

## exercise 5

# vegetation dynamics in the sahelian zone

In Exercise 4 we saw an example of land cover conversion that is the result of human actions. In some regions, major land cover change is caused by climatic changes. One area where this is evident is in the Sahel region of Africa. The Sahel is the transition region between the Sahara desert and the wooded grasslands and tropical rainforests in the central portion of Africa.

We will start this exercise by defining the Sahel using climatic precipitation data. Next we will animate several images to see how vegetation cover changes from year to year. To quantify this, we will calculate mean, standard deviation, and coefficient of variation images. In the last part of the exercise we will use image processing techniques to highlight a drought that took place in 1984.

## BEFORE YOU BEGIN THIS EXERCISE

make sure you have completed the following steps—instructions for them are in the *Tutorial*.

- Start *SEE Image*
- Configure *SEE Image*
- Load the *SEE\_macros*

Because the images we will be using are large we will need to increase the clipboard space allocated to *SEE Image* before we begin. If your instructor has completed this step you should skip it.

## *Do A now.*

The images for this exercise are located in two folders. The first, *SahelSeptNDVI*, contains 13 NDVI September monthly composite images. The second folder, *Sahel1993NDVI*, contains 12 NDVI monthly composite images for 1993.

All of these Sahel images were created by cutting out a window with a width of 800 pixels and a height of 300 pixels from the Africa 8km monthly composite NDVI imagery available from the Goddard DAAC. The upper left image coordinate for this window is X=25, Y=200.

## A

### *changing the clipboard size*

1 — Select 'Options/Preferences'. Change the Undo & Clipboard Buffer Size to 1200. Click OK.

2 — Quit *SEE Image*.

3 — Restart *SEE Image*

NOTE: The images used in this exercise are larger than the image window. You'll need to move the images around inside the window in order to view them entirely. To do this, click on the hand in the Tools window, then move the cursor onto the image. Clicking and holding the mouse button and dragging the hand toward the top or bottom of the image window will move the image within the window.

**B*****opening a precipitation image of africa and overlaying african country boundaries***

1 — Select 'File/Open' and go to Desktop | HD | SEE Image | Data | Veg | vgex5 | AfRainMM.TIF and click on Open.

2 — Select 'Options/Color Tables/System' to color the image.

3 — Select 'File/Open' and then go to Desktop | HD | SEE Image | Overlays | AfCtry.TIF. Click Open.

4 — Activate AfCtry.TIF. Select 'Edit/Select All' followed by 'Edit/Copy Selection'. Close AfCtry.

5 — Activate AfRainMM.TIF. Select 'Edit/Paste'. The overlay image will completely cover the base image at this point.

6 — Select 'Windows/Show Paste Control'.

7 — In the Paste Control window, click and hold the Transfer Mode pop-up menu ('Copy' is the default setting) and select 'Replace'. The country outlines will be overlaid in black. The outlines are a shade darker than the background of the precipitation image and are difficult to see.

8 — Select 'Windows/Hide Paste Control' to close the Paste Control window.

*Do B now.*

**investigating precipitation patterns in africa**

Move the cursor over the different lines in the image and look at the values in the Info window. These values give the approximate annual rainfall in millimeters for the isohyet covered by the cursor. There is some rounding error because of the way SEE Image scales large numbers to the range of 0–255 so you should round the number displayed in the Info window to the nearest 100. For example, at image coordinate X=466 Y=388 the value is 901.19. This value should be rounded to 900mm.

**1a.** Determine the value and color associated with

highest rainfall: value \_\_\_\_\_ color \_\_\_\_\_

lowest rainfall: value \_\_\_\_\_ color \_\_\_\_\_

**1b.** What color lines approximately define the Sahara Desert region? Explain.

Locate the region between 150 mm and 600 mm of rainfall just south of the Sahara.

**2.** What colors define the upper and lower limits of the region?

This transition region between the Sahara and the tropical rainforests of Africa is called the Sahel. The Sahel is sometimes defined by using geographic coordinates. One set of coordinates defines the Sahel as the region between 10°N–25°N, and 18° W–45° W. The problem with using geographic coordinates is that they are a somewhat arbitrary way to define an area that is described by its unique ecological zones. We will explore this region and an alternate way to define it in the rest of the exercise.

## C

*opening an ndvi africa image and overlaying the precipitation isohyets for the sahel*

- 1 — Close all images currently open. Do not save changes unless told to do so by your instructor.
- 2 — Select 'File/Open'. When the file selection window appears, go to Desktop | HD | SEE Image | Data | Veg | vgex5 | SahelSeptNDVI | SahND0993.TIF. Click Open.
- 3 — Select 'Options/Color Tables/DAAC NDVI' to color the image.
- 4 — Select 'File/Open' and go to Desktop | HD | SEE Image | Overlays | SahelRain.TIF to open the precipitation layer for the Sahel.
- 5 — Select SahelRain.TIF. Select 'Edit/Select All' followed by 'Edit/Copy Selection'. Close SahelRain.TIF.
- 6 — Select SahND0993 and then select 'Edit/Paste'. The overlay image will completely cover the base image at this point.
- 7 — Select 'Windows/Show Paste Control'.
- 8 — In the Paste Control window, click and hold the Transfer Mode pop-up menu ('Copy' is the default setting) and select 'Replace'. The precipitation isohyets will be displayed on SahND0993.
- 9 — Select 'Windows/Hide Paste Control' to close the Paste Control window.

## D

*opening, stacking, and animating monthly images for 1993*

- 1 — Close all open images. Do not save changes unless told to do so by your instructor.
- 2 — Select 'File/Open'. Go to Desktop | HD | SEE Image | Data | Veg | vgex5 | Sahel1993NDVI. Select the Open All checkbox. Make sure the Sahel1993NDVI folder is open and an image is selected (it doesn't matter which image is selected) then click Open. All 12 images will open overlaying each other automatically.
- 3 — Select 'Options/Preferences' and then click on the Display Stack Title and Slice Titles radio button if it has not already been selected. Click OK.
- 4 — Select 'Stacks/Windows to Stack'
- 5 — Select 'Options/Color Tables/DAAC NDVI' to color the stack

*Do C now.***investigating ndvi and precipitation values in the sahel**

Move the cursor over the image and note the changing NDVI values in the Info window.

3. What is the approximate range of NDVI values in the Sahel for this September image?

Because the Sahel is a transitional zone it is an area with a great deal of month-to-month and year-to-year variation. To explore the variations we can generate and animate a stack of images.

*Do D now.*

*D, continued*

6 — Select 'Stacks/ Animate'. This cycles through the stack quickly and continuously. To slow down the animation, use the number keys 1–9 to change the speed of the animation. Lower numbers will animate the images at a slower speed, while 9 animates the images the fastest. To stop the animation, click anywhere inside the animated stack window. Note that the title of the stack does not change during the animation to indicate which slice (stack image) is being shown during the animation. To view the stack image by image and retain the slice names with each image, press the period (.) key to look at the next image and the comma (,) key to view the previous image. Notice that this allows you to control how quickly you move through a stack and you are able to see the stack and slice titles. However, with this method you cannot cycle directly from the end of the stack to the first slice in the stack. It is necessary to move backward through the stack to get back to the first slice.

**investigating monthly changes in the ndvi values in the sahel**

View the stack of monthly Sahel images for 1993 through several cycles.

**4a.** Which months show the largest area of high NDVI values?

**4b.** Which months show the largest area of low NDVI values?

**4c.** What region shows the least change in NDVI values? Why might this be expected?

**investigating year-to-year vegetation variations for september in the sahel**

**5.** Would you expect significant changes in vegetation patterns to occur from year to year in September in the Sahel? Explain.

**6.** Based on what you have done so far, what might you do to check for year-to-year variations?

**E***opening and stacking a series of september ndvi images for the sahel*

1 — Close any images that are open. Do not save changes unless told to do so by your instructor.

2 — Select 'File/Open'. When the file selection window appears, go to Desktop | HD | SEE Image | Data | Veg | vgex5 | SahelSeptNDVI. Select the Open All checkbox. Make sure the SahelSeptNDVI folder is open and an image is selected (it doesn't matter which image is selected) then click Open. All 13 images will open overlaying each other automatically.

3 — Select 'Stacks/Windows to Stack'.

4 — Select 'Options/Color Tables/DAAC NDVI' to color the stack.

To look at year-to-year variations you will set up a stack of images for the month of September from 1981 to 1993.

*Do E now.*

Animate the stack and view it through several cycles (refer to procedure D5 for instructions). Locate Lake Chad at the center of the image (blue) and use it as a reference point as you flip through the stack. The most southern point of Lake Chad is near the southern edge of the Sahel.

**7a.** Is there variation from year to year in the NDVI values in the Sahel region for September? Explain.

**7b.** What year shows the most extensive September vegetation in the Sahel?

**7c.** What year shows the least extensive September vegetation in the Sahel?

**7d.** What possible causes might lead to minimum vegetation development in the Sahel?

We can look at the same stack of Sahel images with a precipitation isohyet overlay to look for changes with a reference guide other than Lake Chad.

## F

### *overlaying the precipitation image for the sahel on the stack*

1 — Select 'File/Open' and go to Desktop | HD | SEE Image | Data | Veg | vgex5 | SahelRain.TIF to open the precipitation layer for the Sahel.

2 — Select 'Edit/Select All' followed by 'Edit/Copy Selection'. Close SahelRain.TIF.

3 — Activate SahND0981–SahND0981 and select 'Special/MultiPasteReplace'.

### *Do F now.*

Animate the stack with the overlay (refer to procedure D5 for instructions).

**8.** Review the questions in (7) above again using the overlay stack. Record any changes or additional observations here.

As you look at the September NDVI monthly composites for consecutive years, you will notice that the NDVI values on the edge of the Sahelian region vary significantly from year to year. This is largely because this area is very sensitive to changes in precipitation amounts and timing. In particular, notice how the image for 1984 is very different from the other images. We will discuss why this is the case in the last step of this exercise.

### investigating quantitative changes in september ndvi values for the sahel — a more advanced look

If we want to get a more quantitative measure of the changes in a region over multiple years we can compute a standard deviation on the image stack.

**9.** Before we compute a standard deviation image it is important to begin with images that do not have overlays. Why?

## G

### *opening and stacking a series of september ndvi images for the sahel*

1 — Repeat procedure E.

NOTE: close all open images and do not save unless asked to do so by the instructor.

*Do G and H now.*

Move the cursor over the “ahelSD image while monitoring the values in the Info window.

**10a.** What color represents the largest standard deviation values?

## H

### *calculating a standard deviation of an image set*

1 — Activate the stack SahND0981–SahND0981. Select ‘Special/CalcSDStack’. Enter “SahelSD” for the title. Click OK. The image will take a while to generate. You can monitor the progress by looking at the Processing Line= display in the Info window.

2 — Select ‘Options/Color Tables/Spectrum’ to color the image.

**10b.** What is the range of standard deviation values on the image?

**10c.** What do large standard deviations in NDVI values indicate about a region on an image?

**10d.** Is the Sahel clearly distinguished from the Sahara? From the equatorial rain forests? Explain.

As you have seen, if we calculate a standard deviation image the Sahel is easily differentiated from the Sahara Desert but it blends in with the wooded areas to the south. This is because the NDVI values are higher in the wooded areas and therefore a smaller relative change in NDVI in the wooded areas will appear similar to the relatively high change in the Sahel. To differentiate regions of high change we can calculate a coefficient of variation on the stack of images. The coefficient of variation is calculated by dividing the standard deviation by the mean. This gives us a method that is more sensitive to changes in low NDVI areas.

*Do I now.*

Move the cursor over the SahelCV image while monitoring the values in the Info window.

**11a.** What region has the highest coefficient of variation values?

**11b.** Is the region clearly distinguishable from the Sahara Desert and the equatorial rain forests? Explain.

**11c.** What do high coefficient of variation values indicate about this region?

**11d.** What possible climatic conditions might account for the larger variation in NDVI values in the Sahel?

### **I** *calculating a coefficient of variation image*

1 — Activate the stack SahND0981–SahND0981. Select 'Special/CalcCVStack'. Enter "SahelCV" for the title. Click OK. The image will take a while to generate. You can monitor the progress by looking at the Processing Line= display in the Info window.

2 — Select 'Options/Color Tables/Spectrum' to color the image

**J*****calculate a mean image from september sahel images***

1 — Close SahelSD and SahelCV. Do not save them unless told to do so by your instructor.

2 — Activate the SahND0981–SahND0981 stack. Select 'Special/CalcAvgStack'. Enter "SahelSeptMean" for the title. Click OK.

3 — Close the SahND0981–SahND0981 stack.

**K*****generating a difference image from the september 1984 image and the september average image***

1 — Select 'File/Open'. Make sure the Open All box is not checked. When the file selection window appears, go to Desktop | HD | SEE Image | Data | Veg | vgex5 | SahelSeptNDVI | SahND0984. Click Open.

2 — Select 'Process/Image Math' to activate the Image Calculator.

3 — Select SahND0984 from the uppermost pop-up menu. Select SahelSeptMean from the second pop-up menu (underneath the first one). Select the symbol for subtraction from the Operation pop-up menu. Enter "1" in the box next to the times sign (X) since we don't want to multiply the result by a constant. Enter "0" in the box next to the plus sign (+) since we don't want to add a constant to the resulting image. Type "Sept84-SeptMean" in the box next to the equal sign (=). This will be the name of the output image. Select the Real Result check box since the resulting image pixel values will be outside the 1–254 range. Click OK.

4 — Select 'Options/Color Tables/Spectrum' to color the resulting image.

Looking at the coefficient of variation image you can see the Sahel region is one of high change in vegetation cover throughout the year. Some people have suggested that it may be more appropriate to define the extent of the Sahel by using a coefficient of variation threshold since this provides information about vegetation dynamics.

A more accurate way to look at this variation within the Sahel would be to calculate the coefficient of variation for the monthly data over a period of several years. This can be done as an additional exercise although it will be necessary to increase the amount of memory available to SEE Image as you did in procedure A.

**investigating ndvi value variation in the sahel for a specific year — 1984**

To identify an individual year of significant change we can compare the image for a specific month in a year to the mean of that month generated from images over several years.

***Do J and K now.***

Move the cursor over various regions in the image and notice the values in the Info window.

**12a.** What do positive values represent? Negative values?

**12b.** What range of values do you find in the Sahel?



**12c.** What do the Sahelian NDVI difference values indicate about vegetation in this region this year compared to average September vegetation?

**12d.** What is a possible cause for this difference?

When we subtract the monthly image for September 1984 from the average of all the September monthly composites from 1981 to 1993 we can see that there was a significant difference between the average image and the 1984 image. This difference was caused by a serious drought that was one of the worst in Africa's history.

Below is a table of the precipitation record for a few meteorological stations in the Sahel for the period of May 1–May 30. From the table you can see that 1984 was a very dry year.

Station	Latitude (N)	Longitude (E)	Rainfall (mm) May 1–Oct. 30, 1983	May 1–October 30 30-year average (mm)
Khartoum	15° 36'	32° 32'	1	158
Kassala	15° 28'	36° 24'	98	321
Gedaref	14° 02'	35° 24'	325	579
El Obeid	13° 10'	30° 14'	97	386
El Fasher	13° 28'	25° 20'	69	283
Nyala	12° 04'	24° 53'	182	470
Kadugli	11° 00'	29° 43'	369	764
Abu Nama	12° 44'	34° 08'	371	576
Kosti	13° 10'	36° 40'	86	396
Sennar	13° 33'	33° 37'	193	470
Wad Medani	14° 25'	33° 31'	127	362