

Land Cover Change

**Using
Normalized
Difference
Vegetative
Index**

More Lessons from the Sky
Satellite Educators Association
<https://SatEd.org>

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Content and Internet links, revised and updated June 2023.

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Land Cover Change

Using Naturalized Difference Vegetative Index (NDVI)

Invitation

During my pre- and early teen years, I would sometimes accompany my father as he drove across the Los Angeles basin on business. The typical trip went from the far northeast corner of Los Angeles to the west side near Santa Monica. Many of the freeways that are so used and crowded today did not yet exist. As we travelled city streets, he often remarked that this or that office building had not been there twenty years earlier; it had been a coffee shop or a strawberry field or simply an empty lot. I remember thinking how unique to have memory of the area reaching that far back. As my own children were growing up, I found myself similarly remarking about changes in our area over the previous twenty years. Greek philosopher Heraclitus (c.500 BCE) is credited with the saying, “Nothing endures but change.” In other words, the only constant in the universe is change. Just how has the area in which we live changed over a generation or more? Is there more or less vegetation? Has the number or type of buildings changed? Are there new streets and highways? How is the land being used? How do changes in land use affect the human population and the overall health of the planet? How do human activities and choices affect the quality and type of land cover? Can land cover and land use be measured on a large scale? Are such changes related in any way to global climate change?

This lesson will introduce the learner to *normalized difference vegetative index* imagery. The learner will access and analyze multispectral satellite imagery especially prepared to indicate the amount and productivity of vegetative land cover and thus follow changes over a number of years.

Grade Level:	9-12 (adaptable to lower grades)
Time Requirement:	2-3 class periods
Prerequisites:	None
Relevant Disciplines:	Biology, Chemistry, Physics, Geography

Student Learning Outcomes

By the end of this lesson, students should be able to do the following:

- Obtain satellite imagery showing the normalized difference vegetative index of selected geographic areas at different times.
- Utilize specialized image processing software for image analysis.
- Analyze the imagery to determine the amount and location of vegetation compared to non-vegetative areas in each image.
- Compare the images from different years to document changes in an area over time.
- In the context of the specific subject discipline of the class, research local environmental, cultural, and global change phenomena occurring in the selected area during the time period between images and relate them to the changes indicated in the images (complete assigned Your Turn extension activities).

Teaching Notes

Lesson Description

In this lesson, learners will use satellite-based, remotely sensed, multispectral data to generate and analyze normalized difference vegetative index (NDVI) imagery in order to document changes in the land cover vegetation of a selected area over a number of years. The student actions include selecting an area for study, downloading NDVI imagery of that area for two dates separated by a number of years, and displaying and analyzing the imagery to document change. The documented change is then related to other phenomena of concern to those studying global change.

The activity is computer-based although it can be adapted for use without computers. Students may work individually or in teams of up to four at each computer terminal.

The activity is adaptable to various grade levels. The expectations for quality and depth of analysis will be less for lower grade levels. For example, high school students may be asked to use the software to measure area in a digitized image while middle school students may be asked to make a subjective and relative determination of vegetative area extent. Younger students who do not have access to computers or lack the expertise to utilize the specific software involved, may use pre-printed images prepared by the teacher instead of computers. Any quantitative indications of area, however, will only come from software capable of such measurements. You may optionally select and use only those tutorials that apply to your students and lesson. See the tutorials in the Student Activity pages for more details for students.

Important Terms

Channel (waveband)	Landsat	Productivity
Chlorophyll	Land use	Vegetation
Cultural features	Near infra-red	Vegetative index
Enhanced Thematic Mapper	Phenology	Wavelength band

Assessment Suggestions

- Teamwork and participation if students work in groups
- Quality of completion of tutorial activities
- Correctness and quality of answers to questions in the student activity
- Accuracy of analysis of NDVI imagery
- Accuracy of evidence base for conclusions
- Reasonableness of conclusions related to NDVI imagery and related research of human activities and environmental change in the selected area

Next Generation Science Standards Addressed

The following are the Next Generation Science Standards addressed in this lesson.

Performance Expectations & Disciplinary Core Ideas

Grades 9-12: Waves and Their Applications in Technologies for Information Transfer

- PE- HS-PS4-5 - Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

DCI- HS-PS4.A - Information can be digitized; in this form it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.

Grades 9-12: Waves and Their Applications in Technologies for Information Transfer

PE- HS-PS4-5 - Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

DCI- HS-PS4.C - Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.

Grades 9-12: Ecosystems: Interactions, Energy, and Dynamics

PE- HS-LS2-2 - Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

DCI- HS-LS2.A - Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and non-living resources and from such challenges as predation, competition and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance of species in any given ecosystem.

Grades 9-12: Earth and Human Activity

PE- HS-ESS3-1 - Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

DCI- HS-ESS3.A - Resource availability has guided development of human activity.

Science & Engineering Practices

- Communicate technical information or ideas in multiple formats.
- Use mathematical representations of phenomena or design solutions to support and revise explanations.
- Construct an explanation based on valid and reliable evidence obtained from a variety of sources and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Crosscutting Concepts

- Modern civilization depends on major technological systems.
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Preparation

Internet enabled computers are needed for this activity. Learners can work in teams of

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up to four or individually at each terminal.

There are two image processing software packages used in this lesson. Both are free for download, installation, and use. Both are high quality, professional packages that are suitable for use in an educational setting. Both install quickly and easily in relatively small self-contained folders. They are especially useful in high school and undergraduate levels while easy enough to use for middle school and lower grades.

MultiSpec is from Purdue University. It can be downloaded without charge from <https://engineering.purdue.edu/~biehl/MultiSpec/>. Many teachers trained for the GLOBE program (Global Learning and Observation to Benefit the Environment) may already be familiar with MultiSpec. GLOBE training originally included access to a hyperspectral Landsat data set with the teacher's school centered in the image. MultiSpec was the program of choice for displaying and analyzing those data. GLOBE was developed and is supported by both NASA and NOAA. More information about the GLOBE program, accessing ground data collected by more than 39,000 GLOBE schools in 127 countries, how to become a GLOBE school, and how to participate in GLOBE teacher training can be found at this URL: <https://www.globe.gov/>

MultiSpec installation is simple, quick, and self-contained. Accompanying the program are several sample images. Spend a few minutes with the program and the exercises to get to know the look and feel of the program before you ask students to use it. It should be noted that the developers of MultiSpec continuously update and improve the program and its documentation. If you already have MultiSpec installed, feel free to delete it and download the latest version to obtain the updates.

Developed for critical medical image processing and research at the National Institute of Health, ImageJ is now in the public domain and available free of charge from <https://imagej.nih.gov/ij/>. Full documentation is also available at the same site. One of the versions pre-bundled with Java is recommended. The bundled Java installs automatically and runs only with ImageJ. It does not interfere with any other programs or plug-ins (including Java) already installed on your computer. ImageJ is a stand-alone program; its folder can be installed anywhere on the computer. Windows users are cautioned to avoid installing ImageJ in the default Program Files folder as this folder's security protocols prevent ImageJ updates.

The image data files are downloaded in a single, compressed (.zip) file. To decompress zip files, the use of 7-Zip or StuffIt Expander is recommended. Both are free, highly capable, easy to use, compression/decompression utilities. If the computer used by the students cannot read the zipped archive, you can download and decompress the file set independently. Then copy the data files to each student's NDVIData folder.

The metadata files are given in HTML (.htm) files. Open and read these files with any competent browser.

Your specific implementation of this lesson will depend on how you fit it into your curriculum. That will be based on the subject discipline of the class itself, the level and needs of your students, and your particular classroom situation. If needed for lower grade levels, false color NDVI graphics in PNG (portable network graphics) format can be downloaded from the same USGS web page on which the image data link is found.

The downloaded graphic can be printed and distributed to students.

The Teaching Notes pages are provided in portable document format (.pdf). Adobe Acrobat Reader or equivalent is needed to read and print the PDF file. Adobe Reader can be downloaded free of charge from the Adobe web site listed in the Reference section. The Student Activity pages are provided in Microsoft Word document (.docx) format allowing the teacher to more easily adapt the student pages to the specific needs of the learners, the curriculum, and the teacher's unique classroom situation.

Background

Normalized difference vegetative index (NDVI) images are multispectral images processed with an algorithm designed to highlight vegetated areas distinctive from non-vegetated areas. They are used to study changes in land cover and land use over time. NDVI images are usually false colored with a palette of greens and browns. Generally, more dense chlorophyll-based vegetation results in greener pixels in the image. Browner areas have less or no vegetation.

Since the first satellite with a remote sensor went into orbit around the Earth more than a half century ago, much has been learned about the reflection of electromagnetic energy (light) by various surface features. An explanation of reflectivity and multispectral imaging can be found on the Web page "Using Satellites in Education" accessed at <https://SatEd.org/satellites.htm> or use the link in the Analysis Toolbox accessed from the SEA Lesson Plan Library at <https://SatEd.org/library/Tools.htm>.

One of the characteristics of the green chlorophyll found in plants is its unique reflective properties. Green chlorophyll appears green because it reflects wavelengths of green while absorbing wavelengths of some blue and a lot of red light. Most of the absorbed light energy goes into the photosynthetic process producing oxygen and glucose. Green chlorophyll also reflects most light energy in the near infrared wavelength range.

Data from multispectral remote sensors includes the amount of reflected light in various wavelength bands including visible red, visible blue, visible green, near infrared, and other infrared bands. Specialized multispectral software, such as MultiSpec developed at Purdue University, allow the user to view each wavelength band independently or in combination with other bands. The user simply assigns each band to one of the primary colors of the computer's display monitor (red, green, blue). In the resulting false color image, the user is able to "see" otherwise invisible infrared energy as well as certain features that have become more noticeable in the false color image.

MultiSpec also allows for combining wavelength bands into one channel. Using an algorithm in which the amount of reflectance in the red band is subtracted from the amount of reflectance in the near infrared band and the result divided by the sum of those same two bands, a normalized difference vegetative index image is created. In the images in this lesson, the single channel image appears in 256 gray tones. Pixel values range from 0 to 255. Pixel value indicates the brightness of the pixel. A pixel brightness of 0 appears black because there is no reflected light reaching the sensor. This value is sometimes reserved for pixels for which there is no data available. A pixel value of 254 is the brightest indicating the most light reflected. In these NDVI images, pixel values equal to 255 are often reserved for reflection from surface features that are not land,

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but water.

In NDVI images, higher pixel values represent areas with more chlorophyll and thus more dense vegetative land cover.

NDVI images for this lesson have already been prepared for you by the United States Geological Survey (USGS). Once downloaded from the USGS Phenology web site, the single channel images appear in gray tones. Processing with MultiSpec produces a thematic image with a special color palette applied that indicates vegetative areas in shades of green while non-vegetative areas are shown in shades of brown.

Measurements of area in MultiSpec are difficult when the pixels of a specific color are scattered all around the image. MultiSpec can indicate area in a variety of units but only within a rectangular or polygonal selection boundary. However, the processed image can be saved in GeoTIFF format and then opened in ImageJ, an image processing program from the National Institute of Health. Using ImageJ's threshold tools allows quick determination of the pixel count for any group of pixels. The results of ImageJ measurement are easily imported to Excel for graphing of changes over time, if desired.

Acknowledgements

This lesson is based on the tutorial materials for using MultiSpec, the multispectral imaging software. The tutorial materials were first encountered by the author in training for the GLOBE program in 1995. Updated and more complete MultiSpec tutorial materials were produced by Larry Biehl and David Landgrebe and posted on the MultiSpec site at Purdue University. They were current as of this writing.

Larry Biehl and David Landgrebe at Purdue University's School of Electrical and Computer Engineering and the Laboratory for Remote Sensing developed the multispectral imaging program called MultiSpec. It has evolved into a multispectral imaging and data analysis program that is offered as freeware especially for educational purposes. The web site contains program downloads for Windows and Macintosh based platforms as well as new documentation, tutorial exercises, sample images and more.

This lesson is also based on the use of ImageJ. The original NIH Image software was developed for medical imaging and analysis at the National Institute of Health on a Macintosh platform. When the program was placed in the public domain, the author, Wayne Rasband, rewrote the program in Java for cross-platform use. Rasband continues to update and improve ImageJ. The program enjoys a large user community making frequent contributions to techniques of use and macro development. Updates are easily accomplished if ImageJ is not installed in the *Program Files* folder of Windows Vista or later operating systems.

The United States Geological Survey (USGS) receives and processes Landsat transmissions. The data are checked and archived, then processed again by the Earth Resources Observation Systems (EROS) Data Center into a variety of useful forms which are offered to the general public via several on-line access points. The NDVI images used in this lesson were downloaded from the USGS Remote Sensing Phenology web site at <https://www.usgs.gov/special-topics/remote-sensing-phenology>. This web site offers numerous links to helpful educational background and other useful sites in addition to

being a gateway to NDVI image data.

This lesson arrangement and this edition of Teaching Notes were developed by J.P. Arvedson for the Satellite Educators Association as part of *More Lessons from the Sky* published on-line periodically in the Satellite Educators Association Newsletter. More information about the Satellite Educators Association, its annual Satellites & Education Conference, international collaborative environmental research program for K-12, and access to the online Newsletter can be found at <https://SatEd.org>.

All *More Lessons from the Sky* lesson plans are archived in the on-line SEA Lesson Plan Library available at <https://SatEd.org>. The web site features a description of the library contents, Next Generation Science Standards addressed, several search tools for finding lessons easily, separate resource files for lessons where needed, and the library's Analysis Toolbox.

When duplicating or otherwise using any portion of this lesson or its associated materials, please give full credit to all contributors to the lesson.

Resources

Note: All of these URLs were current and active as of this writing. If any are unreachable as printed, the use of on-line search engines such as DuckDuckGo, Ask, Google, or Bing is suggested to find current links.

_____. "Adobe Reader." Adobe. Adobe. Retrieved June 2023 from <https://get.adobe.com/reader/>

_____. "NOAA POES." Earth Online, European Space Agency. Retrieved June 2023 from <https://earth.esa.int/eogateway/missions/noaa>
Click "Explore Instruments" for information about AVHRR

_____. "Documentation for MultiSpec." MultiSpec, Purdue Research Foundation. Retrieved June 2023 from <https://engineering.purdue.edu/~biehl/MultiSpec/documentation.html>
Access to documentation and training tutorials including NDVI.

_____. "Landsat 7." Landsat Science, National Aeronautics and Space Administration. Retrieved June 2023 from <https://landsat.gsfc.nasa.gov/satellites/landsat-7/>

_____. "The GLOBE Program." The Global Learning and Observations to Benefit the Environment (GLOBE) Program. Retrieved June 2023 from <https://www.globe.gov/>
Access portal for GLOBE Program information including schools, data entry, data retrieval and visualization, project information, and much more.

_____. "Heraclitus." *Wikiquote*. Retrieved June 2023 from <https://en.wikiquote.org/wiki/Heraclitus>
Source of quote "Nothing endures but change."

_____. "ImageJ." National Institute of Health. Retrieved June 2023 from <https://imagej.nih.gov/ij/>

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- _____. "Landsat Science." Landsat Science, National Aeronautics and Space Administration. Retrieved June 2023 from <https://landsat.gsfc.nasa.gov/>
- _____. "MODIS." National Aeronautics and Space Administration. Retrieved June 2023 from <https://modis.gsfc.nasa.gov/>
- _____. "MultiSpec – A Freeware Multispectral Image Data Analysis System." Purdue Research Foundation. Retrieved June 2023 from <https://engineering.purdue.edu/~biehl/MultiSpec/>
Download MultiSpec software, documentation, tutorials, sample images.
- _____. "National Centers for Environmental Information." National Oceanic and Atmospheric Administration. Retrieved June 2023 from <https://www.ncdc.noaa.gov/>
- _____. "Remote Sensing Phenology." United States Geological Survey. Retrieved June 2023 from <https://www.usgs.gov/special-topics/remote-sensing-phenology>
- _____. "StuffIt Downloads." StuffIt, Smith Micro Software, Inc. Retrieved June 2023 from <https://stuffit.com/>
Free software for expanding compressed files; Mac, Windows, and iOS versions.
- National Research Council. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press, 2013. Retrieved June 2023 from <https://nap.nationalacademies.org/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts>
- National Research Council. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press, 2013. Retrieved June 2023 from <https://nap.nationalacademies.org/catalog/18290/next-generation-science-standards-for-states-by-states>
- Pavlov, Igor. 7-Zip. Retrieved June 2023 from <https://www.7-zip.org/>
Free, open-source software for packing and unpacking compressed files in multiple formats; Windows and Linux versions.

Answers to Questions in the Student Activity

1. Based on your reading so far, write a definition of remote sensing *phenology*.
Remote sensing phenology uses satellites to track seasonal changes in plant and animal life cycles on regional, continental, and global scales.
2. Specifically, how are red and near infrared light related to NDVI imagery?
Green plants strongly absorb red light and strongly reflect near-infrared light. Combining these bands of data in a specific algorithm produces the NDVI image. As plant canopy changes from season to season, these reflectance properties also change, thus changing the NDVI image.
3. In what ways can remote sensing phenology be useful?
Remote sensing phenology is useful in predicting long-term trends and detecting impacts of climate change on

ecosystems at multiple scales. Creative students may add uses such as assessing crop conditions, drought severity, or wildfire risk and tracking invasive species, infectious diseases, and insect pests.

4. Which remote sensors actively collect phenological data today? On which satellites are these sensors carried?

Answers may vary depending on how deeply the online information is searched:

- AVHRR on NOAA polar orbiting weather satellites
- MODIS on NASA's Terra and Aqua satellites

5. Many believe a satellite image is a snapshot of a portion of the Earth representing the appearance at one time and in one place only. How is a TIN image different?

Time integrated NDVI (TIN) provides integrated daily interpolated data that spans the entire growing season. It is not a simple snapshot.

6. Write a definition of TIN?

(From the metadata file) "The TIN metric identifies the seasonal net accumulation of photosynthetic activity above the non-growing season baseline in the vegetated canopy at each 1-km x 1-km pixel in the image. ...The TIN is unitless and valid values range from 1 to 100. In the TIN data layer, a cell value of 255 represents water bodies and a cell value of 0 represents the area where TIN could not be detected due to insufficient change in time-series NDVI or due to lack of sufficient input data."

7. What is the time period of these data?

0000Z on Day 104 (April 14) of 1989 (19890104) to 2400Z on Day 102 (April 12) of 1990 (19900102).

Students may need help interpreting the date codes 19890104 and 19900102 to avoid the assumption that 19890104 represents January 4, 1989.

8. List the spatial domain boundaries of the image (latitude of the north and south boundaries and longitude of the east and west boundaries).

West: -128.530059°; east: -65.394649°; north: 51.771338° south: 22.479392°

(See Metadata: Identification_Information > Spatial_Domain > Bounding_Coordinates...)

9. Each pixel of the image represents a "rectangular" area on the ground of what dimensions?

1km x 1km

10. What are the pixel dimensions of the image (how many columns and rows of pixels)?

4587 columns x 2889 rows

11. List the spatial reference information.

Map projection type:	Lambert Azimuthal Equal-Area
Geodetic model type:	Sphere
Longitude of the projection center:	-100.000000
Latitude of the projection center:	45.000000
False easting value:	0
False northing value:	0

12. From the Text Output, what is the range of pixel brightness values in this image (Data Range)?

0 to 255

13. Using the cursor, determine the latitudes of the north and south edges of the image and the longitudes of the east and west edges. How do these latitude and longitude values compare with those found in the metadata file earlier?

West: -128.530059°; east: -75.416353°; north: 48.403055°; south: 22.479392°

The values do not exactly correspond. Both the latitude range and the longitude range of the original image data are a little wider than those of the processed image.

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14. Suggest a common and natural reason for pixels with no data available.
Clouds.
15. Describe what happens to the image when you *Shift-Click* a color swatch.
All pixels of that color change to white while the shift key is depressed making those areas easier to observe.
16. Is this an effective way to determine the area of image represented by those pixels?
Why or why not?
No means by which a pixel count of the highlighted areas or any other measures of area are apparent. Indications of area will be subjective and relative to the apparent size of the other color areas.
17. From the Coordinates information bar, what is the area of the selected area expressed in number of pixels?
Answers will vary. It will depend on the actual area selected by each student.
18. Are all of the pixels in the selected area of the same classification?
Answers will vary. It is unlikely that a selected area will have all pixels of the same classification (color).
19. What percentage of the entire image does the selected area represent?
Answers will vary.
20. Describe how you will determine the area in pixels of all green (non-brown) portions of the entire image?
Answers will vary. The point here is that it is difficult and tedious to measure area in a succession of rectangular or polygonal selection areas and add them together.
21. Assess the accuracy of this means of determining area.
Answer will vary. This is a very inaccurate means of determining area in a digital image.
22. From the information in the Results window, how many pixels represent vegetative areas in this image? What percentage of the entire image does that represent?
From the Results window, the green portion of the image is 6,055,531 pixels or 45.696% of the entire image. (Using thresholding, it can be determined further that the number of data pixels excluding water is 9,688,874. So, the measured green areas represent 62.500% of the land cover.)
23. Refer to Question 10. Show a calculation of the total number of pixels in the entire image.
 $4587 \text{ columns} \times 2889 \text{ rows} = 13,251,843 \text{ pixels}$
24. Show how to calculate the percentage of the image represented by the thresholded area. How does this value compare with the percentage shown in the Results window?
$$\frac{6055531}{13251843} \times 100\% = 45.696\%$$
 This calculated value is the same as that reported by ImageJ.

Land Cover Change

Using Naturalized Difference Vegetative Index

Introduction

During my pre- and early teen years, I would sometimes accompany my father as he drove across the Los Angeles basin on business. The typical trip went from the far northeast corner of Los Angeles to the west side near Santa Monica. Many of the freeways that are so used and crowded today did not yet exist. As we travelled city streets, he often remarked that this or that office building had not been there twenty years earlier; it had been a coffee shop or a strawberry field or simply an empty lot. I remember thinking how unique to have memory of the area reaching that far back. As my own children were growing up, I found myself similarly remarking about changes in our area over the previous twenty years. Greek philosopher Heraclitus (c.500 BCE) is credited with the saying, “Nothing endures but change.” In other words, the only constant in the universe is change. Just how has the area in which we live changed over a generation or more? Is there more or less vegetation? Has the number or type of buildings changed? Are there new streets and highways? How is the land being used? How do changes in land use affect the human population and the overall health of the planet? How do human activities and choices affect the quality and type of land cover? Can land cover and land use be measured on a large scale? Are such changes related in any way to global climate change? This lesson will introduce normalized difference vegetative index imagery. You will access and analyze multispectral satellite imagery especially prepared to indicate the amount and productivity of vegetative land cover and thus follow changes over a number of years.

Preparation

There are several tutorials attached to help guide you to do the following:

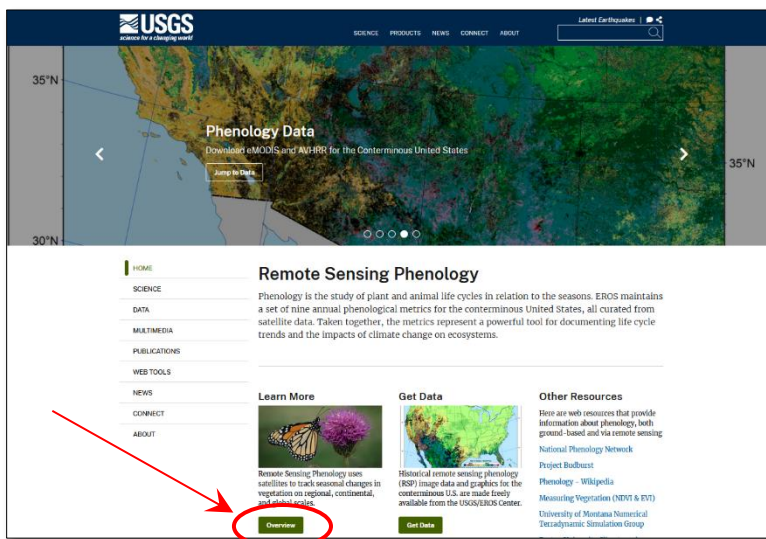
1. Obtain normalized difference vegetative index (NDVI) image data from United States Geological Survey (USGS)
2. Extract information about the image from its metadata
3. Visualize and georeference the image
4. Analyze the image to measure and compare areas of vegetation

Obtaining NDVI Image Data

Downloading USGS Image Data and Metadata

In this part of the activity, you will explore the USGS Phenology web site to find and download NDVI image data and metadata for your analysis.

- 🖥️ Ensure your computer is Internet enabled.
- 🖥️ Create a data folder in the root directory of your computer (or other folder designated by your teacher). Name it NDVIData. Use this folder to store all downloads, saved image files and data for this lesson.
- 🖥️ Launch your browser; visit <https://www.usgs.gov/special-topics/remote-sensing-phenology>.



- 🖥️ Click the Overview button. Explore the information on this Overview page.

1. Based on your reading so far, write a definition of remote sensing phenology.

- 🖥️ Use the browser's Back button to return to the previous page. In the navigation panel on the left side of the screen, click SCIENCE, then select Vegetative Indices. Find and read the article "NDVI, the Foundation for Remote Sensing Phenology" to answer the following questions.


- 2. Specifically, how are red and near infrared light related to NDVI imagery?
- 3. In what ways can remote sensing phenology be useful?

 **Quickly scan the other two articles: "NDVI from AVHRR" and "NDVI from Other Sensors."**

4. *Which remote sensors actively collect phenological data today? On which satellites are these sensors carried?*



 **In the navigation panel, click the DATA link, scroll down the page and click** Conterminous United States Remote Sensing Phenology Metrics Database.

 **Below the page title, click the View Data Release button. Click OK. Close the** Notice to Users.

 **In the navigation panel (upper left of the screen), click CONUS 1 km AVHRR so that the title of the material displayed is** Conterminous U.S. 1 km AVHRR Remote Sensing Phenology Data.

 **Scroll down the options table to Time Integrated NDVI (TIN).**

5. *Many believe a satellite image is a snapshot of a portion of the Earth representing the appearance at one time and in one place only. How is a TIN image different?*

 **Find the date selection drop-down next to the Image Data icon  and select 1989. The data package will be ready to download almost immediately. Your computer will ask where to save the zip file. Navigate to your NDVIData folder and click Save. (NOTE: If your browser settings automatically download the zip file to a default download location, you will need to move the zip file from there to your NDVIData folder.)**

 **Repeat the last step for image data for 2009. Then return the date selector to blank.**

The zipped data package you just downloaded contains several files:

.bsq - A band sequential image file

.bsq.xml - Formatted metadata file readable in an enhanced text editor like Notepad++ or HTMLPad

.HDR - File header information

.html - Formatted metadata file readable in a web browser

The files are combined and compressed into a single zip file that must be unzipped (decompressed) before using. Check with your teacher for help here. If the zip files are a problem, your teacher will provide previously downloaded and unzipped files for you to use.

When the image data is georeferenced, the metadata file is sometimes formatted for viewing in a geographic information system software package such as ArcView, ArcGIS Online, or Envi. The same information is contained in a metadata file formatted in HTML. It will open in your computer's default browser.

 **Open the ...metadata.htm file for the 1989 image data.**


Student Activity

 Scan through the metadata to answer the following questions.

6. Write a definition of TIN?
7. What is the time period of these data?
8. List the spatial domain boundaries of the image (latitude of the north and south boundaries and longitude of the east and west boundaries).
9. Each pixel of the image represents a “rectangular” area on the ground of what dimensions?
10. What are the pixel dimensions of the image (how many columns and rows of pixels)?
11. List the spatial reference information:
 - Map projection type
 - Geodetic model type
 - Longitude of the projection center
 - Latitude of the projection center
 - False easting value
 - False northing value

 Double check your answers to Questions 7-11 with other students’ records to insure you have interpreted the metadata accurately. You will use it soon.

 Close the metadata file.

 Follow the same procedure to download and inspect the metadata for the 2009 TIN image data. Record answers for Question 7-11 for the 2009 TIN next to your 1989 answers. Be sure to label which is which.

 Close the metadata file; close your browser.

Using MultiSpec

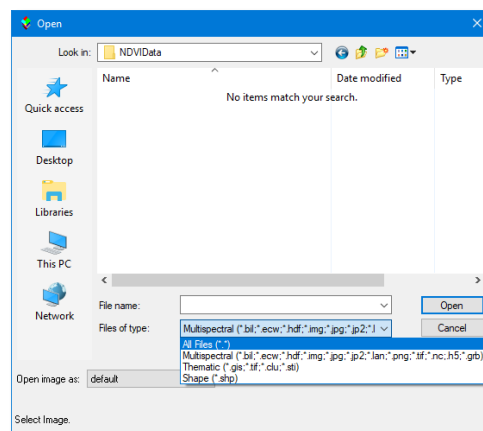
Visualize, Georeference, Create Thematic Classes, Save

Normalized difference vegetative index (NDVI) images are created based on the reflectivity of chlorophyll in plants. Most green plant pigments reflect green and absorb most of the red and some blue light. They also reflect enormous amounts of light with wavelengths in the near infrared range. NDVI images, then, are produced with an algorithm that uses just the red (absorbed energy) and near infrared (reflected energy) data from the remote sensor. The resulting image displays greater pixel brightness where there is more chlorophyll reflecting light and lower pixel brightness where there is less or no chlorophyll. The image is thus divided into vegetative and non-vegetative areas.

Each pixel in the NDVI image you are about to view has a brightness value between 0 and 255 (0 for black or absence of light – in this case 0 = No Data; 255 for most light reflected; and 254 values of gray in between). Specialized imaging software is needed to view and analyze the pixels in the image.

Launching MultiSpec

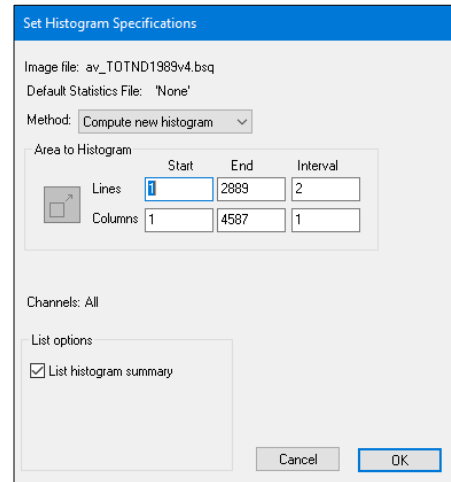
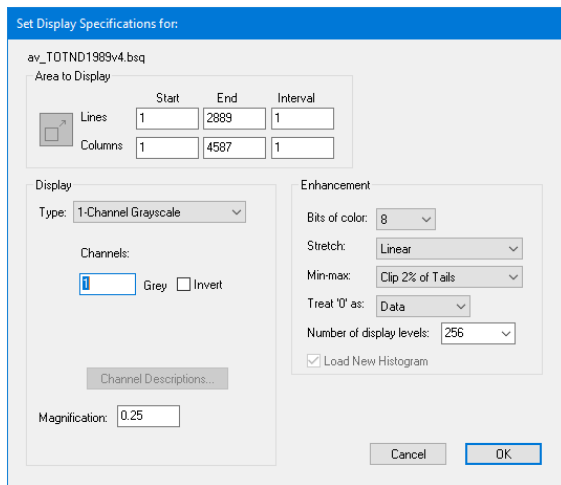
- 📁 **Ensure your computer has MultiSpec installed and your NDVIData folder is easily accessible.**
- 📁 **Launch MultiSpec.**
- 📁 **From the menu bar, click File and select Open Image. Navigate to your NDVIData folder and your NDVI data for 1989.**



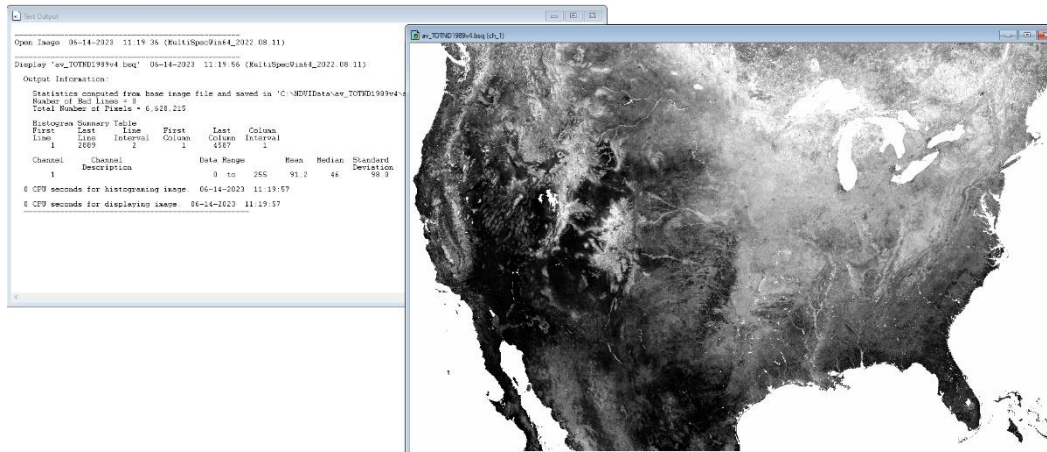
- 📁 **With some computers, you will notice there are no file names listed for selection. If that is the case, click the Files of type drop-down arrow at the bottom of the Open dialogue box. Select All Files.**

Student Activity

- Now the file you downloaded from USGS should be listed. Look for the file with 1989 in the name and an extension of .bsq. Select it and click Open.
- For now, accept the default information shown in the Set Display Specifications for dialogue box fields and click OK.



- If this is the first time this file has been opened by MultiSpec, the program will create a statistics (histogram) file (*.sta) and the Set Histogram Specifications dialogue will be shown. Click OK. The NDVI image you downloaded from USGS is displayed.




One of the two windows open in MultiSpec is the NDVI image. The other is the Text Output window. Three kinds of information appear here: metadata – that is, information (data) about the image data and characteristics of the image recorded in the image file; processing actions you have performed on the image; and results of processing actions performed.

- From the Text Output, what is the range of pixel brightness values in this image (Data Range)?

Finding Latitude and Longitude


 From the menu bar, click Processor and Utilities and select List Image Description.


Again, notice the Text Output window: the metadata include geographic references. That means, with the correct settings, the cursor position can be read as latitude and longitude. That information is also needed to tell the program the dimensions on the ground of each pixel.


 Click the image window to make it the active window. From the menu bar, click View and select Coordinates View. (Alternatively, click Window and select Show Coordinate View.) A Coordinates information bar appears at the top edge of the image frame.

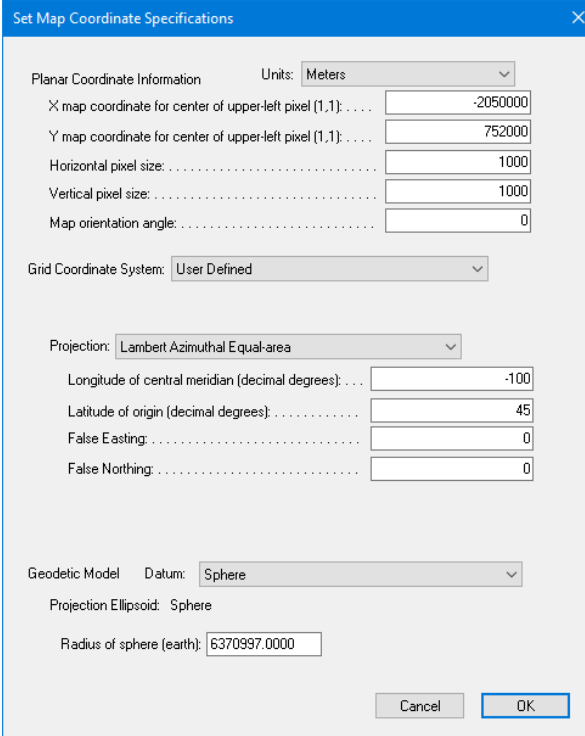
 Click Edit and select Image Map Parameters. The Set Map Coordinate Specifications dialogue box opens. Use the drop-down arrow to change Units to Meters.

 Click the Grid Coordinate System drop-down arrow, and select User Defined.

 Click the Projection drop-down arrow to select the map projection type you recorded from the metadata file. Notice the four projection parameter fields. In each, type the corresponding numbers you recorded from the metadata file.

 Use the drop-down arrow to change the Geodetic Model Datum to the model type recorded from the metadata file. Notice that the Projection Ellipsoid type changes automatically when the Datum field is set.

 Accept the default Radius of the sphere (earth). Click OK.



Set Map Coordinate Specifications

Planar Coordinate Information Units: **Meters**

X map coordinate for center of upper-left pixel (1,1): ... -2050000

Y map coordinate for center of upper-left pixel (1,1): ... 752000

Horizontal pixel size: ... 1000

Vertical pixel size: ... 1000

Map orientation angle: ... 0

Grid Coordinate System: **User Defined**

Projection: **Lambert Azimuthal Equal-area**

Longitude of central meridian (decimal degrees): ... -100

Latitude of origin (decimal degrees): ... 45

False Easting: ... 0

False Northing: ... 0

Geodetic Model Datum: **Sphere**

Projection Ellipsoid: Sphere

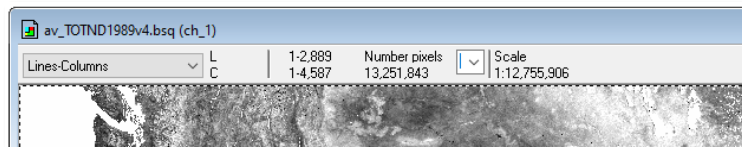
Radius of sphere (earth): 6370997.0000

Cancel OK

Student Activity

 Next, select the entire image with Edit and Select All Image.


Let's look at the Coordinates bar at the top edge of the image window.



With the drop-down set to Lines-Columns, the field to the right of the **L** and **C** shows the **L**ine and **C**olumn numbers of current cursor position on the image or the line and column ranges of the bounding box. The selection or bounding box is outlined with a dotted line. Still further to the right, under the title Number pixels is the number of pixels in the selected area – a means of measuring area. The drop-down arrow will change the area units. Scale relates to the zoom factor.

 Find the field on the Coordinates bar showing Lines-Columns. Click the drop-down arrow and select Lat-Long (Decimal).

Now the line number shown is the latitude and column number is the longitude. Remember, west longitudes and south latitudes are negatives.

 Move the cursor around the image and notice how the latitude and longitude values change.

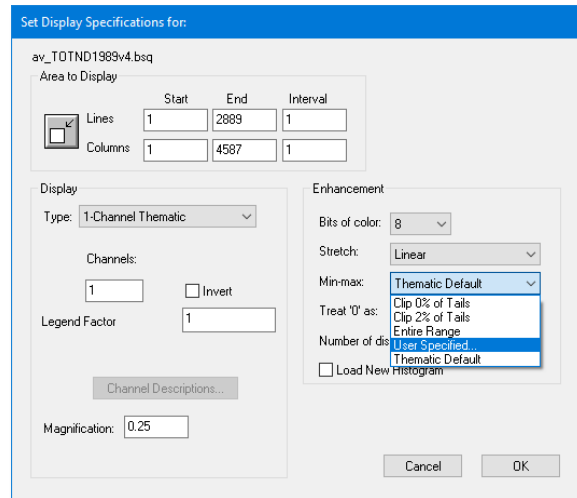
13. Using the cursor, determine the latitudes of the north and south edges of the image and the longitudes of the east and west edges. How do these latitude and longitude values compare with those found in the metadata file earlier?

 Press the Delete key to clear the selection coordinates and erase the bounding box.

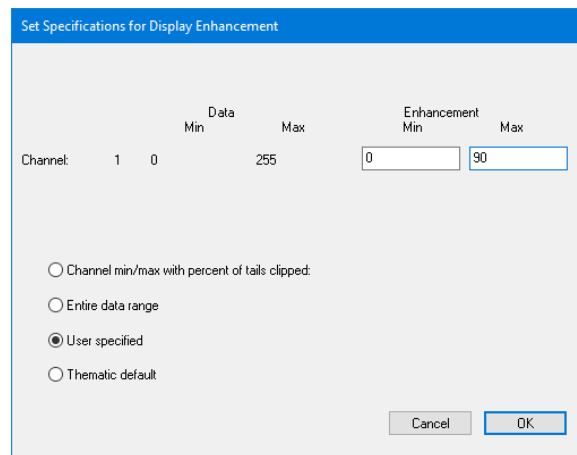
Creating Thematic Classes

Thematic classes are groups of pixel (brightness) values created by MultiSpec when you direct it to do so. Remember, that our interest is in the pixel values that represent more chlorophyll and therefore more vegetation. In this section, you will tell the program to group pixel values into a specified number of classes and use those classes to interpret the image data. The actual values assigned to each class are artificial and relative only to each other. Then ask the program to apply a color palette to make interpretation even easier.

 Click Processor; select Display Image. In the Set Display Specifications for dialogue box, use the drop-down arrow to change Display Type to 1-Channel Thematic.



- Use the drop-down arrow to change Min-Max to User Specified. (For some later years, User Specified may default to Entire Range. That’s OK.) The Set Specifications for Display Enhancement dialogue pops up. Delete the contents of the Enhancement Min field even if it is 0, and type 0. Delete the contents of the Max field, and type 90. The User Specified radio button is automatically selected. Click OK.

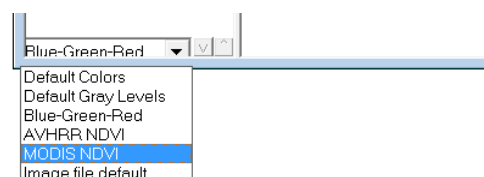


- Back to the Set Display Specifications for dialogue: If the Number of Display Levels did not default to 12, highlight the value in the field and type 12. DO NOT use the drop-down arrow.

Remember, from the metadata we learned that a pixel value of 0 indicates pixels for which there is no data while a pixel value of 255 represents water.

- Use the drop-down arrow to change Treat '0' as to Black. Click OK.

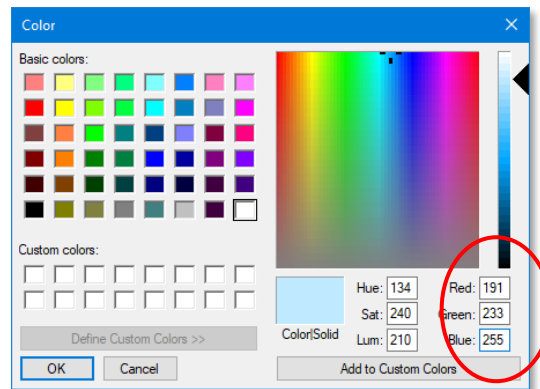
- Find the drop-down arrow for the Palette in the lower-left corner of the image frame. Click it and select MODIS NDVI.



Student Activity

The legend panel is on the left side of the image frame. The field at the top of the legend indicates that the items in the legend are “classes” of pixel values. The pixel values range from 0 to 90. The color swatch next to <0 is black representing pixels with no data; the color swatch next to ≥ 90.0 is white representing water.

- ☐ Double click the white color swatch next to ≥ 90.0 . In the Color dialogue, find the fields for red, green, and blue values in the lower right corner. Highlight the value in the Red field and change it to 191. Similarly, change the Green value to 233 and the Blue value to 255.



- ☐ Click OK.

Your processed, classified, false colored NDVI image is displayed.



In the image, darker green represents areas with greater density of chlorophyll and leafy vegetation. Brown areas represent areas with little or no vegetation. Light blue represents areas of water. Missing data are shown in black.

14. Suggest a common and natural reason for pixels with no data available.

Saving Image, Data, Metadata

MultiSpec creates several files of information about the image processing you have completed. In order to later reload the image as it is displayed now, it is necessary to save the information files as well as the image file itself. The statistics file (also called the histogram file) is created and saved automatically. However, the image itself, the thematic class information file, and the text output file must be saved individually.

First, save the image with its georeference information and color palette.

- 🖱️ **Click once on the image window to activate it. Press the Delete key on the keyboard to clear any selection coordinates. On the menu bar, click File and select Save Image To GeoTIFF As. Navigate to your NDVData folder. Notice the default file name is av_TOTND1989v4(ch_1T).tif where the file extension is .tif. Click Save.**

Next, save the thematic class information:

- 🖱️ **Click File on the menu bar again and select Save Thematic Class Info As. Navigate to your NDVData folder. Accept the default file name of av_TOTND1989v4.clr. Notice the .clr file extension. Click Save.**

Now, save the text output so you have a record of each step you performed when processing the image along with most of the image's metadata.

- 🖱️ **Click once on the Text Output window to activate it. On the menu bar, click File, select Save Text Output As, and navigate to your NDVData folder. Change the default file name to match the name of the image file, av_TOTND1989v4(ch. 1).txt with the .txt file extension. Click Save.**
- 🖱️ **Click to activate the image window. Click File and select Close Image Window. Then, File again and select Exit MultiSpec.**

Repeat the process for the 2009 data. It is important to close and re-launch MultiSpec before proceeding in order to clear and reset the text output buffer.

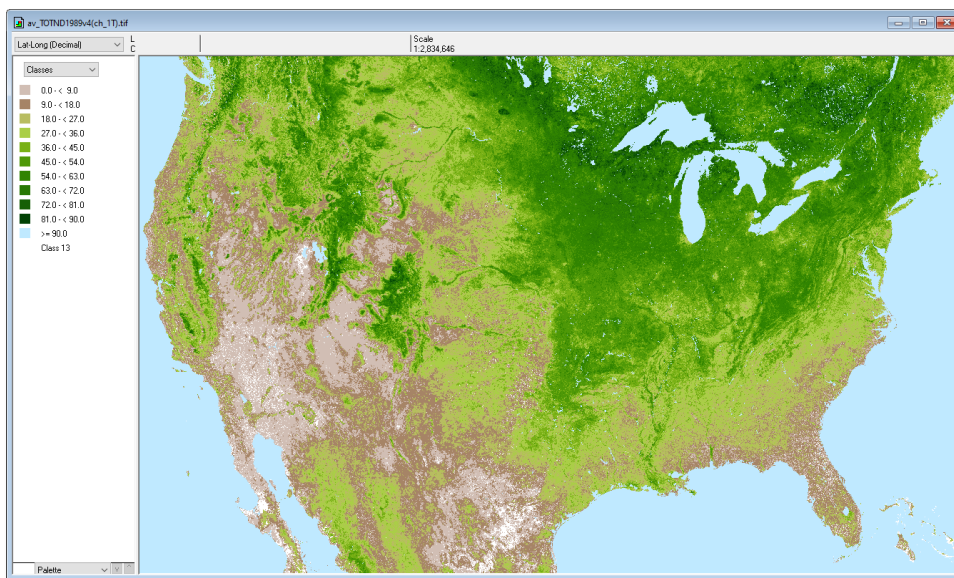
- 🖱️ **Repeat the steps in this Using MultiSpec tutorial for the 2009 image data.**
- 🖱️ **Finally, click File and select Exit MultiSpec.**

Measuring with MultiSpec

Analyzing the Image

It is time to use your NDVI image to determine the area of each image representing vegetation and compare them for changes.

- 📁 **Launch MultiSpec. Click File and Open Image. Navigate to your NDVIData folder. Select av_TOTND1989v4(ch_1T).tif and click Open. The Set Thematic Display Specifications window pops up. Click OK. Your saved image is displayed.**



Look at the legend on the left side of the image window. Newer versions of MultiSpec will automatically load the thematic class information when the image opens so a numeric range is listed for each class. There is also a new class listed without a numeric range for the white color swatch. This class represents the pixels for which there are no data, that is, data are missing. The legend must be updated.

- 📁 **Double-click the name of the class to display the Edit Thematic Class Name dialogue box. Change the name to No Data and click OK. Double-click the No Data color swatch, select black from the Color selection window, and click OK.**

Now the image is ready for analysis using MultiSpec. Just how much of the image represents vegetation? You can use the color swatches in the legend panel to easily highlight the pixel locations of each class.


- 📁 **Move the cursor over one off the non-brown color swatches. Hold down the Shift key then click and hold the color swatch. Also try holding down both the Shift and Control**

keys simultaneously while clicking on the color swatch.

15. *Describe what happens to the image when you Shift-Click a color swatch.*
16. *Is this an effective way to determine the area of the image represented by those pixels? Why or why not?*

A more quantitative means of determining the area of vegetative portions of the image is needed. Before using MultiSpec to measure area, it may be helpful to zoom in.

 **Click the  button to return the image to a magnification of 1.**

 **Move the cursor over the image to any green (non-brown) area. Click and hold to drag a rectangular selection box around a green area. Be sure to avoid including any pixels that are not green.**

17. *From the Coordinates information bar, what is the area of the selected area expressed in number of pixels?*
18. *Are all of the pixels in the selected area of the same classification?*
19. *What percentage of the entire image does the selected area represent?*
20. *Describe how you will determine the area in pixels of all green (non-brown) portions of the entire image?*
21. *Assess the accuracy of this method of determining area.*

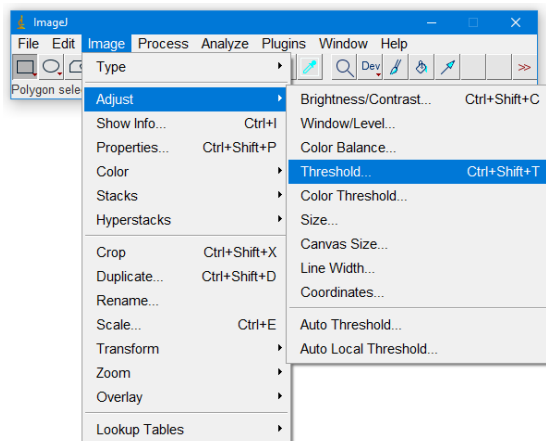
 **Close the image without saving.** Exit MultiSpec.

Measuring Area with ImageJ

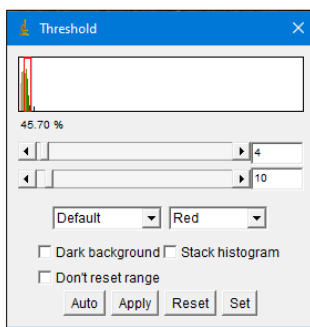
An Easier Way

MultiSpec has many useful features not found in other image processing software packages. However, other packages have features not found in MultiSpec. For example, ImageJ has a tool for adjusting the threshold of the display to include only those pixels with brightness values of interest.

- 📖 **Insure your computer has ImageJ installed and your NDVIData folder is accessible.**
- 📖 **Launch ImageJ. Click File, select Open, navigate to your NDVIData folder and select av_TOTND1989v4(ch_1T).tif. Click Open.**
- 📖 **On the ImageJ menu bar, click Image, move the cursor to Adjust, and select Threshold.**

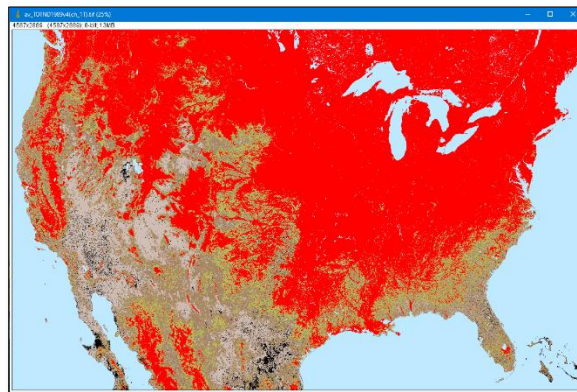


The Threshold window pops-up. Notice the appearance of the image. How has it changed? You will adjust the Threshold sliders until only the green areas are highlighted in red.



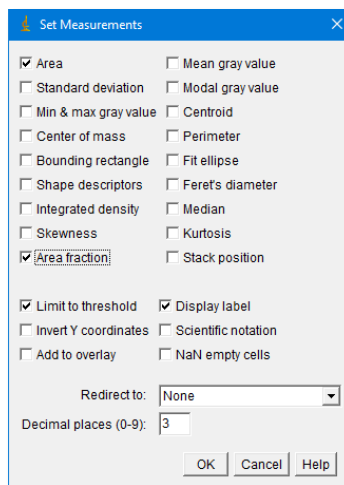
- 📖 **On the bottom slider, click the right arrow button one click at a time until the ocean just turns red. Then click the left arrow button once so the ocean appears blue.**

- On the top slider, click the right arrow button one click at a time until the first non-brown class is uncovered. Then click the left arrow button just once so the first non-brown area is again highlighted in red.



Now all of the vegetative (non-brown) portions of the image are “thresholded” (highlighted in red). Now you will measure the “thresholded” area.

Click Analyze; select Clear Results. Again, click Analyze; select Set Measurements.





- Insure** Area, Min & Max Gray Value, Area Fraction, Limit to Threshold, **and** Display Label **are** checked; all others are unchecked. Click OK.

- Click Analyze, and select Measure (or press **Ctrl-M**) to display the Results window.







- From the information in the Results window, how many pixels represent vegetative areas in this image? What percentage of the entire image does that represent?
- Refer to Question 10. Show how to calculate the total number of pixels in the entire image.
- Show how to calculate the percentage of the image represented by the thresholded area.

Student Activity

How does this value compare with the percentage shown in the Results window?

-  **In the Results window, click File; select Save As. Navigate to your NDVIData folder and save the Results.xls file.**
-  **Follow your teacher's directions to complete all steps of the *Your Turn* activities.**

YOUR TURN

-  Using ImageJ, find the percentage of the 2009 NDVI image that is non-brown. Create a graphic report that compares the two NDVI images 20 years apart. Offer rational reasons for the differences. Is this what you expected? What cultural features (from human activities) have changed? What environmental factors may have influenced the change? Search NOAA and NASA web sites especially NOAA's National Climatic Data Center (NCDC) at <https://www.ncdc.noaa.gov/cdo-web/> for information about weather patterns and climate records over these 20 years that might have influenced these images. *Continue to the next Your Turn activity.*
-  It is generally easier to document the changes in a smaller area than the entire continent. Select an area of particular interest to you in the United States, Mexico, or Canada that is visible in the image. It might be helpful to refer to a map of the area that indicates latitude and longitude. Using MultiSpec, select an area for study so the bounding box is displayed around your region of interest. Click File and select "Save Image Selection to GeoTIFF As," and save the selected area as a separate image file. Open the new *SelectionArea.tif* image using ImageJ, adjust the threshold to all non-brown areas, and measure area. *Continue to the next Your Turn activity.*
-  Once you have determined the area of the entire non-brown portion of the image, adjust the Threshold sliders so that only one class of pixels (one color group) is highlighted in red at a time and measure its area. Repeat this sequence until you have determined the actual number of pixels for each classification of pixel brightness values. If you are careful, the Results window will show a list of pixel class areas for the image in the same order as they are listed in the legend of the MultiSpec image. (If needed, Clear Results and start measuring again.) Identify and describe trends of change for each pixel class over the two decades of the study period. Remembering that higher pixel class values represent more dense vegetation and/or greater concentrations of chlorophyll, how does this information change your report? *Continue to the next Your Turn activity.*
-  Download and process NDVI image data for each year of the same 1989-2009 period. Select the same area of interest in each image and save the selection as a GeoTIFF. When measuring area using ImageJ, **do not** Clear Results so that each year is listed in order in the Results window. When the contents of the Results window are saved to file, it is in Microsoft Excel file format. Open the Results file in Excel. Using Excel's chart tool, create a graph of the Results over 20 years. Describe the graph and relate it to changes in human activities, changing weather patterns, and changing climatic patterns discovered from your research with the NCDC and other sites. *Continue to the next Your Turn activity.*
-  You have studied a single 20-year period for which data are available. Devise a plan to document changes in the decades(s) since 2009. Have your plan approved by your teacher. Carry out your plan. Add this information to your overall report. *Continue to the next Your Turn activity.*
-  In your graphic report, include why you selected this particular area, how it has changed over time based on the NDVI image analysis, and what factors – both natural environmental and human-based – that may have affected the changes.

Land Cover Change

1. Based on your reading so far, write a definition for remote-sensing *phenology*.
2. Specifically, how are red and near infrared light related to NDVI imagery?
3. In what ways can remote sensing phenology be useful?
4. Which remote sensors actively collect phenological data today? On which satellites are these sensors carried?
5. Many believe a satellite image is a snapshot of a portion of the Earth representing the appearance at one time and in one place only. How is a TIN image different?
6. Write a definition of TIN?
7. What is the time period of these data?
8. List the spatial domain boundaries of the image (latitude of the north and south boundaries and longitude of the east and west boundaries).
9. Each pixel of the image represents a “rectangular” area on the ground of what dimensions?
10. What are the pixel dimensions of the image (how many columns and rows of pixels)?
11. List the spatial reference information.

Map projection type:	
Geodetic model type:	
Longitude of the projection center:	
Latitude of the projection center:	
False easting value:	
False northing value:	

12. From the Text Output, what is the range of pixel brightness values in this image (Data Range)?
13. Using the cursor, determine the latitudes of the north and south edges of the image and the longitudes of the east and west edges. How do these latitude and longitude values compare with those found in the metadata file earlier?
14. Suggest a common and natural reason for pixels with no data available.
15. Describe what happens to the image when you Shift-Click a color swatch.
16. Is this an effective way to determine the area of image represented by those pixels? Why or why not?
17. From the Coordinates information bar, what is the area of the selected area expressed in number of pixels?
18. Are all of the pixels in the selected area of the same classification?
19. What percentage of the entire image does the selected area represent?
20. Describe how you will determine the area in pixels of all green (non-brown) portions of the entire image?
21. Assess the accuracy of this method of determining area.
22. From the information in the Results window, how many pixels represent vegetative areas in this image? What percentage of the entire image does that represent?
23. Refer to Question 10. Show how to calculate the total number of pixels in the entire image.
24. Show how to calculate the percentage of the image represented by the thresholded area. How does this value compare with the percentage shown in the Results window?