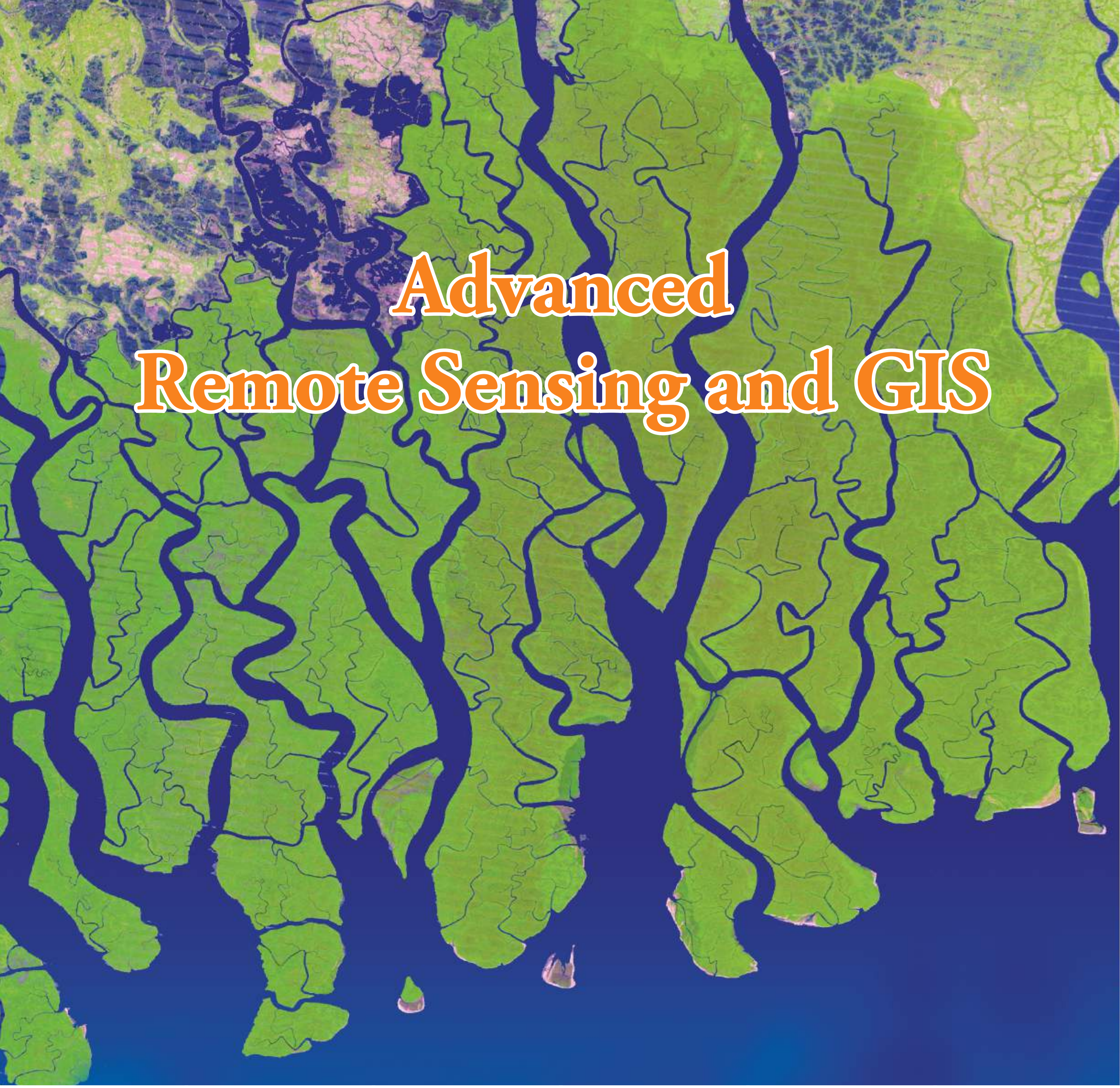

Advanced Remote Sensing and GIS






USAID
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DEPARTMENT OF AGRICULTURE

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পরিবেশ ও বন মন্ত্রণালয়

CEGIS

Advanced
Remote Sensing and GIS

Training Manual Developed by CEGIS, USFS and BFD, 2014-15

Preface

In January 2013, the United States Agency for International Development (USAID), the Bangladesh Forest Department and the United States Forest Service (USFS) began a collaborative project to address capacity needs in geospatial skills for natural resources management for staff of the Bangladesh Forest Department. Through this project, the USFS, together with local partner Center for Environmental and Geographic information Services (CEGIS), developed and carried out a series of workshops and trainings. These manuals consolidate the coursework and materials from three of these trainings:

1) Global Positioning Systems (GPS) 1

2) GPS 2

3) Training of Trainers for GPS

These courses were developed jointly by CEGIS and the USFS and taught by CEGIS. The initial course provided an introduction to maps and hands-on instruction in the use of GPS units. GPS 2 went more in-depth into the GPS technology, providing training in GPS unit operation, data collection, maps, navigation and data storage. The Final course, Training of Trainers, taught a selected group of Bangladesh Forest Department staff how to teach GPS use to their colleagues, with the plan to replicate this training nationwide.

This series of three manuals has been consolidated by CEGIS with input from the Remote Sensing Applications Center (RSAC) and the Flathead National Forest of the USFS. In addition to the course work, the manuals also include valuable reference materials. They can be used as a refresher for participants in these workshops or other workshops on GPS. Students who want to teach themselves about these subjects can also use these manuals as self-guided teaching materials. Finally, these manuals can be used by instructors to teach foresters or others about GPS tools and their applications.

We hope that these manuals are useful to you to refresh and further develop your GPS skills for management and monitoring of natural resources.

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Introduction

The Manual on Advanced Remote Sensing and GIS is for both the Trainees and the Trainers through they have different objectives to achieve.

This Manual has been designed as a resource tool for those who would be using remote sensing and GIS in their area of work. It is expected that the Advanced Remote Sensing and GIS Manual will on one hand, substantially enhance the capacity of those who will be imparting information and knowledge on the subject as Trainers, and on the other hand, develop the capacity of the Trainees to enable them to use these information and knowledge effectively, in their line of work.

It is underscored, that the Trainees or the participants of the training on RS & GIS will benefit more by constantly consulting the Manual, during the post-training period, as it will reinforce their learning of the application of the advanced level of remote sensing and GIS, and to apply the learnt skills, successfully.

The Trainers will go through this Manual to make an assessment of their own knowledge and understanding of the subject, fill their own knowledge gaps on this subject matter, if found any, and decide on the approach to suitably present/facilitate knowledge and skills learning to the Trainees. They may use this Manual as a support material for conducting the sessions.

The contents of the Manual are organized under 5(five) Sections or Lessons. Each Lesson comprises a lecture [composed of several topics that cover the main subject of the Lecture] and an end of lesson knowledge and skills practice session. In addition, key objectives to be achieved after completion of each Lesson have been stated clearly so that the user is focused on the learning being transferred through each of the lessons. Topic-wise detailed notes have also been included as supplementary information. Moreover, notes also include additional reference links. Knowledge and skills practice sessions have been planned and developed with a view to help the users to assess what they learn from each lesson and explore the significance of Introduction of Image Correction and Spectral Indices, standard method of Reference Data collection in Land use/Land cover Mapping Project, Accuracy Assessment of classification product and Change Detection in advanced Remote Sensing and GIS application.

In all, this Manual on Advanced RS & GIS is intended to assist in developing human resource capacity for Bangladesh Forest Department through higher knowledge and skills level on Remote Sensing and GIS concepts and their different applications.

Lesson-1
Introduction to Image Correction and Spectral Indices

Objective

By the end of this lesson, and through the knowledge and skills practice Session 2a and 2b, the participants will be able to:

1. State what is Atmospheric Correction and reasons for Atmospheric Correction of satellite images
2. Say correctly, the different types of Atmospheric correction model.
3. Produce atmospheric corrected Landsat 8 image using Dark Object Subtraction (DOS) Model.
4. Tell the significance of Spectral Vegetation Index
5. Produce the NDVI of Landsat Images

Effects of Atmosphere on Electromagnetic Radiation

Electromagnetic radiation has to travel throughsome distance of the Earth's atmosphere before it reaches the Earth's surface. Particles and gases in the atmosphere affectthe incoming electromagnetic radiation.There are two main effects of atmosphere, scattering andabsorption. The main effect of the atmospheric scattering on remotely sensed data are upwellingatmospheric radiance or path radiance (Slate 1980), and atmospheric absorptionwith multiplicative characteristics.

The absorption caused by water vapor orother gases is very weak in visible wavelengths, and can be ignored. The impact of short wavelengthsis mainly from Rayleigh scattering. However, in near infrared and middle infraredwavelengths, the main impact is from the atmospheric absorption caused by watervapor, carbon dioxide, methane and other gases. The influence of air molecules and aerosol particles scattering can benegligible. Normally, the contents of carbondioxide, carbon oxide and methane are stable, but water vapor is variable.

Sources:
Canada Centre for Remote Sensing. 2007. Tutorial: Fundamentals of Remote Sensing.
Lu, D., Mausel, P., Brondízio, E. and Moran, E.F. (2002) Assessment of atmospheric correction methods for Landsat TM data applicable to Amazon Basin LBA research, International Journal of Remote Sensing.

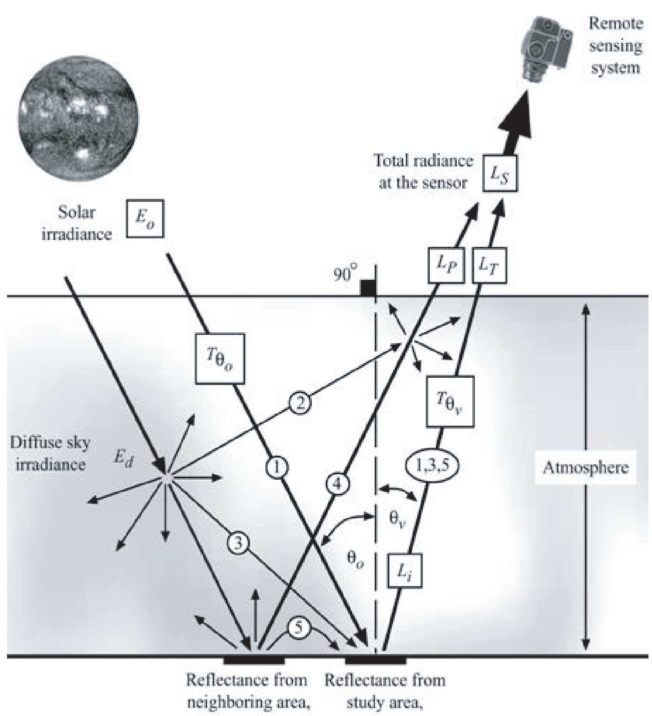
Scattering Effects

Energy (L_T) from Paths 1, 3, and 5 contains intrinsic valuable spectral information about the target of interest. Conversely, the Path Radiance (L_p) from Paths 2 and 4 includes diffuse sky irradiance or radiance from neighboring areas on the ground. This path radiance generally introduces unwanted radiometric noise in the remotely sensed data and complicates the image interpretation process.

Path 1 contains spectral solar irradiance that was attenuated very little before illuminating the terrain within the IFOV.

Path 2 contains spectral diffuse sky irradiance that never even reaches the Earth’s surface because of scattering in the atmosphere. Unfortunately, such energy is often scattered directly into the Instantaneous Field of View (IFOV) of the sensor system.

Path 3 contains energy from the Sun that has undergone some Rayleigh, Mie, and/or nonselective scattering and perhaps some absorption and reemission before illuminating the study area. Thus, its spectral composition and polarization may be somewhat different from the energy that reaches the ground from Path 1.



Path 4 contains radiation that was reflected or scattered by nearby terrain covered by snow, concrete, soil, water, and/or vegetation into the IFOV of the sensor system. It does not actually illuminate the study area of interest. It is better to minimize its effects if possible. Path 2 and Path 4 combine to produce what is commonly referred to as **Path Radiance**, L_p.
Path 5 is energy that reflected from nearby terrain into the atmosphere, but then scattered or reflected onto the study area.

Sources: Jensen, John R., 2007, Remote Sensing of the Environment: An Earth Resource Perspective, 2nd Ed., Upper Saddle River, NJ: Prentice Hall

Atmospheric Correction

When the emitted or reflected electromagnetic energy is observed by a sensor, the observed energy does not coincide with the energy emitted or reflected from the same object observed from short distance. This is due to the sun's position, atmospheric conditions and sensors response. Therefore, in order to obtain the real irradiance or reflectance, those radiometric distortions must be corrected. "Atmospheric corrections" are methods used to convert the radiance measured at the satellite to outgoing radiance measured at the ground.

The very first step is to convert the raw Digital Numbers that the sensor collects into Radiance and it is the most fundamental unit of measure used in Remote Sensing. After converting to Radiance, the next step is to convert it to **Reflectance** a more useful measurement than radiance. Reflectance is a unitless value describing the proportion of radiation striking a surface to the radiation reflected off it. Most atmospheric corrections attempt to remove path radiance (L_p) by subtracting it from total radiance at the satellite.

Note: Atmospheric Correction changes original data, therefore the accuracy and efficacy of those changes is completely dependent on the accuracy of the correction model.

Source: http://wtlab.iis.u-tokyo.ac.jp/~wataru/lecture/rsgis/rsnote/cp9/cp9-1.htm

Reasons for Atmospheric Correction

Analysis using uncorrected data assumes that the radiance of vegetation, soil, water and other objects of interest have sufficiently different reflectance characteristics for differentiation and that atmospheric effects are not sufficiently great to affect their basic spectral separations. Atmospheric Correction is not necessary when a single scene is studied and the atmospheric differences can be reduced by ratio based vegetation indices.

However, with extensive and intensive applications of remotely sensed data in a variety of applications, atmospheric effects become very important. There are at least six reasons in support of radiometric and atmospheric correction for remotely sensed data: (1) multi-temporal remotely sensed data applications such as in land use/cover change detection; (2) across scene (across path) comparison of spectral information of land cover types; (3) multi-sensor data applications such as multiple image mosaic to spatially produce a large image, multi-sensor data integration such as TM and SPOT images; (4) quantitative analysis by combining field survey data with spectral data for applications such as biomass estimation; (5) selected special applications such as using visible TM bands for mapping shoals and aquatic plants beds; and (6) band ratio operations such as vegetation indexes. Atmospheric correction is always necessary if you need to calculate ground reflectance or compare satellite radiance to ground reflectance measurements

DN, Radiance and Reflectance

DN: Rescaled radiance value

Radiance: The amount of radiation coming from an area. To derive a radiance image from an uncalibrated image, a gain and offset must be applied to the pixel values. These gain and offset values - from the image's metadata. Reflectance: The proportion of the radiation striking a surface to the radiation reflected off of it Top-of-atmosphere reflectance (or TOA reflectance) is the reflectance measured by a space-based sensor flying higher than the earth's atmosphere. These reflectance values will include contributions from clouds and atmospheric aerosols and gases. Surface Reflectance is the reflectance of the surface of the Earth. The image has been corrected to eliminate the effects of the atmosphere (i.e. haze, atmospheric particle scattering, etc

Atmospheric Correction Models

According to the model characteristics and complexity, there are three types of models: Physical based calibration models, Image based calibration models, and Relative calibration

Physically-based models are the most complex and highly accurate models used for converting digital numbers into surface reflectance. They require in-situ atmospheric measurements and radiative transfer codes to correct for atmospheric effects. In practice such models have a main disadvantage in that it is often impossible to collect the in-situ atmospheric parameters for many applications, especially when using historical remotely sensed data.

Image based calibration models depend on digital image information that does not require gathering of in situ field measurements during the satellite over flight. Different levels of image-based models have been developed.

The third method relative calibration method focuses on relative atmospheric correction. It is used to remove or normalize the variation within a scene and normalize the intensities between images of same study area collected on different dates. The methods for relative correction can be histogram adjustment, dark-pixel subtraction, and multi-date normalization using a regression model approach.

Image based calibration models

Image based calibration models depends on digital image information that does not require gathering of in situ field measurements during the satellite over flight. Different levels of image-based models have been developed. Three types of Image based calibration models are:

- Apparent reflectance model
- Dark Object Subtraction (DOS) Model
- Improved DOS (COST) Model

Apparent reflectance model is the most straightforward method. It converts apparent or at-satellite reflectance to surface reflectance by correcting sensor gain, bias, solar irradiance and solar zenith angle, but ignoring the correction of atmospheric scattering and absorption.

Dark object subtraction (DOS) model take path radiance into consideration in addition to the function of the apparent reflectance model. It assumes that the multiplicative effect from atmosphere is constant, the surface is Lambertian, the path radiance is uniform and some pixels within the image are in complete deep shadow and their radiance captured by satellite sensor are due to the atmospheric scattering (path radiance). The DOS model (Chavez 1988, 1989, Fraser et al. 1992, Moran et al. 1992, Milton 1994) was used to remove the additive scattering component caused by path radiance based on the assumption that an absolute dark object exists within the image.

The Improved Image-based DOS model (Teillet 1986, Richards 1993, Olsson 1995, Chavez 1996,Jensen 1996, Richter 1997) includes the correction of atmospheric transmittance through optical thickness values at a given wavelength or using the default transmittance values derived from the in situ atmospheric.

Source: Lu, D., Mausel, P., Brondízio, E. and Moran, E.F. (2002) Assessment of atmospheric correction methods for Landsat TM data applicable to Amazon Basin LBA research, International Journal of Remote Sensing

Atmospheric Correction of LANDSAT 8 Data

Steps to atmospheric correction using DOS with Continuous Relative Scatter Lookup Table:

All individual layers of image data may be stacked together to prepare multispectral images for making image processing easier. The Landsat 8 data is provided with a *.mtl text file containing meta data information, which is required to convert the DN values of image data into TOA or at satellite reflectance values. The path or scatter reflectance is established for red band of Landsat 8 using lowest valid value method. Acquire relative scatter values of Blue, Green and NIR band Landsat 8 using Continuous Relative Scatter Lookup Table. The scatter values or path radiance of blue, green and red are subtracted from the TOA reflectance values of the respective bands to get the surface reflectance values.

Steps of Atmospheric Correction of Landsat 8:

Preparation of Multispectral Image

Acquiring Header File Information

DN to TOA Reflectance

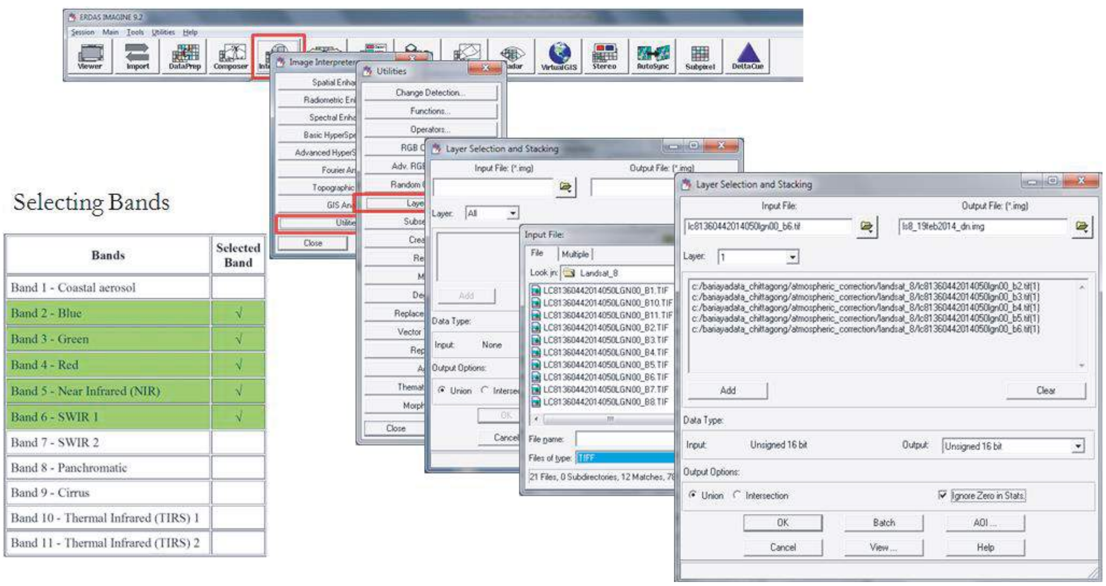
Establish Scatter Reflectance for each band

Computing Surface Reflectance

Source: http://www.gisagmaps.com/landsat-8-haze-removal-table/

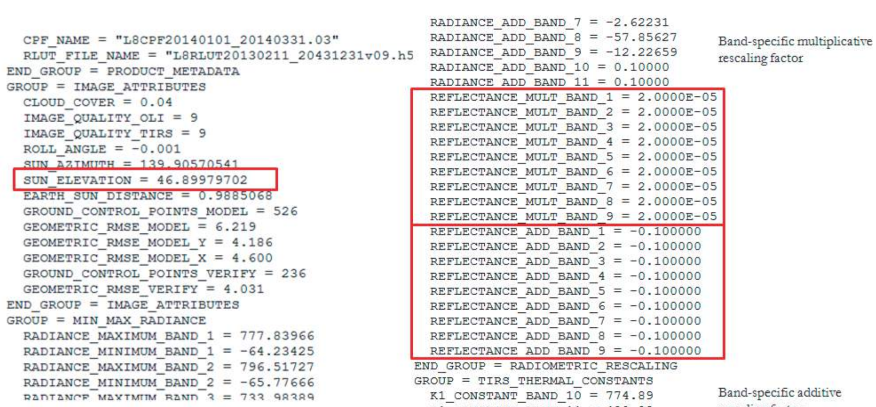
Multispectral Image Data Preparation

ERDAS imagine or any image processing software may be used for multispectral image data preparation. For example, band 2 (blue), band 3 (green), band 4 (red), band 5 (near infrared) and band 6 of Landsat 8 may be stacked together to prepare multispectral data using Image Interpreter > Utilities... > Layer Stack function of ERDAS IMAGINE.



Acquiring Header File Information

Metadata of Landsat 8 image data is stored in the text file with extension of .mlt. Different information such as image acquisition date, sun azimuth and elevation angle, scene center, Band-specific multiplicative rescaling factor and Band-specific additive rescaling factor, etc. is given in the metadata file. The sun elevation angle, band-specific multiplicative rescaling factor and band-specific additive rescaling factor information are used for sun angle correction and convert DN values to TOA reflectance.



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DN to TOA Reflectance Equations

Landsat 8 band data is converted to TOA reflectance using reflectance rescaling coefficients provided in the product metadata file (MTL file). The following equation is used to convert DN values to TOA reflectance as follows:

$$=' \; M\,Q_{cal} + A$$

where,

TOA = *reflectance, without correction for solar angle. Note that does not contain a correction for the sun angle.*

M = *Band-specific multiplicative rescaling factor from the metadata(REFLECTANCE_MULT_BAND_x, where x is the band number)*

A = *Band-specific additive rescaling factor from the metadata (REFLECTANCE_ADD_BAND_x, where x is the band number)*

Q_{cal} = *Quantized and calibrated standard product pixel values (DN)*

TOA reflectance with a correction for the sun angle is then:

$$\rho\lambda = \frac{\rho\lambda'}{\cos(\theta_{SZ})} = \frac{\rho\lambda'}{\sin(\theta_{SE})}$$

Where:

TOA = *planetary reflectance*

SE = *Local sun elevation angle. The scene center sun elevation angle in degrees is provided in the metadata (SUN_ELEVATION)*

SZ = *Local solar zenith angle; SZ= 90° - SE*

Source: http://landsat.usgs.gov/Landsat8_Using_Product.php

Establish Scatter Reflectance

Establish the scatter DN (there are different methods for this) using the Lowest Valid Value from band 4 (red) of Landsat 8.

The Lowest Valid Value Method is a way to establish a basis for DN scatter amount for individual bands; this method uses the lowest DN that is more than any break of values 0 in the low end of the histogram.

Convert the scatter DN (Band 4, Red) to scatter TOA reflectance value using the same equations discussed earlier section.

Acquire relative scatter reflectance values of Blue, Green and NIR band Landsat 8 using Continuous Relative Scatter Lookup Table for the corresponding scatter TOA reflectance value for Band 4 (red).

Landsat 8 DOS Continuous Relative Scatter Lookup Table

Blue	Green	Red	NIR
0.05818	0.02972	0.01201	0.00231
0.05829	0.02981	0.01211	0.00234
0.05839	0.02990	0.01220	0.00236
0.05850	0.03000	0.01230	0.00238
0.05860	0.03009	0.01239	0.00240
0.05871	0.03018	0.01249	[illegible]
0.05881	0.03027	0.0[illegible]	
0.05892	0.03036		
0.05902	0.0304[illegible]		
0.05913	0.[illegible]		
0.05923			

Subtract .01 (1%) reflectance of Dark Object from scatter reflectance of Blue, Green, and Red bands.

Source: http://www.gisagmaps.com/landsat-8-haze-removal-table/

Surface Reflectance

The simple assumption is that within the image, some pixels are in complete shadow and their radiances received at the satellite are due to atmospheric scattering (path radiance). This assumption is combined with the fact that very few targets on the Earth's surface are absolute black, so an assumed one-percent minimum reflectance is better than zero percent. That is why surface reflectance is calculated by subtracting one-percent scatter reflectance of band 2 (blue), band 3 (green), and band 4 (red) from the TOA reflectance value of each pixel.

As long wave lengths NIR and SWIR are affected very little by atmospheric scattering, there is nothing for subtraction. A Spatial Model may be written in ERDAS Imagine to carry out the process quickly.

Source: http://www.gisagmaps.com/landsat-8-atco-guide/

Biophysical Controls of Vegetation Reflectance

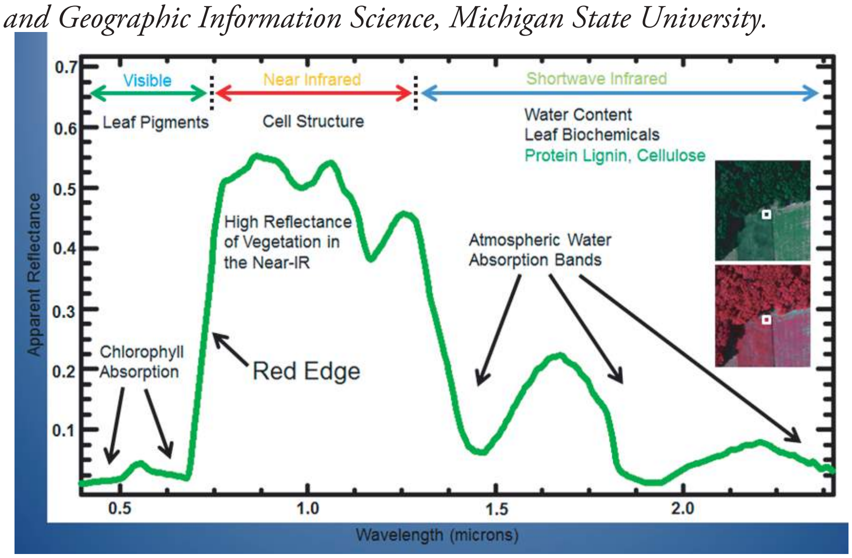
Healthy canopies of green vegetation have a very distinct interaction with certain portions of the electromagnetic spectrum. In the visible regions, chlorophyll causes strong absorption of energy, primarily for use in photosynthesis. This absorption peaks in the red and blue areas of the visible spectrum, while the green area is reflected by chlorophyll, thus leading to the characteristic green appearance of most leaves. At the same time, the near-infrared region of the spectrum is strongly reflected through the internal structure of the leaves. From an energy balance viewpoint, all solar radiant flux incidences upon any object are either reflected, transmitted, or absorbed. As a group, vegetation is unique in its three-segment partitioning of solar irradiance.

In the visible part of the spectrum (400-700 nm), reflectance is low, transmittance is nearly zero, and absorptance is high. The fundamental control of energy-matter interactions with vegetation in this part of the spectrum is **plant pigmentation**.

In the longer wavelengths of the near-infrared portion of the spectrum (700-1350 nm), both reflectance and transmittance are high whereas absorptance is very low. Here the physical control is internal **leaf structures.**

The middle-infrared sector (1350-2500 nm) of the spectrum for vegetation is characterized by transition. As wavelength increases, both reflectance and transmittance generally decrease from medium to low. Absorptance, on the other hand, generally increases from low to high. Additionally, at three distinct places in this wavelength domain, strong water absorption bands can be observed. The primary physical control in these middle-infrared wavelengths for vegetation is in **vivo water content**. Internal leaf structure plays a secondary role in controlling energy-matter interactions at these wavelengths.

Source: Lush P David, (1999), Introduction to Environmental Remote Sensing, Center for Remote Sensing and Geographic Information Science, Michigan State University.

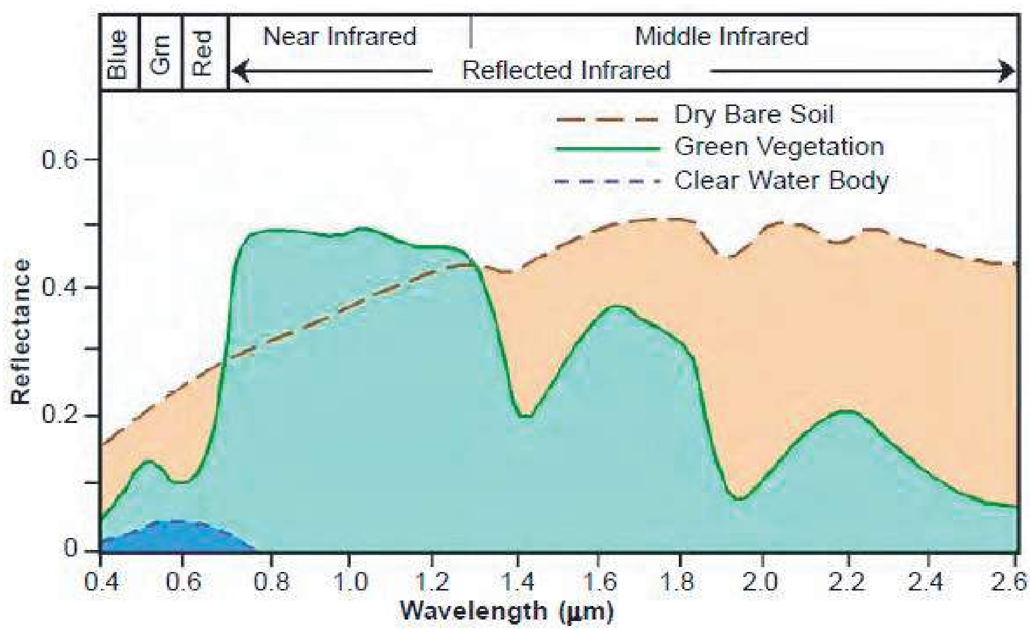


Source: Elowitz, Mark R. "What is Imaging Spectroscopy (Hyperspectral Imaging)?". Retrieved November 27, 2013, from www.markelowitz.com/Hyperspectral.html

Spectral Reflectance of Vegetation, Soil and Water

The spectral signatures produced by wavelength-dependent absorption provide the key to discriminating different materials in images of reflected solar energy. The property used to quantify these spectral signatures is called spectral reflectance: which is the ratio of reflected energy to incident energy as a function of wavelength. The spectral reflectance of different materials can be measured in the laboratory or in the field, providing reference data that can be used to interpret images. As an example, the above figure shows contrasting spectral reflectance curves for three very common natural materials: dry soil, green vegetation, and water.

The reflectance of dry soil rises uniformly through the visible and near infrared wavelength ranges, peaking in the middle infrared range. It shows only minor dips in the middle infrared range due to absorption by clay minerals. Green vegetation has a very different spectrum. Reflectance is relatively low in the visible range, but is higher for green light than for red or blue, producing the green color we see. The reflectance pattern of green vegetation in the visible wavelengths is due to selective absorption by chlorophyll, the primary photosynthetic pigment in green plants. The most noticeable feature of the vegetation spectrum is the dramatic rise in reflectance across the visible-near infrared boundary, and the high near infrared reflectance. Infrared radiation penetrates plant leaves, and is intensely scattered by the leaves' complex internal structure, resulting in high reflectance. The dips in the middle infrared portion of the plant spectrum are due to absorption by water. Deep clear water bodies effectively absorb all wavelengths longer than the visible range, which results in very low reflectivity for infrared radiation.



Source: http://remote-sensing.net/concepts.html

What is a Spectral Vegetation Index ?

A primary goal of many remote sensing projects is to characterize the type, amount and condition of vegetation present within a scene. The amount of energy reflected from a surface is determined by the amount of solar irradiance that strikes the surface, and the reflectance property of the surface. Solar irradiance varies with time and atmospheric conditions, A simple measure of energy reflected from a surface is not sufficient to characterize the surface in a repeatable manner. This problem can be circumvented somewhat by combining data from two or more spectral bands to from what is commonly known as a vegetation index.

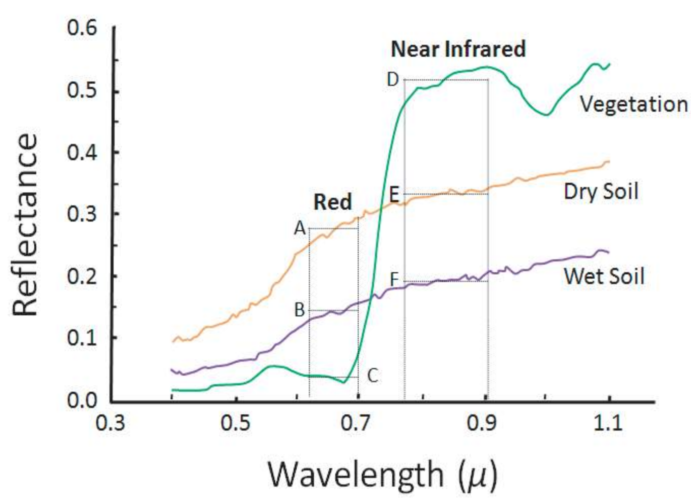
Vegetation Indices (VIs) are combinations of surface reflectance at two or more wavelengths designed to highlight a particular property of vegetation. It is a number that is generated by some combination of remote sensing bands and may have some relationship to the amount of vegetation in a given image pixel. They are designed to enhance the vegetation reflected signal from measured spectral responses by combining two (or more) wavebands, often in the red (0.6 - 0.7 m) and NIR wavelengths (0.7-1.1 m) regions.

It is an indicator that describes the greenness — the relative density and health of vegetation — for each picture element, or pixel, in a satellite image.

Source: Jackson, R.D. and Huete, A.R. (1991) Interpreting Vegetation Indices. Preventive Veterinary Medicine, 11, 185-200

Concept of Vegetation Index

When light strikes a surface, part is reflected, part is transmitted and the remainder is absorbed. The relative amount of reflected, transmitted and absorbed light are a function of the surface and vary with the wavelength of the light. For example, the majority of light striking soils is either reflected or absorbed, with very little being transmitted and relatively little change with wavelength. With vegetation, however, most of the light in the near infrared wavelength is transmitted and reflected, with little absorbed, in contrast to the visible wavelengths where absorption is predominant, with some reflected and little transmitted.



Reflectance spectra for bare dry soil, bare wet soil and full-cover wheat canopy are generalized in the above Figure. The vertical dashed lines labeled red and near infrared delineates the wavelength intervals representative of Bands 3 and 4 of the Landsat TM on Landsat 4 and 5, and Bands 2 and 3 of the high resolution visible (HRV) sensors on the SPOT 1 and 2. Horizontal solid lines labeled A-F indicate the average reflectance within the waveband for the soil and wheat targets. If a wheat field is to be monitored, early in the season only bare soil will be observed by the sensor.

As the plants develop, the output in the red band decreases from A or B, reaching C when the plants fully cover the soil. In the NIR, the output increases from point E or F toward point D.

In general, the wavebands used to calculate VI are chosen such that as one decreases the other increases with increasing vegetation cover.

The DIFFERENCE between NIR reflectance and Red reflectance for soil is much less than for live vegetation

What do Vegetation Indices do ?

Remotely sensed spectral vegetation indices are widely used and have benefited numerous disciplines interested in the assessment of biomass, water use, plant stress, plant health and crop production.

Sparse vegetation such as shrubs and grasslands or sensing crops may result in moderate VI values. High VI values correspond to dense vegetation such as that found in temperate and tropical forests or crops at their peak growth stage.

Generating VI values, researchers can create products that give a rough measure of vegetation type, amount, and condition on land surfaces around the world. VI is especially useful for continental to global-scale vegetation monitoring.

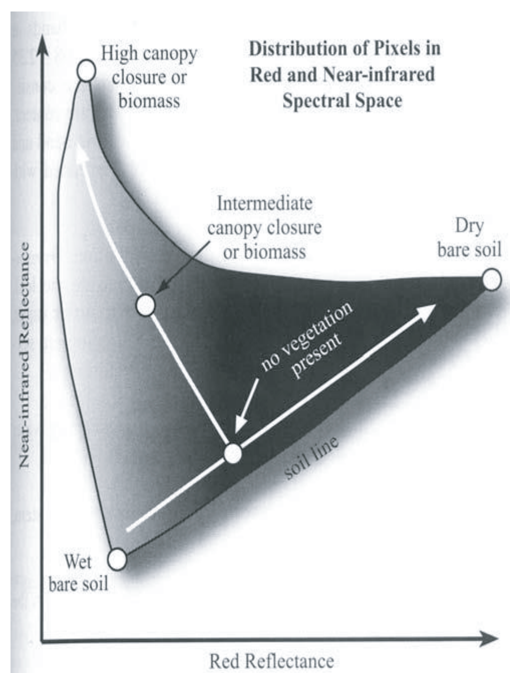
VI values can be averaged over time to establish "normal" growing conditions in a region for a given time of year. Further analysis can then characterize the health of vegetation in that place relative to the norm.

When analyzed through time, VI can reveal where vegetation is thriving and where it is under stress, as well as changes in vegetation due to human activities such as deforestation, natural disturbances such as wild fires, or changes in plants' phenological stage.

Source: http://phenology.cr.usgs.gov/ndvi_foundation.php

Classes of Vegetation Index

Jackson and Huete (1991) classify VIs into two groups: (1) slope-based and (2) distance-based VIs. To appreciate this distinction, it is necessary to consider the position of vegetation pixels in a two-dimensional graph (or bi-spectral plot) of red versus infrared reflectance. The slope-based VIs are simple arithmetic combinations that focus on the contrast between the spectral response patterns of vegetation in the red and near-infrared portions of the electromagnetic spectrum. Slope-based VIs are combinations of the visible red and the near infrared bands and are widely used to generate vegetation indices. Their values indicate both the state and abundance of green vegetation cover and biomass.

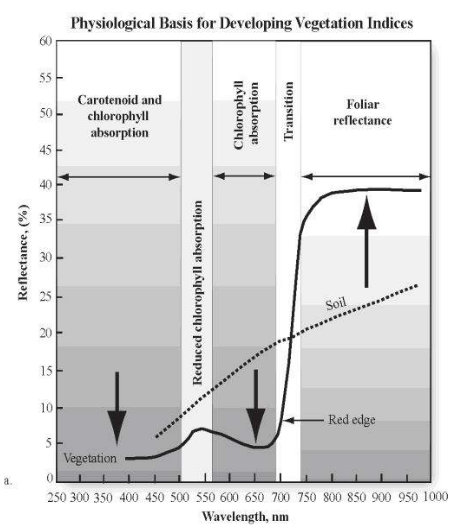


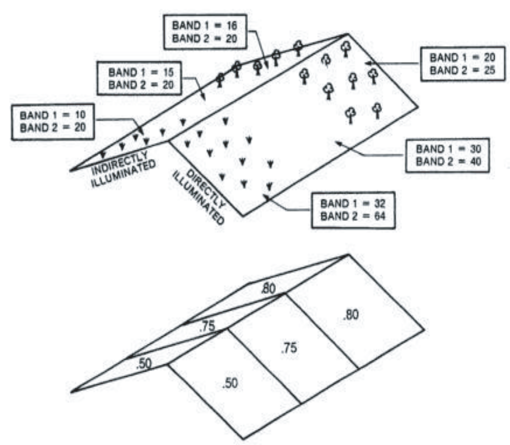
In contrast to the slope-based group, the distance-based group measures the degree of vegetation present by gauging the difference of any pixel's reflectance from the reflectance of bare soil. A key concept here is that a plot of the positions of bare soil pixels of varying moisture levels in the bi-spectral plot will tend to form a line (known as a soil line). As vegetation canopy cover increases, this soil background will become progressively obscured, with vegetated pixels showing a tendency towards increasing perpendicular distance from this soil line. All of the members of this group thus require that the slope and intercept of the soil line be defined for the image under consideration.

To these two groups of vegetation indices, a third group can be added, namely orthogonal transformation VIs. Orthogonal indices undertake a transformation of the available spectral bands to form a new set of uncorrelated bands within which a green vegetation index band can be defined. The Tasseled Cap transformation is perhaps the most well-known of this group.

Ratio Vegetation Index

The Ratio Vegetation Index was originally described by Birth and McVey (1968). It is calculated by simply dividing the reflectance values of the near infrared band by those of the red band. The result clearly captures the contrast between the red and infrared bands for vegetated pixels, with high index values being produced by combinations of low red (because of absorption by chlorophyll) and high infrared (as a result of leaf structure) reflectance. In addition, because the index is constructed as a ratio, problems of variable illumination as a result of topography are minimized.





Value of RVI

High for vegetation
Low for soil, ice, water, etc.
Indicates amount of vegetation
Reduces the effects of atmosphere and topography

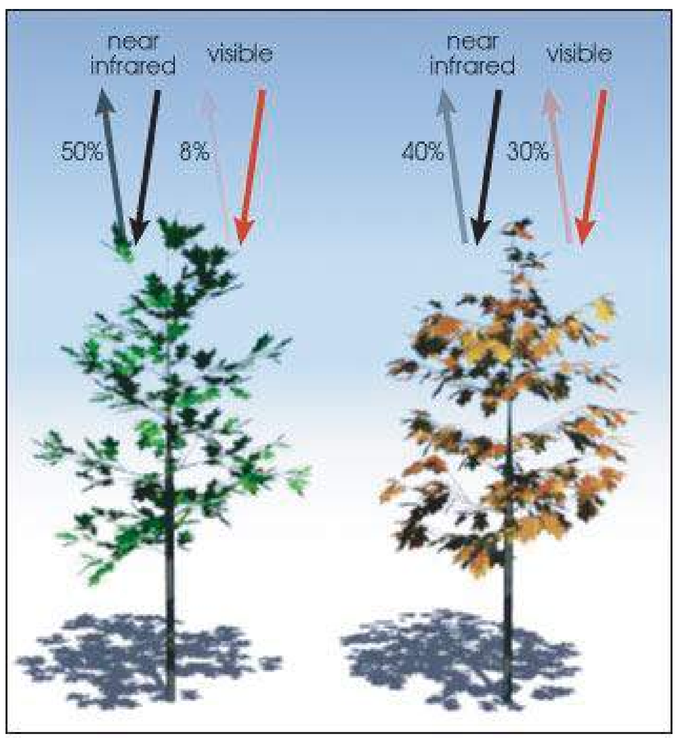
Source: Silleos NG, Alexandridis TK, Gitas IZ, Perakis K (2006) Advances made in Biomass Estimation and Vegetation Monitoring in the last 30 years.

Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) was introduced by Rouse et al. (1974) in order to produce a spectral VI that separates green vegetation from its background soil brightness using Landsat MSS digital data.

It is expressed as the difference between the near infrared and red bands normalized by the sum of those bands. Healthy vegetation (left, in above figure) absorbs most of the visible light that hits it, and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation (right, in above figure) reflects more visible light. It is the most commonly used VI as it retains the ability to minimize topographic effects while producing a linear measurement scale.

In addition, division by zero error is significantly reduced. Calculations of NDVI for a given pixel always result in a number that ranges from minus one (-1) to plus one (+1); however, no green leaves gives a value close to zero. A zero means no vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves.



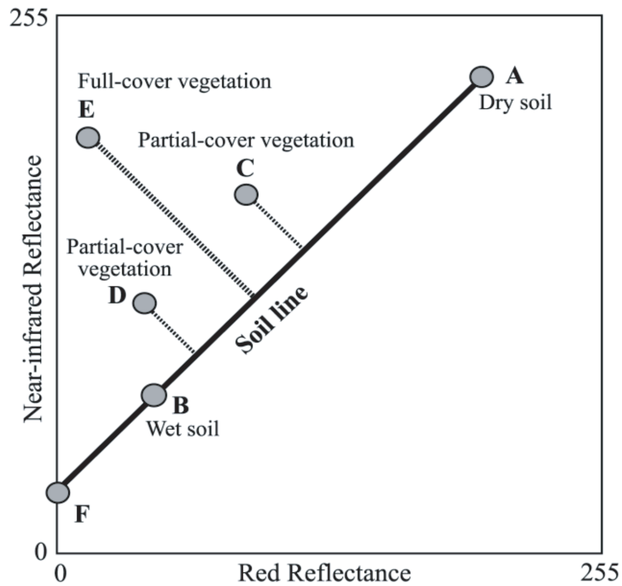
$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72 \qquad \frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$$

Source: Silleos NG, Alexandridis TK, Gitas IZ, Perakis K (2006) Advances made in Biomass Estimation and Vegetation Monitoring in the last 30 years.

Perpendicular Vegetation Index (PVI)

The Perpendicular Vegetation Index (PVI) suggested by Richardson and Wiegand (1977) is the parent index fromwhich the entire group of distance based VIs is derived. The PVI uses the perpendicular distance from each pixel coordinate to the soil line.

The main objective of PVI is to cancel the effect of soil brightness in cases where vegetation is sparse and pixels contain a mixture of green vegetation and soil background.This is particularly important in arid and semi-arid environments.The procedure is based on the soil line. It is obtained through linear regression of the near-infraredband against the red band for a sample of bare soil pixels. Pixels falling near the soil line are assumed to be soil, whilethosefar away are assumed to be vegetation. Attempts to improve the performance of the PVI have yielded three other indices suggested by Perry and Lautenschlager (1984), Bannari et al., (1996), and Qi et al.(1994).



PVI1 was developed by Perry and Lautenschlager (1984) who argued that the original PVI equation is computationally intensive and does not discriminate between pixels that fall to the right or left side of the soil line (i.e., water from vegetation). Given the spectral response pattern of vegetation in which the infrared reflectance is higher than the red reflectance, all vegetation pixels will fall to the right of the soil line. PVI2 Bannari et al., (1996) weights the red band with the intercept of the soil line, similar to PVI3, presented by Qi et al. (1994).

PVI measures the orthogonal distance from the pixel in question to the soil line.

Vegetation, PVI > 0

Soil, PVI = 0

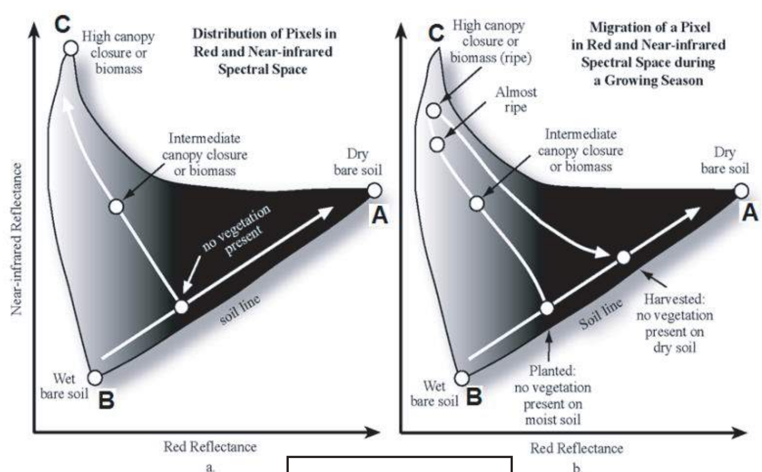
Water, PVI < 0

Tasseled-cap Transformation

Point A in the figure corresponds to the red and NIR reflectance values of the dry soil shown in the Figure. Point B corresponds to the reflectance values for the wet soil and Point C corresponds to vegetation. Thus, values of red and NIR data pairs representing any soil water content for bare soils would fall on the line connecting Points A and B inthe Figure. Point C represents full vegetation cover in the red-NIR space. As vegetation emerges from soil, a red-NIR data pair would move toward Point C, keeping within the bounds indicated by the dotted lines connecting Points B-C and A-C. The shape formed by the dotted and solid lines is of a "Tasseled cap" (Kauth and Thomas, 1976).

The Tasseled-Cap Transformation is a conversion of the original bands of an image into a new set of bands with defined interpretations that are useful for vegetation mapping. A tasseled-cap transform is performed by taking “linear combinations” of the original image bands - similar in concept to principal components analysis. So each tasseled-cap band is created by the sum of image band 1 times a constant plus image band 2 times a constant, etc… The coefficients used to create the tasseled-cap bands are derived statistically from images and empirical observations and are specific to each imaging sensor.

The first tasseled-cap band corres-ponds to the overall brightness of the image. The second tasseled-cap band corresponds to “greenness” and is typically used as an index of photo-synthetically active vegetation. The third tasseled-cap band is often inter-preted as an index of “wetness” (e.g., soil or surface moisture) or “yellow-ness” (e.g., amount of dead/dried vegetation).



Jenson 2007

Source:
Jackson, R.D. and Huete, A.R. (1991) Interpreting Vegetation Indices. Preventive Veterinary Medicine, 11, 185-200. http://wiki.landscapetoolbox.org/doku.php/remote_sensing_methods:tasseled-cap_transformation

Summary of Spectral Vegetation Index

Vegetation Indices should highlight the amount of vegetation and they should reduce atmospheric effects. Indices can be customized for particular applications. You can create custom indices to highlight anything that makes spectra unique and use temporal data just like you use spectral data.

Lesson Review

- ✓ Atmospheric correction and reasons for Atmospheric correction of satellite images
- ✓ Different types of Atmospheric correction models
- ✓ Procedure of atmospheric correction of Landsat 8 image
- ✓ Significance of Spectral Vegetation Index

Lesson-2

Land Use/Land Cover Mapping Project

Objective

By the end of this lesson, and through the knowledge and skills practice Sessions 3, 4, 5a, 5b, 6 and 7 the participants will be able to:

1. State the difference between Land Use and Land Cover
2. Explain the significance of Reference Data Collection in Land Use/Land Cover Mapping Project Phases
3. Collect reference data using recommended guideline of this lesson

Land Use/Land Cover Mapping

The following figures give an example how a Land cover class is used in different ways. There are different Land use classes, like Road, Town/Urban and Barren land. When you prepare a Land cover map of this area, you can include these classes in one **Land cover** unit like Dirt/Rock. More examples of Land use vs Land cover are given below-

Generally, **Land use** is the human use of land. **Land use** involves the management and modification of natural environment or wilderness into built environment, such as settlements and semi-natural habitats such as arable fields, pastures, and managed woods.

On the other hand, **Land cover** is the physical material at the surface of the earth. **Land covers** include grass, asphalt, trees, bare ground, water, etc.

LU Road Urban Barren Land



LC Dirt/Rock Dirt/Rock Dirt/Rock

Why do we do such mapping ?

Assess current resource conditions

- Habitat modeling, timber availability, ecosystem evaluation, disaster mapping

Forest-wide land management planning

Basis for further project-level activities

Long-term monitoring

Source: http://en.wikipedia.org/wiki/Land_use, http://en.wikipedia.org/wiki/Land_cover

Land Use/Land Cover Mapping Project Phases

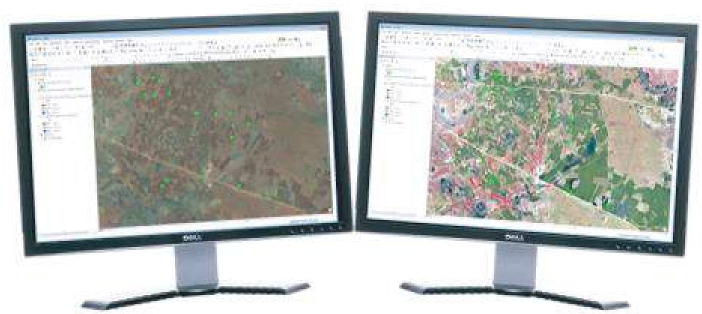
The steps involved in the mapping of LU/LC projects are as follows:

1. Planning
2. Geospatial Data Collection & Preparation
3. Modeling Unit Delineation
4. Reference Data Collection
5. Classification Modeling
6. Draft Map Review and Revisions
7. Final Map Production
8. Accuracy Assessment

The Land Use/ Land Cover Mapping Project Phases have already been discussed in **Lesson-1: Mapping Project Phases** of **Intermediate Remote Sensing and GIS** manual. In this lesson we will elaborately discussed on Reference Data Collection.

Reference Data Collection

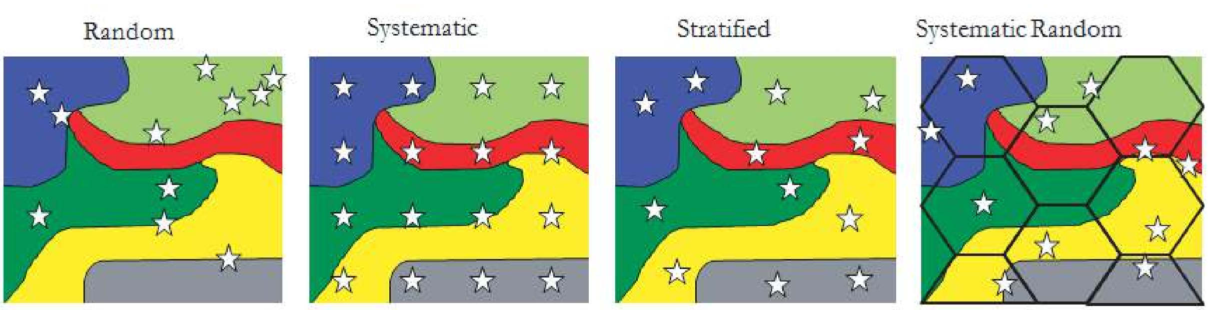
Reference data collection refers to the collection of sample areas that represent the land cover classes being mapped. These areas are used to develop the classification models used to create the maps or used in an accuracy assessment to validate the maps produced. Such data may be collected in the field or from photo interpretation



Reference data (sample) for Training Classification Model should not be random but should be random for accuracy assessment.

Sample totals:

"Rules of Thumb" → n = 20 minimum / map class… 30, 50, 100+



Actually the number of samples per map class depends on size of the study area, distribution of map classes, and accuracy of the final map product.

Uses of Reference Data

Reference data can be used as a Training data and Validation data..

Training Data

- includes field data, photo interpreted data
- used for training the classifier in supervised classification
- may be random or not (i.e., purposive)

Validation Data

- Used for accuracy assessment
- Should be random

This reference data can also be used for accuracy assessment of any classification If reference data is selected randomly, they can be used for BOTH training and validation

Source: http://fas.org/irp/imint/docs/rst/Intro/Part2_6.html

Sources of Reference Data

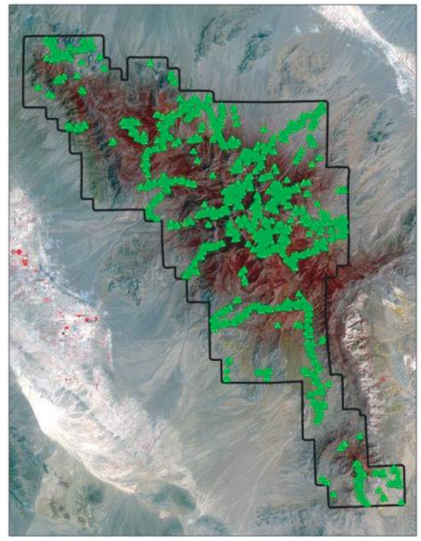
Field collected data is always useful as a reference data. Which **reference data** is used it depends on the available budget of the projects. **Legacy data** can be used to prepare a planning of the whole project. Sometimes a combination of field data and photo interpreted data is used as a reference data.

- Legacy data
  - **Pros**: cheap, potentially abundant, and reliable (?)
  - **Cons**: collected at different scales, different sampling schemes, different sampling protocols, require crosswalk and extensive spatial review

- Photo interpreted data
  - **Pros**: cheap, fast, enables random sampling scheme
  - **Cons**: potentially inaccurate, subjective, limited specificity

- Field-collected data
  - **Pros**: tailored to project specifications, quality assured, creates ground-based familiarity
  - **Cons**: expensive, slow, often biased sample, requires protocol development

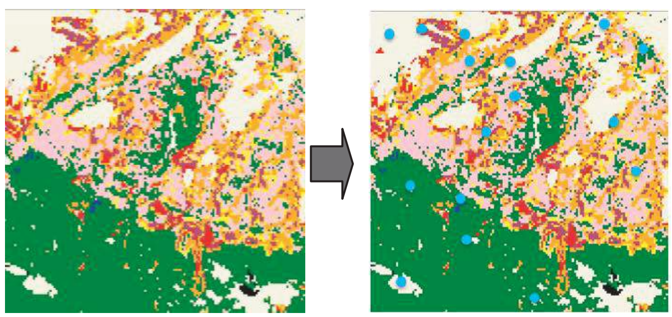
Main approaches to sample placement



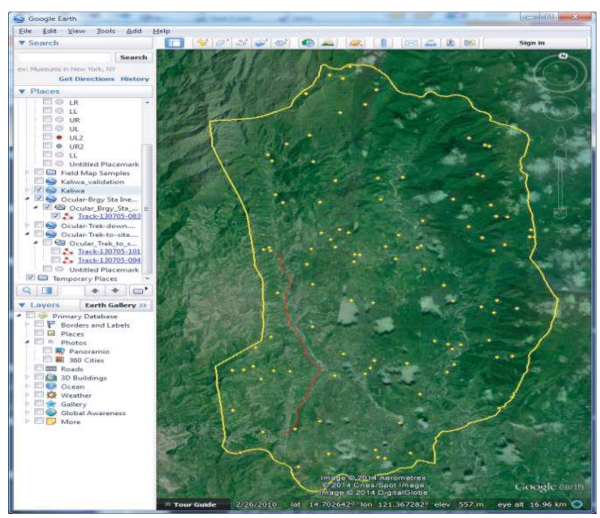
Field sample should be random. Random sample of any classified image can be prepared from ArcGIS software. When you select random sample plot for your field work, you should keep in mind the accessibility to this plot. In addition, field samples should be representative of all classes.

- Random
  - Necessary for unbiased validation
  - Good for training, but under-represents rare classes
  - Access issues for field collection
- Purposive (purposefully selected)
  - Biased for validation
  - Good for training; can target rare classes
- Several potential "Approaches"

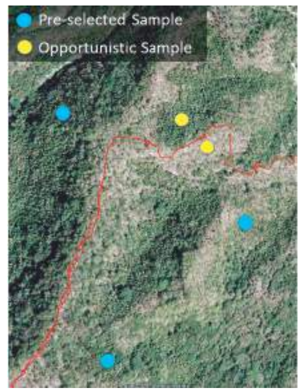
One of the ways of reference data collection is to conduct the unsupervised classification first using the spectral information of satellite data. After that field validation, random sample of each class will be prepared from GIS software like ArcGIS.



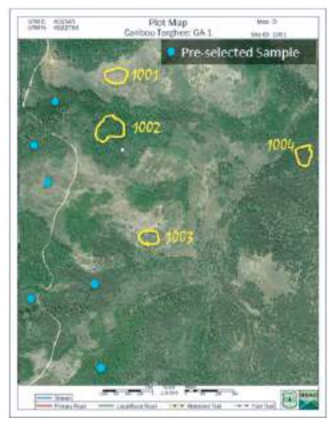
Another way of collecting reference is by using Google Earth. Zoom in the study area of Google Earth software and make sure the recent uploaded image is available on your viewer. Collect samples randomly with high confidence. Try to collect under-represented samples



In the third way of reference data collection, you may select uninterpreted random samples within 500m of access route. Actually buffer distance of access routes depends on the size and objectives of the study area. It is important to select additional sites of unsupervised classes near the access route. During Field sample collection, pre-selected sample will be navigated using GPS. In order to characterize sites using field form, document each sample's coordinate number and photo number in field form. You may also collect additional samples along the way in unique conditions or rare classes.



Using spectral characteristic of pre-selected sample, you can select additional sample points from field map. This additional point may be more accessible compared to pre-selected samples. Back in the office, digitize these samples in Google Earth or ArcMap



In the next step, you may collect additional photo-interpreted data based on knowledge gained in the field. In the next step, combine and compile all of the photo-interpreted data, field GPS data and vantage sample points. At this point, you have to reserve some random data of all classes for accuracy assessment or validation. It is important to remember that an accuracy assessment performed using any non-random data will be biased. In the next step, create a shape file of the field data with proper attribute.

Table

Kaliwa_Training_merged

FID	Shape *	ident	Name	CLASS_NAME	Code	Level 1	Level 2	Level 3
0	Polygon ZM	R1	GL	Other land, natural, grassland	GL	Vegetated	Other Vegetated	Grassland
1	Polygon ZM	R2	BL	Other land, natural, barren land	BL	Unvegetated	Unvegetated	Barren
2	Polygon ZM		GL	Other land, natural, grassland	GL	Vegetated	Other Vegetated	Grassland
3	Polygon ZM		GL	Other land, natural, grassland	GL	Vegetated	Other Vegetated	Grassland
4	Polygon ZM		GL	Other land, natural, grassland	GL	Vegetated	Other Vegetated	Grassland
5	Polygon ZM		GL	Other land, natural, grassland	GL	Vegetated	Other Vegetated	Grassland
6	Polygon ZM		NF4F	Closed forest, broadleaved	NF4F	Vegetated	Forest	Closed forest, broadleaved
7	Polygon ZM		NF4F	Closed forest, broadleaved	NF4F	Vegetated	Forest	Closed forest, broadleaved
8	Polygon ZM		NF4F	Closed forest, broadleaved	NF4F	Vegetated	Forest	Closed forest, broadleaved
9	Polygon ZM		BL	Other land, natural, barren land	BL	Unvegetated	Unvegetated	Barren
10	Polygon ZM		BL	Other land, natural, barren land	BL	Unvegetated	Unvegetated	Barren
11	Polygon ZM	1000	GL	Other land, natural, grassland	GL	Vegetated	Other Vegetated	Grassland
12	Polygon ZM	1001	BL	Other land, natural, barren land	BL	Unvegetated	Unvegetated	Barren
[illegible]	[illegible] ZM	1002	NF4C	Closed forest, conif[illegible]	NF4C	Vegetated	Fore[illegible]	Closed forest, coniferous
[illegible]	[illegible]	[illegible]	NFM	Mangro[illegible]	NFM	Vegetated	[illegible]	[illegible] forest

Characterize an area that is relatively homogenous in the context of the modeling unit (pixel or image object) you will be sampling. Considering possible GPS and image registration errors, sample should be 1.5 pixel widths or 15 m away from other land cover class. During sample collection, you should avoid major barriers and topographic breaks like rivers, ridgelines etc.

Usually, an unsupervised classification is performed in order to create sampling strata. Unsupervised classification is used when:

- You do not know what is out there
- You want to create strata to select sites for reference data collection.

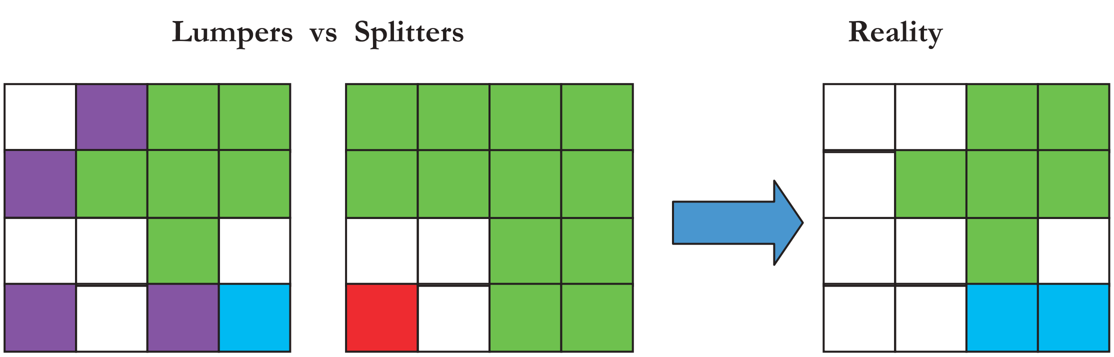
No of clusters in Unsupervised Classification is subjective and depends on the following factors:

1. Size of area you are trying to classify
2. How diverse (heterogeneous) the landscape is
3. Resolution of the data you will be using
   a. Spatial
   b. Spectral
4. The number of classes you will be mapping

In creating categories, there is a major intellectual divide between two conflicting orientations:

Orientation 1 (Lumping): Two things are in the same category unless there is some convincing reason to divide them.

Orientation 2 (Splitting): Two things are in different categories unless there is some convincing reason to unite them.



Source: http://pages.ucsd.edu/~dkjordan/resources/clarifications/Th-Lumpers.html

Reference Site Selection

Reference sites must be homogeneous, representing only 1 class and be at least 3x3 pixels in size, e.g. in case of Landsat the size would be 90m X 90m. Randomly placed sites should be robust and can be used in Accuracy Assessment (AA).

Place sites manually in homogenous area good for training area but not suitable for accuracy assessment.

1. Place sites in homogenous areas, manually
2. Further stratify, using distance to road or trail for ease of accessibility (e.g. within 0.5 km of a road)
    - Remember this biases your sample
3. Opportunistically sample areas in the field
    - Collect sites in classes that are undersampled
    - Collect sites in different physiographic settings
    - Cover full range of variability/expression for each class
    - biased
4. Supplement field sample with random or manual photo interpretation
    - High resolution imagery
    - Especially certain classes
    - Prior to field visit → save money and time

Map Units Design

- From the Forest Service Tech Guide: "A collection of taxonomic units and/or technical groups that share a common definition and label based on their vegetative characteristics."
    - AKA "map classes"
- Should be designed to support management goals
- Establish criteria used to aggregate/differentiate land cover/uses
    - e.g. Classification keys
- Should be informed by existing inventory data
    - Must exist on the landscape
- Must be:
    - Exhaustive – full range of conditions
    - Mutually exclusive – no overlap, ambiguity
    - Field applicable – reliably observed in the field
    - Mappable! – be realistic

A Land use / Land Cover classification key is generated based on map unit

1a. Area is currently being cultivated for agricultural activity…………………… **Agriculture (AG)**

1b. Area not as above ……………………………………………………………………………2a

2a. Area is currently developed for urban or residential use ……………………**Developed (DEV)**

2b. Area not as above ……………………………………………………………………………3a

3a. Area is dominated by open water or a confined water course.……………………**Water (WA)**

3b. Area not as above ……………………………………………………………………………4a

4a. All vascular plants total ≥ 10% cover ……………………………..………………………5a

4b. All vascular plants total <10%cover …………………………………**Sparsely Vegetated (SV)**

5a. Tree cover> 10%………………………………………………………………….……….6a

5b. Area not as above ……………………………………………………………………………7a

6a Tree cover≥ 40% ……………………………………..…….….**Closed Canopy Forest (CCF)**

6a. Tree cover 10% - 40% ………………………….……….….….**..Open Canopy Forest (OCF)**

7a. Shrub cover> 10%……………………………………………………….**.Shrubland (SH)**

7b. Area not as above…….……………………...………………………………….………….....8a

8a. Graminoids/herbs > 10% .……………………………………………………**Grassland (GR)**

8b. Area not as above ………………………………………………………….**Unclassified (UC)**

Data Collection Form

- A data collection form is prepared for the reference data collection. Data Collection form should include:
    - Collector's Name, Collection Date, Site ID, Latitude and Longitude Value or Northing and Easting Values, Aspect, Slope, Map Class, Dominant Vegetation Species, Field Location and specific notes of any site.
- Some necessary items should be carried to field for reference data collection

A simplified Reference Data Collection form is given below-

Bangladesh Field Data Collection Form

Collectors: Gabriel Bellante **Date:** 5/17/2014

Site ID: 001 **Northing:** 2508377 **Easting:** 360546
(UTM, Zone 46N, WGS84)

Aspect: West **Slope:** 30%

Map Class: AG DEV WA SV CCF OCF SH GR UC
(circle one)

Dominant vegetation species: Teak forest
(if applicable)

Field Location: Bariyadhala

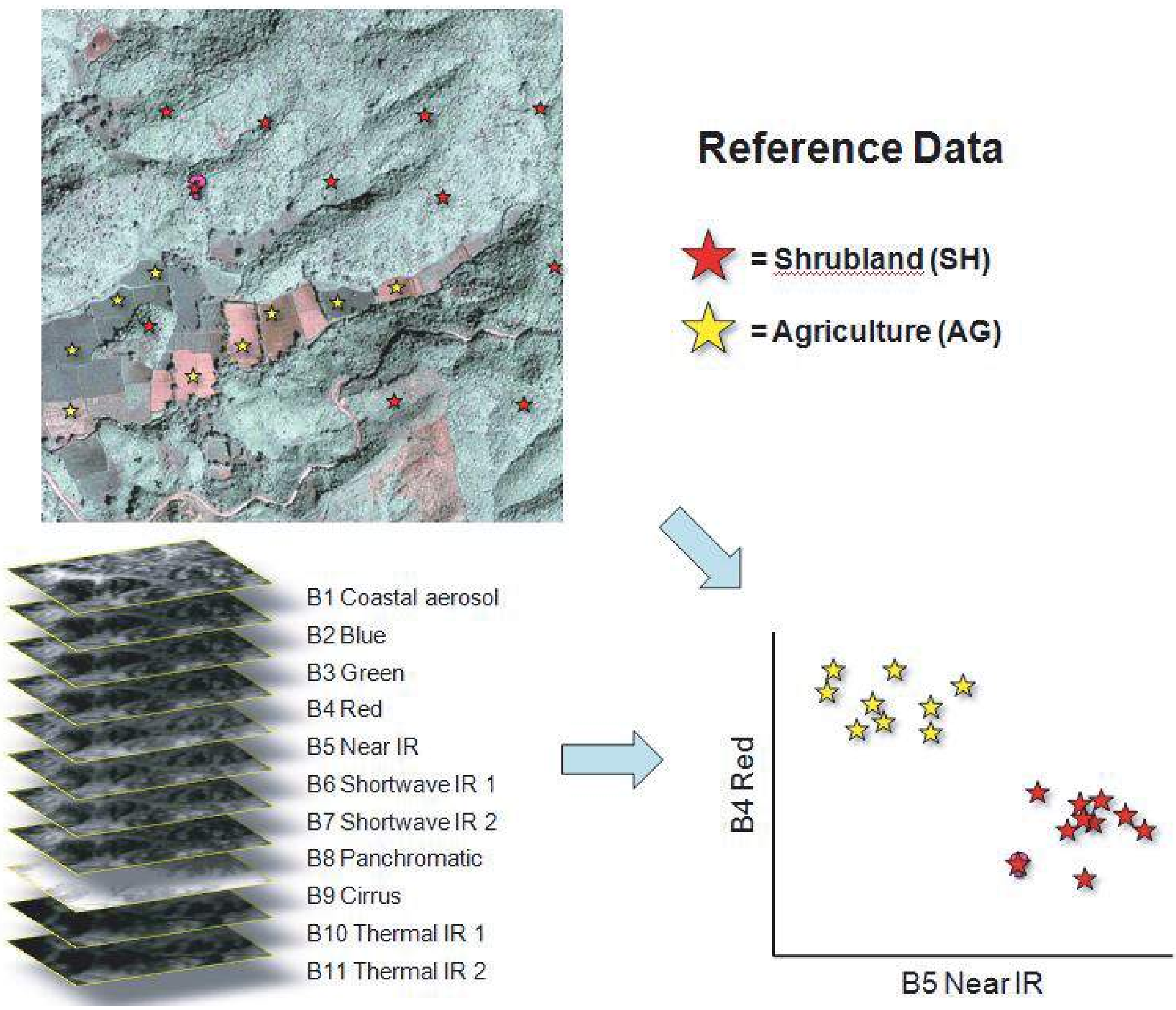
Notes: This area was very recently harvested at the time of data collection

Necessary items like GPS, Field Forms, Camera, Field Maps, Batteries, Whiteboard, Compass, First aid Kits, Clinometers, Binoculars, Clipboard, Sturdy Footwear, Pen/Pencil, Food and Water, Insect repellant should be carried for reference data collection

Classification Modeling

Using the reference data, models are generated to classify unknown areas. A classification model is a statistical tool designed to estimate or predict values of unknown LULC class based on a sample of known LULC reference sites. There are different classification methods to classify your study area like unsupervised classification, supervised classification. If you have available reference data of different Land use/Land Cover class, you can use it as a Signature File to classify multispectral satellite image like Landsat8.

Next Lesson, we are going to discuss how reference data is used in supervised classification and produce the final Land Use/ Land Cover map.



Lesson Review

- ✓ What is Land Use/Land Cover
- ✓ Significance of Reference Data Collection in Land Use/Land Cover Mapping Project Phases
- ✓ Procedure of collecting reference data

Lesson-3
Supervised Classification

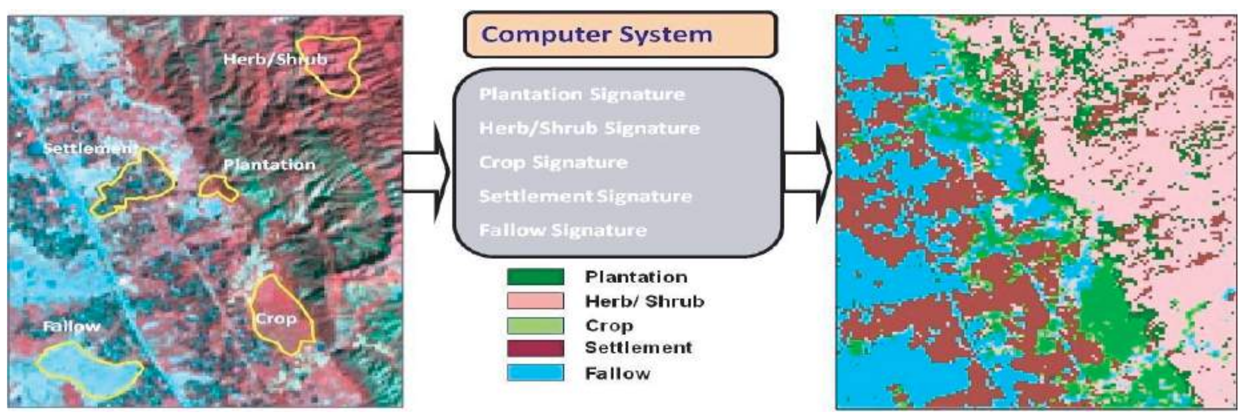
Objective

By the end of this lesson, and through the knowledge and skills practice Session 8, the participants will be able to:

1. State what is Supervised classification
2. Delineate the steps of Supervised Classification
3. Explain the Significance of Training Samples
4. Classify images using suitable decision rule or algorithm.

What is Supervised Classification ?

The analystidentifies homogeneous representativetraining areas of the different surface cover typesof interest, in the imagery.The analyst's familiarity with the geographicalarea and knowledge of the actual surface cover typespresent in the image are basis for selecting appropriate training areas in the image. The numerical information in all spectral bands forthe pixels comprising these areas are used to "train" the computer to recognize spectrallysimilar areas for each class. The computer determines the numerical "signatures" for each training class.After determining the signatures for each class, each pixel in the image iscompared to these signatures and labeled as the class it most closely "resembles" digitally.Thus, in a Supervised Classification we are first identifying the information classes which arethen used to determine the spectral classes which represent them.



Source: Canada Centre for Remote Sensing. 2007. Tutorial: Fundamentals of Remote Sensing.

Steps of Supervised Classification

The first step is to locate the **training samples** for each potential class and define their boundaries in the image. AOI tool of ERDAS IMAGINE is used to define the boundary of training samples.

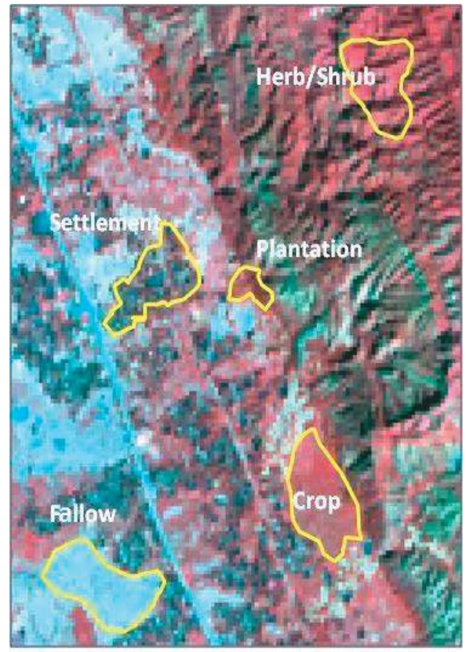
The second step is to collect **signature** for each potential class. A signature is a set of data that defines a training sample and statistical information such as minimum, maximum, mean vector, pixel number, number of bands, and covariance matrix of the potential class. In ERDAS IMAGINE signature collection tools are used to collect signatures of training samples for potential classes.

The third step is to **evaluate the signatures** which can help determine whether the signature data are a true representation of the pixels to be classified for each class. Most frequently used methods in ERDAS Imagine are Alarm and Statistics and Histogram.

The fourth step is to **perform Supervised Classification** process

Sources:
Source: ERDAS Field Guide™. (2005). Norcross, Georgia: Leica Geosystems Geospatial Imaging, LLC.
Source: ERDAS IMAGINE® Tour Guides™. (2006). Norcross, Georgia: Leica Geosystems Geospatial Imaging, LLC.

Training Samples



Training samples are sets of pixels thatrepresent what is recognized as a potentialclass. The computer calculates statistics from the sample pixels tocreate a parametric signature for the class.The following terms are sometimes used interchangeably inreference to training samples. For clarity, they are used in thisdocumentation as follows:

Training sample, or sample, is a set of pixels (a minimum of 9 pixels) selected to represent a potential class. The data file values for these pixels are used to generate a parametric signature.

Training field, or training site, is the geographical AOI in the image represented by the pixels in a sample. Usually, it is previously identified with the use of ground truth data.

Source: ERDAS IMAGINE® Tour Guides™. (2006). Norcross, Georgia: Leica Geosystems Geospatial Imaging, LLC.

Decision Rule or Algorithms

Once a set of reliable signatures has been created and evaluated, thenext step is to perform a classification of the data. Each pixel isanalyzed independently. The measurement vector for each pixel iscompared to each signature, according to a decision rule, oralgorithm. Pixels that pass the criteria that are established by thedecision rule are then assigned to the class for that signature.

There are different decision rules in ERDASIMAGINE. Most commonly used decision rules are :

- Parallelepiped
- Minimum distance
- Maximum likelihood

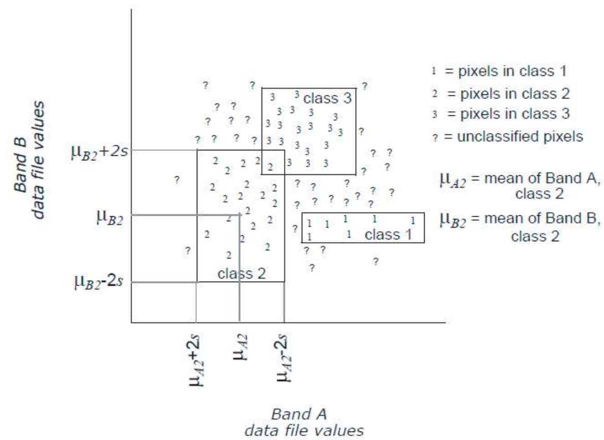
Others…….

Parallelepiped Decision Rule

In the Parallelepiped decision rule, the data file values of thecandidate pixel are compared to upper and lower limits. These limitscan be either of the following:

- The minimum and maximum data file values of each band in the signature,
- The mean of each band, plus and minus a number of standard deviations
- Any limits that you specify, based on your knowledge of the data and signatures. This knowledge may come from the signature evaluation techniques discussed above.

There are high and low limits for every signature in every band. When a pixel's data file values are between the limits for every band in a signature, then the pixel is assigned to that signature's class.



Parallelepiped Classification with Two Standard Deviations as Limits

Source: ERDAS Field Guide™. (2005). Norcross, Georgia: Leica Geosystems Geospatial Imaging, LLC.

Pros and Cons of Parallelepiped Decision Rule

- Does NOT assign every pixel to a class. Only the pixels that fall within ranges.
- Good for helping to decide if you need additional classes (if there are unclassified pixels)
- Problems when class ranges overlap-must develop rules to deal with overlap areas.

Pros:

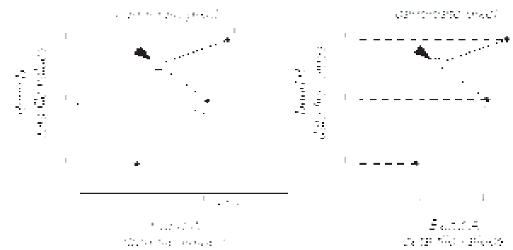
- Fast and simple, since the data file values are compared to limits that remain constant for each band in each signature.
- Often useful for a first-pass, broad classification, the decision rule quickly narrows down the number of possible classes to which each pixel can be assigned before the more time-consuming calculations are made, thus, cutting processing time (e.g., minimum distance, Mahalanobis distance, or maximum likelihood).
- Not dependent on normal distributions.

Cons:

Since parallelepipeds have corners, pixels that are actually quite far, from the mean of the signature,spectrally, may be classified.

Minimum Distance Decision Rule

The Minimum Distance Decision Rule (also called Spectral Distance)calculates the spectral distance between the measurement vector forthe candidate pixel and the mean vector for each signature.The candidate pixel is assigned to the class with the closest mean.



Minimum Spectral Distance

Source: ERDAS Field Guide™. (2005). Norcross, Georgia: Leica Geosystems Geospatial Imaging, LLC

Pros and Cons of Minimum Distance Classifier

Pros:

- Since every pixel is spectrally closer to either one sample mean or another, there are no unclassified pixels.
- The fastest decision rule to compute, except for parallelepiped.

Cons:

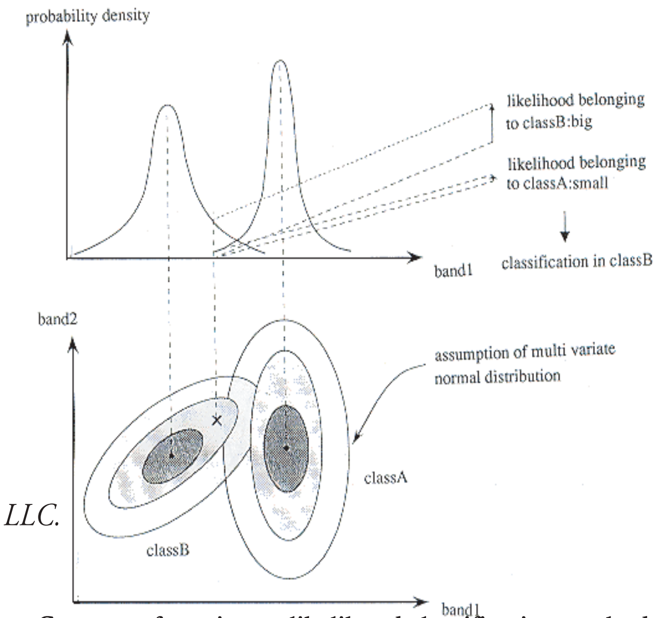
- Pixels that should be unclassified (i.e., they are not spectrally close to the mean of any sample, within limits that are reasonable to you) become classified. However, this problem is alleviated by thresholding out the pixels that are farthest from the means of their classes.
- Does not consider class variability. For example, a class, like an urban land cover class is made up of pixels with a high variance, which may tend to be farther from the mean of the signature. Using this decision rule, outlying urban pixels may be improperly classified.
- Inversely, a class with less variance, like water, may tend to overclassify (that is, classify more pixels than are appropriate to the class), because the pixels that belong to the class are usually spectrally closer to their mean than those of other classes to their means.

Maximum Likelihood Classifier Decision Rule

The Maximum Likelihood algorithm assumes that the histogramsof the bands of data have normal distributions. If this is not thecase, you may have better results with the Parallelepiped orMinimum Distance Decision Rule, or by performing a first-passParallelepiped Classification.

The Maximum Likelihood Decision rule is based on the probability thata pixel belongs to a particular class. It calculates the probability of a pixel being in a certain class and assigns it to the class with the highest probability.

Source: ERDAS Field Guide™. (2005). Norcross, Georgia: Leica Geosystems Geospatial Imaging, LLC.



Concept of maximum likelihood classification method

Source: http://ecoursesonline.iasri.res.in/mod/page/view.php?id=124949

Pros and Cons of Maximum Likelihood Classifier

Pros:

- The most accurate of theclassifiers in the ERDASIMAGINE system (if the inputsamples/clusters have a normaldistribution), because it takesthe most variables intoconsideration.
- Takes the variability of classesinto account by using thecovariance matrix.

Cons:

- An extensive equation that takes a longtime to compute. The computation timeincreases with the number of inputbands.
- Maximum Likelihood is parametric,meaning that it relies heavily on anormal distribution of the data in eachinput band.
- Tends to overclassify signatures withrelatively large values in the covariancematrix. If there is a large dispersion ofthe pixels in a cluster or trainingsample, then the covariance matrix ofthat signature contains large values.

Supervised Classification-Summary

- Supervised Classification uses knowledge of the locations of informational classes to group pixels.
- It requires close attention to development of training data. Typically, results in better maps than unsupervised classifications, if you have good training data.

Lesson Review

- ✓ What is Supervised Classification
- ✓ Steps of Supervised Classification
- ✓ Significance of Training samples
- ✓ Different decision rules or algorithms to perform supervised classification

Lesson-4

Accuracy Assessment

Objective

By the end of this lesson, and through the knowledge and skills practice Session 9, the participants will be able to:

1. State what is Accuracy Assessment
2. Delineate the critical steps in accuracy assessment
3. Assess the accuracy of any classification product.

What is Accuracy Assessment ?

Accuracy Assessments determine the quality of the information derived from remotely sensed data (Congalton and Green, 1999). Assessment is a complex subject and a fairly immature one. Readers with specific interests in accuracy assessment are directed to Congalton and Green's book, Assessing the Accuracy of Remotely Sensed Datafrom which most of the concepts outlined on this page are taken.

Assessments can be either qualitative or quantitative. In qualitative assessments, we determine if a map "looks right" by comparing what we see in the imagery with what we see on the ground. This is not usually done in a rigorous way, but rather in a "quick and dirty" way. General accuracy is the goal in this case, and error and its sources are not as important. This is usually a first cut assessment. However, quantitative assessments attempt to identify and measure remote sensing-based map error. In such assessments, we compare map data with reference or ground truth data (where ground truth data is assumed to be 100% correct).

Source: http://geography.middlebury.edu/data/gg1002/Syllabus_Assignments/Field%20Checking%20Exercise.doc.

Why Assess the Accuracy of the Map ?

Decisions about resources require maps, and effective decisions require accurate maps or at least maps of known accuracy. For centuries, maps have provided important information concerning the distribution of resources across the earth. Maps help us to measure the extent and distribution of resources, analyze resource interactions, identify suitable locations for specific actions, and plan future events. If our decisions based on map information are to have expected results, then the accuracy of the maps must be known. Otherwise, implementing such decisions will result in surprises, and these surprises may be unacceptable.

There are many reasons for performing an accuracy assessment.

First, perhaps the simplest reason is curiosity—the desire to know how good a map you have made.

Second, in addition to the satisfaction gained from this knowledge, we also need or want to increase the quality of the map information by identifying and correcting the sources of errors.

Third, analysts often need to compare various techniques, algorithms, analysts, or interpreters to test which is best. Also, if the information derived from the remotely sensed data is to be used in some decision-making process (i.e., GIS analysis), then it is critical that some measure of its quality be known.

Finally, itis more and more common that some measure of accuracy be included in the contract requirements of many mapping projects. Therefore, a valid accuracy is not only useful, but may be required.

Positional Accuracy vs. Thematic Accuracy

There are two types of map accuracy assessment: positional and thematic.

Positional Accuracy deals with the accuracy of the location of map features, and measures how far a spatial feature on a map is from its true or reference location on the ground (Bolstad, 2005).

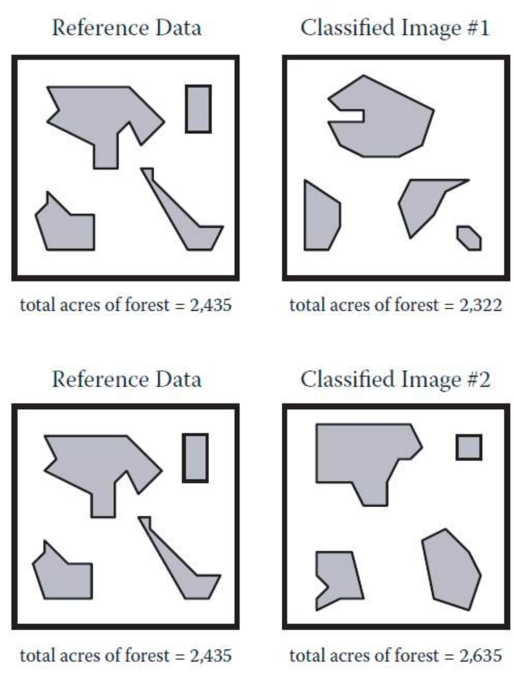
Thematic Accuracy deals with the labels or attributes of the features of a map, and measures whether the mapped feature labels are different from the true feature label. Like, in the picnic example, the earth‘s surface was classified as forest, water, crops, urban, or barren. We are interested in both the accuracy of the location of the features so we can locate our picnic spot in a forest on the shore of a lake, and in the thematic accuracy, so we truly end up in a forest and not in a city, desert, or agricultural field that was erroneously mapped as a forest.

Source: Russell G. Congalton, Kass Green, Assessing the Accuracy of Remotely Sensed Data - Principles and Practices Second edition (2009) CRC Press, Taylor & Francis Group, Boca Raton.

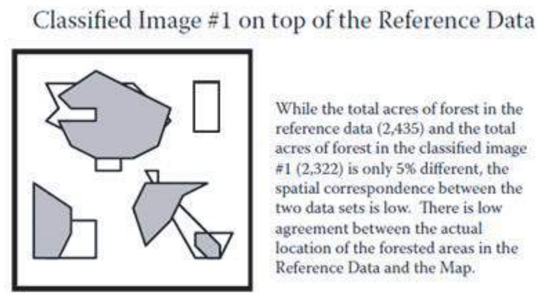
Non-Site-Specific and Site-Specific Assessments

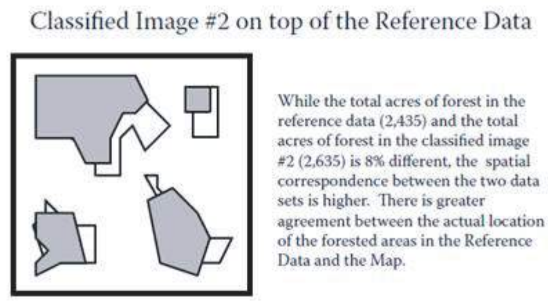
In a non-site-specific accuracy assessment, only total areas for each category mapped are computed, without regard to the location of these areas. Given the obvious limitations of non-site-specific accuracy assessment, there was a need to know how the map generated from the remotely sensed data compared to the reference data on locational basis. Therefore, site-specific assessments were instituted.

A simple example quickly demonstrates the shortcomings of the non-site-specific approach. This Figure shows the distribution of the forest category on both a reference image and two different classifications generated from remotely sensed data. Classification #1 was generated using one type of classification algorithm (e.g., supervised, unsupervised, or nonparametric, etc.), while Classification #2 employed a different algorithm. In this example, only the forest category is being compared. The reference data shows a total of 2,435 acres of forest, while Classification #1shows 2,322 acres and Classification #2 shows 2,635 acres. In a non-site-specific assessment, you would conclude that Classification #1 is better for the forest category because the total number of forest acres for Classification #1 more closely agrees with the number of acres of forest on the reference image (2,435 acres 2,322 acres = 113acres difference for classification #1, while Classification #2 differs by 200 acres).



However, a visual comparison (see right Figure) between the forest polygons on Classification#1 and the reference data demonstrates little locational correspondence. Classification #2, despite being judged inferior by the non-site-specific assessment, appears to locationally agree much better with the reference data forest polygons (see right Figure). Therefore, the use of non-site-specific accuracy assessment can be quite misleading.





Source: Russell G. Congalton, Kass Green, Assessing the Accuracy of Remotely Sensed Data - Principles and Practices Second edition (2009) CRC Press, Taylor & Francis Group, Boca Raton.

Critical Steps in Accuracy Assessment

All accuracy assessments include three fundamental steps:

1. Designing the accuracy assessment sample
2. Collecting data for each sample
3. Analyzing the results

Each step must be rigorously planned and implemented.

First, the accuracy assessment sampling procedures are designed, and the sample areas on the map are selected. We use sampling because time and funding limitations preclude the assessment of every spatial unit on the map.

Second, information is collected from both the map and the reference data for each sample site.

Thus, two types of information are collected from each sample:

Reference accuracy assessment sample data: The position or class label of the accuracy assessment site, which is derived from data collected that are assumed to be correct.

Map accuracy assessment sample data: The position or class label of the accuracy assessment site, which is derived from the map or image being assessed.

Third, the map and reference information are compared, and the results of the comparison are analyzed for statistical significance and for reasonableness.

Designing the Accuracy Assessment Sample

How we sample the map for accuracy will partially be driven by how the thematic classes of the map are distributed across the landscape. Once we know the classification scheme, we can learn more about how the map classes are distributed. Important considerations are the discrete nature of map information, and the spatial interrelationship or autocorrelation of that information.

Sample units are the portions of the map that will be selected for accuracy assessment. There are four possible choices for the sampling unit: (1) a single pixel, (2) a cluster of pixels (often a 3 × 3 pixel square), (3) a polygon (or object), and (4) a cluster of polygons.

Accuracy assessment requires that an adequate number of samples per map class be gathered so that the assessment is a statistically valid representation of the accuracy of the map. The appropriate sample size can and should be computed for each project using the multinomial distribution. However, in our experience, a general guideline or good le of thumbsuggests planning to collect a minimum of 50 samples for each map class for maps of less than 1 million acres in size and fewer than 12 classes (Congalton, et al., 1988b).

In addition to the considerations already discussed, the choice and distribution of samples, or sampling scheme, is an important part of any accuracy assessment. There are five common sampling schemes that have been applied for collecting reference data: (1) simple random sampling, (2) systematic sampling, (3) stratified random sampling, (4) cluster sampling, and (5) stratified, systematic, unaligned sampling.

Source: Russell G. Congalton, Kass Green, Assessing the Accuracy of Remotely Sensed Data - Principles and Practices Second edition (2009) CRC Press, Taylor & Francis Group, Boca Raton.

Collecting Data for Each Sample

The collection of accuracy assessment data requires completing the following three steps while considering both the reference data being collected and the map being assessed:

First, the accuracy assessment sample sites must be accurately located both on the reference source and on the map. Next, the sample unit must be delineated. Sample units must represent exactly the same area on both the reference data and the map. Finally, the reference and map labels must be assigned to each sample unit based on the map classification scheme.

More often, the reference source data are newly collected information that is at least one level more accurate than the remotely sensed data and methods used to make the map. Thus, aerial photography is often used to assess the accuracy of maps made from moderate-resolution satellite imagery (e.g., SPOT and LandsatTM), ground visits are often used to assess the accuracy of maps created from high-resolution airborne imagery, and manual image interpretation is often used to assess the accuracy of automated classification methods.

The next decision in reference data collection involves deciding how information will be collected from the source data to obtain a reliable label for each reference site. Reference data must be labeled using the same classification scheme that was used to make the map. In many instances, simple observations or interpretations are sufficient for labeling a reference sample. In other cases, observation is not adequate, and actual measurements in the field are required. The purpose of collecting reference data for a sample site is to derive the orrectreference label for the site for comparison to the map label.

Analyzing the Results

After collecting reference data, it is represented through an error matrix' or ntingency table'. Error matrices are very effective representations of map accuracy because the individual accuracies of each map category are plainly described along with both the errors of inclusion (commission errors) and errors of exclusion (omission errors)present in the map. In addition to clearly showing errors of omission and commission, the error matrix can be used to compute overall accuracy, producer's accuracy, and user's accuracy, which were introduced to the remote sensing community by Storyand Congalton (1986). Proper use of the error matrix includes correctly sampling the map and rigorously analyzing the matrix results.

Source: Russell G. Congalton, Kass Green, Assessing the Accuracy of Remotely Sensed Data - Principles and Practices Second edition (2009) CRC Press, Taylor & Francis Group, Boca Raton.

Error Matrix

An Error Matrix is a square array of numbers set out in rows and columns which express the labels of samples assigned to a particular category in one classification relative to the labels of samples assigned to a particular category in another classification. One of the classifications, usually the columns, is assumed to be correct and is termed as the reference data'.

The rows are usually used to display the map labels or classified data generated from the remotely sensed image.

Thus, two labels from each sample are compared to one another: Reference data labels: The class label or value of the accuracy assessment site, which is derived from data collected that is assumed to be correct; and Classified data or map labels: The class label or value of the accuracy assessment site derived from the map.

		Reference Data				Row
		D	C	AG	SB	Total
Classified Data	D	65	4	22	24	115
	C	6	81	5	8	100
	AG	0	11	85	19	115
	SB	4	7	3	90	104
	Column Total	75	103	115	141	434

Land Cover Categories

D = deciduous
C = conifer
AG = agriculture
SB = shrub

Source: Russell G. Congalton, Kass Green, Assessing the Accuracy of Remotely Sensed Data - Principles and Practices Second edition (2009) CRC Press, Taylor & Francis Group, Boca Raton.

Overall Accuracy

Overall accuracy is simply the sum of the major diagonal (i.e., the correctly classified sample units) divided by the total number of sample units in the entire error matrix. This value is the most commonly reported accuracy assessment statistic and is probably most familiar to the reader.

However, just presenting the overall accuracy is notenough. It is important to present the entire matrix so that other accuracy measures can be computed as needed and confusion between map classes is clearly presented and understood.

The off-diagonal elements of a contingency table tell us the most about how to improve our remote sensing classification! Should spend lots of time examining ERRORS to figure out what went wrong.

Classified image data	Reference data			
	Water	Forest	Urban	Total
Water	21	6	0	27
Forest	5	31	1	37
Urban	7	2	22	31
Total	33	39	23	95

--Correctly classified: 21 + 31 + 22 = 74

--Total number reference sites = 95

--Overall accuracy = 74 / 95 = **77.9%**

Source: *Russell G. Congalton, Kass Green, Assessing the Accuracy of Remotely Sensed Data - Principles and Practices Second edition (2009) CRC Press, Taylor & Francis Group, Boca Raton.*

Commission Errors and Omission Errors

An error matrix is a very effective way to represent map accuracy in that the individual accuracies of each category are plainly described along with both the errors of inclusion (commission errors) and errors of exclusion (omission errors) presenting the classification.

Errors of Commission: A type on the classified image is not that type on the ground – the type is COMMITTED to the classified image.

Errors of Omission: The type on the ground is not that type on the classified image – the real type is OMITTED from the classified image.

Classified image data	Reference data			
	Water	Forest	Urban	Total
Water	21	6	0	27
Forest	5	31	1	37
Urban	7	2	22	31
Total	33	39	23	95

Omission Error

For water:
5 + 7 = 12
12 / 33 = **36%**

For forest:
6 + 2 = 8
8 / 39 = **20%**

For urban:
0 + 1 = 1
1 / 23 = **4%**

Commission Error

For water:
6 + 0 = 6
6 / 27 = **22%**

For forest:
5 + 1 = 6
6 / 37 = **16%**

For urban:
7 + 2 = 9
9 / 31 = **29%**

Producer's Accuracy and User's Accuracy

Producer‘s and user‘s accuracies are ways of representing individual category accuracies instead of just the overall classification accuracy, and were introduced by Story and Congalton (1986). A quick example will demonstrate the need to publish the entire matrix so that all three accuracy measures can be computed.

Studying the error matrix shown in the above Figure reveals an overall map accuracy of74%. However, suppose we are most interested in the ability to classify hardwood forests so we calculate a roducer‘s accuracyfor this category. This calculation is performed by dividing the total number of correct sample units in the deciduous category (i.e., 65) by the total number of deciduous sample units as indicated by the reference data (i.e., 75 or the column total). This division results in a roducer‘s accuracyof 87%, which is quite good. If we stopped here, one might conclude that although this classification appears to be average overall, it is more than adequate for the deciduous category. Drawing such a conclusion could be a very serious mistake.

A quick calculation of the ser‘s accuracycomputed by dividing the total number of correct sample units in the deciduous category (i.e., 65) by the total number of sample units classified as deciduous (i.e., 115 or the row total) reveals a value of 57%.In other words, although 87% of the deciduous areas have been correctly identified as deciduous, only 57% of the areas called deciduous on the map are actually deciduous on the ground. The high producer‘s accuracy occurs because too much of the map is labeled deciduous.

		Reference Data				Row
		D	C	AG	SB	Total
Classified Data	D	65	4	22	24	115
	C	6	81	5	8	100
	AG	0	11	85	19	115
	SB	4	7	3	90	104
	Column Total	75	103	115	141	434

Land Cover Categories

D = deciduous
C = conifer
AG = agriculture
SB = shrub

OVERALL ACCURACY = (65 + 81 + 85 + 90)/434 = 321/434 = 74%

PRODUCER'S ACCURACY	USER'S ACCURACY
D = 65/75 = 87%	D = 65/115 = 57%
C = 81/103 = 79%	C = 81/100 = 81%
AG = 85/115 = 74%	AG = 85/115 = 74%
SB = 90/141 = 64%	SB = 90/104 = 87%

Source: Russell G. Congalton, Kass Green, Assessing the Accuracy of Remotely Sensed Data - Principles and Practices Second edition (2009) CRC Press, Taylor & Francis Group, Boca Raton.

Lesson Review

- ✓ What is Accuracy Assessment
- ✓ Critical Steps in Accuracy Assessment.

Lesson-5
Change Detection

Objective

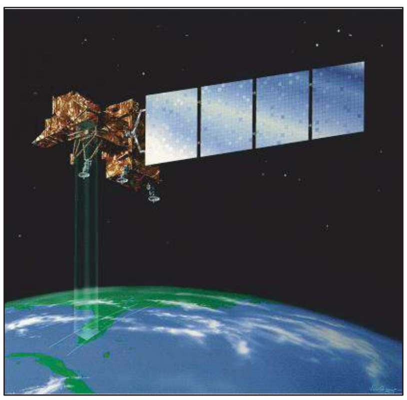
By the end of this lesson, and through the knowledge and skills practice Session10, the participants will be able to:

1. State how changes are monitored using Remote Sensing.
2. Quantify the changes using satellite images of two different dates.

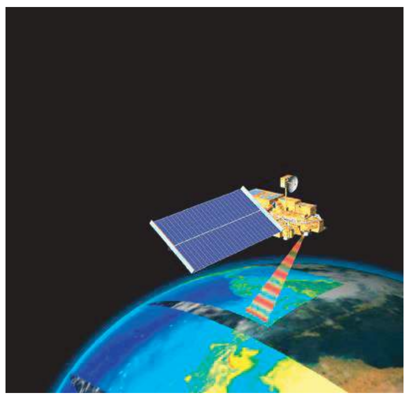
Monitoring Change with Remote Sensing

Satellite and aerial sensors provide consistent, repeatable measurements. There is a lot of data available at different spatial, temporal and spectral resolutions that make change detection possible. Sensors take images of the earth at varying spatial, spectral resolutions at different temporal resolutions and thus, there is an archive of data available to identify changes on the landscape by looking for spectral changes between images.

Landsat and MODIS imagery can easily be downloaded from the http://glovis.usgs.gov/ and http://rapidfire.sci.gsfc.nasa.gov/subsets/ website. In this website, you will found different time series satellite images. SPOT image is not free to download. You can search SPOT imagery from **http://sirius.spotimage.fr/anglais/welcome.htm**. When you compare changes using satellite image, spatial resolution of this time series satellite image should be same.



Landsat



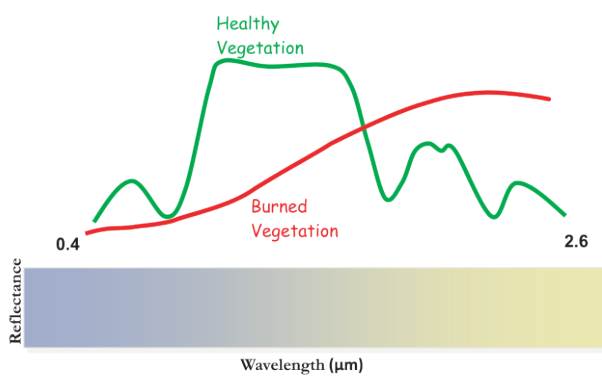
MODIS

SPOT

Source: http://landsat.gsfc.nasa.gov/?page_id=2290 http://oceanmotion.org/guides/fd_3/fd_student_3.htm http://www.geo-airbusds.com/en/148-spot-satellite-imagery-to-update-statewide-mapping-of-alaska

How do we detect change from imagery ?

Changes on landscape can be detected using spectral information of satellite images. For example, a vegetated area shows different spectral signature compared to non-vegetated area.



Change Agents

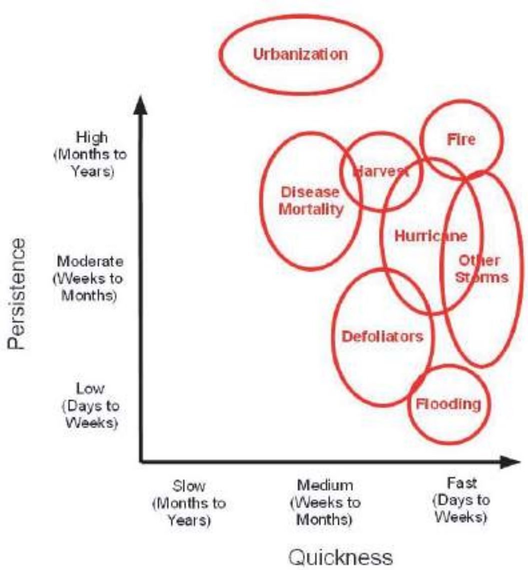
Natural: Wildfire, insect outbreaks, succession, drought or climate change, regeneration, storms, etc. are natural agents that affect the forest area.

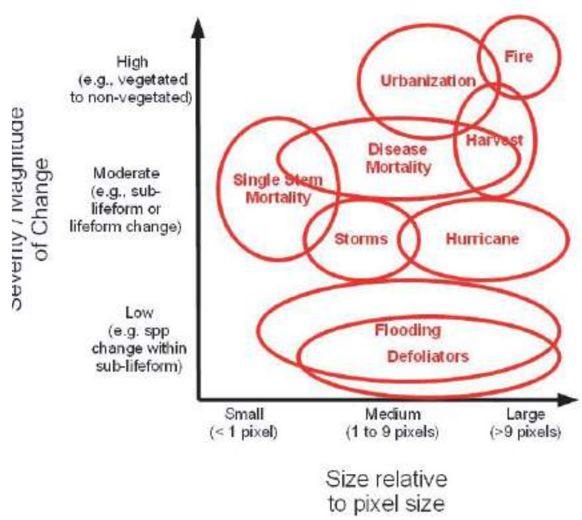
Anthropogenic: Harvest, management, agricultural development, invasive species etc. are Anthropogenic agents that affect the forest area.

Dimensions of Change

The Quickness vs Persistence graph shows the occurrence and persistence of different change agents like flooding, urbanization etc. For example, flooding may occur within a short period of time compared to urbanization. The persistence of flooding may also be low (days to weeks). Urbanization may occur within a week to months. However, persistence of urbanization is high (months to year).

The second graph shows the spatial distribution of these changes agents and their magnitude to change in life form. The spatial distribution of hurricane is medium to large but magnitude of change in life form is moderate.





Analysis Prerequisites

There are some prerequisites that have to be filled up to delineate the changes in land use or land cover. At first, identify the change agent according to your study area and determine frequency for change analysis. For example, the Sundarbans is a large mangrove forest in Bangladesh. If you want to assess the changes in the forest cover after the occurrence of any natural agent, like cyclone, you have to determine the cyclone time period, locate an image in year prior to the cyclone from the dry period, and locate another image after the cyclone from the following year. *These considerations determine appropriate methods and whether or not change can even be detected*

Approaches

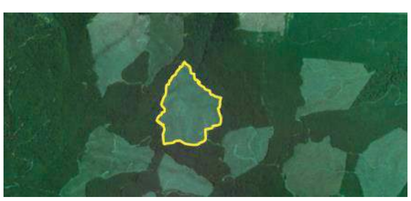
Analysis may be done manually or it can be automated. The advantages and disadvantages of these methods (Coppin et al 2010) are discussed below:

Manual:
You can take advantage of the human brain (texture, tone, size, shape, etc.); however, this is cumbersome and subjective as different analysts can come up with different results.

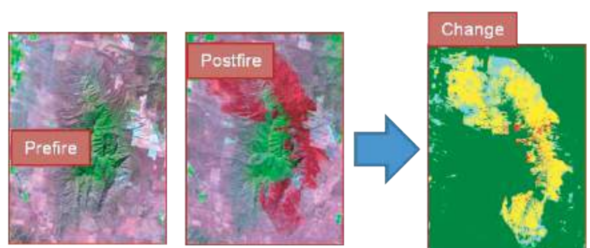
Automated:
Bi-temporal – Comparing the same area at two points in time. Requires analyst to set a threshold separating real change from 'noise'. This method is good for assessing change around a change event such as a disturbance, etc.

Temporal trajectory analysis – comparing the same area over longer time intervals with multiple imagery. These methods take full advantage of long-term data to extract long-term trends (e.g. effects of climate change and slow things). These methods can be fully automated and can minimize the importance of image preprocessing and thresholding can be based on statistical 'goodness of fit' and thus avoiding manual interpretation steps. Tools for conducting this type of trend analyses are available however they are somewhat more complicated and require additional software and knowledge.

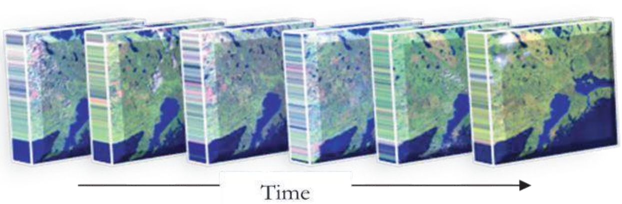
Source: http://www.tandfonline.com/doi/abs/10.1080/01431160310001101675



Manual



Bi-Temporal



Temporal trajectory

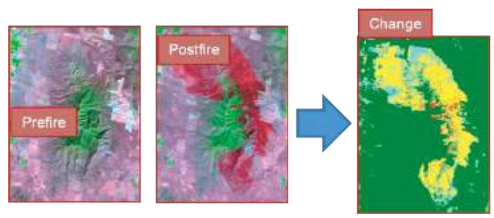
Challenge

Some factors like seasonal variation and phenology, image misregistration, clouds and shadow, radiometric inconsistencies (sensors and its position, sun-angle, atmospheric effects) can mislead the interpretation in change detection.

Cloud free satellite image is suitable for analysis. Shadow also creates problem. The selected image should be in same projection system. If any image is co-registered with other image then the RMS error should be within acceptable limits.

Seasonal variation and crop phenology is also important in change detection. For example, if you want to assess the changes in forest cover of your study area, then you have to select the time series image to include deciduous forest in your forest cover map.

Two-Date Methods Overview



1. Data selection and acquisition
   Imagery and reference data
2. Image processing and enhancement
   Correction, normalization and transformation
3. Analysis
   Quantify differences and create a change map
4. Evaluation
   Accuracy assessment

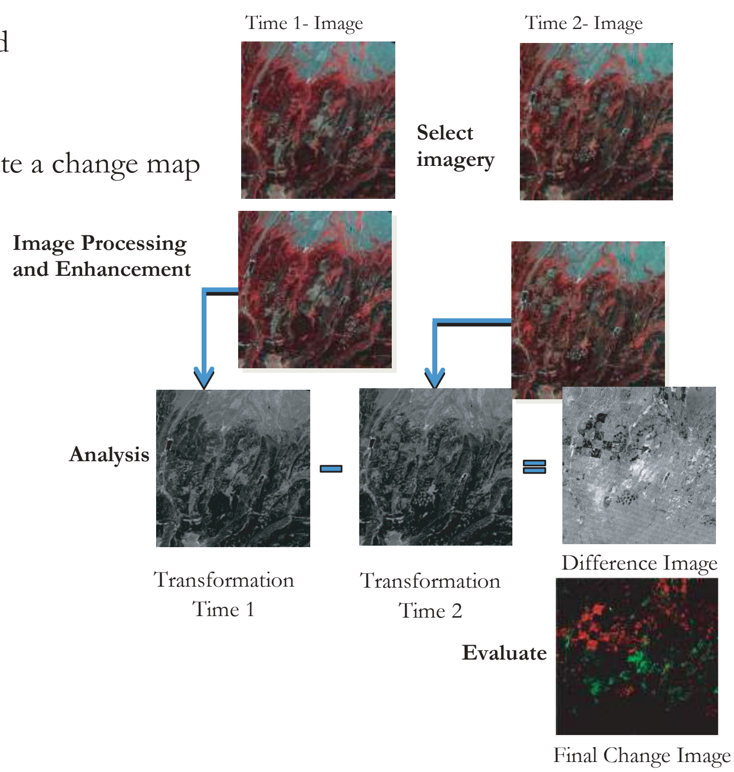


Image Selection - Overview

Four primary considerations while selecting images for change detection (Kennedy et al 2009)

- Type, timing, quality, cost

Goals:

- Capture the change of interest
  - Consider image and change phenomenon resolution (spatial, temporal and spectral)
- Minimize non-target change or 'noise'
  - Select near anniversary dates to minimize illumination and seasonal differences

Source: http://www.sciencedirect.com/science/article/pii/S0034425709000601#

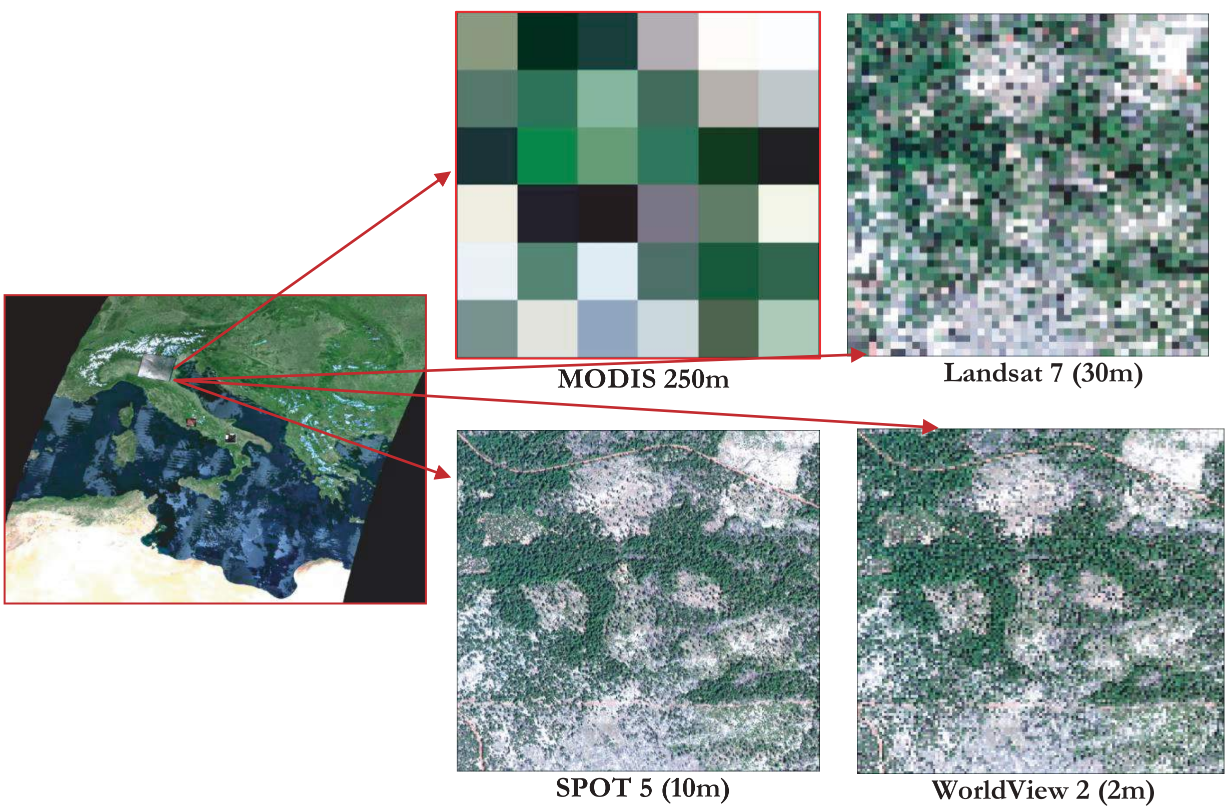
Imagery - Spatial Considerations

Consider the type of change that you want to map. Can't see single trees in a Landsat pixel, can't even really see 'stands' in a MODIS pixel. The following two terms are important:

> Spatial Resolution is the area on the ground captured by a single sensor element, effectively the pixel size.
>
> Extent is the geographic scope of an image, the satellite footprint

There is a trade-off between resolution and extent

Simulated MODIS, Landsat, SPOT and World View-2 data



Imagery - Temporal Considerations

Temporal resolution is the frequency at which images of a given point on the earth are acquired (Kennedy et al 2009). Image timing must be chosen to minimize the influence of unwanted effects on spectral space, since such effects obscure real change or produce the false appearance of change. Key issues to consider are phenological state of the landscape and sun angle.

Seasonal mismatch World View2

March 2011

September 2011

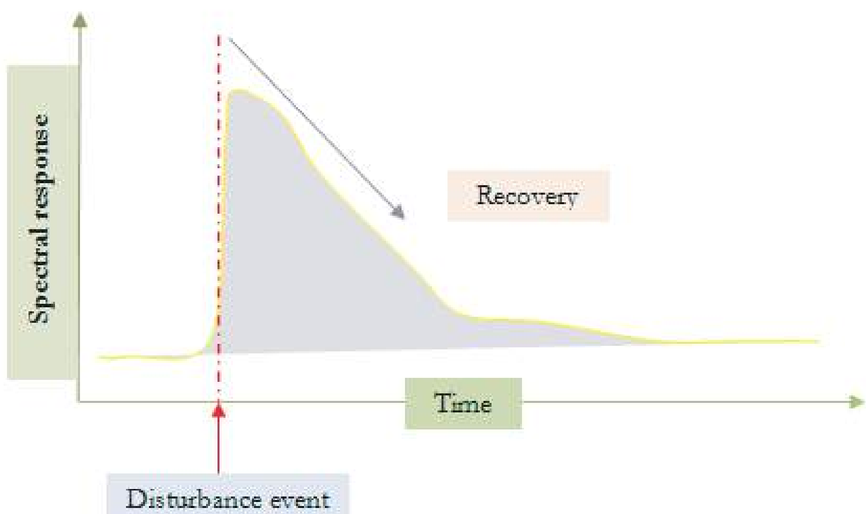


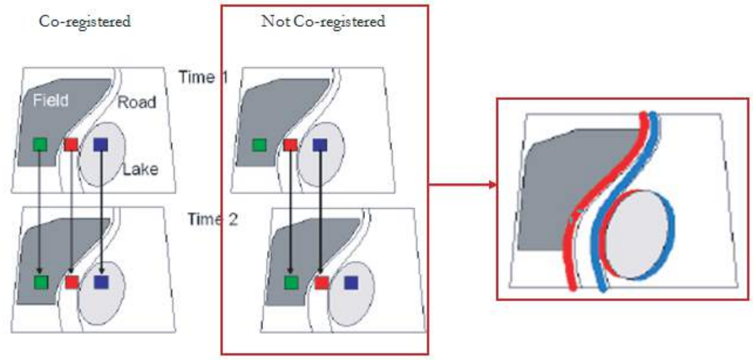
Figure adapted from Kennedy et al 2007

Source: http://www.sciencedirect.com/science/article/pii/S0034425707001216

Image Preprocessing

Geometric Correction

Careful Ground Control Point (GCP) selection is required for geometric correction of satellite images. Accurate and consistent georeferencing is especially important for automatic land cover change algorithms because change detection is performed by overlaying images from different dates. If shifted even slightly, the overlay will show many false changes that are artifacts of the georeferencing error and not due to actual changes in the landscape.



Source: http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=718860&url=http%3A%2F% 2Fieeexplore.ieee.org%2Fxpls%2Fabs_all.jsp%3Farnumber%3D718860

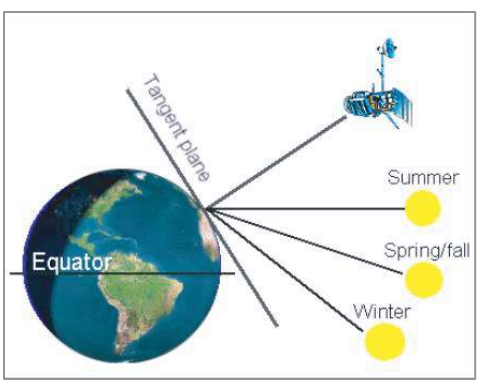
Notes: One study (Dai and Khorram 1998), found that in order to achieve 10% or less errors, co-registration of 0.2 pixels or better was required.

Image Correction

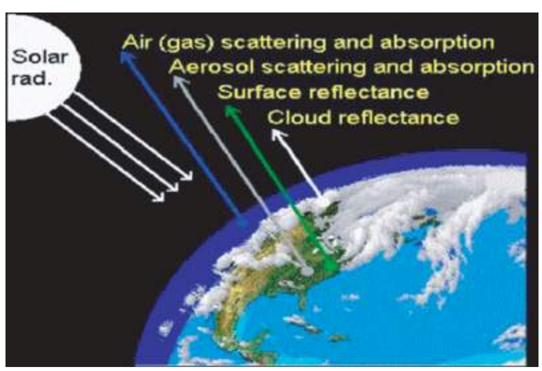
Image corrections are of two types:

- Radiometric correction, which takes into account sensor calibration, illumination and view angle
- Atmospheric correction which considers selective scattering and absorption of light alters reflectance

It's really important to convert digital numbers (DNs) or brightness values recorded by the sensor to meaningful physical units such as **reflectance**. Depending on the project objectives, it may be desirable to also try to correct for atmospheric effects but this is more difficult and not always done.



Radiometric correction



Atmospheric correction

Cloud Masking

Clouds and cloud shadows are a significant issue when conducting remote sensing and will create false information during change detection if not removed from both the pre and post images.

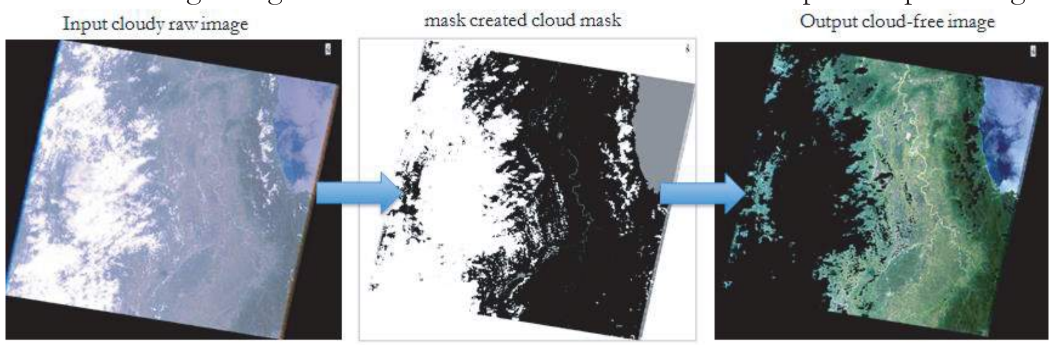
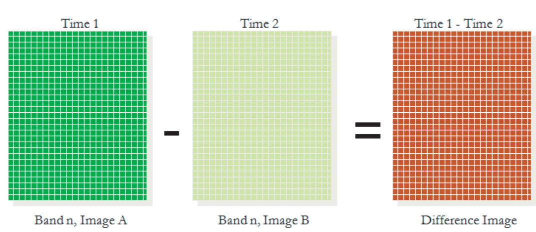


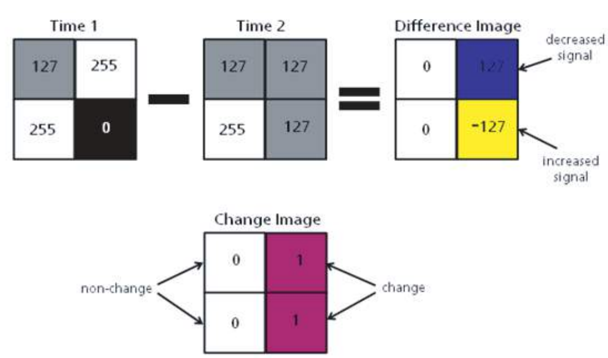
Image Enhancement or Transformation

NDVI (Normalized Difference Vegetation Index), NDMI (Normalized Difference Moisture Index), TC (Tasseled Cap) are indices that are used in vegetation change mapping. NDVI is used to identify green vegetation or not in forest area. MDMI is used in forest health assessment. The Tasseled-Cap Transformation is a conversion of the original bands of an image into a new set of bands with defined interpretations that are useful for vegetation mapping. The advantages of such transformation are to reduce data noise and simplify comparison.

Change Analysis- Image Differencing

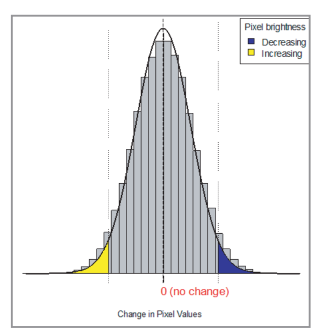
- Use raster math to calculate a difference image (NDVI is common input)
- Pixel values in change image represent spectral change (positive/negative)



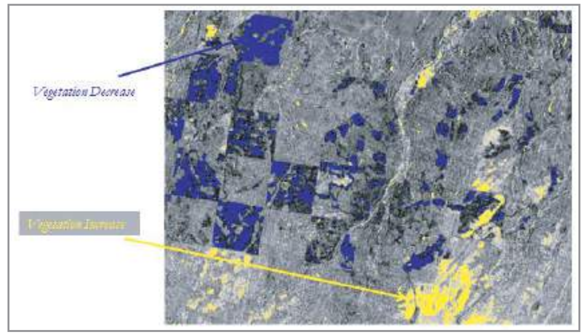


Change Histograms

Even if images are well corrected and well matched, rarely would we expect a pixel to have the same value in Time 1 and Time 2 images. The distribution of changed pixel values will most likely follow normal distribution, with the mean pixel value centered on zero and 'true change' depicted by pixels some distance from this mean.



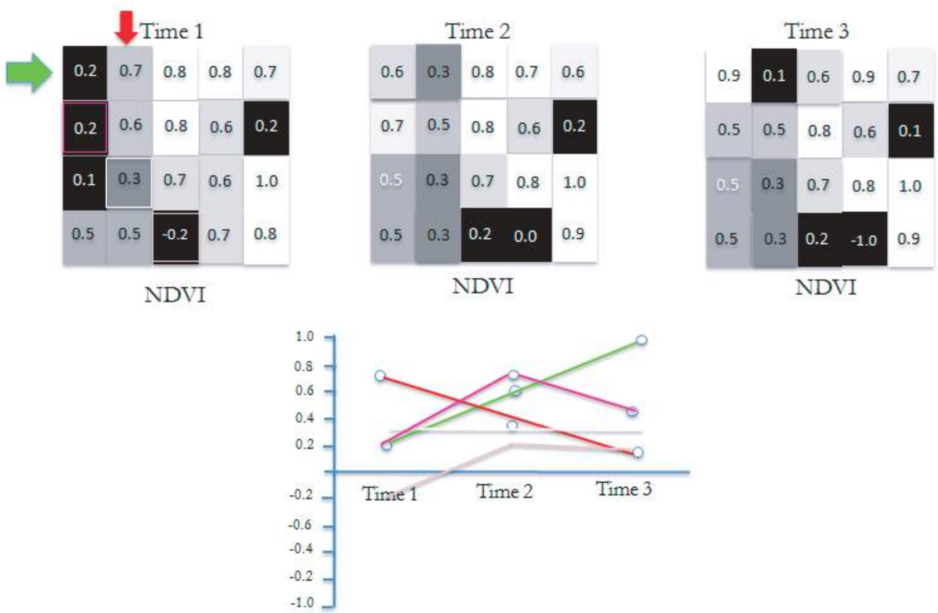
Analysis – Thresholding



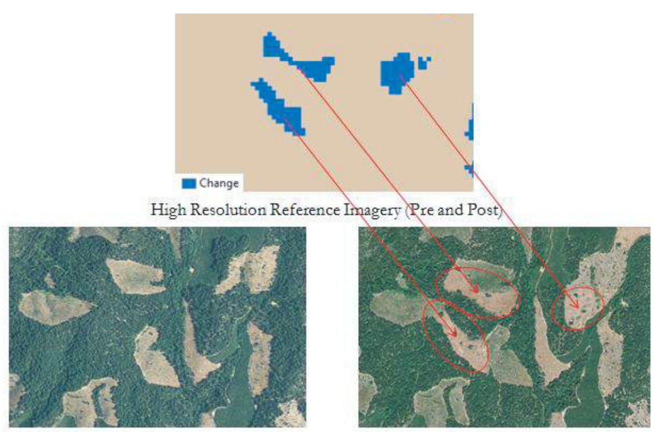
Thresholding is done in order to partition the change images to identify change or no change area. This figure shows the NDVI image difference of forest in North America. Forest harvests show up clearly as decreases in NDVI.

Change Analysis- Temporal Trends

For example, there are 3 Time Series NDVI images. Say NDVI value of one pixel of Time 1 is 0.2, it increased in 0.6 of Time 2 and it increased again 0.9 of Time 3. It indicates the increase in vegetation.



Validation– Accuracy Assessment



Multiple assessment options are available like Quantitative and Qualitative assessment. For Quantitative accuracy assessment, users need to validate reference data, like detail field data and high resolution image. However, uses of Quantitative and Qualitative assessments depend on project goals and resources.

Change Detection – Summary

Time and cost are involved in selecting the appropriate approaches. Selection of suitable satellite image is an important step to complete the whole process smoothly. Expertise in respective field is also required to extract the data and analyze the change detection. The final map should be evaluated by local resource person like Forester of this study area.

Lesson Review

- ✓ Monitor changes with Remote Sensing
- ✓ Procedure to delineate changes using two different dated satellite images

Knowledge and Skills Practice

There are 10 (Ten) Knowledge and Skills Practice sessions in **Advanced Remote Sensing and GIS Manual** that are included with data in the attached CD (with this Manual). The details of Knowledge and Skills Practice sessions with links to their respective Lessons, are given below:

Item	Session	Practice	Knowledge Link
1	Knowledge and Skills Practice 1	Create a Project Directory	
2	Knowledge and Skills Practice 2a	Atmospheric Correction	**Lesson-1:** Introduction to Image Correction and Spectral Indices
3	Knowledge and Skills Practice 2b	Spectral Vegetation Index	
4	Knowledge and Skills Practice 3	Pansharpen Landsat 8 Imagery	**Lesson-2:** Land Use/Land Cover Mapping Project
5	Knowledge and Skills Practice 4	Unsupervised Classification to Develop Sampling Strata	
6	Knowledge and Skills Practice 5a	Using Unsupervised Landsat strata	
7	Knowledge and Skills Practice 5b	Using Google Earth high resolution imagery	
8	Knowledge and Skills Practice 6	Import field collected GPS data	
9	Knowledge and Skills Practice 7	Georectification using GPS data	
10	Knowledge and Skills Practice 8	Subset and Supervised Classification	**Lesson-3:** Supervised Classification
11	Knowledge and Skills Practice 9	Accuracy Assessment	**Lesson-4:** Accuracy Assessment
12	Knowledge and Skills Practice 10	Change Detection	**Lesson-5:** Change Detection

Summary

The Advanced Remote Sensing and GIS Manual is a resource for understanding the various higher level applications of remote sensing and GIS. It covers topics which are presented both in theoretical and practice formats, enabling the user to gain advanced level of knowledge in remote sensing and GIS and apply those to his/her relevant field. Where required, reference links to relevant websites have also been given with the Lectures.

One may not always need to apply all the concepts discussed in this Manual. However, getting introduced to some advanced topics of remote sensing and GIS like Atmospheric Correction of Satellite data and Spectral Indices, Distinguish procedure of Reference Data Collection of Land Use/Land Cover Mapping Project, Accuracy Assessment of Classification Product, Change Detection, gives the user a knowledge of what can be done with remote sensing and GIS in present day. And that is important. We hope all of you have enjoyed the lessons, knowledge and skills practice sessions and the overall program. Best of luck.

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