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Human Impacts

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Evaluating Human Impacts

NCSR curriculum modules are designed as comprehensive instructions for students and supporting materials for faculty. The student instructions are structured in a "generic format" designed to facilitate adaptation in a variety of settings. Where appropriate, the generic version is augmented by a specific instructional module taught in the Pacific Northwest. The purpose of these specific versions is to provide those who are adapting modules greater insight into how the materials are used in a teaching/learning environment. In addition to the instructional materials for students, the modules contain separate supporting information in the "Notes to Instructors" section. The modules may also contain other sections which contain additional supporting information.

This module contains a series of high altitude imagery. To facilitate the use of these images, a PowerPoint format is available. If the module is being downloaded from this website the download version is included at the end of the module. If a hardcopy of the module is being requested a disk with the images will be included with the manual.

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Table of Contents

Evaluating Human Impacts - Module Description 6
One Planet Many People: Atlas of Our Changing Environment 7
Introduction 7
Objectives 7
Procedure 8
Resources 12
Notes to Instructors 13
General Information 13
Geographic Location of Images 14
Image Descriptions 16
Coastal Areas – Gulf of Fonesca, Honduras 16
Coastal Areas – Isahaya Bay, Japan 17
Water – Dead Sea, Jordan 18
Water – Everglades, Florida, United States 19
Water - Lake Victoria, Uganda 20
Temperate Forest – British Columbia, Canada 21
Subtropical Forest – Iguazu, South America 22
Tropical Forest – Laos 23
Tropical Forest – Rondonia, Brazil 24
Cropland – Saudi Arabia 25
Cropland – Santa Cruz, Bolivia 26
Cropland – Tensas Basin, United States 27
Grasslands – Upper Green River, United States 28
Urban Areas – Beijing, China 29
Urban Areas - Las Vegas, Nevada, United States 30
Ecological Footprint Analysis 31
Resources 31
Additional Sources of Information on Evaluating Human Impacts 32
Google Earth and *NASA World Wind* as Tools for Evaluating Human Impacts 34
Google Earth 34
Site Description 34
Minimum System Requirements 35
NASA World Wind 35
Site Description 35
Minimum System Requirements 36
Resources 36

Evaluating Human Impacts - Module Description

The evaluation of human impacts on the environment is an important element of environmental science. Although students may be quite familiar with local impacts such as emissions from a nearby factory or impaired water quality in a local stream, impacts on broader scales of time and space may be less familiar. New technologies are now available that provide educators useful tools to illustrate these impacts. The following activities have been developed using several different approaches and resources to address this need.

This module includes four components:

1. *One Planet Many People – Atlas of Our Changing Environment*

2. Ecological Footprint Analysis

3. A description of other sources of remote sensing imagery and methods for evaluating human impacts

4. An introduction to two sources of remote sensing imagery - *Google Earth* and *NASA World Wind*

One Planet Many People: Atlas of Our Changing Environment

Introduction

Environmental impacts can be observed and measured on many scales. Impacts at the local scale such as an oil spill or runoff from a toxic waste site are probably easiest to identify and understand. Many impacts, however, result from the accumulation of a number of local impacts that occur over a broad area. These impacts are best viewed not on the ground, but from the broader perspectives that can be provided remote sensing technology (by satellite imagery and high altitude photography).

In this activity, you will examine a collection of 15 "before" and "after" paired satellite images from various biomes around the world. The images have been collected and presented in a publication of the United Nations Environmental Programme (UNEP) entitled *One Planet*, *Many People: Atlas of Our Changing Environment* (available at http://www.na.unep.net/). This document provides a comprehensive, visual presentation of scientifically verifiable information on changes in the global environment. The atlas includes photographs, satellite images, maps and descriptions that provide insight into the many ways that humans have impacted the environment.

The following paired images are presented here to illustrate large-scale changes over relatively short timeframes (10- 30 years). They can be used individually or collectively in a number of different contexts.

Objectives

1. To familiarize students with broad-scale environmental changes caused by humans
2. To predict both environmental and social impacts of environmental change based on an examination of remote sensing images
3. To develop the ability to infer trends in environmental impacts based on the examination of remote sensing images

Procedure

A series of paired images will be projected that depict environmental changes caused by humans over a relatively short period of time (generally, 10-30 years). As you view these images and listen to the brief descriptions provided by the instructor, predict the environmental and social impacts that will occur as a result of the observed change. Use the space below to record your answers.

An analysis of the first image is completed to use as a model.

1. Coastal Areas - Gulf of Fonesca, Honduras

Environmental – Altered hydrology resulting in destruction of the mangrove ecosystem and a decline in the biodiversity it supports; degraded water quality (runoff of enriched water from ponds), impacts on fisheries due to bycatch associated with capture of shrimp post-larvae, which are used to stock the ponds seen in the image.

Social – Although new employment opportunities have been provided by this new shrimp farming industry, other industries have been negatively impacted. Rapid development has deprived fisherman, farmers and others access to mangroves, estuaries and seasonal lagoons.

2. Coastal Areas – Isahaya Bay, Japan

Environmental –

Social –

3. Water – Dead Sea, Jordan

Environmental –

Social –

4. Water – Everglades, Florida, United States

Environmental –

Social –

5. Water - Lake Victoria, Uganda

Environmental –

Social –

1. Temperate Forest – British Columbia, Canada

Environmental –

Social –

7. Subtropical Forest – Iguazu, South America

Environmental –

Social –

8. Tropical Forest – Laos

Environmental –

Social –

9. Tropical Forest – Rondonia, Brazil

Environmental –

Social –

10. Cropland – Saudi Arabia

Environmental –

Social –

11. Cropland – Santa Cruz, Bolivia

Environmental –

Social –

12. Cropland – Tensas Basin, United States

Environmental –

Social –

13. Grasslands – Upper Green River, United States

Environmental –

Social –

14. Urban Areas – Beijing, China

Environmental –

Social –

15. Urban Areas – Las Vegas, Nevada, United States

Environmental –

Social –

Resources

UNEP. 2005. One Planet Many People: Atlas of Our Changing Environment. Division of Early Warning and Assessment. United Nations Environment Programme, Nairobi, Kenya. 320 pp.

Notes to Instructors

General Information

Paired images are available from NCSR on a compact disk stored in *PowerPoint*. These images can be projected with standard presentation software and hardware.

There are a number of ways to structure this activity. The instructor may wish to design a lecture around these images, but my preference is to engage students more actively in their interpretation. For example, the images can be projected and brief descriptions of what appears on the image can be given. Students can then work individually or in small groups (my preference) to predict environmental impacts as a result of the change observed. For those instructors whose courses include the social implications of environmental change, this could be added as well.

I have included descriptions and interpretations of these 15 pairs of images below. A world map identifying the location of the paired images is included. Instructors will need to decide how much of this background information should be shared with students to prompt their thinking on environmental and social impacts. For example, if the activity is used at the beginning of an environmental science course, more prompting may be required and less detailed answers expected. As a summative activity at the end of the course, students have a stronger background on issues such as land use, biodiversity loss, agricultural impacts and water quality and answers should be more comprehensive.

Each of these sites represents a more complex environmental issue than can be discussed here. For those who wish to develop a more elaborate activity, the images could be used as an introduction to a research assignment. Pairs or small groups of students could be assigned one of these sites to investigate further and then lead a discussion of what they have learned at a later date.

Assessment

The method of student assessment will depend on how the activity is used. For a stand-alone, small group activity, each student group should submit their analysis of the images by predicting environmental and social impacts. Adequate time should be allocated for viewing the images and subsequent discussions within small groups. As described above, scoring by the instructor will depend on the background and level of sophistication of the students. The "image descriptions" include with this module may be used as a key.

Geographic Location of Images

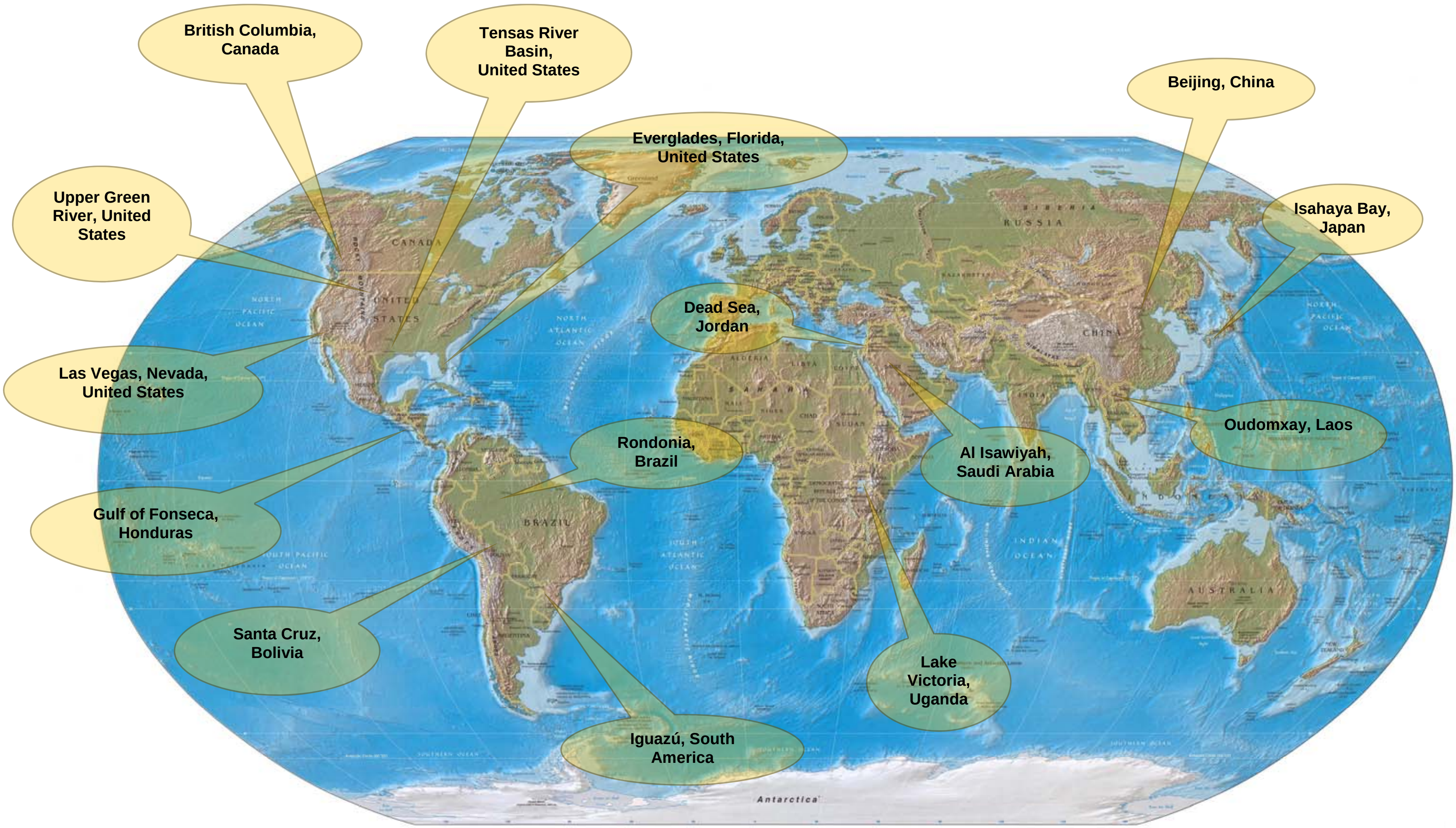
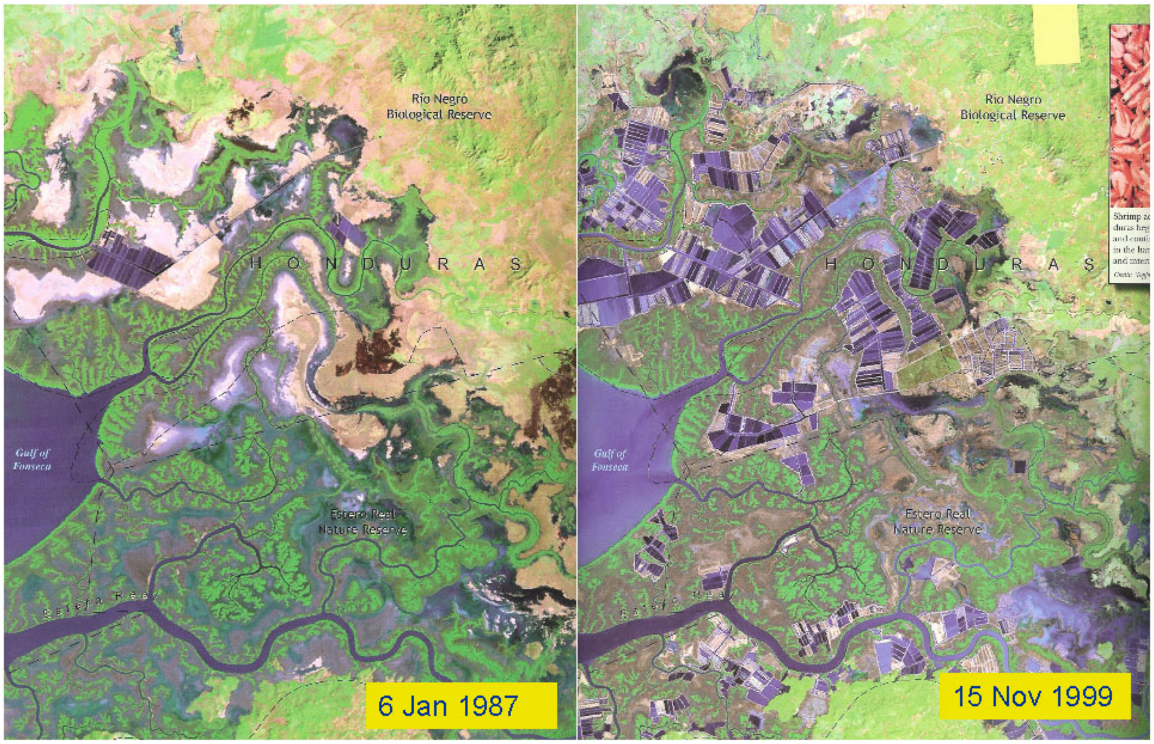


Image Descriptions

Coastal Areas – Gulf of Fonesca, Honduras



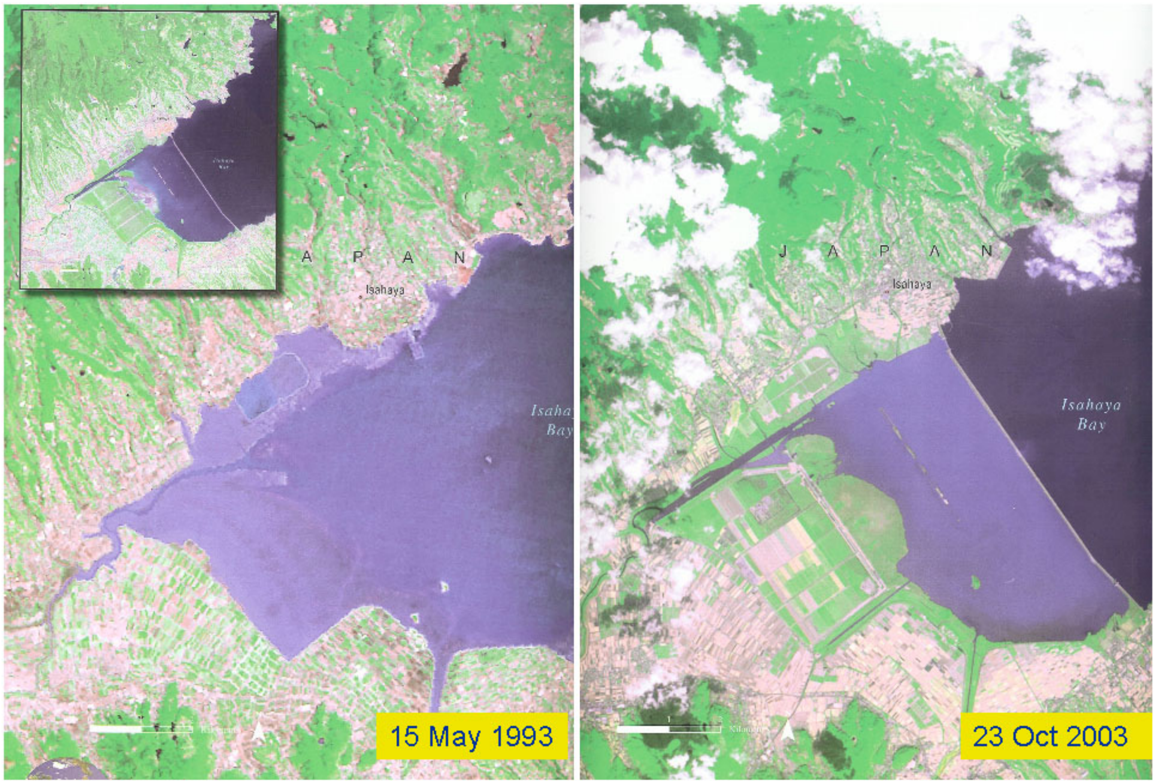
This image illustrates the rapid development (over only 12 years) of shrimp farming in the delta of the Gulf of Fonesca, Honduras. Large areas have been converted from natural mangrove forests and estuaries of the delta into shrimp farms (shrimp aquaculture). Shrimp aquaculture began in the 1970's and continued in the 1980's with the support of international financial organizations and the Honduran government. By the 1990's shrimp aquaculture was one of the country's top grossing industries. The rapid growth of the industry has resulted in both social and environmental impacts:

Environmental – altered hydrology of the area, destruction of mangroves, estuaries and seasonal lagoons resulting in declines of biodiversity; degraded water quality (runoff of enriched water from ponds), impacts on fisheries due to bycatch associated with capture of shrimp post-larvae, which are used to stock the ponds seen in the image. Estimates of direct loss of the mangrove ecosystem due to shrimp farm construction range from 20 - 40 km^2. If conservation measures are not implemented, mangroves will disappear within 20 years.

Note that the Estero Real Nature Reserve is located near the center of the image. What impacts might be expected on this conservation area?

Social – Although new employment opportunities have been provided by this new shrimp farming industry, other industries have been negatively impacted. Rapid development has deprived fisherman, farmers and others access to mangroves, estuaries and seasonal lagoons.

Coastal Areas – Isahaya Bay, Japan



This image illustrates “land reclamation” in Japan’s Isahaya Bay located on the west side of Japan's southwestern-most main islands. The project began in 1989 in an attempt to separate approximately 7500 acres of tidal flats from the bay and turn Japan’s largest marine wetland (tidal flats) into farmland. The straight line across the bay is a 4-mile sea wall that was completed on April 14, 1997. Behind the wall, water is drained or pumped away, drying the tidal flats. The wetland harbored a rich diversity of wildlife and served as a major stopover for birds migrating between Siberia and Australasia. The project was originally proposed in 1952 with the goal of converting tidal mudflats into rice paddies to feed a post-war Japan. Although this need disappeared, an entrenched bureaucracy pushed the project through despite local protests and a 100 billion Japanese yen overrun.

Environmental – In addition to the destruction of wetland habitat and impacts on water quality, the decline of various fisheries in the Ariake Sea has been blamed on the Isahaya Bay Reclamation Project. Net fisheries, diving fisheries and seaweed aquaculture have documented declines since the completion of the dike. "Opened gate surveys" have been demanded by local communities to establish a link between the project and fishery declines. These studies would require the re-opening of the gates in the dike to re-establish a connection between the bay and the sea followed by a monitoring of shellfish, fish and seaweed populations.

Social – Employment in Japan has been traditionally spurred by large public works projects. This is one example that was designed to keep locals "happy and employed". The project brings into question Japan's long-standing culture dominated by a love and sensitivity for the rich natural heritage of this part of the world. Isahaya Bay is known for its production of nori (seaweed) and local farmers contend that the project has negatively impacted the quality and quantity of nori growing in the bay.

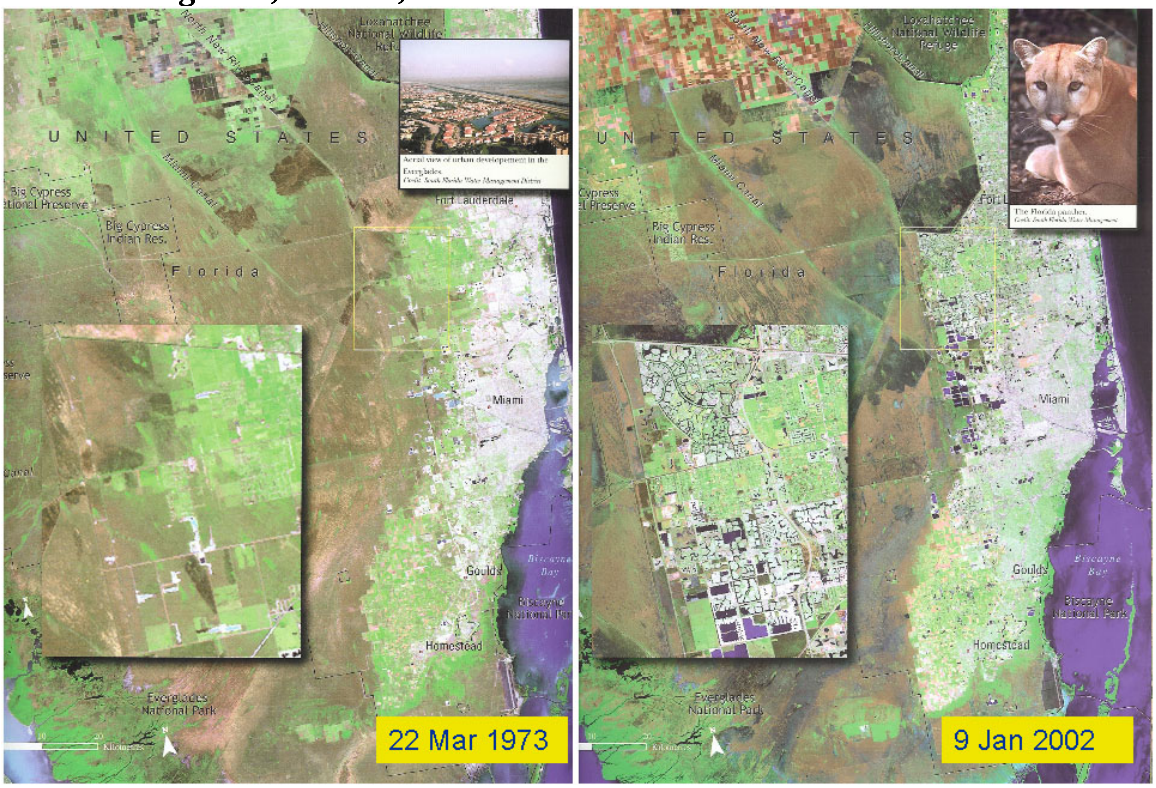
Water – Dead Sea, Jordan

The Dead Sea and the rivers that flow into it are an important source of water for bordering nations of Jordan and Israel. Additionally, significant areas of the Dead Sea are dedicated to evaporation ponds which serve to remove water and leave salt behind. The combination of extractions and accelerated evaporation in these salt works has resulted in a reduction in water level. In recent years this rate of loss has been approximately one meter per year. These images illustrate the dramatic change that has occurred in the area from 1973 to 2002. Water levels have declined and the number of impoundments for salt works has greatly increased. Also, land reclamation projects particularly apparent near the center of the 2002 image have increased the amount exposed arid land around along the coastline. Note that the southern portion of the Dead Sea is now effectively cut off from the northern portion.

Environmental – changes in salinity levels of Dead Sea; water as a limited resource is clearly illustrated in a part of the world where water is in short supply.

Social – the salt works industry provides employment, economic growth and a needed product to residents of these two countries.

Water – Everglades, Florida, United States

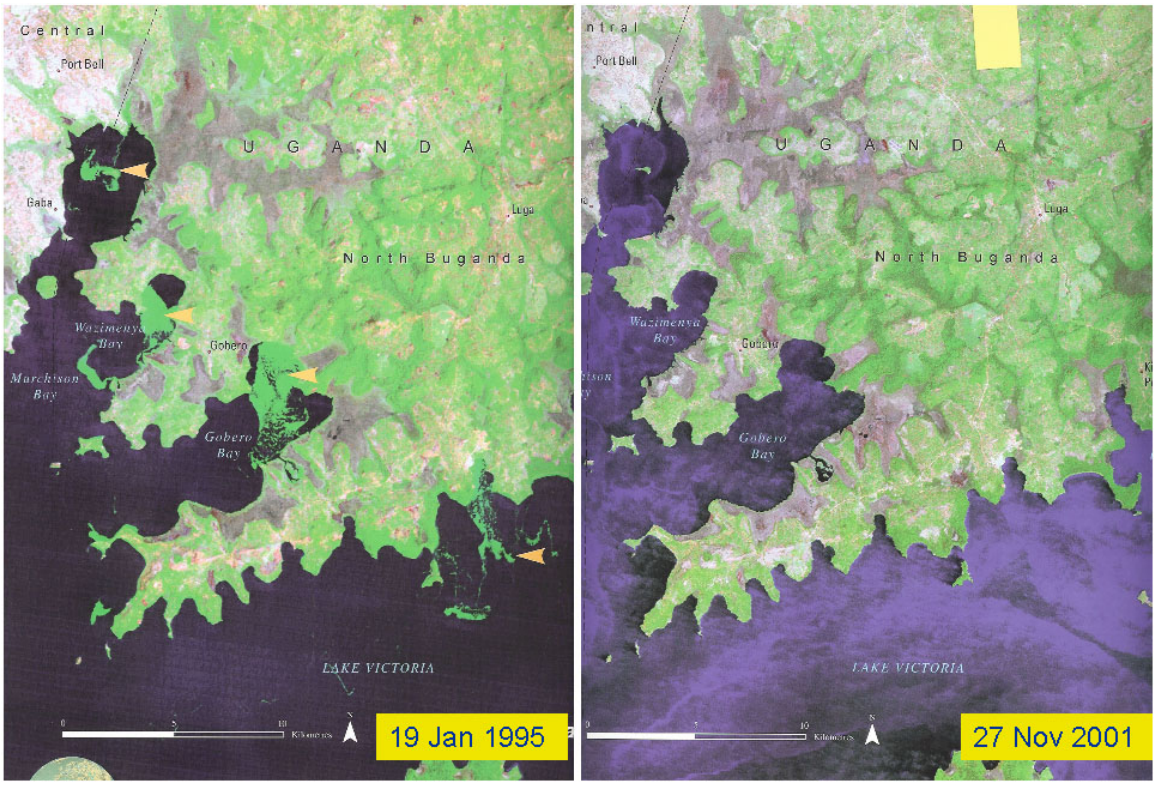


These images illustrate the rapid change in southern Florida that has occurred in the past 30 years. Urban expansion of Ft. Lauderdale and Miami (light gray areas) is one of the most apparent changes. Agricultural land (green, rectangular features), particularly northwest and southwest of Miami along with significant areas of the “Everglades” (mixed green and brown signature to the west of Miami and Ft. Lauderdale) has been converted into an urban landscape. In September 2000, Congress approved funding for the Everglades Ecosystem Project, the largest ecological restoration effort in history. The project is promoted as an example of large-scale implementation of ecosystem management. Some of the planned activities include the construction of wetlands to remove nutrients from agricultural runoff, re-establishing some of the original hydrology of the area and the removal of invasive plants that have become established.

Environmental – Past practices have resulted in the promotion of the spread of invasive species, habitat loss for threatened and endangered species (e.g., Florida panther), and the loss of farmland due to agricultural to urban land conversion. The loss of natural wetlands in the Everglades has resulted in the loss of ecosystem services provided by this area. Water loss due to extractions by agriculture and municipal use results in failed recharge of underlying aquifer placing water supplies at risk. As the only subtropical biome in mainland U.S., south Florida harbors a significant amount of unique biological diversity.

Social – Expanding urban areas require a source of water. Urban expansion removes agricultural land with resulting impacts on farmers. Everglades National Park is frequently visited by tourists who witness a degraded ecosystem and the need for restoration.

Water - Lake Victoria, Uganda

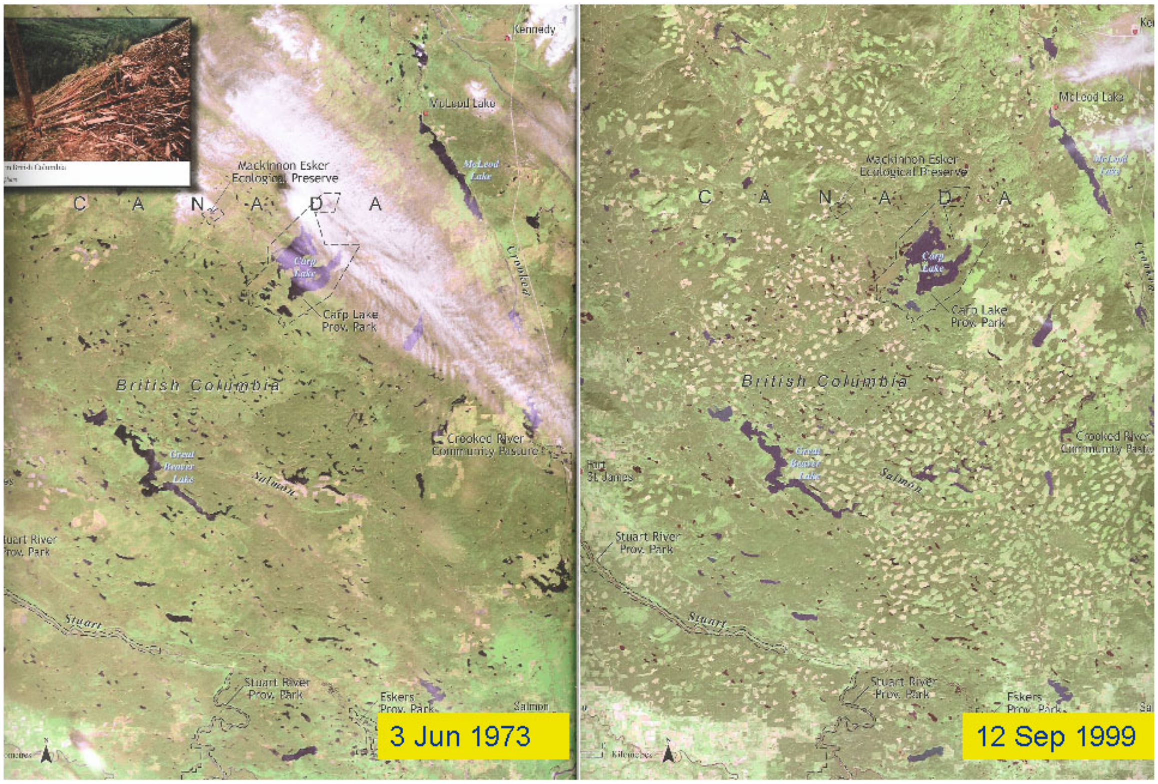


Lake Victoria, one of the largest freshwater lakes in the world. The effects of the unintentional introduction of water hyacinth can be seen in the 1995 image. Yellow arrows point to areas of particularly heavy infestation. This floating aquatic plant disrupted transportation and fishing activities in the region, clogged water intake pipes for municipal water and created habitat for disease-causing mosquitoes and other insects. In 1994, the Lake Victoria Environmental Management Project was formed to address the water hyacinth problem. Mechanical removal was attempted unsuccessfully. The intentional introduction of natural insect predators of water hyacinth has led to more success as the 2001 image illustrates.

Environmental – Invasive species such as water hyacinth frequently compete with native species for resources. The result can be the decline and even extinction of native species. Introduced species are second only to habitat loss as a cause for biodiversity loss. Lake Victoria is also the venue for one of the most celebrated cases of species loss due to species introduction. The Nile Perch was intentionally introduced for game and commercial exploitation. A voracious predator, it consumed many native fish in the lake including a number of native, endemic cichlids which are apparently now extinct. Note that the solution in the water hyacinth case also involved the introduction of an exotic species. Only time will tell if this creates a long-term solution or perhaps another unforeseen problem.

Social – Water hyacinth has contributed to economic harm to shipping and fishing industries as well as increased disease rates among those who live nearby.

Temperate Forest – British Columbia, Canada

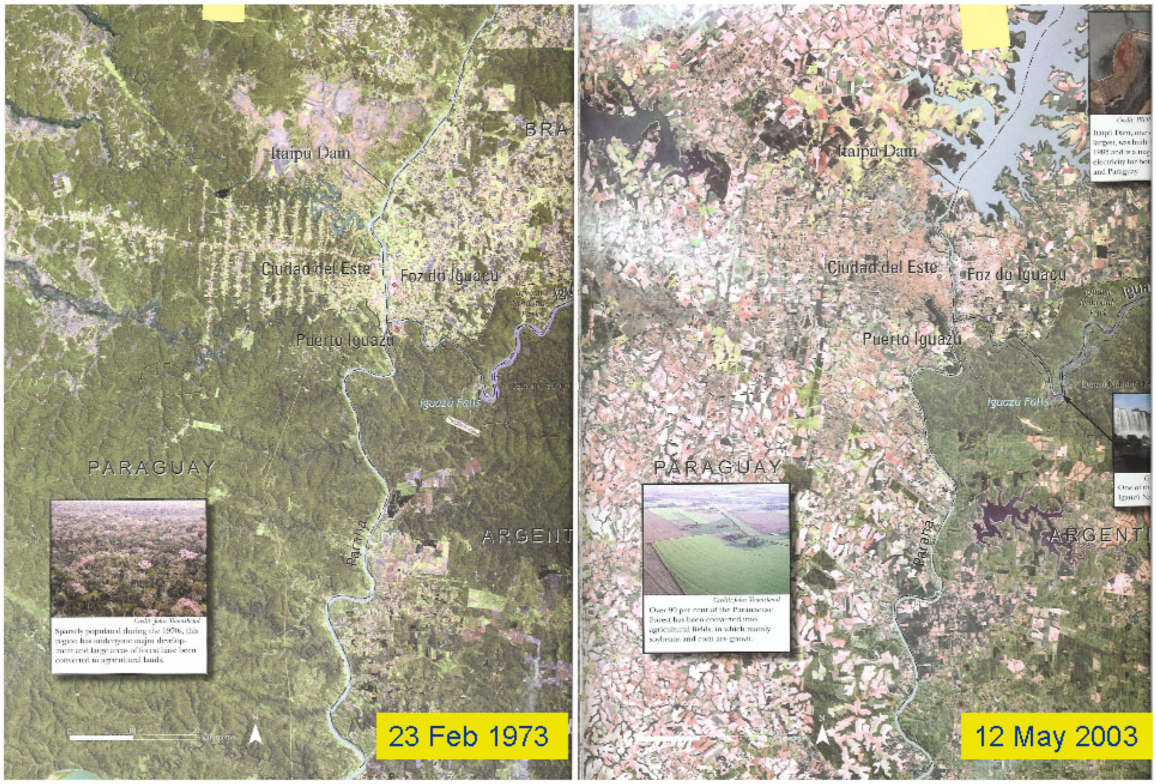


Green areas in 1973 image represent mostly late-successional conifer forests. Less than 30 years later, the 1999 image illustrates the effects of staggered setting logging in which clearcuts are scattered over the landscape.

Environmental – Late successional forests in this area harbor a great diversity of forest organisms. Logging reduces amount of this habitat available but in addition, the patchwork nature of harvest results in greater fragmentation and edge effects which expand the impact on native species. Clearcuts, particularly on steep slopes can also impact downstream water quality due to runoff, roads and landslides.

Social – Economic benefit is the primary benefit of logging in this region where the timber industry is a major player in the provincial economy.

Subtropical Forest – Iguazu, South America

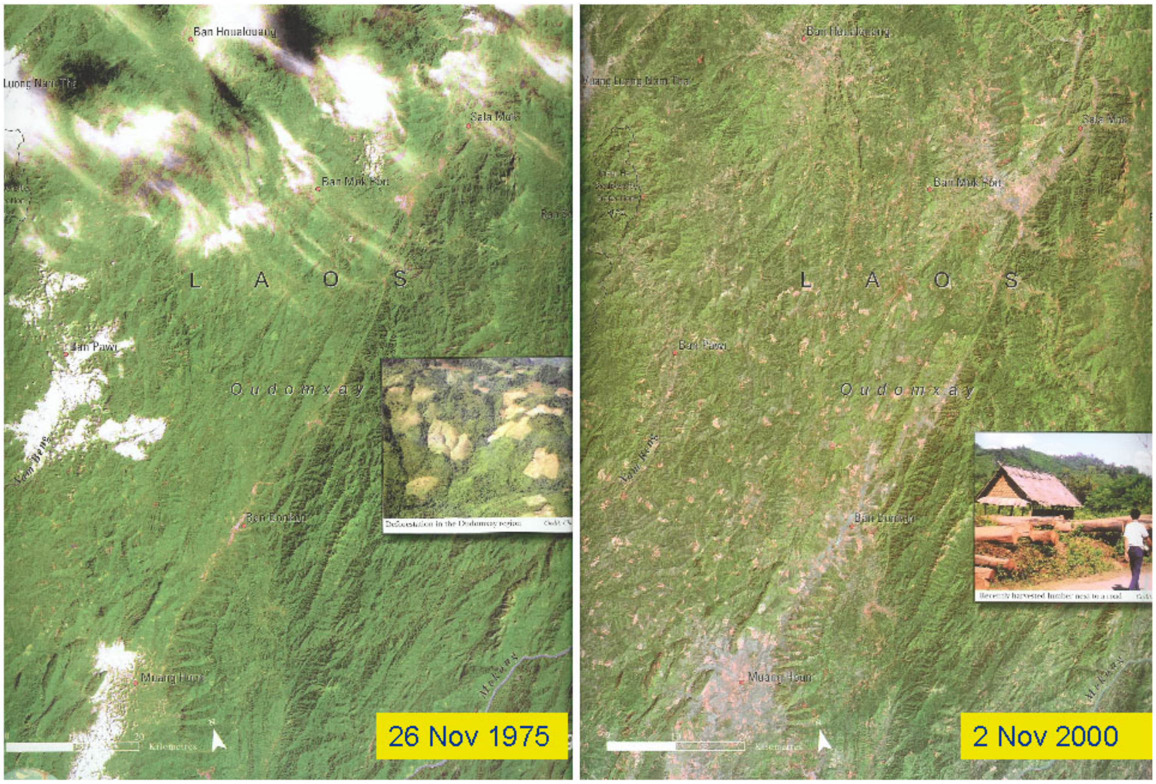


Common borders of Argentina, Paraguay and Brazil are shown in these images. In the 1970's this area was sparsely populated and a classic example of subtropical forests. Iguazu National Park, representing the highly endangered Paranaense Rainforest ecosystem is located at the center of the image. This forest is isolated by natural barriers from surrounding forests and as a result has developed into a unique ecosystem that harbors thousands of endemic plants and animals found nowhere else on Earth. From 1973 to 2003, the area has undergone a dramatic transition. Large expanses of forest in Paraguay, Brazil and to a lesser extent Argentina have been converted largely to agricultural land represented by the mosaic of regular shapes of various colors in the 2003 image. Differences in patterns and extent of this conversion reflect different land use policies in the different countries.

Environmental - Habitat loss and fragmentation would be expected to have a greater than average impact on biodiversity due to the high species density in this region. Impacts on water quantity and quality would also be expected. Forest conversion also results in more carbon dioxide release and less long-term carbon storage with possible implications for global climate change.

Social – Conversion of forests to agricultural lands is a common conversion and expands the capacity for a country to accommodate population expansion. Employment opportunities in the agricultural industries would also be expected to expand. Economic benefits of "native" forests, however, are lost.

Tropical Forest – Laos

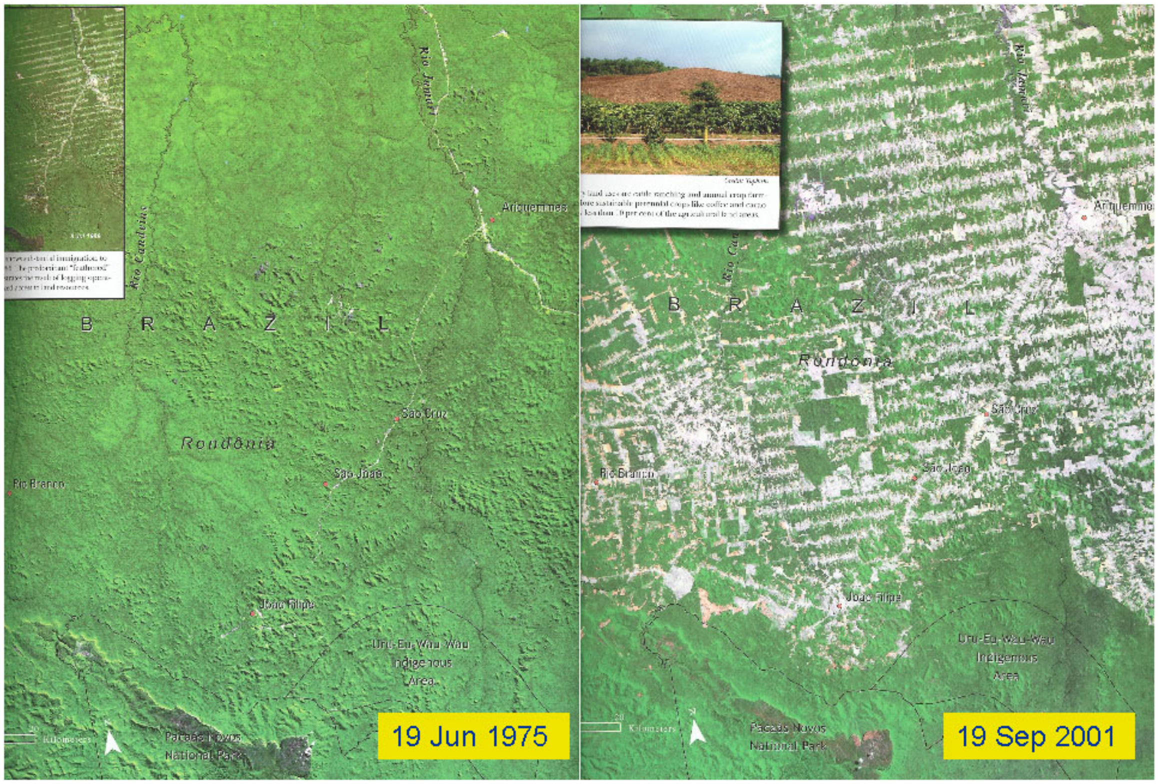


This small southeast Asian country has an abundance of forest and water resources. Images illustrate the impact of agriculture on tropical forest. Patches of forest are burned, cultivated and abandoned to allow growth and recovery and then the process is repeated (slash and burn agriculture or shifting agriculture). This is the primary cause of deforestation in the country. White and light brown patches represent impacted areas which have increased substantially in the 25-year period represented on the paired images.

Environmental - Habitat loss and fragmentation would be expected to have a greater than average impact on biodiversity due to the high species density in this region. Impacts on water quantity and quality would also be expected. Deforestation also results in more carbon dioxide release and less carbon storage with possible implications for global climate change.

Social – Conversion of forests to agricultural lands is a common conversion and expands the capacity for a country to accommodate population expansion. Employment opportunities in the agricultural and timber industries would also be expected to expand (at least temporarily). Sustainable use of forest resources by native cultures is lost.

Tropical Forest – Rondonia, Brazil

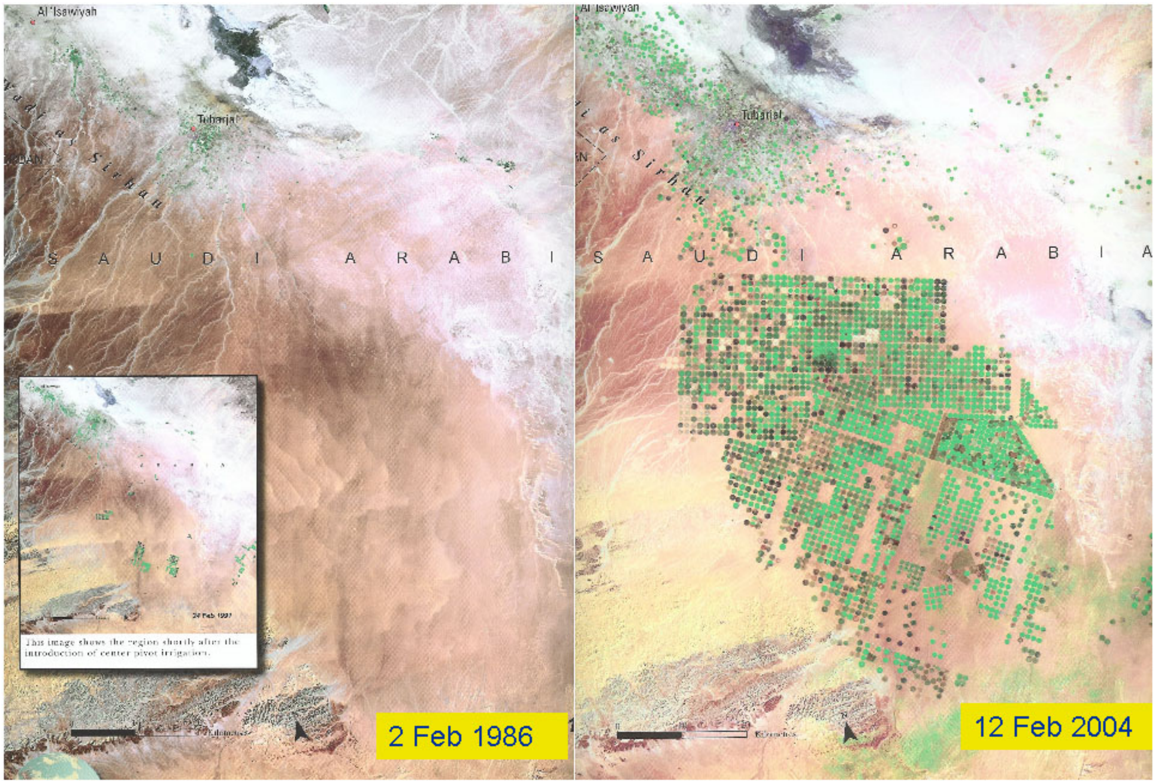


The image illustrates the impact of deforestation in Rondonia, Brazil. The Brazilian government is actively promoting the de-centralization of Brazil's growing population and to exploit undeveloped regions. In 1960 the government completed the Cuiaba-Port Velho highway through the province of Rondonia (seen as white line in image). The highway serves as the access route for infrastructure development in the region which was previously occupied only by indigenous people. A "fishbone pattern" results as clearing is closely associated with main and spur roads. Migration continues into the region via the road network as farmers and loggers seek employment opportunities.

Environmental – Tropical rainforest diversity impacted by habitat loss (land conversion), fragmentation and edge effects. Water quality impacted as well as prevalence of invasive species. Loss of tropical forest results in more carbon dioxide release and less carbon storage with possible implications for global climate change.

Social – Important economic resources are made available to citizens of Brazil. The area was previously occupied by indigenous people therefore their way of life has been negatively impacted. Development provides improved employment opportunities for migrating populations from other areas. However, slash and burn land management emphasizes short-term economic gains over long-term resource sustainablility.

Cropland – Saudi Arabia

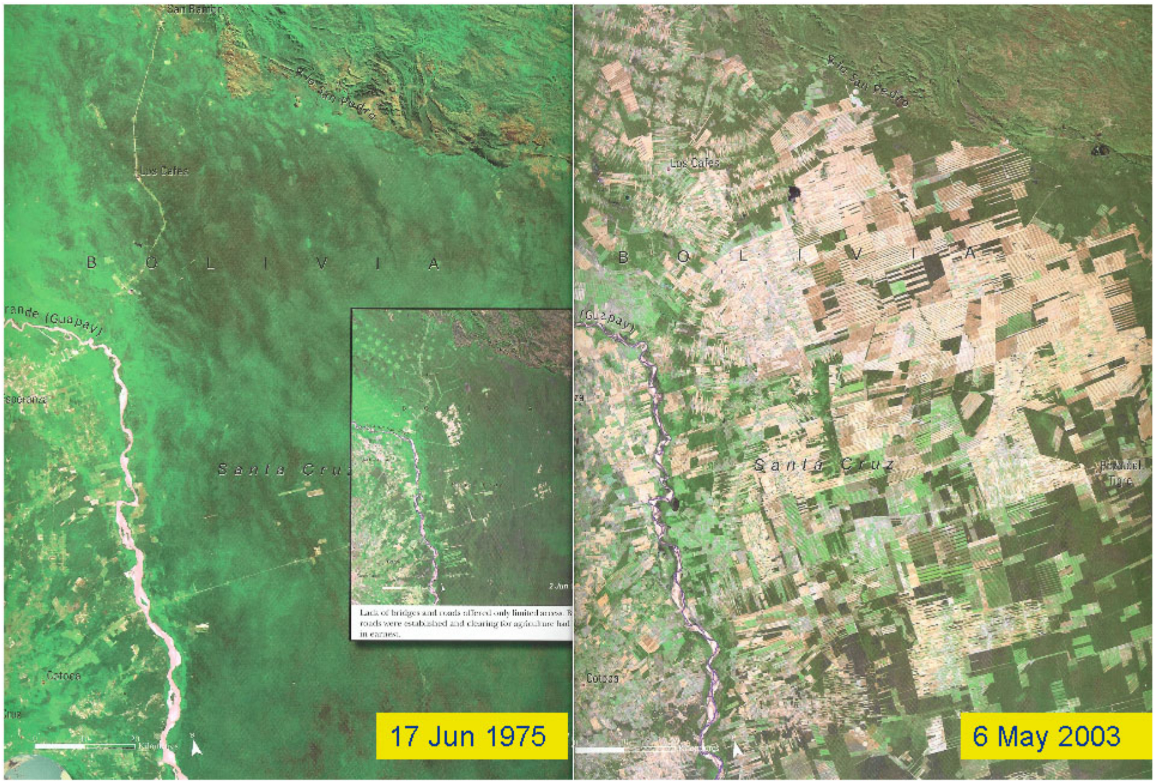


The Middle East is generally rich in oil reserves but lacks water. Saudi Arabia has used oil revenues to adopt some of the best technologies available to farm arid and semi-arid environments. One of those - center pivot irrigation - is illustrated here. Green circles are created by irrigation around a central point. As a result, barren desert was converted into a green, food-producing landscape.

Environmental – The water source for irrigation is an ancient aquifer. Recharge of the aquifer is extremely slow and water is essentially being mined (mostly output with little input). Water quality may also become an issue as water contaminated with agrochemicals makes its way into the underlying aquifer.

Social – Great improvement for people of small towns which prior to irrigation had little capacity for locally-producing food. If not done properly, however, irrigation may lead to salinization of soils and decreased agricultural productivity.

Cropland – Santa Cruz, Bolivia



Forested landscape in Santa Cruz shown in 1975 photo is mostly isolated from human impact due to limited access. By 1986 roads and bridges improved access and led to rapid conversion from forest to pasture and cropland. By 2003, almost the entire area had been converted to agricultural lands.

Environmental – Forest habitat loss with impacts on biodiversity. Agricultural runoff into Rio Grande (Guapay) River which is shown running north to south in the image. Downstream waterways may also be affected.

Social – Increased food production and probably employment opportunities. Star-shaped signatures in northern portion of image represent a unique arrangement of agricultural fields with a small community at the center.

Cropland – Tensas Basin, United States

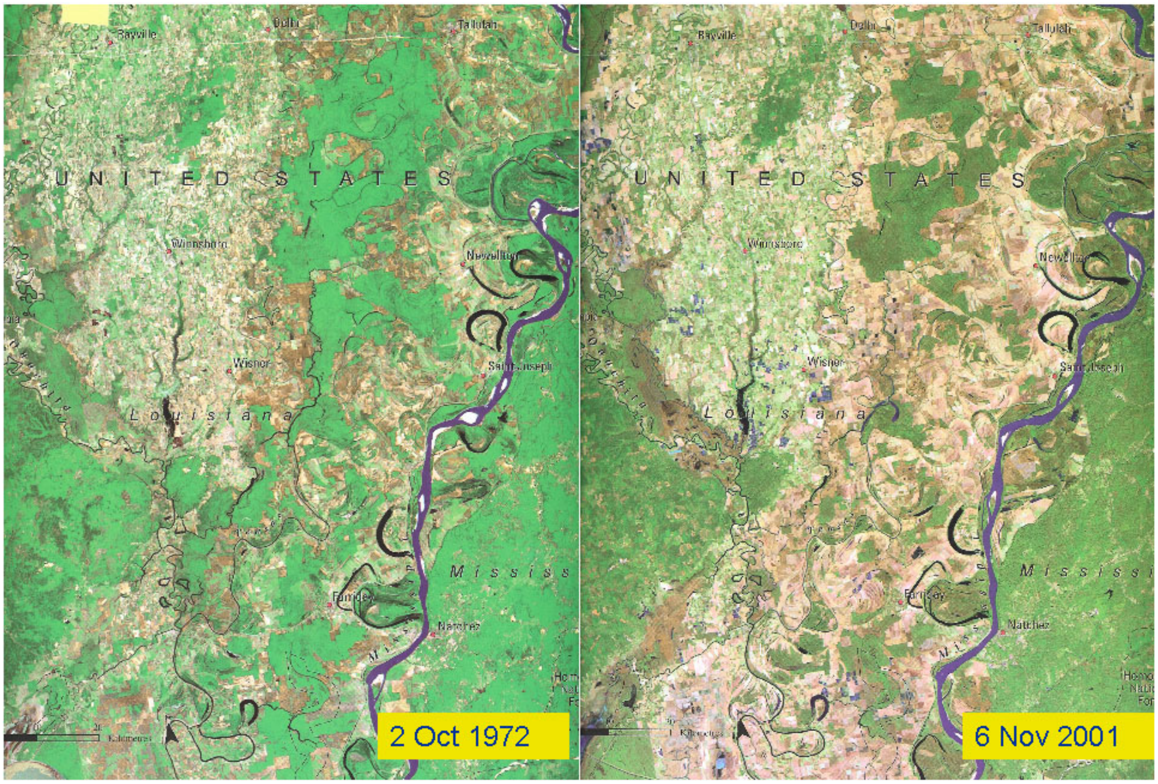


Image shows the Tensas River basin along the Louisiana – Mississippi border. The Mississippi River separates the two states. Historically the watershed was 90% forested – hardwood forest. In the 1960's and 1970's approximately 85% of the area was cleared and planted in soybeans (tan areas in image). The only remaining forests are protected areas – isolated wildlife refuges, management areas and small private parcels. Lands on Mississippi side of the river are less suitable for agriculture, thus forests dominate.

Environmental – Removal of forest has exacerbated flooding problems and increased erosion in the area. Biodiversity declines result from the loss of forest habitat and edge effects on remaining forest fragments. Agricultural runoff of agrochemicals impacts water quality of the Mississippi River and surrounding natural waterways. Runoff also contributes to the "dead zone" in the Gulf of Mexico, a 7000 mi^2 area devoid of the region's usual bounty of fish and shrimp. Fertilizers, livestock manure and outflows from sewage treatment plants all result in artificially high levels of nutrients in the Gulf. This, in turn, causes algae blooms which decompose later in the year consuming much of the dissolved oxygen. The resulting low oxygen levels kill aquatic organisms.

Social – Increased food production and employment in the region but also potential for a negative impact on the downstream fishing industry in the Gulf, which is a major contributor to the regional economy.

Grasslands – Upper Green River, United States

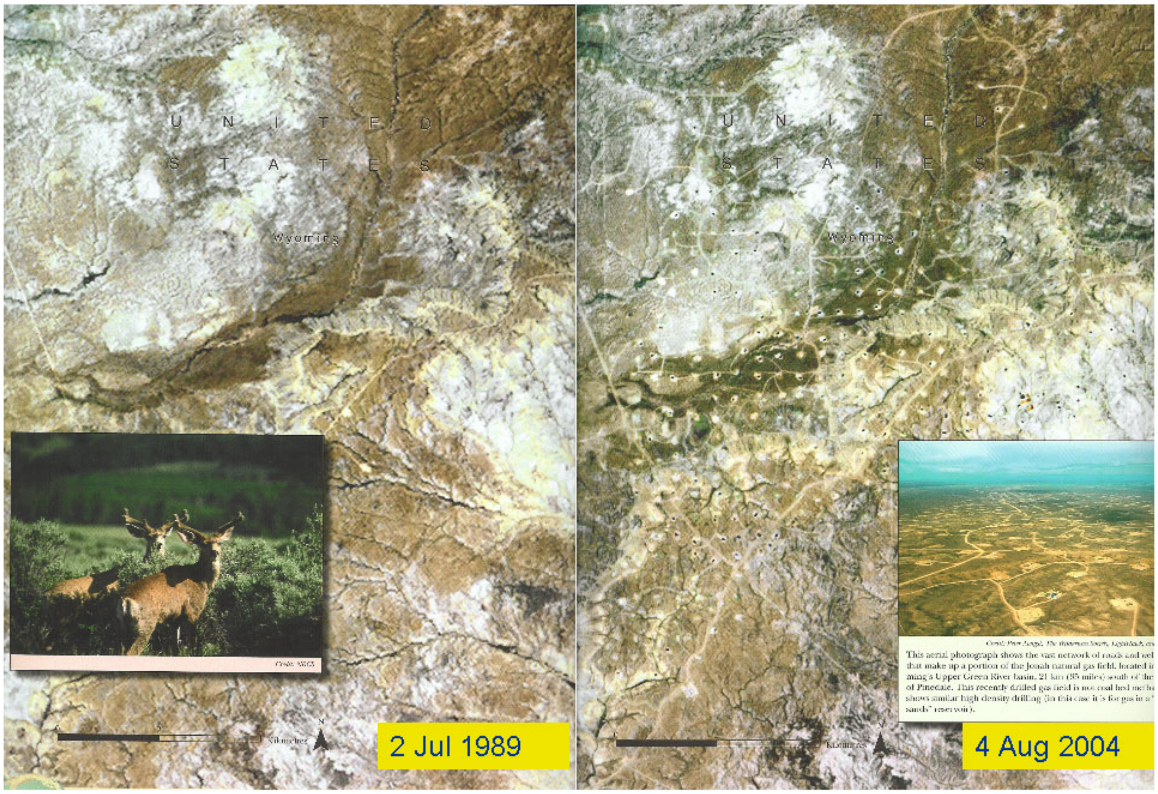
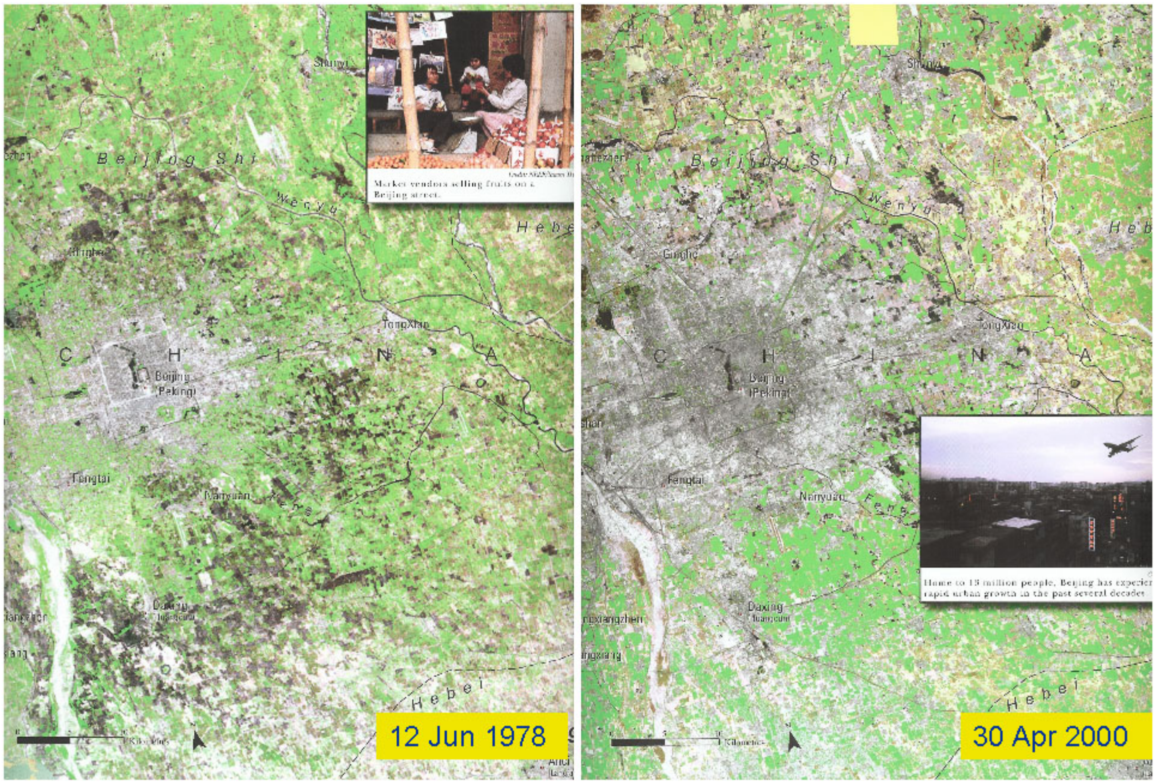


Image illustrates sagebrush steppe in western Wyoming within the Upper Green River Basin. The area is rich in oil and natural gas which have been extracted by the oil and gas industry. Individual wells can be seen in the 2004 image. Over 3000 wells have been approved and development is occurring rapidly.

Environmental – Environmental impacts are largely unknown. The basin does serve as winter range for large herds of pronghorn antelope and mule deer, which migrate between Grand Teton and Yellowstone National Parks. There is also potential for impacts on air and water resources in the region.

Social – Increased domestic access to fossil fuels and increased employment in the oil and gas industry. Potential conflicts with ranchers who graze cattle in this area.

Urban Areas – Beijing, China

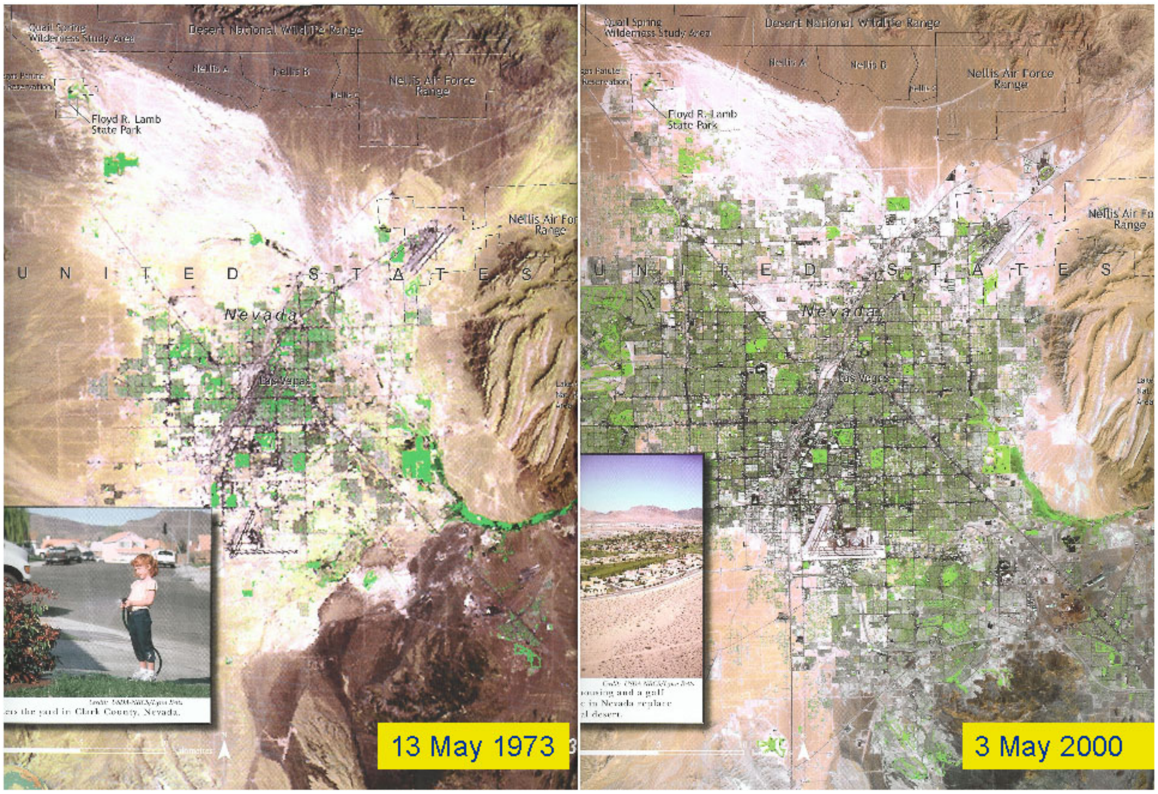


The capital city of the People's Republic of China, Beijing is located in northeast China. It has undergone explosive change since economic reforms were implemented in 1979. The current population exceeds 13 million. Gray – light blue signature represents the urban landscape of the city. The green areas in the 1978 image surrounding the city are deciduous forests. Agricultural lands appear as red, orange and yellow rectangles (crops = rice, winter wheat and vegetables). Explosive expansion has occurred in all directions with urban areas replacing agricultural lands and forests.

Environmental – Forest habitat loss and all of the ills of rapid unregulated development result in impacts on air quality, water quality, wildlife habitat and land use. Air quality in Beijing rates among the worst in the world.

Social – Accommodation for a growing population but, at a price - loss of agricultural land, poor air quality and impacts on human health. Impacts on air quality outside the region (particularly in western U.S. and Canada) have been detected.

Urban Areas - Las Vegas, Nevada, United States



Las Vegas is one of the most rapidly growing cities in the United States. Population growth has largely been driven by the success of the gaming and tourism industries. The great expansion of roads and other urban infrastructure, particularly to the northwest and southeast, can be seen in the images.

Environmental – Water supply is a major concern in this part of the country. The region obtains the majority of its water from the Colorado River which fails to reach its delta in most years due to volume extractions for agriculture and municipal use. The Colorado River is completely allocated. Municipal use (residences, golf courses, hotels and industry) is well above the national average per capita in this desert state. Also, the few vegetated areas that existed on the outskirts of Las Vegas have largely been replaced by urban development.

Social – Population growth has increased from 24,000 (1950) to over 1 million (2005) in a very short time. Water originally allocated for agricultural use has been diverted to meet this growing demand.

Ecological Footprint Analysis

Ecological footprint analysis was developed by William Rees at the University of British Columbia as a method to evaluate the land base required to support the human population. It is essentially an accounting system that estimates the "footprint" of a typical resident in different regions of the world. The average North American, for example, requires about 24 acres to support our consumer lifestyle. A nation's ecological footprint corresponds to the aggregate of land and water area in various ecosystem categories that is required to produce all of the resources that it consumes and to absorb all of the waste it generates using prevailing technology.

Several web sites (listed below) have been developed that allow the calculation of an individual's ecological footprint. Although the complexity of the analysis varies, each is based on lifestyle input (e.g., size of home, transportation, diet, waste generation, etc.) provided by the user. The software then calculates an ecological footprint based on this information.

Students will quickly realize that although the United States accounts for less than 5% of the world population, we consume more than 25% of its key resources. Ecological footprint analysis will demonstrate that if everyone on Earth adopted our consumer lifestyle, approximately six additional planet Earth's would be required to support the population.

The calculation of ecological footprints of students in the classroom provides a useful introduction into human impacts and students seem to enjoy participating in the activity. Comparisons of the footprints of developed and undeveloped countries will stimulate discussion of the concept of sustainability. The footprint calculators could also be used by students to evaluate the impacts that personal lifestyle changes make on environmental impacts.

Resources

Ecological footprint calculators are available at the following web sites:

http://www.earthday.org
http://www.rprogress.org
http://www.redefiningprogress.org
http://www.myfootprint.org

Chambers, N., C. Simmons and M. Wackernagel . 2001. Sharing nature's interest: Ecological footprints as an indicator of sustainability. EarthScan Publ. Ltd., London. 185 pp.

Wackernagel, M. and W. Rees. 1995. Our ecological footprint – Reducing human impact on Earth. New Society Publ., British Columbia, Canada. 176 pp.

Additional Sources of Information on Evaluating Human Impacts

Ayensu, E. 1999. International ecological assessment. Science 286:685-686

Dobson, A.P., et al. 1997. Hopes for the future: Restoration ecology and conservation biology. Science 277:515-522

The Earth Council - Footprints of Nations Report
http://www.ecouncil.ac.cr/rio/focus/report/english/footprint/introduction.htm

This "Rio+5" study was commissioned and financed by The Earth Council, San Jose, Costa Rica. The document is a "Footprints of Nations" report that compares the ecological impact of 52 nations that account for 80% of the world population. There is a downloadable version of the report that contains the data and calculations for the ecological footprints of each country.

USGS Earthshots
http://edcwww.cr.usgs.gov/earthshots/slow/tableofcontents

Thanks primarily to government agencies such as the U.S. Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA), satellite imagery is now widely available on the Internet. These images are especially useful in the evaluation of human impacts on broad spatial scales. This USGS site has several paired images of sites around the world that clearly illustrate changes over time in various landscapes. Detailed interpretation of the imagery is also provided. Riyadh, Saudi Arabia; Rondonia, Brazil and Garden City, New Jersey are among the images provided. Images are generated by EROS satellite data.

Hannah, L., et al. 1994. A preliminary inventory of human disturbance of world ecosystems. Ambio 23:248

King, M.D. and D.D. Herring. 2000. Monitoring Earth's vital signs. Sci. Am. April 2000:92-97.

Meyer, W.B. 1996. Human impact on the Earth. Cambridge (UK): Cambridge University Press

McMichael, A.J., et al. 1999. Globalization and the sustainability of human health ― An ecological perspective. BioSci. 49(3):205-210.

O'Meara, M. 1999. Reinventing cities for people and the planet. WorldWatch Institute Washington, D.C. WorldWatch Paper #147 94 pp.

This article includes a composite of 231 satellite images mapped by the U.S. National Geophysical Data Center that illustrate human-caused lighting (light from natural sources such as fires or lightning has been removed). White areas indicate visible radiation from human settlements.

Several authors. 1997. Human-dominated ecosystems. Science 277:486-525

This special issue of Science *includes a series of nine articles that evaluates our current understanding of human impacts on natural ecosystems.*

Vitousek, P.M. et al. 1997. Human domination of Earth's ecosystems. Science 277:494-499

Witze, A. 1995. The human imprint. Earth Aug. 1995:52-53

This article includes several satellite and space shuttle photographic images that document human impacts on ecosystems. Brief interpretive descriptions of each are included.

Google Earth and *NASA World Wind* as Tools for Evaluating Human Impacts

Until recently, access to and manipulation of high resolution remote sensing imagery was limited to those with specialized training in geographical information systems (GIS). New sources such as *Google Earth* and *NASA World Wind* have now become available that make this ability accessible to the casual user with the click of a mouse. These sources are not meant to replace the more sophisticated GIS since they lack sophisticated analysis tools. However, they open the world of remote sensing to a much broader audience and will probably generate further interest in the remote analysis of the Earth.

Google Earth and *NASA World Wind* provide a digital model of the Earth that is comprised of hundreds of thousands of individual satellite and aerial images that are stitched together. The result is a searchable, high-resolution image of the planet.

Both *Google Earth* and *NASA World Wind* are excellent visualization tools. Three-dimensional viewing of topographic maps, aerial photographs and satellite imagery will bring to life earth features such as landforms, cities and forests. More importantly however, they provide instructors with a palatable method for introducing students to scientific inquiry. Students are placed in an environment where they can ask interesting questions, develop reasonable hypotheses and use the imagery to test these hypotheses.

The technology has broad application in the education of students in natural resources and environmental science. One atmospheric scientist at NASA’s Goddard Space Flight Center stated that, “….it’s just a short matter of time before systems like *Google Earth* are an essential requirement for people in our field. As soon as one group shows that this is useful, everyone will adopt it.” The same could probably be stated for those who teach in this area.

Several NCSR modules incorporate the use of *Google Earth* and *NASA World Wind*. The tools can be used to augment lecture material, introduce a field experience, or develop a stand alone activity. The possibilities are limited only by the imagination of the instructor. In this module we introduce the technology and describe how to access the software.

Google Earth

Site Description

Google Earth is a source of high resolution aerial and satellite imagery that is available for free download (**http://earth.google.com**). Imagery is available for the entire earth's surface and layers may be applied for elevation, terrain, roads and a number of other features. Users can easily navigate from one location to another using a mouse, keyboard or navigation controls provided with the software. Although the resolution varies from site to site, at many locations users can zoom in to the level of individual trees and buildings. Users can search for rivers, towns, business addresses and latitude and longitudinal coordinates. The user interface is intuitive and should be easily learned by faculty and students.

Other features include the ability to mark separate study sites and "fly" to them for more detailed study. Elevation data is provided and can be manipulated to exaggerate the elevation effect. A "tilt" function allows users to change their perspective while viewing hilly terrain. Distance between features and the dimensions of features can be measured with a measuring tool. The user defines the endpoints for the line as well as units of measure.

For all of its strengths (cost, ease of use, availability, etc.), *Google Earth* does have some drawbacks. The resolution of images is uneven. In some areas individual trees can be resolved while in others, high elevation images can be seen clearly but zooming in results in images that are unclear. USGS topographic maps are not available with this software. Advanced (GIS-like) features such as measuring distance along a user-defined path and determining area within polygons are available, but these come only with *Google Earth Plus* and *Google Earth Pro* versions which must be purchased.

Minimum System Requirements

Windows 2000 or XP
Pentium 3, 500Mhz
128M RAM
400MB disk space
3D-capable video card with 16Mbytes of VRAM
Internet connection

NASA World Wind

Site Description

World Wind is open source software that provides access to high resolution aerial and satellite imagery. Imagery is available for the entire Earth's surface and layers may be applied for elevation, terrain, roads and a number of other features. *World Wind* can be downloaded for free at **http://worldwind.arc.nasa.gov**. The user interface features the ability to "search", "navigate", "zoom", "tilt" and "rotate" and to run some canned simulations. Vertical exaggeration can be manipulated to improve visualization of hilly terrain. Several "layers" of satellite and aerial imagery are available that allow you to image any place on Earth. Three dimensional views of terrain are based on various sources of Landsat satellite data. Coverage for these images is excellent (worldwide) but resolution is significantly less (30 m/pixel) than other layers described below. Unlike *Google Earth, World Wind* features U.S. Geological Survey (USGS) topographical maps for the most areas in the United States.

Some high resolution images are also available. For example, USGS Ortho Imagery is particularly useful and available for most areas in the United States. This layer allows for high resolution (1 m/pixel) viewing of 3-D aerial photography. *World Wind* also features USGS Urban Area imagery for selected cities which provides images of very high resolution (0.25 m/pixel). This allows the user to view urban landscapes in dramatic detail to the level of seeing individual buildings and cars.

The date of the images depends on the data source for each layer and varies from about 1990 to 2004. USGS topographical maps may be somewhat older. It is unlikely that you will be able to see the world in real-time using these tools anytime soon. Images are public domain, thus educational use of these images does not require copyright permission.

Minimum System Requirements

Windows 2000 or XP
700Mhz CPU
128M RAM
1GB disk space
3-D graphics card
Internet connection

Resources

Bazilchuk, N. 2006. The greatest map on earth. Conservation in Practice 7(3):35-37

Butler, D. 2006. The web-wide world. Nature 439(7078):776-778.

http://earth.google.com
Google Earth is described and can be downloaded from this site.

http://worldwind.arc.nasa.gov
NASA World Wind is described and can be downloaded from this site.

http://landsat.gsfc.nasa.gov
Additional information on Landsat satellite imagery may be obtained from this site.