FEWS NET

FAMINE EARLY WARNING SYSTEMS NETWORK

FEWS NET Tools User Manual

Version 3.3.0 Plugin for QGIS

September 2025

FEWS NET provides tools to help mitigate or prevent humanitarian crises. FEWS Tools is a powerful user-friendly tool for climate data analysis. This manual is intended for users of the FEWS Tools plugin for QGIS.

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Introduction

Summary

The FEWS Tools are a set of agroclimatic analysis tools developed by member organizations of FEWS NET, including the United States Geological Survey (USGS) and the Climate Hazards Center (CHC) at the University of California, Santa Barbara (UCSB). Designed for analysis of rainfall, temperature, and evapotranspiration data, these tools offer a range of functions crucial for climate analysis in agricultural development.

The latest version, FEWS Tools 3.3.0, is available as a plugin for QGIS and has been tested for compatibility with QGIS version 3.34 LTR (see Appendix A for basic QGIS concepts). These user-friendly tools can be used to:

- Analyze large quantities of climate data in raster format.
- Create visual representations of climate-data summaries.
- Calculate seasonal anomalies.
- Blend climate station values with satellite data to create improved datasets.
- Calculate seasonal trends.
- Facilitate drought analysis.
- Compare groups of years within a time series.
- Calculate agriculture water balance using the function for the Water Requirement Satisfaction Index (WRSI).

Using the Manual

This manual is organized into 11 chapters and presents examples and exercises to help you understand the different applications of the FEWS Tools analysis functions.

Chapter 1: Overview provides a brief tour of the various functions available in FEWS Tools.

Chapter 2: Settings provides details on setting up the program and downloading data.

Chapter 3: Data Management provides a review of the different data types used, data availability and more.

Chapter 4: Climatological Analysis explains how to calculate statistics, trends, and SPI, among other functions, for a set period (e.g., dekad, month, season) using GeoCLIIM functionality.

Chapter 5: Rainfall Summaries shows how to calculate seasonal totals, averages, and anomalies.

Chapter 6: Climate Composites describes seasonal analysis among a group or two groups of non-consecutive years within a time series.

Chapter 7: Contour Tool explains how to visualize spatial rainfall distribution based on contour lines.

Chapter 8: Calculate Difference in Averages shows a way of estimating trends by comparing changes in averages between two periods within a time series.

Chapter 9: BASIICS explains the process of blending station and raster data to create improved climate fields.

Chapter 10: Extract Statistics explains how to create spatial summaries of historical data for a single or a set of polygons.

Chapter 11: GeoWRSI Analysis Functions - explains the implementation of the Water Requirements Satisfaction Index (WRSI).

Appendix A: QGIS-overview provides links to basic QGIS instructions for viewing, editing, and creating shapefiles and rasters.

Download installation manual

For updates and video tutorials, go to https://help.fews.net/en/tools

Glossary

1. **CHIRPS** – Climate Hazards InfraRed Precipitation with Stations
2. **CHIRP** – Climate Hazards InfraRed Precipitation
3. **Dekad** – 10 days total precipitation
4. **IRE** – Improved rainfall Estimates, a blend of station with raster data using GeoCLIM
5. **Pentad** – Five days total precipitation
6. **SPI** – Standardized Precipitation Index

Section 1
Overview and Settings Functions

Chapter 1: Overview

Figure 1-0 *The FEWS Tools main toolbar. Setting functions (1a), data management functions (1b) GeoCLIM analysis functions (1c), and GeoWRSI functions (1d).*

1.0. The FEWS Tools Main Toolbar

a. Setting Functions
   i. Workspace Settings
   ii. Output Directory Settings
   iii. Add/Edit Datasets
   iv. Add/Edit Regions

b. Data Management Functions
   i. Import climate data archives
   ii. Download climate data
   iii. View list of available data

c. GeoCLIM Analysis Functions
   i. Climatological data analysis; average, SPI, etc.
   ii. View rainfall summaries
   iii. Climate composites
   iv. Make contours
   v. Calculate long-term changes in averages
   vi. BASIICS: raster-station blending, station interpolation
   vii. Extract statistics from raster datasets

d. GeoWRSI Analysis Functions
   i. Add/Edit Crops
   ii. WRSI Settings
   iii. Run WRSI
   iv. Climatological WRSI/SOS Analysis
   v. WRSI Output Settings

Summary

Figure 1-0 above shows the primary tools available in the FEWS Tools plugin. These tools consist of settings, data management, and analysis methods for both GeoCLIM and GeoWRSI. This chapter briefly describes the main functions, and the following chapters look at each tool in detail.

Settings Functions

1.1. Setup the Workspace 

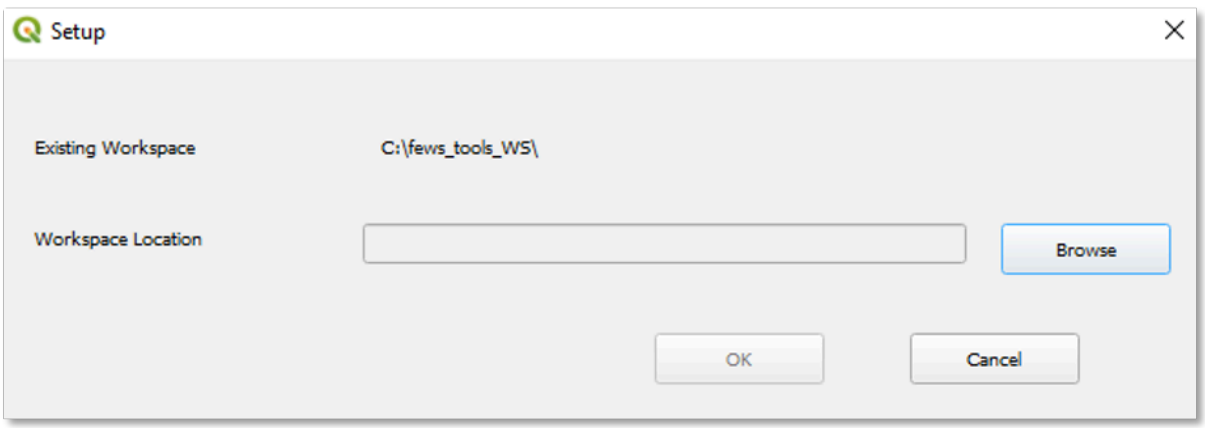


Figure 1-1 *Setup allows you to change the workspace directory.*

The default location of the workspace is `C:\Users\[USER]\Documents\fews_tools`. However, you can change the location to a different drive based on memory availability and access, see Figure 1-1. See more about how to change the workspace in [Chapter 2.](#)

1.2. Output Options 

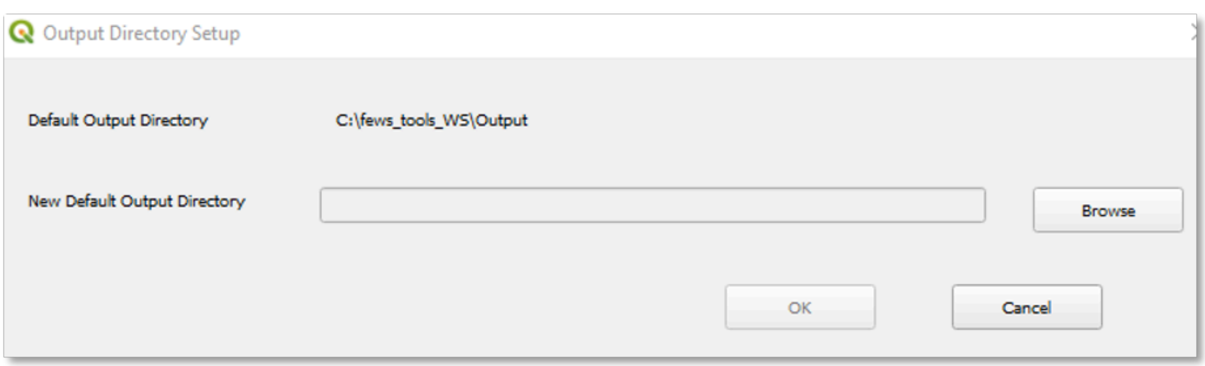


Figure 1-2 *You can change the default output directory.*

You can change the default output directory where the results from the different functions are deposited. This is done in case you want to save all the results for a given project in the same place. Browse to the new directory and click the **OK** button, see Figure 1-2.

1.3. Add/Edit Datasets 

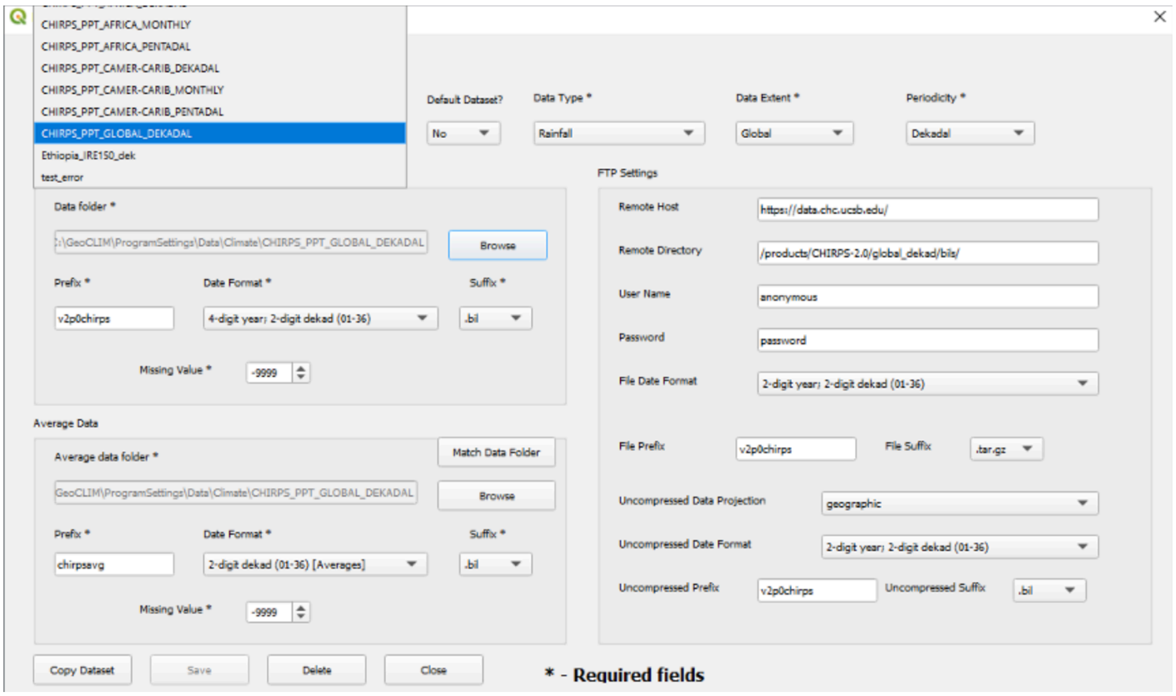


Figure 1-3 *FEWS Tools requires datasets to be registered before they could be used by the different functions in GeoCLIM or GeoWRSI.*

The FEWS Tools plugin requires that raster data be registered in the database to be used by the different functions. The registration is done by completing the **Add/Edit Datasets** form, Figure 1-3. The tool includes a few dataset definitions by default, but you could add others. See Chapter 2 for more information on how to add new datasets.

1.4. Add/Edit Regions 

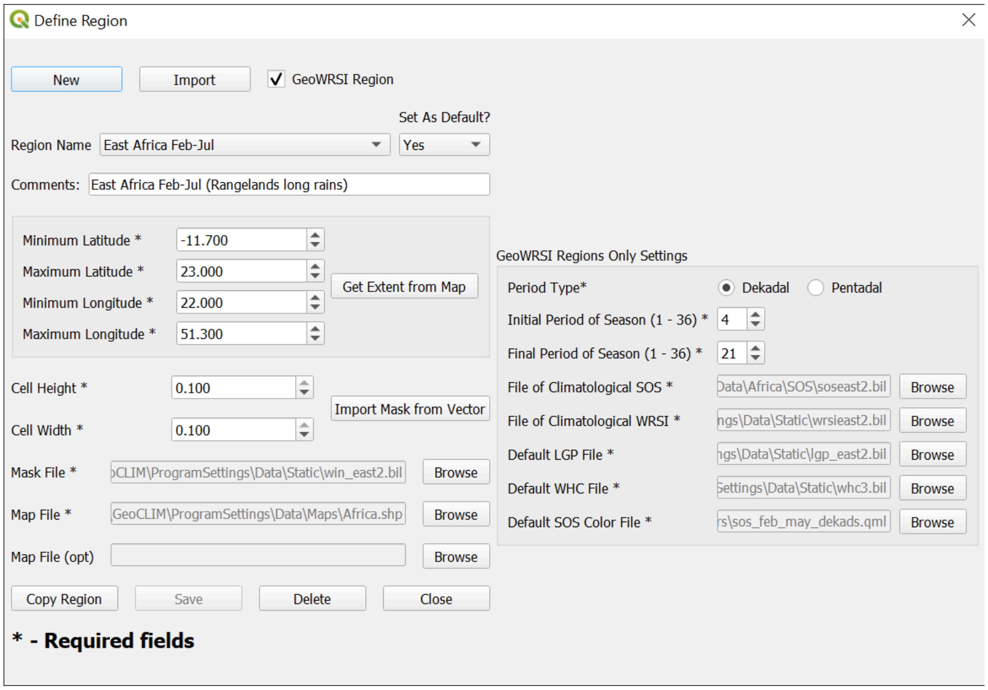


Figure 1-4 *Starting on version 3.1.0, FEWS Tools include functionality to run the GeoCLIM and Water requirement Satisfaction Index (WRSI) using the same region.*

FEWS Tools runs on predefined areas of study or regions. A region is composed of the lat/lon box and a mask file which is a raster dataset that further defines the region of interest, see Figure 1-4. See more about how to create or edit regions in Chapter 2.

Data Management Functions

1.5. Import Climate Data Archives

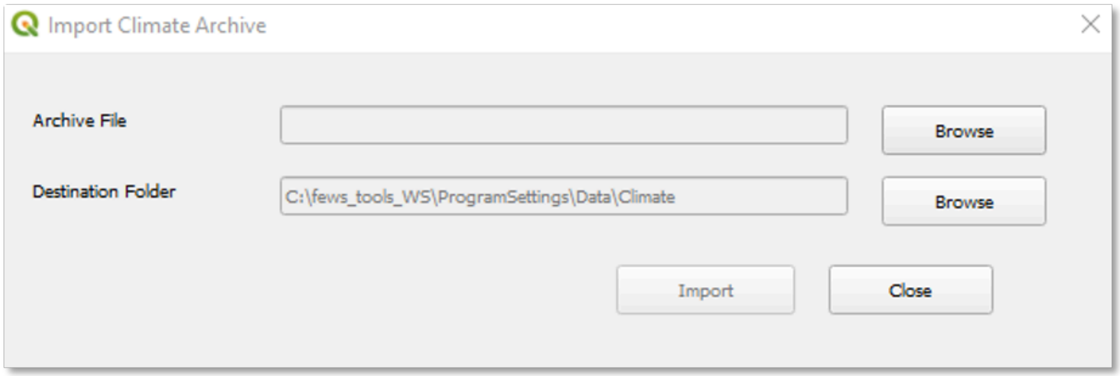


Figure 1-5 *One way of making Climate data available in FEWS Tools is through importing archives.*

An archive is a compressed file containing data for a climate variable including all the settings to make the dataset ready to be used in the program. The **Import Climate Archives** tool, Figure 1-5, makes datasets available in FEWS Tools. These archive files are useful for sharing data among GeoCLIM users. For information on creating data archives, see Chapter 3.

1.6. Download Climate Data

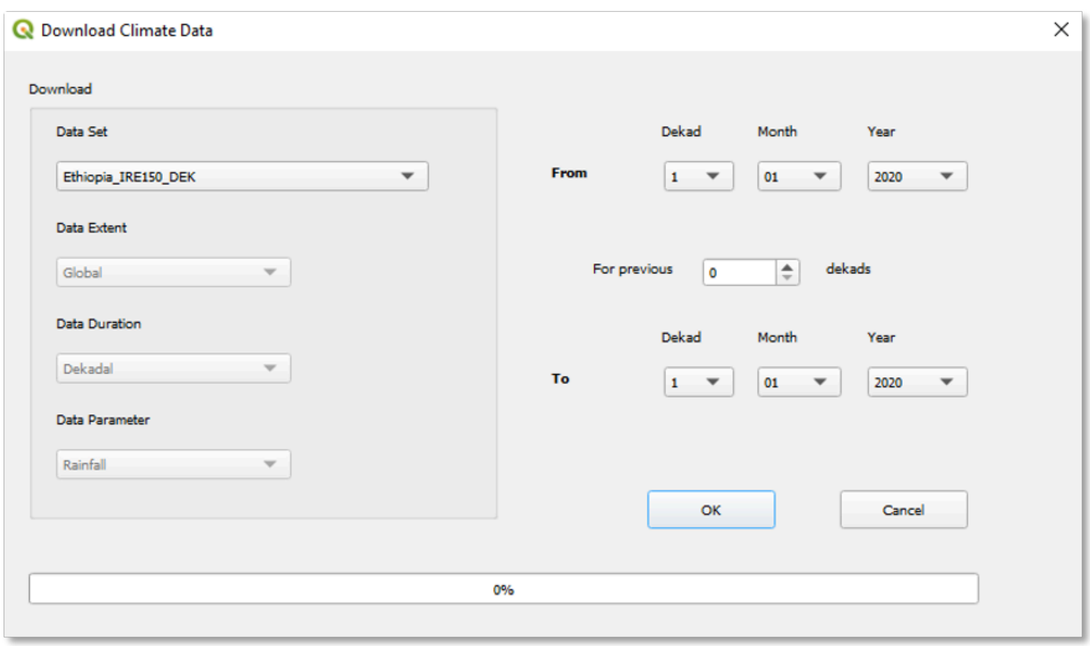


Figure 1-6 *You can download Rainfall, Temperature, or Evapotranspiration data directly from an online location such as an FTP site using the Download Climatic Data Tool.*

The **Download Climate Data** tool, Figure 1-6, facilitates bulk downloads of available climate data via FTP, HTTP, or HTTPS from different sources (e.g., UCSB, USGS, etc.). See Chapter 3 for more information on FEWS Tools data management.

1.7. View Available Data

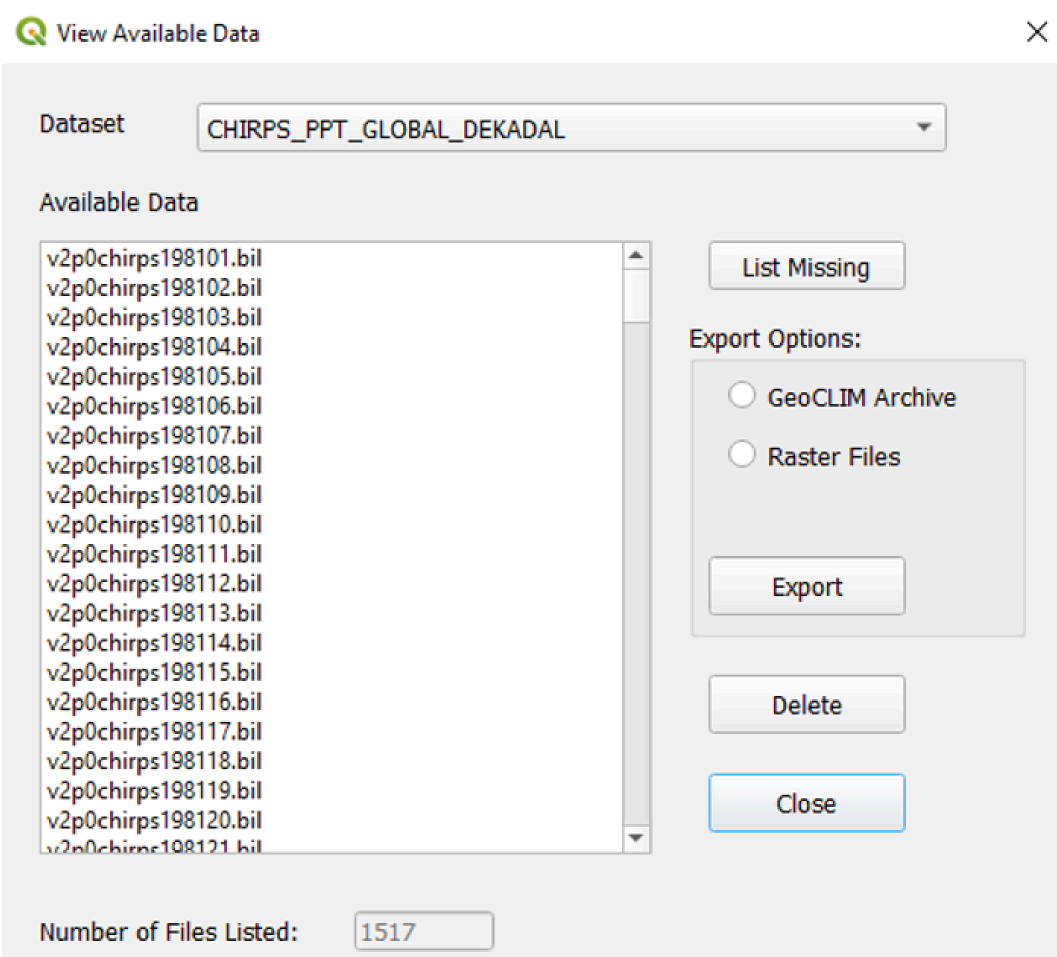


Figure 1-7 *This function allows you to list the available data for each of the climate variables.*

The **View Available Data** tool, Figure 1-7, provides a list of the data files available for the climate dataset selected (rainfall, mean temperature, minimum temperature, maximum temperature, or potential evapotranspiration). Figure 1-7 shows an example of a list of dekadal (+- 10-day) total rainfall starting on the first dekad of January 1981 (19810101). The **List Missing Data** button provides a list of any missing dates of the climate dataset selected between the first and the last date in the time series. You can export data, from the selected climate dataset to different formats (single `*.bil` or `*.tif, *tiff` files, or as an archive) for sharing or backup. See Chapter 3 for more information on creating archives.

GeoCLIM Functions

1.8. Rainfall Climatological Analysis

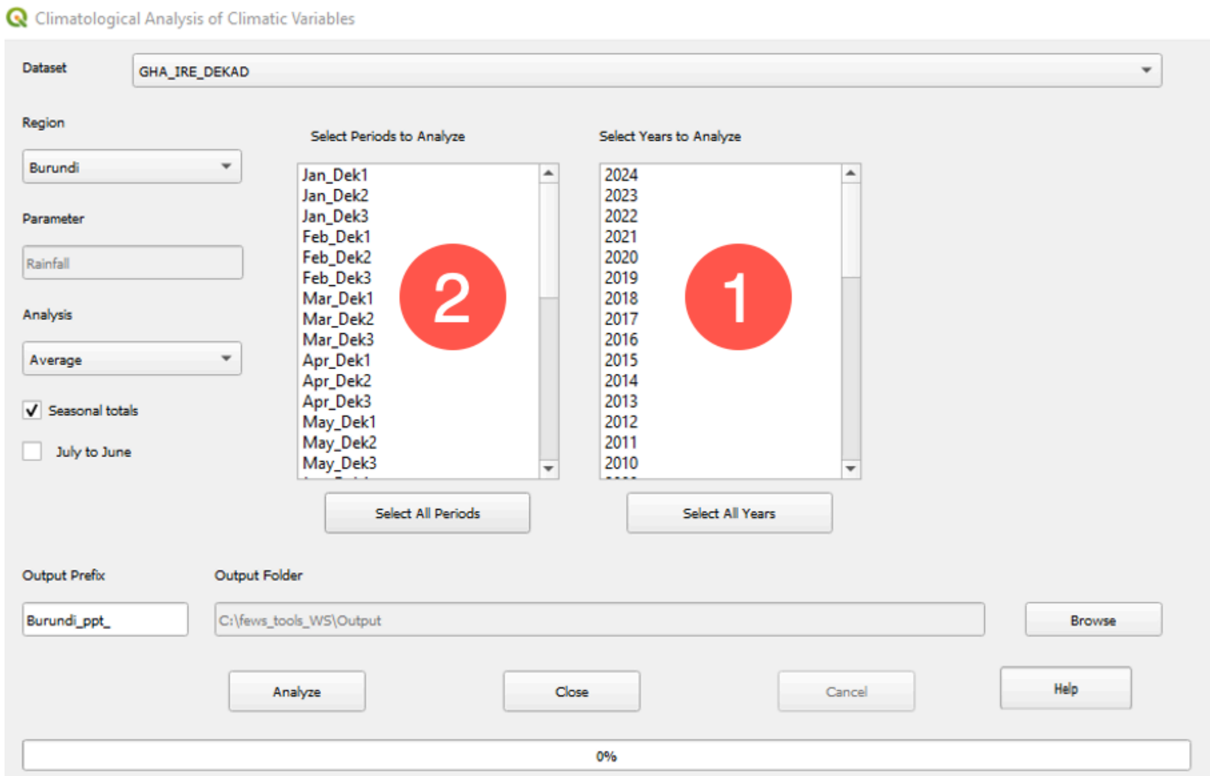


Figure 1-8 *This tool facilitates the calculation of statistics, trends and standardized precipitation index among other functions.*

The **Climatological Analysis of Climatic Variables** tool, Figure 1-8, is designed to calculate and display the averages, trends, SPI, and other statistical characteristics of rainfall, evapotranspiration, and temperature data. The tool displays all the years (1) and periods (2) (months, dekads, or pentads) available for a selected climate dataset. See Chapter 4 for a more in-depth discussion of this tool.

1.9. Rainfall Summaries

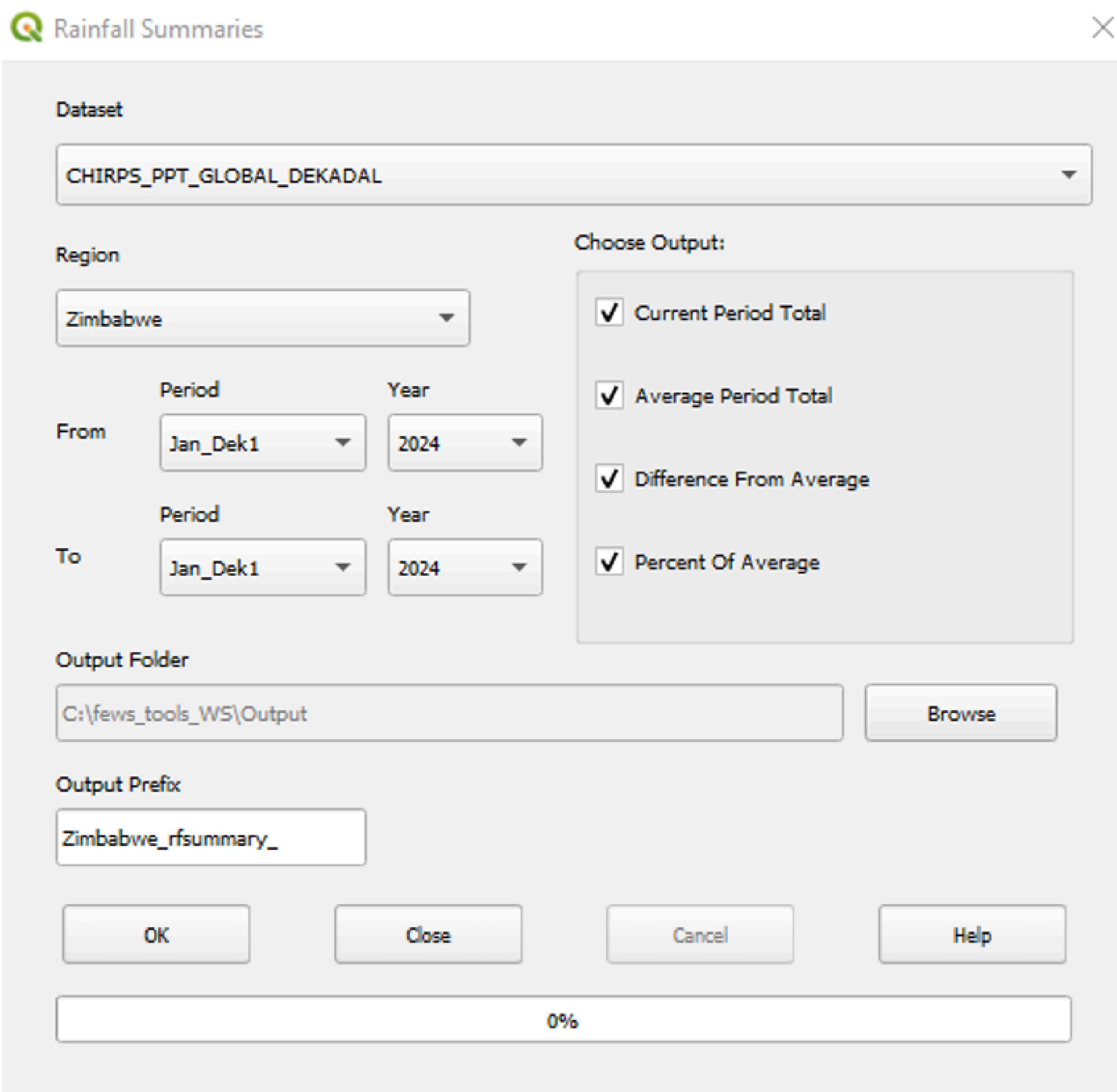


Figure 1-9 *The rainfall summaries tool calculates rainfall total and anomalies for a selected period.*

The **Rainfall Summaries** tool (Figure 1-9) calculates the total rainfall, the long-term average, the difference, and the percent of the long-term average for a selected region and range of dates. More details on this tool are available in Chapter 5.

1.10. Climate Composites

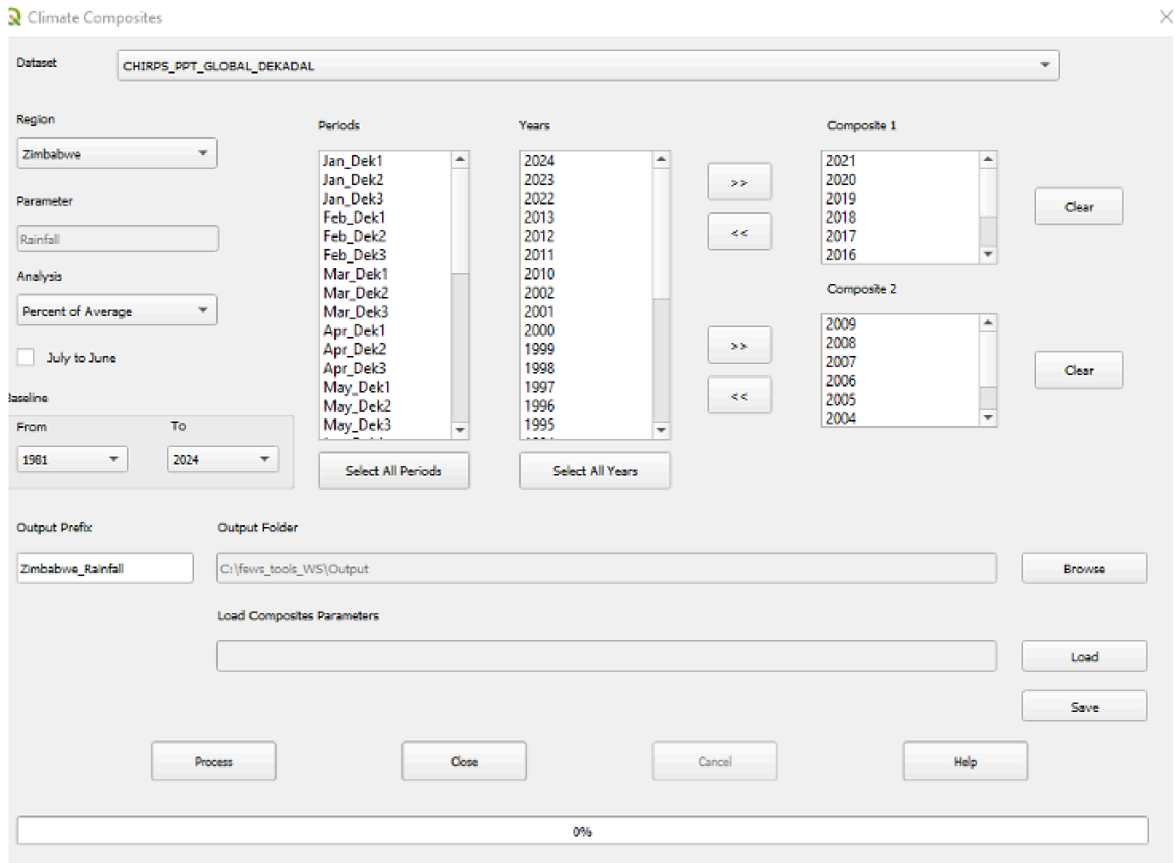


__Figure 1-10__ The Climate Composites tool facilitates the seasonal analysis for one or between two groups of [could be non-consecutive] years.

The **Climate Composites** tool facilitates the seasonal analysis for one or two groups of years. The tool calculates the seasonal average from a group of years, as well as comparing the seasonal rainfall performance between two groups of years, by calculating the percent of average, anomalies, and standardized anomalies (Figure 1-10). See Chapter 6 for more details.

1.11. Make Contours

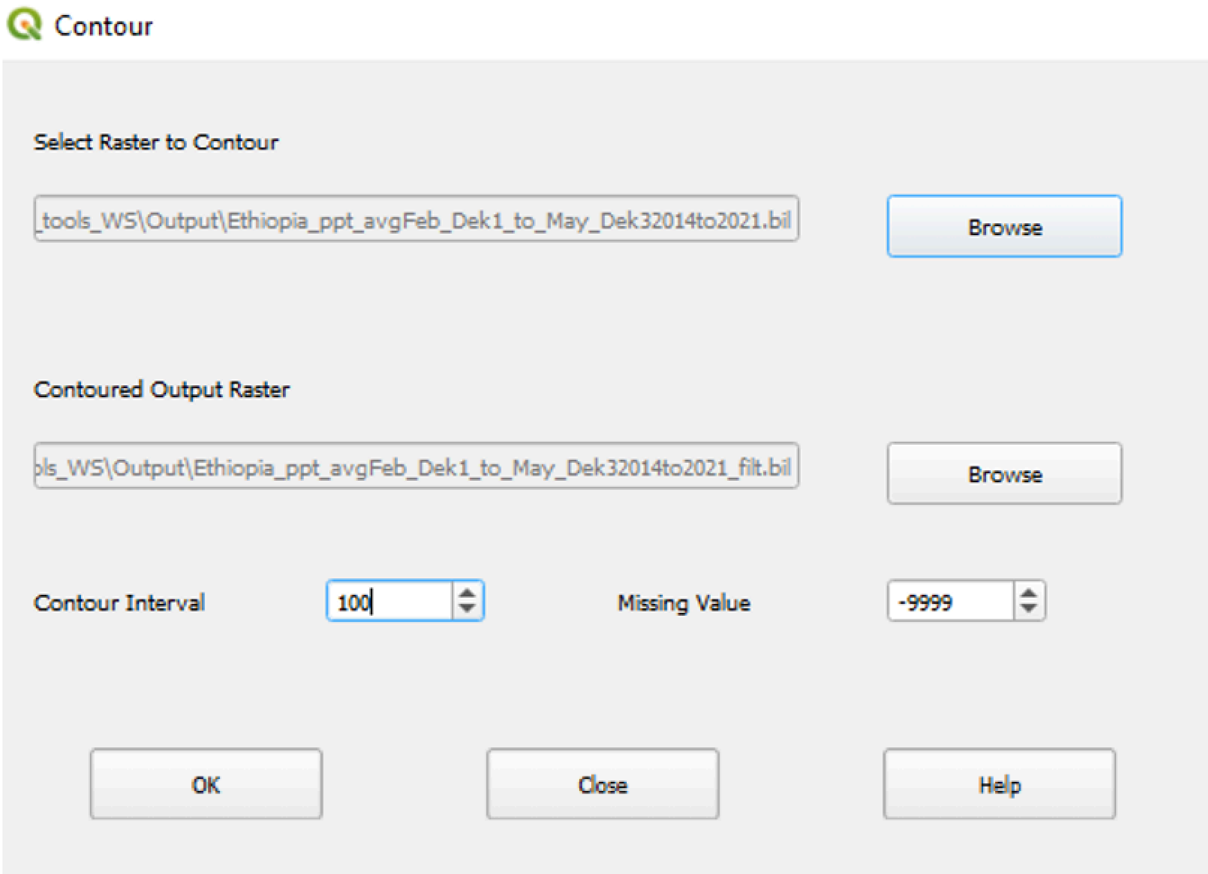


Figure 1-11 *Display rainfall data based on contour intervals.*

The **Make Gridded Contours** tool (Figure 1-11) displays smoothed contours for a specified interval based on a raster (*.bil or *.tif, *tiff) file. This tool helps identify changes in rainfall patterns within a region of interest. Read more about making contours in Chapter 7.

1.12. Climate Trends - Changes in Average

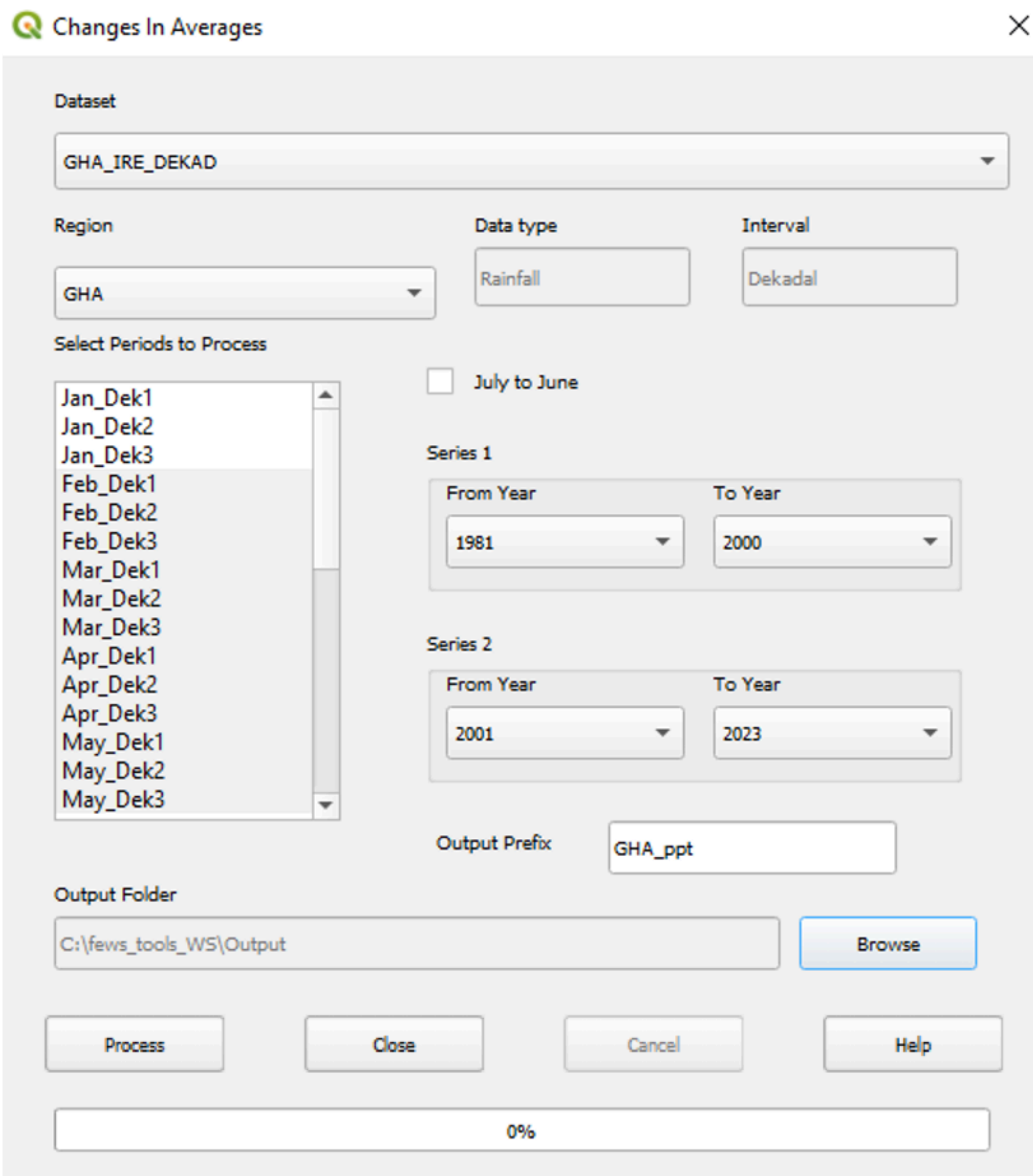
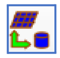


Figure 1-12 *The Climate Trends tool compares the average rainfall for two periods of time, identifying trends.*

The **Climate Trends - Changes in Averages** tool (Figure 1-12) identifies trends by calculating the difference in average between two periods (denoted as **Series 1** and **Series 2**). See Chapter 8 for more details.

1.13. Batch Assistant Tool 

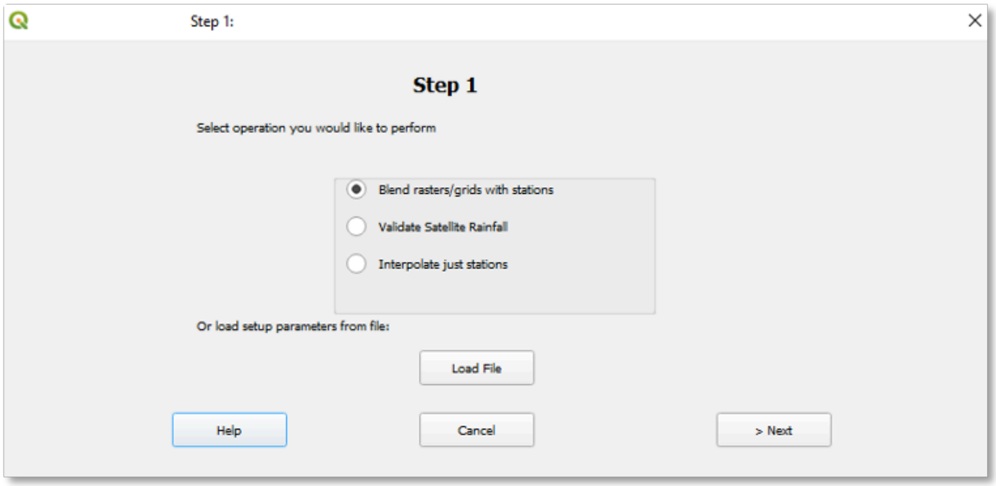


Figure 1-13 *The Batch Assistant tool has functions to: validate satellite estimated data using station values, blend station data with raster (BASIICS) and to interpolate station data.*

The Batch assistant tool (Figure 1-13) allows you to validate satellite-based data using climatological stations, blend climatological stations with raster data (BASIICS), and interpolate just stations. The function allows you to save the settings to run frequent processes, such as updating the time series every 10 days. This section contains the following modules:

1. **Blend rasters/grids with stations**: This function blends raster (e.g., satellite data, etc.) with stations available for a specific period to create a new and improved climate dataset.

2. **Validate Satellite Rainfall**: Validates a raster dataset using station data by comparing the point-to-pixel value for each station.

3. **Interpolate just stations**: This function uses inverse distance weighting (IDW) process to interpolate station values. See Chapter 9 for more information.

1.14. Extract Statistics from Raster Datasets

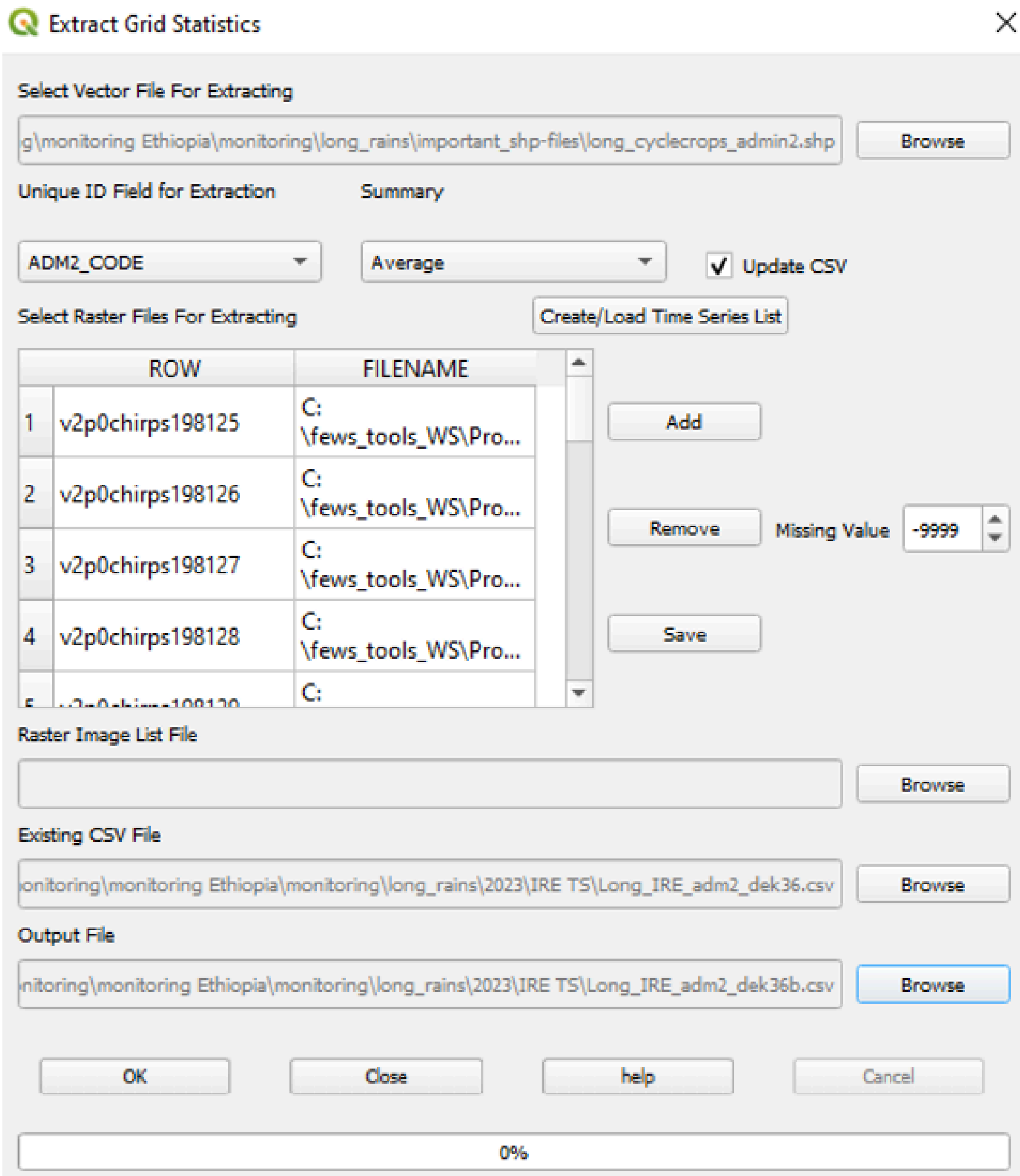


Figure 1-14 *Extract summary spatial statistics such as average, count, maxi/min, etc., for each polygon.*

The **Extract Grid Statistics** tool summarizes raster information by zones defined in a vector file (polygons such as districts, provinces, watersheds, etc.). This tool produces a table with the summary statistics for each polygon (sum, maximum, minimum, range, or standard deviation). This extraction can be applied to a single or a set of climate raster files (Figure 1-14). For more on this tool, see Chapter 10.

GeoWRSI Analysis Functions

1.15. Add/Edit Crops

This section explains the GeoWRSI crop parameters that are used as inputs to the model. You can change these parameters to create new crops that the GeoWRSI can run, but this should be done with sufficient theoretical and agronomic background. See Figure 1-15.

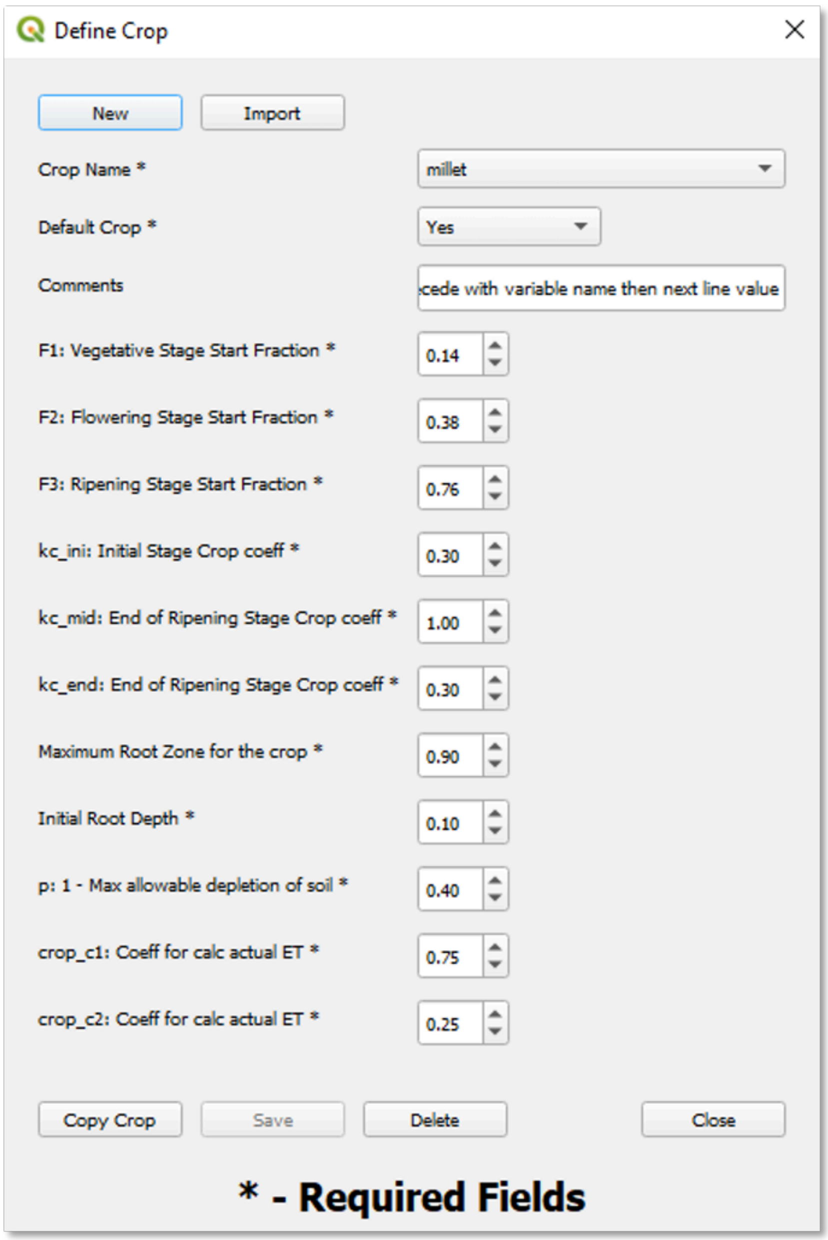


Figure 1-15 *This form contains parameters that describe the characteristics of the crop in a way that allows it to be modeled by the GeoWRSI.*

1.16. WRSI Settings

This section allows you to select the region and crop to be analyzed, the method for calculating the start of the season, the length of growing period, the water holding capacity (WHC) file, define or create a mask file, and select the precipitation and potential evapotranspiration. See Figure 1-16.

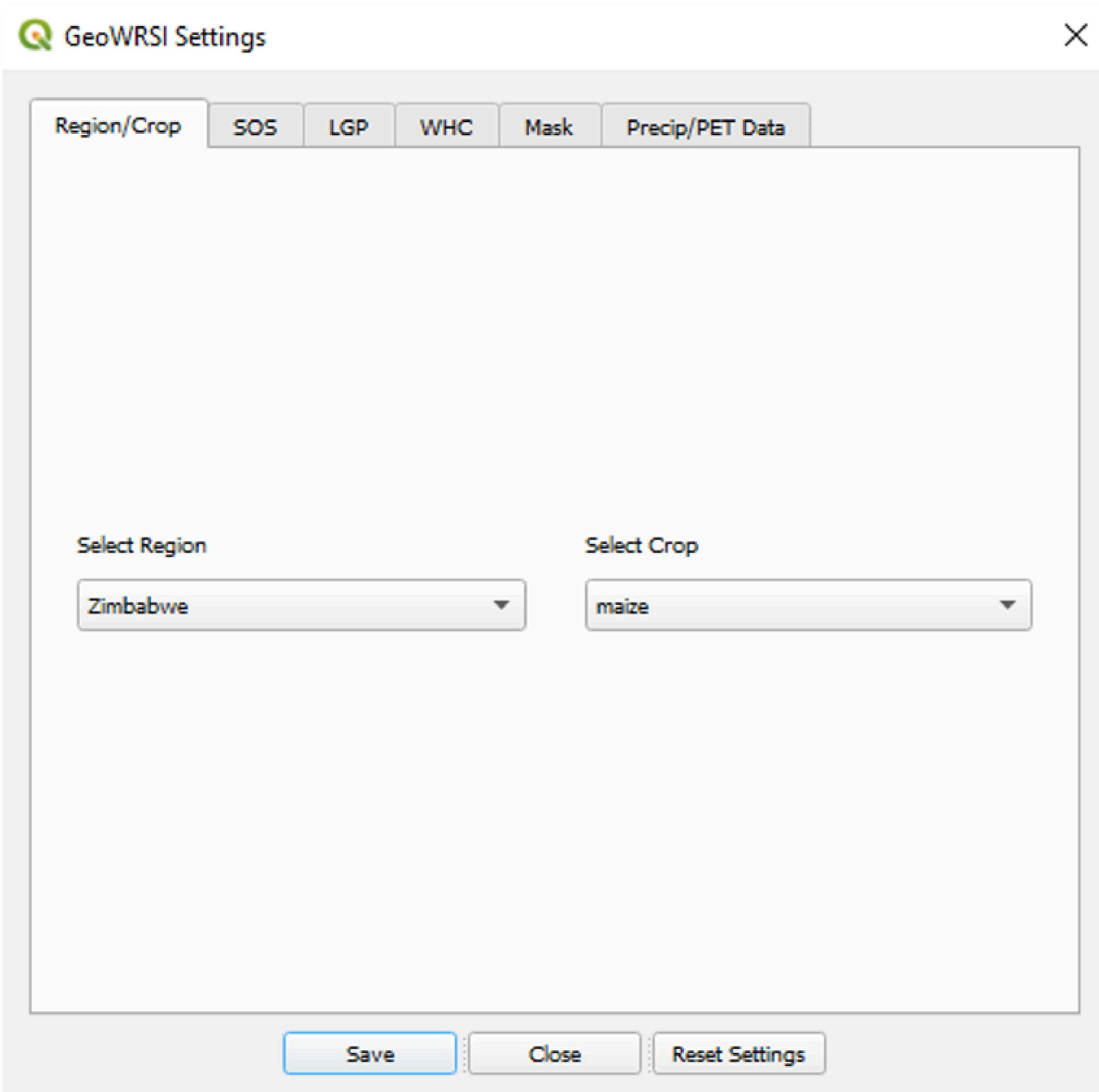


Figure 1-16 *This form allows you to define the settings to run the WRSI for a region.*

1.17. Run GeoWRSI

This function brings the settings saved on the previous section and allows you to select the year or years for which to run WRSI. See Figure 1-17.

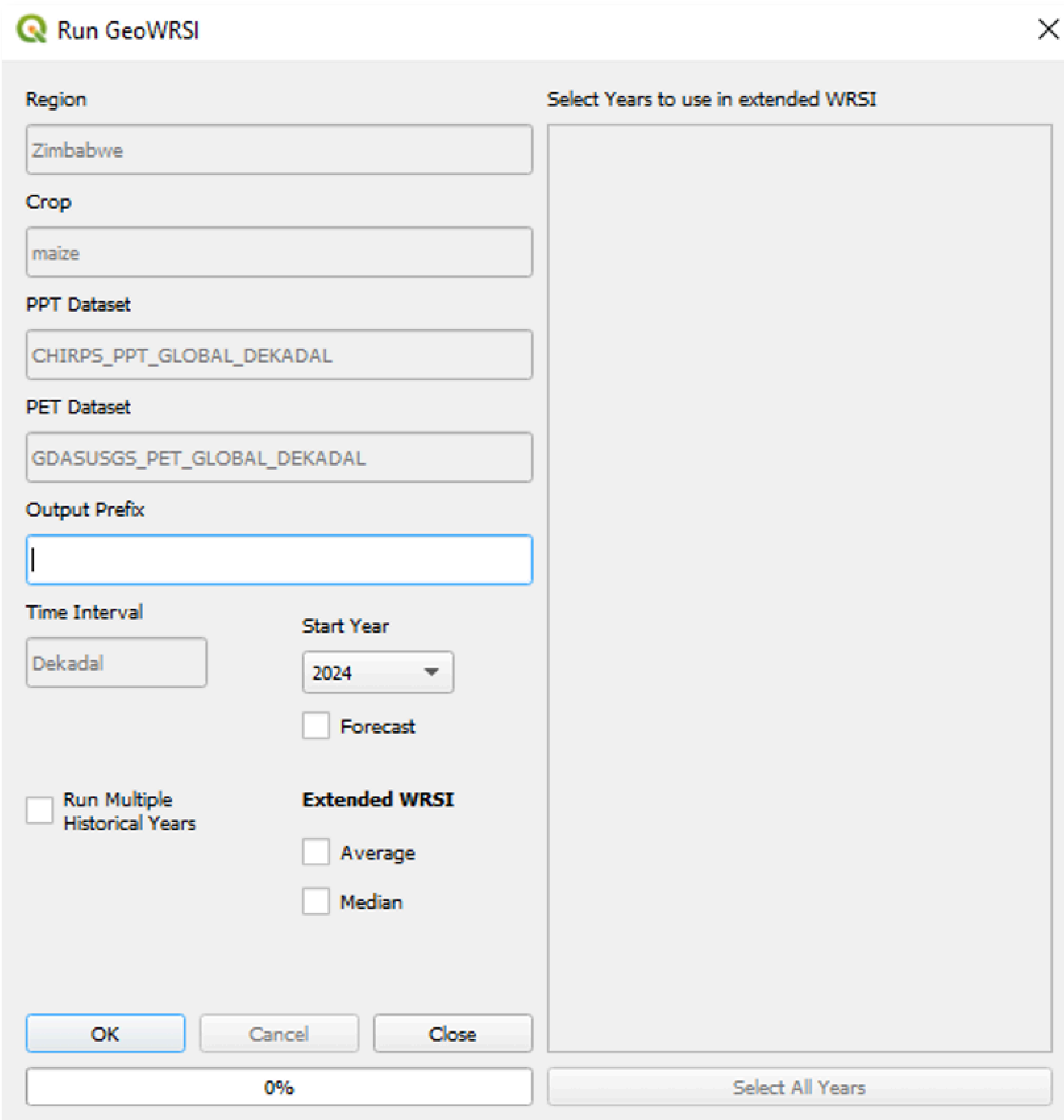


Figure 1-17 *Once the settings are complete, you can select the year or multiple years to run WRSI.*

1.18. Climatological WRSI/SOS Analysis

This function allows you to calculate average end of season WRSI or average start of season, based on the number of years available. See Figure 1-18.

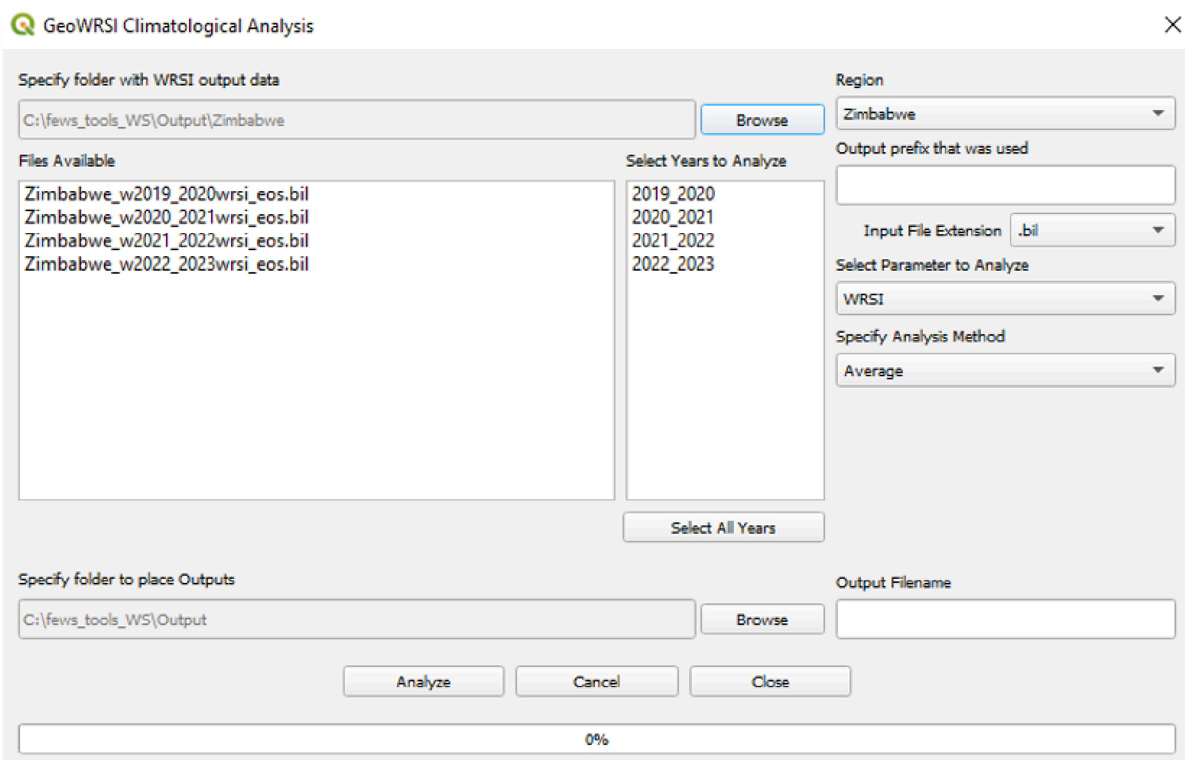


Figure 1-18 *The GeoWRSI climatological analysis tool allows to calculate average WRSI or SOS.*

1.19. WRSI Output Settings

The GeoWRSI tool allows you to set the outputs that the tool will produce, as well as the directory where all the products will be saved. See Figure 1-19.

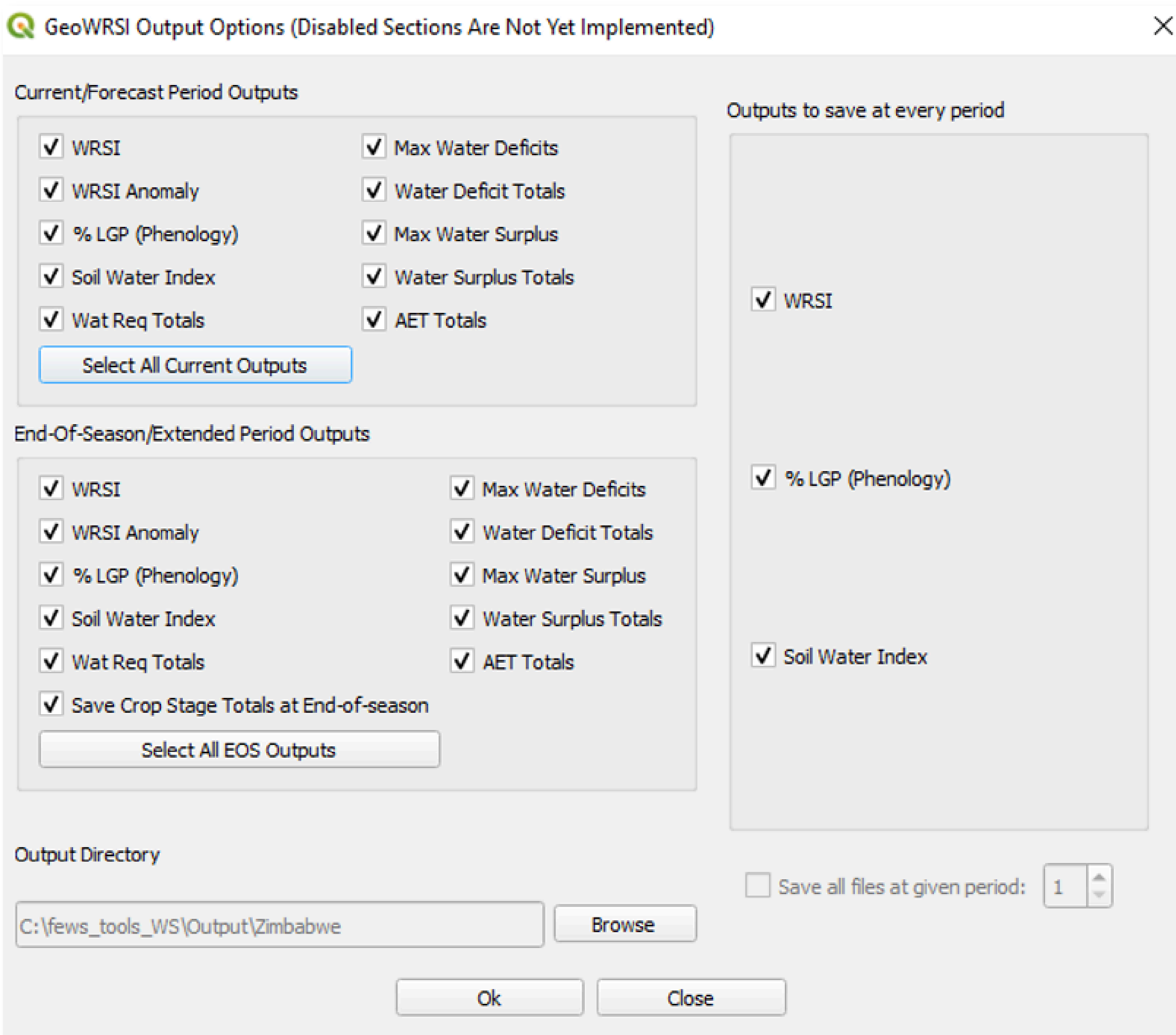


Figure 1-19 *This function allows you to select the WRSI outputs.*

Chapter 2: Settings

Summary

Before you start working with the FEWS Tools plugin, there are several settings to consider. First, you need to designate a workspace directory, which serves as a repository for all map related files, and all the raster data that you download or create. Additionally, you must set the area of work (region) and the dataset that you are going to use to conduct your analysis. This chapter provides detailed description on how to setup FEWS Tools including the following topics:

1. Workspace directory structure.
2. How to change the workspace.
3. How to change the default output directory.
4. How to add/edit a new climate dataset.
5. How to add/edit a new region.

2.1. Review of the Workspace Directory Structure

Once the program is installed, the default directory (in Windows Vista, 7, and 10) is: `C:\Users\<USER>\Documents\fews_tools_WS`. Where `<USER>` is the Windows username. There are two subdirectories in the workspace directory: `Output` and `ProgramSettings` (Figure 2-1). The Output directory holds all the results by default. The ProgramSettings directory contains the colors used for the output maps, the Data directory that contains climate data, shapefiles and masks, and all the files needed to run the WRSI. Figure 2-1 shows an outline of the contents of ProgramSettings.

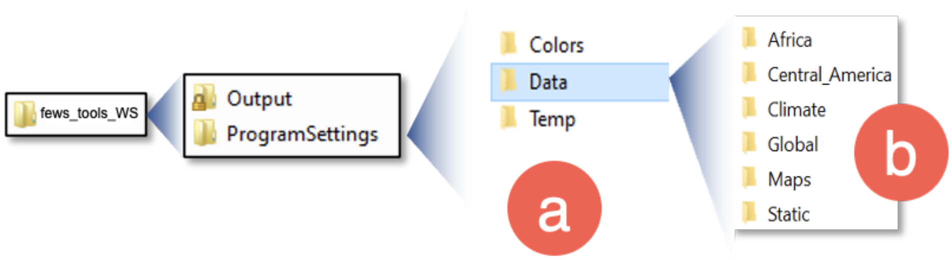


Figure 2-1 *The fews_tools workspace directory contains two subdirectories: the* Output *where all the results are saved by default, and the* ProgramSettings *that contains the* Data *directory among others.*

> **NOTE**: The default path to climate data within fews_tools workspace is:
> `C:\Users\<USER>\Documents\fews_tools_WS\ProgramSettings\Data\Climate.`

Contents of the `ProgramSettings` directory:

- **Colors**: Contains color files for map legends produced by GeoCLIM.
- **Data**: (Figure 2-1(b)) contains the following directories:
    - **Africa/Central_America/Global** – Contains required files to run WRSI.
    - **Climate** – Stores all downloaded and imported data. See section 2.4 on how to make a dataset available for analysis in GeoCLIM.
    - **Maps** – Contains all the shapefiles for the maps of the regions and countries required by the different functions. You can add shapefiles/maps as needed.
    - **Static** – Contains the masks for the different regions. Masks are maps in raster format that are used to define the area of interest (region) and ignore the rest of the data. For example, FEWS Tools contains rainfall data for the entire continent of Africa, but the analysis may be needed only for the country of Kenya. The mask would have a value of 1, in the area of interest (e.g., land areas of Kenya) and a value of 0 (zero) outside the area of interest. The results from the different functions will be given only for Kenya.
- **Temp**: This directory stores temporary files.

> **NOTE**: Another important path to keep in mind is that of the `fews_tools` directory that contains all the program files. Make sure you back up the `fews_tools.sqlite` file that is inside the `fews_tools` directory.
> `c:\Users\[users]\AppData\Roaming\QGIS\QGIS3\profiles\default\python\plugins\fews_tools\`

2.2. Changing the location of the fews_tools workspace

The default workspace is on the `C:\Users\<USER>\Documents\fews_tools_WS`, the C:\ drive is, sometimes, too small to hold all the data outputs that the FEWS Tools produce. It is recommended that you change the workspace to another drive. This will move only the fews_tools_WS to the new directory while the program files are kept on the original `c:\users\[users]\AppData\Roaming\QGIS\QGIS3\profiles\default\python\plugins\fews_tools\` directory, mentioned above.

To change the workspace, follow the steps below:

1. From the FEWS Tools toolbar in QGIS, select the **Initial Setup/Workspace Settings** icon. See red box in Figure 2-2.
2. Browse to the new location in the **Workspace Location** field.
3. Click **OK**.

Figure 2-2 *To change the workspace, select the workspace setting icon and define the new path.*

NOTE: When changing the workspace, you do not have to create the "fews_tools_WS" directory in the new drive location. The tool will automatically create the directory inside the folder you choose. For example, if you want the workspace to be `D:\fews_tools_WS`, select D:\.

2.3. Changing the default output directory

The plugin allows you to separate the results depending on the project you are working on by selecting the output directory. Click on the icon in the red box in Figure 2-3 and browse to the new directory.

Figure 2-3 *The FEWS Tools plugin allows you to select the default output directory.*

2.4. Making new data available for FEWS Tools

The FEWS Tools plugin requires climate datasets in raster (`*.bil` or `*.tif, *.tiff`) format. There are four ways of adding climate data to FEWS Tools:

1. By downloading existing data such as CHIRPS, CHIRP or any other datasets that comply with the required format.
2. By creating your own dataset. See chapter 9 for instructions on how to blend station values with a raster dataset.
3. By interpolating climate stations. See chapter 9 for instructions on how to interpolate station values only.
4. By importing a data archive, see chapter 3 on how to import archives.

Raster datasets in FEWS Tools are managed by the **Add/Edit Dataset** function, see red box in Figure 2-4.

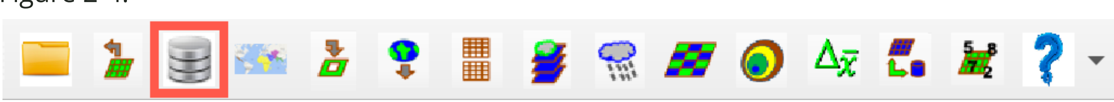


Figure 2-4 *To define a new dataset, complete the Add/Edit Dataset form.*

If you select methods 1), 2) or 3), mentioned above, to add data to FEWS Tools, the dataset must first be defined in the tool in order to work with the different functions. Method 4) adds the data definition automatically; see Import archives.

2.4.1. Define a new dataset in FEWS Tools

The definition of a climate dataset includes the following:

- The location and name of the directory containing the data
- The name-format of the raster files
- The missing-data value
- Where applicable, the FTP information for the dataset updates.

To define a climate dataset, follow these steps:

1. Create a new sub-directory in the data repository in `X:\fews_tools_WS\ProgramSettings\Data\Climate\`, (where X:\ is your drive, i.e., C:\ or D:\) and copy the raster data (tif, tiff or *.bil and *.hdr files) if you have them. Otherwise, if you are planning to download the data, we'll show you how to add the FTP information. Let's add the CHIRPS global dekadal dataset, as an example. To do this, create a new directory in the ..\climate data repository, called `CHIRPS_PPT_GLOBAL_DEKADAL`. The CHIRPS files are in the following ftp site
   *.bil https://data.chc.ucsb.edu/products/CHIRPS-2.0/global_dekad/bils/.
   *.tif https://data.chc.ucsb.edu/products/CHIRPS-2.0/global_dekad/tifs/
   Visit the site to get familiar with the data format.

2. Open the dataset definition form by clicking on the **Add/Edit Dataset** icon, in the red box in Figure 2-4. If this is the first time you open the form, the information you see is for a default dataset. You could either copy the current dataset, by clicking on the **Copy Dataset** button, and modify the existing information to reflect the dataset that you want to define or click the **New** button to start entering the information for the new dataset.

3. Complete the **Dataset Name**, for this example, `CHIRPS_PPT_GLOBAL_DEKADAL`, (Figure 2-5 (1)).

4. **Default Dataset?** Select Yes to ensure that all the functions will have this dataset selected by default, (Figure 2-5 (2)).

5. **Data type**, in this case is Rainfall. (Figure 2-5 (3)).

6. **Dataset Extent**, select global, (Figure 2-5 (4)).

7. **Periodicity**, select Dekadal, (Figure 2-5 (5)).

8. In the **Current Data** section (blue box in Figure 2.5), browse to the Data folder that you created on step 1, (Figure 2-5 (6)).

9. Define climate data file name as follows.
   The file name in a climate dataset must have the following format:
   <prefix> <date-format> <suffix> where:

a. *prefix* is a set of characters before the date that could be associated with the dataset name, descriptor, or source; (Figure2-5(7)).

b. *Date format* Pulldown Menu: The date is composed of the <year> and <period of time (pentad, dekad, or month)>. The FEWS Tools program has a variety of pre-defined formats for the date; for example, YYYYMM corresponds to the 4-digit year followed by the 2-digit month (i.e., 01, 02, 03...12). The date formats available depend on the periodicity selected on (7) above. Try changing the periodicity and see how the date formats also change. See Figure 2-5 (8).

c. *Suffix* Pulldown Menu: The suffix corresponds to any character after the date, including the extension of the file (e.g., .bil) (Figure 2.5 (9)).

d. For example, to name the rainfall total for the 36th dekad of 1991 from CHIRPS 2.0, the name of the BIL file is "v2p0chirps199136.bil." In this case, the prefix is v2p0chirps, to indicate that it is CHIRPS 2.0 data, the date-format is comprised of a 4-digit year (1991) and a 2-digit dekad (36), and <suffix> is the extension for a BIL file including the "." (.bil).

10. Fill out the **Missing Value**; for example, the missing value in CHIRPS is -9999 (Figure 2-5 (10)).

11. In the **Average Data** section, green box in Figure 2.5, click on the **Match Data Folder** button (Figure 2-5 (11)); this copies the path from the Data folder onto the Average Data folder to ensure that the long-term averages are saved into the same directory as the dataset files. This step becomes handy when updating the GeoCLIM averages.

12. Fill out the prefix, date-format and suffix (.bi, .tif, or .tiff) for the average files (Figure 2-5 (12)).

13. The missing value should be the same as defined for the current data, Figure 2-5 (10).

14. The **FTP Settings** section, yellow box in Figure 2.5, contains the necessary information to download data updates. If the dataset that you are defining does not have FTP information, this section can be empty (Figure 2-5 (13)). To setup the FTP for global CHIRPS dekads https://data.chc.ucsb.edu/products/CHIRPS-2.0/global_dekad/bils/, follow the steps below:

    a. Add the name of the remote host https://data.chc.ucsb.edu/. (Figure 2-5 (13a)).
    b. Add the remote directory where the data are located /products/CHIRPS-2.0/global_dekad/bils/. (Figure 2-5 (13b)).
    c. Add "anonymous" as the Username. (Figure 2-5 (13c)).
    d. Add "password" as the Password. (Figure 2-5 (13d)).

e. Enter the date format for v2p0chirps198101.tar.gz. in this case 4-digits year 2-digits dekad. (Figure 2-5 (13e)).
f. Enter the file prefix, in this case "v2p0chirps", and suffix ".tar.gz" (Figure 2-5 (13f)).
g. The Uncompressed Data Projection is "geographic." (Figure 2-5 (13g)).
h. The scale factor (Figure 2-5 (13h)).
i. The Uncompressed Date format in our example is 4-digits year 2-digits dekad. (Figure 2-5 (13i).
j. Enter the uncompressed prefix and suffix, "v2p0chirps" and ".bil" respectively. (Figure 2-5 (13j).

15. Once the form is completed click on the **Save** button. See chapter 3 for how to download data.

The complete **Define climate Dataset** form for *.bil data should look like Figure 2-5. Figure 2-5-a shows the form for data in *.tif or *.tiff format.

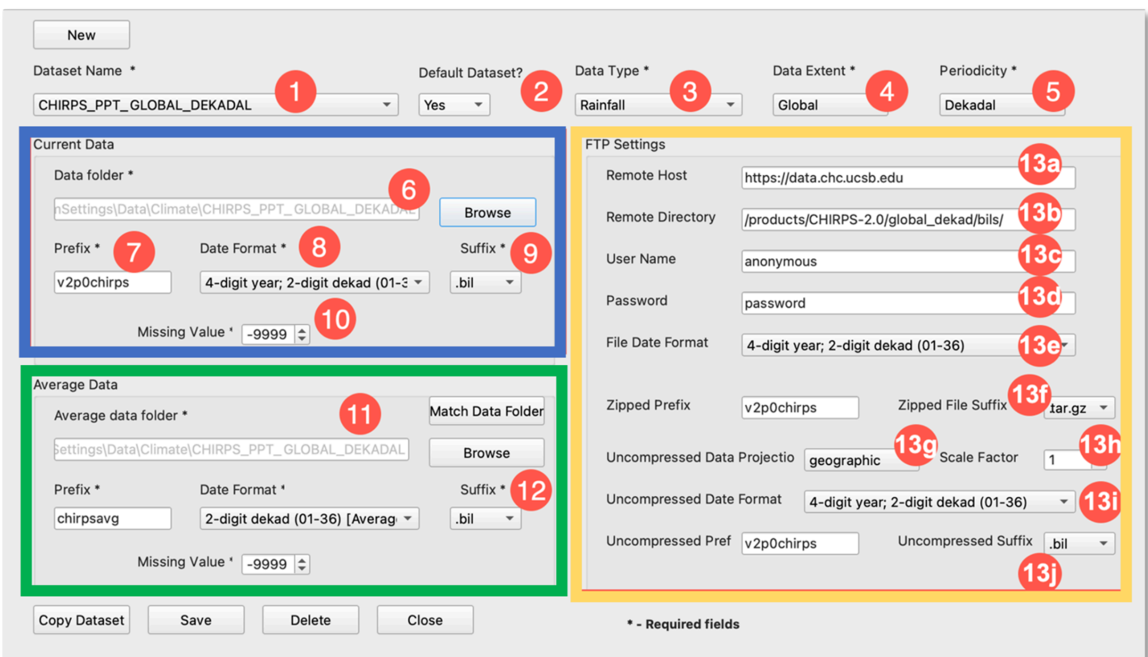


Figure 2-5 *All datasets must be defined before they can be used in the FEWS Tools.*

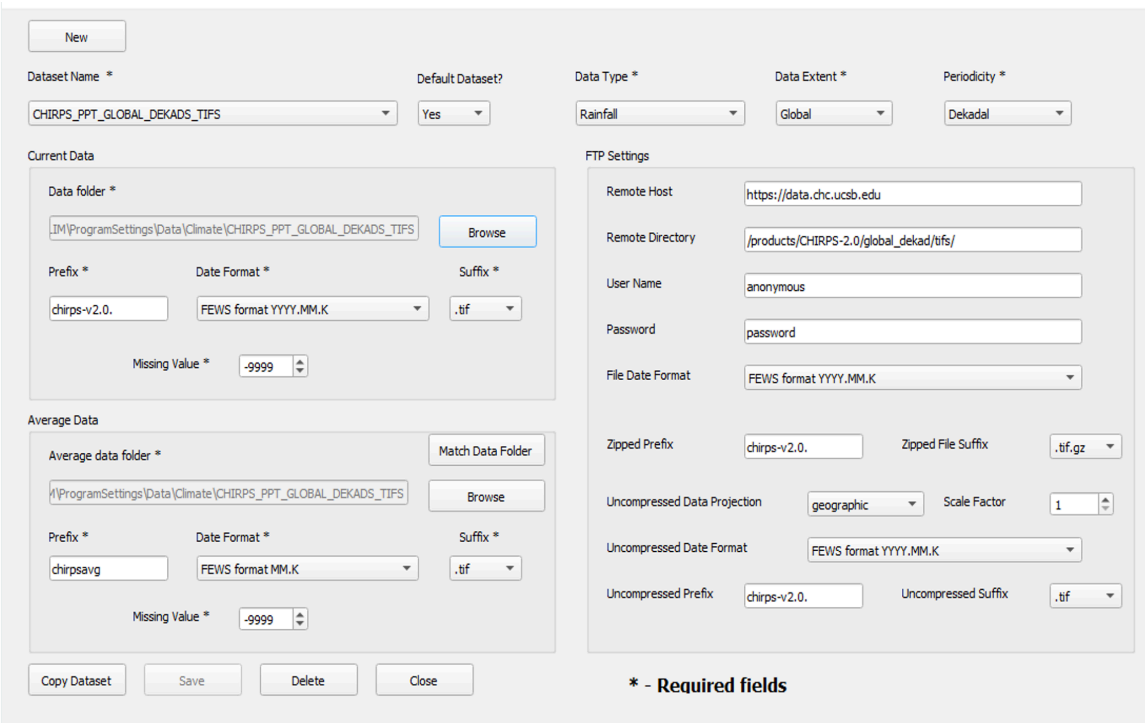


Figure 2-5-a *This is an example of the complete form for the definition of data in *.tif format to be used in FEWS Tools.*

NOTE: To learn more about the data formats used in FEWS Tools, see chapter 3.

2.5. Regions

The FEWS Tools work on specific areas of interest called Regions. The definition of a Region includes the maximum/minimum latitude and longitude, a default mask, and a set of vector maps that delineate the Region. A region could be defined to work with both GeoCLIM or GeoWRSI functions. There is a set of predefined regions in the tool, but you can always define a new one. Figure 2-10 shows the complete region form.

To define your own region, you must have the following information ready.
To work with climate data only:

- Maximum and minimum latitude for your area of interest.
- Maximum and minimum longitude for your area of interest.
- A mask file, a raster file with value of 1 for the area of interest and “0” for the areas outside (see how to create a mask on section 2.5.1).
- A polygon shapefile that delineates the area of work (i.e., watershed boundaries, administrative unit, country, etc.)

- At least one polygon shapefile to overlay the results.

To work with WRSI, add the following:

- The period number for dekads (1 – 36) for pentad (1 – 72), when the average start of season occurs
- The dekad number when the average end of season occurs
- A raster file with the dekad number for the start of season
- A raster file with the climatological WRSI
- A raster file with the water holding capacity
- A color file for the start of season

2.5.1. Create a new region in FEWS Tools

To define a region to work with GeoWRSI, see Chapter 11.

To define a new region in GeoCLIM, follow the steps below:

1. Open the **Define Region** form by clicking on the **Add/Edit Region** button, see red box in Figure 2-6 below.

Figure 2-6 *Select the Add/Edit Region icon to define a new region.*

2. Once the form opens, see Figure 2-10, it shows the information for the default region. You could either copy the region by clicking on the **Copy Region** button and edit the fields with the new information, and save it as the new region, or click on the **New** button. For example, let's create the region for Central America and the Caribbean including the northern part of South America, see area in black in Figure 2-8 below. To do this step, a polygon shapefile was prepared covering only the area of interest.
3. **Region Name**: Add the name for the new region and click ok.
4. **Set as Default?** Select yes to ensure that this region is selected when you open any function.
5. **Comments** Add any information to help describe the region.
6. Enter the minimum and maximum latitude and longitude for the new region. In our example, we are using the lat/lon for Central America and the Caribbean. This step could be done in two ways:
    a. Entering the values by hand.

b. Extracting the coordinates from an existing map as follows: Click on the **Get Extent from Map** and select one of the geographic options offered by default. For our example we select the shapefile for the region of interest. The tool retrieves the coordinates automatically, see figure 2-7.

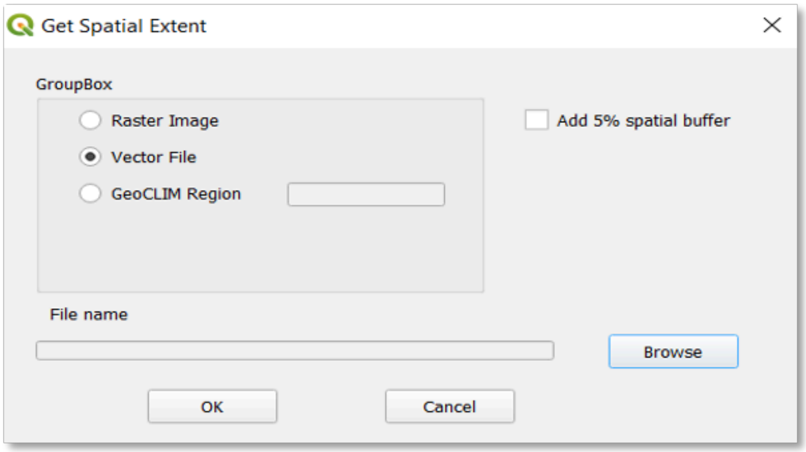


Figure 2-7 *The coordinates for the region could be obtained from an existing map.*

7. **Cell Size**: Enter the output cell size, in the case of CHIRPS it is 0.05 decimal degrees.
8. **Mask File**: Browse to `X:\fews_tools_WS\ProgramSettings\Data\Static` to select the mask file. If you do not have a mask file, you can create one at this point. Masks are raster images that are used to include only the desired area of interest in the analysis and ignore the surrounding areas. A mask is a raster dataset with pixel-value of “1” for the area of interest and “0” for outside of it. The mask facilitates the execution of the algorithms on the areas where the pixel value=1 while excluding areas where pixel values=0. You can create a mask using a shapefile of the area of interest (i.e., administration unit, watershed, etc.) following the steps below:
    a. On the region definition form click on the **Import Mask from Vector** button.
    b. Browse to select the shapefile for the area of interest, in our example the shapefile is CentralAmerica.shp, see Figure 2-8.

Figure 2-8 *The mask defines the area of interest, the black zone shows the mask for Central America, the Caribbean and the northern part of South America.*

   c. Browse to save the output mask in the `~\fews_tools_WS\ProgramSettings\Data\Static` directory. The program gives the name automatically, see Figure 2-9. Make sure that the **Outside the Map Polygon** is selected.
   d. Click **Import** to create the mask.

9. **Map File**: select a vector layer in shapefile format depicting polygons related to the region of interest, such as political boundaries, watersheds, etc. The map file is overlaid on the product. A second map file is optional.
10. Click on **Save** to keep your new region

You are now ready to work with GeoCLIM functions. See Figure 2-10 for an example of a completed form and Figure 2-11 for an example of the result (average rainfall) using this region. The image shows the Central America and Caribbean region (lat/lon), the analysis result is limited by the mask.

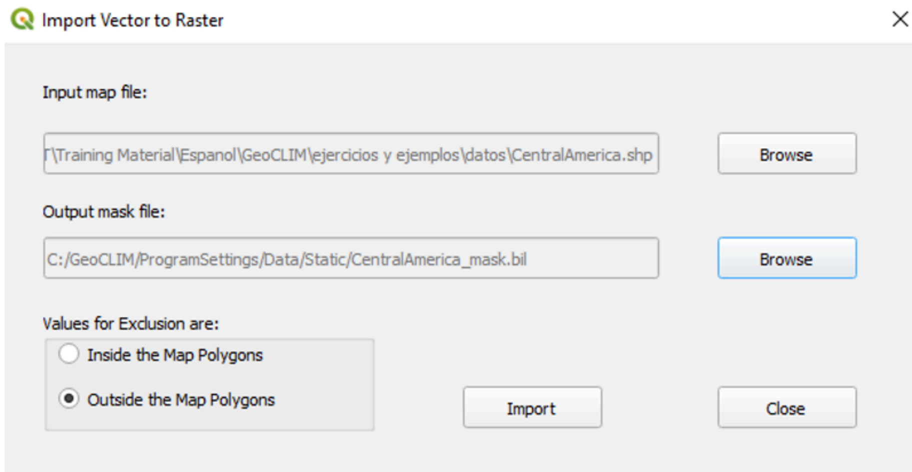


Figure 2-9 *The mask file facilitates running the GeoCLIM functions for specific areas of interest.*

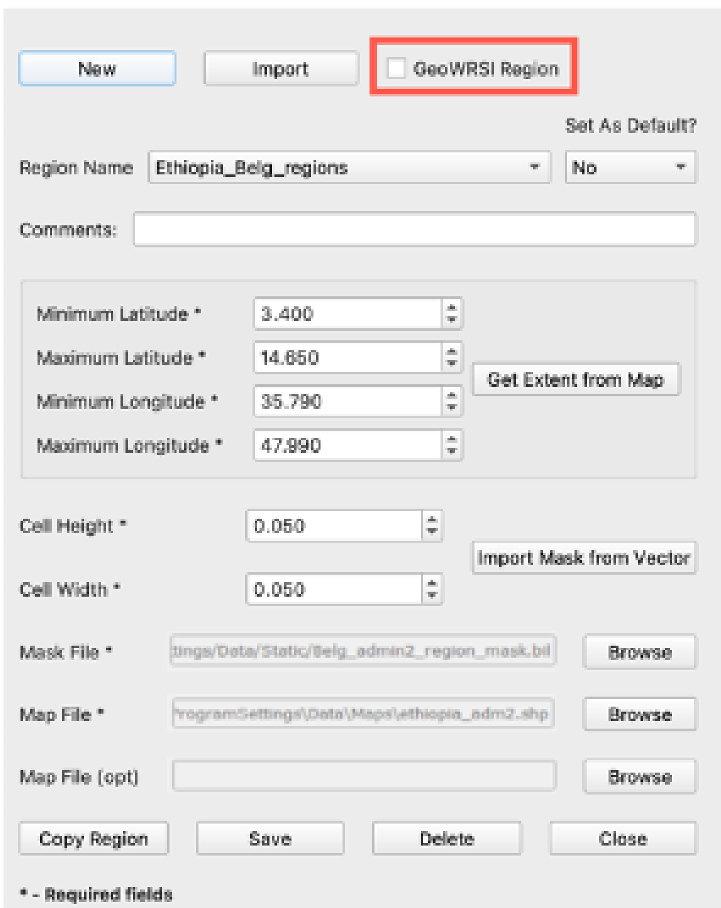


Figure 2-10 *GeoCLIM runs on specific areas of interest defined by lat/lon and a mask file, called Regions. You can add/edit WRSI parameters by clicking on the red box, see* *[Chapter 11]**.*

> **NOTE**: Use the **Import** button on the data Definition form to import regions used on the Visual Basic version of the GeoCLIM.

Global data: CHIRPS data are produced in two versions, a preliminary version that is available every five days, two days after the end of the pentad (2nd, 7th, 12th, 17th, 22nd, and 27th), and a final version that is released every month, on the middle of the following month, for example: the final data for April is available after May 15th. To conduct monitoring analyses, we use the final available data and complement it with preliminary data.

The FEWS Tools plugin provides predefined settings to download final CHIRPS for global, Africa and Central America windows: https://data.chc.ucsb.edu/products/CHIRPS-2.0/

To download dekadal global preliminary CHIRPS:
https://data.chc.ucsb.edu/products/CHIRPS-2.0/prelim/ select the format *.tiff, *.tif or *.bil.

To download dekadal global final CHIRPS:
https://data.chc.ucsb.edu/products/CHIRPS-2.0/global_dekad/ select the format *.tiff, *.tif or *.bil

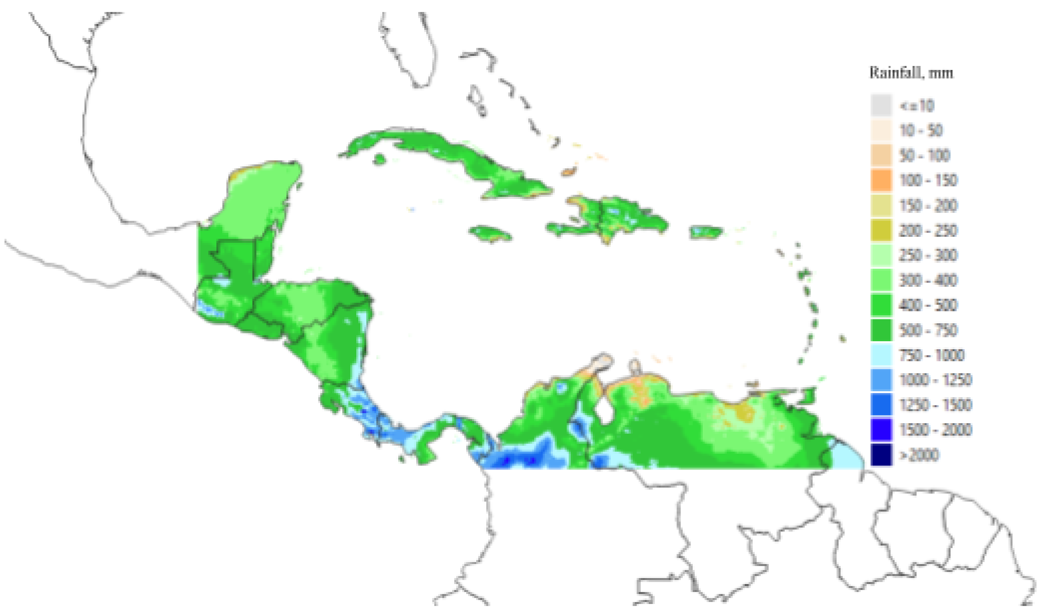


Figure 2-11 *The mask file defines the area of work. In this example, the region and mask cover the area in color.*

> **NOTE**: The size of the region **must** be smaller or equal to the size of the climate dataset. Otherwise, the region becomes unavailable when selecting the dataset. In other words, if you do not see your region in the pulldown menu, after selecting your dataset, it may be because the geographic extent of the region is bigger than that of the dataset.

2.6. The FEWS Tools database: fews_tools.sqlite file

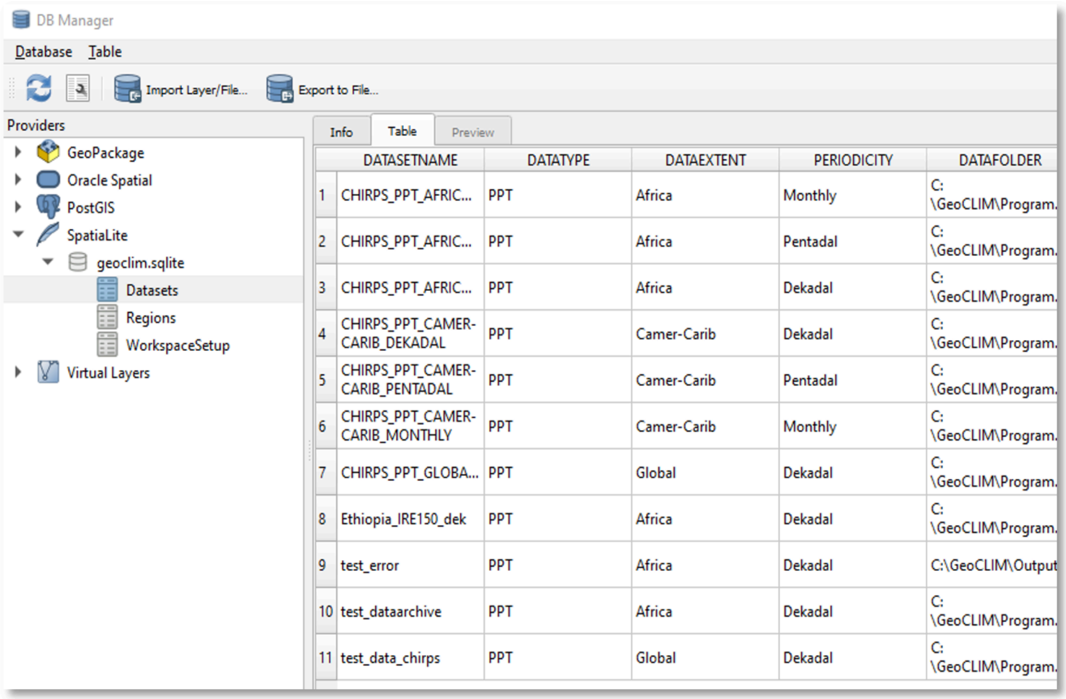


Figure 2-12 *You could see the content of the fews_tools.sqlite file on the Database pulldown menu on the main QGIS toolbar.*

The fews_tools.sqlite file that is found in the fews_tools directory in the following path `c:\Users\[user]\AppData\Roaming\QGIS\QGIS3\profiles\default\python\plugins\fews_tools\` holds all the changes mentioned in this chapter such as workspace changes and all the datasets and regions that you add or edit. You can see the content of the fews_tools.sqlite by clicking on the **Database** pulldown menu on the main QGIS toolbar. Select the **DB manager** and open the `SpatialLite/ fews_tools.sqlite`. Please explore the content of the file, see Figure 2-12. Remember that all changes must be done through the setting in the FEWS Tools main toolbar. Please backup the `fews_tools.sqlite file` periodically to ensure that you have all the settings saved.

NOTE: Sometimes the directories to the **fews_tools** folder are hidden, just go on the file explorer path, and type the next directory. You should be able to see the next directory in the list. Continue selecting directories until you get to **fews_tools**.

NOTE: For existing users of QGIS/GeoCLIM, (for versions before 3.1), place the geoclim.sqlite file that you have saved, into the fews_tool directory after installing the new version. Restart QGIS, follow the instructions and all the content in the Geoclim.sqlite file will be copied to the fews_tools.sqite file. After that, back up only the fews_tools.sqlite file to save your settings.

2.6.1. Connecting the fews_tools.sqlite file

In case the fews_tools.sqlite file does not show on the QGIS DB_manager/SpatiaLite menu, connect it as follows:

1. In the QGIS main Menu, select **Layer/Add Layer/Add SpatiaLite Layer**, see Figure 2-13a below, to open the Data Source Manager SpatiaLite dialog box.
2. Click on **New** button, navigate to the fews_tool folder (`C:\Users\Pedreros\AppData\Roaming\QGIS\QGIS3\profiles\default\python\plugins\fews_tools`) then select fews_tools.sqlite file and click on **OK** button, see Figure 2-13b.
3. Click on Connect button, then on Close button.
4. From QGIS Main Menu, select Database/DB Manager to open the DB Manager dialog box.
5. Open **SpatiaLite**, then `fews_tools.sqlite` to view its content.

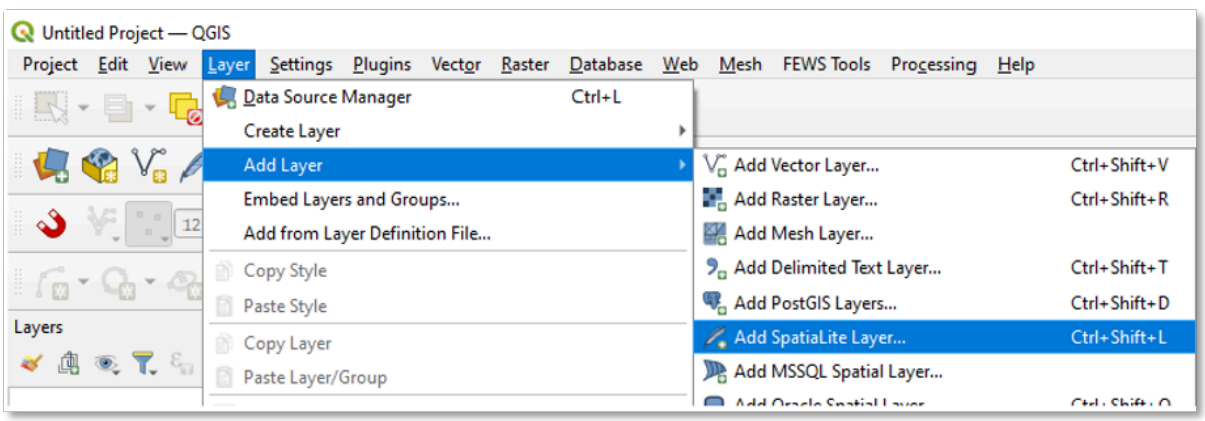


Figure 2-13a *To add a new SpatiaLite file to the DB_management, go to layers and add a layer.*

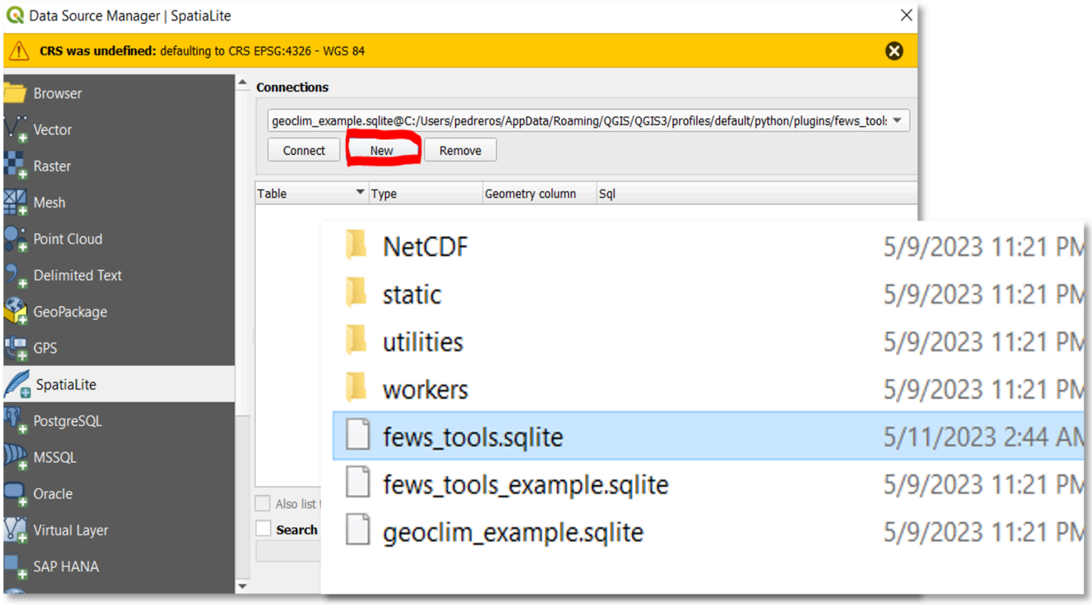


***Figure 2-13b** Select New and navigate to the fews _tools directory and select the fews_tools.sqlite.*

Section 2
Data Management Functions

Chapter 3: Data Management in FEWS Tools Plugin

Summary

This chapter examines the data management in the FEWS Tools plugin for QGIS, including the different types of data formats used, downloading data, data availability, and data import/export using archives.

3.1. Data types

GeoCLIM uses four main data types: raster data in BIL format BIL (`* .bil`) and GeoTIF (`*.tif` or `*.tiff`), vector data in shapefile format (`*.shp`), tables in comma-delimited format (`*.csv`), and data Archives.

3.1.1. Characteristics of the raster dataset

A band interleaved by line (`BIL`) dataset contains two files: a (`*.bil`) file and a header file (`*.hdr`). The `.bil` file is a binary file that contains the pixel values (e.g., rainfall, temperature, etc.), while the `HDR` file contains the characteristics of the dataset, such as the geographic location, pixel size, and depth.

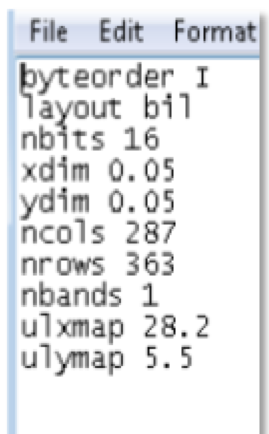


***Figure 3-1** Example of a HDR file.*

The header file is an ASCII text file; it can be generated or edited from a text editor (e.g., Notepad). For example, Figure 3-1 shows that the header file contains information about the number of columns (`ncols`), number of rows (`nrows`), number of bits per pixel (`nbits`), and size of pixel (`xdim` and `ydim`), among others. Figure 3-1 also shows the xdim and ydim values corresponding to the horizontal (x-dimension) and vertical (y-dimension) dimensions of a pixel with a size of 0.05 degrees, which is about 5 kilometers. The `ulxmap` and `ulymap` correspond to the x-axis and the y-axis coordinates of the center of the upper-left pixel of the raster image. There are additional keywords that the header could have (Figure 3-2) (ArcMap 10.3 Help, ESRI). Sometimes, if the header file is incorrect, you may need to modify it so that the data is read correctly by the program.

> **NOTE**: By default, the BIL dataset pixel type used is unsigned integers, unless the keyword "pixeltype" is used in the HDR file, and its value is "signedint".

Keyword	Acceptable Value	Default
nrows	Any integer > 0	None
ncols	Any integer > 0	None
nbands	Any integer > 0	1
nbits	1, 4, 8, 16, 32	8
pixeltype	SIGNEDINT	Unsigned Integer
byteorder	I = Intel; M = Motorola	Same as host machine
layout	bil, bip, bsq	bil
skipbytes	Any integer ≥ 0	0
ulxmap	Any real number	0
ulymap	Any real number	nrows - 1
xdim	Any real number	1
ydim	Any real number	1
bandrowbytes	Any integer > 0	Smallest integer ≥ (ncols x nbits) / 8
totalrowbytes	Any integer > 0	For bil: nbands x bandrowbytes; for bip: smallest integer ≥ (ncols x nbands x nbits) / 8
bandgapbytes	Any integer ≥ 0	0

Figure 3-2 *The header file is composed of a series of key words and their respective accepted values. Source: ArcMap 10.3 Help, ESRI.*

An important keyword in the header file is the `pixeltype` since it defines the type of value, `unsigned` (+), or `signed` (+ or -) a pixel could have. For example, rainfall data could only have `unsigned` (+) values since precipitation is only positive. However, if you look at the header file for CHIRPS, it uses `signed` values (+ or -) since the `nodata` value is -9999. In the example in Figure 3-1, the `pixeltype` is missing, so the program assumes that the data is unsigned; in the case of CHIRPS, we would have to add a new line on the header file defining the `pixeltype` as `signedint`. Another keyword to keep in mind is the `nbits` because it indicates the number of bits per pixel or the depth of the raster image (e.g., nbits=16 bit means that a pixel in the raster dataset can have any one of 2^{16} = 65536 unique values). Figure 3-3 (ESRI, Support 2016) shows a list of values a raster dataset could have depending on the pixel depth or `nbits` value.

unsigned 1 bit = 0 to 1
unsigned 2 bit = 0 to 4
unsigned 4 bit = 0 to 16
unsigned 8 bit = 0 to 255
signed 8 bit = -128 to 127
unsigned 16 bit = 0 to 65535
signed 16 bit = -32768 to 32767
unsigned 32 bit = 0 to 4294967295
signed 32 bit = -2147483648 to 2147483647
floating point 32 bit = -3.402823466e+38 to 3.402823466e+38

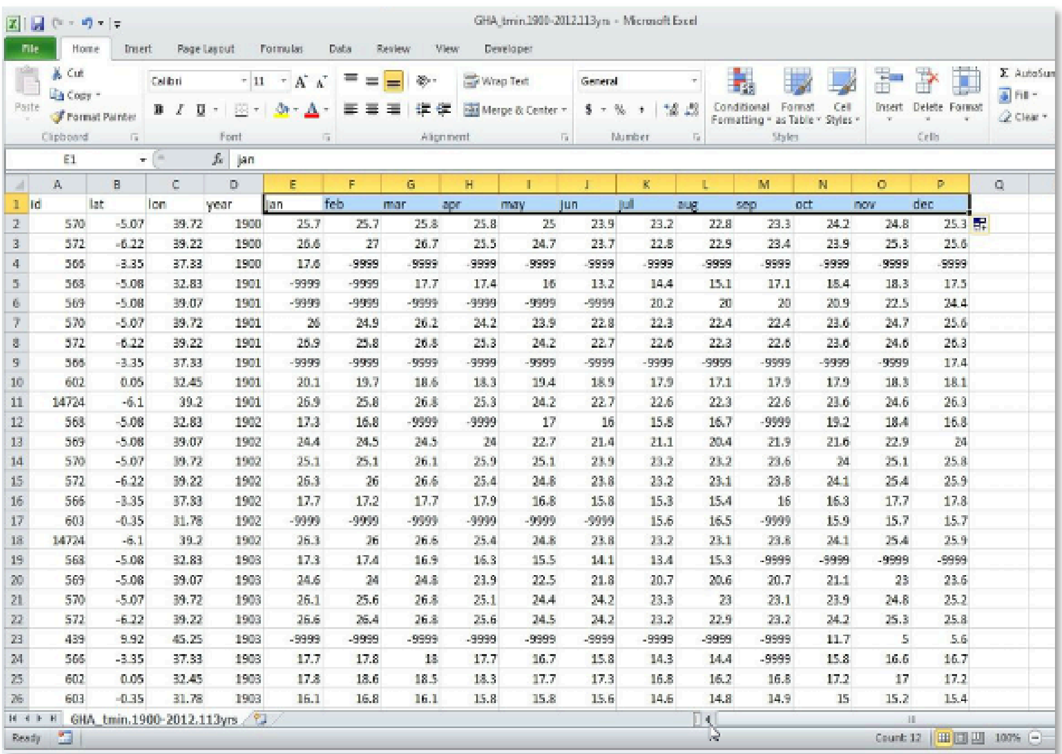
Figure 3-3 *The range of values a dataset could store depends on the nbits.*

3.1.2. Vector data

Another type of data used in FEWS Tools is vector data in shapefile format (`*.shp`). To get more information about how to open, create, or edit shapefiles in QGIS, go to Appendix A.

3.1.3. Tables

The GeoCLIM program uses tables in comma-delimited format (`*.csv`) as input and output data. For example, tables are inputs in the process of blending raster data with station values (**BASIICS**) or validating raster data. For the blending process, the CSV table must have columns for **ID, latitude (lat), longitude (long), year,** and **time period** (pentads, dekads, or months), such as the months of January-December in Figure 3-4. The ID, lat, lon, and year columns do not have to be in any order, and additional columns are permitted. However, the time-period columns need to be consecutive (Figure 3-4).



id	lat	lon	year	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
570	-5.07	39.72	1900	25.7	25.7	25.8	25.8	25	23.9	23.2	22.8	23.3	24.2	24.8	25.3
572	-6.22	39.22	1900	26.6	27	26.7	25.5	24.7	23.7	22.8	22.9	23.4	23.9	25.3	25.6
566	-3.35	37.33	1900	17.6	-9999	-9999	-9999	-9999	-9999	-9999	-9999	-9999	-9999	-9999	-9999
568	-5.08	32.83	1901	-9999	-9999	17.7	17.4	16	13.2	14.4	15.1	17.1	18.4	18.3	17.5
569	-5.08	39.07	1901	-9999	-9999	-9999	-9999	-9999	-9999	20.2	20	20	20.9	22.5	24.4
570	-5.07	39.72	1901	26	24.9	26.2	24.2	23.9	22.8	22.3	22.4	22.4	23.6	24.7	25.6
572	-6.22	39.22	1901	26.9	25.8	26.8	25.3	24.2	22.7	22.6	22.3	22.6	23.6	24.6	26.3
566	-3.35	37.33	1901	-9999	-9999	-9999	-9999	-9999	-9999	-9999	-9999	-9999	-9999	-9999	17.4
602	0.05	32.45	1901	20.1	19.7	18.6	18.3	19.4	18.9	17.9	17.1	17.9	17.9	18.3	18.1
14724	-6.1	39.2	1901	26.9	25.8	26.8	25.3	24.2	22.7	22.6	22.3	22.6	23.6	24.6	26.3
568	-5.08	32.83	1902	17.3	16.8	-9999	-9999	17	16	15.8	16.7	-9999	19.2	18.4	16.8
569	-5.08	39.07	1902	24.4	24.5	24.5	24	22.7	21.4	21.1	20.4	21.9	21.6	22.9	24
570	-5.07	39.72	1902	25.1	25.1	26.1	25.9	25.1	23.9	23.2	23.2	23.6	24	25.1	25.8
572	-6.22	39.22	1902	26.3	26	26.6	25.4	24.8	23.8	23.2	23.1	23.8	24.1	25.4	25.9
566	-3.35	37.33	1902	17.7	17.2	17.7	17.9	16.8	15.8	15.3	15.4	16	16.3	17.7	17.8
603	-0.35	31.78	1902	-9999	-9999	-9999	-9999	-9999	-9999	15.6	16.5	-9999	15.9	15.7	15.7
14724	-6.1	39.2	1902	26.3	26	26.6	25.4	24.8	23.8	23.2	23.1	23.8	24.1	25.4	25.9
568	-5.08	32.83	1903	17.3	17.4	16.9	16.3	15.5	14.1	13.4	15.3	-9999	-9999	-9999	-9999
569	-5.08	39.07	1903	24.6	24	24.8	23.9	22.5	21.8	20.7	20.6	20.7	21.1	23	23.6
570	-5.07	39.72	1903	26.1	25.6	26.8	25.1	24.4	24.2	23.3	23	23.1	23.9	24.8	25.2
572	-6.22	39.22	1903	26.6	26.4	26.8	25.6	24.5	24.2	23.2	22.9	23.2	24.2	25.3	25.8
439	9.92	45.25	1903	-9999	-9999	-9999	-9999	-9999	-9999	-9999	-9999	-9999	11.7	5	5.6
566	-3.35	37.33	1903	17.7	17.8	18	17.7	16.7	15.8	14.3	14.4	-9999	15.8	16.6	16.7
602	0.05	32.45	1903	17.8	18.6	18.5	18.3	17.7	17.3	16.8	16.2	16.8	17.2	17	17.2
603	-0.35	31.78	1903	16.1	16.8	16.1	15.8	15.8	15.6	14.6	14.8	14.9	15	15.2	15.4

Figure 3-4 *GeoCLIM accepts tables in comma delimited format (CSV).*

3.1.4. Climate data archives in FEWS Tools

A climate data archive is a compressed file with the ending '.climdata' that contains a group of files of a specific climatic variable. The Archive contains the necessary information to define the data in the FEWS Tools plugin. This is an easy way to save a copy of the dataset, or part of it, that has been defined in the tool or to share data between users. See section 3.4 for instructions on how to create an Archive.

3.2. Download data

The plugin allows you to download data for those datasets that include FTP information on their definition form. To download data, follow the steps below:

1. Click on the Download Data by Date icon on the main toolbar. See red box in Figure 3-5.

Figure 3-5 *To download data using FEWS Tools, make sure that the ftp information is included in the dataset definition. Click on the download icon and complete the form.*

2. Select the dataset that you want. Figure 3-6 **(1)**.
3. The **Data Extent (2), Duration (3) and Parameter (4)** should change accordingly. Figure 3-6.
4. Select the starting and ending date. Figure 3-6.
5. Click ok to start the download. Figure 3-6.

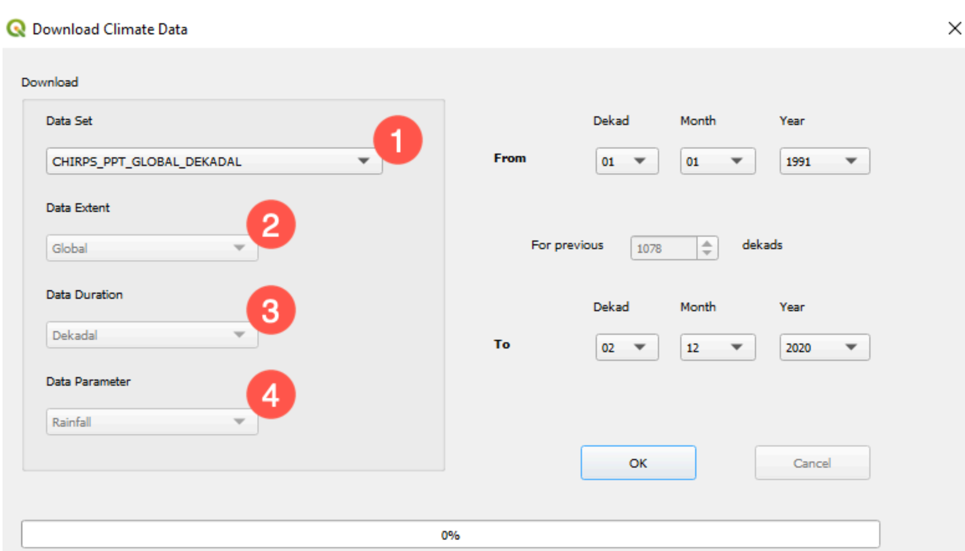


Figure 3-6 *Download data by date for a selected dataset.*

Global Data: CHIRPS data are produced in two versions, a preliminary version that is available every five days, two days after the end of the pentad (2nd, 7th, 12th, 17th, 22nd, and 27th), and a final version that is released every month, on the middle of the following month, for example: the final data for April is available after May 15th. To conduct monitoring analyses, we combine the final available data and complement it with preliminary data.
The FEWS Tools plugin provides predefined settings to download final CHIRPS for global, Africa and Central America windows:
https://data.chc.ucsb.edu/products/CHIRPS-2.0/
To download dekadal global **preliminary** CHIRPS:
https://data.chc.ucsb.edu/products/CHIRPS-2.0/prelim/ select the format *.tiff, *.tif or *.bil.
To download dekadal global **final** CHIRPS:
https://data.chc.ucsb.edu/products/CHIRPS-2.0/global_dekad/ select the format *.tiff, *.tif or *.bil.

3.3. Data availability/export data

The **View Available Data** function, see red box in Figure 3-7 facilitates the following:

a) Display a list of files in your dataset
b) Display a list of missing files in the timeseries
c) Deletes files in the dataset.
d) Exports the dataset or part of it into an archive in the same file format.

To check the available datafiles in your dataset click on the **View Available Data** icon on the main toolbar.

Figure 3-7 *To view the data available to run the GeoCLIM/GeoWRSI functions, click on the View Available Data icon and select the desired dataset.*

The function will open the information for the default dataset. Select the desired dataset from the pulldown menu. The **Available Rainfall Data** tool also allows you to identify the missing data in the time series, Figure 3-8. Click on **List Missing Data** to obtain a list of missing files in the time series. Select the complete or part of the dataset and click on the **Export** button to save the selected files into a data archive that could be shared with other users. A data archive is a compressed file that includes all the files, selected on the **Available Rainfall Data** tool, together with the data-definition information.

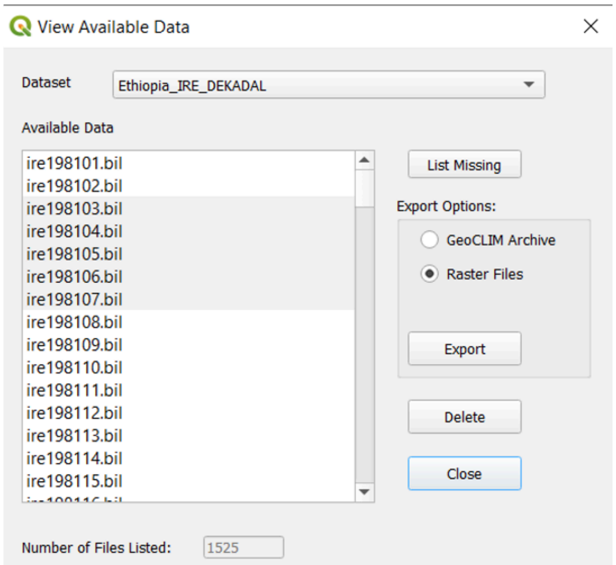


Figure 3-8 *The View available Data tool allows to list the data files in the time-series for a selected climate dataset.*

3.4. Create an Archive

To create an archive, follow the steps below:

1. Open the **View Available Data** tool.
2. Select a climate variable.
3. Select the entire or part of the time-series to be added to an archive.
4. Click **Export.**
5. Give a name to the new archive and click **OK** .
6. Select the destination directory.
7. Click **OK** . A new file with "`.climdata`" format is created in the destination directory.

3.5. Importing archives

To import an archive, follow the steps below:

1. Open the **Import Climate Data Archives** tool from the toolbar. See Figure 3-9.
2. Browse to the archive to be imported and click **Import**.

To ensure that the archive imported correctly, open the **View Available Data** function, and click on the dataset pulldown menu and select the new dataset.

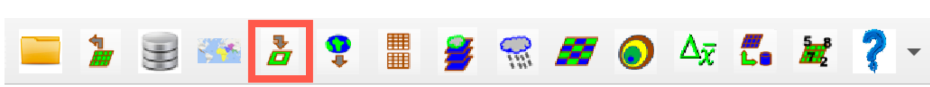


Figure 3-9 *FEWS Tools allows you to share with other users a complete or part of a dataset using a data archive.*

Section 3
GeoCLIM Analysis Functions

Chapter 4: Climatological Analysis

Summary

Figure 4-1 *The Climatological Analysis tool facilitates the calculation of statistics among other functions for climate variables.*

The **Climatological Analysis** tool (red box in Figure 4-1) facilitates the calculation of statistics, trends, and frequencies (among others) for rainfall, temperature, and evapotranspiration. The tool uses data that have already been downloaded or imported into the FEWS Tools data directory (see chapter 2 for how to manage data in FEWS Tools). You can analyze a climate time-series or just a selected subset, such as the March-April-May season for a given number of years such as El Niño years; for example, you may select 1982-83, 1986-87, 1987-88, 1991-92, 1997-1998, 2002-03, 2009-10, 2015-16.

The **Climatological Analysis** tool includes the following analysis methods:

- **Average**: Calculates the temporal average value for each pixel for a period or group of periods using the years selected.
- **Median**: Calculates the midpoint value of a frequency distribution for the selected climate variable for a group of periods using the selected years.
- **Standard deviation**: Calculates the standard deviation in a frequency distribution for the selected climate variable for a group of periods using the selected years.
- **Count**: Counts the number of valid values by pixel in a time-series.
- **Coefficient of variation**: Calculates the Coefficient of Variation (CV), which is the ratio of the SD to the mean in percent.
- **Trend**: Calculates a linear trend using a regression analysis of the seasonal values and time.
- **Percentiles**: Produces a raster map with the rainfall value for each pixel corresponding to the percentile rank requested.
- **Frequency**: Calculates the number of times a range of values has occurred in the time-series.
- **Standardized Precipitation Index (SPI)**: Presents a rainfall anomaly as a normalized variable.

4.1. Running climatological Analysis

To open the climatological analysis tool, Click on the **Rainfall Climatological Analysis** icon on the GeoCLIM toolbar (Figure 4-2).

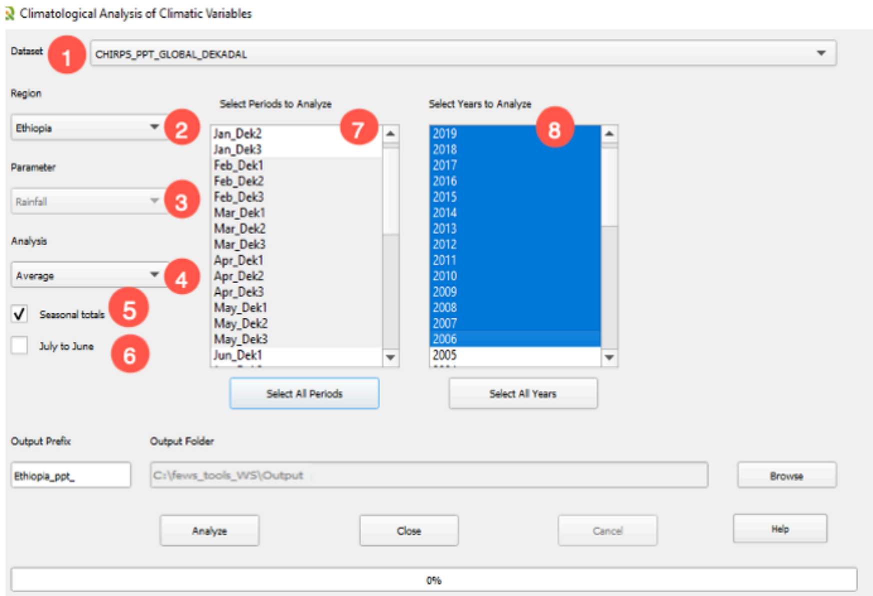


Figure 4-2 *The Climatological Analysis tool facilitates the calculation of statistics, trends, SPI among other analysis, using the complete or part of the time series for a season.*

To use the tool, follow the steps below:

1. Select the dataset from the **Dataset ˅** pulldown menu, (Figure 4-2 (1)). This will make available the regions that are within the geographic domain of the dataset. If your region is not available, make sure that the lat/lon box of your region is inside the domain of the dataset.
2. Select the region of interest (Figure 4-2 (2)), (see chapter 2 to set up a region).

NOTE: The number of regions available depend on the geographic extent of the dataset. If your region does not show up after selecting the dataset, make sure that your region is inside the geographic domain of the dataset.

3. The Parameter field is filled automatically with the name of the climate variable (Rainfall, Avg Temperature, Min Temperature, Max Temperature, or Evapotranspiration) depending on the dataset selected, see (Figure 4-2 (3)).
4. Select the type of analysis from the **Analysis ˅** menu (Figure 4-2 (4)).

5. Check the ■ **Add up seasonal totals** box as shown in (Figure 4-2 (5)), to indicate that the analysis will be done using the seasonal totals.
6. If the season to analyze goes across years, for example, Oct to March, check the ■ **July to June** Sequence checkbox (Figure 4-2 (6)).
7. Select the periods comprising a season of interest on the left panel. The data period (pentads, dekads, or months) is based on the selected climate dataset. In this case, the data period is 10 days totals (dekads) (Figure 4-2 (7)).
8. Select the years of interest on the right panel (Figure 4-2 (8)).
9. (Optional) Modify the **Output Folder** field if you want to save outputs in a different location than the default path.
10. Modify the **Output Prefix** if necessary.

NOTE: Make sure the last year selected contains a complete season; otherwise, there will be a "missing data" error message that would prevent the tool from running.

The output from this analysis is displayed on the **QGIS** canvas (Figure 4-3). This result is also saved in the output folder together with the seasonal totals for each year, as raster data sets in the same format as the input data.

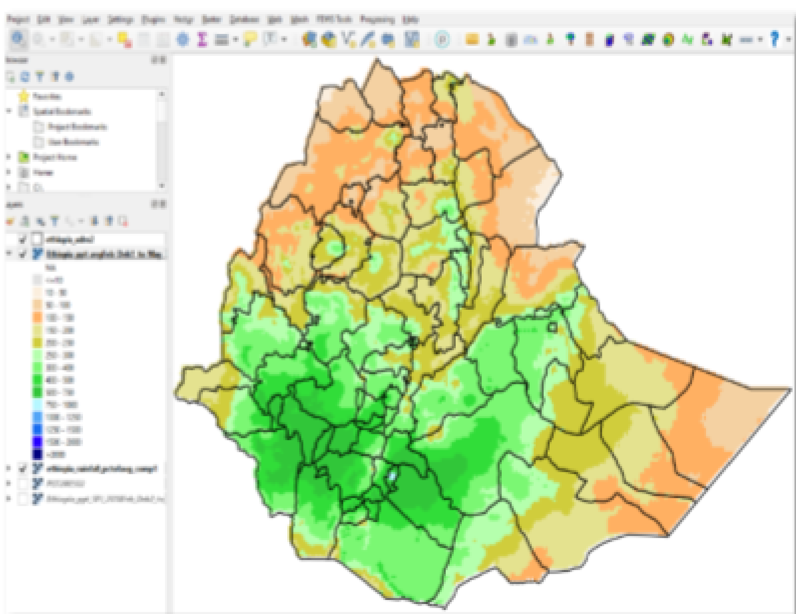


Figure 4-3 *Average rainfall for the period Feb dek01-May dek03 1981-2010.*

NOTE: If multiple periods are selected (e.g., March-April-May) and the ■ **Add up seasonal totals box** is NOT checked, the process runs for each month, and the results are displayed on the QGIS canvas.

4.2. Updating dataset averages

FEWS Tools uses the average for each period (pentad, dekad, or month) for calculating anomalies. The **Climatological Analysis** tool calculates the average for every period based on the information saved during the dataset definition, (see Settings, chapter 2). To calculate the average, follow the steps below:

1. Select the Dataset, Figure 4-4(1)
2. Select all the periods, Figure 4-4(2)
3. Select the years to be used in calculating the average, Figure 4-4(3). Make sure that all the years selected have data for all the periods.
4. Check the ■ **Update dataset averages** box, Figure 4-4(4)
5. Click on Analyze. The raster-file outputs are saved in the folder and with the prefix defined on the climate dataset definition.

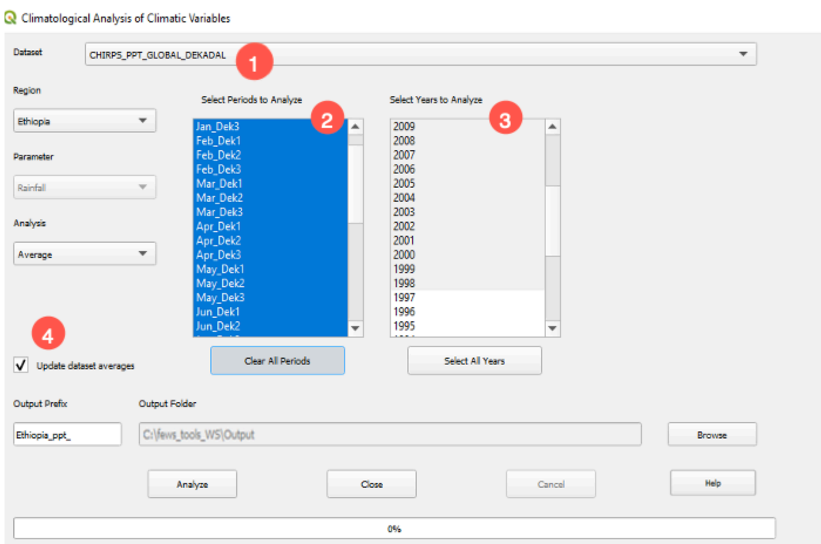


Figure 4-4 *The Climatological analysis tool allows us to calculate the average for each period (month, dekad or pentad) for the dataset.*

NOTE: The ■ **Update dataset averages** option creates the average for the geographic extend of the dataset.

4.3. Analysis Methods

4.3.1. Average

The **Average** analysis method calculates the temporal average value for each pixel for a period, for example, the month of May, dekad 3, or a season (May-June-July) using the years and region selected. Figure 4-5 shows the average rainfall using CHIRPS data for the period May to July 1981-2013, for the selected region (EAC). In other words, the map represents the average of all May-June-July rainfall totals from 1981 to 2013.

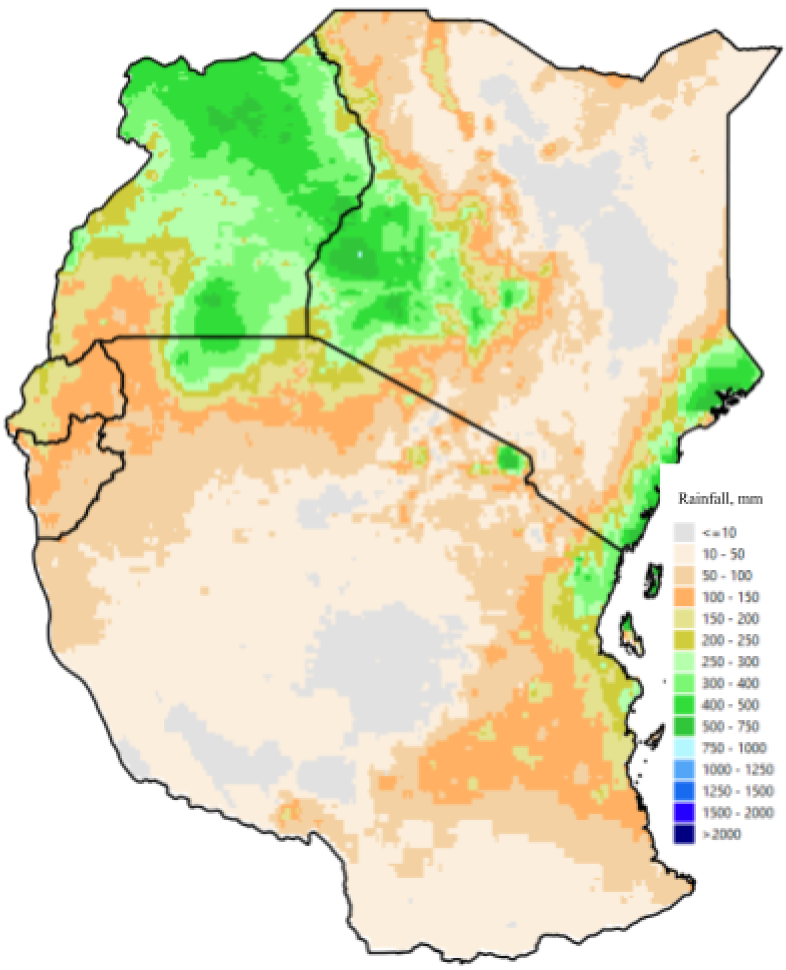


Figure 4-5 *Average rainfall (mm) for the May-July season for the years 1981-2013.*

To calculate the average, follow the steps below:

1. Start the **Climatological Analysis** tool, as described in section 4.1
2. Select the dataset
3. Select the region
4. Select Average from the analysis methods list
5. Check the ■ **Seasonal totals** option
6. Select May Dek1 to July dek3 on the left panel and 1981-2013 on the right
7. Click on **Analyze** to run the tool.

NOTE: When the ■ **Seasonal totals** option is not checked, the average is calculated for each period selected (pentad, dekad, or month). In the example above, the module would calculate the average for May dekad 1; 1981-2013, May dekad 2; 1981-2013, etc., until July Dekad 3.

NOTE: A by-product of this process is a seasonal total file in raster format saved for each year in the output directory.

4.3.2. Median

The **Median** analysis method calculates the midpoint value of a frequency distribution for the selected climate variable. Figure 4-6 shows an example of median output calculated for May-to-July rainfall totals for the years 1981-2013.

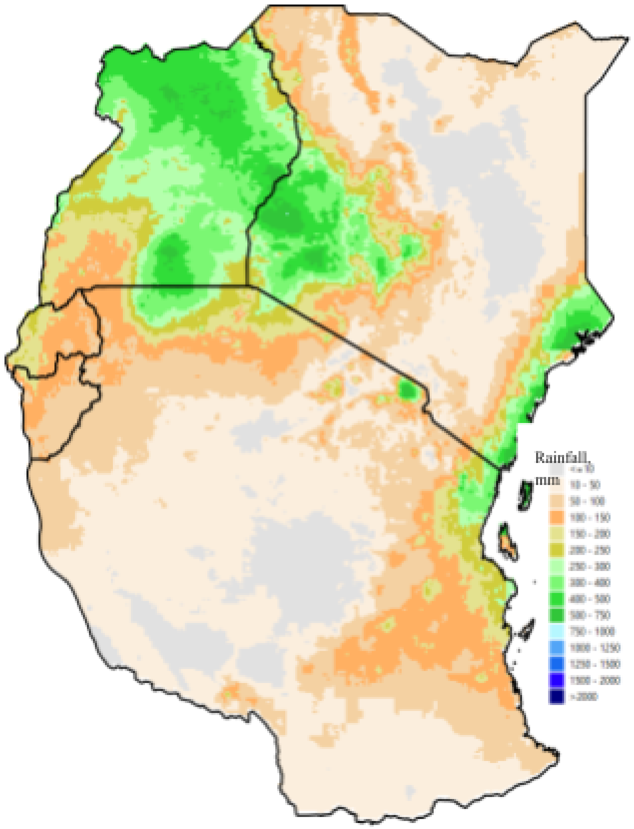


Figure 4-6 *Median (mm) for the season May-July for the years 1981-2013.*

To calculate the median, follow the steps below:

1. Start the **Climatological Analysis** tool, as described in section 4.1
2. Select the dataset
3. Select the region
4. Select the season on the left panel and the years on the right panel
5. Check the ■ **Seasonal totals** option
6. Select Median from the analysis methods list
7. Click on **Analyze** to run the analysis

4.3.3. Measuring variability with standard deviation and coefficient of variation

FEWS Tools provides two different methods of estimating variability. The standard deviation (SD) shows the variability within the time-series over the selected years for each pixel, while the coefficient of variation (CV) shows the SD as a percent of average, facilitating the comparison of the variability among regions.

4.3.3.1. Standard deviation

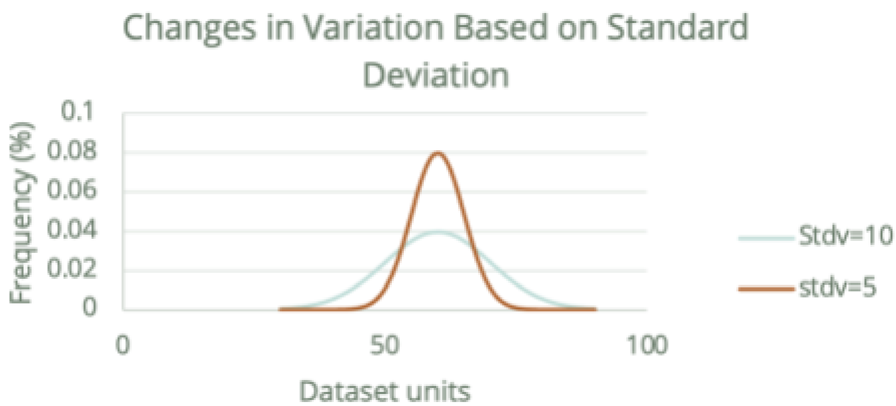


Figure 4-7 *The distribution of two data sets with the same mean and different SD. The orange line shows a low SD (stdv=5) indicating low variability within the data; values are closer to the mean. The blue line shows the distribution of a more variable data set (stdv=10).*

The standard deviation (SD) is a measure of variation or how spread out the data are from the mean. An increase in the SD indicates that the data is more variable (Figure 4-7). See Figure 4-8(a) for an example of an SD product using FEWS Tools.

4.3.3.2. Coefficient of variation.

The Coefficient of Variation (CV) is the ratio of the SD to the mean

$$CV = \left(\frac{SD}{average}\right) * 100.$$

SD	Mean	CV
171mm	721mm	24%

Table 4.1 *The CV is the ratio of the SD over the mean.*
Figure 4-8 (a.1) and (a.2) show an example of low and high SD, respectively. But this information alone does not allow us to determine which area is more variable. The CV allows us to compare different magnitudes of variation or between regions with different means. Figure 4-8 (b) shows that even though regions 1 and 2 have low/high SD when compared to the average amount of rainfall, area 1 is more variable.

To calculate standard deviation or coefficient of variation, follow the steps below:

1. Start the **Climatological Analysis** tool, as described in section 4.1
2. Select the dataset
3. Select the region

4. Select the season on the left panel and the years on the right panel
5. Check the ■ **Seasonal totals** option
6. Select Standard Deviation or Coefficient of Variation from the analysis methods list
7. Click on **Analyze** to run the analysis

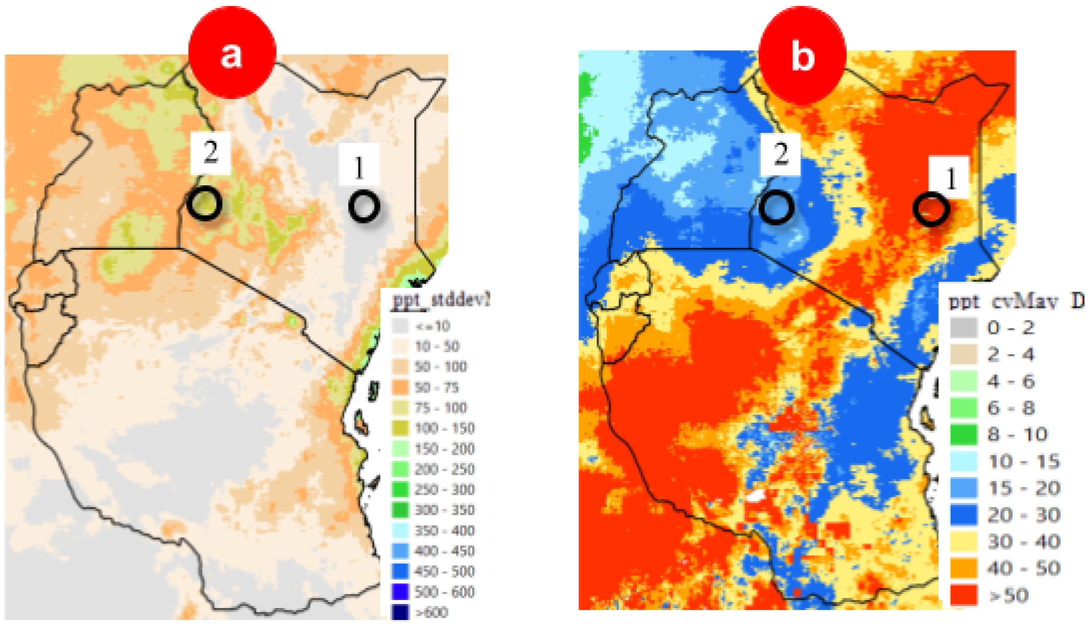


Figure 4-8 *(a) shows the SD of rainfall (mm), (b) presents the CV (SD as a percent of the mean) allowing the comparison among areas. The SD of areas 1 and 2 shown as low/high value but 1 is highly variable compared to area 2, as shown by the CV.*

4.3.4. Count

The count analysis method on the **Climatological Rainfall Analysis** tool shows the number of pixels in the selected years, with valid values (any values which are not missing value). The example in Figure 4-9 shows the count as 40 (1981-2020) for all pixels, which means there are no missing values in the time-series used in the analysis.

To calculate count, follow the steps below:

1. Start the **Climatological Analysis** tool, as described in section 4.1
2. Select the dataset
3. Select the region
4. Select the season on the left panel and the years on the right panel
5. Check the ■ **Seasonal totals** option
6. Select Count from the analysis methods list
7. Click on **Analyze** to run the analysis

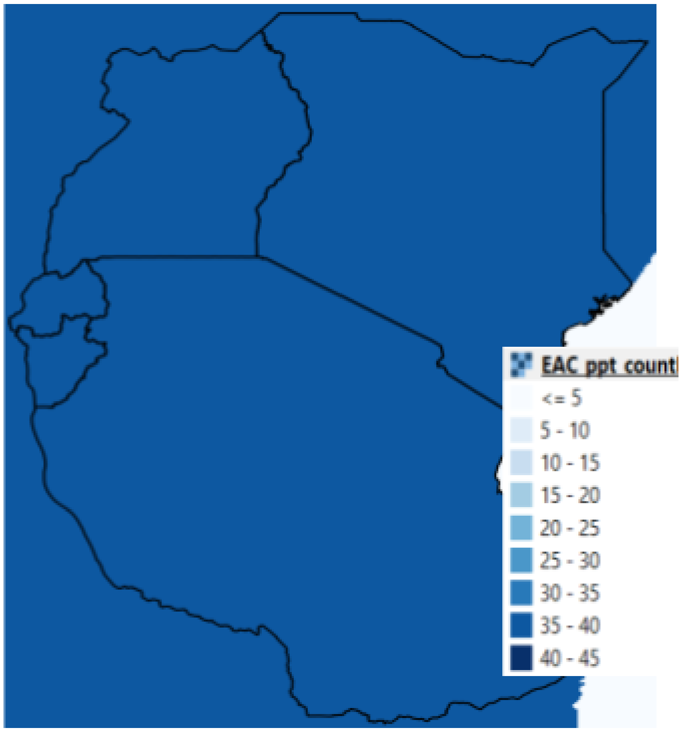


Figure 4-9 *The function counts the number of valid values in the time series. In the example, there is no missing data and there are 40 values.*

4.3.5. Trend

The trend is an analysis technique that helps us identify a change in the expected value of a variable that occurs over a long period of time. The trend analysis method first calculates the total seasonal rainfall for each selected year and then calculates a linear trend using a regression analysis of the seasonal values and time (Figure 4-10). This function produces two maps; one is the slope of the regression which represents the trend, and the other is the coefficient of determination (r-squared, or r2), which represents the strength of the relationship.

To calculate the trend, follow the steps below:

1. Start the **Climatological Analysis** tool, as described in section 4.1
2. Select the dataset
3. Select the region
4. Select the season on the left panel and the years on the right panel
5. Check the ■ **Seasonal totals** option
6. Select Trend from the analysis methods list
7. Click on **Analyze** to run the analysis

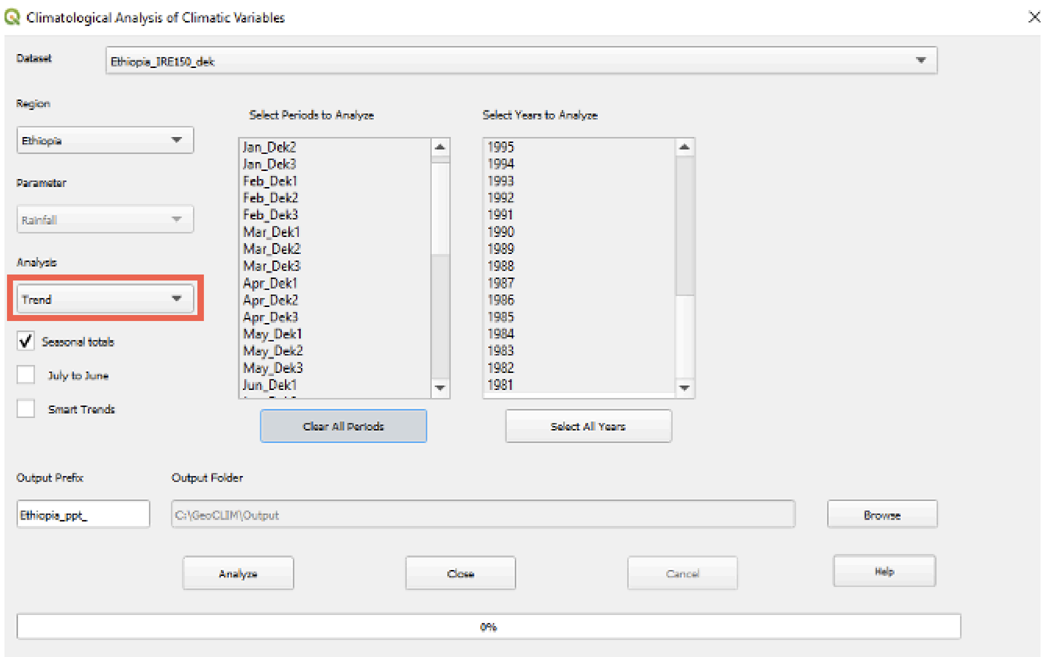


Figure 4-10 *To calculate the trend for a climate variable, select the season, make sure that the* ***Seasonal totals*** *option is checked, and select the years to be used in the calculation.*

Figure 4-11 shows the results of the Trend analysis method for the annual rainfall total in Ethiopia for the period 1981 – 2016, using the Improved Rainfall Estimates (IRE), see chapter 10 on how to create IRE data. Figure 4-11 (1) shows the slope of the regression line, or the trend for each pixel in mm/decade of increasing (green-blue) or decreasing (pink-red) rainfall. The legend shows these results per decade (10 years). Figure 4-11 (2) shows the coefficient of determination (r-squared, or r2) (multiplied by 100) of the linear regression between the variable and time as an indication of the reliability of the trend. It is important to use both maps to develop a conclusion about trends in an area. For example, points a, b, and c show three sites with strong trends and different r2.

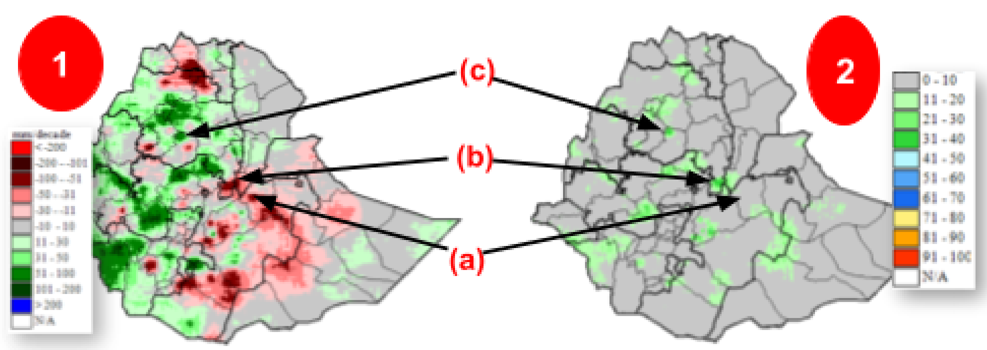


Figure 4-11 *The trend analysis method in GeoCLIM produces two outputs. (1) Shows the slope of the regression in mm per decade decrease (pink-red) or increase (+ green-blue) and (2) shows the r2 of the regression.*

Based on Figure 4-11 (1) and (2), site (a) has a 71mm decrease per decade (dark red) with r2= 9% (grey), site (b) shows a 75mm decrease per decade (dark red) with r2 = 36% (dark green), while site (c) shows 89mm increase per decade (dark green) with r2 = 35% (dark green). Sites (a) and (b) have similar trends, but the r2 values show that site (b) has the strongest correlation. Also, sites (b) and (c) have similar r2 shown as green color. Figure 4-12 shows the regression plots of total annual rainfall against time for sites a, b, and c. The annual total for the period 1981–2016 was extracted using the Extract Statistics function in GeoCLIM, for each site, and plotted using Excel. The plots in Figure 4-12 corroborate the difference in r2 by showing how close the points are to the regression line. Site (a) shows the points scattered, while sites (b) and (c) show the points closer to the regression line.

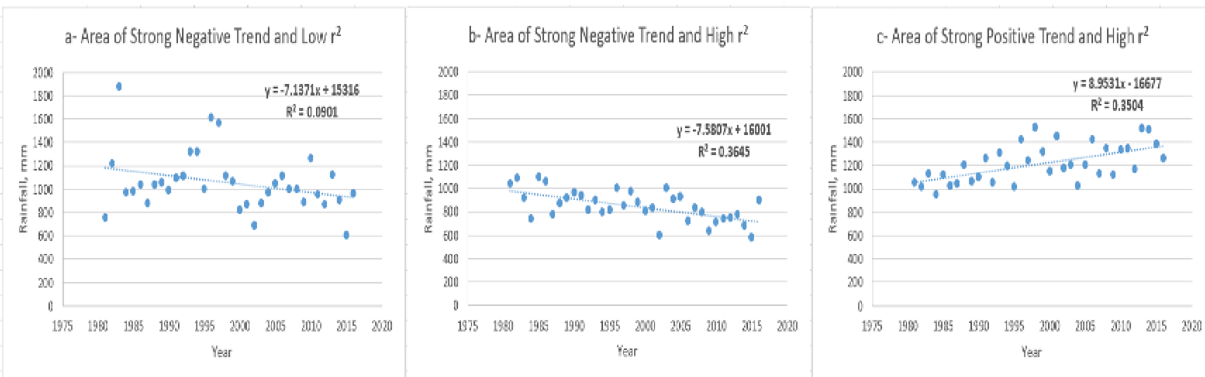


Figure 4-12 *It is important to evaluate the strength of the relationship (r2) before making conclusions about the trend. Plots show three regions that present strong trends on Figure 4.12 with different r2.*

NOTE: It is important to use both maps to develop a conclusion about trends in an area, since the trend map shows how much change there has been in the time period we are analyzing, and the r2 map shows the reliability of the trend. The trend with a larger r2 value suggests a more robust trend, while the weaker r2 indicates that this trend may be by chance.

4.3.6. Percentiles

A percentile is a statistic that specifies the value below which a certain percent of observations in a ranked dataset will fall. Percentiles are calculated at breakpoints ranging from 0 to 100. The 0th percentile corresponds to the lowest value. The 100th percentile is the highest. The 50th percentile is the median value. To calculate a percentile value, we first must rank the time-series, and then identify the value associated with the nth percentile position.

For example, if the 20th percentile is 80 mm of rainfall, then we would expect that 20% of the time, rainfall would be less than or equal to 80 mm. One way of using percentiles is to answer questions like: “if we have the time series for the total FMAM season from 1981-2017 (table 4.2), what would we expect a 1-in-5-year dry event to look like?” To explore this question, we could calculate the 20th percentile. Statistically, we would expect rainfall of this amount or lower once every five years.

Another use of percentiles is when we have a value, let's say the rainfall total for the FMAM for 2017=216 mm, and we would like to know what percentile that value represents, or how frequent a value like this happens. Using the data in table 4.2 (see Note below on how the data was obtained) and the PERCENTRANK function in Excel, we find that 216 mm is the 71st percentile or greater than 71% of the values in the dataset. The **Percentiles** function in GeoCLIM produces a raster map with the rainfall value for each pixel corresponding to the percentile rank requested.

To calculate a given percentile for your region of interest, follow the steps below:

1. Start the **Climatological Analysis** tool, as described in section 4.1
2. Select the dataset
3. Select the region
4. Select the season on the left panel and the years on the right panel
5. Check the ■ **Seasonal totals** option
6. Select Percentile from the analysis methods list
7. Enter the percentile rank desired (Figure 4-13 (1))
8. Click on **Analyze** to run the analysis.

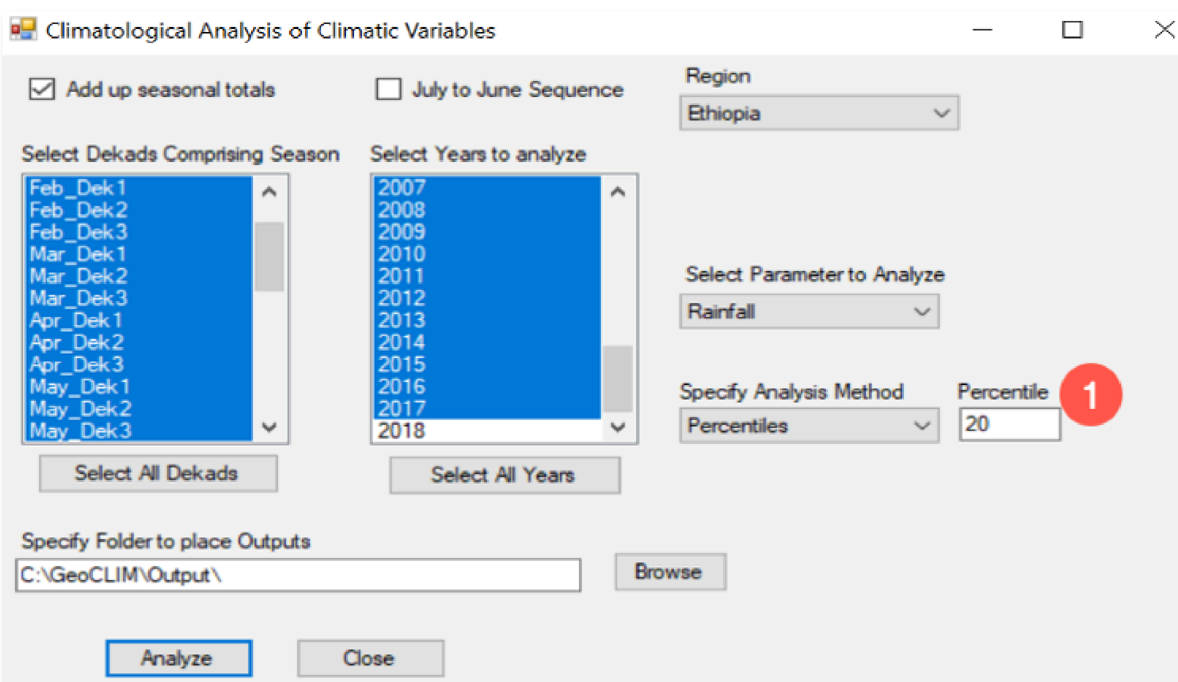


Figure 4-13 *The Percentiles method in GeoCLIM produces a raster map with the rainfall value for each pixel corresponding to the percentile rank.*

This function in GeoCLIM helps answer questions such as, what are the low/high values (e.g., 15th/90th percentiles) in the time-series? (Figure 4-14). Table 4.2 shows the time-series for the FMAM seasonal total for the period 1981-2017 for point (A) in Figure 4-14. The result of the PERCENTILE.EXC function in Excel shows that the 20th percentile is = 105.

	Feature	prec_FMAM	
1	2009	35	
2	2008	44	
3	1984	61	
4	1999	66	
5	2011	79	
6	2015	94	
7	2000	103	
8	1994	107	105->20th percentile
9	2013	120	
10	1992	121	
11	1998	121	
12	2007	123	
13	1997	133	
14	1982	134	
15	1988	146	
16	2001	153	
17	1991	154	
18	2003	162	
19	2004	163	
20	2012	163	->50th percentile
21	1990	171	
22	2014	175	
23	2010	180	
24	2005	181	
25	2006	197	
26	1995	207	
27	2017	216	->71th percentile
28	1983	217	
29	1989	225	
30	1996	227	
31	1993	228	
32	1986	232	
33	2002	239	
34	1981	244	
35	2016	277	
36	1985	291	
37	1987	298	

Table 4.2 *Seasonal total FMAM 1981-2017 for point A in Figure 4-14.*

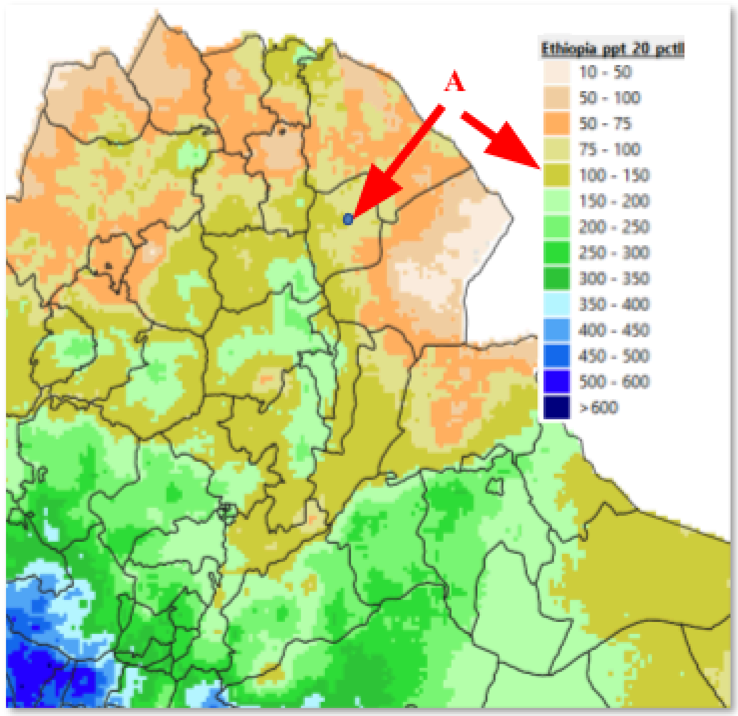


Figure 4-14 *An example of rainfall accumulation (mm) corresponding to the 20th percentile rank for the FMAM season. This percentile rank defines a set of low frequency dry events. The default legend was modified to represent the data.*

NOTE: Table 4.2 was created using the **Extract Statistics** tool for a point shown in Figure 4-14.

4.3.7. Frequency

The Frequency Analysis tool in GeoCLIM allows users to determine how often seasonal rainfall totals fall within a defined range over a selected period of years.

- On the left panel on (Figure 4-15), users select one or more periods (dekads in the example) to define the season of interest (e.g., March 1st to May 3rd).
- On the right panel, users choose the set of years to include in the analysis.
- The "Between" and "and" fields (highlighted in red) specify the rainfall range in millimeters.

Based on the selected range, the tool counts the number of years in which the seasonal total falls within that range.

This helps users evaluate how often a season is unusually dry, average, or wet, and how frequently rainfall has fallen below critical thresholds—such as the minimum needed to support a given crop.

The output consists of two main products:

- A frequency map showing the spatial distribution of how often the seasonal rainfall met the selected range criteria.
- A percent map showing the percentage of years that seasonal rainfall fell within the selected range, based on the total number of years analyzed.

To calculate the frequency of a range of values, follow the steps below:

1. Start the **Climatological Analysis** tool, as described in section 4.1
2. Select the dataset
3. Select the region
4. Select the season on the left panel and the years on the right panel
5. Check the ■ **Seasonal totals** option
6. Select **Frequency** from the analysis methods list
7. Fill in the values **Between** and **And** to define the range of values
8. Click on **Analyze** to run the analysis

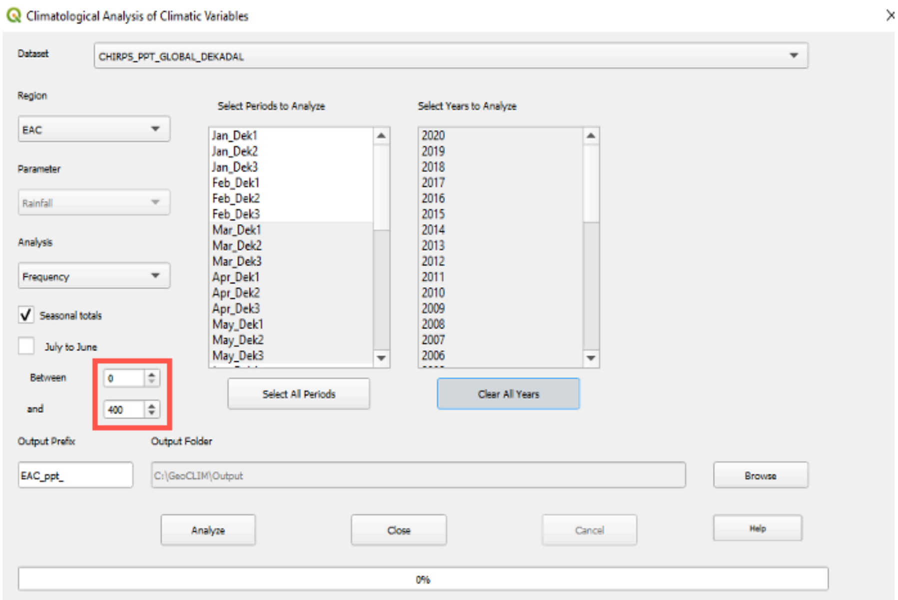


Figure 4-15 *The Frequency Analysis tool allows users to define a rainfall range (red box) and calculates*

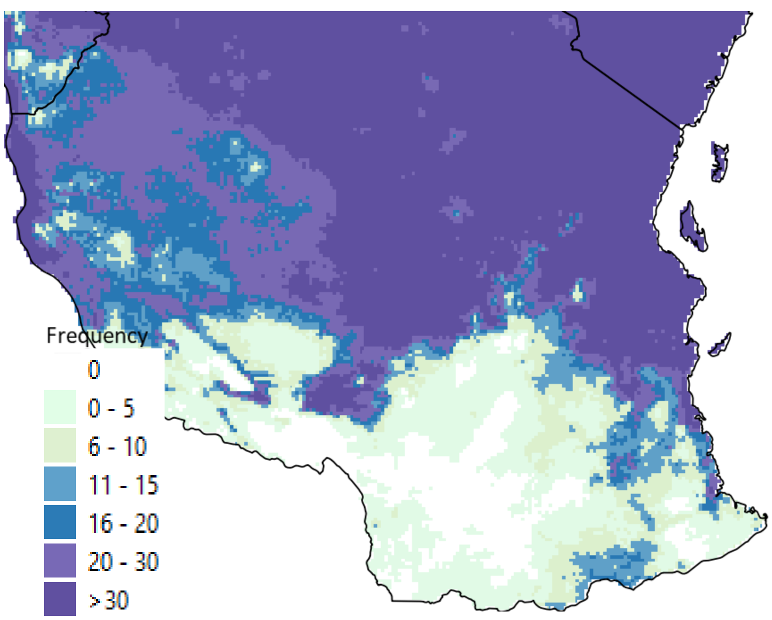


Figure 4-16 *Map output showing how many times seasonal rainfall totals fell within the selected range. over the chosen time period.*

4.3.8. Standardized Precipitation Index (SPI)

The Standardized Precipitation Index (SPI) measures how much precipitation deviates from the historical average over a selected time period, expressed in standard deviation units (z-scores). It uses long-term precipitation records to determine the mean and standard deviation.

Since precipitation data is not normally distributed, especially over shorter periods, it is first fitted to a gamma distribution and then transformed into a normal distribution. This enables comparison across different locations and timescales.

SPI is flexible and can be computed at various timescales (e.g., 1, 3, 6, 12 months), making it suitable for detecting short-term agricultural droughts and longer-term hydrological deficits.

- SPI > 0: Wetter than median
- SPI < 0: Drier than median
- SPI < -1.0: Moderate drought (~1-in-6 years)
- SPI < -1.5: Severe drought (~1-in-15 years)
- SPI < -2.0: Exceptional drought (~2% frequency)

For agricultural monitoring, SPI at short timescales (1–3 months) helps identify water stress during planting and early growth stages.
(Source: McKee et al., 1993)

To calculate the SPI for a year or multiple years, follow the steps below:

1. Start the **Climatological Analysis** tool, as described in section 4.1
2. Select the dataset
3. Select the region
4. Select the season (Figure 4-17 (1))
5. Check the ■ **Seasonal totals** option and select **SPI** from the analysis methods list (Figure 4-17 (2))
6. Select the group of year to make the time series (Figure 4-17 (3))
7. Select a single or a group of years for which SPI is to be calculated (Figure 4-17 (4))
8. Click on **Analyze** to run the analysis

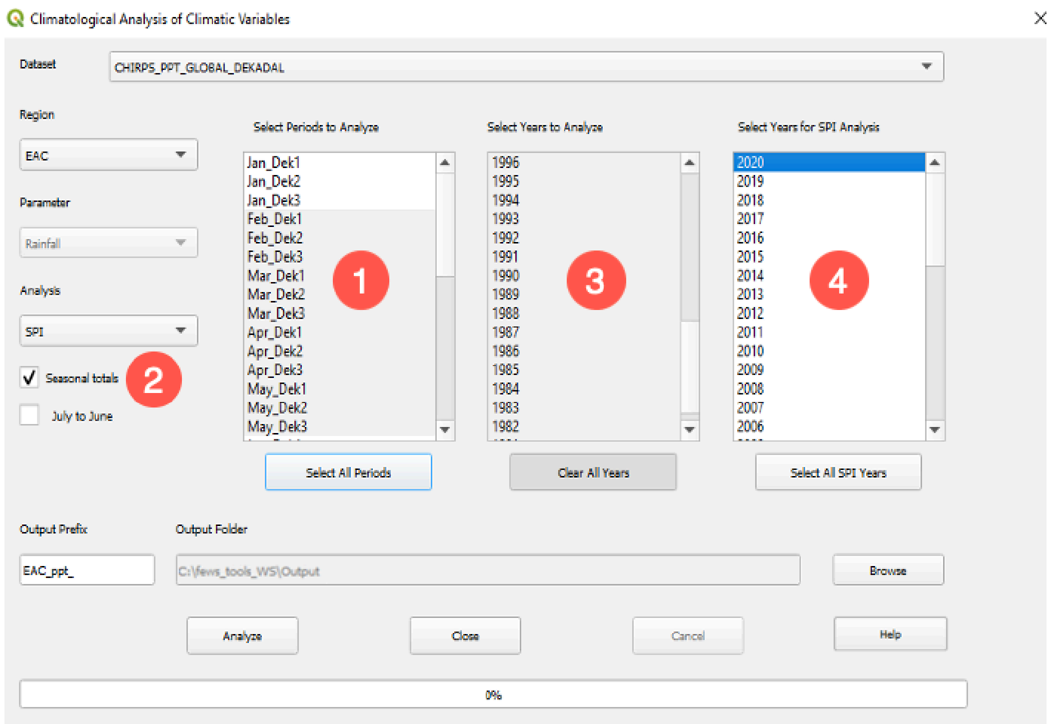


Figure 4-17 *GeoCLIM allows you to calculate the SPI for a single or multiple years.*

The resulting map shows, in tones of yellow to dark-brown, the areas that received below the median rainfall during the period of analysis. Colors light-blue to red indicate above median rainfall. See Figure 4-18.

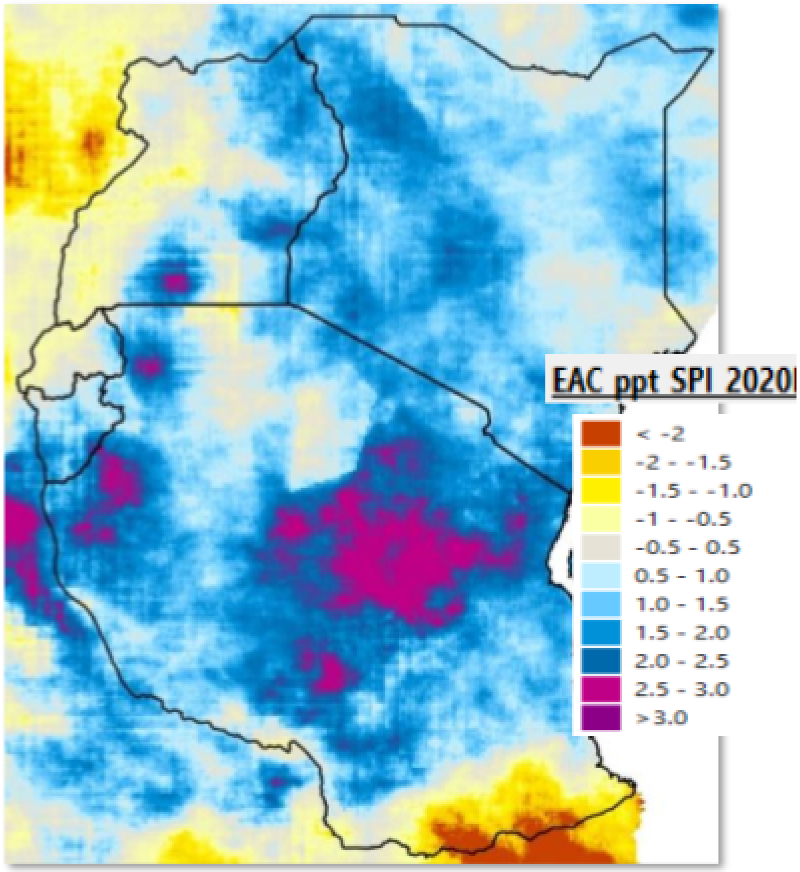


Figure 4-18 *SPI Feb-May 2020 (CHIRPS 1981-2020). The GeoCLIM SPI raster output is in units of [SPI * 100], but the legend shows actual SPI values.*

Chapter 5: View and Explore Rainfall Summaries

Summary

Figure 5-1 *The Rainfall Summaries tool facilitates the calculation of total and anomalies for a season.*

The Rainfall Summaries tool helps users assess how rainfall in a selected period compares to the historical average for that same period.

The **Rainfall Summaries** tool (red box in Figure 5-1) facilitates the calculation of:

1. **Current Period Total**: total rainfall for the selected period.
2. **Average Period total**: long-term average for the selected period.
3. **Difference from Average**: (current period total – average period total)
4. **Percent of Average**: (current period total / average period total) *100

The outputs provide answers to practical questions like: “What is the average for the period June dek1 to Aug dek3” and “How different was June dek1- Aug dek3 2012 from average?”

5.1. Requirements

To use the **Rainfall Summaries** tool, the selected climate dataset must have dataset averages available (see Update dataset averages in section 4.2). These are the averages defined in the dataset definition form, see chapter 2 for more information. If the averages do not exist, a window message shows up, allowing you to open the **Climatological Analysis of Climatic Variables** tool to calculate the averages as follows: (See Figure 5-2).

1. Select the dataset
2. Select all the periods
3. Select the number of years to be used in calculating the averages
4. Check the box update dataset averages

The tool uses the information entered in the data definition form to calculate the averages for the domain of the dataset.

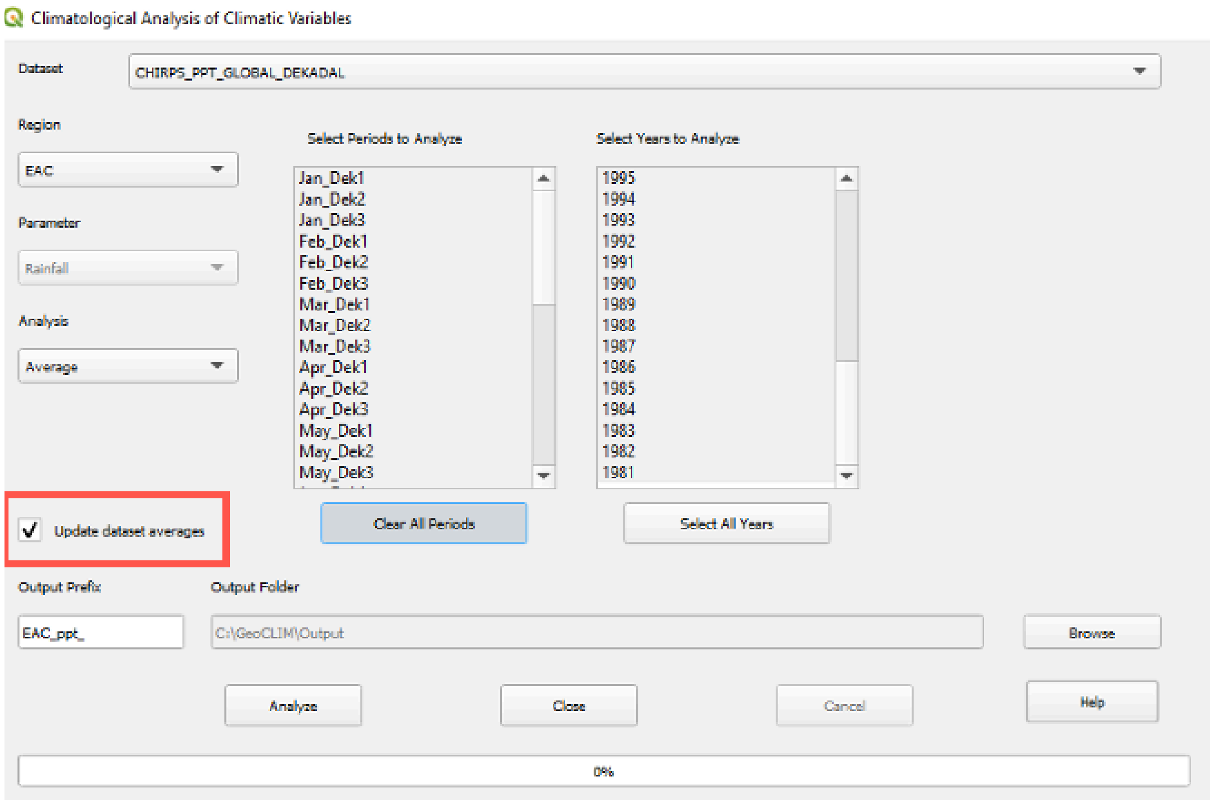


Figure 5-2 *In order to calculate rainfall summaries you need to have averages for all the periods (pentads, dekads or months).*

5.2. Calculate seasonal total and anomalies

Once the averages are available, close the Climatological Analysis tool to go back to the **Rainfall Summaries** tool, Figure 5-3.

1. Select the period of analysis (defined by the **From** and **To** date)
2. Select the summaries to be displayed
   a) **Current Period Total**
   b) **Average Period Total**
   c) **Difference from Average**
   d) **Percent of Average**
3. Click **OK** to run the tool

NOTE: You might have to edit the legend to represent your data better. See appendix A for how to edit the legend in QGIS.

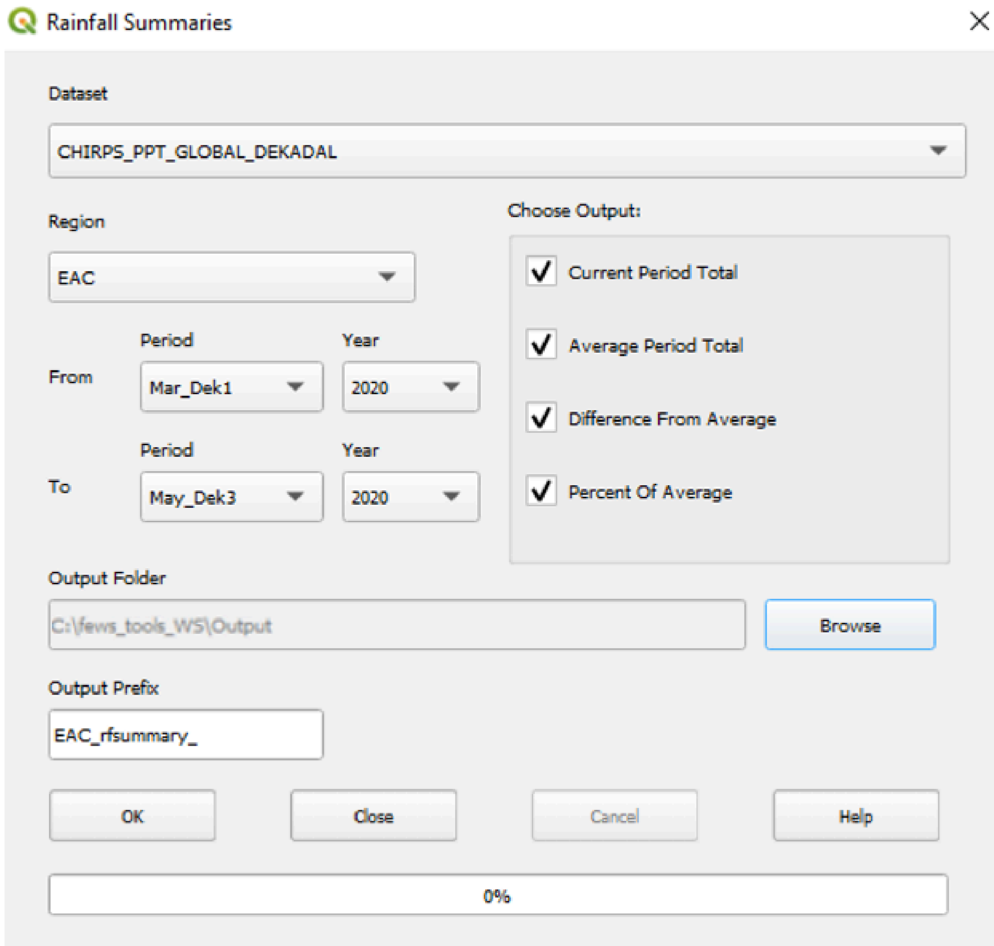


Figure 5-3 *The Rainfall Summaries function facilitates the calculation of anomalies for a period.*

NOTE: Even though the tool calculates all four products, it only displays the one you select.

Chapter 6: Climate Composites

Summary

Figure 6-1 *The Climate Composites facilitates the analysis of a season among a group of years or compares the seasonal rainfall performance among two groups of years.*

The **Climate Composites** tool (red box in Figure 6-1) facilitates the analysis of a season among a group of years or compares the seasonal rainfall performance among two groups of years. For example: comparing the difference in rainfall conditions of the May–July (MJJ) season during El Niño and La Niña years in Central America. The **Climate Composites** tool calculates the seasonal average for a single group of years (EL Niño), the percent of average, as well as anomalies or standardized anomalies for one or two groups of years using an average baseline period.

6.1. Average

This function calculates the seasonal average for a group of years. El Niño (1982-83, 1986-87, 1987-88, 1991-92, 1997-1998, 2002-03, 2009-10, 2015-16) and La Niña (1988-89, 1998-99, 1999-00, 2007-08, 2010-11).

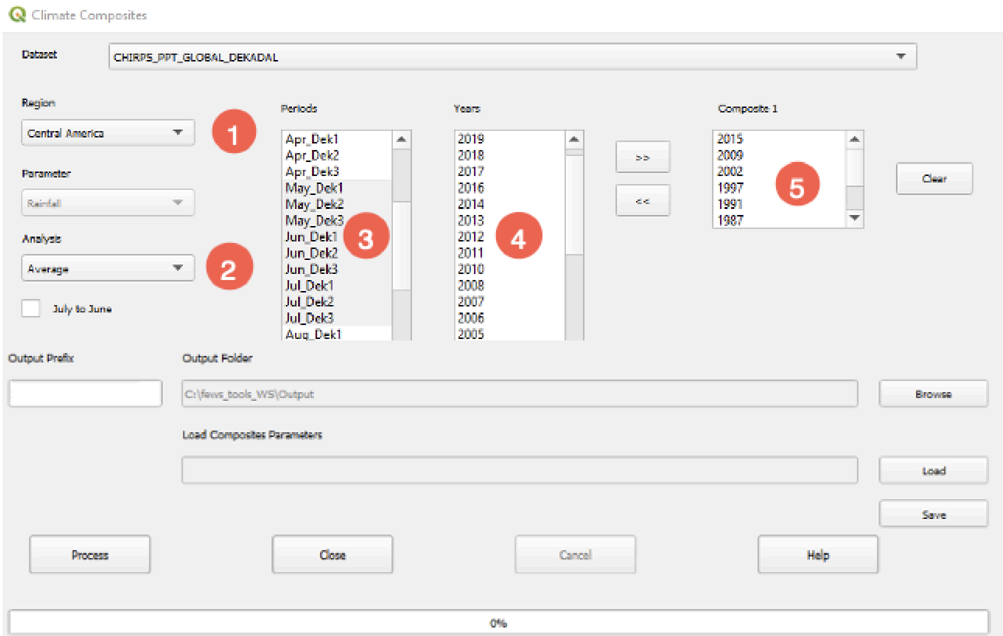


Figure 6-2 *The Composites tool calculates the seasonal average from a group of years, among other functions.*

To calculate the seasonal average for a group of years, follow the steps below:

1. Select the region of interest (Figure 6-2 (1))
2. Select the method: In this case, select Average (Figure 6-2 (2))
3. Select the season to be analyzed (Figure 6-2 (3))
4. Select the years to be included for composite 1 (Figure 6-2 (4))
5. Move the selected years to the **composite 1** box by clicking the **>>** button (Figure 6-2 (5)).
6. Click on **Process**. Figure 6-3 shows the results.

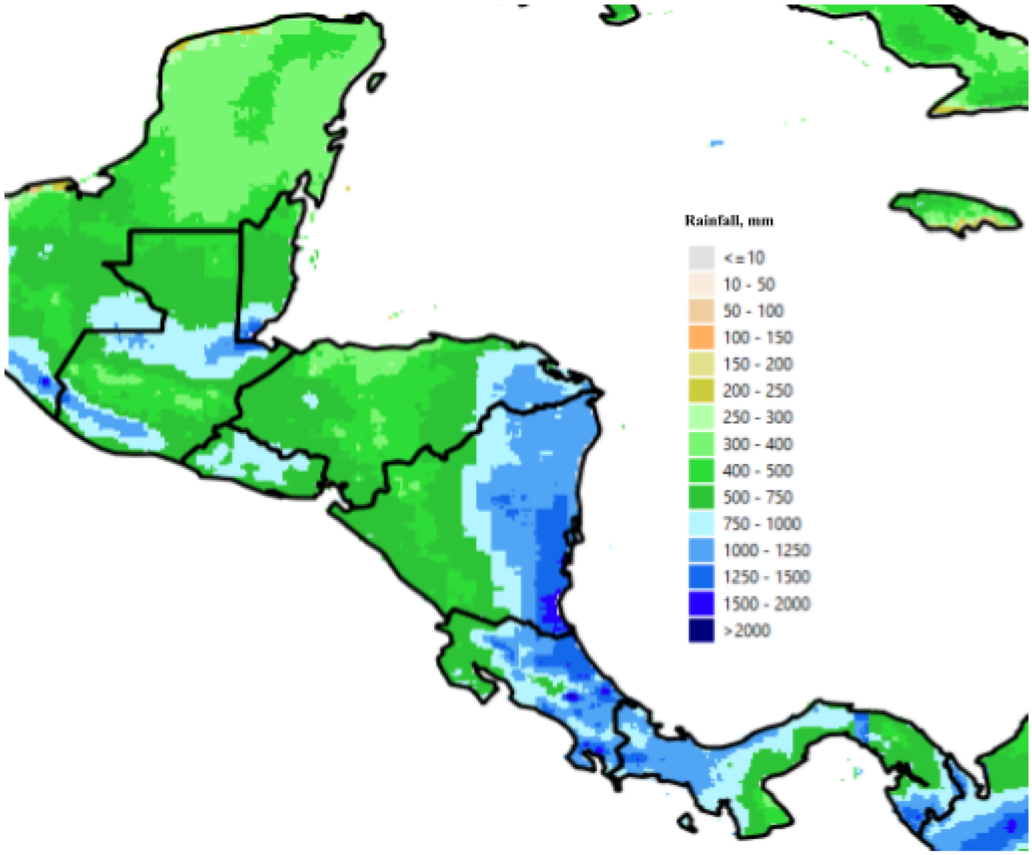


Figure 6-3 *Average rainfall for El Niño years in Central America for the May - July season, composite1.*

6.2. Percent of Average (Applies to composite 1 and composite 2)

The **Percent of Average** allows for the analysis of a single group of years or the comparison between two groups of years. Figure 6-4 shows the input parameters: (1) La Niña years (composite 1), (2) El Niño years (composite 2), and (3) the Baseline, which indicates the period to be used to calculate the average.

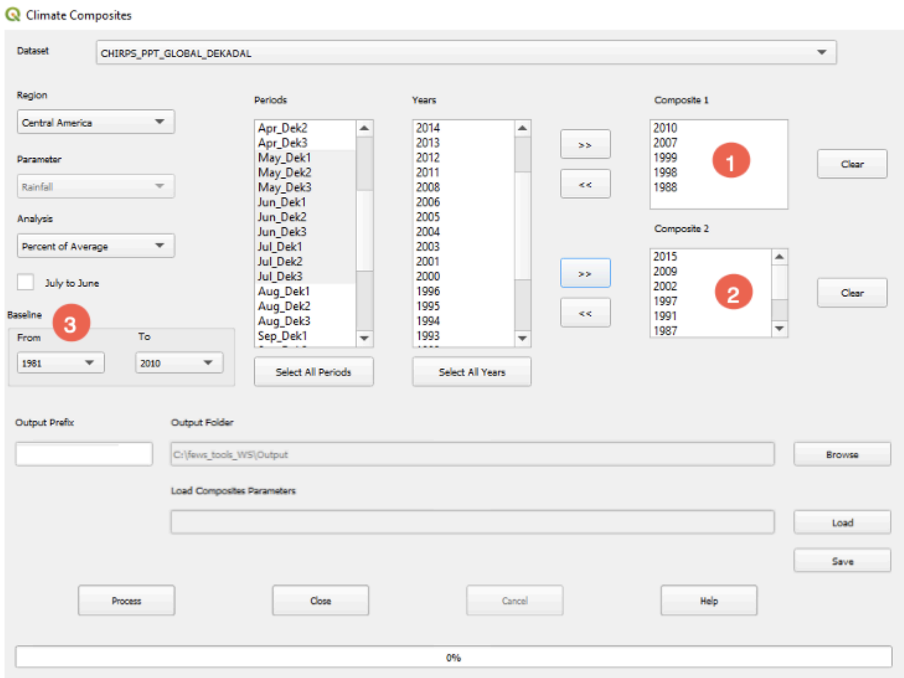


Figure 6-4 *The composites function calculates the percent of average for a single group of years or compares two groups of years.*

To calculate the percent of average for composite 1 (Eq. 6.1):

$$Pct_{comp1} = \left(\frac{average_{comp1} + (0.05*ltavg) + 0.1}{average_{baseline+}(0.05*ltavg) + 0.1} \right) *\ 100 \qquad (6.1)$$

1. If composite 2 is empty, the program saves pct_comp1 as the final output and displays the product.
2. If composite 2 is **not** empty, the program calculates the difference between the two composites as shown by Eq. 6.2:

$$pct_{comp} = \left(\frac{\left(average_{comp1} - average_{comp2}\right) + 0.1}{average_{baseline} + 0.1} \right) *\ 100 \qquad (6.2)$$

If (average_comp1 - average_comp2) = 0 or average_baseline = 0 then ((average_comp1 - average_comp2) / average_baseline) = 0, otherwise the results will come from Eq. 6.2. In our example, Figure 6-5 shows that rainfall is higher during La Niña years in most of the Pacific coast of Central America.

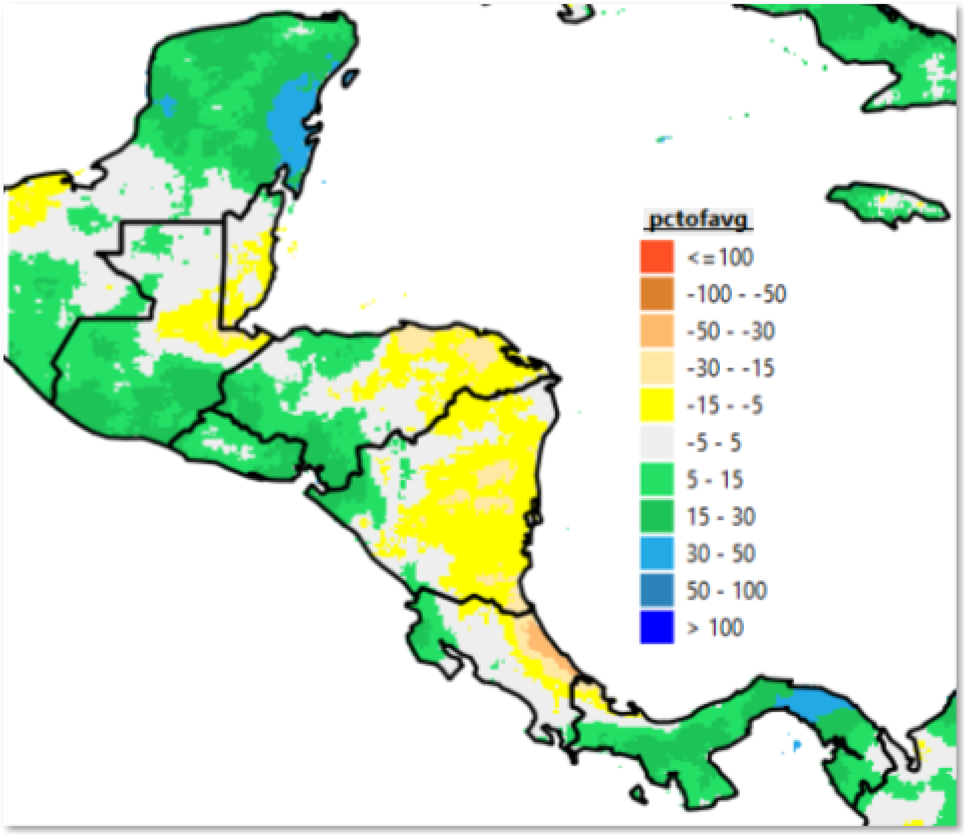


Figure 6-5 *Percent of average for composites 1 (La Niña) and 2 (El Niño). In this example, the positive values indicate that precipitation during La Niña years is higher, on average, than during El Niño years.*

6.3. Anomaly (Applies to composite 1 and composite 2)

This analysis method calculates the average for each composite and the baseline; then, it calculates the anomaly for each composite (Eq. 6.3).

$$anom_{compN} = average_{compN} - average_{baseline} \qquad (6.3)$$

1. If composite 2 is empty, the $anom_{comp1}$ is saved as the final output and displayed on the QGIS canvas.
2. If composite 2 is not empty, the program calculates the difference between the anomalies of the two composites (Eq. 6.4).

$$anom_{comp} = anom_{comp1} - anom_{comp2} \qquad (6.4)$$

Figure 6-6 shows the results of the calculation of the anomalies for El Niño/La Niña example.

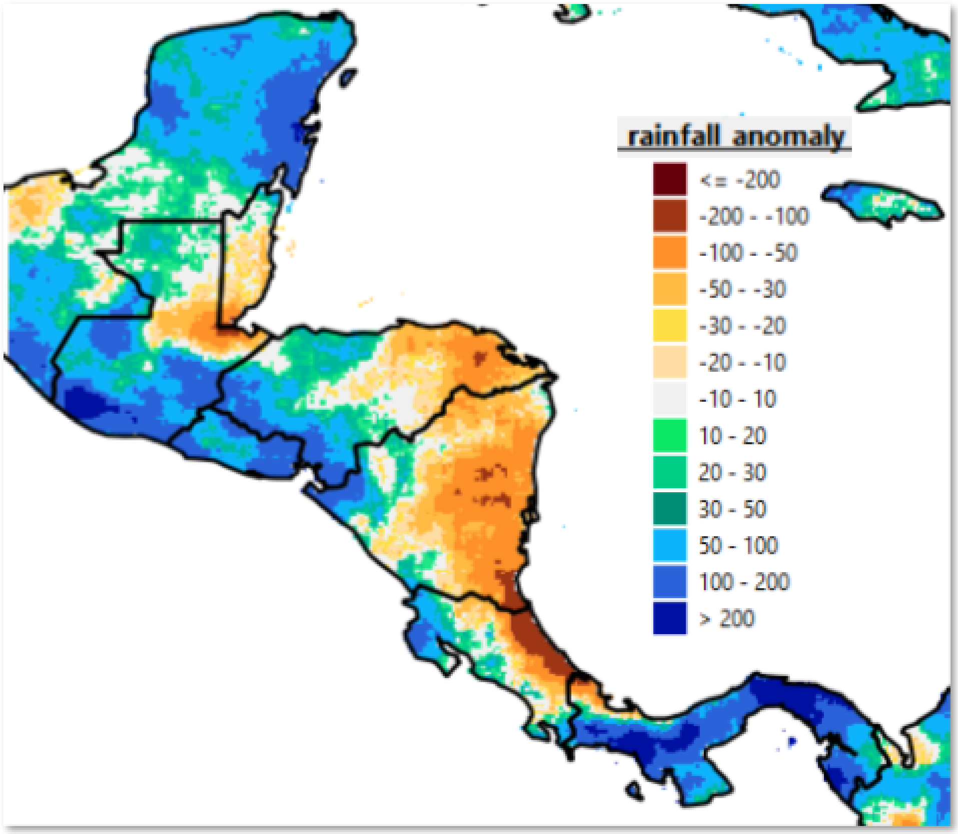


Figure 6-6 *The positive anomalies show areas were, on average, La Niña years have higher values than El Niño. The results are shown in mm. The default legend was modified based on the range of values.*

6.4. Standardized Anomaly: (Applies to composite 1 and composite 2)

This analysis method calculates the difference anomaly, for the average seasonal precipitation, for each group of years and expresses it as a percent of the standard deviation. The function then subtracts the results of composite 2 from composite 1 and expresses it in terms of standard deviations away from the mean. The method:

1. Validates if data exist for the selected years for composites 1 and 2, and baseline.
2. Calculates the standard deviation, including all the available years.
3. Calculates the average for the composites and baseline.
4. Calculates anomaly for each composite.
5. Calculates the standardized anomaly for each composite (Eq. 6.5.)

$$stdanom_{compN} = \left(\frac{\left(average_{compN} - average_{baseline}\right) + 0.1}{stdev_{available\ years} + 0.1}\right) * \ 100 \qquad (6.5)$$

Where $stdev_{available\ years}$ is the standard deviation for all the years in the climate dataset for the selected period (e.g., period: May-July, composite1: El Niño years, baseline: 1981-2010, climate dataset: 1981-2017).

6. If composite 2 is empty, the function saves $stdanom_{comp1}$ as the final output and displays it in the **Spatial Data Viewer**.
7. If composite 2 is **not** empty, the function calculates the difference between the two composites as follows:

$$stdadnom_{comp} = \ stdanom_{comp1} - stdanom_{comp2} \qquad (6.6)$$

The results in Figure 6-7 show the difference between composite 1 and 2 in terms of the standard deviation of the complete climate dataset. The areas in blue/purple show how much wetter on average El Niño years are than La Niña years, with the difference expressed in terms of standard deviations from the mean.

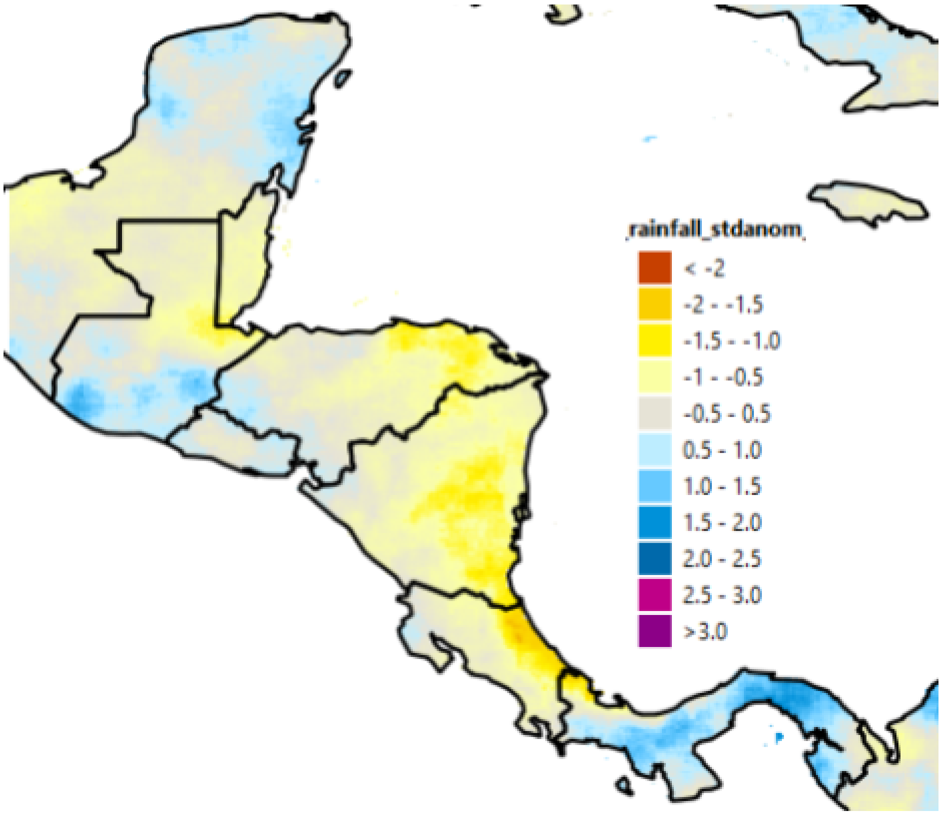


Figure 6-7 *This function calculates standardized anomaly, which is the difference in anomaly of the average precipitation for a group of years (composite 1), expressed as a percent of the standard deviation. If composite 2 exists, the function calculates the difference between the two standardized anomalies.*

NOTE: The raster values on the map shown in Figure 6-7, are numbers with a scale factor of 100, since GeoCLIM does not work with decimals values. However, the legend shows the number of standard deviations from the mean.

Chapter 7: Contour Tool

Summary

Figure 7-1 *The Make Contours tool delineates areas within a defined interval value in a climate-variable.*

The **Make Contours** tool (red box in Figure 7-1) delineates areas within a defined interval value in a climate variable. Analyzing contours from different periods of time helps to identify changes in a variable within a region. For example: we could identify the changes in rainfall-receiving areas with more than 350 mm during the Belg season (Feb-May) in Ethiopia in the last 40 years, by comparing the contours for average rainfall in the period 1981-2001 and 2002-2020.

7.1. Making contours

To run the tool, follow the steps below:

1. Open the **Make Contours** tool from the GeoCLIM main toolbar
2. Specify the BIL input file; in this example, we are using the average February-May rainfall season for the period 1981-2001 (Figure 7-2 (1).)
3. The tool automatically specifies the output file (Figure 7-2 (2).)
4. Select a contour interval value. In this case, 350 for an interval of rainfall of 350 mm (Figure 7-2 (3).)
5. Change the missing value if necessary
6. Click **OK** to run the tool.

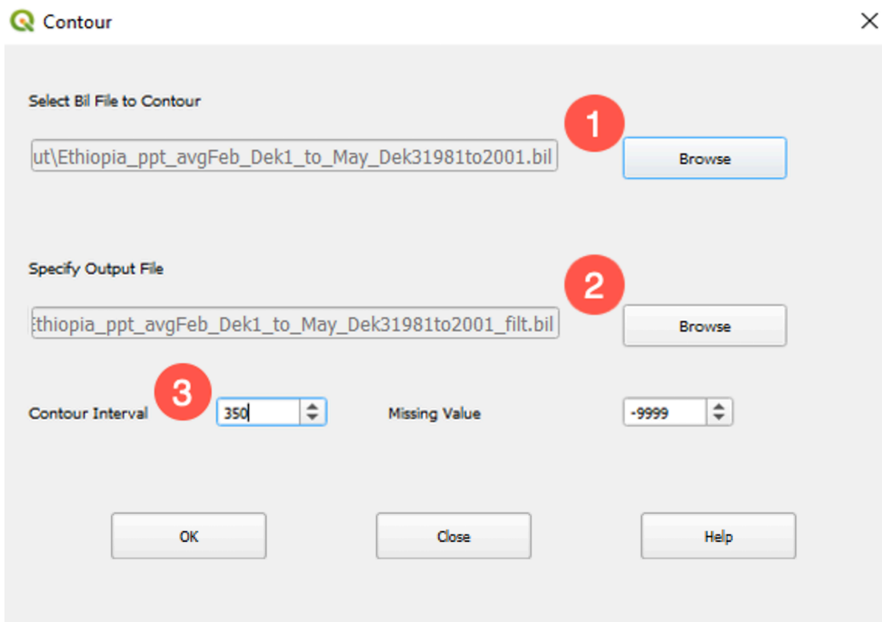


Figure 7-2 *GeoCLIM facilitates the delineation of areas within a range of rainfall values.*

After calculating the contours for both periods of time, the results show an increase/decrease in rainfall in polygons 1/2, respectively in Figure 7-3.

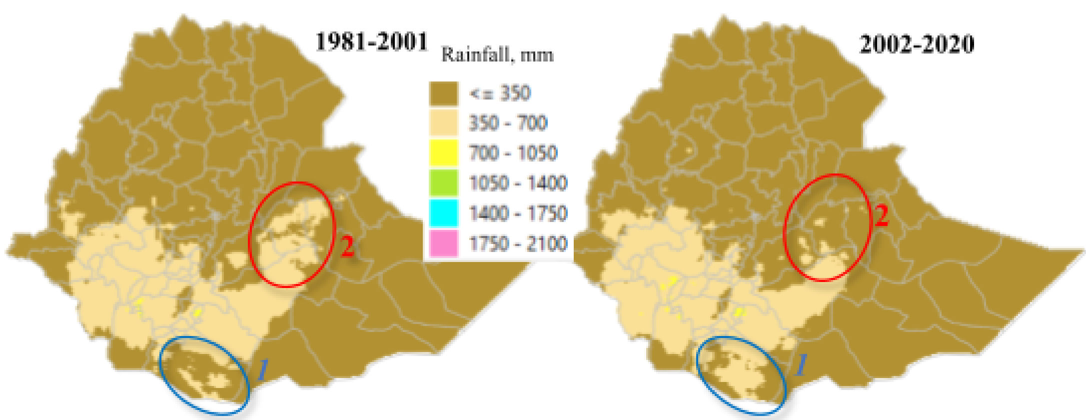


Figure 7-3 *The 350 mm interval of average rainfall for the Feb-May season, during the periods 1981-2001(map on the left), 2002 – 2020 (map on the right), show reduction of rainfall in areas in red circles.*

To further identify the difference between the two periods, we can overlay the areas with more than 350 mm, as shown in Figure 7-4 (A). The image shows that the area that receives more than 350mm is shrinking in the eastern part of the country. We then compare the results to a population map and see that rainfall is decreasing in highly populated areas, Figure 7-4 (B).

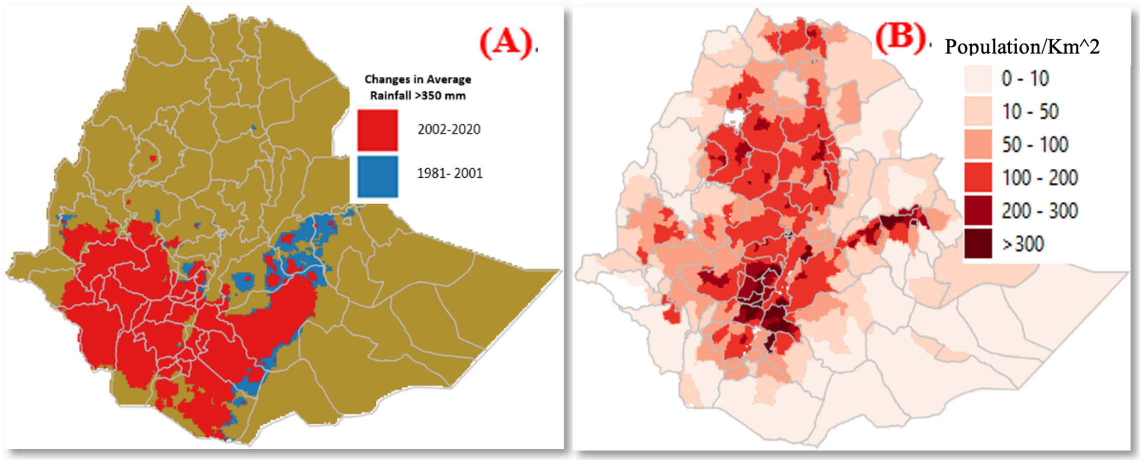


Figure 7-4 *Changes in rainfall patterns during the Belg season in Ethiopia. Image A shows the changes in areas that receive > 350mm. Image B shows the population per Km^2.*

The map in Figure 7-4 (A) was produced as follows:

1. Use GeoCLIM to calculate average 1981-2001 and 2002 -2020
2. Use the Contours tool at a given interval (350mm for this example.)
3. Use the raster calculator in QGIS to create a binary layer; values greater than 350 = 1 and values less than 350 = 0. (layer < 350) * 0 + (layer >= 350) * 1
4. Use the Raster/conversion/polygonize tool in QGIS to create polygons from the binary layers
5. Overlay the two resulting polygon shapefiles

Chapter 8: Calculate Long-Term Changes in Averages

Summary

Figure 8-1 *The Long-Term Changes in Averages tool facilitates the comparison of two periods to determine changes in rainfall patterns.*

Another way to estimate changes in climate patterns is by comparing the averages between two periods within a time-series. The **long-Term Changes in Averages** tool (red box in Figure 8-1) allows you to estimate the trend by dividing the time-series into two groups of years and calculating the difference in average between the two groups (difference = group2-group1).

8.1. Calculating changes in averages

To run the tool, follow the steps below:

1. Open the **long-Term Changes in Averages** tool from the GeoCLIM main toolbar, see Figure 8-1.
2. Select the season to be analyzed, see Figure 8-2 (1)
3. In series 1, select the first period of time, see Figure 8-2 (2)
4. In series 2, select the second period, see Figure 8-2 (3)
5. Click **Process** to finish

Figure 8-3 shows the output map result of the change in average from the 1981-2001 period (series 1) compared to the 2002-2020 period (series 2), for the June-September season. The result shows areas with increasing (green-blue) and decreasing (pink-red) mm of rainfall during the 2002-2020 period.

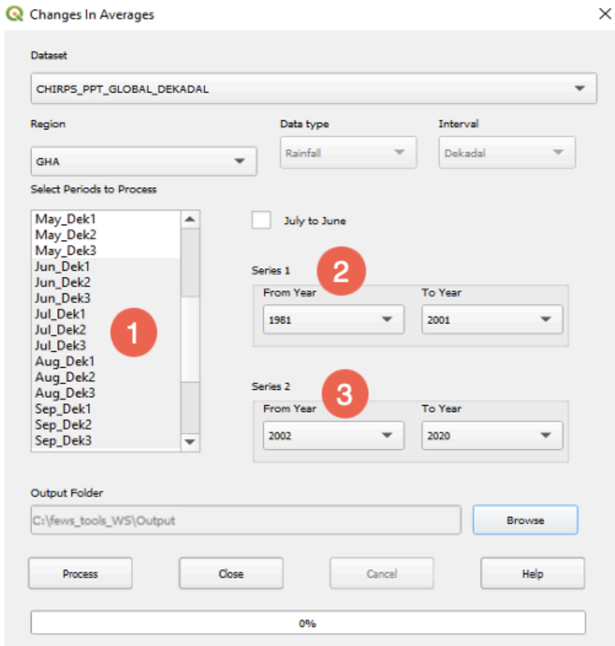


Figure 8-2 *The Long-Term Changes in Averages tool allows you to identify changes in climate patters by calculating the differences in averages between two periods of time in a time series.*

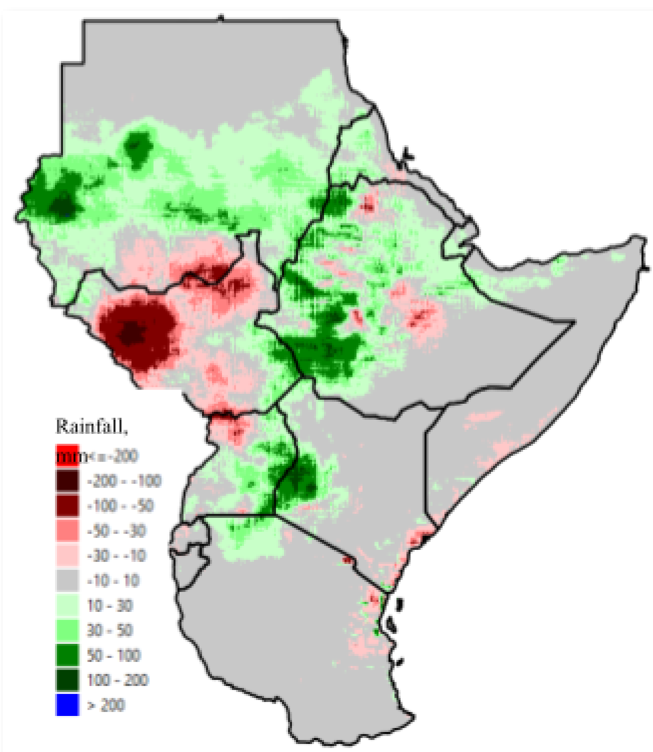


Figure 8-3 *Difference in averages; green-blue colors show an increase in the latter period (series 2) while pink-red colors show a decrease in rainfall in that same period. The legend is given in mm per decade.*

Chapter 9: Background-Assisted Station Interpolation for Improved Climate Surfaces (BASIICS)

Summary

Figure 9-1 *The Background-Assisted Station Interpolation for Improved Climate Surfaces, (BASIICS) algorithm in GeoCLIM facilitates the improvement of climate variables by blending raster data with local stations, among other functions.*

Satellite data provide useful information on climate variables (rainfall, temperature, and evapotranspiration) patterns. However, sometimes, satellite-estimated data contain biases and inaccuracies due to incorrect or limited ground data used during calibration. Some raster data also have a low spatial resolution, meaning the size of the pixel is too large for the area of interest. Such data could be improved by combining them with ground station information using the **Background-Assisted Station Interpolation for Improved Climate Surfaces**, (BASIICS) algorithm in GeoCLIM. See icon in red box in Figure 9-1.

The BASIICS tool includes the following processes as shown in Figure 9-2:

- Blend climate raster/grids with stations (BASIICS)
- Validate satellite data using ground station values
- Interpolate stations only

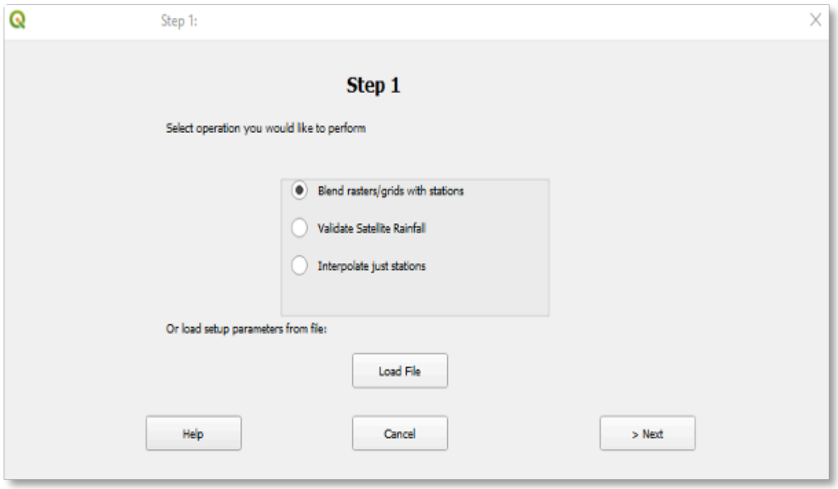


Figure 9-2 *There are three options available in the BASIICS tool; (1) Blend stations and raster data, (2) Validate Satellite Rainfall and (3) Interpolate Just Stations.*

The following three-step process is recommended to produce improved gridded datasets:

1. Use the download function or import the raster datasets to be improved, see chapter 2.
2. Use the **Validate Satellite Rainfall** to determine if the satellite and station data are correlated.
3. If they are correlated, blend the two datasets to produce improved rainfall estimates. Save the settings to a file so you could use it later to update the improved rainfall times series.

9.1. Validate satellite-based rainfall

The **Validate Satellite Rainfall** option allows you to evaluate grid/raster datasets (e.g., satellite-based rainfall estimates) using discrete points in space (e.g., rain gauges). The validation helps to determine if the two datasets are correlated to help in deciding if the blending option can be used with the two datasets to improve the raster using the point values by a blending process. The validation process first extracts values from a raster/grid at all locations where the point data have valid values (i.e., non-missing values. Missing values can be specified in the inputs). The results are: 1) A shapefile with the points that were included in the process. 2) A field of the interpolated values. 3) A .csv table that contains the station values, the corresponding grid value together with diagnostic information on the least-squares regression between the observed/in situ data value at the points being evaluated and the extracted grid values along with an R-squared output value. Once the correlation has been determined, then the raster and station data can be blended into an improved dataset.

To validate raster data, follow the three steps below:

9.1.1. Step 1: Select the BASIICS option

1. Click on the **BASIICS** icon from the GeoCLIM main toolbar to open the dialog box (Step 1) (Figure 9-1)
2. Select the ■ **Validate Satellite Rainfall** option. See Figure 9-2
3. Click on the **> Next** button to proceed to Step 2

9.1.2. Step 2: Dataset and station parameters

Complete the form with raster and station data information. This form is made of 3 sections, (Figure 9-3).

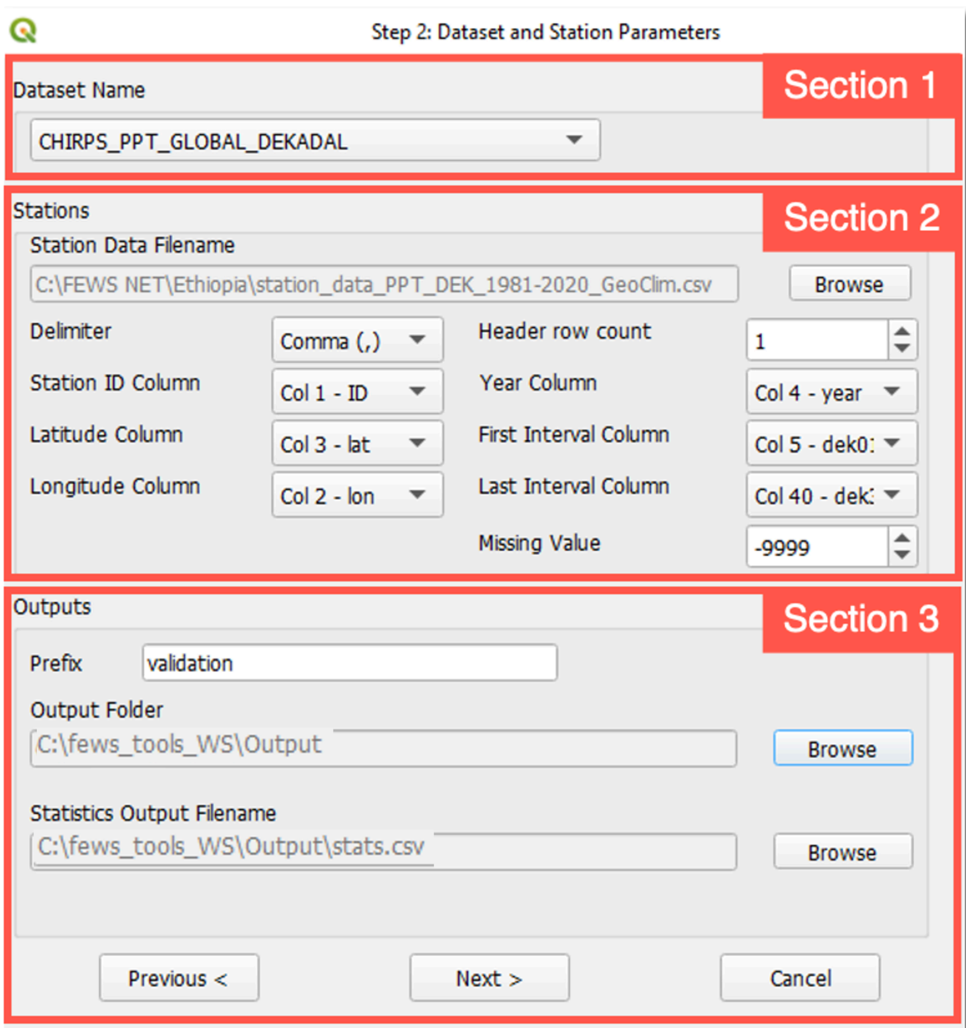


Figure 9-3 *Step 2 allows you to enter the raster and station information for the validation.*

9.1.2.1. Section 1: Grid Dataset Name

This section relates to the raster/grid input parameters. This process allows validation of climate datasets that have already been registered in GeoCLIM. To select the climate dataset to be validated, use the **GeoCLIM dataset ∨** pulldown menu.

9.1.2.2. Section 2: Stations

This section relates to the station input parameters.

1. The tool assumes that all station data are in a single csv file. Browse to select the file that contains the station data. See an example in Figure 9-4 of the file format. See the Data Management chapter for more information on the format of the table and other file types in GeoCLIM.

2. After selecting the station file, the tool identifies the header row and automatically completes the fields. Make any necessary changes to ensure that all field have the correct specification. When all the specifications are defined, move to section 3.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
ID	FEWSID	lon	lat	year	month01	month02	month03	month04	month05	month06	month07	month08	month09	month10	month11	month12
14741	63932002	33.6	-9.3	1985	115	269	258	915	250	82	46	18	30	68	234	90
14688	63844007	38.4	-5.1	1984	72.8	19.2	172.7	913	306.9	295.4	114	40.1	98.8	202.8	165.1	186.5
14658	63790003	37.6	-3.2	1990	128.8	172.1	514.3	878.9	150.1	41.7	35	23.3	6.2	96.6	222.3	187.9
14661	63791001	37.1	-3.2	1984	23.4	37.1	64.1	821.1	275.2	158.9	87.3	21	23.8	49.4	117.5	101.1
14691	63844010	38.6	-5.2	1984	101.3	64.1	151.8	788.7	279.3	246.8	133.7	37.6	96.5	230.7	457.7	320.3
14657	63790002	37.3	-3.3	1988	93.5	8	166	756.7	371.5	217	26.5	38.5	54	3.5	111.5	72.5
14728	63887003	36.7	-8.6	1993	280	161	607	752	293	27	36	6	0	0	111	100

Figure 9-4 *The CSV table with station data must contain a statin ID, lon, lat, year and a column for each pentad, dekad or month.*

9.1.2.3. Section 3: Outputs

1. Specify the output prefix for all raster files created with the interpolation of the input stations.
2. Select the output folder.
3. Select the name for the statistics output file.

9.1.3. Step 3: Date parameters

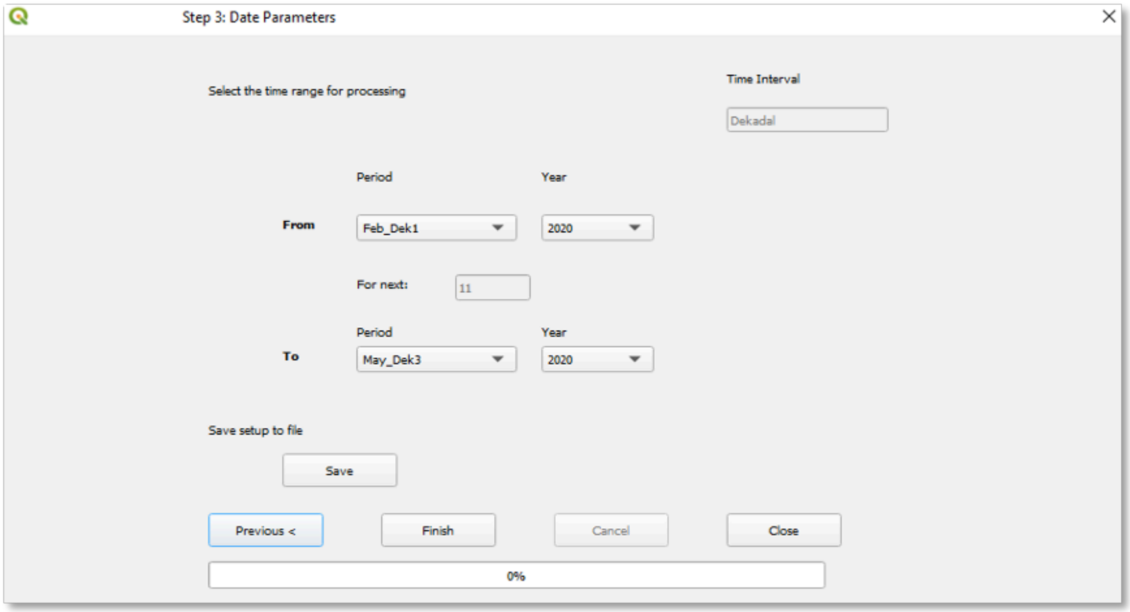


Figure 9-5 *Step 3 allows you to select a period to validate and save the settings to use later.*

Select the validation period as follows (see Figure 9-5).

1. The time interval (e.g., month, dekad, or pentads) for the selected raster dataset is automatically displayed. Select the time range From and To of the raster data to validate. The time period and time interval are based on the selected climate dataset definition. In this example we are using dekads, see Figure 9-5. And we are validating from (Feb dekad 01) to (May dekad 03), 2020.
2. Save the setup. At this step, you can save the validation settings so you could open it from step 1, edit and reuse it.
3. Click on the Finish button to run the process.

Outputs: The validation process creates the following outputs:

1. A shapefile, for each period, containing all the stations that were used in the process.
2. An interpolated field, for each period, using the IDW process. See Figure 9-6.
3. A scatterplot showing the satellite rainfall field values against the station values (Figure 9-6a).
4. A CSV file with columns containing the metadata for each station together with the station value, the corresponding raster value, and the at-station interpolated value. These at-station interpolated values are produced to improve comparability between the gridded/raster data and the station data. The CSV file includes statistics showing the correlation of the rainfall field and station data (Figure 9-6c).

These outputs provide the basis to decide if it is appropriate to blend the stations and the raster datasets.

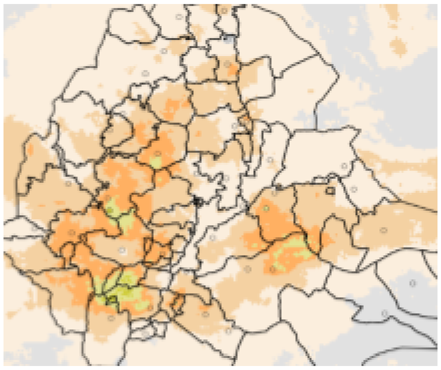


***Figure 9-6a** The validation process produces an interpolation field together with a shapefile containing all the points included.*

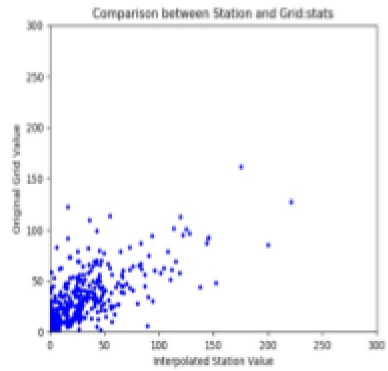


***Figure 9-6b** Scatterplot of interpolated station value on X and raster (CHIRPS) value on Y.*

Name	FileName	Long	Lat	StnVal	InterpAtSt	GridVal
TIADIG11	202015	39.447	14.278	3	2.92	18
HAAISH21	202015	42.578	10.757	11	11.02	4
TICHER11	202015	39.767	12.542	0	0.98	22
WODUBI2	202015	41.01	11.723	0	0.39	1

***Figure 9-6c** Text file that includes a list of the station value and its corresponding raster value for each date together with statistics describing their relationship.*

9.2 Creating Improved Rainfall Estimates (IRE) Using BASIICS

Summary

The Background-Assisted Station Interpolation for Improved Climate Surfaces (BASIICS) blending algorithm combines point rainfall observations (e.g., rain gauges) with a gridded background (e.g., satellite estimates such as CHIRPS) to produce an improved gridded rainfall field.

At locations where stations overlap with the background grid, BASIICS extracts the pixel value corresponding to each station location. Two types of calculation are then made:

- **Ratio** = Station value ÷ Pixel value
- **Anomaly** = Station value − Pixel value

Both ratios and anomalies are spatially interpolated using a modified inverse-distance weighting (IDW) method that incorporates concepts from kriging. We will focus a big part of this chapter to understand the interpolation process. This produces two continuous fields:

1. An interpolated ratio field
2. An interpolated anomaly field

BASIICS then applies a two-step correction:

1. **Multiplicative correction**:
   Corrected = Interpolated Ratios × CHIRPS
2. **Additive correction**:
   Final Estimate = Corrected + Interpolated Anomaly

The combination of these two corrections yields the final BASIICS rainfall estimate - also known as the Improved Rainfall Estimate (IRE) - which more closely reflects ground observations while retaining the spatial consistency of the background field.

9.2.1. Step 1: Select BASIICS option

1. Click on the **BASIICS** button from the GeoCLIM main toolbar. See Figure 9-1.
2. Select the ■ **Blend rasters/grids with stations** option. At this point you can click on the **Load File** button to load previously saved settings or click on the **> Next** button to start a new blending process. See Figure 9-7.

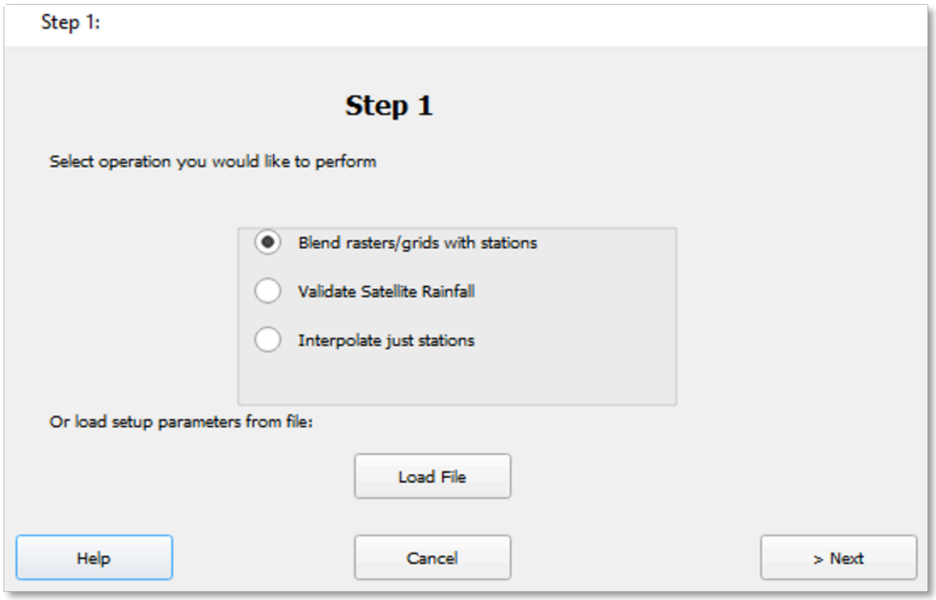


Figure 9-7 *Select the Blend raster/grids with stations option.*

9.2.2. Step 2: Datasets and interpolation parameters

The program expects two types of data as described below:

1. A point dataset with values at discrete locations in space (example: rain gauges)
2. A grid dataset with values varying continuously over space (for example, a satellite-based rainfall estimate grid or a climatic average). For the algorithm to be used effectively, the two datasets need to be correlated.

Complete the form with raster and station data information. This form is made of 5 sections, see (Figure 9-8).

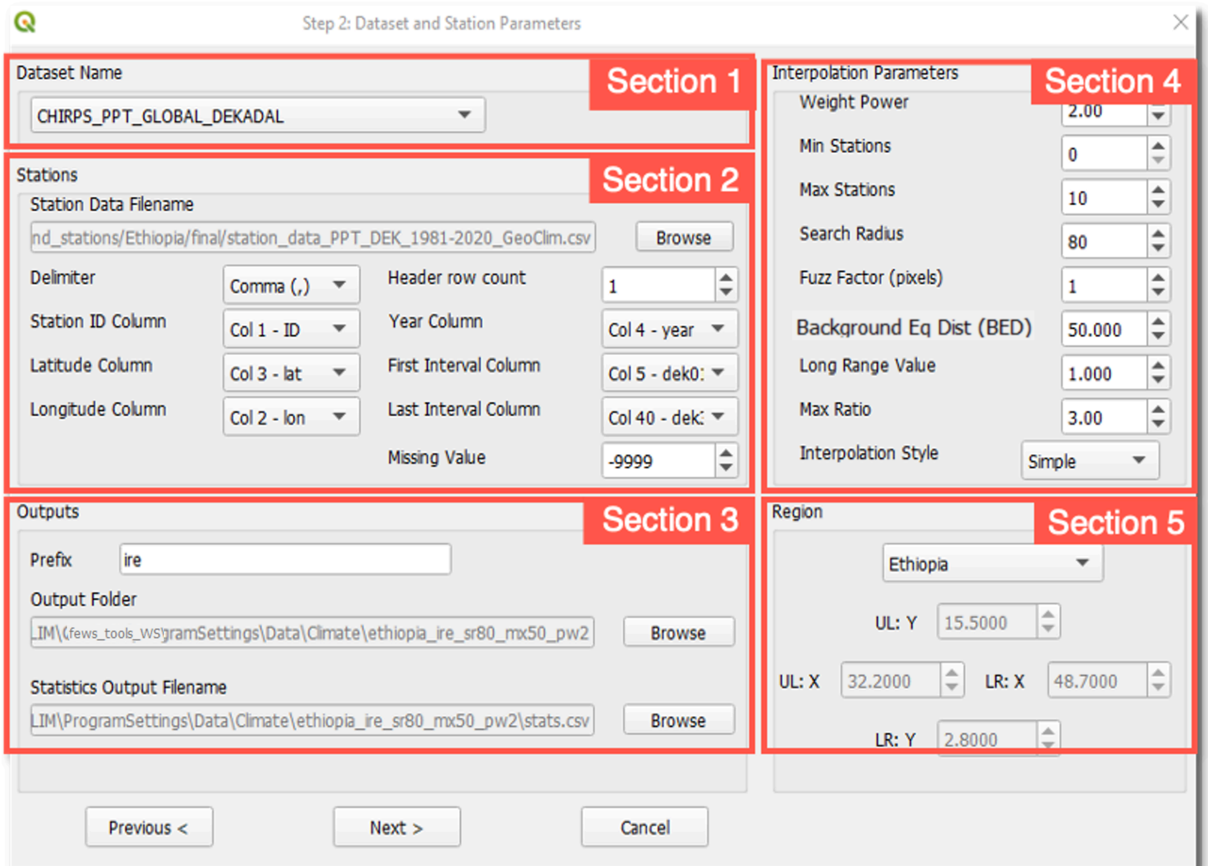


Figure 9-8 *Step 3 of the blending process requires information about the raster data, the stations, the output location, the interpolation parameters, and the geographic domain.*

9.2.2.1. Section 1: Select the gridded climate dataset

This section relates to the raster/grid input parameters. This process allows the improvement of climate datasets that have already been registered in GeoCLIM. To select the climate dataset to be used in the blending process, use the **Dataset Name ∨** pulldown menu. In this example we are going to blend CHIRPS dekadal data with stations.

9.2.2.2. Section 2: Select station table

This section relates to the station input parameters.

The tool assumes that all station data are in a single csv file. Browse to select the file which contains the station data. See an example in Figure 9-9 of the file format. The order of the columns is not important, but must include the following:

1. A unique station identifier ID, in a single column.
2. A column with longitude in decimal degrees.
3. A column with latitude in decimal degrees.
4. A column with year value (yyyy).
5. A series of consecutive columns for the number of periods (72 for pentads, 36 for dekads, or 12 for months).
6. Any missing data should be completed with a single Missing Value, for example (-9999).

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
ID	lon	lat	year	dek01	dek02	dek03	dek04	dek05	dek06	dek07	dek08	dek09	dek10	dek11
GOBAHI41	37.4167	11.6	1981	0	0	0	0	0	0	0	0	0	0	0.3
TIMEKE12	39.5312	13.4705	1981	0	0	0	0	0	0	5.5	4.5	14	0	5.6
TIILAI11	39.63	13.53	1981	0	0	0	0	0	0	2.4	4.9	5.6	0	11.6

Figure 9-9 *The CSV table with station data must contain a station ID, lon, lat, year and a column for each pentad, dekad or month.*

Once you select the station file, the tool identifies the header row and automatically completes most of the fields. Make any necessary changes to ensure that all fields have the correct specification.

9.2.2.3. Section 3 – Outputs

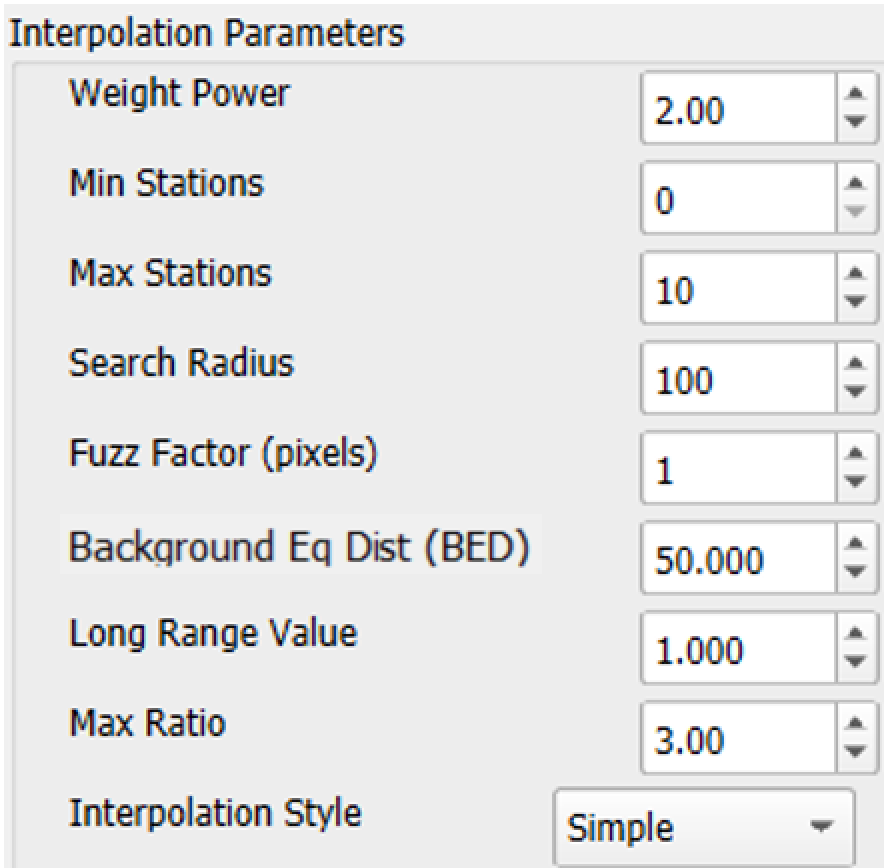
In the third section, you can specify the output directory where to save the blended products. At this point, you have two options: (1) create a new dataset or (2) update an existing dataset.

1. Create a new dataset: This first option allows you to create a new dataset in the correct format so it works with the GeoCLIM functions; for example, you are blending, for the first time, your stations with the historical data of CHIRPS or CHIRP and want to create a new dataset from the results. To do this:
   a) Provide a prefix for the output files.
   b) Browse to the GeoCLIM data repository. For example: `X:~\fews_tools_WS\ProgramSettings\Data\Climate\new_dataset` where X:~ is the path to your GeoCLIM workspace.
   c) The path on the **Statistics Output Filename** field changes automatically when you define the output directory.

d) Make sure to complete the fields in sections 4 and 5 before continuing. (See sections 4 and 5 for complete explanation of the parameters).
e) Click **Next** after completing all the fields.
f) A dialog box appears asking **Do you want to create a new dataset from outputs**?
   i) Click on **Yes**.
   ii) Enter a new name with no spaces.
   iii) Select the data type.
   iv) Select the extent of the data. If your region is outside of Africa or Central America, please select global.
   v) Click **OK** to move to Step 3.

2. Update an existing dataset: The second option is to add the latest record to an existing dataset. For example, you are blending the latest CHIRPS dekad with the stations and updating the time series you created previously.
   a) In the **Output folder** field, browse to the existing directory `X:~\fews_tools_WS\ProgramSettings\Data\Climate\existing_dataset` where X:~ is the folder containing the workspace.
   b) The path on the Statistics Output Filename field changes automatically when you specify the output directory.
   c) Make sure to complete the fields in sections 4 and 5 before continuing. (See sections 4 and 5 for complete explanation of the parameters).
   d) Click **Next** after completing all the fields.
   e) A dialog box appears asking **Do you want to create a new dataset from outputs?**
      i) Click on **No** to move to Step 3.

9.2.2.4 Section 4 – Interpolation Parameters



The program provides a set of options to adjust the parameters of the interpolation (Figure 9-10).

Figure 9-10. *The blending process includes several parameters that can be modified. Make sure you fully understand these parameters before making changes. Otherwise, it is recommended to leave the default values. A description of each parameter is provided below.*

9.2.2.4.1. Weight Power (WEIGHTPOWER)

The **weight power** is the exponent applied to the inverse of the distance when calculating station weights, see Equation 9-1. It determines how quickly the influence of a station decreases with distance from the interpolation point, See Figure 9.11.

$$wi = \frac{1}{di^{p}} \quad \text{Eq 9-1.}$$

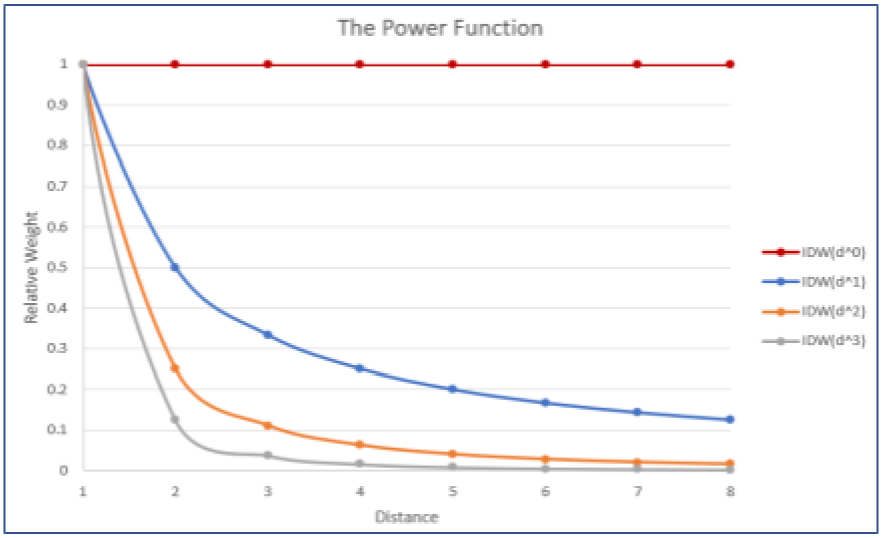


Figure 9-11 *The power indicates how fast the relative weight decreases as distance increases.*

- p = 0 → all stations have equal weight (no true interpolation).
- p = 1 → slow decay, distant stations still matter.
- p = 2 → faster decay, closer stations dominate.
- p ≥ 3 → very strong local influence, risk of bullseyes.

9.2.2.4.2. Search Radius, Min Stations, Max Stations

- **SEARCHRADIUS**: Maximum distance (in km) to search for stations around each pixel.
- **MINSTNS**: Minimum number of stations required for interpolation.
- **MAXSTNS**: Maximum number of stations allowed for interpolation.

At each pixel, the algorithm finds the nearest stations within the search radius. The number of stations used is limited between MINSTNS and MAXSTNS.

Example:
If SEARCHRADIUS = 200 km, MINSTNS = 2, and MAXSTNS = 10:

- If 7 stations are found within 200 km → all 7 are used.
- If fewer than 2 are found → the pixel will have a missing value.

To avoid missing values, it is recommended to set **MINSTNS = 0**, so that a value is always produced (with the background field filling gaps).

9.2.2.4.3. Fuzz Factor (FUZZFACTOR)

The **fuzz factor** generalizes the influence of stations to the pixel scale by introducing a small uncertainty in station locations.

- Distances are increased by (pixel size × fuzz factor).
- Prevents pixels containing a station from replicating the exact station value.
- Helps reduce the “bull’s eye” effect around stations.

FUZZFACTOR = 0 → pixels near a station are as close as possible to the station value.

9.2.2.4.4. Background Equivalent Distance

The **Background Equivalent Distance (BED)** represents the assigned distance of the BK station that carries the value of the background raster (e.g., CHIRPS) at the pixel location.

- **Smaller BED → stronger background influence** (solution tends toward CHIRPS even near stations).
- **Larger BED → weaker background influence** (nearby stations dominate; background mainly anchors far from stations).

9.2.2.4.5. Long Range Value (LR_VALUE)

It is the value assigned to the BK station (the conceptual-station that represents the background field) which is placed at the BED distance from each pixel. The Simple interpolation starts by adding the BK station to the IDW process.

Where it applies

- **Blending → Simple (idw_s):** LR is the ratio value for the BK station.
- **Interpolate Stations Only → Simple:** LR is a constant baseline (there is no CHIRPS raster here); the BK station still uses LR at distance BED.
- **Not used: Ordinary (idw_o)** in either mode (no BED/LR term is added).

Units
None (ratio units).

How it enters the interpolation (Simple style)
For a pixel x, a BK station with weight

$$wBK = \frac{1}{BED^p} \quad \text{Eq 9-2}$$

is added to the IDW process. The value contributed by that station is:

- **Ratio surface:** value BK = LR
- **Anomaly surface:** value BK = 0 (baseline anomaly is zero)

After this seed term, nearby stations are added with their usual IDW weights.

Recommended settings (best practice)

- **Ratio surface: LR = 1** (keeps background unbiased).
- **Anomaly surface: LR = 0** (no additive bias).
  Changing LR away from these values **overwrites the natural behavior**:
- **LR = 0 (ratio):** suppresses the background (values collapse where no stations).
- **LR > 1 (ratio):** inflates remote areas toward LR (unphysical).
- **LR < 1 (ratio):** deflates remote areas.
  For these reasons, LR should normally remain at **1 (ratio)** and **0 (anomaly)**.

NOTE: Long range should always be set to 1, unless you know that the background grid has a specific bias from the stations by a specific amount, then you use that bias as the long range value.

9.2.2.4.6. Max Ratio (MAXRATIO)

The **maximum ratio** limits extreme values of the station/grid ratio used in the multiplicative correction.

- Ratio = Station value ÷ Grid value
- Large ratios can lead to exaggerated corrections when interpolated and applied to distant pixels.

Example:
Station value = 10 mm, grid pixel = 1 mm → ratio = 10.
If interpolated, this ratio could cause a nearby grid pixel of 30 mm to be scaled up toward 300 mm.

By default, **MAXRATIO = 3**, meaning any ratio > 3 is reset to 3. This prevents unrealistic "run-away" values. Users may adjust this threshold, but very high cut-offs are not recommended except for special cases.

9.2.2.4.7. Interpolation Style (INTERPOLATIONALGORITHM)

Two IDW algorithms are available:

- **Simple (idw_s)** → includes the background field (recommended/default).
  - BED is used.
  - The background pixel contributes as an additional weight.
  - Influence of the background increases as the distance to real stations increases.

- **Ordinary (idw_o)** → standard IDW.
  - Weights depend only on surrounding stations.
  - Background field does not contribute.

9.2.2.5. Section 5 Region - geographic location

Define Map Limits: Allows you to define the interpolation area (Figure 9-12). Make sure that the area is smaller or equal to the gridded dataset. This area can be defined by using the extent of an existing GeoCLIM Region or other spatial data (raster or vector). This option helps to speed up the interpolation process.

To run the blending process, follow the steps below:

1. Choose the region from the list.
2. Click on **Next** To move to step 3.

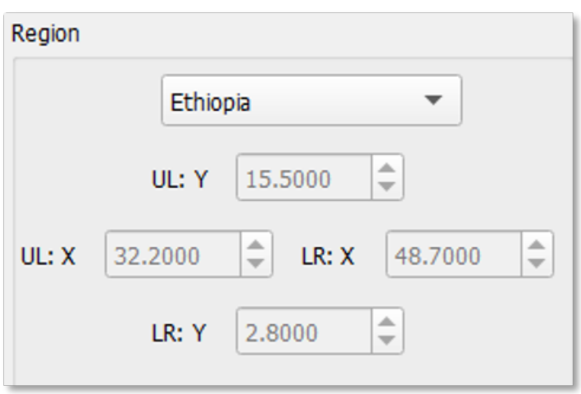


Figure 9-12 *Select the region (basin, admin unit, etc.) for the new data.*

9.2.2.6. Example: Estimating rainfall value at Location *x*

To illustrate how BASIICS works, we build an example step by step. We aim to estimate the rainfall at the target pixel **x**—shown in red in Figure 9-13 (left)—using the surrounding gauge stations. Each nearby station contributes its observed value Si and its distance to pixel **x**, di, as depicted in Figure 9-13 (right). These distances are then used to compute station weights in the basic IDW interpolation; we examine this process in more detail in the next section. What makes BASIICS different, however, is the inclusion of a **background field**, in this case CHIRPS. This background field is introduced through an **imaginary background station (BK)** placed at pixel **x**. This station is assigned a weight in the IDW process as if it were located at a fixed distance - the **Background Equivalent Distance (BED) -**. By doing so, BASIICS combines the influence of ground stations with the CHIRPS background field in a consistent interpolation framework.

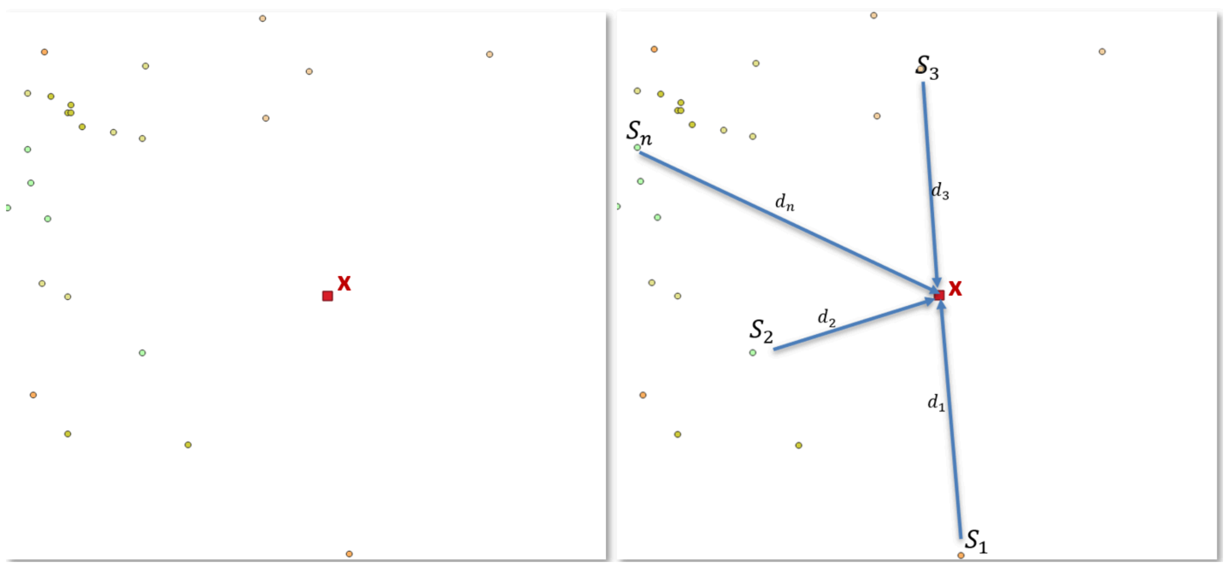


Figure 9-13 *shows the stations used to estimate location* ***x****. The first step is to calculate the distance from each station to X.*

9.2.2.6.1. Inverse Distance Weighting (IDW) and BASIICS Parameters

Let's first see how regular IDW would deal with this example.

IDW interpolation estimates the value at an unknown point as a weighted average of nearby station values. The influence of each station decreases with distance: closer stations exert more weight, while distant stations contribute less. A maximum distance, or **Search Radius**, is typically specified to ensure that only stations within a practical range affect the interpolation.

See more about IDW here
https://pro.arcgis.com/en/pro-app/latest/tool-reference/3d-analyst/how-idw-works.htm

Formally:

$$Z(x) = \frac{\sum_{i=1}^{n} \frac{Zi}{di^p}}{\sum_{i=1}^{n} \frac{1}{di^p}} \quad \text{Eq 9-3}$$

where:

- Z(x) = interpolated value at location x
- Zi = value at station i
- di = distance between location x to be estimated and station i
- p = weighting power (controls how quickly influence decreases with distance), see figure 9.11

The distance from each station to the location **x**, combined with the power P, is used to estimate the weight or in other words the influence each station will have in estimating **x**. Figure 9-11 shows the effect of the different P values in how fast the weight of the station value decreases with distance.

9.2.2.6.2. Incorporating the Background Field

Up to this point, we have illustrated a **standard IDW interpolation**, where the estimate at location **x** depends only on the surrounding stations, see Figure 9-14 left. In our case, however, there is an important difference: We also have a **background field** — in this case, CHIRPS — which provides spatially continuous rainfall estimates, even in areas where no stations are available, see panel on the right on Figure 9-14. In this section we introduce two new concepts. The background (BK) station shown in yellow, and the **Background Equivalent Distance (BED),** see panel on the right on Figure-14. The main purpose of the BK station is to allow the background field to influence the interpolation process at each pixel, having a relatively stronger influence as surrounding stations become further than BED away from the pixel being interpolated to.

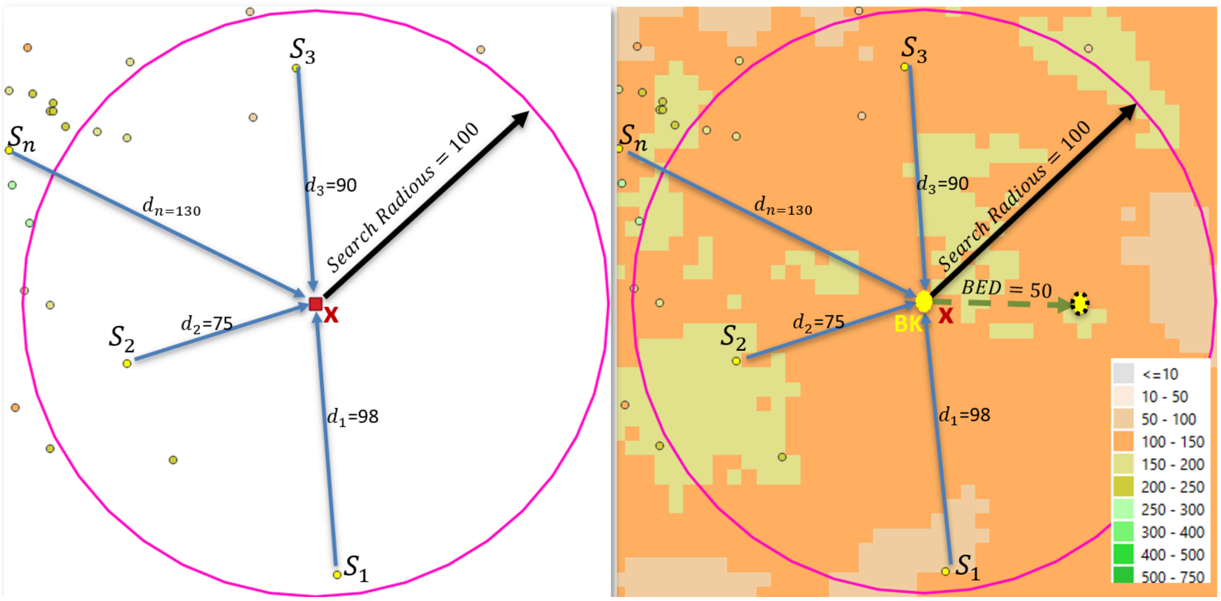


Figure 9-14. *Illustration of the interpolation geometry used in the BASIICS method.* ***Left****: Standard Inverse Distance Weighting (IDW) setup for pixel* ***x*** *where nearby gauge stations S1,…,Sn within a 100-km search radius contribute to the estimate.* ***Right:*** *In the "Simple" interpolation style, the CHIRPS satellite background is included. The value of CHIRPS is introduced as a conceptual background station (****BK****), placed at pixel* ***x*** *but weighted as if it were located at a fixed Background Equivalent Distance (BED = 50 km). This allows for the* ***blending of satellite data with gauge observations****, giving satellite data more influence in areas where station coverage is sparse.*

BASIICS is a modified IDW process that incorporates a background field by adding a **conceptual (imaginary) station** at every pixel **x** being estimated. We will refer to this conceptual station as **BK** (for **BacKground**). There is a BK station at every pixel **x** that we are estimating. Since all the stations in the process are assigned a weight based on their distance to the pixel **x**, the station BK also is assigned a weight as if it were at a distance BED. See right panel on Figure 9-14.

9.2.2.6.3. Let's summarize the BK station (Simple style)

- **Location:** BK is placed at the pixel **x** being estimated.
- **Weight:** BK is given the IDW weight of a station located at the **Background Equivalent Distance (BED)**:

$$wBK = \frac{1}{BED^p}$$ as shown on Eq 9-4

- **Value:** BK represents the background field (e.g., **CHIRPS**).
    - In the **ratio** surface, BK's value is the **Long Range (LR)** baseline, typically **1**, which corresponds to

      CHIRPS/CHIRPS=1.

    - In the **anomaly** surface, BK's value is **0**, which corresponds to

      CHIRPS−CHIRPS=0.

- **Role:** BK anchors the interpolation so that, far from stations, ratios relax toward **LR (=1)** and anomalies toward **0**, causing the final estimate to revert smoothly to the background.

> **Note**: BK does not inject the raw CHIRPS value directly into the ratio or anomaly interpolation. CHIRPS is applied afterward in the multiplicative step, see section 9.2.2.6.5. for more details.

9.2.2.6.4. Creating the Improve Rainfall Estimate (IRE)

As mentioned in the introduction to the BASIICS process, the Improved Rainfall Estimate (IRE) is produced through two main correction steps: **multiplicative** and **additive**. In this section, we focus on completing both steps by applying the framework and parameters discussed earlier—such as **Search Radius**, **Minimum/Maximum Stations**, **Weight Power**, **BED**, **Long Range and background station**, **Max Ratio**, and **Fuzz Factor**.

To begin, we perform the multiplicative correction by interpolating the required ratios across the spatial domain. These interpolated ratios are then used as input for the additive correction step, ensuring that both spatial and observational adjustments are applied effectively.

9.2.2.6.5. Multiplicative correction

This is the first step in adjusting satellite-based rainfall estimates, in our case CHIRPS, using gauge observations, see Figure 9-15. This step works by calculating the ratio between observed rainfall at stations and the corresponding CHIRPS pixel value, then interpolating these ratios across space to generate a correction surface. This surface is applied multiplicatively to the satellite data, effectively scaling the CHIRPS values to better match ground observations. The goal is to correct for systematic biases in satellite data before applying further local adjustments through the additive correction.

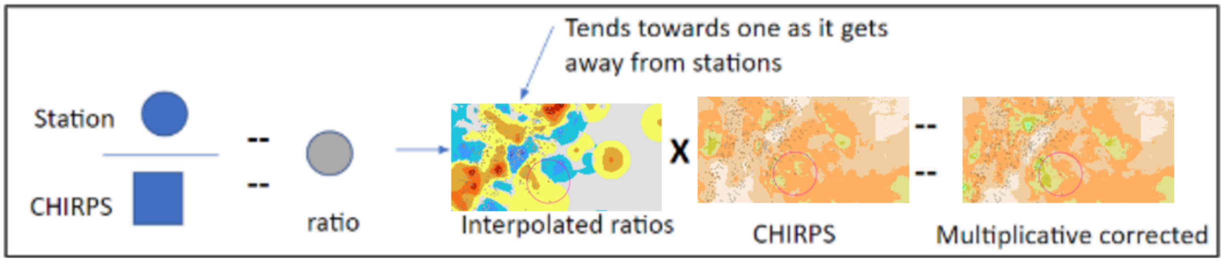


Figure 9-15. *Workflow of the multiplicative correction in BASIICS. Station observations are first compared to CHIRPS estimates to generate station-to-satellite rainfall ratios. These ratios are then interpolated across the domain, producing a continuous ratio field that tends toward 1 in areas far from stations. Finally, this ratio field is multiplied with the CHIRPS rainfall field, resulting in the multiplicatively corrected rainfall estimate.*

Let's look at the Interpolating ratios process:

$$\hat{R}(x) = \frac{\sum_{i=1}^{n} ri * wi(x) + LR * wBK}{\sum_{i=1}^{n} wi(x) + wBK} \quad \text{eq 9-5}$$

Definitions:

- $\hat{R}(x)$ = interpolated ratio value at pixel x
- r_i = ratio at station i (station ÷ CHIRPS)
- $w_i(x) = 1/d_i^p$, IDW weight of station i at pixel x
- d_i = distance from pixel x to station i
- p = IDW power parameter
- w_{BK} = IDW weight of the background station (BK), always included
- LR = long-range ratio value assigned to BK (commonly set to 1)

An epsilon (ε) is used internally to avoid divide-by-zero.

BASIICS generates a continuous ratio surface across the domain. This surface is produced with a modified IDW scheme that respects the search radius and station-count constraints, caps extreme values using the Max Ratio setting, and includes the background pixel as a conceptual station (BK) in Simple mode. Far from gauges, ratios relax toward the Long-Range value (LR = 1), ensuring that the multiplicative correction remains unbiased where station influence is weak. Figure 9-16 below displays a typical interpolated ratio field.

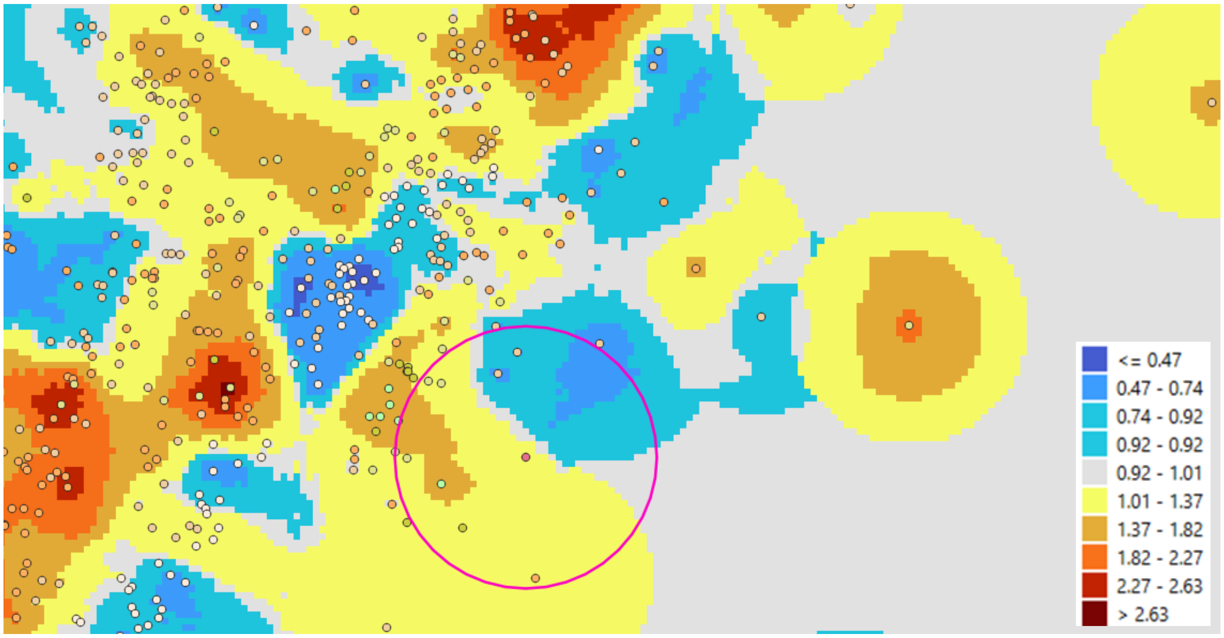


Figure 9-16. Interpolated ratio field R^(x). *Ratios (station/CHIRPS) are first capped by **Max Ratio** at gauge locations and then interpolated with BASIICS process. Warmer colors (> 1) indicate stations wetter than CHIRPS; cooler colors (< 1) indicate stations drier than CHIRPS. The magenta circle marks the search radius around the example pixel. In **Simple** style (used here), the background station **BK** pulls ratios toward **LR = 1** away from gauges.*

With the multiplicative correction applied, the large-scale bias between CHIRPS and station observations has been adjusted, producing a corrected rainfall field. However, local differences may still remain, as station observations can capture finer-scale variability that CHIRPS does not fully represent. To address this, we apply the **additive correction**, which incorporates station anomalies into the estimate.

9.2.2.6.6. Additive correction

This is the second step in the BASIICS process and is applied after the multiplicative adjustment. While the multiplicative correction removes large-scale biases between CHIRPS and station data, the additive correction focuses on reducing local differences. It does this by calculating anomalies (station − CHIRPS) at gauge locations, interpolating these anomalies across space, and then adding the interpolated anomaly field to the multiplicatively corrected rainfall. This step ensures that localized deviations captured by the stations are incorporated into the final estimate, improving spatial detail and accuracy in the **Improved Rainfall Estimate (IRE)**. The workflow for this step, and its role in generating the final Improved Rainfall Estimate (IRE), is illustrated in **Figure 9-17**.

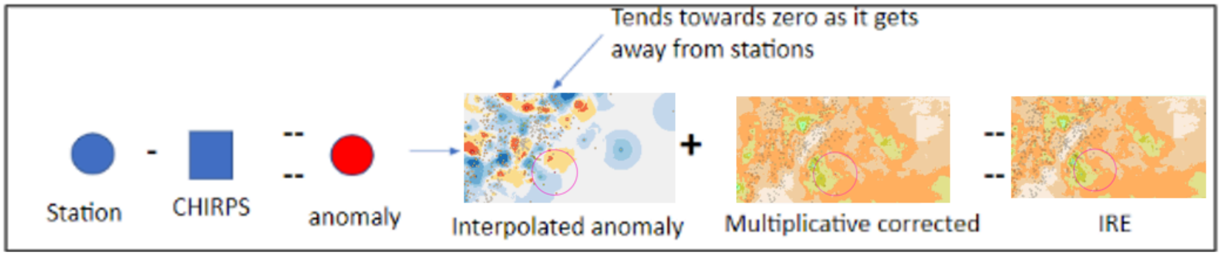


Figure 9-17. *Workflow of the additive correction in BASIICS. Station observations are compared to CHIRPS values to compute rainfall anomalies (station − CHIRPS). These anomalies are then interpolated across space, producing a continuous anomaly field that tends toward zero in areas far from stations. This interpolated anomaly surface is added to the multiplicatively corrected rainfall field, yielding the final Improved Rainfall Estimate (IRE).*

Interpolating anomalies

$$\hat{A}(x) = \frac{\sum_{i=1}^{n} ai * wi(x) + 0 * \ wBK}{\sum_{i=1}^{n} wi(x) + wBK} \quad \text{eq 9-6}$$

Equation for interpolating anomalies in the BASIICS process. The anomaly at each station is interpolated across space using IDW weights, while the background station (BK) always contributes a value of zero.

Definitions:

- $\hat{A}(x)$ = interpolated anomaly value at pixel x
- a_i = anomaly at station i (station − CHIRPS)
- $w_i(x)$ = $1/d_i^p$, IDW weight of station i at pixel x
- d_i = distance from pixel x to station i
- p = IDW power parameter
- w_{BK} = IDW weight of the background station (BK), always included
- $0 \cdot w_{BK}$ = background station anomaly contribution, which is always zero

Once (station − CHIRPS) anomalies are computed, the same interpolation framework is applied to create a continuous anomaly surface. Close to gauges, the field reflects observed local departures; away from gauges, the field trends to zero, preventing artificial additive bias. This anomaly surface is then added to the multiplicatively corrected CHIRPS field to yield the final

Improved Rainfall Estimate (IRE). The map on Figure 9-18 illustrates a typical interpolated anomaly field and the station distribution used in that period.

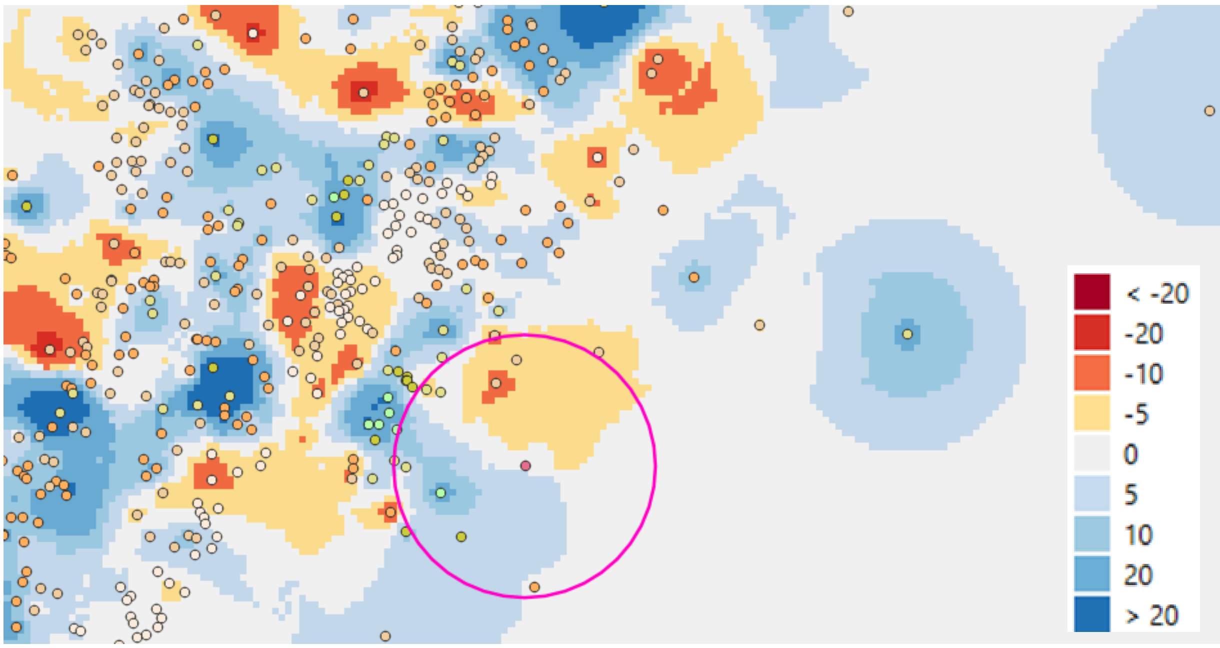


Figure 9-18. Interpolated anomaly field A^(z) for the additive correction. *The map of station anomalies (station − CHIRPS, in mm) interpolated over the domain. Reds are negative anomalies where CHIRPS is wetter than stations; blues are positive anomalies where stations report more rainfall than CHIRPS; the pale band around 0 indicates near-agreement. The magenta circle delineates the Search Radius used in the example; only stations inside that neighborhood can influence the interpolated anomaly at the example pixel, subject to the Min/Max Stations settings.*

9.3. Step 3: Date Parameters and saving settings

To save the date parameters and settings follow the steps below (Figure 9-19):

1. The time interval (e.g., month, dekad, or pentads) for the selected raster dataset is automatically displayed.
2. Select the time range **From** and **To** of the data to blend. The time period and time interval are based on the selected climate dataset definition. In this example we are using dekads, see figure 9-19. And we are blending from Feb (dekad 01) to May (dekad 03) 2020.
3. Save the setup. At this step, you can save the blending settings so you could open it from step 1, edit and reuse it.
4. Click on the **Finish** button to run the process.

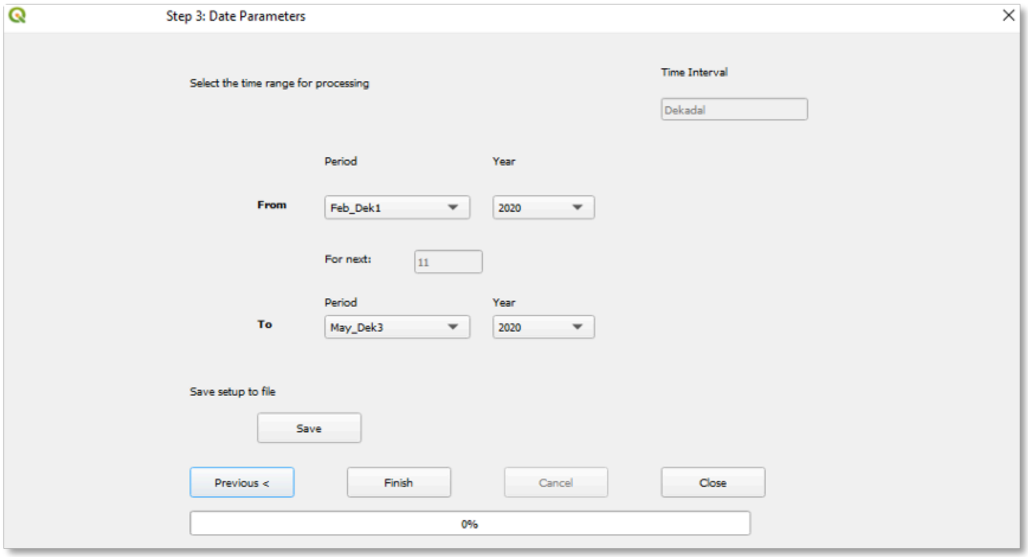


Figure 9-19 *Step 3 allows you to define the time range for the blending process and you could also save the setting to use later.*

9.4. Outputs

The blending process creates the following outputs:

1. A shapefile, for each period, containing all the stations that were used in the process.
2. The blended field, for each period. See Figure 9-16a.
3. The interpolated ratios and interpolated anomalies fields, for each period.
4. Three scatterplots showing the relationship of the original grid and the station values (Figure 9-16b) for example.
5. A CSV file, (Figure 9-16c) containing the metadata for each station together with the following columns:
    a) Station value
    b) Corresponding raster value
    c) The BASIICS value at station location
    d) Cross-validated BASIICS value. Indicates the BASIICS value at the station location without including that specific station in the process. This value responses to the question, what would be the value at this pixel if the station were not there.
    e) Cross validated interpolation only. Pixel value of interpolation of stations only, without including the corresponding station.

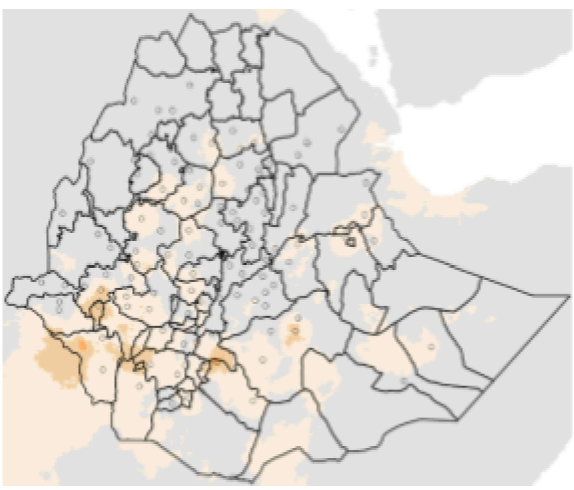


Figure 9-20a *BASIICS field with participating stations.*

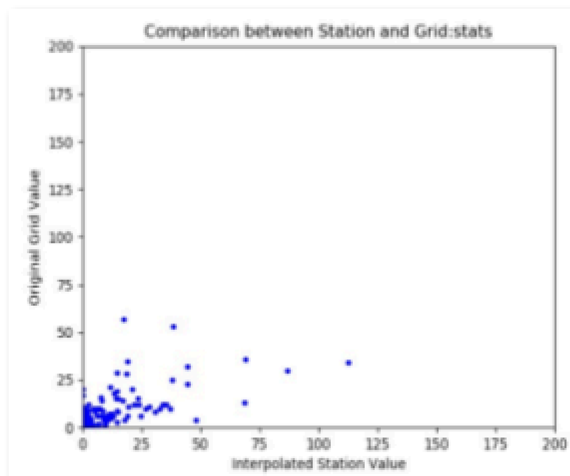


Figure 9-20b *comparison between station and raster values.*

Name	FileName	Long	Lat	StnVal	GridVal	BASIICSval	XValidatedBASIICS	XValidatedNoGrid
SHADDI21	202032	38.748	9.019	0	2	0	0.14	0
GOADET1:	202032	37.493	11.274	0	2	0	0.74	0
HAAISH21	202032	42.578	10.757	0	2	0	2	-9999
SHALEM11	202032	39.033	10.033	0	1	0	0.33	0
WOAMBA	202032	39.217	11.203	0	2	0	0.36	0
SHAMBO2	202032	37.87	8.97	0	0	0	0	0

Figure 9-20c *CSV table with information at station location.*

9.5 BASIICS Workflow

This section describes the workflow outline based on documentation provided by the programming team.

1. **Read station file**
    - Reads in the selected station file's data and splits it into two separate temporary CSV files:
        - **"Region Stns" CSV**: station ID, latitude, and longitude within the region's extents.
        - **"Region Data" CSV**: data for each station within the region's extents.

2. **Generate station-to-station list**
    - From the "Region Stns" CSV, generate stn_2_stn_list, where each index contains: [station, [ordered list (closest to furthest) of stations within search radius]]

3. **Generate station-to-pixel list**
    - From the "Region Data" CSV, generate stn_2_pixel_list, where each index contains: [[row of pixel, col of pixel], [ordered list (closest to furthest) of stations within search radius]]

4. **Split data by period**
    - From the "Region Data" CSV, split into separate CSV files for each period.
    - Store paths in split_csv_file_list.

5. **Calculate Fuzzy Distance**
    - Calculate and set the "Fuzzy Distance" from the "Fuzz Factor" for later IDW calculations.

6. **Initialize stats file**
    - Create stats.csv with header row.

7. **Loop through each period**
    a. Set base name for outputs (e.g., 2017.03.1 for 2017, March, dekad 1) (column B).
    b. Verify/get matching CSV for period from split_csv_file_list.
    c. Verify CHIRPS input grid file exists and return filename.
    d. Build station dictionary stn_dic from using outputs from steps b and c above:
        i. Keys = station ID (column A). Values = Longitude (C), Latitude (D), Stn_val (E).
        ii. Set Grid_val (F) by reading in the CHIRPS file from step c and getting the value at

station location.

e. Interpolate station values using 'ordinary' type via cointerpolate_stations_idw, setting:

- Xvalidated_stn_val (I)

f. Remove entries with missing data.

g. Create station shapefile from stn_dic. From steps d,e,and f.

h. Output initial stats to basiics_v2p0chirps<base_name>.stat.txt (first section: least squares stats comparing station values X and grid values Y).

i. **Calculate station ratios** and add to stn_dic:

- Formula: (Interpltd_stn_val+ϵ)/(Grid_val+ϵ)(Interpltd_stn_val + \epsilon) / (Grid_val + \epsilon)(Interpltd_stn_val+ϵ)/(Grid_val+ϵ) or Max Ratio if larger.
- ε = 10.0.

j. Interpolate station ratios via cointerpolate_stations_idw, setting:

- Intrpltd_ratio_val
- Xvalidated_ratio_val

k. Calculate Calculate the interpltd ratio and anom vals, this will set the "Int_ratio_x_grid_val", "Xval_ratio_x_grid_val", and "Anomaly_val"

i. Int_ratio_x_grid_val = Intrpltd_ratio_val × Grid_val

ii. Xval_ratio_x_grid_val = Xvalidated_ratio_val × Grid_val

iii. Anomaly_val = Interpltd_stn_val − Int_ratio_x_grid_val

l. Interpolate anomaly values via cointerpolate_stations_idw, setting:

- Interpltd_anomaly
- Xvalidated_anomaly

m. Calculate **Ratio + Anomaly**, setting:

i. Intrpltd_ratio_plus_anom = Int_ratio_x_grid_val + Xvalidated_anomaly

ii. Xvalidated_ratio_plus_anom_val = Xval_ratio_x_grid_val + Xvalidated_anomaly

n. Start **Blending steps**:

i. Interpolate station ratios to the pixel array → Interpolated Ratios Array → save as <base_name>_ratio.tif

ii. Multiply Interpolated Ratios Array × CHIRPS grid → Interpolated Ratios X Grid Array

iii. Extract values from Interpolated Ratios X Grid Array at stations → Interp_array_val

iv. Calculate anomalies: Interpltd_stn_val − Interp_array_val → Intrpltd_stn_minus_intrpltd_grid

v. Interpolate Intrpltd_stn_minus_intrpltd_grid with simple IDW, relaxing

anomalies to 0 farther from stations → anomaly array → save as <base_name>_anom.tif
vi. Final blended array = Interpolated Ratios X Grid Array + anomaly array → save as <base_name>.tif

o. Extract values from final blended array at stations → final_basiics_val (G).

p. Create <base_name>.crossval_graph.jpg:

- X: final_basiics_val (label: "BASIICS Pixel Value")
- Y: Xvalidated_ratio_plus_anom_val (label: "Cross-validated BASIICS Value")

q. Create <base_name>.stngrid_graph.jpg:

- X: Intrpltd_ratio_plus_anom & final_basiics_val (label: "BASIICS Pixel Value")
- Y: Grid_val (label: "Original Grid Value")

r. Output least squares stats (sections 2, 3, 4) with cross-validated stats to "base_name".stat.txt from step h

s. **PRINT OUT stats.csv** here for all the station data columns above.

8. **After loop completes**
    - Read back in stats.csv for all periods.

9. **Create cumulative stats.crossval_graph.jpg**
    - X: column G (BASIICS Pixel Value)
    - Y: column H (Cross-validated BASIICS Value)

10. **Create cumulative stats.stngrid_graph.jpg**
    - X: column G (BASIICS Pixel Value)
    - Y: column F (Original Grid Value)

11. **Generate comparison statistics** in stats.csv:
    - G vs F
    - G vs H
    - G vs I

Chapter 10: Extracting Raster Statistics and Time Series

Summary

The Extract Grid Statistics function (red box in Figure 10-1) calculates summary statistics for a polygon (or a set of polygons) from a shapefile, using a raster or set of rasters from the selected climate dataset. The tool allows to calculate (Average) the spatial average within each polygon, (Count) the number of pixels with a valid value within the polygon, (Maximum) the maximum value within each polygon, and so on with each of the other parameters. For example, we can calculate the spatial average of precipitation for each district for each month from 1981 to the present. This produces a CSV table that could be analyzed using Excel.

Figure 10-1 *The Extract Grid Statistics tool calculates summary statistics for a polygon (or a set of polygons) from a shapefile, using a raster or set of rasters fields.*

10.1. Extract Statistics

To extract summary statistics for a set of polygons, follow the steps below:

1. Open the **Extract Statistics from Raster Data using Shapefile** tool from the GeoCLIM toolbar.
2. Select a shapefile containing the polygons of interest (e.g., districts) and select a unique ID field (a data field in the shapefile that will uniquely identify each polygon, such as district names) Figure 10-2 (1).
3. Select the type of summary for the pixels within the polygon, see the **Summary˅** pulldown menu, Figure 10-2 (2).
4. Select the raster file(s). Figure 10-2 (3): Click on the **Add** button and browse to the directory where the raster files are located.
5. Select the files to be used in the process.
6. Click **Open**.
7. Back on the **Extract Grid Statistics** window, specify the output directory if necessary.
8. Click **OK**.

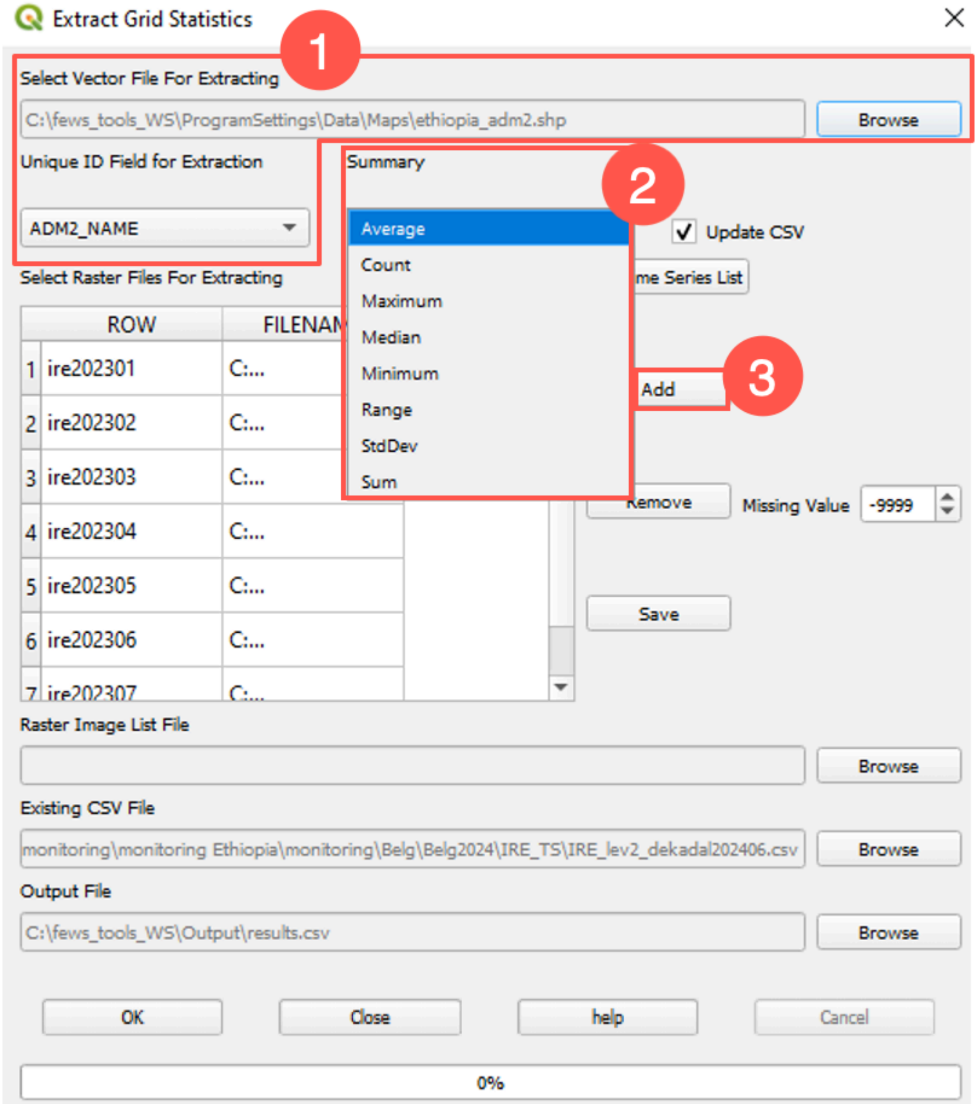
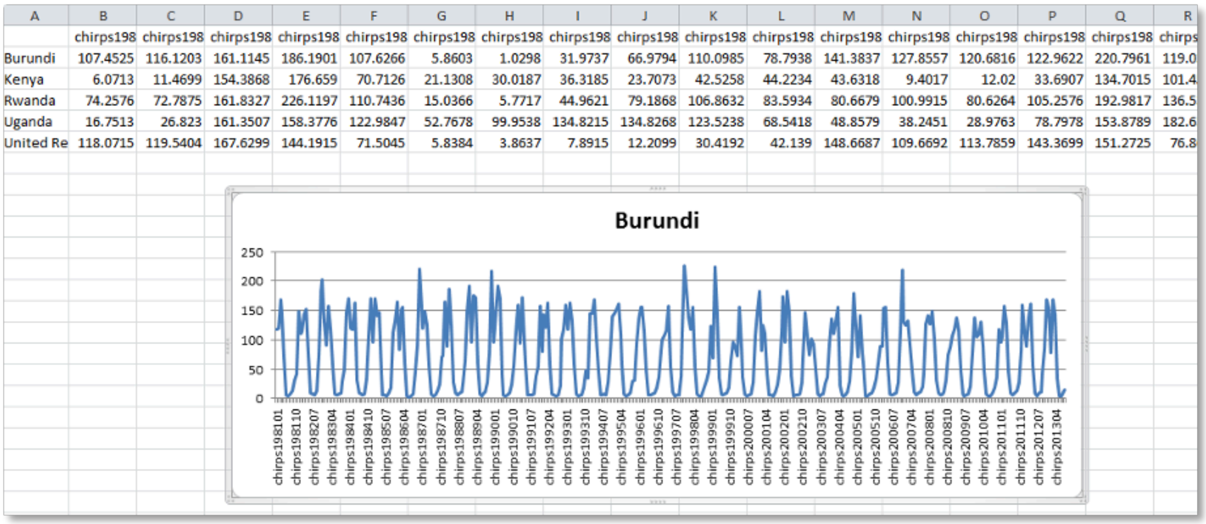


Figure 10-2 *The Extract Statistic function calculates the spatial statistics for each raster data set, using polygons of the selected shapefile. The output is a table containing a row for each polygon and a single column value (statistics selected) for each raster.*

10.2. Results

The **Extract Grid Statistics** tool produces a CSV table file with rows corresponding to the polygons from the input shapefile. Columns contain the summary value for each raster file selected. Figure 10-3 shows the output CSV table in Excel for the spatially averaged rainfall using CHIRPS dekads for each of the countries in the EAC region. To do additional analysis of the results, such as the production of time series plots, open the CSV file in Microsoft Excel (or another spreadsheet program).



A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
	chirps198	chirps198	chirps198	chirps198	chirps198	chirps198	chirps198	chirps198	chirps198	chirps198	chirps198	chirps198	chirps198	chirps198	chirps198	chirps198	chirps
Burundi	107.4525	116.1203	161.1145	186.1901	107.6266	5.8603	1.0298	31.9737	66.9794	110.0985	78.7938	141.3837	127.8557	120.6816	122.9622	220.7961	119.0
Kenya	6.0713	11.4699	154.3868	176.659	70.7126	21.1308	30.0187	36.3185	23.7073	42.5258	44.2234	43.6318	9.4017	12.02	33.6907	134.7015	101.4
Rwanda	74.2576	72.7875	161.8327	226.1197	110.7436	15.0366	5.7717	44.9621	79.1868	106.8632	83.5934	80.6679	100.9915	80.6264	105.2576	192.9817	136.5
Uganda	16.7513	26.823	161.3507	158.3776	122.9847	52.7678	99.9538	134.8215	134.8268	123.5238	68.5418	48.8579	38.2451	28.9763	78.7978	153.8789	182.6
United Re	118.0715	119.5404	167.6299	144.1915	71.5045	5.8384	3.8637	7.8915	12.2099	30.4192	42.139	148.6687	109.6692	113.7859	143.3699	151.2725	76.8

Figure 10-3 *The resulting table has a row for every polygon and every column represents the summary value for each raster.*

This tool facilitates updating the time series of a group of polygons for the purpose of monitoring the rainy season. You can complete the time series using CHIRPS final, CHIRPS prelim, and the forecast for the next decade. For example, for each polygon in column A in Figure 10-4, the time series includes CHIRPS-final data from 1981 dek01 to 2024 dek03, CHIRPS-prelim dekads 04 and 05, and forecast dekad 06.

A	B	C	BGM	BGN	BGO	BGP	BGQ	BGR	BGS	BGT	BGU
Feature	v2p0chirps198101	v2p0chirps198102	v2p0chirps202:	v2p0chirps202:	v2p0chirps202:	v2p0chirps2024	v2p0chirps2024	v2p0chirps202403	2p0chirps202404	v2p0chirps202405	/2p0chirps202406
Qala-e-Kah	12	10	1	2	1	3	3	4	2	4	12
Pusht Rod	14	9	0	2	1	3	3	4	3	4	13
Shib Koh	9	9	0	1	1	3	3	3	1	2	10

Figure 10-4 *Historical final CHIRPS (blue) + prelim CHIRPS (orange) + 10 day forecast (pink).*

Section 4
GeoWRSI Analysis Functions

Chapter 11

Summary

See video [GeoWRSI Meeting with Diego-20250721_140045-Meeting Recording.mp4]

The GeoWRSI is a geospatial, stand-alone implementation of the Water Requirements Satisfaction Index (GeoWRSI), as implemented by the U.S. Geological Survey (USGS) for the Famine Early Warning Systems Network (FEWS NET) activity. The program runs a crop-specific water balance model for a user-selected crop in a user-specified region in the world, using raster data inputs. The program produces a range of outputs which can either be used qualitatively to help assess and monitor crop conditions during the crop growing season or regressed with yields to produce yield estimation models and yield estimates. In addition, the program has several tools for validation, enhancement and analysis of both input and output datasets. Other tools are available to post-process the water balance outputs so that they can be used for yield estimation.

Technically, the Water Requirements Satisfaction Index (WRSI) is the ratio of seasonal actual crop evapotranspiration (AETc) to the seasonal crop water requirement, which is the same as the potential crop evapotranspiration (PETc). Originally developed by the Food and Agriculture Organization (FAO), the WRSI has been adapted and extended by USGS in a geospatial application to support FEWS NET monitoring requirements. Yield reduction estimates based on WRSI contribute to food security preparedness and planning. As a monitoring tool, the crop performance indicator can be assessed at the end of every 10-day period during the growing season. As an early warning tool, end- of-season crop performance can be estimated using long-term average meteorological data.

11.1. Setting the GeoWRSI

To get started, there are three key settings you need to be familiar with. First, you'll set up the region for your analysis. Second, you'll configure the outputs to save. Finally, you'll set the WRSI parameters. Although there is an additional setting for crop parameters, we won't need to adjust that one frequently. Let's begin by focusing on these initial three settings.

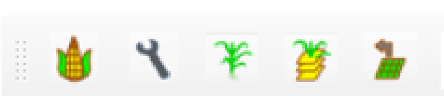


Figure 11-1 *The GeoWRSI toolbar includes icons (left to right) for crop setting, water balance settings, running the WRSI, climatological WRSI/SOS analysis and output settings.*

11.1.1. Regions

The FEWS Tools plugin allows you to set a region to work only with climate data using the GeoCLIM functions. Or add a parameter to run the water balance. Once you select GeoWRSI Region (see red box on Figure 11-2), a new form opens up with the parameter to run the WRSI at 10 or 5 days time steps, (see blue box on Figure 11-2). The tool comes with a set of predefined regions for different areas in Africa and Central America.

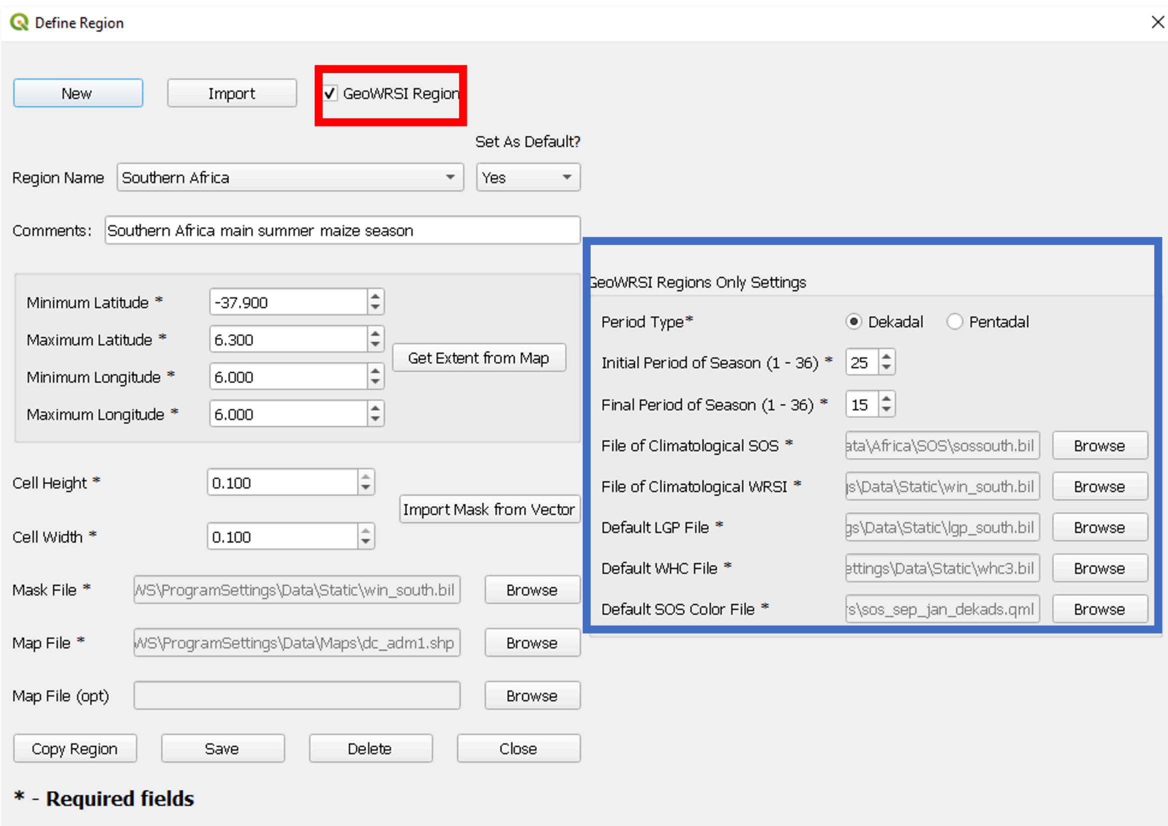


Figure 11-2 *FEWS tools allows you to use the Region setting form for both the GeoCLIM and GeoWRSI.*

11.1.2. Output settings

Specify the outputs that you want to save from the WRSI run by selecting the relevant outputs from the *GeoWRSI output options* dialog box (Fig 11-3). You can select outputs to save at the (1) Current/Forecast PEriod, (2) End of season/extended period and (3), every period (ie, dekad or pentad). Only 3 outputs can be saved at every period, namely WRSI, phenology, and soil water index.

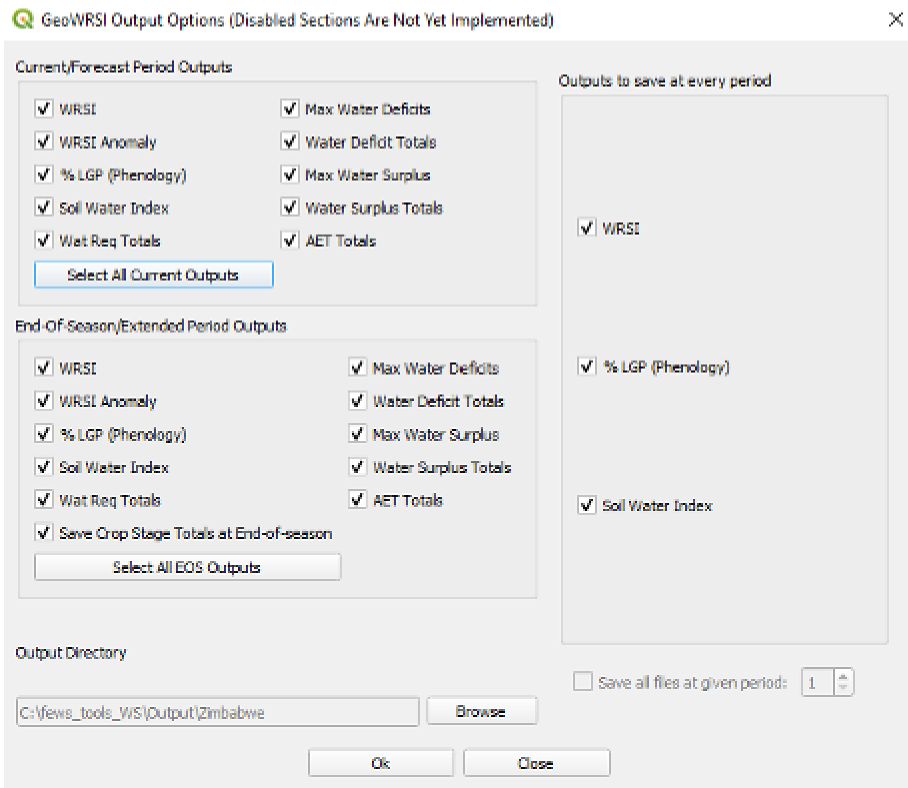


Figure 11-3 *The GeoWRSI allows you to save all or a subset of outputs.*

11.1.3. Setting the water balance parameters

A number of different water balance parameters can be specified for the WRSI run, including the region to run, the crop type, the start of season definition, the length of growing period (LGP) definition, the water holding capacity (WHC) definition, the mask definition, and the datasets to drive the model run. These settings are accessed from the WRSI Settings tool (Figure 11-4).

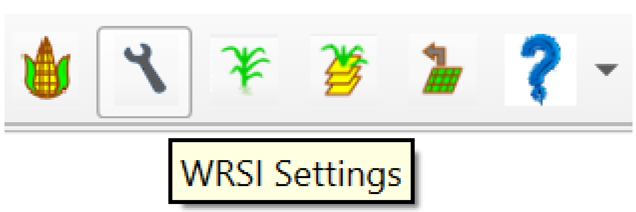


Figure 11-4 *The WRSI settings allows to define the Region, the crop type, Start of Season, Length of Season, Water Holding Capacity among other parameters to run the WRSI.*

This opens up a dialog box where the different model parameters can be set (Figure 11-5). While several different parameters can be set as defined above, the most common parameters to set are the crop type and the region.

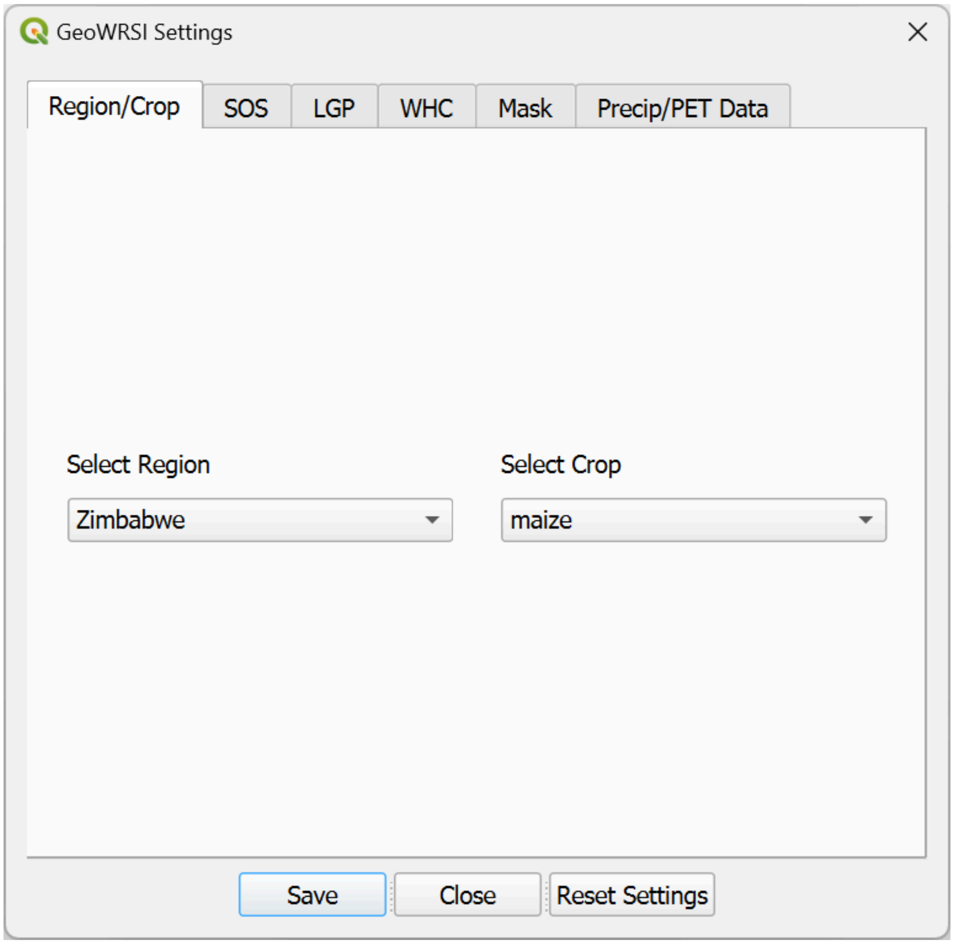


Figure 11-5 *Select first the region and crop type.*

Selecting the SOS, LGP,WHC, Mask and Precp/PET Data tabs allows these additional parameters to be changed as well (Figure 11-6). Unless you have a specific reason for changing these additional settings (e.g. to use a known planting that is different from the onset of rains), it is common practice to leave the additional settings unchanged. If you have changed the settings in the past for a special model run (e.g. to determine the potential impacts of planting for crops in different specific dekads of the same season), it is important to go through the different settings and ensure that they are all reset to the default setting, or that they are on the required setting.

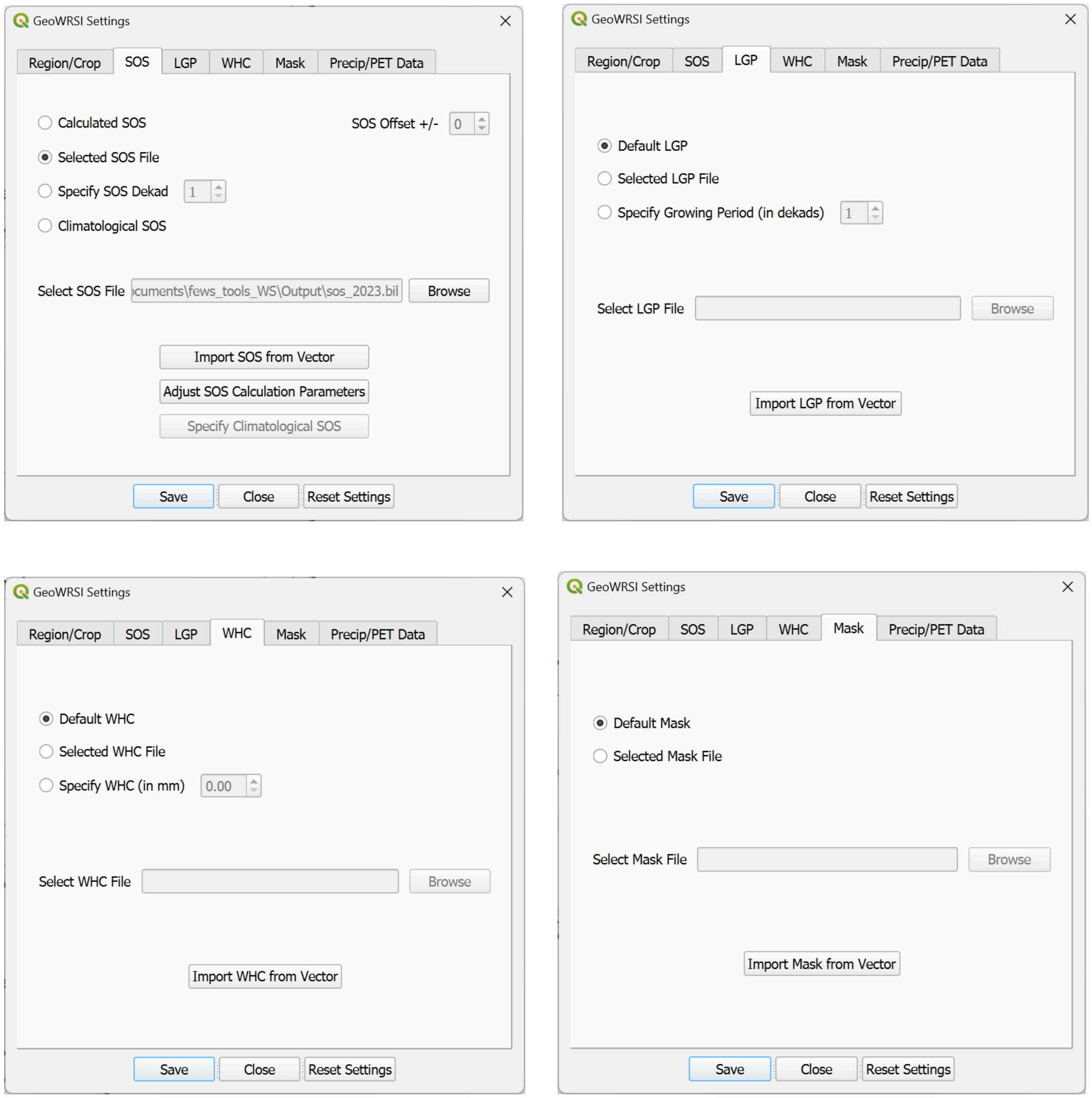


***Figure 11-6** Continue selecting each tab and define the corresponding variable.*

Worth special mention is the Precip/PET data tab (Figure 11-7. Users need to ensure that they are running the WRSI model using the intended datasets. For example whether they are using CHIRPS or a locally improved rainfall dataset (See Chapter 9)

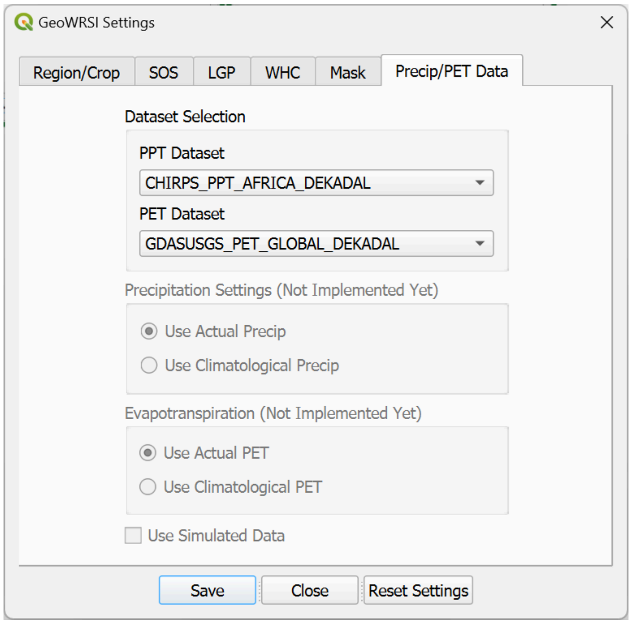


Figure 11-7 *Finally select the precipitation and evapotranspiration.*

11.2. Running the WRSI

To run the WRSI model, click the "Run WRSI" button(Figure 11-8)

Figure 11-8 *Once the settings are defined, you are ready to run the WRSI.*

The program prompts whether the precip (PPT) dataset contains a forecast period or not (Figure 11-9).

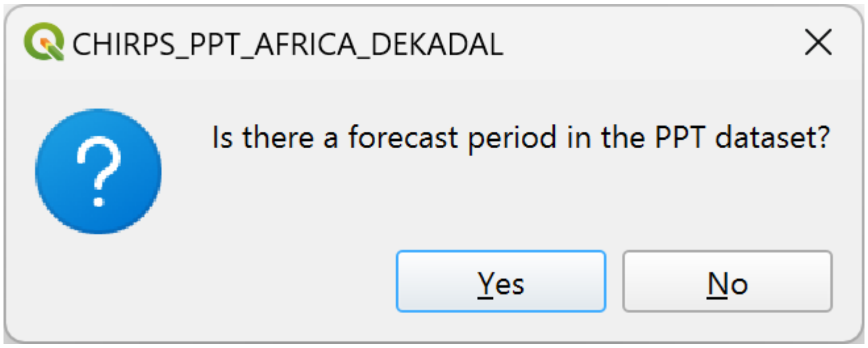


Figure 11-9 *Confirm if there is precipitation forecast data.*

Click no, unless you have downloaded and processed compatible forecast data. The forecast period function is a useful tool that allows you to forecast what the WRSI will be in the next period. Forecast period data are typically CHIRPS-GEFS, which is compatible with CHIRPS. To use the forecast period function, download a forecast dataset such as the CHIRPS-GEFS data from the CHC Products Collections , convert it to a format compatible with the CHIRPS data, and copy it into the active precip data directory (for the precip dataset that is being used to run WRSI).

Under “Start Year”, select the season/year for which to run the WRSI. The year referred to the year the WRSI run starts. So, for example, to run the WRSI for 2020/2021, select 2020, then click OK. The Water Balance model will start running. When it’s running, you will see a progress bar (% at the bottom).

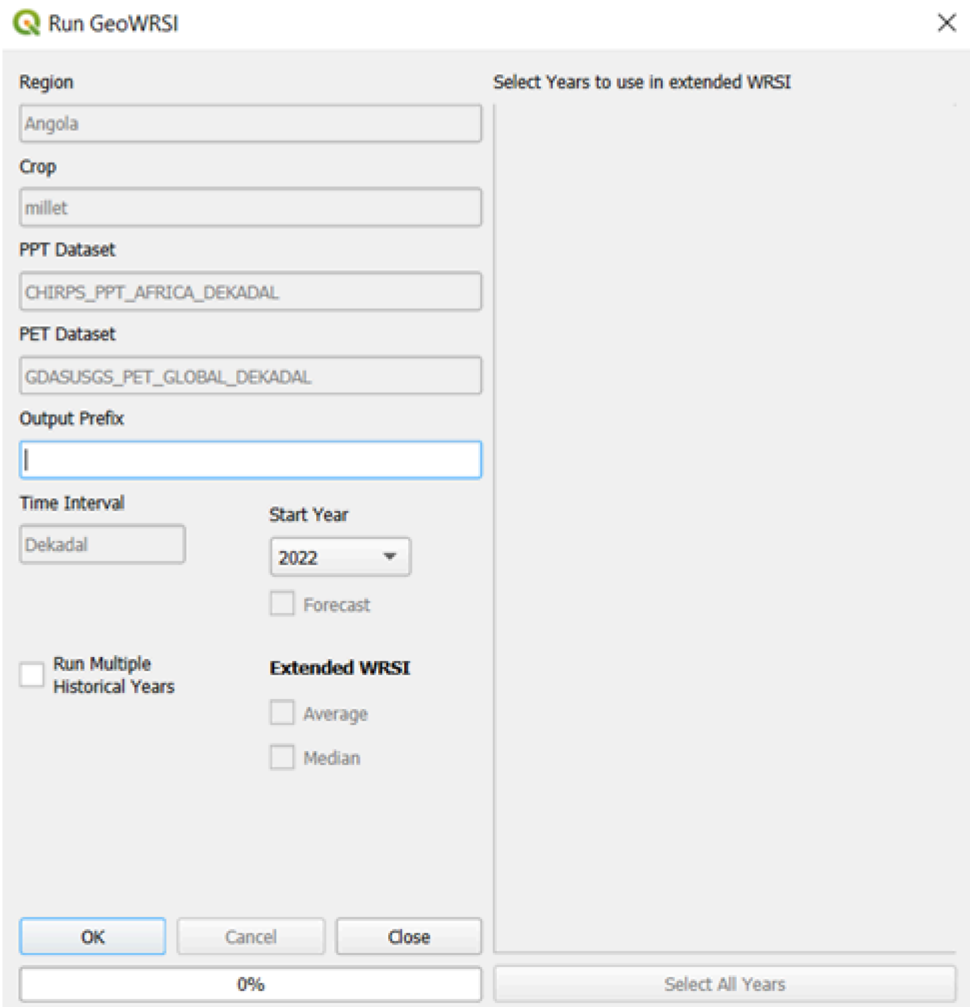


Figure 11-10 *When ready, select the year and a prefix for the current run.*

You can also run WRSI for multiple years by checking the "Run multiple historical years" box (Figure 11-11). The years options will appear on the right of the dialog box, allowing you to choose the years you want to run the WRSI.

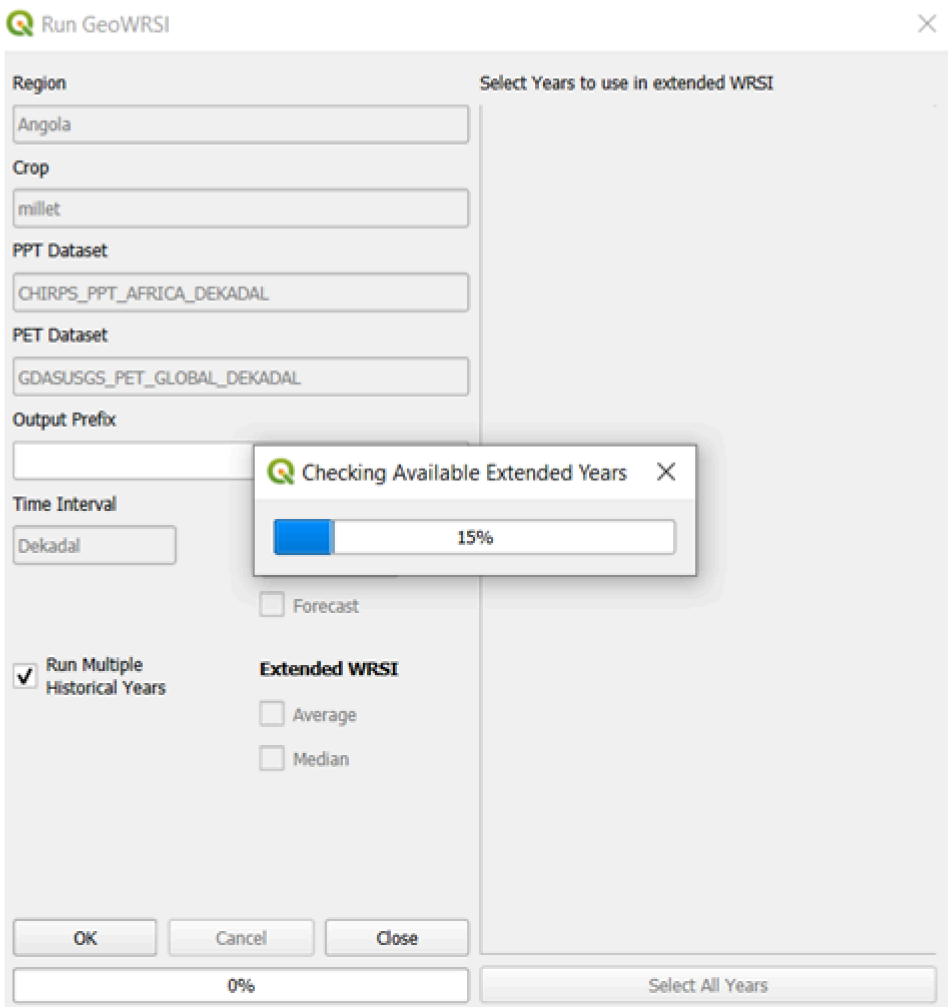


Figure 11-11 *Select the Run Multiple year box if you want to run the process for many years.*

Towards the end of the run, a dialog box will appear asking if you would like the animator to be initialized? You can click yes/no.

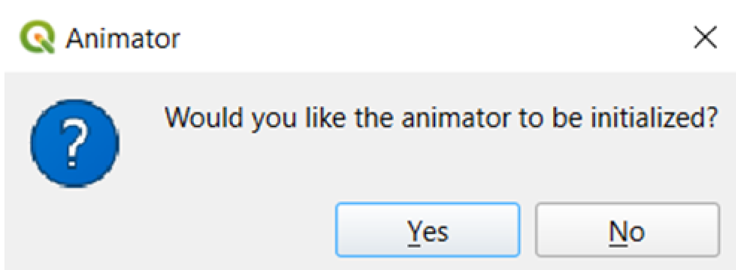


Figure 11-12 *The animator facilitates navigating the data in the QGIS canvas.*

The animator (Figure 11-13) enables display of the progression of the WRSI and other parameters over the course of the growing season. Clicking “yes” allows the animation of results to be displayed along with the other standard GeoWRSI outputs at the end of the run. Make sure that the last pulldown menu on the right is set to ‘source timestamps’ and the two curly blue arrows are ‘Set to Full Range.’

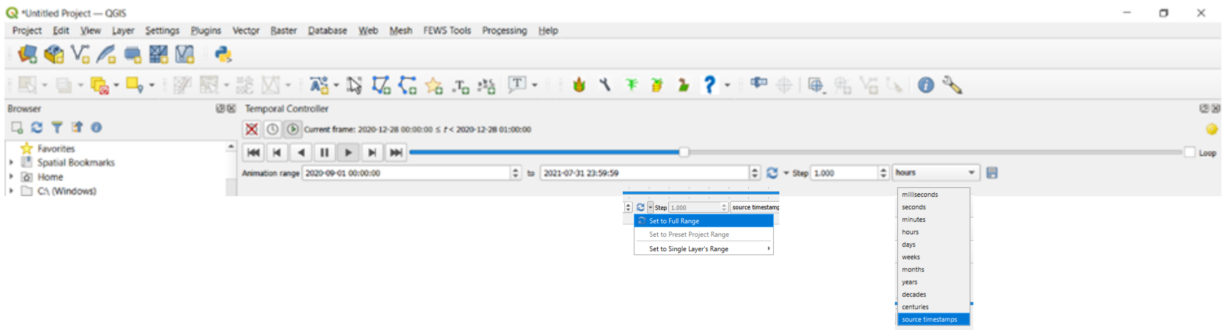


Figure 11-13 *You can click forward/backward through the different WRSI products.*

After completing the WRSI run, click ”No” to continue working with WRSI or “Yes” to close the window and view the results.

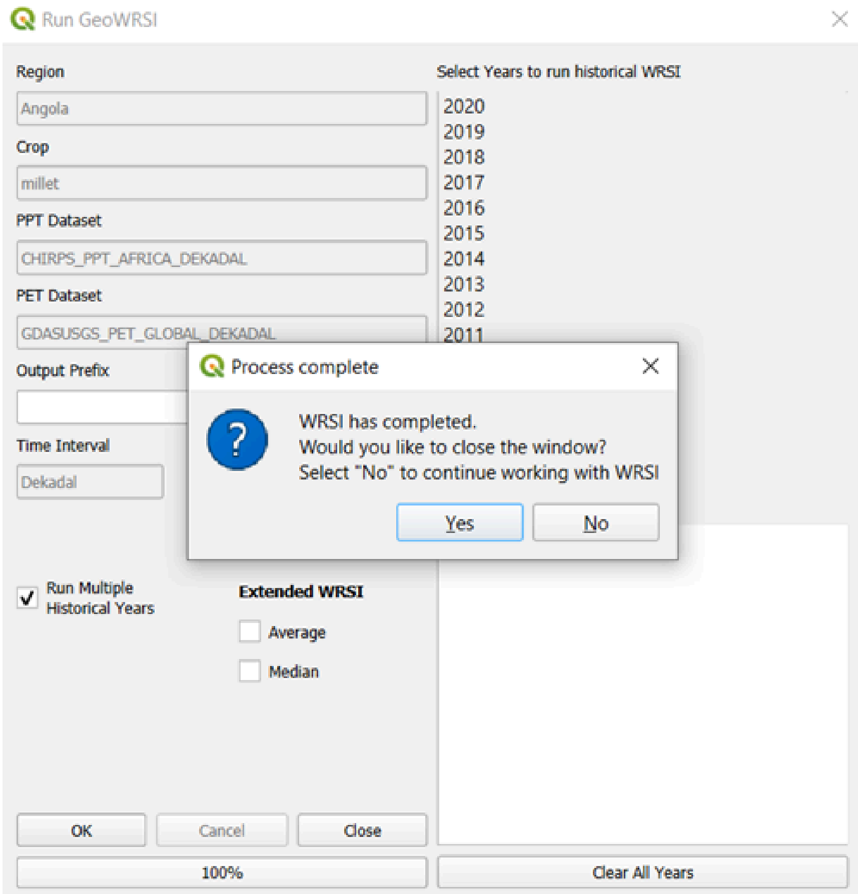


Figure 11-14 *Close the window if you want to see the results.*

Close the Run GeoWRSI window to see results. At this point you must complete the settings for the animator, as described on Figure 11-13, before you can use it.

On the left side of the screen, you will find the Table of Contents with various parameters to select (Figure 11-15 and 11-16)

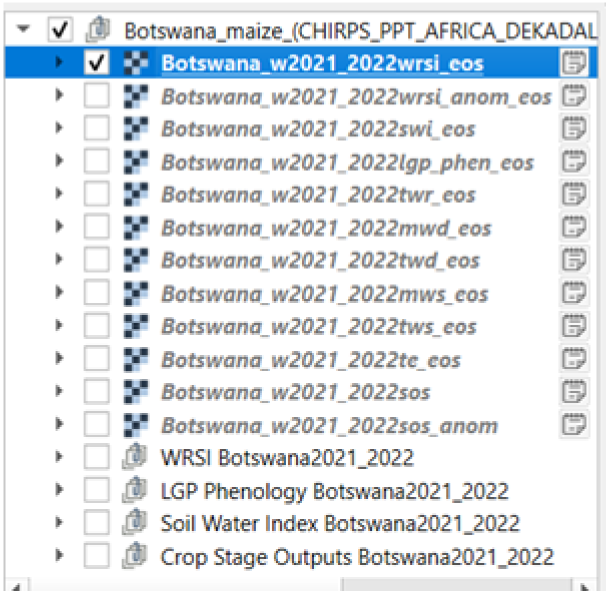


Figure 11-15 *The layers panel of WGIS lists the different products.*

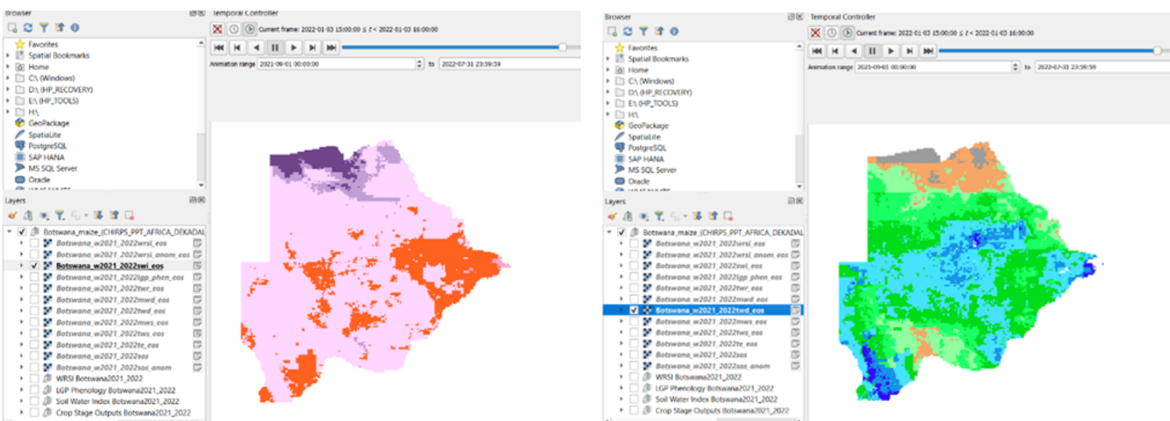


Figure 11-16 *The canvas in QGIS shows the maps. Use the animator to navigate through the different products.*

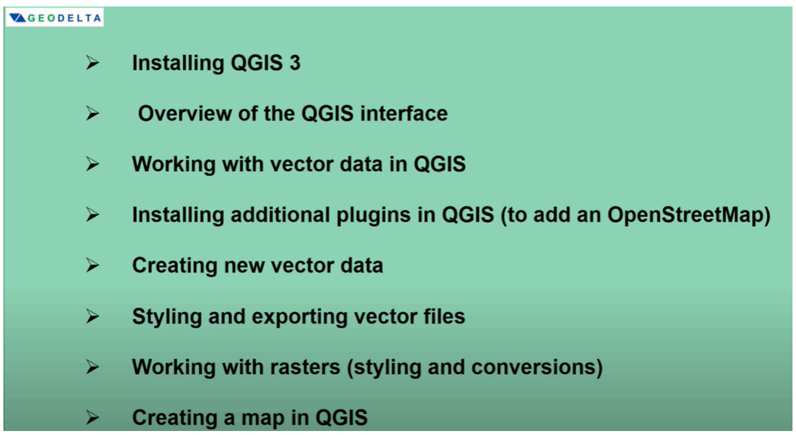
You can check boxes next to them to view each parameter individually. Additionally, you can move the animator bar to observe outcomes at different times.

Appendix A

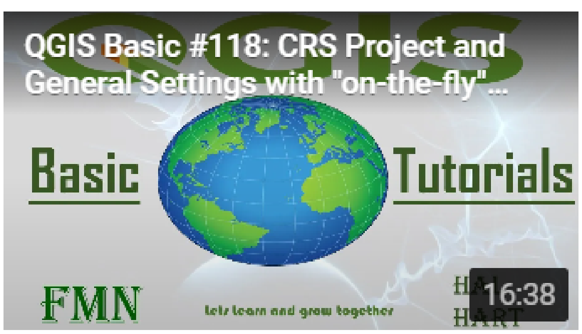
Summary

This section presents basic concepts of QGIS that are useful in the analyzes of climate data using FEWS Tools. Please find links to useful videos that present a variety of topics from uploading data to changing coordinate systems.

1. QGIS Basics
   a) https://youtu.be/NHolzMgaqwE



2. Loading Excel tables into QGIS https://youtu.be/rJwDrnJl4xg
3. Coordinates systems in QGIS https://youtu.be/p71qfALmdII



Acknowledgements

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1. Climate Hazard Center (CHC), University of California, Santa Barbara

2. Contractor for United States Geological Survey (USGS), EROS Center

3. United States Geological Survey (USGS), EROS Center

4. University of Nairobi, Kenya

5. IGAD Climate Prediction and Application Center (ICPAC)

6. United States Agency for International Development (USAID)

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