Precision agriculture

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Outline

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Course objectives: The objective of this course is to provide theory as well as hands-on skill to students for various applications in Remote-sensing (RS), GIS and related technology for precision agriculture.

"*It would be a simple matter to describe the earth's surface if it were the same everywhere. The environment, however, is not like that: there is almost endless variety.*"

— Webster and Oliver (1990)

Meaning and definition

- Management of **variability** in the dimensions of both space and time!
- Any component of production agriculture – plant genetic resource, production inputs, farm machinery, and farm operators – are variable.
- All of these can be included in the realm of precision agriculture, not only the soil.
- Aspects include:
  - Variability of soil resource base
  - Weather
  - Plant genetics
  - Crop diversity
  - Machinery performance
  - Most physical, chemical and biological inputs used in the crop production (synthetic/natural)
- By necessity, all are framed within the context of the variable socio-economic aspects of production agriculture.
  - to be successful on the farm, precision agriculture must fit the needs and capabilities of the farmer and must be profitable.

- Managing soil and crops in space and time is the sustainable management principle for the 21st century, exemplified by:
  - Farming by soilscapes
  - Managing zones within the field
  - Managing the non-crop period
- Concerns of the technology:
  - assistive technologies enabling the efficient use
  - agronomic feasibility
  - environmental efficacy
  - performance with respect to economic and social impacts

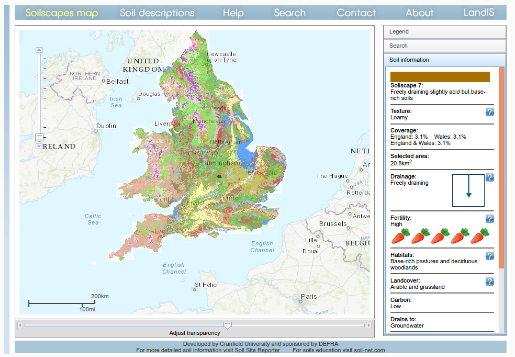


Figure 1: Georefrenced soilscapes map of UK. Source: http://www.landis.org.uk/soilscapes/

Known names of Precision agriculture

Farming by the foot, farming by soil, variable rate technology (VRT), spatially variable farming, prescription farming, site-specific crop production, site-specific management...

Stafford (1996)

"The targeting of inputs to arable crop production according to crop requirements on a localized basis"

- 4R principle:
  - Right thing
  - Right place
  - Right time
  - Right way

NRC, Board on Agriculture Committee, US

"A management strategy that uses information technologies to bring data from multiple sources to bear on decisions associated with crop production."

“Precision agriculture is the application of technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production for the purpose of improving crop performance and environmental quality.”

Precision versus Accuracy

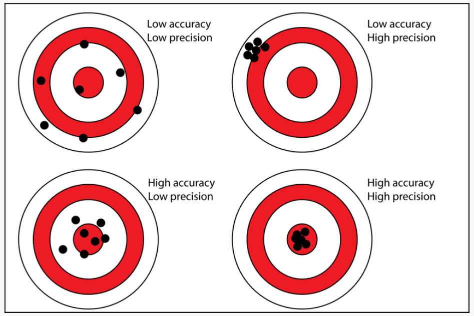


Figure 2: Precision verus accuracy. Something can be precise but not accurate.

- Nature of computers makes it easy to imply more *precision* than was possible in various aspects of data collection, analysis, computation in precision agriculture.
- Precision refers to the limits on the measurement scale between which the true measurement is believed to lie, implied by the number of digits reported for a measurement.
  - A pH of 5.4 or 5.44

The idea

- Intuitively appealing
  - scientific principles of management of soils, crops, and pests
  - arguing against a management philosophy that aims at matching inputs to the exact needs everywhere is not easy.
- Successful implementation of precision agriculture depends on numerous factors, including:
  - the extent to which conditions within a field are known and manageable,
  - the adequacy of input recommendations,
  - the degree of application control,
  - the degree of support through private and public infrastructures,
  - the expectations of individual (how do you know maximum potential has been reached?)

Basic components

- Measurement and understanding of variability
- Use information to manage this variability by matching inputs to conditions within fields using **site-specific management recommendation**
- Mechanism to control the accuracy of site-specific inputs
- Provide for the measurement and recording of the efficiency and efficacy of these site-specific practices in order to assess value on and off the farm.

Precision fertilizer management: An example use case

- In conventional farming system, blanket application of high amounts of nitrogen fertilizer has been in practice.
- Soil's nutrient mobility potential (due to soil physical and chemical properties), soil moisture, crop/variety specific demand and field micro-variations are unaccounted.
  - N losess are due to NO_3^- leaching and NH_4^+ volatilization
  - Higer cost of production (added cost of input fertilizer purchase in order to compensate for loss)
- Collecting in-season biomass sample for analysis is cost prohibitive, labor intensive and destructive.

Enabling technologies

1. Computers
2. Global positioning system (GPS)
3. Geographic information system (GIS)
4. Sensors
5. Application control

Early history

- Pierre Robert is often regarded as the father of precision farming
- In 1982, Robert defended his PhD dissertation titled "Evaluation of some remote sensing techniques for soil and crop management"
  - Showed that color infrared (CIR) aerial photography could be used to detect "Problems relating to drainage, erosion, germination, grass and weed control, crop stand damage and machinery malfunction."
  - Suggested that CIR data could be used to build a "farm information and management system containing precisely located natural and cultural data to improve cost efficiency of future cultural practices. Such improvement could come, for example, from adjusting seed density, herbicide control or fertilization in response to detected field problems"
- Notes that anomalous reflectance patterns from row-cropped fields were associated with soil series boundaries

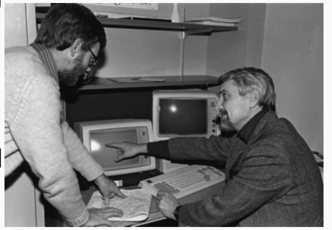


Figure 3: Pierre Robert explaining his computerized farming by soil map database (circa 1985) to Jim Anderson at the University of Minnesota.

Outline

- Soil sampling
- Geostatistics and GIS
- Farming by soil
- Variable rate fertilizer
- Site specific farming and management zones
- GPS
- Automated tractor navigation and robots
- Yield mapping
- Variable rate herbicide application
- Variable rate irrigation
- Remote sensing
- Proximal sensing of soil and crops

Precision agriculture in Nepal

- Attempt to land categorization using digital soil map
- Micropropagation nurseries
- Drip irrigation system
- Use of cropping systems model of decision making
- Use of laser land leveler
- Rice planter
- Drone sprayer

Figure 4: PMAMP, Chitwan using drones in the rice field for pesticide spray. The introduced drone of given design cost around NRS 1,500,000. It sprays the pesticide or liquid fertilizer 20 times as efficiently (requires lesser spray volume) as traditional hand held sprayer.

Figure 5: An agriculture engineer operating rice transplanter. The PMAMP, Chitwan is trialing with mechanical aids to paddy plantation, management and harvest. The instruments are a four-wheel-drive riding-type rice planter, a combined harvester and plastic trays. A rice planter machine shown allows farmers to sow six saplings at a time instead of one and decreases the labour by 40-50 percent. The saplings are treated and kept in a tray that then efficiently places them into the soil. The machine can cover one bigha (around 72,900 square feet) of land per hour.

Figure 6: Use of drum seeder in rice seeding (useful for DST). It has three drums for applying seeds and two hoppers for applying Granulated Urea, which were placed over a shaft.

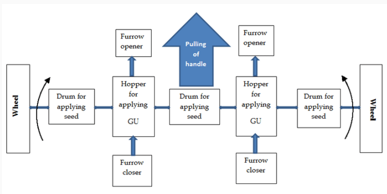


Figure 7: Seed cum ferti till drill

Figure 8: Laser guided drag bucket for land levelling. This ensures a flat table-top like land surface which increases water use efficiency as irrigated water reaches every part of the field with minimal run-off or water-logging. It reduces irrigation times in rice by 47-69 hours/hectare per season and in wheat by 10-12 hours/hectare per season. Increases yield by about 8 percent.

Specific use cases in PA

- Soil water monitoring/ Inefficient or broken drainage
- Seed germination, plant density and crop growth rate,
- Viral, microbial, fungal diseases and insects' pests diagnostics,
- Weeds and other unwanted plant species monitoring,
- Plant nutrient deficiency diagnostics and management,
- Soil health and Soil-Microbes analysis,
- Food nutrients composition and Phyto-chemicals analysis,
- Weather forecast for cultivation
- Calendar for agricultural crop cultivation

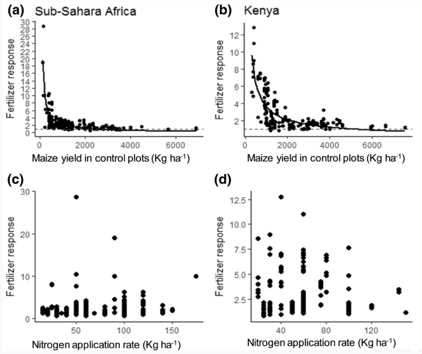
Limitations

- Land come with fixed size
- Despite all of these state of precision agriculture from a systems perspective is analogous to the early days of no-tillage crop production.
- No perfect form of precision agricultural systems exist as of yet!
- Only components of traditional crop management systems have been addressed separately regarding their potential for site-specific management, most notably soil fertility.
- Management parameters that vary spatially, those with high temporal correlations (e.g., liming) will be more easily managed with precision agriculture than those with large temporal variance (e.g., mobile insects).

Outline

Soil test crop response (STCR)

- STCR is technique based on soil testing which aims to make quantitative fertilizer recommendation for the profit maximizing dose of fertilizer in the given parcel of land for a specific crop.
- Testing generally involves analysis of chemical constitution as well as physical attributes of the soil with standardized protocols. Primarily, STCR study aim to:
  - Study the relationship between soil test values for available N, P, K and yield response to important crops.
  - Derive yield equations as function of fertilizer compositions for crops to make site specific recommendation.



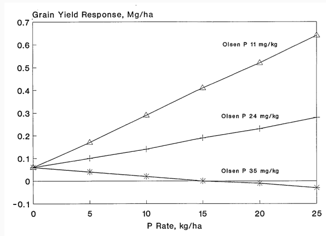
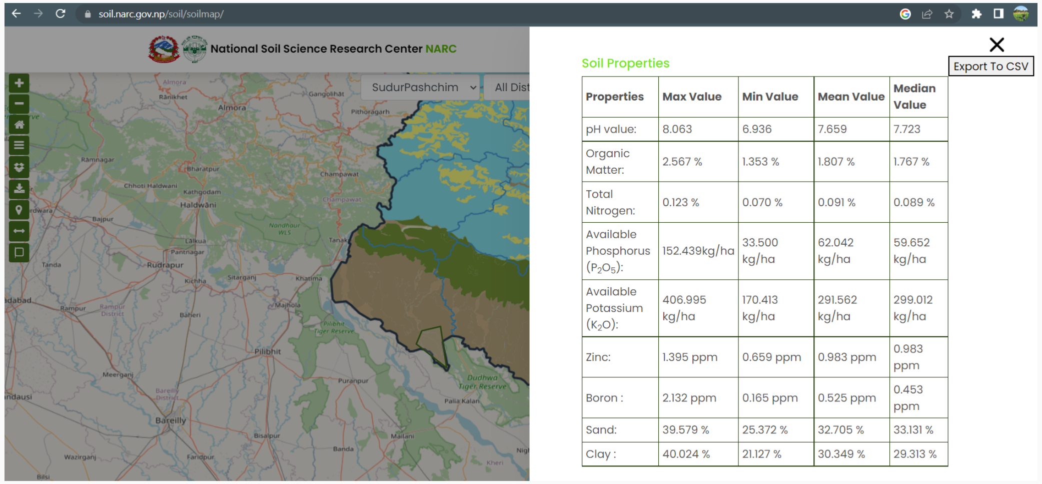


Figure 9: Fertilizer response (FR) as function of maize yield in the unfertilized control plots (a, b) or N application rate (c, d) for Sub-Saharan Africa (a, c) and Kenya (b, d). Dashed lines represent no fertilizer response to the fertilizer (FR = 1). The solid lines describe non-linear relationship function as: FR = $32,244(\text{control yield})^{-0.7}$ with significant associations for Kenya and FR = $83(\text{control yield})^{-0.5}$ with significant associations for Sub-Saharan Africa; Source: Ichami et al. (2019)

- Soil mapping has been widely used to develop statistical models of the relationships between environmental variables and soil attributes.
- Obvious applications of soil mapping include:
  - determining and mapping the spatial distribution of the variability in soil chemical properties of the agricultural lands
  - develop soil test based fertilizer prescription under Integrated Plant Nutrition System (STCR-IPNS) for various crops and soils
  - evaluate the extent to which fertilizer needs of crops can be reduced with the conjoint use of organic manures
  - evaluation of various soil test methods for their suitability under field conditions
- Field level soil sampling and testing services (as campaigns and routine tests) in Nepal are offered by
  - Government organizations (Central Soil Testing Laboratory, Provincial Soil Testing Laboratory, Municipal level soil testing laboratories, National Soil Research Center (NSSRC)-NARC, University Departments (Central Department of Geology))
  - Non-government Organizations
  - Private laboratories

Digital soil map (of Nepal)



Properties	Max Value	Min Value	Mean Value	Median Value
pH value:	8.063	6.936	7.659	7.723
Organic Matter:	2.567 %	1.353 %	1.807 %	1.767 %
Total Nitrogen:	0.123 %	0.070 %	0.091 %	0.089 %
Available Phosphorus (P_2O_5):	152.439kg/ha	33.500 kg/ha	62.042 kg/ha	59.652 kg/ha
Available Potassium (K_2O):	406.995 kg/ha	170.413 kg/ha	291.562 kg/ha	299.012 kg/ha
Zinc:	1.395 ppm	0.659 ppm	0.983 ppm	0.983 ppm
Boron :	2.132 ppm	0.165 ppm	0.525 ppm	0.453 ppm
Sand:	39.579 %	25.372 %	32.705 %	33.131 %
Clay :	40.024 %	21.127 %	30.349 %	29.313 %

Figure 10: Digital soil map of Nepal, showing soil attributes for selected region (South-eastern part of Kailali district). NARC's National Soil Science Research Center (NSSRC) in partnership with USAID's Nepal Seed and Fertilizer (NSAF) project developed the web based application.

- Digital Soil Map (DSM) is a computer-assisted production of digital maps of soil properties. This is developed by using mathematical and statistical models that combine soil information from laboratory analysis with environmental variables (soil forming factors).
- Soil mapping is assisted for realistic appraisal of environmental factors (allowing for adjustment) that affect soil properties.
  - Covariate layers are generated using satellite images (raster data)
  - Important factors are topographic data, vegetation, precipitation, temperature, soil parent material, land cover type, landform classes.
- DSM uses advanced computational algorithms that use both soil sample data and environmental variables to generate maps. It does not only use spatial autocorrelation as the means to interpolate the data, but also considers soil forming factors. Also, the process can be automated so that newer versions of the map can be developed faster once new soil samples are collected. As soil properties are combined with environmental variables, a smaller number of soil samples would be enough to generate DSM compared to conventional soil map.

- Recently 'Digital Soil Map Management Guidelines, 2078' has been implemented.
- Digital soil map for Nepal provides access to location-specific information on soil properties for any province, district, municipality or a particular area of interest. The interactive map provides information that will be useful to make new crop-and site-specific fertilizer recommendations for the country.
  - Soil map: https://soil.narc.gov.np/soil/soilmap/
  - Crop map: https://soil.narc.gov.np/crop/cropmap/
- Spatial resolution of the maps is 250 m.
- Prepared using soil information from 23,273 soil samples collected from the National Land Use Project, Central Agricultural Laboratory and Nepal Agricultural Research Council. The samples were collected from 56 districts covering seven provinces. These soil properties were combined with environmental covariates (soil forming factors) derived from satellite data and spatial predictions of soil properties were generated using advanced machine learning tools and methods.
- Help to increase crop yields and also the nutritional value of these crops

Outline

- Farmers commonly split large, undulating crop fields, even those at similar elevation range or contour, into a patchwork of small sub-plots in plane areas of Nepal.
- Use of hotbeds, coldframes, shade house in horticulture.
- Drone assisted diagnostics and prescription agriculture (DADAPA)
- Cloud marketing system (CMS)

Issues with precision agriculture in Nepal

- Implementation of PA is fundamentally different for developed and developing country.
- Average land holding in Nepal is <0.6 ha per household.
- More than 80% of the farmers are smallholder and are practicing subsistence farming.
- Modern form of precision farming hinges on skilled human resources for its adoption
  - knowledge about IoT and IT technologies
  - use of recent innovations and research
- Lays emphasis on extensive mechanization
- Adds to the cost of smallholder
- Financial support systems are underdeveloped
- Slower adoption rate (social structure); besides being technology averse, smallholders may often hinder the progress of expansion of technology
- Existing infrastructure bottleneck

Possible solutions

- professional human resource development;
- policy initiated and/or supported investments into infrastructure;
- affordable handsets and reduced device costs;
- available and affordable access to Internet for the farmers funded by different institutions (public or donor financed);
- solutions between low- and high-level services (e.g. between SMS and 4 or 5G networks).
- development and open publication of site specific soil maps, supported by public institution.

Outline

Geoinformatics: definition, concepts, tools and techniques and issues in Nepalease agriculture

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Meaning and definition

- Science and technology dealing with the structure and character of spatial information, its capture, its classification and quantification, its storage, processing, portrayal and dissemination, including the infrastructure necessary to secure optimal use of this information.
- Categorized under technical geography
- Relies upon the theory and practical implications of geodesy.
- Geography and earth science increasingly rely on digital spatial data acquired from remotely sensed images analyzed by geographical information systems (GIS), photo interpretation of aerial photographs

- For analysis of geographic information:
  - geospatial analysis and modeling (geocomputation),
  - geovisualization
- Also deals with:
  - development of geospatial databases,
  - information systems design,
  - human-computer interaction and
  - wired and wireless networking technologies

Areas of geoinformatics

- Cartography
- Geodesy
- Satellite navigation
- Photogrammetry
- Remote sensing
- Spatial analysis
- Web mapping
- Navigation

Digital earth

- Digital Earth is the name given to a concept coined by former US vice president Al Gore in 1998, that describes a virtual representation of the Earth that is spatially referenced and interconnected with the world's digital knowledge archives. Furthermore, the greater part of this knowledge store would be free to all via internet.
- The global dimension of the digital earth concept is perhaps best captured by two excerpts from Beijing declaration on digital Earth:
  - Digital earth is an integral part of other advanced technologies including: Earth observation, geo-information system, global positioning systems, communication networks, sensor webs, electromagnetic identifiers, virtual reality, grid computation, etc. It is seen as a global strategic contributer to scientific and technological developments, and will be a catalyst in finding solutions to international scientific and societal issues;
  - Digital earth should play a strategic and sustainable role in addressing such challenges to human society as natural resource depletion, food and water insecurity, energy shortages, environmental degradation, natural disaster response, population explosion, and, in particular, global climate change.

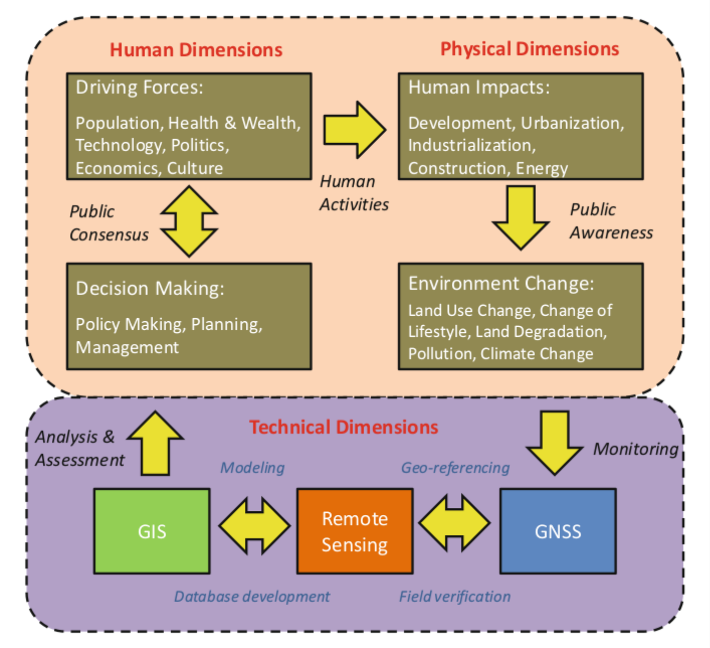


Figure 1: Conceptual framework for wide applications of geo-informatics

Applications

- Urban planning and land use management,
- in-car navigation systems,
- virtual globes,
- public health,
- local and national territory management,
- environmental modeling and analysis,
- military,
- transport network planning and management,
- agriculture,
- meteorology and climate change,
- oceanography and atmosphere modeling,
- business location planning,
- architecture and archaeological reconstruction,
- telecommunications,
- criminology and crime simulation,
- aviation and maritime transport
- biodiversity conservation

- agro-ecological zonation;
- quantitative assessment of soil carbon dynamics and land productivity;
- soil erosion inventory;
- integrated agricultural drought assessment and management.
- cropping system analysis
  - information on existing cropping systems in a region with respect to areal extent of crops,
  - crop vigors/ yield and yearly crop rotation / sequence practices is important for finding out agricultural areas with low to medium crop productivity where sustainable increase in crop production can be achieved by adoption of suitable agronomic management packages including introduction of new crops etc.

Outline

Cartography

- Study and practice of making and using maps. Combining science and aesthetics and technique, cartography builds on the premise that reality can be modeled in ways that communicate spatial information effectively. [1].
- Objectives of traditional cartography:
  - Set the map agenda and select traits (roads, land masses, political boundaries) of the object to be mapped.
  - Represent the terrain of the mapped object on flat media (projection)
  - Reduce the complexity (generalization).
  - Organize the elements of the map to best convey its message (map design)

Design matters!

[1] https://proj.org/usage/projections.html

- Coordinate reference system defines how the visual mapping of spatial data should be done
  - CRS has projection parameters, which is configurable giving a variation in mapping
- Modern cartography constitutes theoretical and practical foundations of GIS and Geographic information science[2].
- EPSG Geodetic Parameter Dataset (also EPSG registry) is a public registry of geodetic datums, spatial reference systems, Earth ellipsoids, coordinate transformations and related units of measurement. Originally created by European Petroleum Survey Group (EPSG). Each entity is assigned an EPSG code between 1024-32767, along with a standard machine-readable well-known text (WKT) representation.

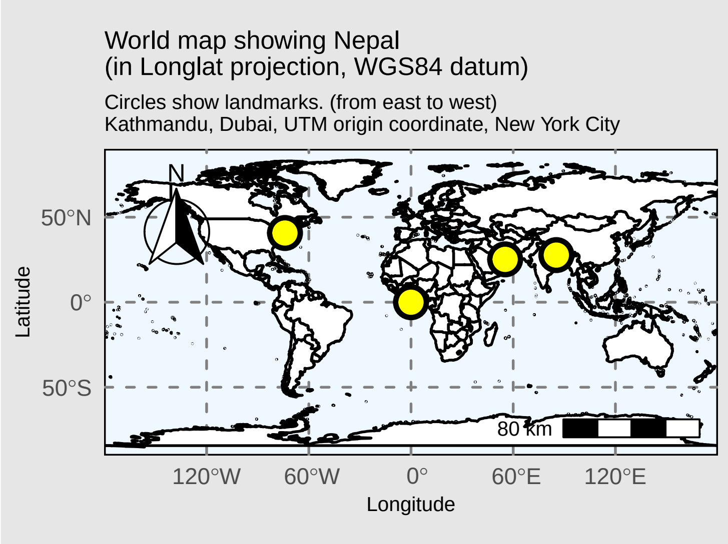
[2] Overview of CRS (in R) is available at: https://www.nceas.ucsb.edu/sites/default/files/2020-04/OverviewCoordinateReferenceSystems.pdf

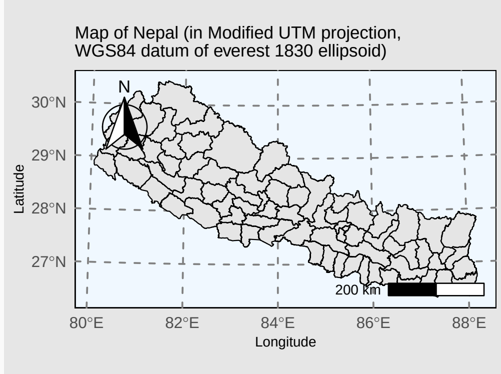
Tools and techniques

Map types

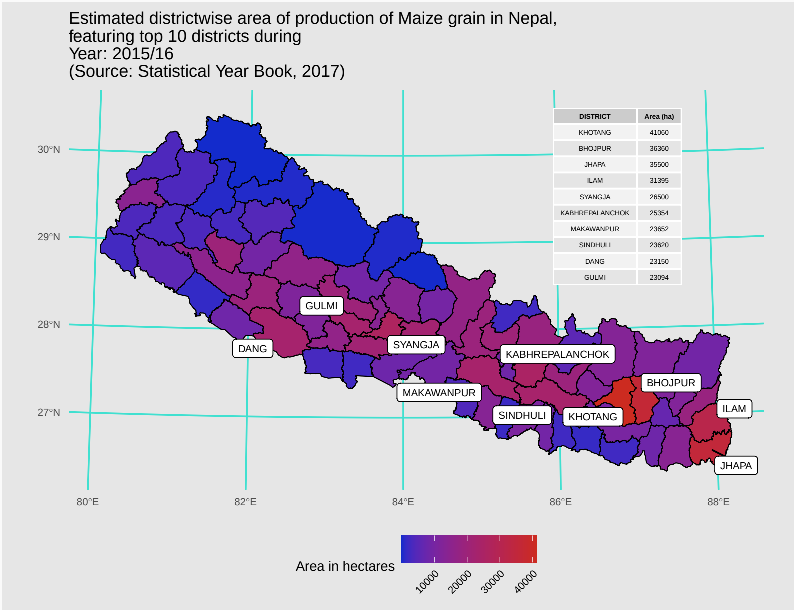
- General vs. thematic cartography
  - General:
    - Intended for general audience and containing a variety of features. Bear many reference and location systems.
  - Thematic:
    - Specific geographic themes
    - Oriented toward specific audiences
    - Dot map showing corn production in different districts of Nepal divided into numerical choropleth classes.
    - With the increasing volume of geographic data, thematic cartography has become increasingly useful and necessary to interpret spatial, cultural and social data

General cartography





Thematic cartography



DISTRICT	Area (ha)
KHOTANG	41060
BHOJPUR	36360
JHAPA	35500
ILAM	31395
SYANGJA	26500
KABHREPALANCHOK	25354
MAKAWANPUR	23652
SINDHULI	23620
DANG	23150
GULMI	23094

Projections

- Projections map the spherical 3D space to a flat 2D space [3].
- Projections are coordinate operations that are technically conversions but since projections are so fundamental to PROJ we differentiate them from conversions.

Projection	Projection	Projection	Projection	Projection	Projection	Projection	Projection	Projection	Projection
Adams Hemisphere in a Square	Cassini (Cassini-Soldner)	Eckert VI	Modified Stereographic of 50 U	Laborde	McBryde-Thomas Flat-Polar Sinusoidal	New Zealand Map Grid	Putnins P4’	Oblique Stereographic Alternative	van der Grinten II
Adams World in a Square I	Central Cylindrical	Equidistant Cylindrical (Plate Carrée)	Guyou	Lambert Azimuthal Equal Area	Mercator	General Oblique Transformation	Putnins P5	Gauss-Schreiber Transverse Mercator (aka Gauss-Laborde Reunion)	van der Grinten III
Adams World in a Square II	Central Conic	Equidistant Conic	Hammer & Eckert-Greifendorff	Lagrange	Miller Oblated Stereographic	Oblique Cylindrical Equal Area	Putnins P5’	Transverse Central Cylindrical	van der Grinten IV
Albers Equal Area	Equal Area Cylindrical	Equal Earth	Hatano Asymmetrical Equal Area	Larrivee	Miller Cylindrical	Oblated Equal Area	Putnins P6	Transverse Cylindrical Equal Area	Vitkovsky I
Azimuthal Equidistant	Chamberlin Trimetric	Euler	HEALPix	Laskowski	Space oblique for MISR	Oblique Mercator	Putnins P6’	Times	Wagner I (Kavrayskiy VI)
Airy	Collignon	Fahey	rHEALPix	Lambert Conformal Conic	Mollweide	Ortelius Oval	Quartic Authalic	Tissot	Wagner II

Projection	Projection	Projection	Projection	Projection	Projection	Projection	Projection	Projection	Projection
Aitoff	Colombia Urban	Foucaut	Interrupted Goode Homolosine	Lambert Conformal Conic Alternative	Murdoch I	Orthographic	Quadrilateralized Spherical Cube	Transverse Mercator	Wagner III
Modified Stereographic of Alaska	Compact Miller	Foucaut Sinusoidal	Interrupted Goode Homolosine (Oceanic View)	Lambert Equal Area Conic	Murdoch II	Patterson	Robinson	Tobler-Mercator	Wagner IV
Apian Globular I	Craster Parabolic (Putnins P4)	Gall (Gall Stereographic)	Interrupted Mollweide	Lee Oblated Stereographic	Murdoch III	Perspective Conic	Roussilhe Stereographic	Two Point Equidistant	Wagner V
August Epicycloidal	Denoyer Semi-Elliptical	Geostationary Satellite View	Interrupted Mollweide (Oceanic View)	Loximuthal	Natural Earth	Peirce Quincuncial	Rectangular Polyconic	Tilted perspective	Wagner VI
Bacon Globular	Eckert I	Ginsburg VIII (TsNIIGAiK)	International Map of the World Polyconic	Space oblique for LANDSAT	Natural Earth II	Polyconic (American)	S2	Universal Polar Stereographic	Wagner VII
Bertin 1953	Eckert II	General Sinusoidal Series	Icosahedral Snyder Equal Area	McBryde-Thomas Flat-Polar Sine (No	Nell	Putnins P1	Spherical Cross-track Height	Urmaev V	Web Mercator / Pseudo Mercator
Bipolar conic of western hemisphere	Eckert III	Gnomonic	Kavrayskiy V	McBryde-Thomas Flat-Pole Sine (No	Nell-Hammer	Putnins P2	Sinusoidal (Sanson-Flamsteed)	Urmaev Flat-Polar Sinusoidal	Werenskiold I
Boggs Eumorphic	Eckert IV	Goode Homolosine	Kavrayskiy VII	McBride-Thomas Flat-Polar Parabolic	Nicolosi Globular	Putnins P3	Swiss Oblique Mercator	Universal Transverse Mercator (UTM)	Winkel I
Bonne (Werner lat_1=90)	Eckert V	Modified Stereographic of 48 U	Krovak	McBryde-Thomas Flat-Polar Quartic	Near-sided perspective	Putnins P3’	Stereographic	van der Grinten (I)	Winkel II
Cal Coop Ocean Fish Invest Lines/Stations									Winkel Tripel

- Projections are generally given a name so that they can be easily identified and referenced on a map.
  - named after the person(s) who invented them (eg Mercator); or aspects of the projection (eg Equidistant Conic); or a combination of the two (eg Lambert Conformal Conic).
- All projections result in some distortion of the relationships between features on the sphere when they are projected onto a flat surface. These distortions include:
  - direction between a feature and surrounding features
  - distance between a feature and surrounding features
  - shape of any feature
  - size of any feature
- Only ‘projection’ which has all the features without distortion in a globe.
- This problem is in part due to the changing relationship between latitude and longitude.
  - Near the Equator a ’block’ of $1^\circ \times 1^\circ$ latitude and longitude is almost a square, while the same ’block’ near the poles is almost a triangle.
- Technical terms used to describe the line of latitude or longitude where this imaginary ‘piece of paper’ touches the Earth are:
  - latitude – standard parallel
  - longitude – central meridian

Basic Projection Types

- This describes how a map shows the positional relationship between two features, and their size and shape.
- Depending on their intended use, projections are chosen to preserve a particular relationship or characteristic. These include:
  - Equal-Area: correctly shows the size of a feature
  - Conformal: correctly shows the shape of features (A map can not be both equal-area or conformal – it can only be one; or the other; or neither.)
  - Equidistant: correctly shows the distance between two features
  - True Direction: correctly shows the direction between two features

Basic Projection Techniques

- For an imaginary ‘piece of paper’ touching the Earth, there are 3 basic techniques used to create a projection and therefore a map. These are:
  - azimuthal: the imaginary ’piece of paper’ is flat, this is usually used over Polar areas
  - conical: the imaginary ’piece of paper’ is rolled into a cone, this is usually used in mid-latitude areas (approximately $20^\circ - 60^\circ$ North and South)
  - cylindrical: the imaginary ’piece of paper’ is rolled into a cylinder, this is usually used over Equatorial areas or for World Maps
- Each of the basic techniques have different distortions and therefore limitations to their use.

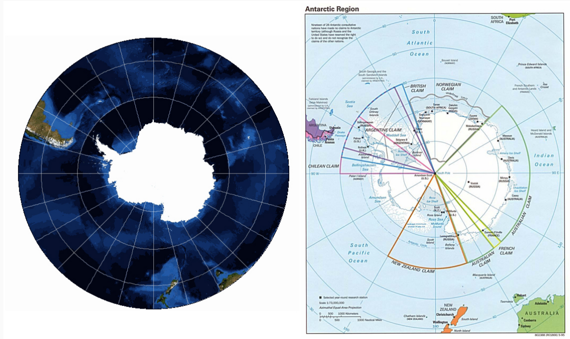


Figure 2: Azimuth is a mathematical concept with relates to the relationship between a point and the ‘flat piece of paper’ that ’touches’ the Earth. Maps produced using Azimuthal Projections (often called polar projections) techniques have lines of longitude fanning out from the centre and lines of latitude as concentric circles. It is usually measured as an angle. The projection have distortions increasing away from the central point.

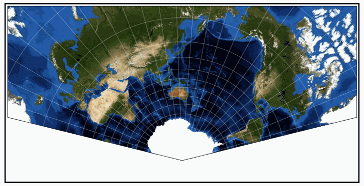
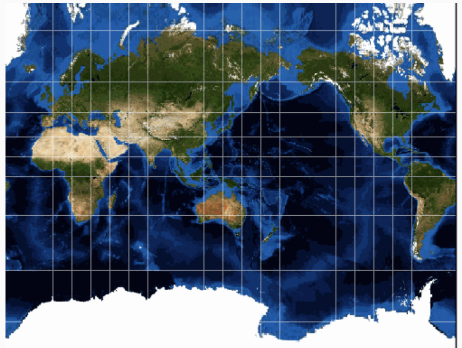
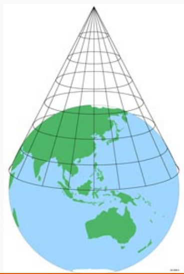


Figure 3: This map is centred on central Australia and the Standard Parallel is 25° South. Note how the shapes of land masses near the Standard Parallel are fairly close to the true shape when viewed from space. This includes Australia, South America and the ’tip’ of Africa. Also note how land masses furthest away from the Standard Parallel are very distorted when compared to the views from space. Particularly note how massively large northern Canada and the Arctic icecaps look.





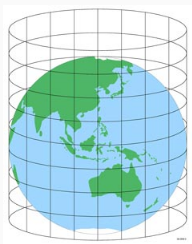


Figure 4:
This follows the concept of a ’piece of paper’ being rolled into a cylinder and touching the Earth on a circular line. Notice the huge distortions in the Arctic and Antarctic regions, but the reasonable representation of landmasses out to about 50° north and south. Projection information: Mercator; centred on 140° East and the Standard Parallel is the Equator

Mercator projection

- Standard map projection for nautical purposes because of its ability to represent lines of constant true direction.
- The cylinder is usually positioned over the Equator, but this is not essential (but always has the Equator as its Standard Parallel).
- Its construction is such that the lines of longitude and latitude are at right angles to each other - this means that a world map is always a rectangle.
- The lines of longitude are evenly spaced apart. But the distance between the lines of latitude increase away from the Equator.
- Despite some distortions the Mercator projection is generally regarded as being a conformal projection. This is because within small areas shapes are essentially true.
- Tiles from Google Maps, Open Street Maps, Stamen map are projected in Mercator (assigned EPSG code: 3857)

Universal Traverse Mercator (UTM) projection

- UTM coordinate comprises a zone number, a hemisphere (N/S), an easting and a northing. Eastings are referenced from the central meridian of each zone, & northings from the equator, both in metres. To avoid negative numbers, ‘false eastings’ and ‘false northings’ are used:
- Eastings are measured from 500,000 metres west of the central meridian. Eastings (at the equator) range from 166,021m to 833,978m (the range decreases moving away from the equator); a point on the the central meridian has the value 500,000m.
- In the northern hemisphere, northings are measured from the equator - ranging from 0 at the equator to 9,329,005m at 84 degree N). In the southern hemisphere they are measured from 10,000,000 metres south of the equator (close to the pole) - ranging from 1,116,915m at 80 degree S to 10,000,000m at the equator.
- Nepal lies in the UTM zone of 440N and 450N. The scale factor is 0.9996 for the central meridian. 10 49’ east or west of central meridian has the scale factor of 1.
- Norway/Svalbard: the designers of UTM made two exceptions to the rule. The part of zone 31 covering western Norway is transferred to zone 32, and the zones covering Svalbard are tweaked to keep Svalbard in two zones (it’s easier to understand looking at a map). These widened zones are viable partly because zones are much narrower so far north, so little precision is lost in merging them.

Coordinate reference system (CRS)

- Latitude/Longitude
  - WGS84 (EPSG: 4326)
  - Commonly used by organizations that provide GIS data for the entire globe or many countries. CRS used by Google Earth
- NAD83 (EPSG:4269)
  - Most commonly used by U.S. federal agencies.
- NAD27 (EPSG: 4267)
  - Old version of NAD83
- Projected (Easting/Northing)
  - UTM, Zone 10 (EPSG: 32610)
  - Zone 10 is used in the Pacific Northwest

```
## Coordinate Reference System:
##   User input: EPSG:26919
##   wkt:
## PROJCRS["NAD83 / UTM zone 19N",
##     BASEGEOGCRS["NAD83",
##         DATUM["North American Datum 1983",
##             ELLIPSOID["GRS 1980",6378137,298.257222101,
##                 LENGTHUNIT["metre",1]]],
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##         ID["EPSG",4269]],
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##         METHOD["Transverse Mercator",
##             ID["EPSG",9807]],
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##             LENGTHUNIT["metre",1],
##             ID["EPSG",8806]],
##         PARAMETER["False northing",0,
```


Use in precision agriculture

1. Agricultural mapping
   - Current and future variations in the rainfall
   - Crop output and temperature of the soil
   - Farm resource and structure mapping
2. Soil analysis
   - Mapping of soil type and crop suitability
   - Nutrient and fertilizer status mapping
3. Data combination
   - Realistic appraisal of farm production to assist insurance
   - Farmers could access data of their crops across the seasons to compare and contrast

4 Increased interaction

- Humans have better sense of space and time than any other variables
- Using machinery and GIS (including on-ground data), interventions could be more efficiently and effectively applied.

5 Assembly of information to develop systems based models

- Various layers of information such as soil moisture, nutrients, elevation, topography, irradiance, cloud cover, etc. could aid in feeding into growth models
- These could be translated into recommendation systems for precise implementation.

6 Real-time mapping
7 Raising alert and disaster mapping
8 Historical data comparison
9 Boosting production

Outline

Current state

- GIS based technology has already permeated through engineering discipline and seen its applications.
- Recently, natural resource management (forest, watershed) operations also have begun making use of geo-spatial data.
  - tracking of forest and shrubland coverage using geo-spatial data
  - monitoring of wildlife species using GPS tracker
- Agriculture have a long experience of poor information management system, which is in-part responsible for its dwindling state

Issues and concerns

- Although input availability and use are major factors affecting production, decision making on farmer level regarding these issues are still not informed by data
- Most farmers are resource poor and non-commercial cultivators
  - only heavily mechanized farmholds can exploit technology at fullest.
  - geoinformatic technologies only provides benefit at scales
- Data management and computational environments are not tailored for use among farmers in Nepal
- Only limited open database provide contextual data relevant for Nepal
- Data publications by government institution are very unorganized and contingent.
- Data privacy issues

- Most farmers are reluctant to trust computer or digital systems for decision making, due to
  - farmers do not have knowledge of how information systems work
  - systems being still immature have sometimes produced unreliable outcomes
- Government is still ignorant of the possibilities geo-informatics has for agriculture system

Outline

Crop discrimination, crop cutting, yield monitoring, soil mapping

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Outline

Outline

Crop area and crop production assessment

- Information about crop area and production is crucial for planning of economic development initiatives, allocation of resources and monitoring the achievements
- Area and production statistics has great importance for planners
  - preparation of national accounts of food crops
  - decision making on export/import and price
  - day to day management of the crop sector
- Statistical Information on Nepalese Agriculture (the annual agri-statistics publication) hosts acerage, crop production and basic farming household statistics.
- The data collection is entrusted to extension staff, who carry out crop cut **surveys** to assess crop yield.

- Crop cutting surveys are field surveys in which production data are collected through direct measurement for estimating yield of major field crops, paddy and wheat.
- The technique was developed during 1940s and 1950s.
- A **plot** is **randomly** selected of a given size in the field of a specific crop and its produce is harvested following specified methodology.
- The harvested yield rate is calculated as the weight of the harvested crop divided by the area of the plot.

$$\text{Estimated crop yield} = \frac{\text{Weight of harvest crop}}{\text{Area of the selected plot}}$$

Steps in Crop-cutting

- Selecting a field of mature crop ready for harvest
- Identifying the south-west corner of field from where crop cut has to be done
- Randomly demarcating the crop-cutting plot of a specified size (generally 10 or 20 msq)
- Meticulously determining the plants to be included in the crop-cut plot
- Harvesting of crop cut plot
- Threshing and winnowing to get cleaned harvest
- Weighing and adjusting the harvet to a specified level of moisture content
- Converting the harvest to a standard unit, for example tons per hectare.

Crop cutting survey design and selection

- The design adopted in the survey is stratified multi-stage random sampling
  - Districts are taken as strata
  - Specific local units (municipalities) are the first stage units
  - Fields growing the crop under crop cutting experiments are the second stage units
  - Experimental plots of specified size are the ultimate stage units
- In the strata, list of all villages with area growing the experimental crop is obtained
- Generally in a district with 30 local units, 8-10 municipals are selected by SRS.
- In field selection, agriculture technician proceeds to the selected village.
  - Cultivators are listed and serial number assigned to their fields
  - Fields are selected by SRS

General considerations

- Area of selected field should be more than the total area of CCE plot.
- The experimental crop in the field is not meant for seed production or demonstration.
- If experimental crop is not germinated or has failed (cattle or pest damaged, affected by disease or heavy rainfall, inadequate rainfall), field is still considered for selection.
- The crop cutting experiment should not be conducted in the selected field if a part or whole of the selected field has already been harvested.

Locating of experimental plot

- Identification of south-west corner of the field (for consistency purpose in all surveys)
- Start from SW corner of the field and measure in steps the length and breadth of the field
- From the total number of steps of both length and breadth, deduct seven steps from each
- Select experimental plot randomly (using a pair of random numbers to locate row-column combination)
  - for example, if the length is 86 steps, the remainder is 86-7 = 79 and the breadth is 45 steps the remainder is 45-7 = 38
  - select two random numbers one for length (<79) and other for breadth (<38)
  - locate the plot based on selected pair of numbers, and fix a peg at that point.

Harvesting and yield estimation

- Harvested when crop is fully mature
- Date is fixed by the field assistant in consultation with the cultivators concerned
- Produce from the plot is harvested before the harvest of the entire field
- Threshing, winnowing, weighing of the harvested produce and recording of green/fresh produce
- Driage experiments are performed to get marketable form of produce from cultivating fields.
  - dry a fixed quantity of harvested produce (generally 1 kg) in the experimental plot by keeping the produce for a few days for drying and weighing the produce everyday till the weighings on two successive days reveal “negligible” reduction in weight

- Weight of marketable produce of crop may be obtained by applying the moisture level recorded with the moisture meter to the normal level of moisture of the produce as per:

$$WG_{14\%} = FW \times \frac{100 - MCG}{100 - 14} = FW \times \frac{100 - 20}{100 - 14}$$

where:

- FW = Fresh weight,
- MCG (in %) = Moisture content of grain when fresh (say 20%),
- WG_{14} (in %) = Weight of grain adjusted to 14% moisture content.

Crop cutting

Requirements for crop cutting experiment

- Measuring tape (~30m and above)
- Weighing balance
- Small gunny bags for driage experiment
- Hessian cloth
- Four straight, long bamboo pegs each of 1m length with spikes at one end and irron collars at the other end.
- Record book

Estimation

- In countries with regular agricultural reporting system, crop area (A) is obtained from records on complete enumeration basis.
- Average crop yield (Y) is estimated by CCE on a sample basis.

$$\text{Crop production}(P) = A \times Y$$

- In countries where cadastral maps are available not no regular reporting system, both A and Y are estimated on the basis of sample surveys.
- Usually large sample of villages (primary units) is selected for crop area estimation. This provides estimate of A
- CCE are carried out in a sub-sample of the primary units selected for area enumeration. This provides estimate of Y.

Estimation

- Estimating yield from a district survey:
  - Number of stratum (s): S
  - Area under the crop in the s^{th} stratum: a_s
  - Number of villages (i): n_s
  - Number of field (j) in the i^{th} village: n_{si}
  - Experimental plot selected

If y_{sij} be the observed yield from the selected plot of the j^{th} field of the i^{th} village of the s^{th} stratum, then

Estimated average of green yield for the s^{th} stratum is:

$$\hat{\hat{Y}}_s^g = \frac{1}{n_s}\sum_{i=1}^{n_s}\frac{1}{n_{si}}\sum_{j=1}^{n_{si}} y_{sij}$$

Estimate of the district level average yield of the dry marketable produce per hectare is given by:

$$\hat{\hat{Y}}^m = d \times f \times \frac{\sum_{s=1}^{S} a_s \hat{\hat{Y}}_s^g}{\sum_{s=1}^{S} a_s}$$

Where:

- d: driage ratio,
- f: conversion factor for green yield to dry marketable produce per hectare i.e. rice = 2/3 of paddy.

Remote sensing for crop cut surveys

- Utility of remote sensing data to identify areas under specific crops can be understood with following assessment:

“Any crop can be mapped with multispectral scanner data if, and only if, the spectral values associated with the crop are detectably different from the values of the other features to be mapped.”

- Concept of “ground truth” or reference data is essential to reliable identification of data.

Outline

- Cells in plant leaves effectively scatter light because of the high contrast in the index of refraction between water-rich cell contents and inter-cellular air spaces.
- Plants that are engaged in photosynthesis use blue and red light as energy sources. They reflect little light back from these wavelengths.
- The underlying principle for using NIR is that plants with different nutrient levels reflect light differently in specific wavelengths.

Direct advantages

- Fast and non-destructive,
- Once calibrated correctly, reliably measures biophysical and biochemical vegetation variables
- Covers a large spatial area at once
- Temporal imaging helps analyze crop growth processes

- Researchers use portable spectroradiometer such as the PSR+ to study vegetation in-situ and confirm, modify, and better understand hyperspectral remote sensing data from satellites such as Sentinel, or plane flyovers.
- By capturing and analyzing data such as leaf area index (LAI) and canopy chlorophyll content, vegetation can be modeled and compared to vegetation indices to reveal
  - health, stress, infestation, pollution, climate changes, drought, fertilization, etc.
- Following indices are used to describe the state of vegetation:
  - NDVI (Normalized Difference Vegetation Index),
  - SR (Simple Ratio),
  - SAVI (Soil Adjusted Vegetation Index),
  - ARVI (Atmospherically Resistant Vegetation Index)

Figure 1: PSR-1100f Spectral Evolution spectroradiometer commonly used in remote sensing of vegetation.

- Vegetation extraction from remote sensing imagery is the process of extracting vegetation information by interpreting satellite images based on the interpretation elements such as the image color, texture, tone, pattern and association information, etc.
- Diverse methods (broadly grouped) either as supervised or as unsupervised depending on whether or not true ground data are inputted as references.
- General steps involved in vegetation mapping include
  - image preprocessing (improve the quality of original images, highlighting the distinguishing features)
  - image classification (results in the assignment of each pixel of the scene to one of the vegetation groups defined in a vegetation classification system or a membership matrix of the vegetation groups if fuzzy classification is adopted)

Normalized difference vegetation index

- NDVI is a simple graphical indicator that can be used to analyze remote sensing measurements, assessing whether or not the target being observed contains live green vegetation – hence provides measurement of crop health.
- Current research has proved that the NDVI images can even be obtained using the normal digital RGB cameras by some modifications in order to obtain the results similar to those obtained from the multispectral cameras
- First normalized difference spectral index was formulated by Kriegler et al. in 1969.
- Rouse et al. first applied the NDVI in the great plains in 1973.

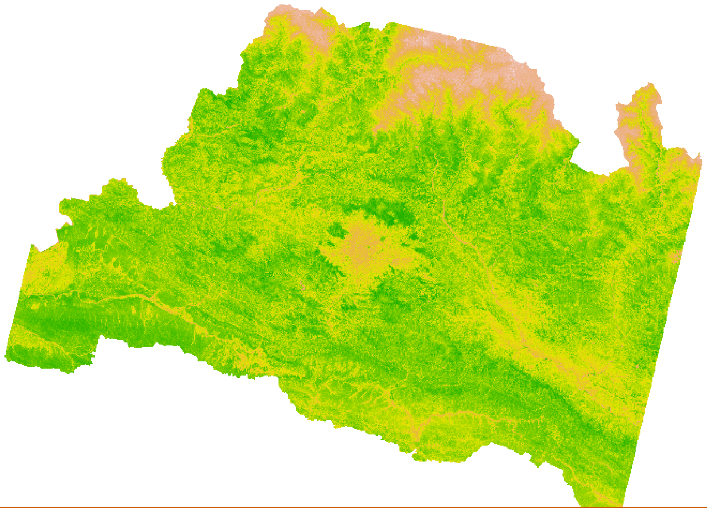
- Green plants absorb solar radiation in the PAR spectral region and wavelengths longer than about 700 nm are too large to be used, hence reflected back.
- Live green plants appear relatively dark in the PAR and relatively bright in the near-infrared
- By contrast, clouds and snow tend to be rather bright in red (and visible wavelengths) and quite dark in the NIR.
- Early instruments of Earth Observation, such as NASA’s ERTS and NOAA’a AVHRR, acquired data in visible and near-infrared spectrum. Strong differences in plant reflectance was then used to determine their spatial distribution.

NDVI is calculated from these individual measurements as follows:

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

where Red and NIR stand for the spectral reflectance measurements acquired in the red (visible) and near-infrared regions, respectively. These spectral reflectances are themselves ratios of the reflected radiation to the incoming radiation in each spectral band individually, hence they take on values between 0 and 1. By design, the NDVI itself thus varies between -1 and +1.

NDVI of Bagmati Province (April 25, 2022)



Practical – NDVI (of Bagmati Province) calculation in QGIS

Refer to the qgis project file “qgis_bagmati_province_LC09_raster,” for use in calculation of NDVI.

Outline

(Refer to the section on STCR in Lecture 1.)

Outline

Remote sensing: concepts and applications; Image processing and interpretation

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Outline

Outline

Background

- History may be traced back to the first pre-historic explorer who climbed a nearby hill to study the lay of the land.
- During first half of 19th century, Louis Jacques Mande Daguerre and Joseph Nicephore Niepc invented a photographic device, a foundation for modern photography and a means to record a remotely sensed image.
- In 1859, Gaspard Félix Tournachon Clateu (later known in the literature as Félix Nadar) took the first known aerial image from a balloon.

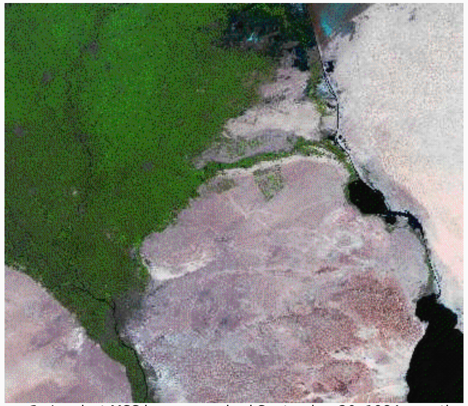


Figure 1: Landsat MSS image acquired September 20, 1984 over the Nile Delta area.

Meaning

- Remote sensing provides data at a synoptic global level that is impossible to replicate with in situ measurements.
- Remote sensing imagery used for the identification of earth surface features is dependent upon measurable variations in electromagnetic field strength. Variations are mainly three types:
  1. Spectral
  2. Spatial
  3. Temporal

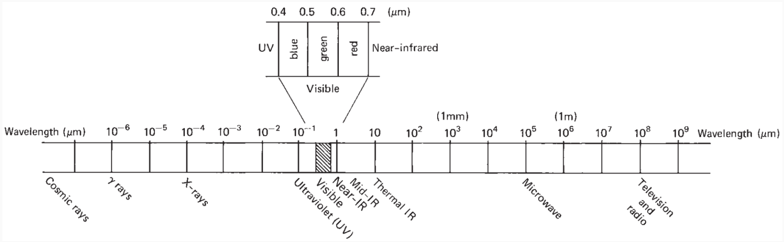


Figure 2: Electromagnetic spectrum

(Refer to Section 1.2 of Lillesand, Kiefer, and Chipman (2015) for “Energy sources and radiation principles” and 1.3 and 1.4 for detailed exploration of theoretical basis of electromagnetic wave information generation.)

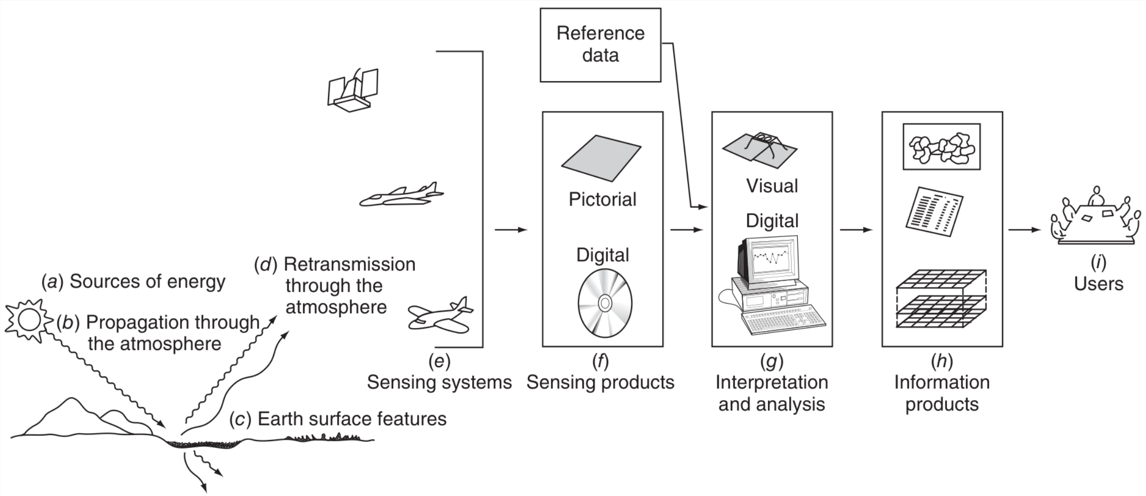


Figure 3: Electromagnetic remote sensing of earth

- As developments in novel image processing algorithms and community around use and communication of image data continue, scientific value of remotely sensed data grow to the extent that never anticipated information are extracted.
- However, there are tradeoffs between the local detail of the measurements (radiometric resolution, number of spectral bands) and the spatial scale of the area being measured.
- Remote sensing is a more rapid means to sample multiple crop parameters from spectral indices such as NDVI.
  - Productive canopy surface (LAI)
  - Productivity and yield potential
  - Photosynthetic capacity

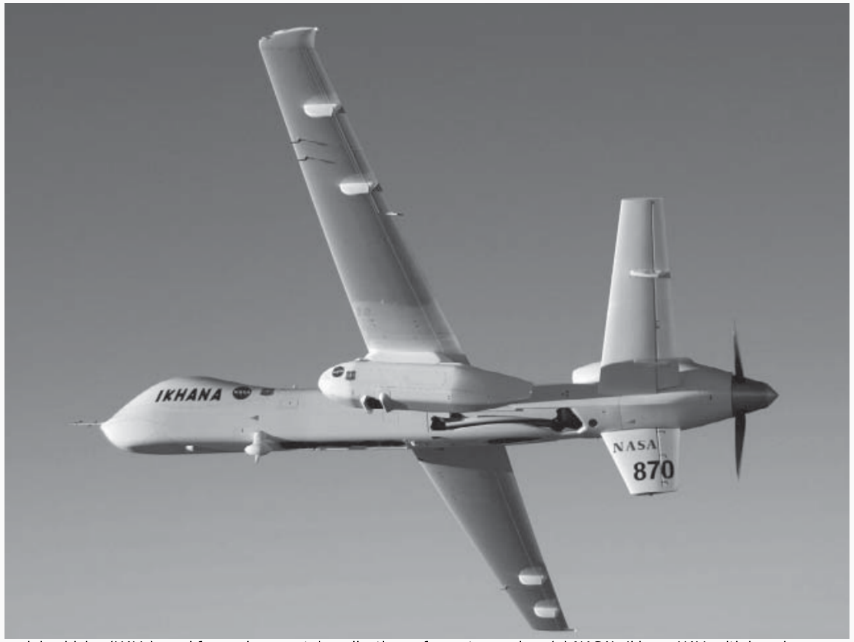


Figure 4: Uninhabited aerial vehicles (UAVs) used for environmental applications of remote sensing. (a) NASA's Ikhana UAV, with imaging sensor in pod under left wing.

Area calculation

- Process of measuring areas using aerial photographs can be accomplished in many ways.
- Accuracy of area measurement is a function of not only the measuring device used, but also the degree of image scale variation due to relief in the terrain and tilt in the photography.
  - accurate measurements are obtained from vertical photos of areas of low relief
- Simple scales may be used to measure the are of simply shaped features
  - area of a rectangular field can be determined by simply measuring its length and width
  - area of circular feature can be computed after measuring its radius or diameter

Numerical problem

A rectangular agricultural field measures 8.65 cm long and 5.13 cm wide on a vertical photograph having a scale of 1:20000. Find the area of the field at ground level.

$\longrightarrow$

Ground length $=$ Photo length $\times \frac{1}{S} = 0.0865m \times 20,000 = 1730m$

Ground width $=$ Photo width $\times \frac{1}{S} = 0.0513m \times 20,000 = 1026m$

Ground area $= 1730m \times 1026m = 1,774,980m^2 = 177ha$

- For measuring irregularly shaped features, a simplest technique uses transparent grid overlay consisting of lines forming rectangles or squares of known area.
- The grid is placed over the photograph and the area of a ground unit is estimated by counting the number of grid units that fall within the unit to be measured.

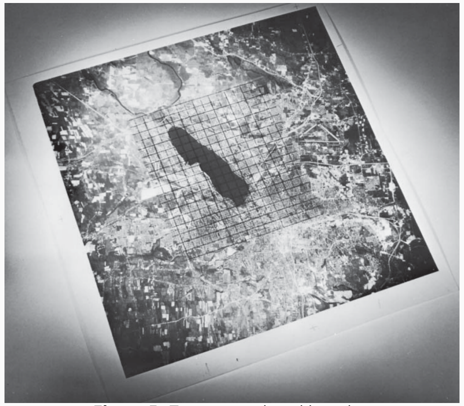


Figure 5: Transparent dot grid overlay.

Numerical problem

A flooded area is covered by 129 dots on a $25-\mathrm{dot}/\mathrm{cm}^2$ grid on a 1:20,000 vertical aerial photograph. Find the ground area flooded.

$\longrightarrow$

Dot density $= \frac{1\ \mathrm{cm}^2}{25\ \mathrm{dots}} = 16,000,000\ \mathrm{cm}^2/\mathrm{dot} = 0.16\ \mathrm{ha}/\mathrm{dot}$

Ground area $= 129$ dots $\times\ 0.16\ \mathrm{ha}/\mathrm{dot} = 20.6\ \mathrm{ha}$

Landsat imagery

- 2022 marks 50th anniversary of the continuous planetary land coverage gathered by the Landsat imaging system.
- Instruments on the Landsat satellites have acquired millions of images and can be viewed through the U.S. Geological Survey (USGS) “EarthExplorer” [1] website.
- Current version of the landsat (Landsat-9) was launched in September 27, 2021
- Currently Landsat program is managed jointly by:
  - NASA
  - USGS
- Landsat 7 data has eight spectral bands with spatial resolutions ranging from 15 to 60 m (49 to 197 ft); the temporal resolution is 16 days.
- Landsat images are usually divided into scenes for easy downloading. Each Landsat scene is about 115 miles long and 115 miles wide (or 185 kilometers long and 185 kilometers wide).
- Landsat imagery is coarse in spatial resolution compared to using other remote sensing methods, such as imagery from airplanes.

[1] https://earthexplorer.usgs.gov/

Applications of Landsat imagery

- Agriculture risk management
- Government mapping
- Agricultural water use monitoring
- Global security monitoring
- Support for fire management
- Detection of forest fragmentation
- Detection of forest change
- World agriculture supply and demand estimates
- Vineyard management and water conservation
- Flood mitigation mapping
- Agricultural commodities mapping
- Waterfowl habitat mapping and monitoring
- Coastal change analysis
- Forest health monitoring
- Wildfire risk assessment
- Fisheries, forestry, shrinking inland water bodies, fire damage, glacier retreat, urban development, and discovery of new species

Table 1: Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). TIRS bands are acquired at 100 meter resolution, but are resampled to 30 meter in delivered data product

Bands	Wavelength (micrometers)	Resolution (meters)
Band 1 - Ultra Blue (coastal/aerosol)	0.435 – 0.451	30
Band 2 - Blue	0.452 – 0.512	30
Band 3 - Green	0.533 – 0.590	30
Band 4 – Red	0.636 – 0.673	30
Band 5 – NIR	0.851 – 0.879	30
Band 6 – SWIR 1	1.566 – 1.651	30
Band 7 – SWIR 2	2.107 – 2.294	30
Band 8 – Panchromatic	0.503 – 0.676	15
Band 9 – Cirrus	1.363 – 1.384	30
Band 10 – Thermal 1	10.60 – 11.19	100* (30)
Band 11 – Thermal 2	11.50 – 12.51	100* (30)

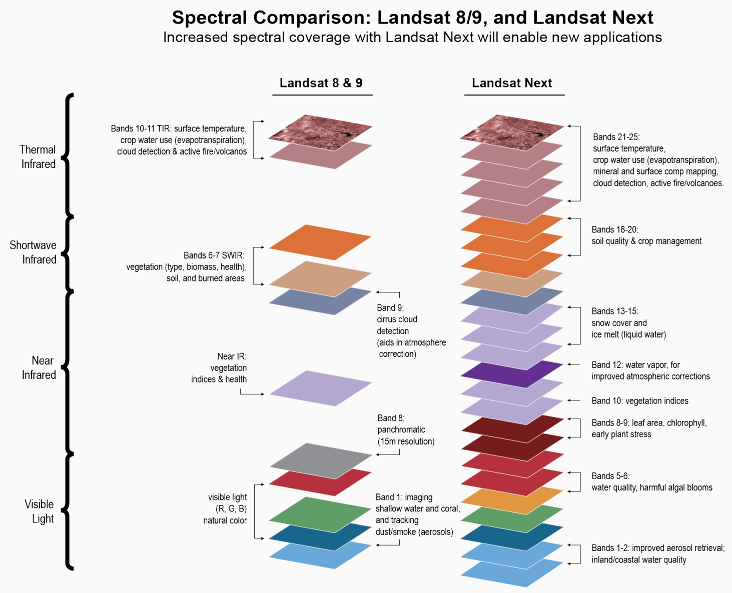
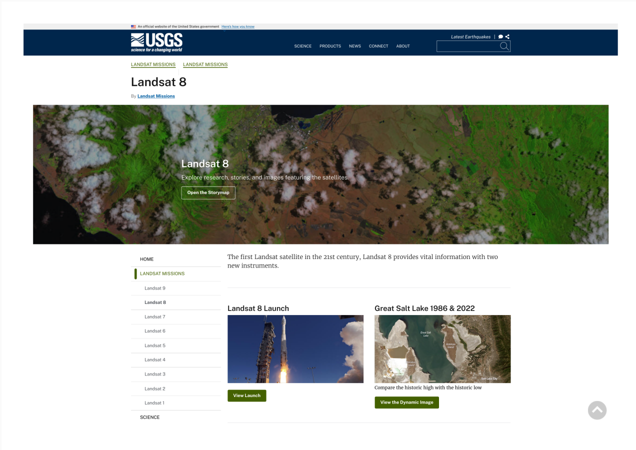
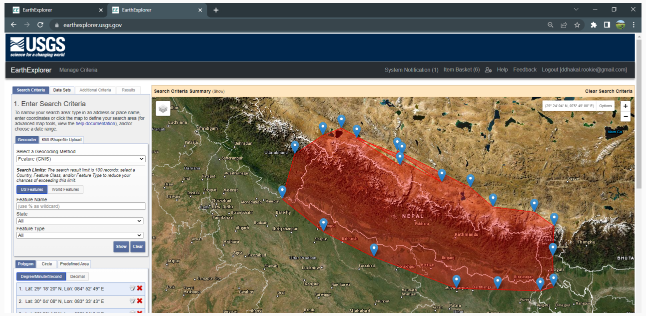


Figure 6: Source: https://upload.wikimedia.org/wikipedia/commons/8/88/L8and9-to-LandsatNext-BandComparison.png

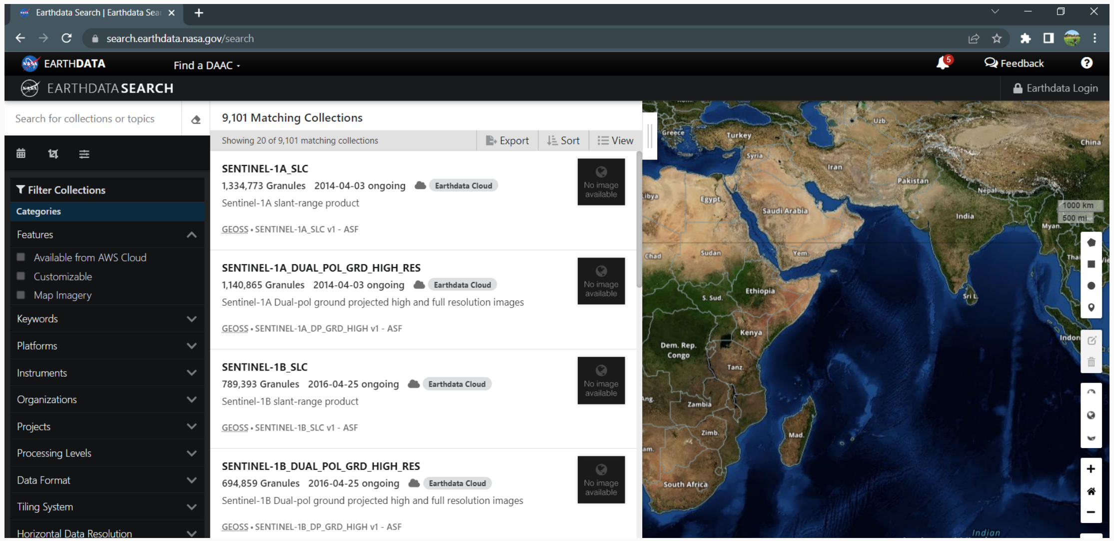
Outline

Landsat Missions of USGS



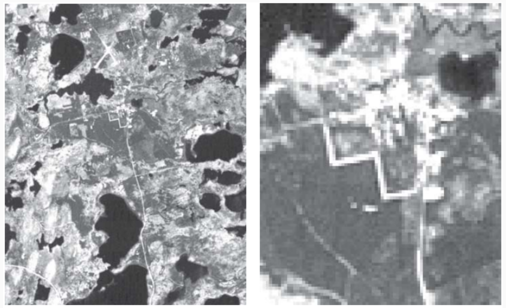


Sentinel mission of NASA



Outline

- An image is generic term for any pictorial representation of data.
  - a pictorial record from a “thermal scanner” (electronic scanner) would be called a “thermal image.”
- Not all images are photographs. (Try calling a ‘thermal image’ a ‘thermal photograph!’)
- Spectral characteristics are not always fully evaluated in visual interpretation efforts because of the limited ability of the eye to discern tonal values on an image and the difficulty of simultaneously analyzing numerous spectral images.
- In applications where spectral patterns are highly informative, it is therefore preferable to analyze digital, rather than pictorial.



34	36	35	36	39	46	35	37
36	38	34	31	32	38	32	30
32	31	33	35	37	37	35	30
32	35	44	57	56	38	30	28
57	58	55	60	65	42	26	26
50	47	39	37	60	48	28	27
26	27	25	23	51	51	32	26
26	28	28	22	43	54	36	25
27	26	28	23	37	54	37	24
28	26	26	24	31	53	40	25

Figure 7:
The image shown in upper left is actually composed of a two-dimensional array of discrete picture elements, or pixels. They intensity of each pixel corresponds to the average brightness, or radiance, measured electronically over the ground area corresponding to each pixel. A total of 500 rows and 400 columns of pixels are shown. Whereas the individual pixels are virtually impossible to discern in first image, they are readily observable in the enlargements shown in upper right (100 row x 80 column) and lower left (10 row x 8 column). These enlargements correspond to sub-areas located near the center of the first image. In the lower right is shown the individual *digital number (DN)* also referred to as 'brightness value' or 'pixel value' – corresponding to the average radiance measured in each pixel shown on the left. These values result from quantizing the original signal from the sensor into positive integer values using a process called 'analog-to-digital (A-to-D) signal conversion'.

Preprocessing

- To remove noise and increase the interpretability of image data (essential when a time series of imagery is used or when when multiple image operation such as join is required to account for an area encompassed by many images to make these images compatible spatially and spectrally)
- All images after image preprocessing should appear as if they were acquired from the same sensor (Hall et al. 1991).
- Image processing sensors are usually categorized into levels (0, 1A, 1B, 2A, 2B, 3A, 3B with image quality gradually increased). For example, for most sensors, level 3A means that radiometric correction, geometric correction and orthorectification have been processed for the images.
- Factors such as seasonal phenology, ground conditions and atmospheric conditions can contribute to variability in multi-temporal spectral responses that may have little to do with the remote sensed objects themselves (Song and Woodcock 2003)

- Image preprocessing commonly comprises a series of operations,
  - including but not limited to bad lines replacement,
  - radiometric correction,
  - geometric correction,
  - image enhancement and masking (e.g. for clouds, water, irrelevant features) although variations may exist for images acquired by different sensors.
  - bad line replacement (fills in missing lines with the line above, below or with an average of the two) to determine the overall quality of the images (e.g. missing data lines) through visually previewing the images band-by-band
  - cloud imposes a big noise in mapping vegetation cover for identifying and thus has to be removed or masked.
    - neural network to detect cloud in SPOT VEGETATION images
    - cloud-free space shuttle photograph to detect and remove (mask) unwanted cloud covers in Landsat TM scenes

Image pre-processing: Radiometric correction

- radiometric correction normally involves the process of correcting radiometric errors or distortions of digital images to improve the fidelity of the brightness values. radiometric correction methods (absolute and relative correction):
  - complex mathematical models that describe the main interactions involved (certain parameters (i.e. the atmospheric composition) must be known before applying them).
  - methods based on the observations of reference targets (e.g. water or desert land) whose radiometry is known.

Image pre-processing: Geometric correction

- geometric correction to avoid geometric distortions from a distorted image and is achieved by establishing the relationship between the image coordinate system and the geographic coordinate system using the calibration data of the sensor, the measured data of position and altitude and the ground control points

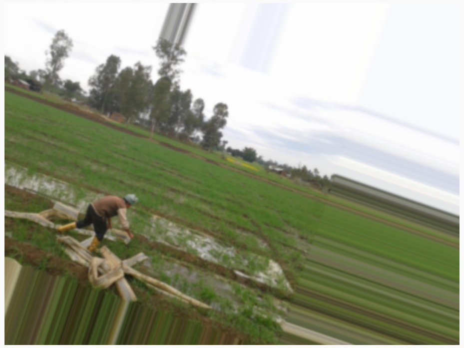


Image pre-processing: Image enhancement

- image enhancement is aimed to emphasize and sharpen particular image features (i.e. particular species of vegetation) for visualization purpose
  - gray scale conversion,
  - histogram conversion,
  - color composition,
  - color conversion between red-green-blue (RGB), and
  - hue–saturation–intensity transform (HSI), etc.

Outline