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

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Outline

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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.

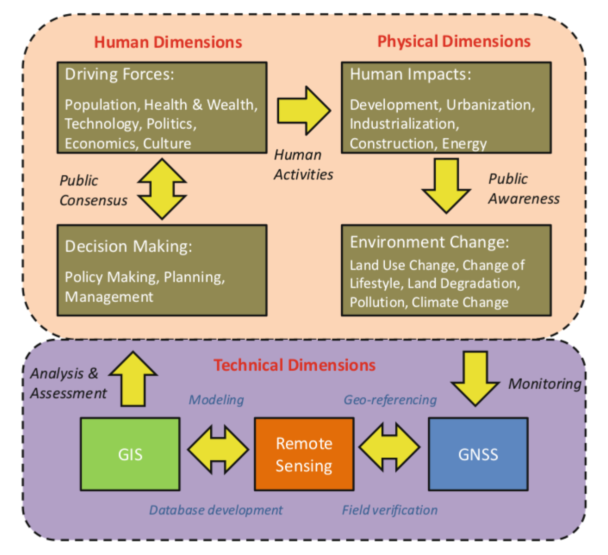

Figure 1: Conceptual framework for wide applications of geo-informatics

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.

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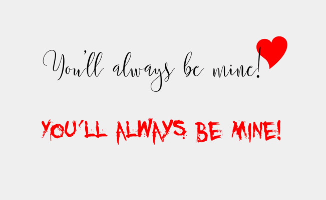
Cartography

- 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

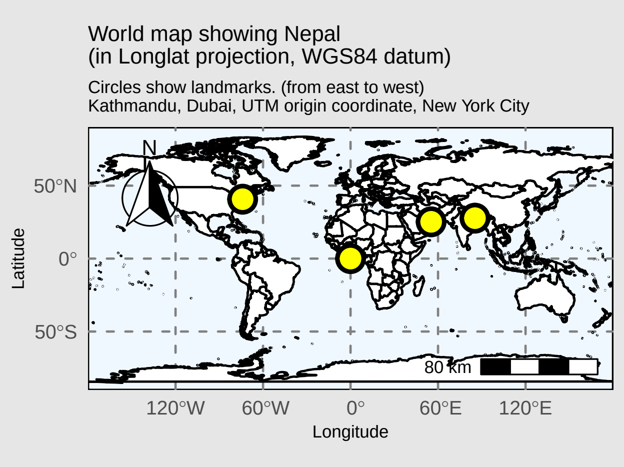
- Coordinate reference system defines how the visual mapping of spatial data should be done
    - CRS has projection parameters, which is configurable giving a variation in mapping
- Modern cartography constitutes theoretical and practical foundations of GIS and Geographic information science[2].
- EPSG 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.

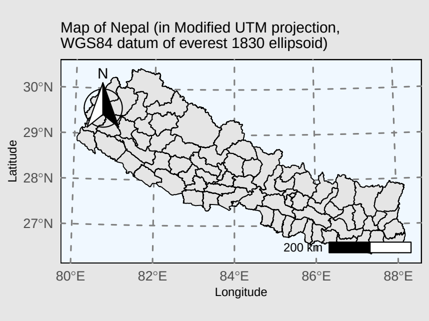
[2] Overview of CRS (in R) is available at: https://www.nceas.ucsb.edu/sites/default/files/2020-04/OverviewCoordinateReferenceSystems.pdf

Map types

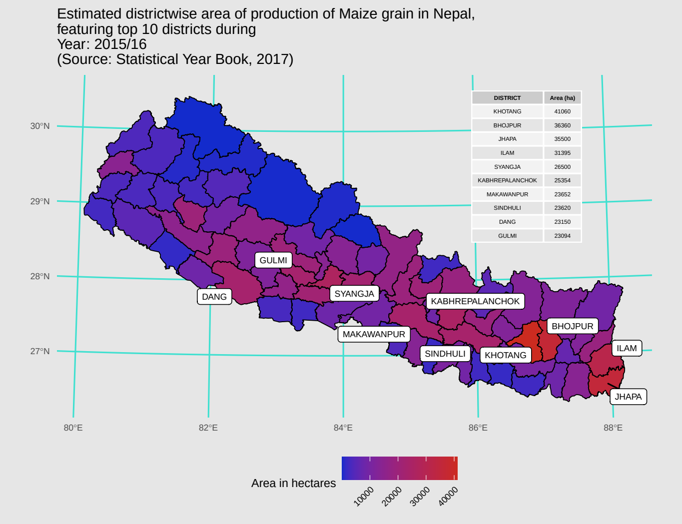
- General vs. thematic cartography
  - General:
    - Intended for general audience and containing a variety of features. Bear many reference and location systems.
  - Thematic:
    - Specific geographic themes
    - Oriented toward specific audiences
    - Dot map showing corn production in different 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.

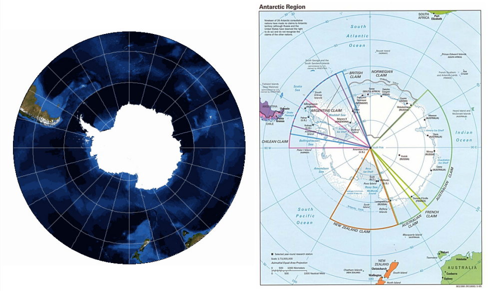


Figure 2: Azimuth is a mathematical concept with relates to the relationship between a point and the 'flat piece of paper' that 'touches' the Earth. Maps produced using Azimuthal Projections (often called polar projections) techniques have lines of longitude fanning out from the centre and lines of latitude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

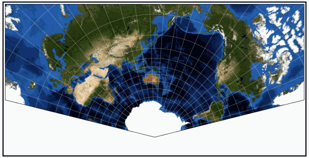
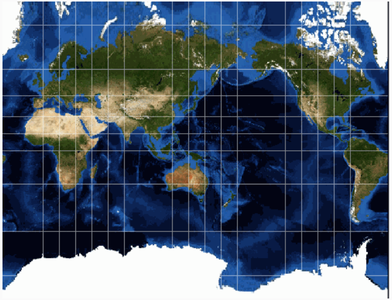
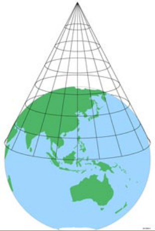


Figure 3: This map is centred on central Australia and the Standard Parallel is 25° South. Note how the shapes of land masses near the Standard Parallel are fairly close to the true shape when viewed from space. This includes Australia, South America and the 'tip' of Africa. Also note how land masses 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.





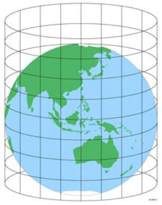


Figure 4:
This follows the concept of a 'piece of paper' being rolled into a cylinder and touching the Earth on a circular line. Notice the huge distortions in the Arctic and Antarctic regions, but the reasonable representation of landmasses out to about 50° north and south. Projection information: Mercator; 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]]],
##         PRIMEM["Greenwich",0,
##             ANGLEUNIT["degree",0.0174532925199433]],
##         ID["EPSG",4269]],
##     CONVERSION["UTM zone 19N",
##         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

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References