Satellite Images for Land Cover Monitoring

Navigating Through the Maze
Introduction
Policy makers, managers, scientists and the public can view the changing environment using satellite images. More than 60 Earth observing satellites are collecting images of the Earth's surface. Remote sensing satellite systems for land cover assessment are operated by a growing number of countries including India, the United States, Japan, France, Canada and Russia.

The focus of this publication is satellite systems for land cover monitoring. On the reverse is a table that compares a selection of these systems, whose data are globally available in a form suitable for land cover analysis. We hope the information presented will help you assess the utility of remotely sensed images to meet your needs.

What is Remote Sensing?
Remote sensing is the discipline of observing the Earth’s surface without being directly in contact with it. It allows us to obtain information about our planet and humans activities from a distance, which can reveal interesting features that may not be possible or affordable from ground level. This gives a global perspective on changes and the interaction of our complex biosphere components.

The tools for remote sensing are sensors installed on planes or satellites. Airborne sensors are typically photographic cameras. Although an important source of environmental information, airborne image collections often are poorly documented and for small areas. In many countries the collection of airborne photographs is restricted.

Satellite sensors acquire images of the Earth and transmit the data to ground receiving stations located throughout the world. Once these raw images are processed and analyzed, they can document changing environmental conditions like pollution, global climate change, natural resource management, urban growth, sustainable development and much more.

Even though many satellite sensors monitor the earth, which sensor to use depends on the type of environmental information needed.

What Can Remote Sensing Do For You?
Remote sensing plays an integral role in environmental assessment. Remote sensing will never replace fieldwork but it offers great support in:

- Remote and difficult to access areas like dense forests, glaciated areas, swamps, high elevations, etc.
- Areas undergoing rapid changes.
- Countries with poor infrastructure and limited transportation.
- Areas of natural hazards: flooded areas, active volcanic regions, forest fire areas, etc.
- Constructing a broad overview or a detailed map of a large area.

Remote sensing techniques can increase the speed in which one can analyze a landscape and therefore help make quick and focused decisions.

Some applications include:

Agriculture and Forestry
- Discriminate vegetation, crop, and timber types.
- Measure crop and timber acreage.
- Estimate crop yields.
- Measure change in forest cover.
- Assess drought impact.
- Determine soil conditions.

Land Use Mapping and Economic Planning
- Map and monitor land cover changes.
- Monitor urban growth.
- Map of land-water boundaries.
- Site power plants and other industries.
- Site for transportation and transmission routes.

Geology and Geomorphology
- Recognize different rock types.
- Map major geologic units.
- Monitor surface mining and reclamation.
- Site solid waste storage.
- Monitor volcanic activity.

Water and Coastal Resources
- Determine surface water areas.
- Monitor environmental effects of humans activities.
- Map floods and flood plains
- Determine the extent of snow and ice.
- Measure glacial features.
- Map shoreline changes.
- Trace oil spills and pollutants.

Attention should also be paid to the fact that remote sensing allows multi-temporal analysis. This means that an area of interest can be monitored over time so that changes can be detected. This allows us to analyze phenomena like vegetation growth during different seasons, the extent of annual floods, the retreat of glaciers or the spread of forest fires or oil spills.
Issues that Affect Selection of Images

Satellites and their sensors can differ in many ways. Most satellite sensors image the Earth with several bands where a band is sensitive to a specific range of wavelengths within the electromagnetic spectrum. The sensors discussed here are those sensitive to visible and infrared wavelengths. Beyond these wavelengths the interpretation of the data can become very specialized. However for some applications, wavelengths such as those used in radar sensors, are very important.

The defining characteristics of a sensor are the size of an image, the region of the Earth that can be seen, the smallest feature that can be distinguished, the bands used, how often images are collected, and when was the sensor in operation. Important non-technical issues include acquisition costs and data sharing limitations. Licensing agreements vary over time, by product, by sensor and by organization.

How much area does an image cover?
The area covered by a single satellite image is defined by the path width and the distance along the path. The path width is limited by how far to each side the sensor can see. The path width can vary from as little as 8 kilometers to over 2000 kilometers. The distance along the path is more arbitrary. For high-to-medium resolution sensors the tendency is to create nominally square images. The image length for low resolution images may be an entire path.

Most Earth observing satellites orbit from pole to pole and are sun-synchronous, that is they always pass overhead at the same time of the day. Overlap between paths is least near the equator and most at upper latitudes. Areas close to the pole may not be covered at all. In contrast, some weather satellites are geostationary. They monitor only one hemisphere, but at all times of the day.

What is spatial resolution?
Spatial resolution of digital satellite sensors is the distance along the ground between samples. As the satellite moves across the Earth surface it records the brightness of the surface at regular intervals. The spatial resolution of a digital sensor is distinct from that of a photographic camera. The former is based on sampling rates, while the latter is based on the grain size in the film. If you zoom into a photograph, the image will degenerate into random noise. A satellite image will decompose into tiny black and white or colored squares or picture elements called pixels.

If a satellite image has a spatial resolution of 30 meters this means that one pixel in the image represents a square of 30 x 30 meters on the Earth’s surface. In an image of this resolution one cannot see small buildings, but can definitely see a football field. Some sensors image the Earth with a very low resolution, more than 1 km, suitable for general land cover mapping of large features or monitoring vegetation vigor. Others, with a resolution of 1 meter, can resolve individual trees and are suitable for validation of coarser images.

What is spectral resolution?
As spatial resolution is a sampling of space, spectral resolution is a sampling of the electromagnetic spectrum. Conceptually many narrow bands would allow different types of land cover to be more easily distinguished. In reality, much of the information contained in narrow bands may be redundant. Sensor designers attempt to optimize the selection of the bands so that they can best distinguish between different types of land cover with the fewest number of bands. Typical bands are: blue, green, red, near infrared, mid infrared and thermal infrared.

The blue band has the best penetration of water, so is useful for coral reef and sea grass monitoring. Conversely, the blue band is very sensitive to moisture in the atmosphere, so in humid climates is very noisy. The green band is relatively high and the red band is relatively low for vegetation. The near-infrared bands are high for vigorously growing vegetation. Mid or short wave infrared bands are sensitive to moisture. Thermal infrared bands are sensitive to emitted thermal radiation, such as hot spots in a city or the temperature distribution of a lake.

What are repeat cycles and dates of operation?
The orbital paths of most operational satellites are fixed. The repeat cycle of a sensor is the number of days before an area can be seen again. The repeat cycle varies from every day to weeks. Some sensors have overlapping paths and some sensors are pointable which effectively reduces the period between repeat coverage.

The repeat cycle is critical for two reasons. One, some types of change or monitoring require frequent observations. Two, cloud cover may obscure the ground. Sensors with long repeat cycles, which tend to be high spatial resolution sensors, may only acquire a cloud free image once every several years in some climates.

How do these characteristics interact? Wide paths tend to be associated with low spatial resolution. High spatial resolution means large data volumes. Wide paths are linked to short repeat cycles.

Tradeoffs exist between spatial and spectral resolution. To achieve high spatial resolutions some sensors have a panchromatic band, which is essentially a very wide band.
Spatial Extent: The total area covered by an image. The width of the image is the pixel width. The length of an image is not always constant, although a tendency exists for approximately square images. The nominal number of scenes needed to map Africa (30,264,000 km²) and Costa Rica (50,000 km²) are provided for each sensor. The actual number of scenes may be considerably higher depending on overlap and the shape of the country.

Spatial Resolution or Pixel Size: The spatial resolution of a sensor is a function of how frequently the sensor samples the ground. The pixel size is usually close to the sampling rate of the sensor. Objects on the ground need to be considerably larger than the spatial resolution to be detected. Example images are 375-by-375 pixels. The estimated number of land pixels for Africa and Costa Rica are provided for each sensor. Estimates are in millions of pixels.

Objects collect light in different parts of the electromagnetic spectrum. Black: Green: high for forest biomass; Red: Near IR: high for vegetation; Mid IR: sensitive to moisture variation; Thermal IR: emitted.

Repeat Cycle and Dates in Operation: Frequent coverage increases the chances of cloud-free images. Multiple images within a growing season allow knowledge of plant physiology to be used in land cover mapping. Images collected through many years allow the detection of land use and land cover change. In some cases more than one satellite is operational, decreasing the period between coverage.

Questions That Need to Be Asked Before Using Satellite Images

Other More Specialized Sensors Important for Land Cover Monitoring

- Radars have all-weather capability for quantifying variation in surface roughness that is crucial for monitoring floods, fires, oil spills, wind speed and wind direction. Examples of radar sensors include Radarsat, ERS, ERS, IRS-C, Seaswift, and Seaswift.
- Cameras were carried on many older satellites and continue to be used on many manned space missions. The older photographic images extend the environmental record back to 1962 and many are of high spatial resolution. Examples of space photography include Corona, Argon, Shuttle, Gemini and Apollo handheld, and TR-50, KVIR-100, MK-4, and KFA-1000.
- Sensor on geostationary satellites have the unique ability to provide continuous coverage of a region. These satellites are at much higher altitudes than are most Earth observing satellites and are designed for weather monitoring. A critical ability of sensors on these satellites is to monitor cloud cover and to provide rainfall estimates. Examples of these satellites include GMS, GOES-E, GOES-W, GOMS, Meteosat, and Ina.
- Further information on new sensors as they are launched and on other specialized sensors such as DMSP, ATS, TRMM, MISR, and QuickScat can be found at http://www.usasp.net.
## Satellite Remote Sensing for Environmental Assessment and Monitoring

Satellite sensors are available with resolutions from 1 m to 1 km. These resolutions are suitable for both large area and local applications.

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<thead>
<tr>
<th>In remote areas, satellite images may provide the only practical source of information.</th>
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<tbody>
<tr>
<td>For some applications, such as land cover analysis over large areas, no cost effective alternative exists.</td>
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<tr>
<td>Satellite images can be effectively analyzed either by image interpretation or by computer analysis.</td>
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<tr>
<td>Many satellite sensors collect images for the entire world.</td>
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<tr>
<td>Satellite image archives exist that document the Earth’s surface back to the early 1960s.</td>
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<td>Many of the satellite images can be acquired at no cost or at the cost of reproduction with no restrictions on image sharing.</td>
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<tr>
<td>In all cases, expert and local knowledge should be used to validate or guide the analysis of satellite images.</td>
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## Disclaimers

The views expressed in this text do not necessarily reflect those of the agencies cooperating in this project. Satellite sensor specifications may be approximated or summarized. The designations used and material presented above do not imply the expression of any opinion whatsoever on the part of the cooperating agencies concerning the legal status of any country, territory, city, or area or of its authorities, or of the delineation of its frontiers or boundaries.

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## Satellite Systems for Land Cover Monitoring

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For further information on remote sensing view:

http://www.na.unep.net/

or contact:

Dr. Ashbindu Singh  
Regional Coordinator, North America  
UNEP Division of Early Warning and Assessment,  
EROS Data Center, Sioux Falls, SD 57198  
Phone: 605-594-6107 or 6117  
Fax: 605-594-6119  
Email: info@na.unep.net