LESSON 7: Quantifying Land Changes Over Time using Landsat

PURPOSE/QUESTION

To analyze Landsat satellite imagery to locate areas of urbanization and deforestation and determine short term and long term impacts on the earth system.

GRADE LEVEL

9-12

TIME TO COMPLETE

2 – 45 minute class periods if starting with ***Getting to know your Satellite Imagery***
2 – 55 minute class periods for Lesson 7

STANDARDS

See appendix below-page13

NOTE Appendix 3 provides links to reading resources and further learning.

LEARNING OUTCOMES

- Students will be introduced to Landsat imagery, the iterative nature of mapping, and how to identify land cover types in images.

A Landsat 5 image of Texas acquired on September 3, 2011. Possum Kingdom Lake with a burn scar near center of the image

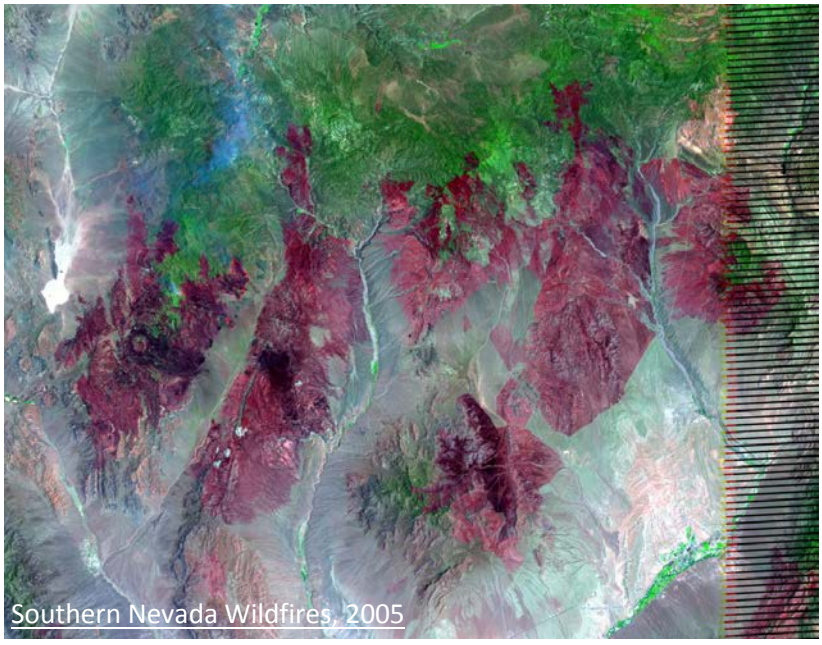
STUDENT OBJECTIVES

- Learn the difference between true color and false-color infrared images.
- Identify physical features of the land on a false-color infrared image

This Landsat 7 image was acquired using bands 3, 2, 1 and the panchromatic band on February 13, 2000.

TEACHER BACKGROUND

To enable students to analyze land cover change; to help them grasp the extent, significance, and consequences of land cover change; and to introduce them to the perspective of space-based observations



Southern Nevada Wildfires, 2005

Why study land cover change?

Our land is changing. Land covered by forest is changing to farmland, land covered by farmland is changing to suburbs; cities are growing. Shorelines are shifting; glaciers are melting; and ecosystem boundaries are moving. As human population numbers have been rising, natural resource consumption has been increasing both in our country and elsewhere. We are altering the surface of the Earth on a grand scale. Nobel Prize recipient Paul J. Crutzen has said, "Humans have become a geologic agent comparable to erosion and [volcanic] eruptions…"

Land cover change has effects and consequences at all geographic scales: local, regional, and global. These changes have enabled the human population to grow, but they also affect the capacity of the land to produce food, maintain fresh water and forests, regulate climate and air quality, and provide other essential "services." (See Foley, et. al, in **Appendix 3**. (found in the folder for this lesson)) It is critical for us to understand the changes we are bringing about to Earth's systems, and to understand the effects and consequences of those changes for life on our planet. Landsat satellites enable studies of change at the regional or landscape scale.

The first step in understanding change is monitoring, and the second step is analysis. Doing this activity will enable your students to take these steps at an introductory level.

Teacher Preparation

1. Review the whole activity, including the background material provided. You may also wish to read some of the publications listed in ***Appendix 3*** (found in the folder for this lesson).
2. Students will be making a map of land cover types (five or six), using a transparency with a grid on it. Teachers can either identify the four or five land cover types they want to be used by students, or they can have students themselves decide what land cover types they want to use. The exercise of having students decide their own land cover types can (a) provoke valuable thinking and (b) help students to learn that their decisions are shaped by the questions they will ask of the Landsat images of change. Middle schools students will need more guidance with this task than high school students will need.

   If you wish to identify the land cover types for your students before the activity, make that list for them. Each land cover type needs to be represented on the map by a letter or symbol, such as:

S	Suburban
U	Urban
H	Highways and Roads
F	Forest
G	Grassland
W	Water

3. Download, print, and make student copies of:
   Landsat satellite images — one set of 1990 and 2000 images per student in both the "7,4,2" color combination and the "3, 2,1" color combination. If color printing costs are a limiting factor, print just the "7, 4, 2" color combination. Images: 1991/3,2,1; 1991/7,4,2; 2000/3,2,1; 2000/7,4,2 (~3 Mb/ea.)

   Transparencies with ***grid*** (found in the folder for this lesson), one per student, with a few extra in case of student mistakes) Student Guide (below) and GLOBE activity, ***Getting to Know Your Satellite Imagery***, including worksheets.

4. Make sure the pens your students will use for the land cover maps on transparencies will work well for outlining areas of land cover. The pens should have fine tips.

Classroom Management

In **Step 3** students familiarize themselves with the 1991 Landsat image and identify whatever features and land cover types that might be recognizable to them. Students may need some guidance, so encourage them to recall what they learned from the GLOBE activity in **Step 3**. Be sure they read and understand "About the Colors of Landsat Images," (found in this lesson's folder) provided in the **Guide for Students, Step 4**. Point out that features with straight lines, rectangles, and perfect circles are usually made by people.

In **Step 4** students determine five or six specific land cover types to be seen in the satellite image, and they make a class list. Students in Grades 9-10 may be more adept at this task than students in earlier grades. So at this point you may wish to hold a guided class discussion about how to study the image and what the land cover types might be. Use the land cover key provided in Appendix 1 (found in the folder for this lesson) if needed.

Step 4 also entails students deciding whether or not the land cover types of interest are pervious or impervious to water. You may wish to have a guided discussion with your students on what that means. For short background reading on the question, please go to Appendix 2 (found in the folder for this lesson).

In **Step 6** students count all the grid squares representing different land cover types in a satellite image. This can be a very time consuming task, depending on the size of the area under investigation. So for this project, teachers may wish either to have the whole class deal with just a fraction of the satellite image, or to assign different student groups to examine different portions of the total image. Dividing the image into quadrants is a useful approach. After student groups have recorded data about their assigned quadrants of the image, the class can compile data from all student groups. Compiled student data can also be used by individual students to complete the final calculations and analysis for the activity.

Step 7 is optional, written for classes in which more than one group quantifies land cover change in the same geographic area of the satellite image.

PREREQUISITE KNOWLEDGE & SKILLS

- Basic ability to understand and interpret visual representations of Earth's surface from above, such as maps and aerial photographs. (bird's eye view)
- Meaning of wavelengths of light
- Be able to define, at an introductory level, "electromagnetic spectrum".
- Classroom activity – Getting to Know your Satellite Imagery (recommended for junior high school students or students with little understanding or experience with aerial photographs)
- Watch –
  - "Satellites" – about the role of Earth observing satellites in helping to monitor changes on our planet.
  - "Phoenix" – about the growth of this city in Arizona

MATERIALS & TOOLS

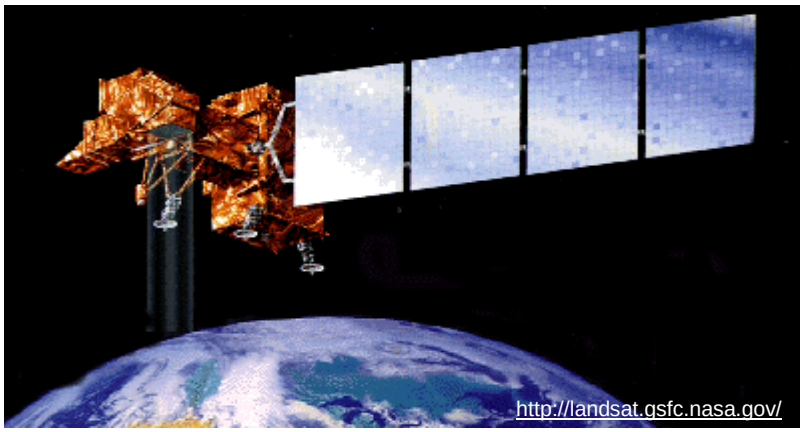
- Computer with Internet connection
- Ability for all students to watch a 20 minute video and a minute visualization
- Must be able to print a classroom set of the maps (links found on page 13) for students to use during both the prerequisite activity and the main activities.
- Optional - Any available maps, aerial photographs, or other representations of the area of interest, both historical and current, as well as literature about how the land has changed
- Grid on white paper (one grid per pair of students)

VOCABULARY

- Aerial view/bird's eye view
- Pixel
- Electromagnetic spectrum
- Wavelength
- False color
- True color
- Infrared
- Pervious surface
- Impervious surface
- Qualitative
- Quantitative

LESSON LINKS

- The Electromagnetic Spectrum (diagram)
- Movie about Satellites
- Animation over time of Phoenix, AZ
- Getting to Know your Satellite Imagery
- Color prints of Landsat satellite images of Phoenix, AZ



PROCEDURE-

A Beginning Look at Landsat Imagery

1. Read – *About the Colors of Landsat images* ***(Could assign as homework, but would need to supply Landsat true and false color images.)***

Work in pairs for steps 2 through 9

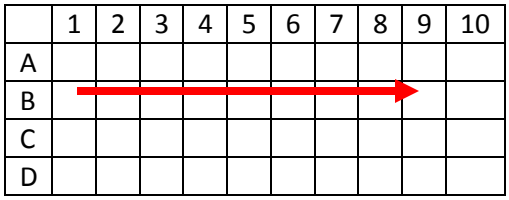
2. **Identify types of land cover in the 1990 image.**
    a. With your partner, identify the types of land cover you find in the 1990 satellite image. Identify five or six types. Some examples of land cover types are urban, suburban, water (lake, river, or ocean), forest, grassland, wetland, shoreline, or anything you see covering significant amounts of the land surface. Be prepared to share your list with the class.
    b. Now work as class to create a list of the land cover types in the satellite images.
    c. As a class, decide which of your land cover types allow water to penetrate the surface (are pervious), and which types do not (are impervious). Keep both a class record and your own personal record in your science notebook. Knowing which surfaces are pervious v. impervious will be important later in the activity.

3. **Visually compare the 1991 and 2000 Landsat images.**
    a. Spend some time with your partner examining the two images. Familiarize yourself with the similarities and differences in these images that are about a decade apart. Get a general sense of how much the land cover has changed over that time: where, how, and by how much. **Focus on one part of the geographic area at a time to identify specific areas of change.**
    b. Read the following notes before doing **Student Worksheet for Step 3**.
        - **Something to be aware of** is that the 1990 image and the 2000 image show different seasons of the year. The 1991 Phoenix image shows the land cover on March 18, 1991, and the 2000 Phoenix image shows the land cover on April 19, 2000. (We would have provided images of the same seasons for this activity if it had been possible, but it was not.) As you compare the two images of land cover, keep the difference in seasons in mind.
        - **Pointers about the Desert Ecosystem** – Remember that the natural ecosystem of Phoenix is desert. Areas that show visible bright green have likely received water lately.

    Now you are ready to complete **Student Worksheet for Step 3** where you will write about what you observe and think as you visually assess the changes from 1991 to 2000. Include any questions or concerns you have, or anything you find confusing.

4. **Make a map of land cover types in 1991 using a transparency with grid** (provided by your teacher).
    a. You did **qualitative** assessment of about a decade of land cover change in **Step 3**; now you will begin a **quantitative** assessment of the change.
    b. Place your transparency with grid over the 1991 satellite image. Mark the corners of the image on the transparency so that if you move the transparency off the satellite image you can put it back again exactly where it was.
    c. Using the classification scheme for land cover types that your class decided upon in **Step 1**, make a map of land cover change by tracing carefully around each land cover type with a colored marker. Remember, you decided as a class which kinds of land cover were pervious to water and which kinds were impervious. Label each area with your symbol for its land cover type and also with your symbol for either pervious or impervious (probably P or I).
    d. Make a legend for your transparency grid, which is now becoming a map. Be sure to label this map with the year the satellite image was made, and with your name, your partner's name (if you're working with a partner), and today's date.

5. **Comparing your 1991 land cover map to 2000 Landsat satellite image, count and record the numbers of grid squares representing land cover that have changed from pervious to impervious, or from impervious to pervious.**
    a. Place the transparent 1991 land cover map over the 2000 Landsat image, and identify the dominant land cover –pervious or impervious – for **each grid square** on the map.
    b. There are two roles in this step. One student partner compares the 1991 map to the 2000 satellite image and identifies the grid squares that have changed – from pervious to impervious land cover or from impervious to pervious land cover. The other partner marks the equivalent changed squares in the grid provided on **Student Worksheet for Step 5**.
    c. Systemically study each square on your grid map to determine whether or not there has been change so that you include each grid square. One way to do that is to work from upper left to right across each row, one row at a time.



You may notice that some grid squares contain more than one land cover type. The most dominant land cover type in that grid square dictates which land cover type to assign to that square. For example, if a square is 75 percent Vegetation and 25 percent Water, use the code for Vegetation. Some students may disagree about which type is dominant. Professional land cover analysts occasionally disagree too.

6. Calculate the percent change from pervious and impervious surface area, using the Student Workshop provided.

7. If another team of students in your class analyzed land cover change in the same geographic area you did, compare the results of their work on **Step 6** to your team's work on that step.

    Did your team identify the same kinds of land cover changes as the other team did?

    If your team did identify the same kinds of land cover as another team, did the two teams arrive at the same percent change from pervious to impervious surface area (or from impervious to pervious surface area)? If not discuss between teams how your perceptions and/or methods of calculating change may have been different. Provide notes about this discussion on the **Student Worksheet Step 7**.

8. Respond to questions on the **Student Worksheet** for this step.

    EXTENSION:

9. Assuming the same general rate and nature of change, make a predictive map of land cover in the 2025 for the same geographic area. Describe and explain the 2025 map and any ecological consequences that might be expected from the change.

    Describe the map and any changes you project from pervious to impervious surface or from impervious to pervious surface. (Remember to take the effects of major transportation arteries and geologic features such as mountains and rivers into account). Explain why you have predicted this kind and amount of change.

Student Worksheet for Step 3: Visually Comparing 1990 and 2000 Landsat Images

Name: Date:

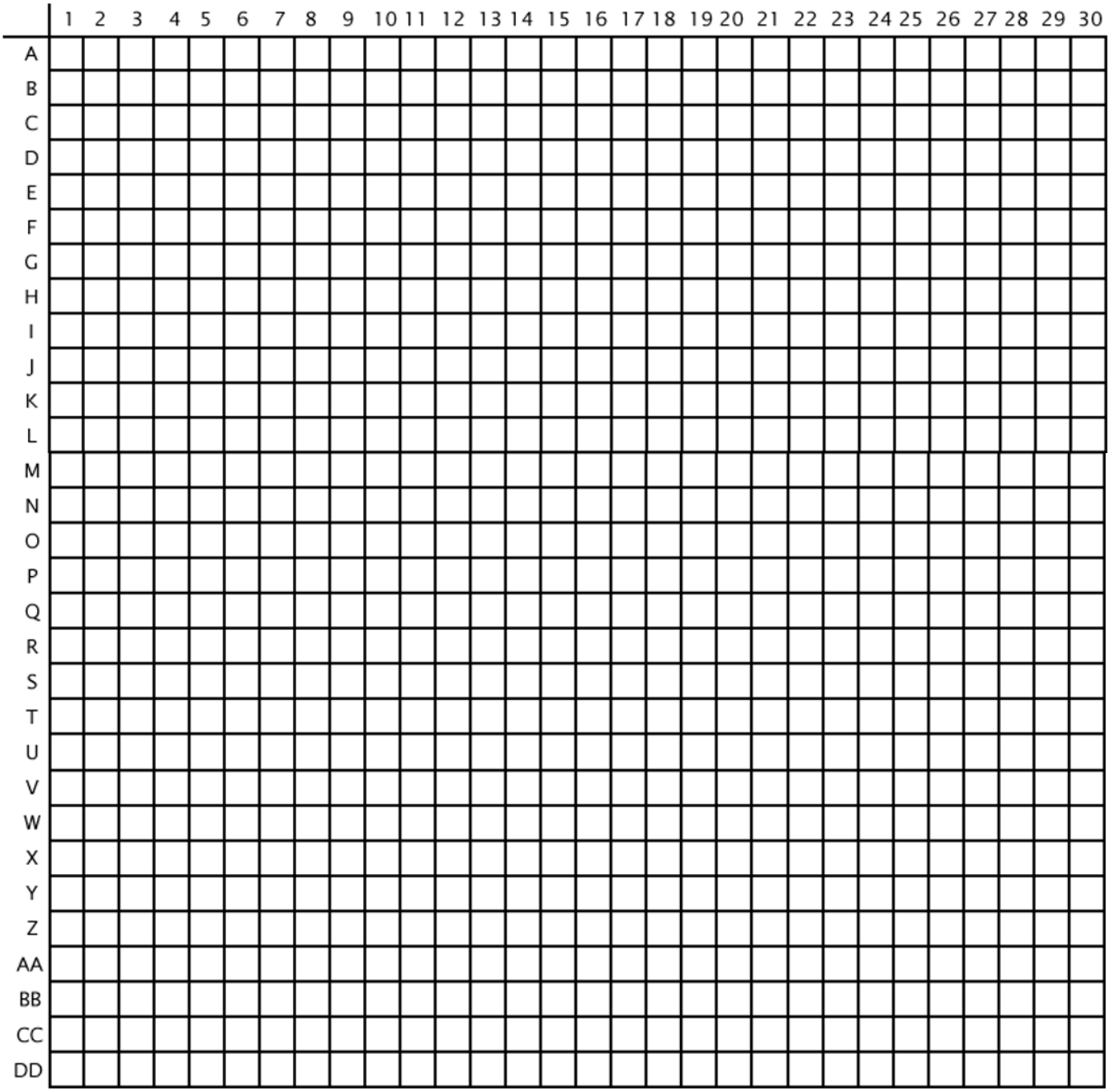
Use this worksheet to record notes about your visual comparison of the 1990 and 2000 Landsat images.

Here's a tip: Don't try to study all of the two images at one time. Choose one small geographic area to look at, and compare it with that same area in the 2000 image. Then choose another. What changes in land cover from 1990 to 2000 do you see? What land cover types seem to have decreased in extent? What types seem to have increased? Identify specific areas of change and which quadrant of the image they're in: northeast, northwest, southeast, or southwest. Make note of any questions or concerns you have, or anything you find confusing.

Student Worksheet for Step 5: Recording Land Cover Changes

Names: Date:

Use this worksheet to indicate grid squares representing land cover types that have changed from 1990 to 2000. Use one symbol to represent change from pervious to impervious surface, and another symbol to represent change from impervious to pervious surface. If no change has occurred, leave blank. *(One worksheet will serve two students for this step.)*



Student Worksheet for Step 6: Calculating Percent of Land Cover Type Changes

Name: Date:

Use this worksheet to calculate the percent change from pervious to impervious surface area.

Referring to your records from Step 5, note the following numbers:

(a) Total number of squares on the transparency grid (a)

(b) Number of grid squares that changed from pervious to impervious land cover types between 1990 and 2000

(c) Number of grid squares that changed from impervious to pervious land cover types between 1990 and 2000

Which number is larger, (b) pervious to impervious, or (c) impervious to pervious?

In most geographic areas where land cover types are changing, (b) will be larger than (c).
If (c) is larger than (b), your geographic area is not experiencing urban growth.

To determine the percent of land cover changed from pervious to impervious, calculate the following:

$$\frac{\textit{(value for b) X (100)}}{\textit{value for a}}$$

To determine the percent of land cover changed from impervious to pervious, calculate the following:

$$\frac{\textit{(value for c) X (100)}}{\textit{value for a}}$$

Student Worksheet for Step 7:
Comparing Different Teams' Results for the Same Areas of Change

Name: Date:

Complete this worksheet if another team of students in your class analyzed land cover change in the same geographic area your team did.

1. Compare your two teams' completed Student Worksheets for Step 8, "Recording Land Cover Changes." How do the teams' worksheets differ, if at all? Describe differences in the space provided below. Please be as specific as you can.

2. Compare your completed Student Worksheets for Step 9. How do your two teams' worksheets differ, if at all? Please be as specific as you can.

3. What, if anything, do the difference between teams' results tell you about science as a human activity?

4. If you have any other comments about the differences between your team's results and the other team's results, please write them here:

Student Worksheet for Step 8

Name: Date:

Write your responses to the questions below in the space provided.

1.

(A) How comfortable are you with the accuracy of your data and the conclusions you drew from this information? Why?

(B) How might you improve the accuracy of your map and your calculations, if at all?

2. Which land cover type changed the most, and which land cover type changed the least? Why do you think this is the case?

3. Researchers indicate that if ten percent of the land cover in a given watershed changes, the water cycling through that watershed changes in significant ways. Water quality is affected, and run-off increases.

   A. How concerned should people be about the cycling of water in the area you have studied with Landsat?

   B. What specific ecological effects of land cover change should be looked into for the geographic area you studied? (Consider air, water, soil, and living things.)

   C. What data would we need to investigate some of those ecological effects?

LESSON 7-APPENDIX

WEB ADDRESSES FOR HYPERLINKS

PREREQUISITES

- **Bird's eye view**
  http://www.nrcan.gc.ca/earth-sciences/geography-boundary/remote-sensing/fundamentals/1223
- **Wavelengths of light**
  http://science-edu.larc.nasa.gov/EDDOCS/Wavelengths_for_Colors.html
- **Electromagnetic spectrum**
  http://missionscience.nasa.gov/ems/
- **Getting to Know Your Satellite Imagery**
  http://landsat.gsfc.nasa.gov/education/resources/GLOBE_getting2know.pdf
- **Satellites**
  http://landsat.gsfc.nasa.gov/education/resources/Satellites.mov
- **Phoenix**
  http://landsat.gsfc.nasa.gov/education/resources/Phoenix.mov

VOCABULARY

- **Aerial view/bird's eye view**
  http://en.wikipedia.org/wiki/Aerial_view
- **Pixel**
  http://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=P
- **Electromagnetic spectrum**
  http://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=E
- **Wavelength**
  http://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=W
- **False color**
  https://www.google.com/search?hl=en&rls=com.microsoft:*&q=false+color&tbs=dfn:1&tbo=u&sa=X&ei=UewmTrD7N6nr0gHgopy5Cg&ved=0CBUQkQ4&biw=1259&bih=858
- **True Color**
  http://en.wikipedia.org/wiki/True-color#True_color
- **Infrared**
  http://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=I
- **Pervious surface**
  https://www.google.com/search?hl=en&rls=com.microsoft%3A*&biw=1259&bih=858&tbs=dfn%3A1&q=pervious&oq=pervious&aq=f&aqi=g6g-s1g3&aql=&gs_sm=e&gs_upl=21750l23468l0l23968l8l8l0l0l0l0l172l1079l0.8l8
- **Impervious surface**
  https://www.google.com/search?hl=en&rls=com.microsoft%3A*&biw=1259&bih=858&tbs=dfn%3A1&q=impervious+surfaces&oq=impervious&aq=1&aqi=g10&aql=&gs_sm=c&gs_upl=19501l19782l0l22016l2l2l0l0l0l0l187l265l1.1l2
- **Quantitative**
  https://www.google.com/search?hl=en&rls=com.microsoft%3A*&biw=1259&bih=858&tbs=dfn%3A1&q=quantitative&oq=quantitative&aq=2&aqi=g-e1g9&aql=&gs_sm=c&gs_upl=21734l26828l0l28750l12l11l0l0l0l0l203l1454l4.6.1l11
- **Qualitative**
  https://www.google.com/search?hl=en&rls=com.microsoft%3A*&biw=1259&bih=858&tbs=dfn%3A1&q=qualitative&oq=qualitative&aq=0&aqi=g10&aql=&gs_sm=c&gs_upl=18923l26454l0l29063l36l23l3l3l3l0l187l1640l7.8l16

MAPS NEEDED

- **1991/3.2.1**
  http://change.gsfc.nasa.gov/data/phoen/classroom/phoen1991-321-q4.tif
- **1991/7.4.2**
  http://change.gsfc.nasa.gov/data/phoen/classroom/phoen1991-742-q4.tif
- **2000/3/2/1**
  http://change.gsfc.nasa.gov/data/phoen/classroom/phoen2000-321-q4.tif
- **2000/7.4.2**
  http://change.gsfc.nasa.gov/data/phoen/classroom/phoen2000-742-q4.tif

LEARNING LINKS

- **The electromagnetic spectrum diagram**
  http://mynasadata.larc.nasa.gov/science-processes/electromagnetic-diagram/
- **Movie about Satellites**
  http://landsat.gsfc.nasa.gov/education/resources/Satellites.mov
- **Animation over time of Phoenix, AZ**
- http://landsat.gsfc.nasa.gov/education/resources/Phoenix.mov
- **Getting to Know your Satellite Imagery**
  http://landsat.gsfc.nasa.gov/education/resources/GLOBE_getting2know.pdf

LESSON 7-STANDARDS

National Science Education Standards

Unifying Concepts and Processes

- Systems, order, and organization
- Evidence, models, and explanation
- Change, constancy, and measurement

Standard A – Science as Inquiry

- Abilities necessary to do inquiry
- Understandings about scientific inquiry

Standard B – Physical Science

- Interactions of energy and matter

Standard D – Earth and Space Science

- Energy in the earth system

Standard E – Science and Technology

- Understandings of technological design

Standard F – Science in Personal and Social Perspectives

- Population growth
- Natural resources

Standard G – History and Nature of Science

- Science as a human endeavor

National Education Technology Standards

Standard 1: Creativity and Innovation

- Use models and simulations to explore complex systems and issues
- Identify trends and forecast possibilities

Standard 4: Critical Thinking, Problem Solving, and Decision Making

- Collect and analyze data to identify solutions and/or make informed decisions.

Standard 5: Digital Citizenship

- Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior.

Standard 6: Technology Operations and Concepts

- Understand and use technology concepts
- Select and use applications effectively and productively
- Troubleshoot systems and applications

National Council of Teachers of Mathematics Standards

Algebra

- Understand patterns, relations, and functions
- Use mathematical models to represent and understand quantitative relationships
- Analyze change in various contexts

Measurement

- Understand measurable attributes

Data Analysis and Probability

- Develop and evaluate inferences and predictions that are based on data

Process

- Connections
  - Recognize and apply mathematics in contexts outside of mathematics

Climate Literacy Principles

Principle 3: Life on Earth depends on, is shaped by, and affects climate.
Principle 4: Climate varies over space and time through both natural and man-made processes.
Principle 5: Our understanding of the climate system is improved through observations, theoretical studies, and modeling
Principle 6: Human activities are impacting the climate system.

Energy Literacy Principles

Principle 1: Energy is a measurable quantity that follows physical laws.
Principle 7: The energy choices made by individuals and societies affect quality of life.

LESSON 7-ESSENTIAL QUESTIONS ANSWER KEY

The following is information that is applicable to the type of information students are expected to have in regards to both lessons 7 and 8.

When students are looking at changes in any of the NASA images available, whether Phoenix for lesson 7 or one of the many Landsat images from lesson 8 students will see changes from natural landscapes to more man-made landscapes and/or having urban areas grow beyond its initial boundaries. It's important for students to identify what types of land cover are visible and how they are changing – the document, *About Colors of Landsat Images*, is a critical tool to have available as students are making observations.

Equally important for students to comprehend about the images they are analyzing are changes from pervious to impervious and impervious to pervious surfaces. These surfaces have a significant effect on weather and climate and can have significant consequences to cities and outlying areas.

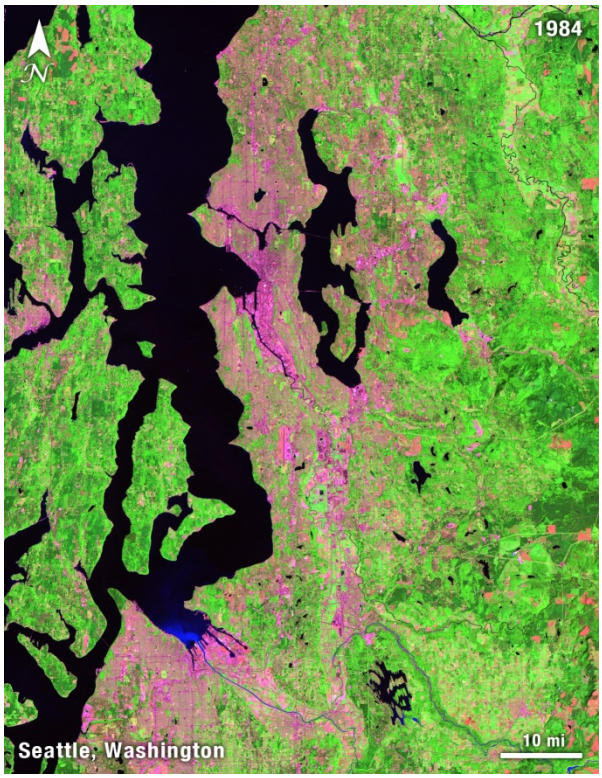
Students will need to identify ecological consequences to areas of urbanization and deforestation.

Having students consider the detrimental effects placed on water ways, air, soils, food and water availability, housing, and wildlife is a critical connection. These ecological areas, these pieces of the city or forest system will have an impact on their lives and therefore you will be able to answer the "why it matters" or "why are we learning this".

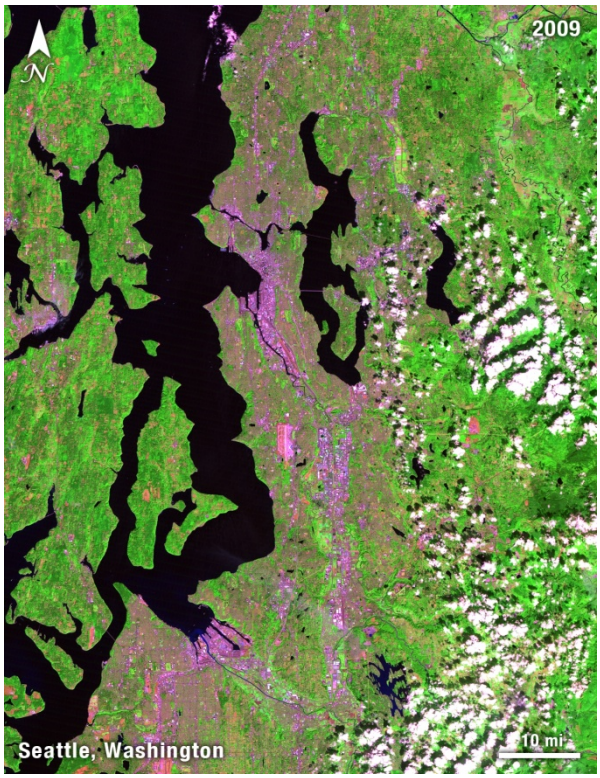
Name: _____ Date: _____

Science Concept Quiz

Lesson 7: Quantifying Land Changes Over Time Using Landsat



Seattle, WA 1984



Seattle, WA 2009

In the Landsat images above changes have occurred over the 25 year time span. **Which statement best supports the changes that have occurred in these false color images?**

A. Clouds in the 2009 image make it impossible to identify a change.
B. There are significantly more green tones in the 2009 image which allow one to distinguish between kinds of vegetation and see boundaries for bodies of water.
C. The 2009 image shows many areas with blue tones which are useful in identifying human-made features.
D. There are significantly more red and pink tones in the 2009 image which denote a change from vegetation to human made features.

_____ points out of 20

I. Answer

A.○ B.○ C.○ D.○

_____ points out of 15

II. What is the main concept behind the question?

1. Formulating a hypothesis
2. Difference between true and false color images
3. Infrared wavelengths
4. Change over time

_____ points out of 25

III. Provide the reasoning for choosing your answer in part II.

_____points out of 40

IV. Why are the other responses in part I not the best answer choice?

1.

2.

3.

4.

Teacher Answer Key

1. C

2. 4

3. Answers will vary. The statement asks to identify changes that have occurred in the past 25 years.

4. Answers will vary.

   A) There is not enough cloud cover in the 2009 image obstructing one from making observations about land changes over time.

   B) Yes green tones allow scientists to distinguish between kinds of vegetation and see boundaries for bodies of water, but there is not an increase in green tones from the 1984 to the 2009 image.

   C) There are many areas with blue tones. In my work on *Quantifying Land Changes Over Time Using Landsat* I learned that theses tones help scientists observe different kinds of vegetation and monitor vegetation health, as well as, identify human-made features such as roads, buildings, and parking lots.

   D) Although there is a change over the 25 year time span from areas with vegetation to areas with much less vegetation which could mean more human-made features, there is a significant decrease not increase in red and pink tones from 1984 to 2009.

Student Name
Teacher/Class
Date

Lesson 7: Quantifying Land Changes over Time Using Landsat

How could knowledge gained from Landsat images help climate scientists make predictions about changes in a cities or regions climate?

What Is the Expectation?

Use new lesson knowledge and student readings to support your position

Visual representations if applicable

Key vocabulary

Evidence of on grade level spelling and grammar usage