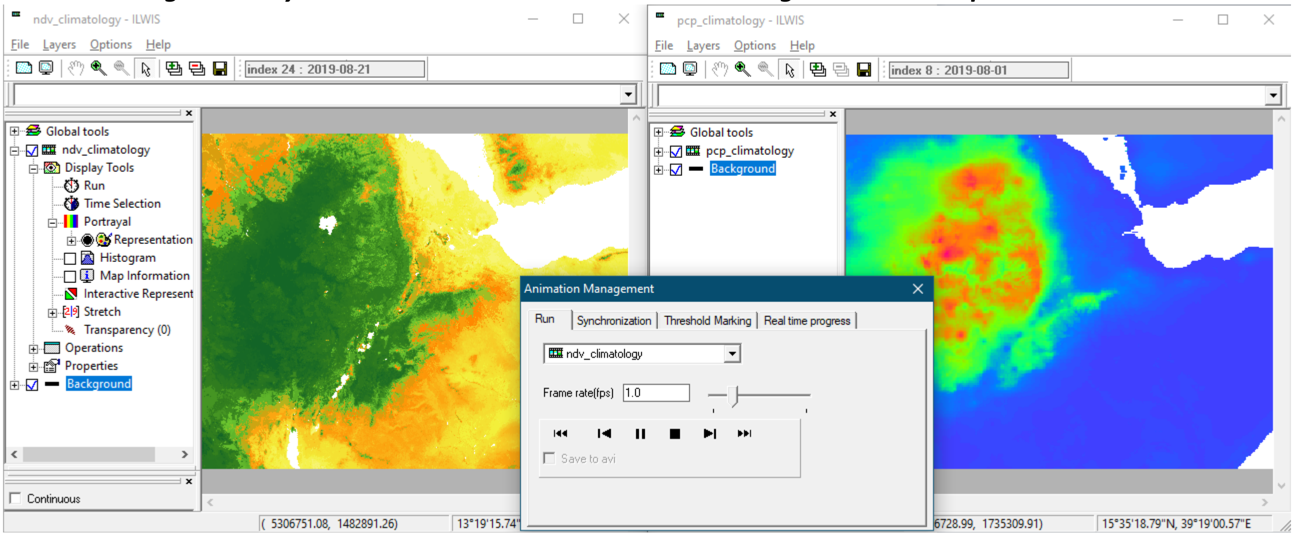
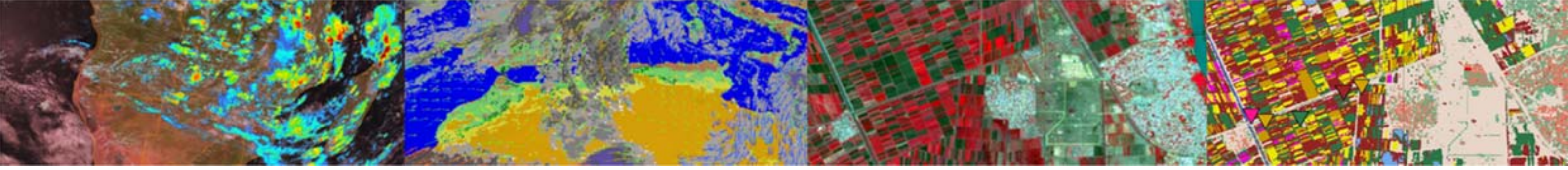


Figure 25: Synchronized animation visualization using the time stamp attribute



Close both animation map windows and the Animation Management window when done. Even more is possible, e.g. using the Threshold Marking to highlight interesting events, or combining animations in the same map window, or in 3D with the so-called space time cube. Although this goes beyond the purpose of these introductory exercises, please feel free to experiment.



3.6 Calculations on Time Series

Next to visualization of time series as animations, also calculations can be performed on map lists. To demonstrate the map list calculation functionality an aridity index (AI) is going to be calculated to obtain an impression using a numerical indicator of the degree of dryness of the climate at a given location. Here the AI as proposed by De Martonne is used (Gebremedhin et. al, 2018). The 'De Martonne' Aridity index ($Index_{DM}$) defines aridity as the ratio of precipitation to mean temperature according to the equation below and classifies these into different climate types.

$$Index_{DM} = \frac{P}{t + 10}$$

Where:
P = annual average precipitation (mm)
t = annual average temperature in degrees Celsius

Table 1: Aridity index classification De Martonne

Climate type	Aridity Index
Arid	0 - 10
Semi-arid	10 – 20
Mediterranean	20 - 24
Semi-humid	24 - 28
Humid	28 - 35
Very humid	35 - 55
Extremely humid	> 55

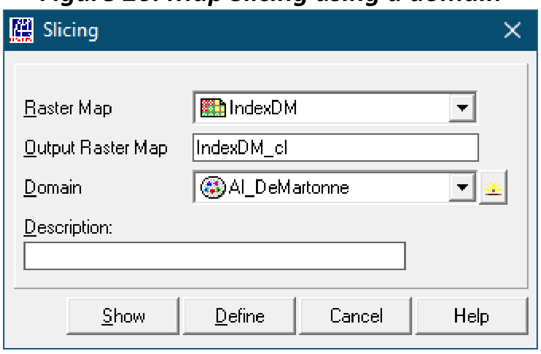
To calculate the annual average precipitation, right-click the map list "pcp_climatology", from the context sensitive menu select the operation "Statistics" > "MapList Statistics", ensure the statistical function is "Sum", and specify as output map name "pcp_sum". Click "Show", check the resulting map and close the map window. Repeat above described procedure, but now use the map list "at_avg_climatology" and as statistical function "Average", call the output map "temp_avg". Inspect the resulting map and close the map window as well.

Now calculate the 'De Martonne' index as follows, type the expression below on the command line in the main ILWIS window and press <enter>:

```
IndexDM:=pcp_sum/(temp_avg+10)
```

Display the map "IndexDM". Note that the data range is continuous (floating point values). In order to classify the map into the different climate types as provided in the table above a 'slicing' operation has to be performed. Open the domain "AI_DeMartonne" and inspect the class boundaries defined. This domain can be applied to classify the index map into several classes. In order to do this, from the main ILWIS menu, select the operation "Operations" > "Image Processing" > "Slicing", as Raster map select "IndexDM", as domain "AI_DeMartonne" and as output raster map specify "IndexDM_cl" and press "Show". Inspect the resulting map obtained.

Figure 26: Map Slicing using a domain



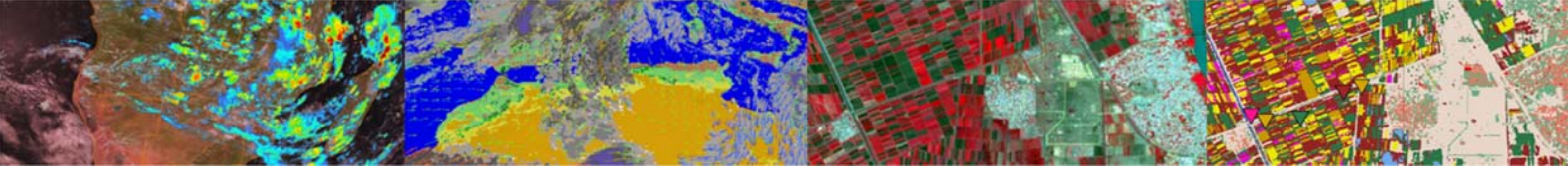
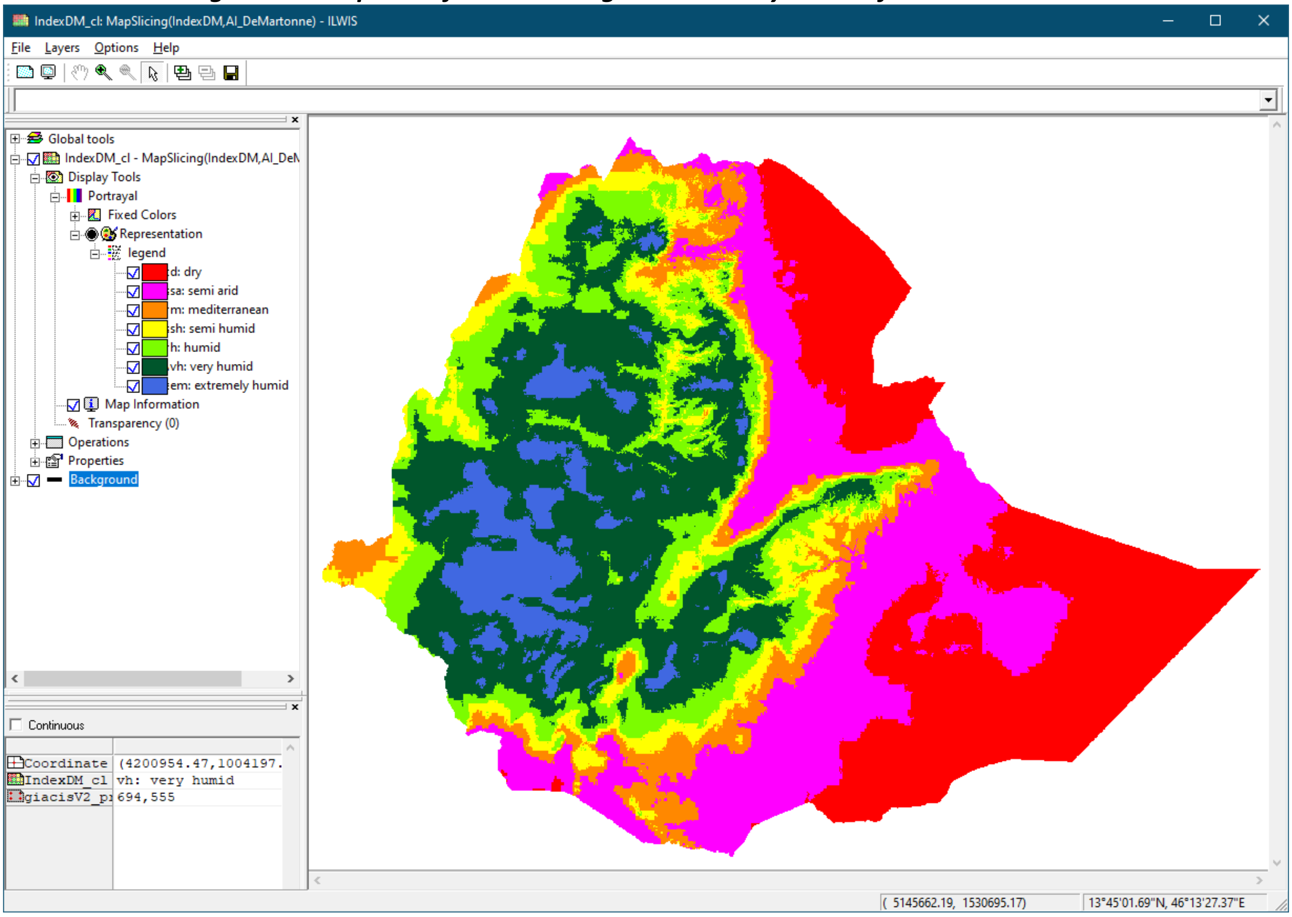


Figure 27: Map classified according to the Aridity Index of De Martonne



As already observed before, there is a large variability in precipitation in time and space. Also an index is available to evaluate the rainfall distribution and rain concentration. Here the Precipitation Concentration Index (PCI) method according to Michiels, Gabriels and Hartmann (1992) is going to be applied. In this index, the higher the PCI, the more irregular and greater the precipitation variability. To estimate this variability the input required is the monthly precipitation for a given year in mm/month. A yearly monthly precipitation map list is required to execute the calculations. The index applied firstly determines the coefficient of variation (CV):

$$CV = 100 \times \frac{s}{\overline{Pi}}$$

Where:

$\overline{Pi}$ = the arithmetic mean of the monthly rainfall per year

s = standard deviation of the data set sampled from the population

Subsequently the Precipitation Concentration Index (PCI) is related to the coefficient of variation (CV) using the following equation:

$$PCI = \frac{100}{12} \times \left[1 + \left(\frac{CV}{100}\right)^2\right]$$

Finally the classification as provided in the table below is applied to characterize the PCI.

Table 2: Precipitation Concentration Index classes

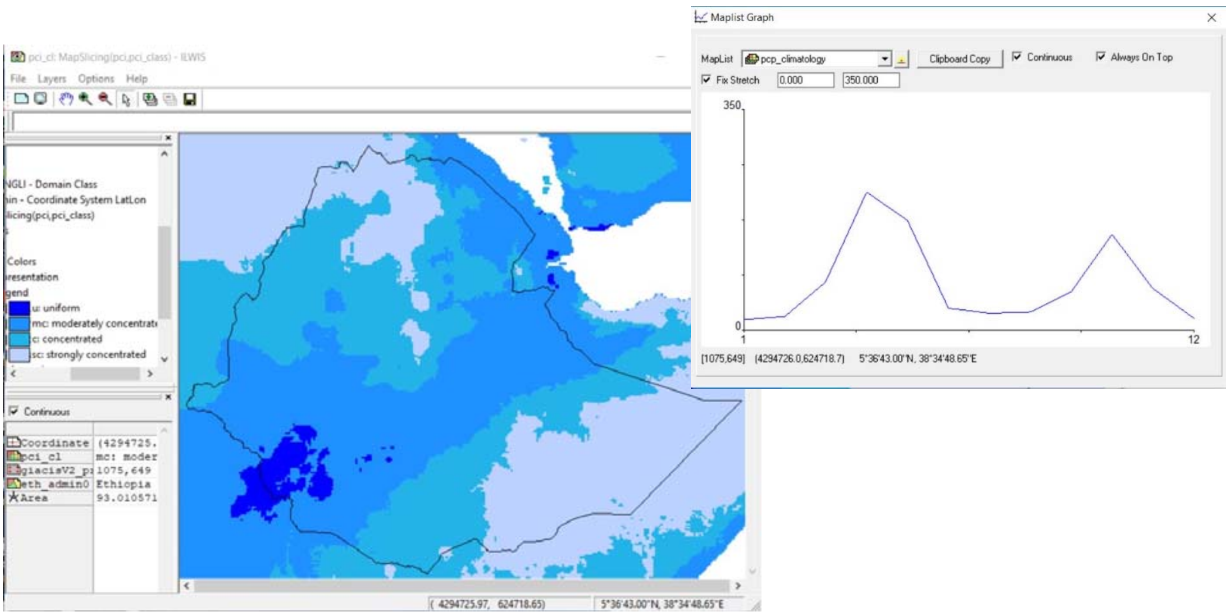
PCI Temporal Concentration	PCI Index
Uniform	< 10
Moderately concentrated	11 - 15
Concentrated	16 - 20
Strongly concentrated	> 20

As for this example various computations are required, an ILWIS script is prepared. Open the script “PCI_calc” and check the content under the tab “Script” and under the tab “Parameters”. Note that this script only requires 1 parameter, in the script defined as ‘%1’, which is the map list having the monthly precipitation values. For further information on ‘Scripts’ consult the “Help” option from the main menu, under “Index” look for “Script”.

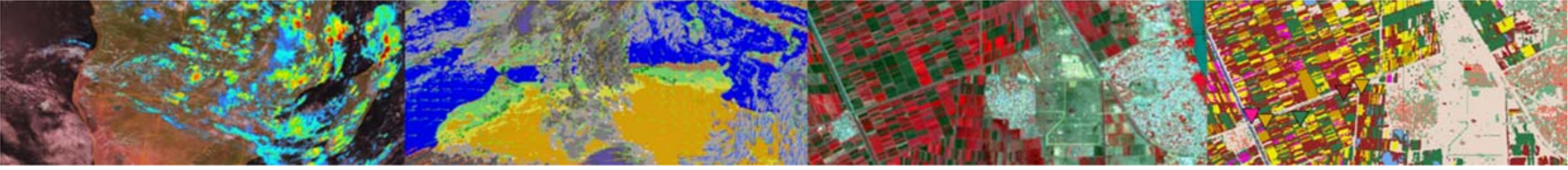
Click the “Run Script” button to run the script. For the Monthly Precipitation (mm) select the map list “pcp_climatology” and wait till the processing is completed. Open the maps “pci” and “pci_cl”. The first map shows the continuous values, the second one is classified according the table above.

To check the result, from the main ILWIS menu select the option “Operations” > “Statistics” > “MapList” “MapList Graph”. As MapList select “pcp_climatology”, activate the options “Fix Stretch”, “Continuous” and “Always on Top”. Now move the cursor over the map “pci_cl”and check the monthly mean rainfall distribution over various parts of the country and compare these with the classification obtained. Your results should resemble those provided in the figure below, depending on the cursor location. Also display the map “IndexDM_cl” and compare these results with the Aridity Index of De Martonne calculated before. Note that all map windows and the table graph window are linked when moving the cursor over one of the map window displays.

Figure 28: Precipitation Concentration Index Map and monthly precipitation graph



Before you continue, close all open map and table or graph windows. Another way to get an appropriate visual impression of the temporal developments is by visualizing the time series along a section. For this purpose a Hovmöller Diagram can be used. From the map list “ndv_climatology” display the map “a0101”, use as Representation “ndv_byte253”.

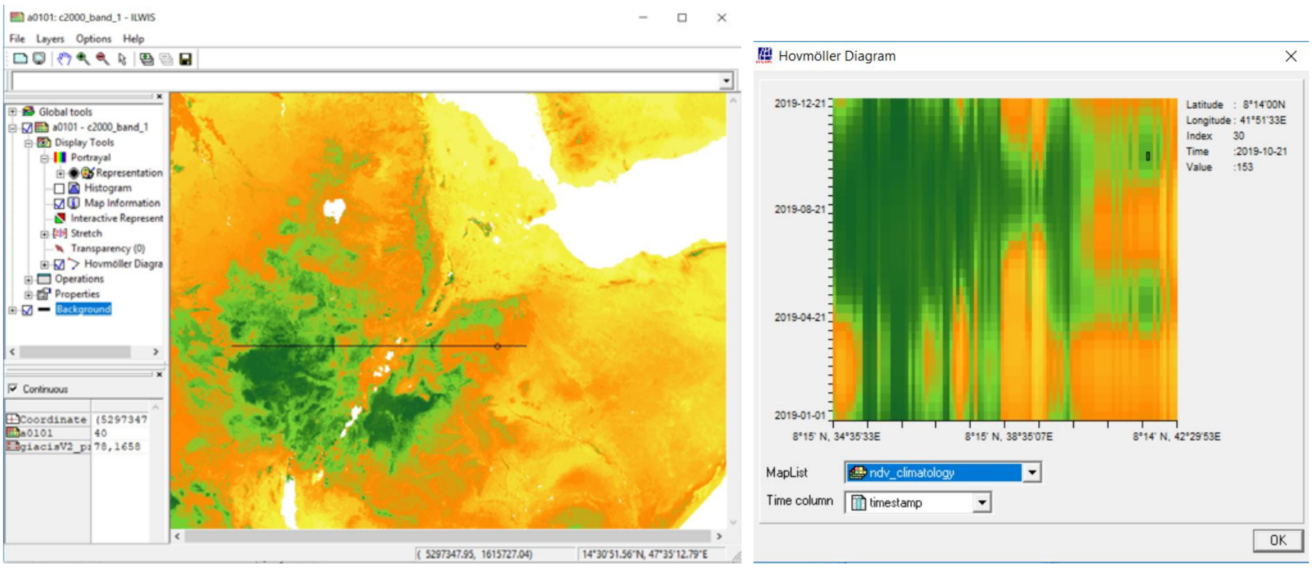


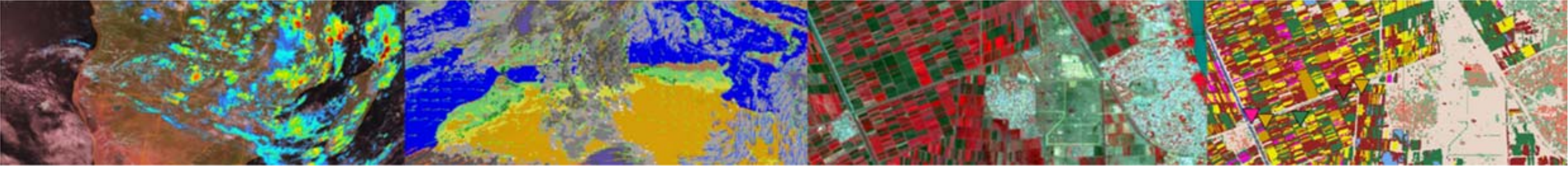
Right-click the “Display Tools” and from the context sensitive menu activate the option “Hovmöller Diagram”. In the map legend check the box in front of the “Hovmöller Diagram” option. In the Hovmöller Diagram window, select as Map List “ndv_climatology”. Note that a time column “timestep” is used, the year is not relevant as here we are using the climatology!

On the ndvi map a line can be drawn, by left-clicking the mouse and displacing the mouse to the destination location and left-clicking the mouse again.

In the Hovmöller Diagram window the track is shown over time. By clicking on a location in the Hovmöller plot the corresponding location can be seen as a circle along the line on the map. From the figure below the vegetation changes over the yearly cycle can be very nicely observed, some parts remain green through the year, others have only one green season, also some areas can be observed, on the eastern part, with two distinct seasons. Draw a few different sections and inspect the temporal vegetation response over the year.

Figure 29: Hovmöller Diagram over a section from west to east over central Ethiopia





3.7 Combining processed information: calculation of potential soil erosion over Ethiopia

Within the previous exercises attention was given to the terrain, the rainfall volume - distribution and climate as well as the vegetation response. All these elements could be combined to get a qualitative impression on potential soil erosion. Universal Soil Loss Equation (USLE) is a commonly applied soil erosion model, see also Wischmeier and Smith (1978). The Universal Soil Loss Equation is expressed as:

$$A = R \times K \times LS \times C \times P$$

A represents the potential long-term average annual soil loss
R is the rainfall and runoff factor
K is the soil erodibility factor
LS is the slope length-gradient factor
C is the crop/vegetation and management factor
P is the support practice factor

Although it is not possible to compute the long-term average annual soil loss, we have a number of relevant elements. Once more display the following maps and check their values: “pcp_sum”, “pci”, “sti_mod”, “indexDM”. The first 2 maps provide an indication of the ‘R’ factor, the 3rd map represents the ‘LS’ factor.

Further information on the ‘C’ factor can be derived from the NDVI climatology. To do this, the sum of the NDVI over the year is going to be calculated. Right-click the map list “ndv_climatology”, from the context sensitive menu select the options “Statistics” > “MapList Statistics”, ensure the statistical function is “Sum”, specify as output map name “ndv_sum”. Click “Show”, check the resulting map and close the map.

The ‘C’ factor could be complemented by De Martonne Aridity Index, as this index is representing the overall climatological conditions. The lacking information is on the soil erodibility (‘K’ factor) and support practices (‘P’ factor), therefore a modified formulation to get a qualitative impression of the potential soil erosion is used here.

Type the following equation in the command line of the main ILWIS menu and press <enter> to execute the expression:

```
Pot_erosion:=(pci*pcp_sum*sti)/(ndv_sum*indexDM)
```

Now classify the map using the domain “pot_erosion”. In order to do this, from the main ILWIS menu, select the option “Operations” > “Image Processing” > “Slicing”, as Raster map select “Pot_erosion”, as domain “pot_erosion” and as output raster map specify “pot_erosion_cl” and press “Show”. Inspect the resulting map obtained. Note that the class intervals used in this domain are selected arbitrary, higher values are more prone to erosion.

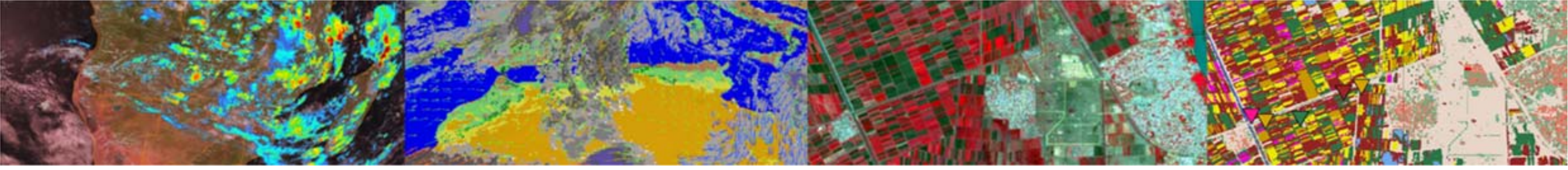
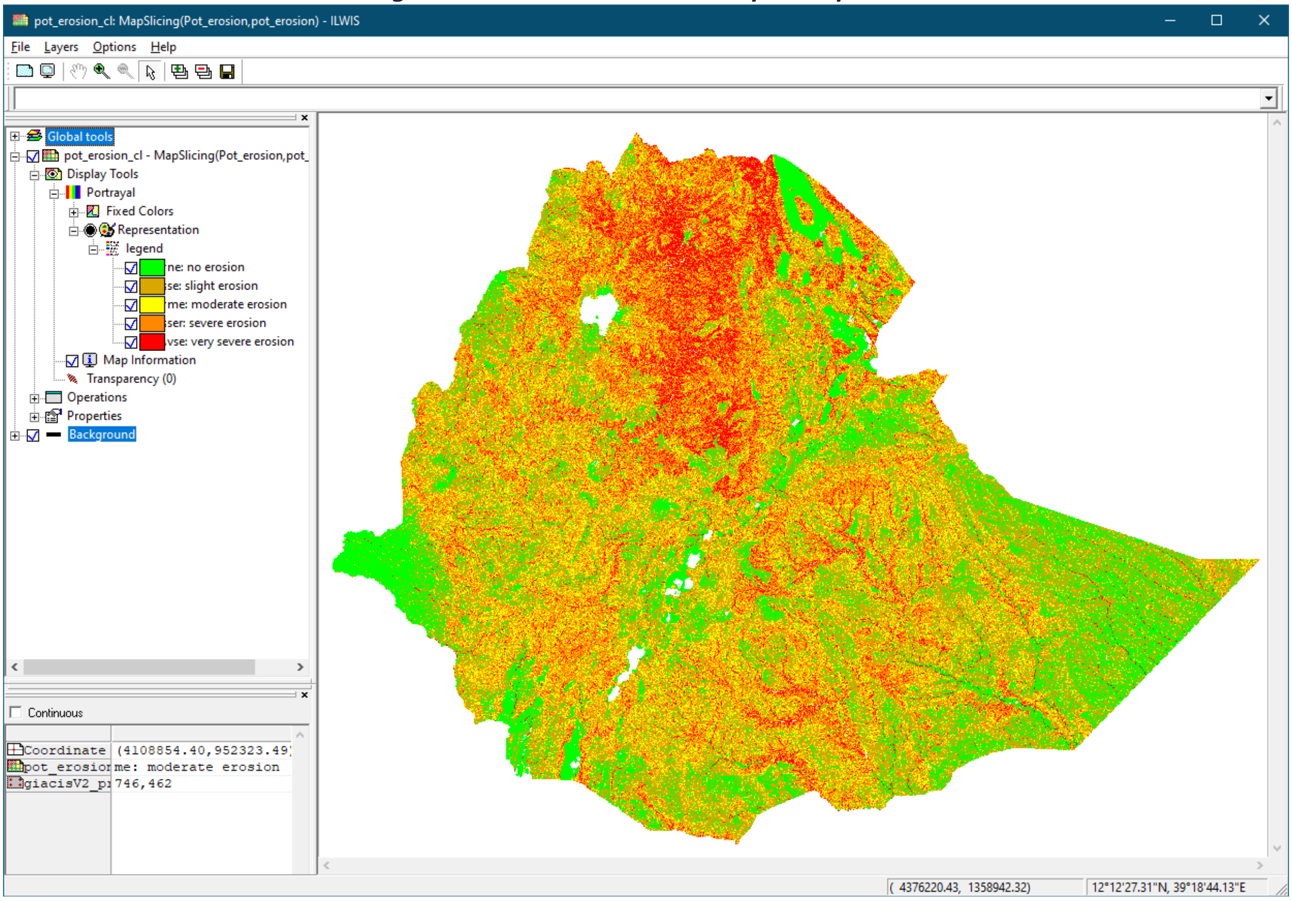


Figure 30: Potential erosion map Ethiopia



Display the polygon map “Landuse2” and check the classes of this map. Open the table “Landuse2”. From the table menu, select “Columns”, “Add Column”. As column name specify “reclass”, as value range 0 to 1, with a precision of 1, press “OK”. The new column is added at the far right of the table, and is prefilled with ‘?’ (undefined) values. Put the cursor there to type (overwrite) those. For the classes ‘Barren Lands’, ‘Shrubland’, ‘Cultivation’ and ‘Grassland’ enter the value “1”, for all other enter the value “0”. Note that you can resize the table so that the column “reclass” gets near the class names, to easier see that data is entered in the correct row. Close the table when done (it is saved automatically).

Now a new mask-map is going to be created only showing the land use classes, specified by the value ‘1’. These are the areas which are agriculturally used (for crops and cattle) and susceptible to erosion and therefore are priority areas to be further investigated to see if further watershed and soil conservation measures are required. The other classes specified are having permanent (dense) vegetation cover like forests and plantations, or represent swamps and water bodies.

To do so, the newly created column “reclass” will be used in an “attribute map” operation, whereby a new raster map is created using data from the selected attribute. Right-click with the mouse on the raster map “Landuse2”, from the context sensitive menu select the option “Raster Operations” > “Attribute Map”, from the Attribute Map of Raster Map window, use as Attribute “reclass” and as output map specify “landuse_reclass”, and click Show. Inspect the values obtained and close the map

Type the following equation in the command line of the main ILWIS menu, which will create the potential conservation map, and press <enter> to execute the expression:

Pot_conservation:=iff(landuse_reclass=1,pot_erosion_cl,?)

Display the map. This map is going to be used to create a final output map which can be presented to planners and policy makers.

Keep the map “Pot_conservation” open. Add to the map window the map “colshadow” as an additional layer. By default it is added on-top. Use the layer manager on the left of the map to move “colshadow” below “Pot_conservation”. Then set the transparency of layer “Pot_conservation” to 45 %. Adjust the map window so that the full extent of the map “Colshadow” is shown. Now add another layer from the base maps: add the vector map “rivers”. Under its “Display Tools” > “Portrayal” change its color, to single color “Dodgerblue”. Also open its “Display Tools” > “Segment Representation” > “Line style”, and increase the line thickness to “2”. Press “Apply” and “Close”. Now add the raster map “Eth_inland_water”. Finally add the polygon map “ETH_Admin0”, uncheck under the Display Tools the option “Areas. Open the option “Boundaries” > “Line style”, specify as line thickness “2”, “Apply” and “Close”.

Keep the map window open, but go back to the ILWIS Main Window to open the table “ETH_M_Town” and type the following expression on the table command line and press “OK”:

Large_medium:=iff(pop>=20000,pop,?)

A new column is added to the table that we can use to display only the larger cities of Ethiopia. Check the results (the new column is the rightmost column of the table) and close the table.

Return to the map window that we were composing. Now add the point map “eth_m_town”. Under the Display Tools of “eth_m_town”, open the option “Display Attribute”, select the attribute “Pop”. Double click on the option “Symbolization”, select as symbol “filled-circle”, press “Apply” and “Close”. Go to “Portrayal” > “Fixed Colors”, change the coloring option to “Single Color”, and double-click “Single Color” to change it to “Red”. Press “Apply” and “Close”. Open the option “Symbolization” > “Stretching”, as “Scale Exaggeration” specify “6”, activate the option “Stretch”, select as attribute column “Large_medium” and press “Apply” and “Close”.

With all information layers added, we can now proceed creating the map layout. First adjust the map display window to the map extent. Open the option “Global Tools”, available at the top of the left hand map layer window.

Open “Annotations”, activate the option “Border”. Double click on “Border”, and as ”Step” specify “2”, “Apply” and “Close”.

Back in the “Global Tools”, find and activate the option “Grid”. Then double click on “Grid”, and as ”Grid Spacing” specify “400000”, “Apply” and “Close”. Open the option “Grid”, set the transparency to 70 %, “Apply” and “Close”.

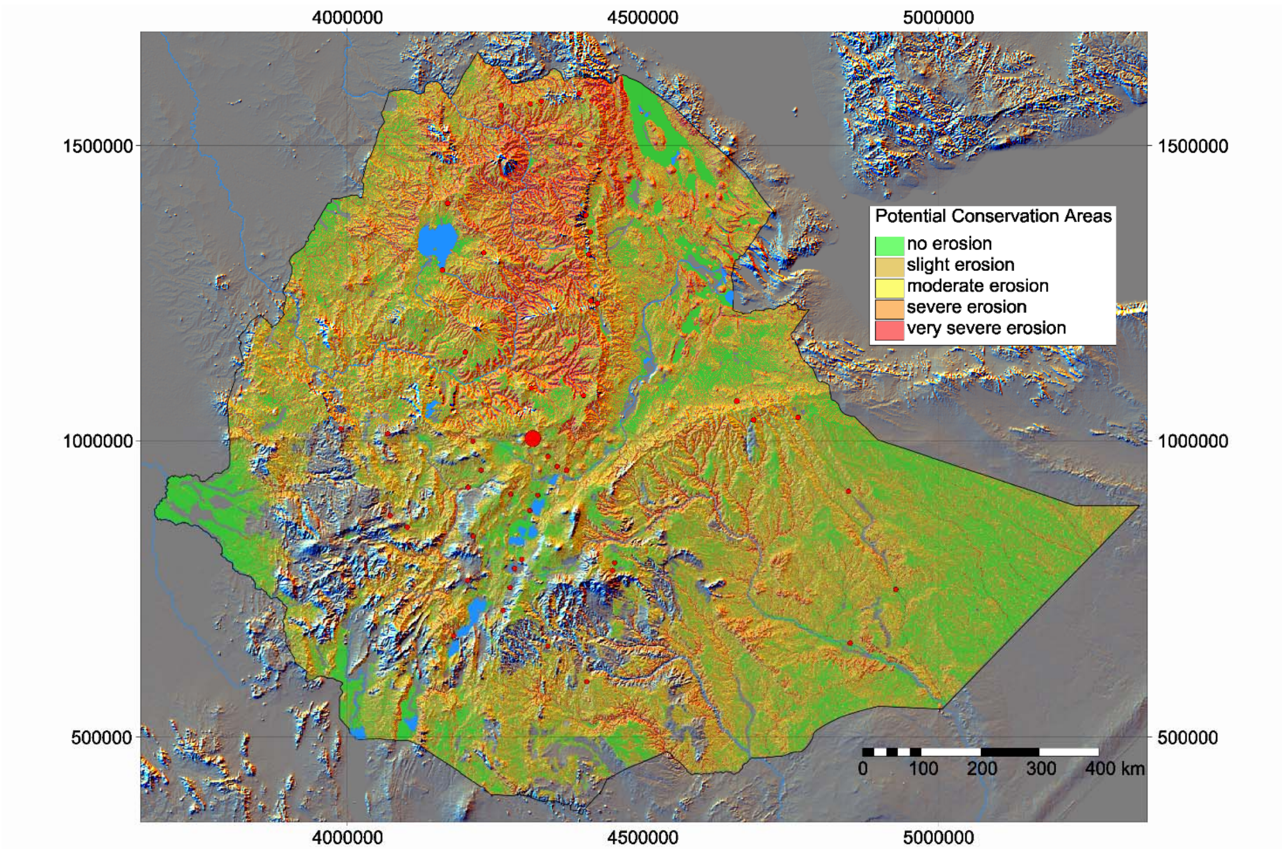
Double Click the layer “Pot_conservation”, right-click with the mouse on the option “Display Tools” and activate the option “Annotations”. Now open the Annotations section in the map legend below and activate the option “Legend” as well. Open the legend options by clicking the “+” before it, and double click on “Appearance”, change the title to “Potential Conservation Areas”. Also activate the options “Draw Boundary” and “Background Colour” and as background color select “White”. Press “Apply” and “Close”. Now double click on “Size & Position” and modify the position of the legend, position it somewhere in the northeast corner of the map, press “OK” when satisfied.

Finally, under “Global Tools” > “Annotations” activate the option “ScaleBar”. Double click on the Scalebar option to change its properties, and adjust the X and Y-position and move the bar to the SE corner of the map, as number of intervals specify “4”, activate the options “1st interval divided into smaller parts”, “Labels of every interval” and “Use Kilometers”, “Apply” and “Close”.

Once all is done and you are satisfied with the outcome (ignore the visual dominance of the rivers and country boundary), from the menu of the map window, select the option “File” > “Save View” and specify as Map View Name “Pot_conservation_map” and press “OK”. You can close the map window and open the mapview created, all layers, including their representations should be restored. The only issue is the dimensions of the map window, this might need to be adjusted.

To transfer the map to be used for reporting, from the map window menu, select the option “Layers” > “Copy” > “OK”. The map is now on the clipboard. You could open ‘Word’ and paste it into a new document or select the program named ‘Paint’ and save it as a new picture file. Your final results should resemble those given in the figure below. Vector lines are now shown with an appropriate line thickness.

Figure 31: Creating a map layout showing the potential conservation areas for Ethiopia



3.8 Mosquito habitat suitability mapping

The entire life cycle of a mosquito, from an egg to an adult, takes approximately 9-12 days in tropical areas. Female mosquitoes lay eggs in a variety of fresh or brackish bodies of water. Eggs are ready to hatch from a few days to several months after being laid. Eggs hatch when submerged in water. Larvae are aquatic and develop into pupae in as little as 5 days. After adult mosquitoes emerge: male mosquitoes feed on nectar from flowers and female mosquitoes feed on humans and animals for blood to produce eggs. After feeding, female mosquitoes will look for water sources to lay more eggs. For more information see Centres for Disease Control and Prevention (2018).

Climate is a key determinant of both the geographic distribution and the seasonality of malaria. Without sufficient rainfall, mosquitoes cannot survive, and if not sufficiently warm, parasites cannot survive in the mosquito; temperature and humidity are key to longevity. Only older females can transmit malaria and this process takes a minimum of nine days when temperatures are warm (30°C) and will take much longer at cooler temperatures.

In order to derive the locations having suitable weather conditions, also called the comfortable anticipated conditions for infectious agents, the method further elaborated below can be applied.

Based on the forecasts produced by the Global Forecasting Model, the 10 day 6 hourly forecasts are processed and daily forecasts (issued at 00:00 UTC) for selected parameters are produced (using automated processing routines at ITC) for:

- Temperature, both Minimum and Maximum Temperatures (°C)
- Rainfall (mm)
- Humidity (%)

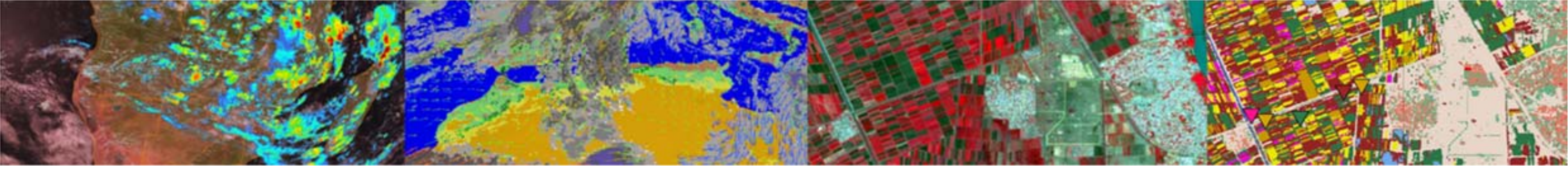
In order to get an idea of suitable habitats for mosquito development the following calculations are performed based on the 10 day weather conditions derived from these GFS Forecast:

- Rainfall: threshold used is more than 30 mm over the 10 day forecasting period
- Minimum and Maximum Temperature: thresholds defined are mean temperature over the 10 day period between 18 to 32 degrees Celsius respectively
- Relative Humidity: average humidity over the 10 day period should be equal or greater than 60 %

In order to derive the final comfortable anticipated conditions suitability map each of the 3 conditions have to be fulfilled. This implies that on a daily basis, when a new weather forecast is issued, the weather conditions for the next 10 days are evaluated if they are suitable for mosquito development. If this is done over the anticipated life cycle of a mosquito we can obtain a reasonable forecast of where to expect mosquitos and eventually older female mosquitos which might transmit malaria.

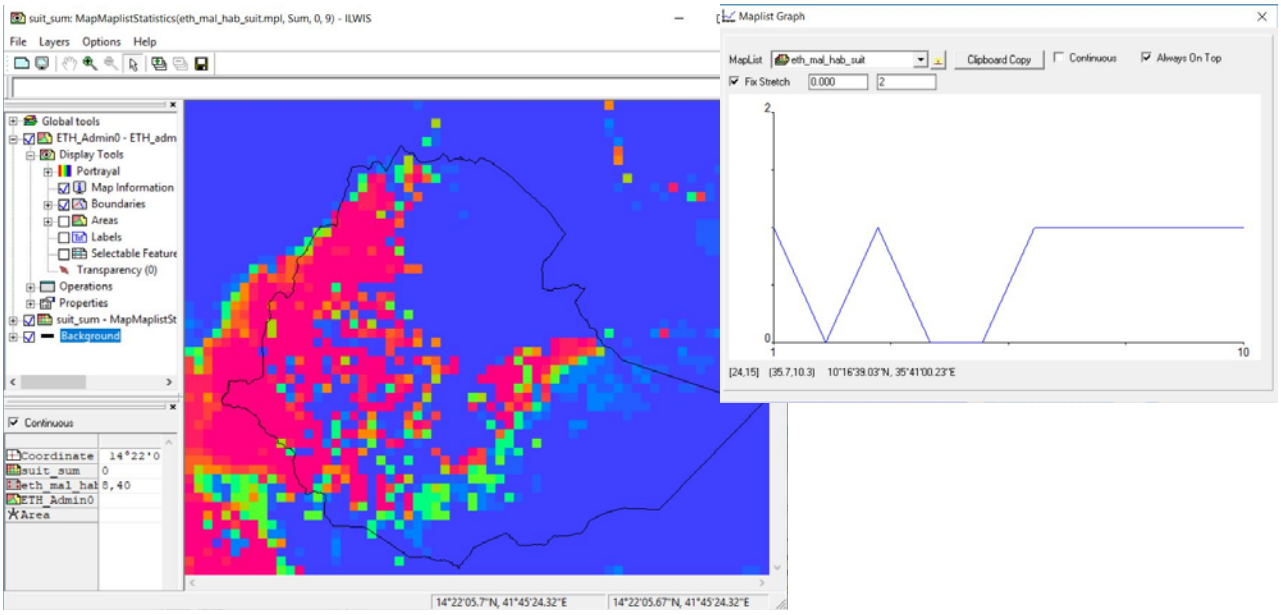
Open the map list “eth_mal_hab_suit” and display the map “eth_mal_hab_suit20190601_fin”, add the polygon map “ETH_Admin0”, boundary only. Note that the map has only values of 0 (representing next 10 day weather conditions as unsuitable) or 1 (representing next 10 day weather conditions as suitable) for the given forecasting day. Each day a comfortable anticipated conditions suitability map is produced (providing the forecast for the next 10 days) and by adding the maps, for each pixel in the map the period for which all conditions are favorable will show the highest map values.

Close the Map List catalog. To calculate the comfortable anticipated conditions for mosquito development, right-click the map list “eth_mal_hab_suit”, from the context sensitive menu select the options “Statistics” > “MapList Statistics”, ensure the statistical function is “sum”, specify as output map name “suit_sum”. Display the map and check the values. From the main ILWIS menu select the option



“Operations” > “Statistics” > “MapList” > “MapList Graph”. As MapList select “eth_mal_hab_suit”, activate the option “Fix Stretch”, as maximum stretch value specify “2”, also activate the options “Continuous” and “Always on Top”. Now move the cursor over the map “suit_sum” and check the daily based 10 day forecast suitability classification over various parts of the country. Your results should resemble those provided in the figure below, depending on the cursor location.

Figure 32: Habitat suitability for mosquito development



The map list graph shows the temporal distribution of the weather conditions over each of the forecasting days. In the case of the example above the conditions have remained consistently suitable using the forecasts for the last 5 days over the time period and will remain suitable for the next 10 days as well, as the last day represents the 10 day forecast. In general the conditions are mostly suitable in western Ethiopia, you can compare it also with the rainfall climatology map for the month of June. To do this, overlay another layer over “suit_sum”, by selecting the option “Add Layer” from the map window menu and selecting the map “pcp_avg_jun”. Under the Display Tools of “pcp_avg_jun”, change the transparency from 0 to 100, back and forth, to visually see the relationship between the precipitation occurrence and the habitat suitability.

The GFS uses a coarse spatial resolution (0.25 degrees). Again for visualization purposes to inform planners and health agents, which are organized in administrative units, the map as presented in the figure above does not look very appealing and is therefore not useful. To improve the visualization, the raster data can transformed to a point map and this point map is subsequently interpolated to the Georeference which is used throughout these exercises. To do this, a script has been prepared. Open the script “smooth_valuemap_mosquito”, check the content (for the tabs ”Script” and “Parameters”) and run the script. As input map name select “suit_sum”, as Georeference “GiacisV2_proba_eth” and as output map “suit_sum_res”, and press “OK”. Note this operation can take some time! When finished, open the raster map “suit_sum_res.mpr” as well as the vector map “suit_sum_res.mps” to see the result. Close the maps when done.

Now we will cross the two maps, the ETH_Woredas map with the mosquito habitat suitability map. From the main ILWIS menu, select the options “Operations” > “Raster Operations” > “Cross”. As first map select “ETH_Woredas” and as second map “suit_sum_res”, as output cross table specify “woreda_suit” and press “Show”.

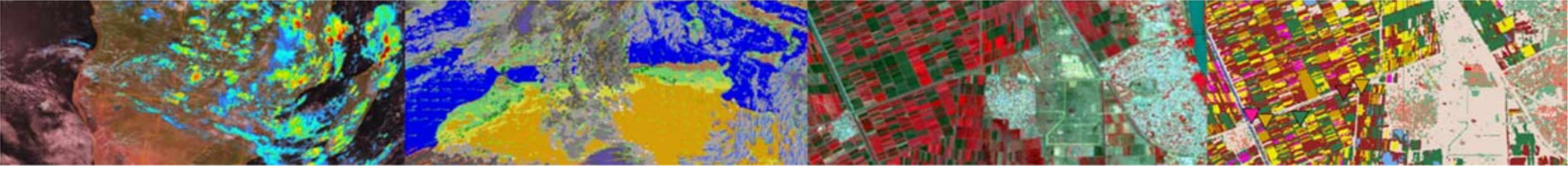
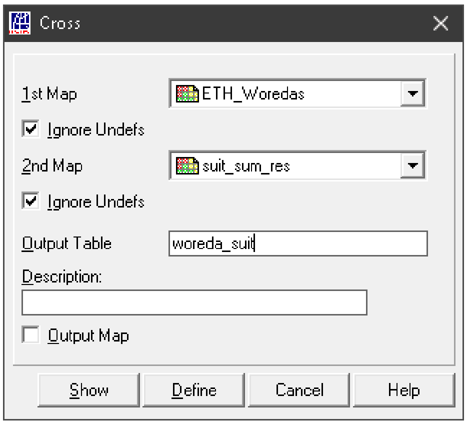
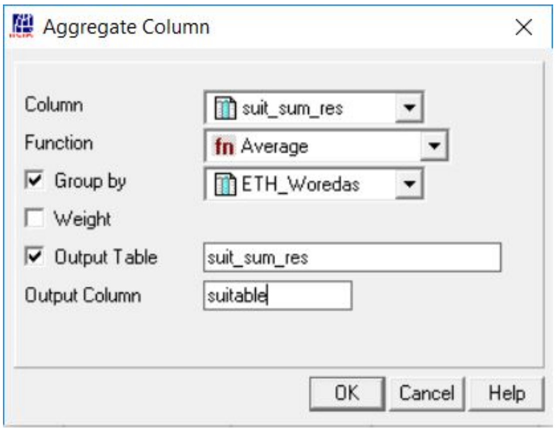


Figure 33: Cross Map interface



Check the content of the table which contains all unique combinations of values of the two maps. Now we will aggregate the column “suit_sum_res”. From the table menu, select the option “Columns” > “Aggregation” and specify the other settings as given in the figure below and subsequently press “OK”.

Figure 34: Aggregate column settings



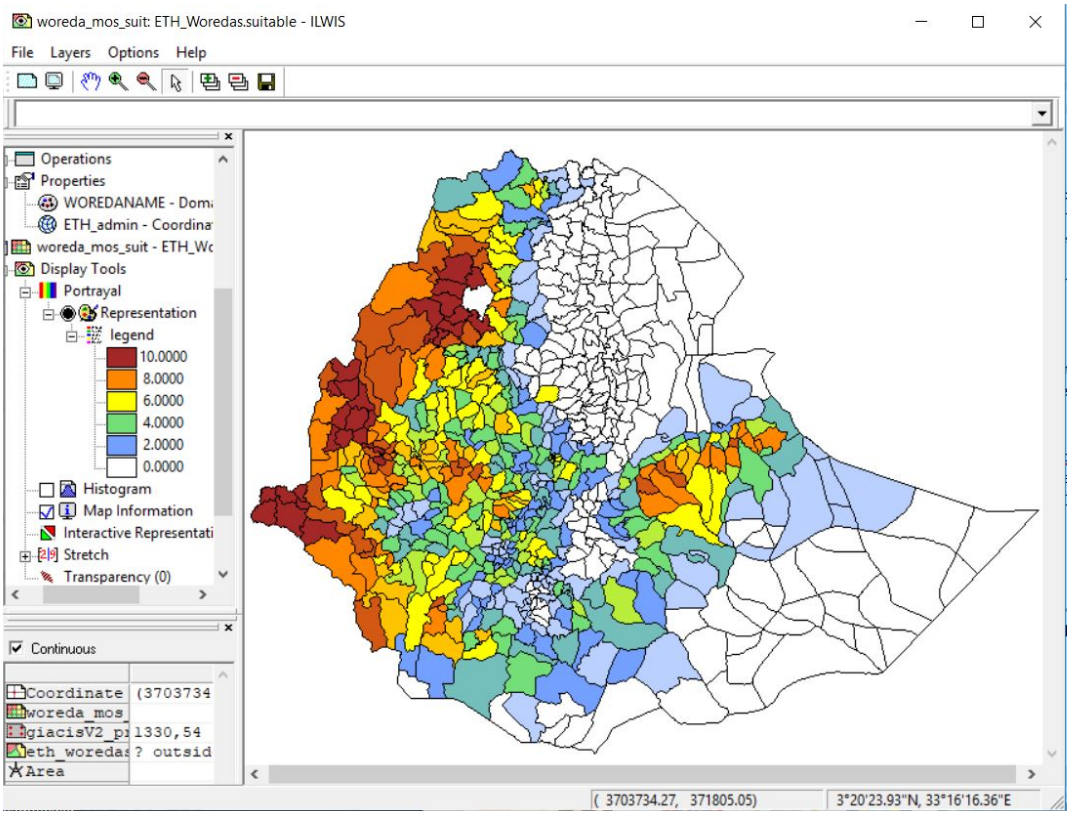
Close the table “woreda_suit” and open the table “suit_sum_res”. Check the content and then close the table. Right-click with the mouse on the raster map “ETH_Woredas”, select the “Properties” and ensure that the check box “Attribute Table” is activated. Use the drop down list to select “suit_sum_res” and press “OK” (replace the table “woreda_rain” from an earlier step in this exercise). Once more display the map “ETH_Woredas” and now check the map / table values in the lower left hand pixel information window (in particular the values for “ETH_Woredas” and “suitable”). Close the map.

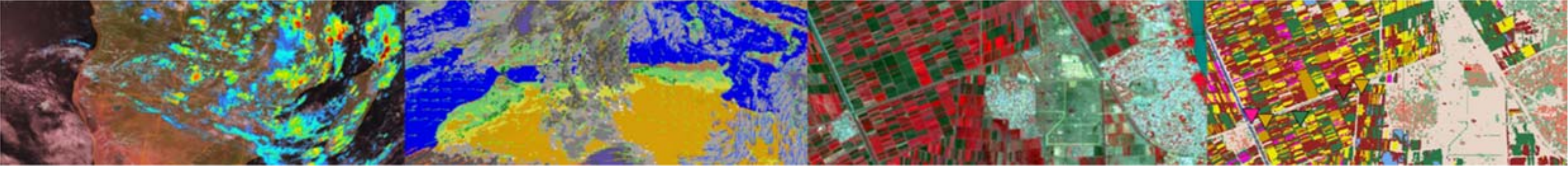
Now create a raster attribute map using the data from the attribute table. Right-click with the mouse on the raster map “ETH_Woredas”, from the context sensitive menu select the option “Raster Operations” > “Attribute Map”, from the Attribute Map of Raster Map window, use as Attribute “suitable” and as output map specify “woreda_mos_suit”, and press Show. Once the maps is displayed, select as Representation “mal_suit”, add the polygon map “ETH_Woredas” as a layer, and display only the boundaries. Your results should resemble those in the figure below.

The map produced shows with the highest values those woredas where the prevailing weather conditions are most suitable for mosquito development. As the map is valid for the next 10 days, appropriate actions, to deal with or prevent malaria related health issues, can be implemented by the responsible government authorities. Every day a new map can be produced, which takes into consideration the weather forecasts of the last couple of days, together with the new weather forecasts. The weather information from the previous days could be replaced by the actual weather information, not relying only on the forecast for the past couple of days.

All GFS forecasting information used here is produced on a daily basis and can be downloaded from http://filetransfer.itc.nl/pub/mpe/gfs_6p/. Each zip file contains information on precipitation, air temperature (min, max), humidity, potential and actual evapotranspiration. All data is in ILWIS format and you therefore only need to download the *.zip file and unzip it on your system. This would be required when other threshold settings have to be applied, e.g. higher rainfall (more 30 mm) or other temperature or humidity thresholds.

Figure 35: Mosquito habitat suitability map forecast as from 20190610 for the next 10 days, per woreda in Ethiopia





3.9 Retrieving statistics using a regular grid

In exercise 3.7 you created the maps ‘ndv_sum’ and ‘pcp_sum’. Now we are going to examine the relationship between these 2 maps for Ethiopia only to quantify the relationship between the precipitation climatology and the overall greenness / ndvi. This implies we have to clip the area first. In order to do so execute the following 2 expressions from command line within the ILWIS main window, and press <enter>:

```
Eth_ndv_sum:=iff(ETH_Admin0="Ethiopia", ndv_sum,?)
Eth_pcp_sum:=iff(ETH_Admin0="Ethiopia", pcp_sum,?)
```

Display both maps created, you can use the default Representation. Note that water in the Eth_ndv_sum map has the value of ‘0’. Create a new map list, from the main ILWIS menu, select the options “File” > “Create” > “Map List”, specify as Map List name “Eth_pcp_ndv” and add the two layers “Eth_pcp_sum” and “Eth_ndv_sum” by pressing the “>” button to the right map listing, subsequently press “OK”.

Now we are going to create a regular grid, using a sampling distance of approximately 15 km. First a new map is created, from the main ILWIS menu, select the options “File” > “Create” > “Raster Map”, specify as Map List name “Grid”, as Georeference select “giacisV2_proba_eth” and as Domain “Value”, press “OK” and close the map.

Now this map is aggregated to the desired sample scheme resolution. From the main ILWIS menu, select the options “Operations” > “Raster Operations” > “Aggregate Map”, specify as Map List name “Grid”, as Group Factor select “15”, Function is “Average”, activate “Group” and as Output map specify “Grid15”, press “Show”, close the map. Note that also a new Georeference “Grid15” is created, open this georeference and inspect the number of rows, columns and pixel resolution.

Now we are going to add for each pixel in the empty map a consecutive number (note the number of columns in the map!), to do so use the following map calculation expression and press <enter>:

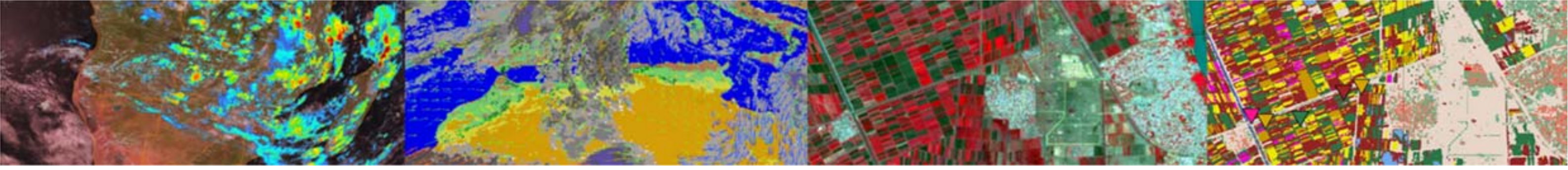
```
grid15c:=ifundef(grid15,%c+(%L-1)*114,0)
```

Check the resulting map. This raster map is now going to be transformed to a point map, from the main ILWIS menu, select the options “Operations” > “Vectorize” > “Raster to Points”, specify as Raster Map “Grid15c” and as Output Point Map “Grid15c”, press “Show”. If all is correct you should have a point map having a maximum value of 10146 (which is 89 * 114 – being the dimensions of the input map!).

Final step is to create a point map with a unique number, not a value as in the previous map. To do this, select from the main ILWIS menu the options “Operations” > “Spatial Reference Operations” > “Unique ID”, specify as Input Map the point map “Grid15c” and as Output Point Map “Grid15c_ID”, press “Show”. Keep the left mouse button pressed and move it over the point map. Note the ID’s of the points, like ‘Pnt 6545’, etc.

The point map with unique ID’s is now going to be crossed with the map list ‘Eth_pcp_ndv’. Select from the main ILWIS menu the options “Operations” > “Point Operations” > “Cross”, specify as Point Map the point map “Grid15c_ID” and as Map List “Eth_pcp_ndv’” and as output point map “Grid15_cross”, press “Show”. Once the map is displayed, move the cursor over the map and check the pcp and ndv values from the lower left pixel information window. Close the map.

Open the table “grid15_cross”. You will note that within the columns ‘eth_pcp_sum’ and ‘Eth_ndv_sum’ there are undefined observations (shown as “?”), as these are points situated outside



Ethiopia. Because of the occurrence of the value ‘0’ for water in the ndv map, we have to make a small adjustment to disregard these observations. To do so, type the following expressions in the table window command line and press <enter>:

```
Eth_ndv_sum_cor:=iff(eth_ndv_sum>0,eth_ndv_sum,?)
Eth_pcp_sum_cor:=iff(eth_ndv_sum>0,eth_pcp_sum,?)
```

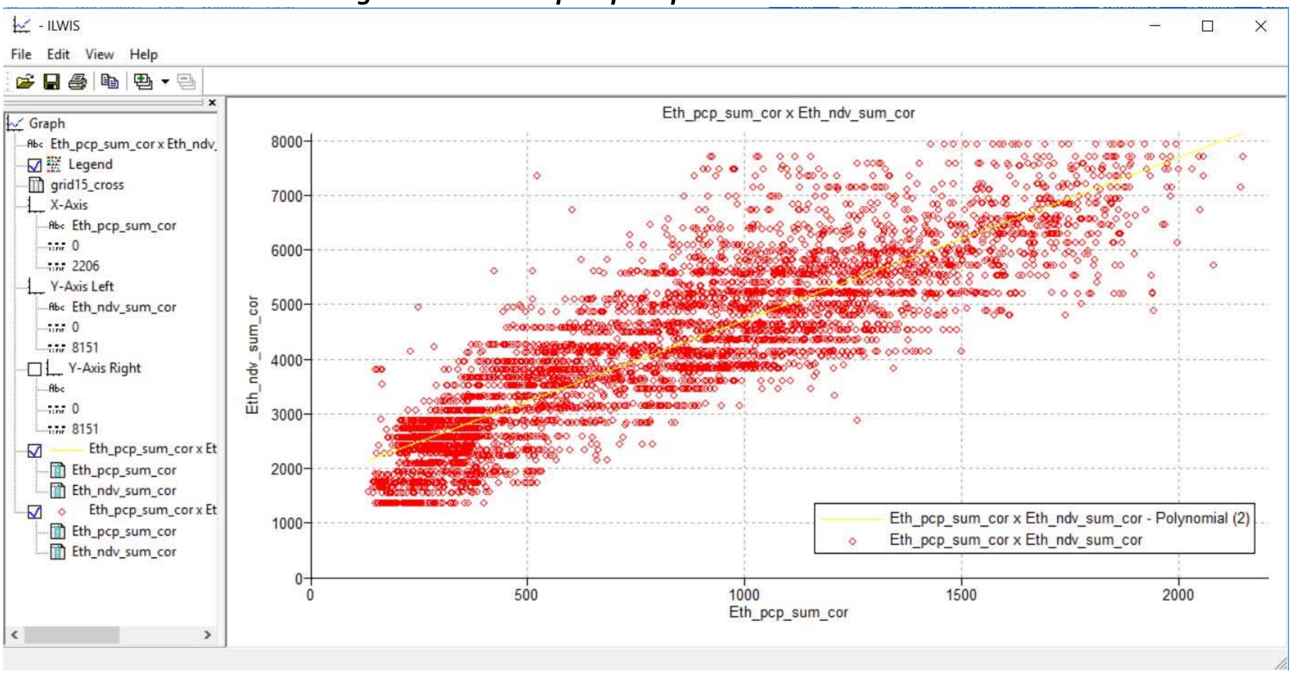
Two new columns are added, also assigning ‘not a number’, when there is an occurrence of water. Now we can derive some statistics. First check is the correlation between the two variables. From the table menu select the options “Columns” > “Statistics” and as Function select ‘Correlation’, as column select “Eth_pcp_sum_cor” and as second column “Eth_ndv_sum_cor”, press “OK”. Correlation between the two variable is highly positive, 0.875. Press “OK” to close the window.

It is also possible to make a scatter plot and calculate / visualize a regression function. In the table window menu press the icon ‘create graph’, on the X-axis select the column “Eth_pcp_sum_cor” and as Y axis “Eth_ndv_sum_cor”, press “OK”.

Now from the graphic plot window, select from the menu the options “Edit” > “Add Graph” > “Least Square Fit”, as X-column select the column “Eth_pcp_sum_cor” and as Y column “Eth_ndv_sum_cor”, as Function select Polynomial, use as Nr. of Term “2” (for linear regression) and press “OK”. Double click in the left hand legend on the item ”Eth_pcp_sum_cor x Eth_ndv_sum_cor - Polynomial (2)”, now also the regression formula can be obtained, here Y = 1746.204161 + 2.976117 * X.

Note that all kinds of modifications can be made to properly visualize your graph, here just the defaults are used, see also the figure below.

Figure 36: Scatter plot precipitation versus ndvi

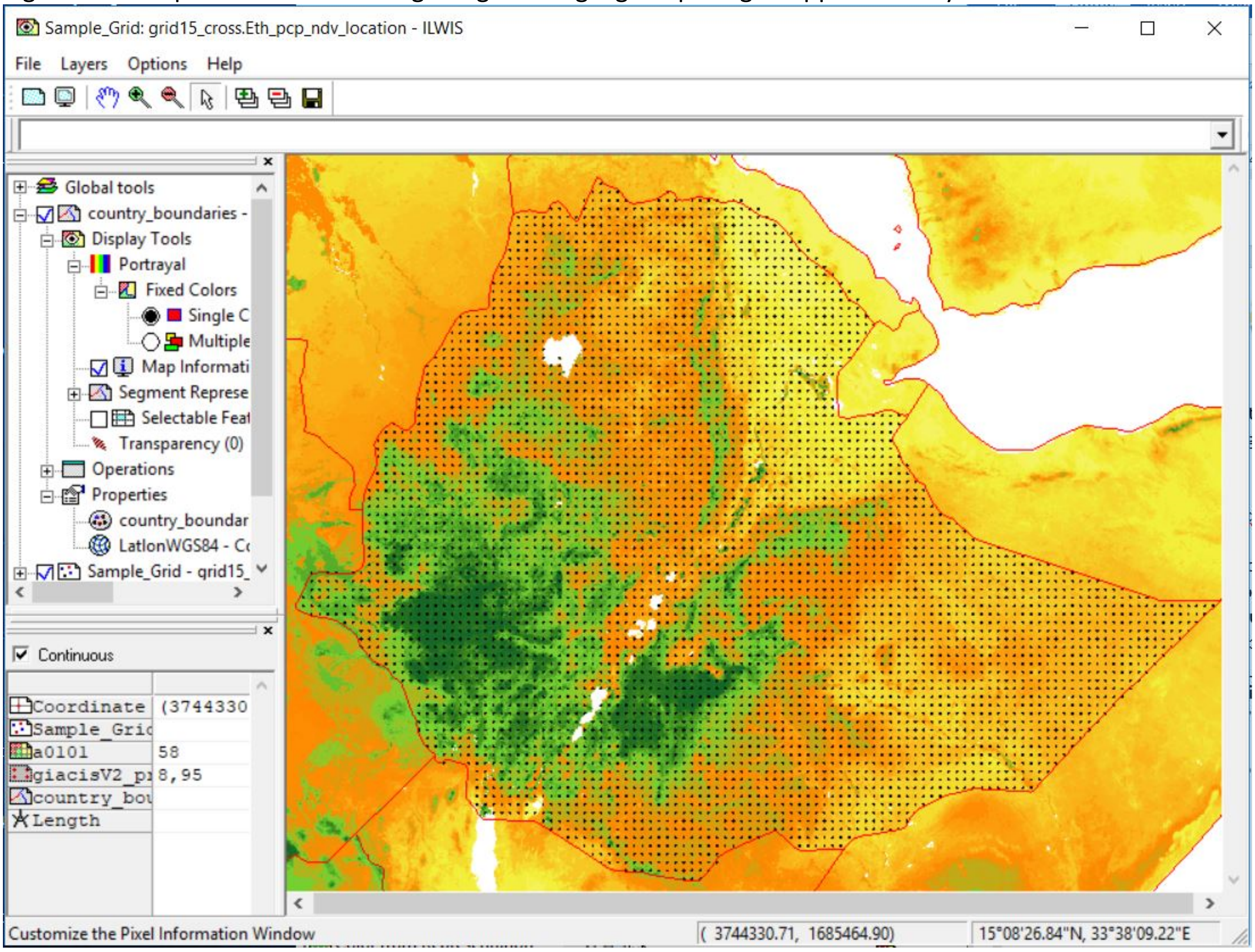


Finally the map showing the sample locations is going to be prepared. Close all open maps, tables and graphs. Open the table “grid15_cross”, type the following expressions in the table window command line and press <enter>:

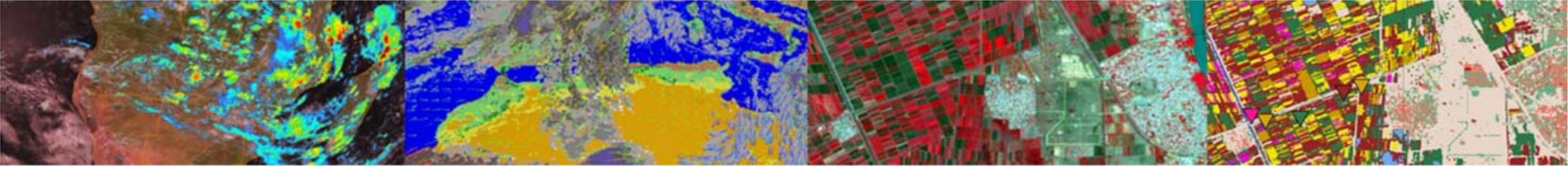
```
Eth_pcp_ndv_location:=iff(eth_ndv_sum>0,1,?)
```

Inspect the newly created column, close the table. Now from the main ILWIS menu, select the options “Operations” > “Point Operations” > “Attribute Map”. As point map select “Grid15_cross”, use the default table and select as Attribute “Eth_pcp_ndv_location”, as Output Map specify “Sample_Grid” and press “Show”. Add the ndv map “a0101”, drag the map in the left hand legend below the point map, as Representation use “ndv_byte253”. Open the display tools for the point map, double click “Symbolization” select as Symbol “filled-circle” and as symbol scale “0.15”, press “Apply” and “Close”. Also add the country boundaries, colour “Red”. See also the figure below.

Figure 37: Sample locations for a regular grid using a grid spacing of approximately 15 km



Also note the option in the left hand Map Legend under “Global Tools” > activate the option “Distance Measurer”. Measure the X and Y distance on the map between the sample locations.



4 Additional exercise – Calculation of the Start of Season

This is an exercise you have to do yourself. The question is to determine the Start of Season (SoS) for agricultural activities over Ethiopia. Start ILWIS and navigate to the sub-directory '\additional_exercise'

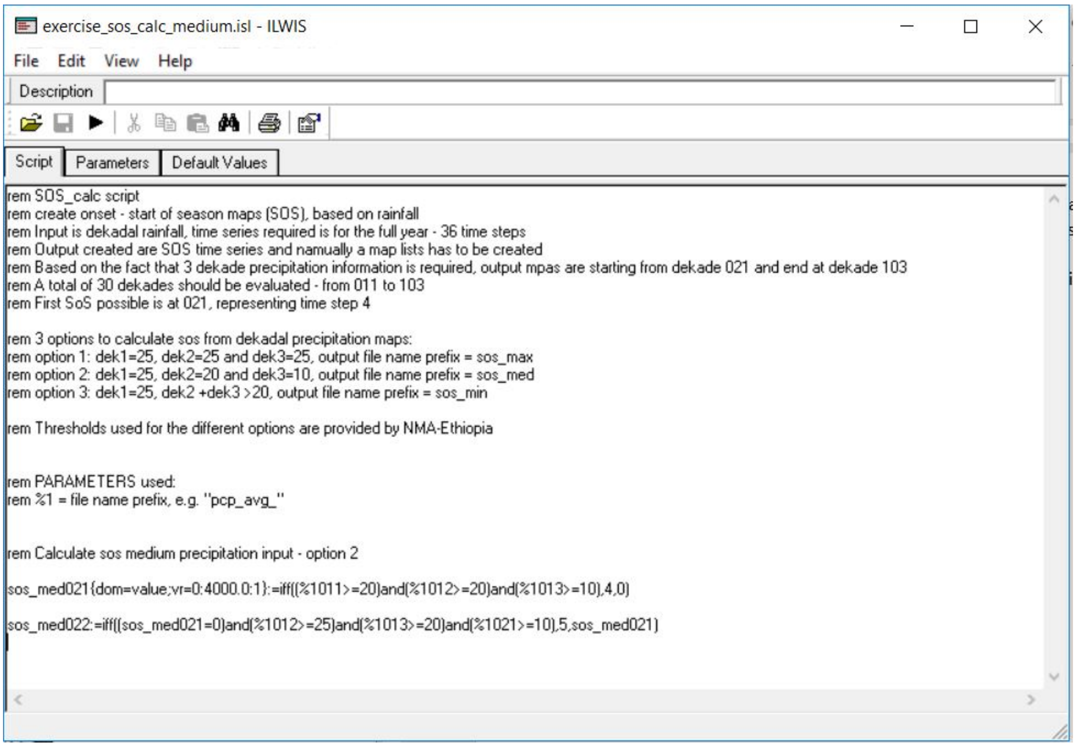
Provided is a map list of the precipitation climatology, containing 36 layers, 3 layers per month representing the average rainfall (in mm) of the integration time. Dekad number 011 refers to the 1st 10 day period in January, dekad 123 represents the last dekad of December.

Before planting of agricultural crops can commence, a certain minimum amount of rainfall is required to ensure sufficient soil moisture. Based on experiences from the Agro-Meteorological section of the National Meteorological Agency of Ethiopia, in the 3 preceding dekads the rainfall should be at least: dekad -3 = 25 mm, dekad -2 = 20 mm and dekad -1 = 10 mm. So prior to the start to plant the crops this amount of rainfall should at least have been received.

Once the Start of Season is initiated, the areas should be assigned the time step value for the year, from 4 to 36 (note that the first 3 dekads are required to provide the initial rainfall amount!) , although values higher than 30 (representing dekad 103) are not realistic, as growing season is too short for the main crops grown (like teff, barley and wheat), therefore after this time step it is assumed none of these crops are planted anymore. Note as well that some areas receive very little rainfall and do not meet the Start of Season criteria at all, these are mostly in the lower elevated areas and because of the low rainfall these are excluded.

To calculate the SoS, a start has been made to develop a script. Two sample calculation lines are included. The rest you have to develop yourself. See also the picture below.

Figure 38: Sample script to calculate Start of Season using medium rainfall thresholds



exercise_sos_calc_medium.isl - ILWIS

File Edit View Help

Description

Script | Parameters | Default Values

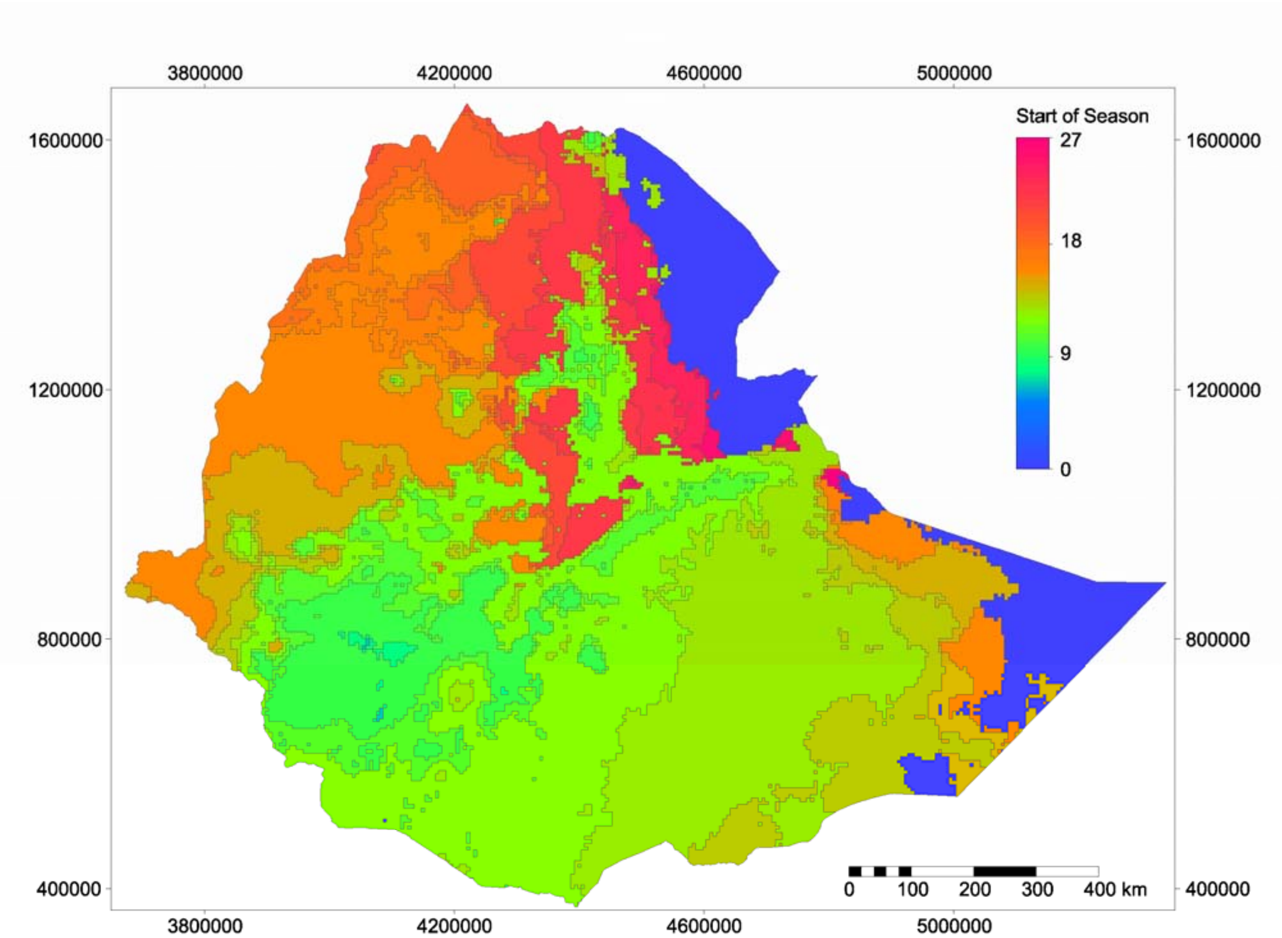
```
rem SOS_calc script
rem create onset - start of season maps (SOS), based on rainfall
rem Input is dekadal rainfall, time series required is for the full year - 36 time steps
rem Output created are SOS time series and namually a map lists has to be created
rem Based on the fact that 3 dekade precipitation information is required, output mpas are starting from dekade 021 and end at dekade 103
rem A total of 30 dekades should be evaluated - from 011 to 103
rem First SoS possible is at 021, representing time step 4

rem 3 options to calculate sos from dekadal precipitation maps:
rem option 1: dek1=25, dek2=25 and dek3=25, output file name prefix = sos_max
rem option 2: dek1=25, dek2=20 and dek3=10, output file name prefix = sos_med
rem option 3: dek1=25, dek2 +dek3 >20, output file name prefix = sos_min

rem Thresholds used for the different options are provided by NMA-Ethiopia


rem PARAMETERS used:
rem %1 = file name prefix, e.g. "pcp_avg_"


rem Calculate sos medium precipitation input - option 2

sos_med021{dom=value;vr=0:4000.0:1}:=iff((%1011>=20)and(%1012>=20)and(%1013>=10),4,0)

sos_med022:=iff((sos_med021=0)and(%1012>=25)and(%1013>=20)and(%1021>=10),5,sos_med021)
```

Before you start first have a look at the sos_max.avi, this animation can be opened with Windows Media player. This animation is looping twice through the season, showing the change of SoS over the country.

Review the script “exercise_sos_calc_medium” and continue adding the calculations for the dekads 023 to 103. Once this is done the map showing the SoS of dekad 103, which is the last dekad of October, should resemble the picture below. Use the country mask to clip Ethiopia and calculate the statistics. These should resemble the statistical listing below.

Look at your results also as an animation. Write a small report and submit your results, including a map and statistics. Indicate how the SoS is developing over Ethiopia, when and where it starts, how it develops over the country.

Figure 39: Start of Season (using medium thresholds) for Ethiopia



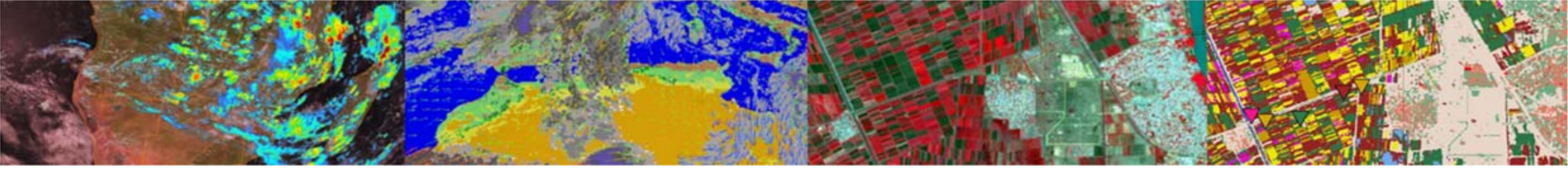
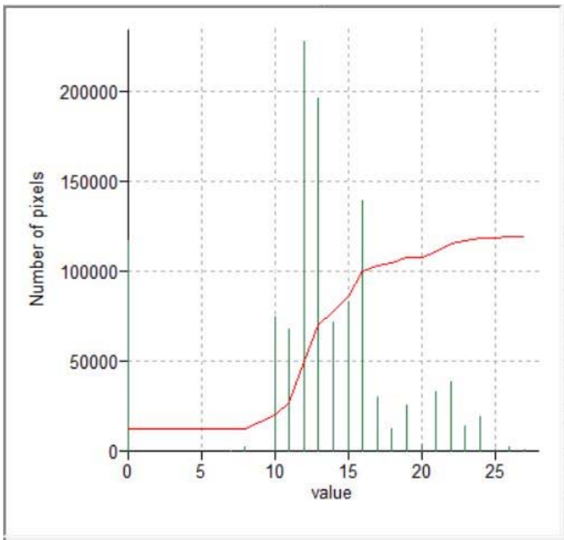


Figure 40: Statistical representation of the Start of Season



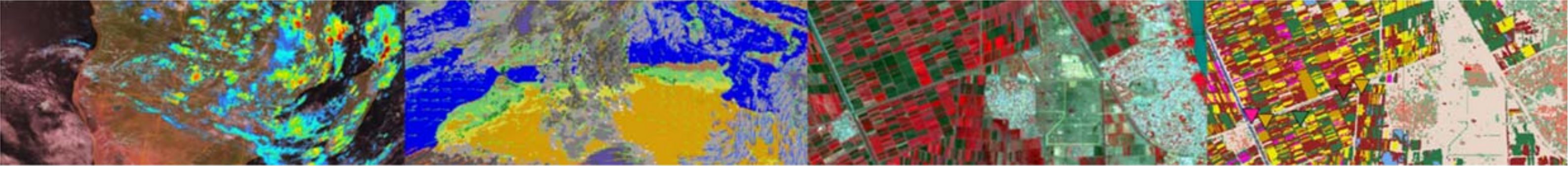
	value	npix	npixpct	pctnotund	npixcum	npcumpct
1	0	117676	5.10	10.09	117676	5.10
2	7	259	0.01	0.02	117935	5.11
3	8	2644	0.11	0.23	120579	5.23
4	10	74877	3.25	6.42	195456	8.47
5	11	67722	2.94	5.80	263178	11.41
6	12	227811	9.88	19.53	490989	21.29
7	13	196323	8.51	16.83	687312	29.80
8	14	71591	3.10	6.14	758903	32.90
9	15	83504	3.62	7.16	842407	36.52
10	16	139856	6.06	11.99	982263	42.58
11	17	30101	1.30	2.58	1012364	43.89
12	18	12927	0.56	1.11	1025291	44.45
13	19	26154	1.13	2.24	1051445	45.58
14	20	4079	0.18	0.35	1055524	45.76
15	21	33377	1.45	2.86	1088901	47.21
16	22	39146	1.70	3.36	1128047	48.90
17	23	14149	0.61	1.21	1142196	49.52
18	24	19320	0.84	1.66	1161516	50.35
19	25	1426	0.06	0.12	1162942	50.42
20	26	2934	0.13	0.25	1165876	50.54
21	27	833	0.04	0.07	1166709	50.58

5 Concluding remarks

Going through the exercises has assisted you in getting familiar with some of the capabilities offered by the ILWIS 386 software. Many of the GIS and RS capabilities are not addressed within these short exercises.

Quite an archive exists with older version documentation, exercises together with sample data. In general only the ILWIS user interface has changed and additional functionality has been added. Links to older documentation and user information is provided at:

- https://www.itc.nl/ilwis/users-guide/
- https://52north.org/software/software-projects/ilwis/ilwis-3/user-guide/
- https://www.itc.nl/about-itc/organization/scientific-departments/water-resources/geonetcast/application-manual/



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