

Training Manual

on

Application of Remote Sensing (RS) & GIS in Agriculture

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History of GIS: Early History of Mapping and Cartography in Bangladesh

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Introduction

Geographic Information Systems (GIS) and cartography have played a crucial role in Bangladesh's development, from early colonial land surveys to modern satellite-based geospatial analysis.

1. Pre-Independence Era: Colonial Surveys (1760–1947)

Key Developments:

- 1760s–1800s: The British East India Company conducted the first systematic land surveys for taxation and revenue collection (e.g., Cadastral Surveys).
- 1850s: The Great Trigonometrical Survey of India (under Sir George Everest) established geodetic control points in Bengal.
- Early 1900s: Topographic maps were created for military and administrative purposes, often hand-drawn with limited accuracy.

Legacy:

- Many colonial-era maps are still used as reference documents in land disputes.
- The District Gazetteers included early geographic and demographic data.

2. Post-Independence: Early Modernization (1947–1971)

Key Developments:

- 1950s: Establishment of the Survey of Pakistan, which continued cadastral and topographic mapping.
- 1960s: Introduction of aerial photography for floodplain and riverine mapping.

Limitations:

- Manual cartography dominated, with slow updates.
- Limited accessibility of maps for civilian use.

3. Birth of GIS in Bangladesh (1971–1990s)

Key Milestones:

- 1973: Creation of the Survey of Bangladesh (SOB), responsible for national mapping.
- 1980: Establishment of SPARRSO (Bangladesh Space Research and Remote Sensing Organization), introducing satellite remote sensing.
- 1989: First use of Landsat imagery for flood monitoring.

Early GIS Applications:

- Disaster Management: Cyclone and flood mapping.
- Agriculture: Crop monitoring using NOAA AVHRR data.

4. Digital Revolution (1990s–2010s)

Key Advancements:

- 1991: First digital topographic maps developed by SOB.
- 1997: Digital AEZ map and digitized LRIS by BARC
- 1998: Launch of Bangladesh's first GIS-based land record system (DLRS – Digital Land Record System).
- 2000s:
 - Google Earth (2005) increased public access to geospatial data.
 - River erosion studies using RS and GIS gained importance.

Institutional Growth:

- Bangladesh Agricultural Research Council (BARC) adopted GIS for soil mapping.
- Local universities (e.g., BUET, KU) introduced GIS courses.

5. Modern Era (2010–Present): AI, Drones, and Big Data

Recent Developments:

- 2013: Bangladesh Satellite-1 project initiated (launched in 2018).
- 2016: Digital Bangladesh Vision promotes GIS for smart agriculture & urban planning.
- 2020s:
 - Drone-based land surveys by SOB.
 - AI-powered flood prediction models (e.g., using Sentinel-1 SAR data).

Key Applications Today:

- ✓ Disaster Management: Real-time flood mapping (e.g., FFWC uses GIS).
- ✓ Agriculture: Soil test-based fertilizer recommendation (Khamari App).
- ✓ Urban Planning: Dhaka's Detailed Area Plan (DAP) uses GIS.

6. Challenges & Future Directions

Persisting Challenges:

- Fragmented data across agencies (SoB, BARC, LGED).
- Limited open-data policies.
- Shortage of skilled GIS professionals.

Future Opportunities:

- National GIS Policy for data standardization.
- Expansion of drone & IoT-based mapping.
- Integration with AI (e.g., automated land classification).

Conclusion

From colonial land surveys to AI-driven geospatial analytics, Bangladesh has made remarkable progress in GIS and cartography. With continued investment in satellite technology, digital infrastructure, and workforce training, Bangladesh can leverage GIS for sustainable development, climate resilience, and smart agriculture.

Provide an Overview of using Geospatial Data for Effective Monitoring, Evaluation, and Resource Management

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Data Acquisition and Advanced Sources

This is the foundation of any powerful spatial M&E system, focusing on acquiring location-specific, high-quality data.

Advanced Remote Sensing Platforms

Remote sensing provides large-scale, repeatable coverage for change detection.

- **High-Resolution Satellite Imagery:** Used for detailed land use mapping and asset verification.
- **Commercial (e.g., Maxar):** High spatial resolution (sub-meter) but costly.
- **Public (e.g., Sentinel, Landsat):** Lower spatial resolution (10–30 meters) but free, with high temporal resolution (frequent revisit times) essential for time-series analysis.
- **UAV/Drone Imagery:** Provides on-demand, extremely high-precision data for small areas (e.g., measuring construction volumes or assessing immediate disaster damage).
- **LiDAR and Radar (SAR):**
 - LiDAR (Light Detection and Ranging) creates accurate 3D models (Digital Surface/Terrain Models - DSM/DTM), vital for flood modeling and biomass estimation.
 - Radar (SAR) penetrates clouds and works day/night, making it essential for monitoring changes in forestry, agriculture, and flood extent, regardless of weather.

In-Situ & Mobile Data Collection

This involves ground-truthing and collecting data directly in the field with precise locations.

- **GNSS Integration (GPS/Galileo):** Ensures all collected field data is accurately georeferenced.
- **Mobile GIS Applications:** Tools like Survey123 or KoboToolbox allow staff to collect structured data in the field (photos, attributes) that automatically integrate into a spatial database in real-time.

Big Data & Cloud Processing

Leveraging cloud infrastructure to handle massive datasets.

- **Google Earth Engine (GEE):** A powerful platform for large-scale, multi-temporal analysis (e.g., monitoring deforestation rates across an entire country over two decades without needing to download terabytes of data).
- **Integration with IoT/Sensor Data:** Linking real-time sensor measurements (e.g., air quality, water flow) to their geographic location for continuous, spatial monitoring.

Advanced Spatial Analysis for M&E

This section details how to transform raw spatial data into meaningful metrics for evaluation.

Change Detection and Trend Analysis

Used to quantify the impact of an intervention over time.

- **Multi-temporal Imagery:** Comparing satellite images from before (baseline) and after (endline) an intervention to quantitatively measure change (e.g., calculating the area of new forest grown in a reforestation project).
- **Time Series Analysis (NDVI/NDWI):** Analyzing trends in spectral indices like Normalized Difference Vegetation Index (NDVI) to monitor crop health or Normalized Difference Water Index (NDWI) to track water body fluctuations.

Geostatistical Analysis

Techniques used to understand patterns and spatial dependency.

- **Hotspot Analysis (Getis-Ord Gi):** Identifies statistically significant clusters of high or low values (e.g., finding areas with an unusual concentration of disease cases, or project beneficiaries).
- **Interpolation (Kriging):** Creates a continuous surface of predicted values from a limited set of sample points (e.g., estimating soil nutrient levels or population density across a whole region based on field samples).

Network and Proximity Analysis

Analyzing relationships between locations based on distance, time, and connectivity.

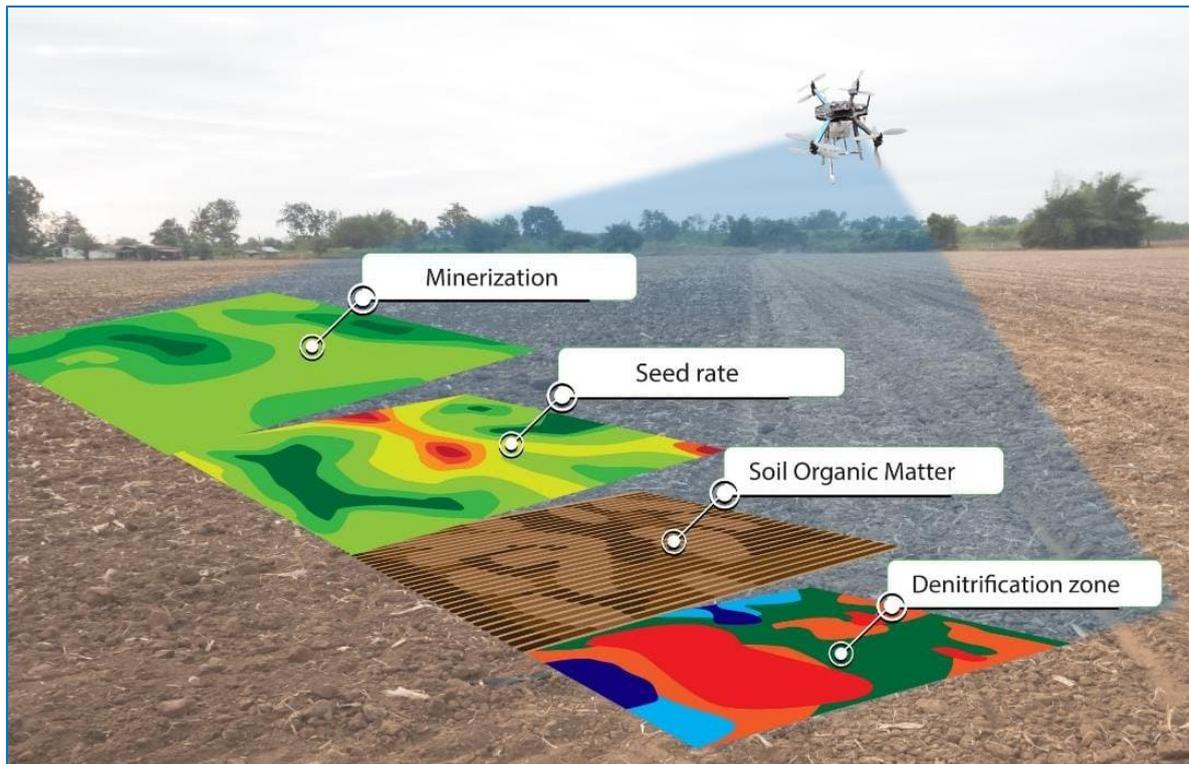
- **Service Accessibility:** Calculating the actual travel time (not just straight-line distance) to essential services (e.g., nearest clinic or school) to evaluate equity in service delivery and identify underserved populations.
- **Optimal Resource Placement:** Using GIS modeling to determine the best strategic location for a new facility (e.g., a distribution center or health post) based on existing infrastructure, population need, and terrain.

Resource Management Applications

Practical, high-impact use cases where spatial data drives efficiency and sustainability.

Natural Resource Management (NRM)

- **Land Use/Land Cover (LULC) Mapping:** Creating high-accuracy maps that classify every square meter of land to monitor compliance, track biodiversity loss, and inform conservation policies.
- **Precision Agriculture:** Using satellite-derived spectral indices (NDVI) and prescription maps to vary the application of fertilizer, water, or pesticides within a field, maximizing yield while minimizing resource waste.



Disaster and Risk Management

- **Vulnerability Assessment:** Creating complex maps by overlaying hazard layers (e.g., flood zones, seismic risk) with layers of social and physical assets (e.g., population density, roads, hospitals) to identify areas most at risk.
- **Rapid Damage Assessment:** Automatically comparing pre- and post-disaster high-resolution imagery to generate quick estimates of infrastructure damage for resource allocation.

Urban and Infrastructure Management

- **Asset Management:** Mapping all public assets (e.g., roads, streetlights, utility lines) with their exact location and condition, allowing for predictive maintenance scheduling and efficient budget allocation.
- **Urban Sprawl Monitoring:** Quantifying the rate and direction of urban expansion using time-series LULC analysis to ensure planning accommodates sustainable growth.

Visualization and Communication (M&E Reporting)

The final, critical step: translating complex analysis into clear, actionable information for stakeholders.

- **GIS Dashboards:** Creating dynamic, interactive web-based interfaces that link key M&E data (KPIs, graphs) directly to a map. This allows decision-makers to view real-time project status and filter data spatially (e.g., instantly see all project sites with budget overruns in a specific region).
- **Map-Based Storytelling:** Utilizing web-GIS platforms to combine engaging cartography, narrative text, and multimedia elements into compelling visual reports that communicate project impact and evaluation results effectively to non-technical audiences.

- **Transparency and Accountability:** GIS provides an objective, verifiable, and location-specific record of all activities, from asset placement to intervention boundaries, which significantly enhances donor and stakeholder trust.

Next Steps for Training

The concepts covered are best solidified through practical application. A beneficial next step would be to focus on a Case Study (e.g., monitoring a large-scale agricultural infrastructure project or an environmental conservation effort) to apply these advanced concepts practically using real-world data and tools.

Which is in our next lecture (Case Study).

CASE STUDY-BACKGROUND

This is a detailed case study demonstrating the practical application of advanced GIS and Remote Sensing concepts (as outlined in the training manual) for monitoring and managing a large-scale agricultural initiative.

Case Study: Monitoring the "Green Belt Initiative" (GBI)

Project Goal: To increase national food security by establishing 50,000 hectares of high-yield irrigated farmlands across four regional districts over a five-year period, focusing on sustainable water and fertilizer use.

Challenge: The project requires real-time monitoring of crop health, early detection of pest/disease outbreaks, optimization of variable rate irrigation (VRI), and accurate calculation of yield impact for M&E reporting.

CASE STUDY

Data Acquisition and Advanced Sources

The M&E framework for the GBI relies on a layered approach to data collection, ensuring both broad coverage and high local detail.

Advanced Remote Sensing Platforms

- **Sentinel-2 Imagery (Temporal and Spectral):**
 - Purpose: Provides free, high-frequency (5-day revisit) imagery to monitor the entire 50,000-hectare area weekly.
 - Data Used: Multispectral bands are used to calculate spectral indices like NDVI (crop health) and NDWI (water stress) over the entire project area.
- **UAV/Drone Imagery (Spatial Resolution):**
 - Purpose: Used selectively by field teams for ground-truthing and rapid assessment of high-risk areas identified by satellite data (e.g., a field showing sudden NDVI decline).

- Data Used: Ultra-high resolution (sub-5 cm) RGB and near-infrared imagery to identify specific weed types or insect damage spots.
- ***LiDAR/SAR Data (3D and Non-Optical):***
 - Purpose: SAR (Radar) is used every two weeks, regardless of cloud cover, to monitor soil moisture levels in flood-prone sections. LiDAR data is used once at the baseline for accurate Digital Elevation Models (DEMs) for irrigation planning.

In-Situ & Mobile Data Collection

- ***Mobile GIS Applications (KoboToolbox/Survey123):***
 - Purpose: Field officers use mobile devices for real-time data collection.
 - Data Collected: Accurate GNSS-georeferenced data on pest sightings, soil sampling locations, irrigation system maintenance issues, and farmer interviews, all linked directly to the spatial database

Big Data & Cloud Processing

- ***Google Earth Engine (GEE):***
 - Purpose: Used for baseline analysis and historical context.
 - Process: GEE processes 20 years of historical Landsat data to establish the baseline land cover/land use (LULC), historical drought indices, and maximum potential crop yields for the four districts. This baseline is crucial for attributional M&E.

Advanced Spatial Analysis for M&E

The collected data is moved beyond simple mapping into powerful analytical models to generate actionable insights.

Change Detection and Trend Analysis

- ***Time Series NDVI Analysis:***
 - Process: Weekly Sentinel-2 NDVI values are plotted over the entire growing season for every agricultural parcel.
 - Result: The system automatically flags any field where the NDVI value drops below the historical average growth curve for more than two consecutive weeks, indicating a significant, persistent stress (water shortage, nutrient deficiency, or disease).
- ***Change Detection for LULC (Pre- and Post-Intervention):***
 - Process: Comparing the GEE historical LULC map (baseline) with the current year's end-of-season map to quantify the net increase in actively cultivated and irrigated land, directly measuring the project's reach and impact.

Geostatistical Analysis

▪ *Kriging for Soil Quality Mapping:*

- Process: Sparse soil samples collected via Mobile GIS (measuring Nitrogen, Phosphorus, Potassium - NPK) are used in a Kriging interpolation model to create a continuous, smooth surface map of NPK deficiency across the entire project area.
- Result: This continuous surface is used to divide fields into different management zones based on nutrient levels.

▪ *Hotspot Analysis (Getis-Ord Gi):*

- Process: Real-time field observations of pest infestations (collected via Mobile GIS) are analyzed using Hotspot Analysis.
- Result: Identifies statistically significant spatial clusters (hotspots) of infestation, confirming the outbreaks are not random and guiding targeted pest control teams.

Resource Management Applications (NRM & Infrastructure)

The analytical output directly informs critical resource allocation decisions.

Precision Agriculture

▪ *Variable Rate Fertilization (VRF):*

- Application: The NPK deficiency map generated by Kriging (Section 2B) is used to create prescription maps.
- Action: These maps are uploaded to VRF-capable farm equipment, ensuring only the deficient zones receive specific amounts of fertilizer, preventing overuse, pollution, and saving costs.

▪ *Precision Irrigation:*

- Application: NDWI (from Sentinel data) and SAR-derived soil moisture levels identify fields under water stress.
- Action: The system generates weekly recommendations for farmers, prioritizing water distribution to the areas of highest need, maximizing water use efficiency across the 50,000 hectares.

Optimal Resource Placement

▪ *Service Accessibility Analysis (Network Analysis):*

- Process: Uses road networks and farm locations to calculate the travel time from each farm to the nearest GBI technical support office and the nearest major market.
- Action: If analysis shows large clusters of farms are over 60 minutes from a support office (low accessibility), it justifies the need to locate a new satellite office or resource depot in that location to ensure equitable service delivery.

Visualization and Communication (M&E Reporting)

The final, actionable step is translating complex geospatial data into simple, dynamic communication tools.

GIS Dashboard (Real-Time Monitoring)

- **Structure:** A dynamic web dashboard is created for project managers and donors.
- **Components:**
 - Map Window: Shows the status of all 50,000 hectares. Fields are color-coded based on their NDVI status (Green: Healthy, Yellow: Stress, Red: Critical).
 - KPI Panel: Displays aggregate metrics (e.g., Percentage of fields below average NDVI, Total hectares requiring irrigation, Days since last major pest hotspot).
 - Interactive Filters: Allows users to filter data by district, crop type, or intervention stage.
 - Goal: Provides a single, real-time picture of project performance and allows drill-down investigation into specific fields.

Map-Based Storytelling (M&E Impact Reporting)

- **Format:** An interactive web Story Map is generated for the final donor report.
- **Content:**
 - Baseline Slide: Shows the GEE historical LULC map, highlighting the initial barren/low-yield area.
 - Intervention Slide: Overlays the location of new irrigation infrastructure (mapped by field teams) and the areas targeted by VRF.
 - Impact Slide: Presents the Change Detection results (Section 2A), showing the final measured increase in irrigated land and comparing actual yield to the historical GEE-derived potential yield, clearly articulating the project's success and attribution.

Transparency and Accountability

- **Geospatial Audit Trail:** The M&E system maintains a verifiable, location-specific record of every critical activity (e.g., the coordinates of every new irrigation pump, the date of every fertilizer application based on the prescription map, and the exact boundaries of every farm). This objective record enhances accountability to stakeholders.

Basic Concepts of GIS Technology

Abid Kamal

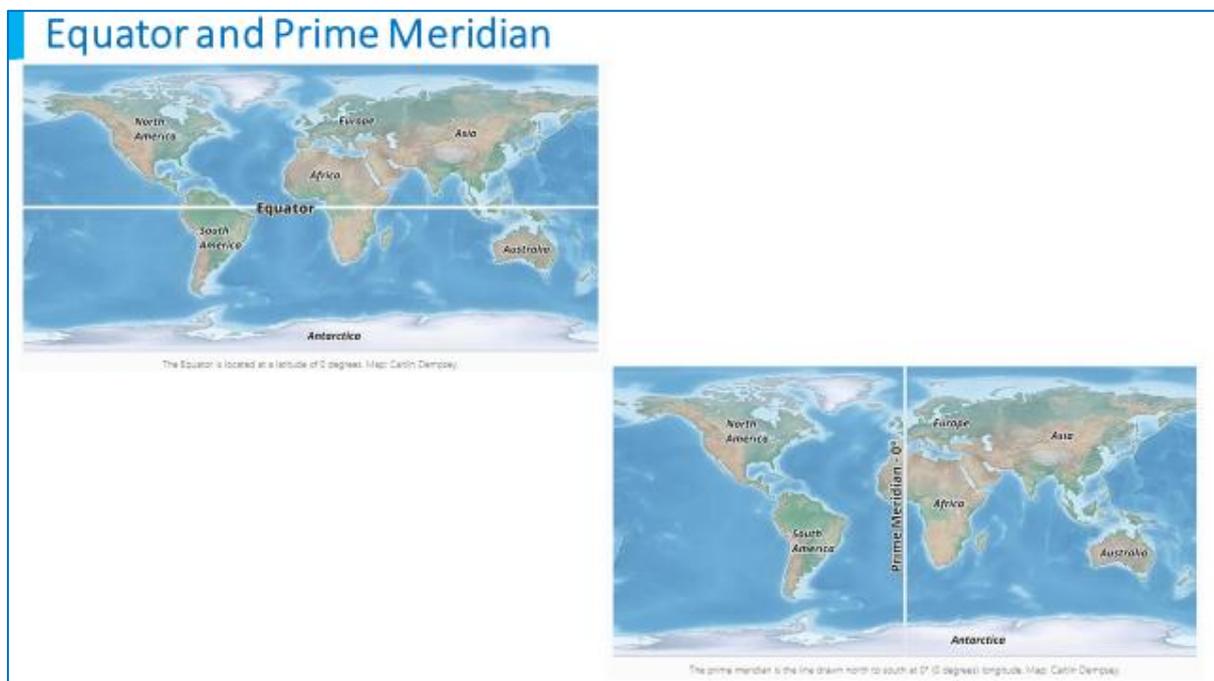
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1. Equator and Prime Meridian

The **Equator** is an imaginary line that circles the Earth horizontally at its widest point. It lies midway between the North Pole and the South Pole and divides the planet into the **Northern Hemisphere** and **Southern Hemisphere**. It is assigned the value **0° latitude**, serving as the starting point for measuring distances north or south.



The **Prime Meridian** is another imaginary line that runs vertically from the North Pole to the South Pole. It passes through Greenwich, London, and divides the Earth into the **Eastern Hemisphere** and **Western Hemisphere**. It is defined as **0° longitude**. The Prime Meridian helps create a global reference grid when combined with the Equator.

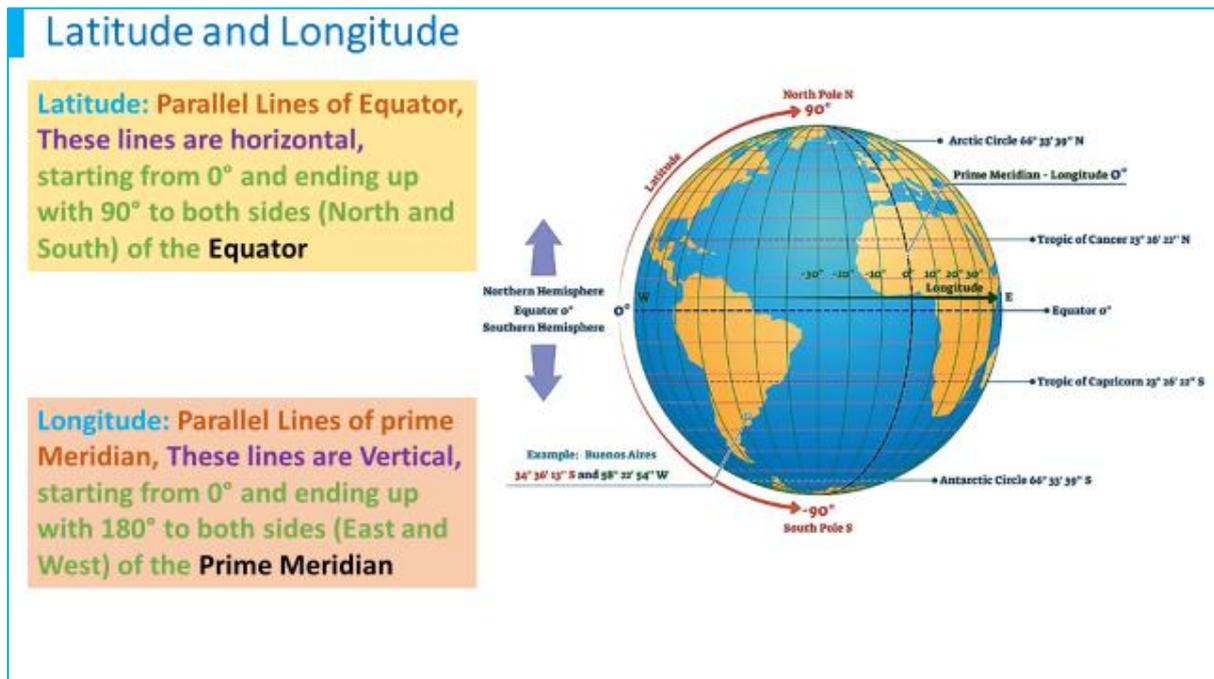
Together, these two lines form the foundation for the Earth's geographic coordinate system, allowing every location to be described using numerical values.

2. Latitude and Longitude

The Earth's surface is divided using a network of lines known as **latitude** and **longitude**.

Latitude

- Lines of latitude, also called **parallels**, run east–west.
- They measure how far north or south a point is from the Equator.
- Latitude values range from **0° at the Equator** to **90° at the poles**.
- Positive values indicate the Northern Hemisphere, and negative values indicate the Southern Hemisphere.



Longitude

- Lines of longitude, called **meridians**, run north–south.
- They measure how far east or west a point is from the Prime Meridian.
- Longitude values range from **0° to 180° east** and **0° to 180° west**.

Together, latitude and longitude allow us to identify any location on Earth using a pair of coordinates (for example, 23.8103° N, 90.4125° E for Dhaka).

3. Geographic Coordinate System (GCS)

A **Geographic Coordinate System** represents locations on the Earth's spherical surface. Instead of a flat map, GCS uses a **3D ellipsoid or spheroid** to approximate Earth's shape.

A GCS consists of:

1. **An ellipsoid** – a mathematical model of Earth's shape.
2. **A datum** – the connection between the ellipsoid and real-world locations.
3. **Units of measurement** – usually degrees of latitude and longitude.

Because it is based on a curved surface, GCS is ideal for storing global data. However, GCS is **not suitable for accurate distance, area, or direction measurements** on flat maps—these require projected coordinate systems.

4. What is GIS?

A **Geographic Information System (GIS)** is a technology that integrates maps, data, and analysis tools to understand spatial patterns and relationships.

GIS can:

- Collect and store location-based data
- Analyze spatial relationships (e.g., distance, patterns, clustering)
- Produce maps and visualizations
- Support decision-making in fields like environment, urban planning, agriculture, disaster management, and public health

GIS connects “**where** something is” with “**what** something is,” making it a powerful tool for solving real-world geographic problems.

5. GIS Data Types

a. Vector Data

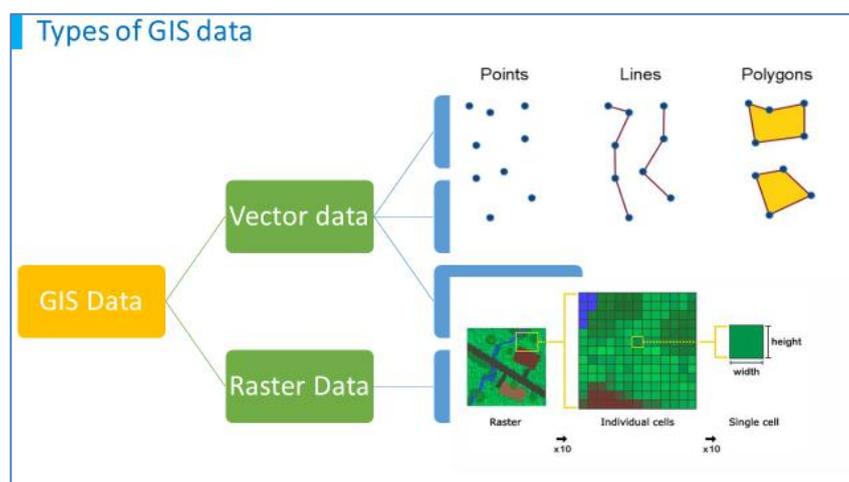
Vector data uses geometric shapes to represent real-world features:

- **Points** for single locations (e.g., tube wells, schools)
- **Lines** for linear features (e.g., roads, rivers, pipelines)
- **Polygons** for areas (e.g., districts, agricultural fields, lakes)

Vector data provides:

- High precision
- Clean boundaries
- Easy attribute management

It is ideal for mapping administrative boundaries, infrastructure, and land parcels.



b. Raster Data

Raster data represents the Earth's surface through a grid of **cells or pixels**. Each pixel holds a value, such as:

- Reflectance values in satellite imagery
- Elevation (from DEMs)
- Soil moisture
- Temperature or rainfall values

Raster data is best for:

- Continuous phenomena
- Environmental monitoring
- Remote sensing analysis

The detail depends on pixel size; smaller pixels mean higher resolution.

6. Shapefile Format

A **Shapefile** is one of the most commonly used vector data formats in GIS. It was developed by Esri and remains popular due to its simplicity and compatibility.

A shapefile is not a single file—it is a collection of files with the same name but different extensions, including:

- **.shp** – geometry of the features
- **.shx** – index file
- **.dbf** – attribute table (stores data in tabular form)
- **.prj** – projection information (optional but important)

Limitations:

- Cannot store complex relationships
- Maximum 10-character field names
- No support for large datasets or advanced data types

Despite these limits, shapefiles are ideal for quick sharing and simple analysis.

7. Geodatabase

A **Geodatabase (GDB)** is a modern method for storing and managing large volumes of GIS data in a structured environment.

Two common types:

1. **File Geodatabase (.gdb)** – stored as a folder on your computer
2. **Enterprise Geodatabase** – stored in a database server and supports multiple users

Advantages:

- Efficient storage of large spatial datasets
- Support for topological rules
- Can store multiple feature classes, raster datasets, tables, and relationships
- Faster performance than shapefiles

Geodatabases are recommended for large projects, organizations, and long-term data management.

8. Map Scale

Map scale indicates the relationship between a distance on the map and the corresponding distance on the ground.

Examples:

- **1:5,000** – 1 cm on the map = 50 m on the ground
- **1:50,000** – 1 cm = 500 m
- **1:1,000,000** – 1 cm = 10 km

Types of scale:

- **Large-scale maps** show small areas in great detail (e.g., ward or village maps).
- **Small-scale maps** show large areas with less detail (e.g., national maps).

Scale influences accuracy, symbolization, and the visual appearance of spatial features.

9. GIS Software

Various software tools support GIS tasks. Popular examples include:

QGIS

- Free and open-source
- Widely used worldwide
- Strong community support
- Suitable for beginners and professionals

ArcGIS

- Commercial software by Esri
- Advanced analysis capabilities
- Ideal for organizational and enterprise settings

Other Tools

- **GRASS GIS** – advanced open-source analysis
- **GeoServer** – for publishing spatial data on the web
- **Google Earth Engine** – cloud-based remote sensing and analysis
- **MapInfo, ERDAS Imagine, ENVI** – specialized for image analysis

Each software offers unique tools for mapping, editing, analysis, and visualization.

10. Map Projection and Coordinate System

A **map projection** is a mathematical method of converting the Earth's curved surface (3D) into a flat map (2D). Since the Earth is round, all projections introduce some form of distortion (area, shape, distance, or direction).

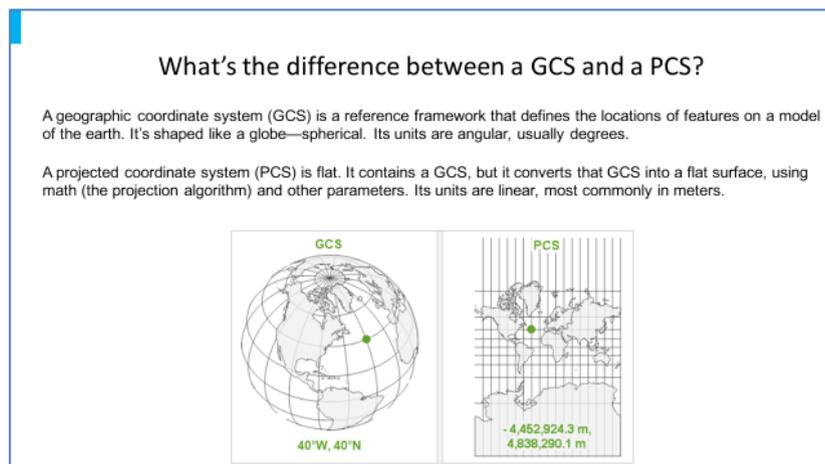
Different projections preserve different properties:

- **Equal-area projections** – preserve area
- **Conformal projections** – preserve shape
- **Equidistant projections** – preserve distance
- **Azimuthal projections** – preserve direction

A **Projected Coordinate System (PCS)** combines:

- A map projection
- Linear units (meters or feet)
- A coordinate grid (e.g., UTM)

PCS is essential for accurate measurement and spatial analysis on flat maps.



11. Datum

A **Datum** defines the position of the ellipsoid relative to the Earth's surface. It provides the base reference for measuring geographic coordinates.

Two key components:

1. **Ellipsoid** – mathematical shape approximating Earth
2. **Anchor point(s)** – physical locations where the ellipsoid is aligned with Earth

Examples:

- **WGS 84** – used by GPS and global datasets
- **NAD 83** – used in North America
- **BTM Gulshan 303** – used for national mapping in Bangladesh

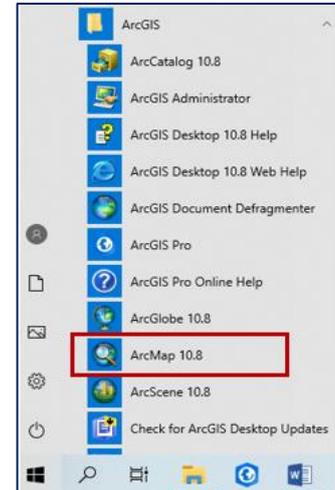
Different datums can produce coordinate differences of several meters to hundreds of meters.

Geo-referencing Techniques, Create and Edit Shapefiles

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Start ArcMap and open map document

- From the Windows taskbar, click **Start > All programs > ArcGIS > ArcMap** to open the ArcMap. Depending on which Windows operating system is in use, there may be a bit of difference in navigation to open ArcMap.
- If you have shortcut icon on your desktop or pinned in taskbar, double-click on it to start ArcMap.
- In the resulting ArcMap window, click **Existing Maps > Browse for more**.
- Browse to the drive on which the tutorial data has been stored (e.g. **D:\ArcGIS Training\Training Data\Exercise MXD**) and click **Ex_05.mxd > Open**. This opens the list of layers in Table of Contents in the left side and their graphical display in the right side of ArcMap application window.



Georeferencing Image data

The purpose of georeferencing is to make satellite, aerial as well as terrestrial imageries useful for GIS mapping and the process adds geographic information to the image so that GIS can place the image in its appropriate real world's location. Given that a scanned enumeration area (EA) map is stored as image format. Now we are going to add coordinates to this image to place just like it is in real world's location.

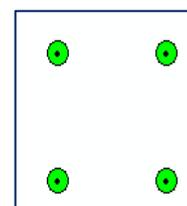
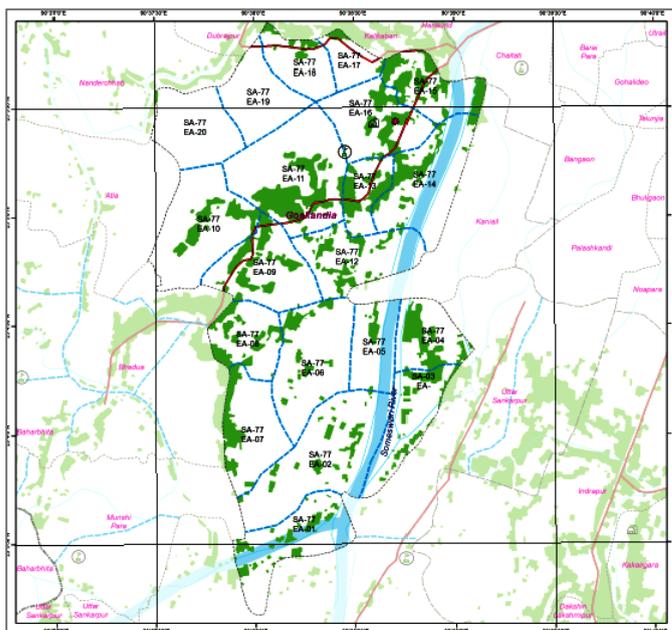
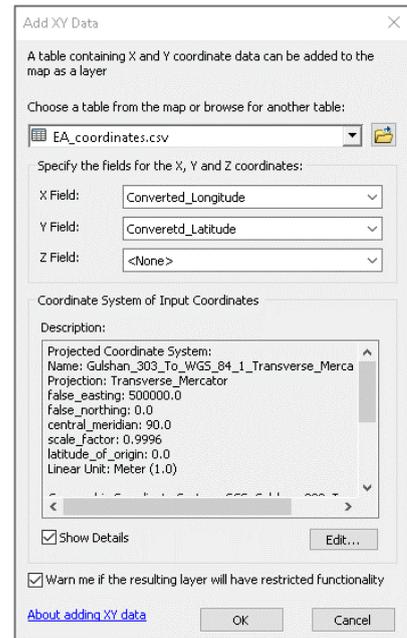
- Tick the **EA_Map_Goakandia_original.jpg** stored in **ToC** and explore the image, especially the coordinates in image border. These coordinates are showing the real world location but do not exactly represent the place in ArcMap as it is not georeferenced. Now we will add the real world coordinates to this image in ArcMap to represent the exact location as it appears in real world. If you notice the coordinates carefully, you would see that the interval is 30 seconds among the labelled coordinates.
- Now open the **EA_coordinates.csv** in **Excel** from working folder. Four coordinate values from **EA_Map_Goakandia_original.jpg** image have been selected for this exercise, stored in excel in separate column and converted from **Degree/Minute/Second** to **Degree** format by using simple formula of **Degree+ minutes/60 + Seconds/3600**.
- Now check the **EA_Map_Goakandia.jpg** stored in **ToC** which has four parallel connecting lines of latitude $25^{\circ}5'30''$ and $25^{\circ}3'30''$ and longitude $90^{\circ}37'30''$ and

90°03'30". The four lines meet at four cross points of which coordinate values are considered for this exercise.

- Observe the selected coordinates in the image border carefully. You would realize that the selected four coordinates are taken from four different corners of the image

Note that when we are georeferencing an image adding its coordinate data, we need to consider the latitude and longitude values distributed more or less equally throughout the map. We need to consider coordinates in four sides of the image for balanced georeferencing and avoiding errors.

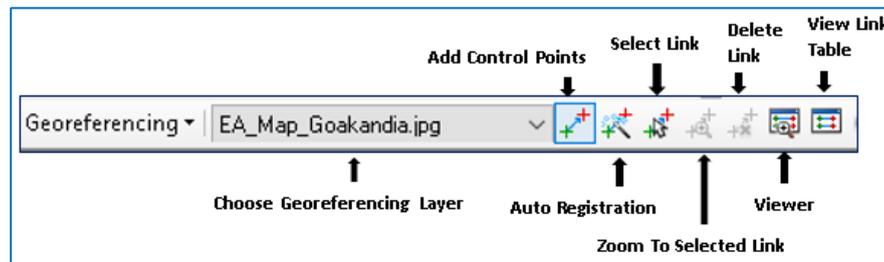
- In ArcMap from menubar, click **File> Add Data >**  **Add XY Data. Window appears.**
- Browse **EA_cordinates.csv** table from working folder in **Choose a table from the map or browse for another table.**
- In **X Field** select **Converted_Longitude** and in **Y Field** select **Converted_Latitude.**
- Click **Ok > OK** in next window. Now the XY values are added to **ToC** as new point layer.
- Change the symbol into **Circle 3** from **Symbol Selector** window as we did earlier.
- If we zoom into the points on map display, you would see four points which are in a similar position of the points found from connecting lines on **EA_Map_Goakandia.jpg.**



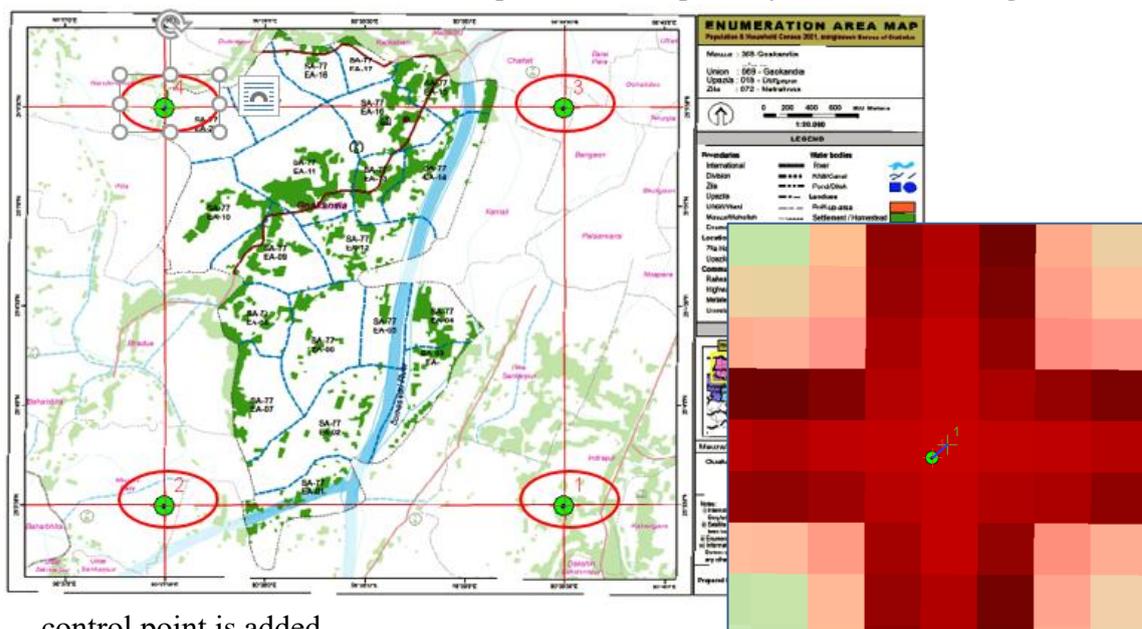
- Now we need to develop connections between two points in similar position, e.g. the point symbol at the top left is in similar position of meeting point of latitude 25°05'30"

and longitude 90°37'30" lines. We would connect them together since they are respective points.

- From menu bar click on **Customize > Customize Mode**. **Customize** window appears. Check **Georeferencing** from the list of **Toolbars** and click **Close**. The **Georeferencing** tool appears on the toolbar in **ArcMap**. This tool is used to georeference raster and CAD data.



- Turn on **Auto Adjust** in the **Georeferencing** pulldown or dropdown list Georeferencing ▾.
- Set **EA_Map_Goakandia.jpg** as the target layer in the georeferencing toolbar since it has the cross points for the coordinate values.
- Choose **Fit to Display** from the georeferencing pulldown.
- Using **Zoom In** tool  from **Tools**, zoom in to the cross point of latitude 25°5'30" and longitude 90°37'30" on image unless the pixels are very clear. Target the center of the most middle pixel of the cross point.
- Click on **Add Control Points** in **Georeferencing** tool from toolbar.
- When the **Add Control Points** is active, click on the center of the most middle pixel of the zoomed cross point and then find the respective point (the top left one we have targeted) and click in the middle of the point symbol. Now the connected line appears between in the center of the cross point and the point symbol. At this stage, the first



control point is added.

- Now, follow the same procedure for the remaining points. Remember that first click should be on image since we are georeferencing the image and then next click should be on respective point symbol to assign that coordinate value to the cross point. Also remember that this process should be done precisely.
- When four control points are added to the image, the four point symbols appears right on the four cross points and image will be set at right place.
- If you add a control point that is problematic, you can open **View Link Table** from **Georeferencing** tool and un-check it or use the delete control point tool to remove it.
- Now that we have all four control points added, examine the link table. This table shows which of the added points fit best with the **1st order Polynomial (Affine)** in **Transformation** at the bottom.
- Un-check the points with the biggest errors (maximum 0.05 at **Residual**) and notice how the fit of all of the other points improves.

Link	<X Source>	Y Source	X Map	Y Map	Residual_x	Residual_y	Residual
4	683.96827901	-458.91916359	90.62500000	25.09170000	-0.00000644	-0.00000570	0.0000860
2	690.96849731	-1912.94068520	90.62500000	25.05830000	0.00000644	0.00000569	0.0000859
3	2006.93344670	-452.94468596	90.65830000	25.09170000	0.00000645	0.00000570	0.0000861
1	2014.95266362	-1905.96922053	90.65830000	25.05830000	-0.00000644	-0.00000570	0.0000860

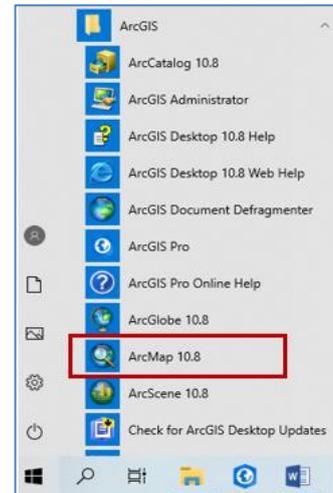
- From the **Link** table, save your control points as a text file in working folder as **Control_points.txt** by clicking on **Save** button  in table. This will allow user to pick up and refine this georeferencing project later. Close the table by clicking x tab in the top right corner of the table window.
- Choose **Update Georeferencing** from the Georeferencing pulldown.
- Open the working folder and notice that new **JGWX** and **XML Document** files have been created.
- Check the **Spatial Reference** properties of **EA_Map_Goakandia.jpg** image. Note that it has inherited the Coordinate Reference Systems from the data frame.

Finally, save the map document with all your work done in this exercise and exit ArcMap.

Feature Extraction from Satellite Images in ArcGIS

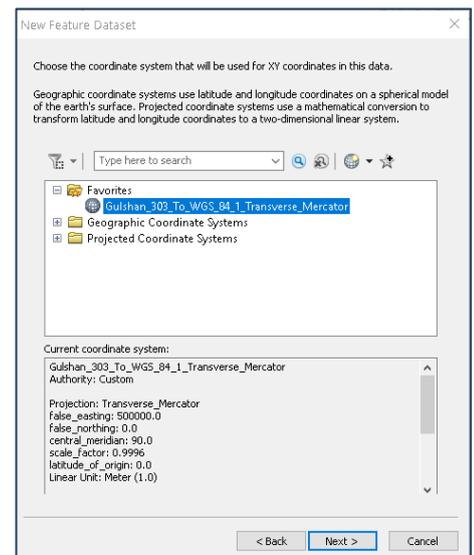
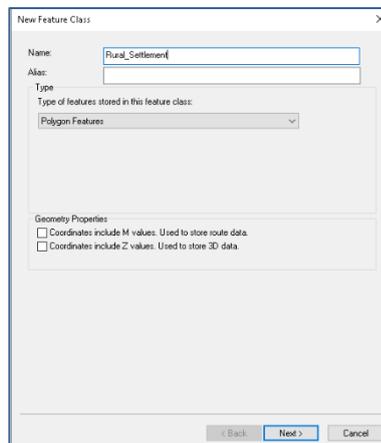
Start ArcMap and open map document

- From the Windows taskbar, click **Start > All programs > ArcGIS > ArcMap** to open the ArcMap. Depending on which Windows operating system is in use, there may be a bit of difference in navigation to open ArcMap.
- If you have shortcut icon  on your desktop or pinned in taskbar, double-click on it to start ArcMap.
- In the resulting ArcMap window, click **Existing Maps > Browse for more**.
- Browse to the drive on which the tutorial data has been stored (e.g. **C:\ArcGIS Training\Training Data\Exercise MXD**) and click **Ex_12.mxd > Open**. This opens the list of layers in Table of Contents in the left side and their graphical display in the right side of ArcMap application window.



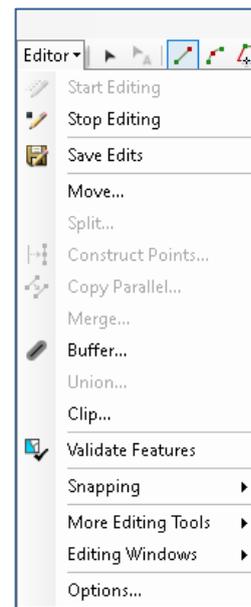
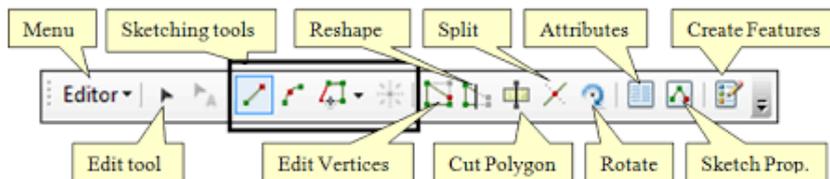
Creating shapefile/ Feature Class

- **Open** and **extend** the working geodatabase in **Catalog Tree** window as explained in **Exercise 07**
- Right-click **Training_geodatabase.mdb** and click **New > Feature Class**
- **New Feature Class** window appears.
- Type **Rural_settlement** for Name and select Polygon features from the dropdown list of **Type of features stored in this feature class** in **Type**. Click **Next**.
- In next window, from **Favorites** select **Gulshan_303_To_WGS_84_1_Transverse_Mercator** and click **Next > Next** in next window > finally **Finish**.
- New **Feature Class/ Shapefile** called **Rural_Settlement** is created in geodatabase and automatically added to **ToC**.
- The alternative way to create a shapefile is to extend the working folder in **Catalog Tree** window as explained in Exercise 07 and **right-click** the folder and click **New > Shapefile**. Then follow the same procedure just explained above
- Now create another shapefile called **Building_footprint** of **Polygon** features and same coordinate system.



Exploring Editor toolbar

- Click the **Editor Toolbar** button  on the Standard toolbar to display the Editor Toolbar.
- The dropdown list of **Editor Menu** has options to start editing session clicking on **Start Editing**, saving edits by clicking on **Save Edits**, stop editing mode by using **Stop Editing**.
- **Editor Toolbar** appears with a package of tools to draw or edit new features.



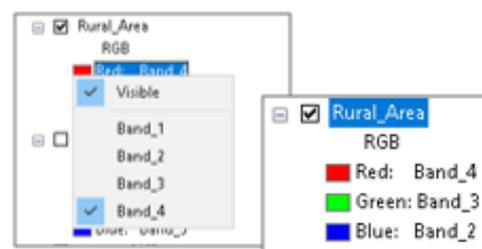
- **Sketching tools** help draw or digitize a feature.
- **Reshape, Split, Cut Polygon, Rotate, Edit Vertices**- these tools help to edit or modify any feature drawn.
- **Create Features** help to select the feature you want to edit and the **Construction tool** such as **Polygons, Auto Complete Polygon, Rectangle, Circle** etc. required for new feature.
- **Edit tool** helps select the feature that you want to edit and use other tools to start the operation.

Settlement Extraction

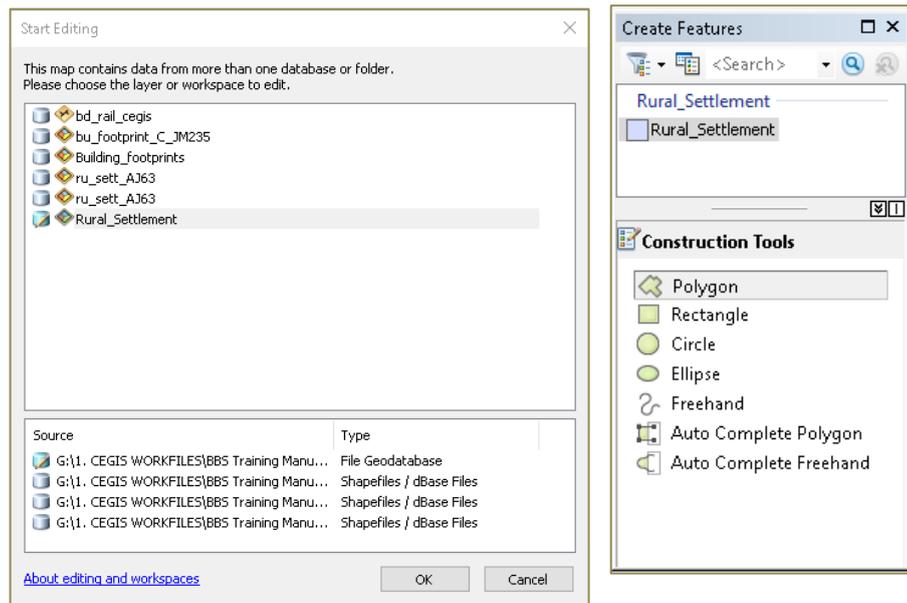
Now we are going to extract rural settlement and urban footprints from satellite images using Editor tool. Rural settlements will be drawn in **Rural_Settlement.shp** file and building footprints will be drawn in **Building_footprint.shp**.

Rural settlement extraction

- Browse working folder and drag and drop **Rural_Area** image into ToC.
- Note that Rural **Settlement** layer should be on top of **Rural_Area** in the ToC to view the edits on satellite image.
- Change the **Red, Green, Blue** band combination into **band 4, 3,2** consecutively by clicking the colored rectangle symbol and selected desired band one by one to better visualization of vegetation since we are going to consider homestead vegetations for rural settlement. In case of any confusion, Band combination is changed temporarily to **3,2,1** to interpret settlements.
- In **Rural_Settlement** layer, click on the symbol in rectangle shape and select **Hollow** in **Symbol Selector** window. Change the **Outline color** into **Yellow** and **Outline width** into **1.5** to make the edits eye catchy.
- In **Editor Toolbar**, click **Start Editing** to start the edit session. **Start Editing** window appears with the layers added to ToC.



- Select **Rural_Settlement** and click **Ok > Continue** in the next window if there is any .
- Now **Edit tool**  is active as a mouse pointer on map display and is selected in toolbar.
- Click on **Create Features**  button in **Editor** toolbar. A **Create Features** window appears.
- Click on **Rural_Settlement** and below you should be getting the options in **Construction Tools**. Select **Polygon** over there.



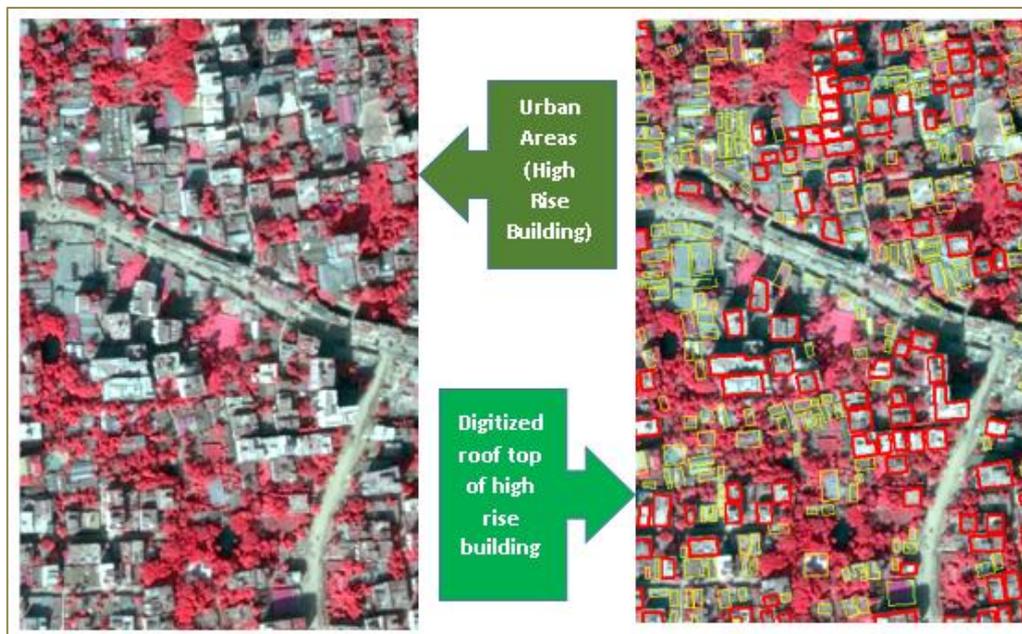
- Now the editing mode is active since the mouse pointer is changed into an addition sign +.
- Use **Zoom in**  and **Pan**  in **Tools** from toolbar to find the desired area to start drawing feature and use the scale from **1:1200** to **1:1500**.
- Now follow the settlement boundary line and keep clicking until you get the shape of the boundary.
- **Double click** to finish drawing polygons. The digitized polygon or feature remains selected on map display. The selection will be gone when it is saved or when the next feature will be drawn.
- The first settlement is drawn already and a record is added to attribute table of **Rural_Settlement** layer which is on the fly. We need to save the edits.
- To save the drawing features, click **Save Edits** in Editor menu.
- If you don't get the drawings perfectly, use **Reshape, Split, Cut Polygon, Rotate, Edit Vertices** tools in **Editor Toolbar** and save the edits. But make sure that before you use these tools, the feature that you want to edit or change the shape should remain selected.
- When all the settlements are drawn and saved , click **Stop Editing** in **Editor Menu**.
- Now the rural settlent is extracted in **Rural_Settlement** layer from given satellite image. Explore the attribute table to see the records and get out of it by clicking **Close** tab.

N.B: An example shapefile called **Example_Rural** is provided in the working geodatabase for your convenience to have a look and get idea on how to draw the shapes or the boundary lines. To view it, drag and drop the layer in ToC and change the symbol color into **Hollow** for better visualization. This example layer has the rural features in some parts of **Rural_Area** image. Please continue digitizing settlements in **Rural_Settlement** layer for your practice.

Building footprints extraction

- Browse working folder and drag and drop **Urban_Area** image into ToC.
- Note that **Building_footprint** layer should be on top of **Urban_Area** in the ToC to view the edits on satellite image.
- Change the **Red, Green, Blue** band combination into **band 4, 3,2** . In case of any confusion, Band combination is changed temporarily to **3,2,1**to interpret settlements.
- In **Building_footprint** layer, click on the symbol in rectangle shape and select **Hollow** in **Symbol Selector** window. Change the **Outline color** into **Yellow** and **Outline width** into **1.5** to make the edits eye catchy.
- In **Editor Toolbar**, click **Start Editing** to start the edit session. **Start Editing** window appears with the layers added to ToC.
- Select **Building_footprint** and click **Ok > Continue** in the next window if there is any .
- Now **Edit tool**  is active as a mouse pointer on map display and is selected in toolbar.
- Click on **Create Features**  button in **Editor** toolbar. A **Create Features** window appears.
- Click on **Building_footprint** and below you should be getting the options in **Construction Tools**. Select **Polygon** over there.
- Now the editing mode is active since the mouse pointer is changed into an addition sign +.
- Use **Zoom in**  and **Pan**  in **Tools** from toolbar to find the desired area to start drawing feature and use the scale from **1:1200** to **1:1500**.
- Now follow the edge of buildings and keep clicking until you get the shape of the building.
- **Double click** to finish drawing polygons.
- The first building is drawn already and a record is added to attribute table of **Building_footprint** layer which is on the fly.
- To save the drawing features, click **Save Edits** in Editor menu.
- If you don't get the drawings perfectly, explore use **Reshape, Split, Cut Polygon, Rotate, Edit Vertices** tools in **Editor Toolbar** and save the edits.
- When all the settlements are drawn and saved , click **Stop Editing** in **Editor Menu**.
- Now the rural settlent is extracted in **Building_footprint** layer from given satellite image. Explore the attribute table to see the records and get out of it by clicking **Close** tab.

N.B: An example shapefile called **Example_Urban** is provided in the working geodatabase for your convenience to have a look and get idea on how to draw the shapes or the boundary lines. To view it, drag and drop the layer in ToC and change the symbol color into **Hollow** for better visualization. This example layer has the rural features in some parts of **Urban_Area** image. Please continue digitizing urban settlements in **Building_footprint** layer for your



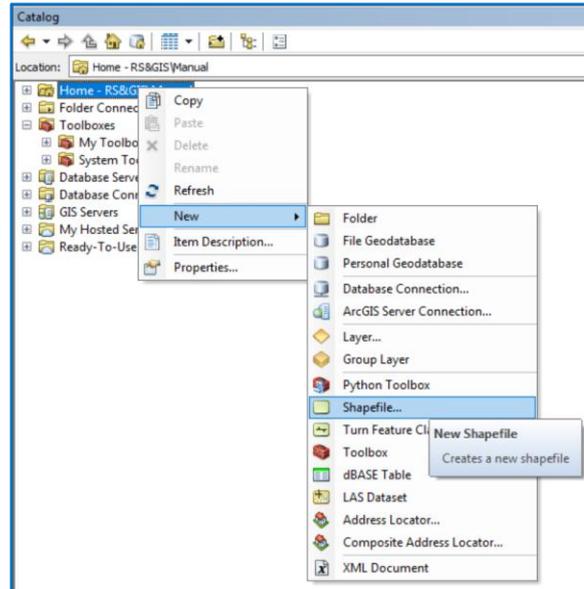
practice.

Finally, save the map document with all your work done in this exercise and exit ArcMap.

Create A New Shapefile

You can create new shapefiles in ArcCatalog or by using the Create Feature Class tool. When you create a new shapefile, you must define the types of features it will contain, whether those features will represent routes (m-values), and whether those features will be three-dimensional (z-values). These properties can't be modified after the shapefile has been created. You can also define the coordinate system of the shapefile. If you choose to define the shapefile coordinate system later, it will be classified as **Unknown** until then. The process of defining the new shapefile's attributes is separate from creating the shapefile itself. After creating the item, define its attributes by right-clicking it in ArcCatalog and clicking Properties. Because it must contain at least one attribute column. ArcCatalog adds a default column to the shapefile when it is created. For shapefiles, an integer column named Id is added as an attribute. Add the appropriate attributes to your shapefile. After the new attributes have been added as part of the shapefile, you can delete the default column if you decide you don't want to use it.

1. Select a folder or folder connection in the Catalog tree.
2. Click the File menu, point to New, then click Shapefile.
3. Click in the Name text box and type a name for the new shapefile.
4. Click the Feature Type drop-down arrow and click the type of geometry the shapefile will contain.
5. Click Edit to define the shapefile's coordinate system.
6. Select, import, or define a new coordinate system.
7. It's highly recommended that you define the shapefile's coordinate system now; however, you can postpone this step until a later time. For more information, see Fundamentals of a shapefile's coordinate system and Click OK.
8. If the shapefile will store polylines representing routes, check Coordinates will contain M values.
9. If the shapefile will store three-dimensional features, check Coordinates will contain Z values and Click OK.



The new shapefile appears in the folder's contents.

Editing Features in a Shapefile

Digitizing, the process of converting features into a digital format, is one way to create data. There are several ways to digitize new features. These include digitizing on-screen or heads up over an image, digitizing a hard copy of a map on a digitizing board, or using automated digitization.

Interactive, or heads-up digitization, is one of the most common methods. In this method, you display an aerial photograph, satellite image, or orthophotograph on-screen as a basemap, then you draw features, such as roads, buildings, or parcels, on top of it.

In hard-copy digitizing, you use a digitizing table connected to a computer that converts positions on the table surface into digital x,y coordinates as you trace them with a handheld puck (a pen or mouse like device).



Figure: Sketching a new polygon feature

Automatic digitization is another method of digitizing features. The ArcScan for ArcGIS extension enables you to perform automatic or interactive raster-to-vector data conversion with high precision and little or no operator intervention during the data capture stage.

Starting an Edit Session

Editing occurs in an edit session. During an edit session, you can create or modify vector features or tabular attribute information. When you want to edit, you need to start an edit session, which you end when you're done. Editing applies to a single workspace in a single ArcMap data frame, where a workspace is a geodatabase or a folder of shapefiles. If you have more than one data frame in your map, you can only edit the layers in one data frame—even if all data is in the same workspace. Although you can edit data in different coordinate systems, it is generally best if all the data you plan to edit together has the same coordinate system as the data frame.

Creating Features with Feature Templates

Creating features is accomplished through the use of feature templates. Feature templates define all the information required to create a feature: the layer where a feature will be stored, the attributes a feature is created with, and the default tool used to create that feature. Templates also have a name, description, and tags that help you to find and organize them. If templates are not present when you start editing, they are automatically created for each layer in the current editing workspace. Templates are saved in map document (.mxd) and layer file (.lyr).



Figure: Create new templates wizard

A layer can have multiple templates associated with it, where each template has different default settings. For example, if you have a roads layer with classifications of freeway, major highway, and local road, you could have three different templates with each one having a different default attribute for the type of road. This makes it easier for you to create the new type of road you want from the start. To create a local road feature, simply click the local road template and new features are automatically created as a local road and attributed and symbolized properly. You still need to add other, nondefault attribute values after you create the feature.

Using Snapping while Editing

Snapping allows you to create features that connect to each other so that your edits are more accurate and have fewer errors. With snapping, your pointer will jump, or snap to, edges, vertices, and other geometric elements when it nears them. This enables you to position a feature easily in relation to the locations of other features. As you move your pointer around the map, it snaps automatically to points, endpoints, vertices, and edges. All the settings you need to work with snapping are located on the Snapping toolbar, including enabling and disabling snapping types and setting snapping options. The main snap types are buttons on the toolbar, but additional ones are available on the Snapping menu.

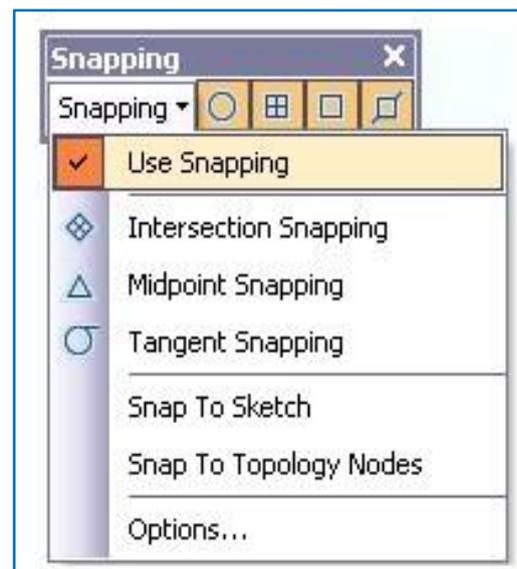


Figure: Snapping tools

Creating Points

Points are the simplest features to create. Simply click a point template in the Create Features window and the Point tool is automatically activated. Click the map where you want to add the point. You can right-click the map or use snapping to help you create points at exact locations.

Creating Lines and Polygons (Segments)

To create segments in lines or polygons, you will most commonly use the Line tool (with line templates) and the Polygon tool (with polygon templates). While these tools are used with different template types, they behave similarly. To create segments, simply click the map where you want to place vertices.

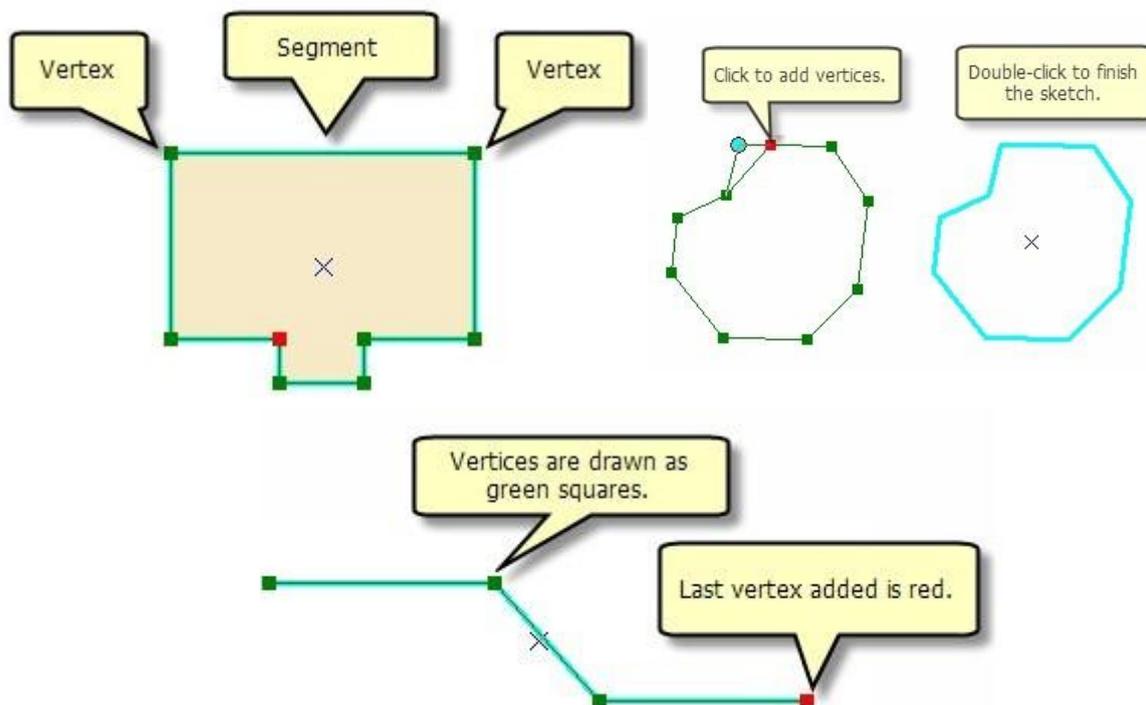
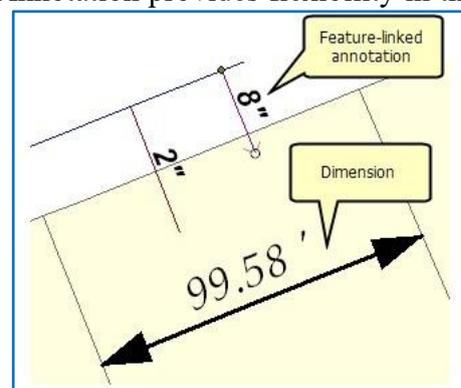


Figure: Creation of points, line polygon

Creating Text Features

You can store map text as annotation in a geodatabase. Annotation provides flexibility in the appearance and placement of your text because you can select individual pieces of text and edit them. Dimension features are a form of annotation designed to express distance measurements. Like other types of features, geodatabase annotation and dimension features are created inside an edit session, using feature templates and the tools on the Create Features window. Some annotation feature classes, such as standard annotation, stand alone in the geodatabase. Standard annotation is



Overview of ArcGIS

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The ArcCatalog application provides a Catalog window that is used to organize and manage various types of geographic information for ArcGIS Desktop.

Items in the Catalog Tree View

Folder Connections-Connections to file folders containing datasets and ArcGIS documents.

Toolboxes- Geo-processing tools and scripts used in ArcGIS.

Database Servers-SQL Server Express instances configured to store desktop or workgroup geodatabases.

Database Connections-Connections to databases and enterprise geodatabases.

GIS Servers-Connections to ArcGIS Server and OGC server sites.

My Hosted Services-When you connect to and sign in to a portal,

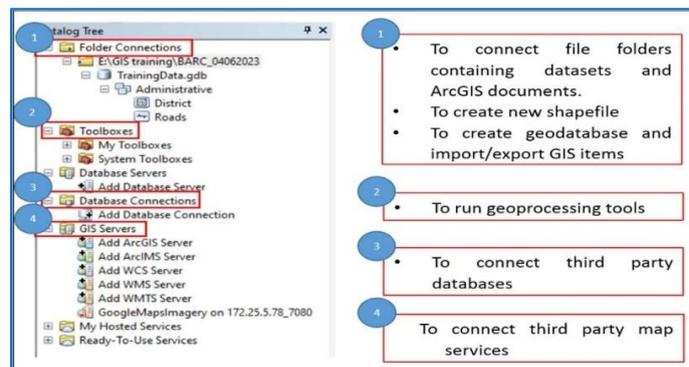
you can access the weblayers and web maps you own or that have been shared with you.

Ready-To-Use-Services-When you connect to ArcGIS Online, you can access a set of publicly available worldwide services.

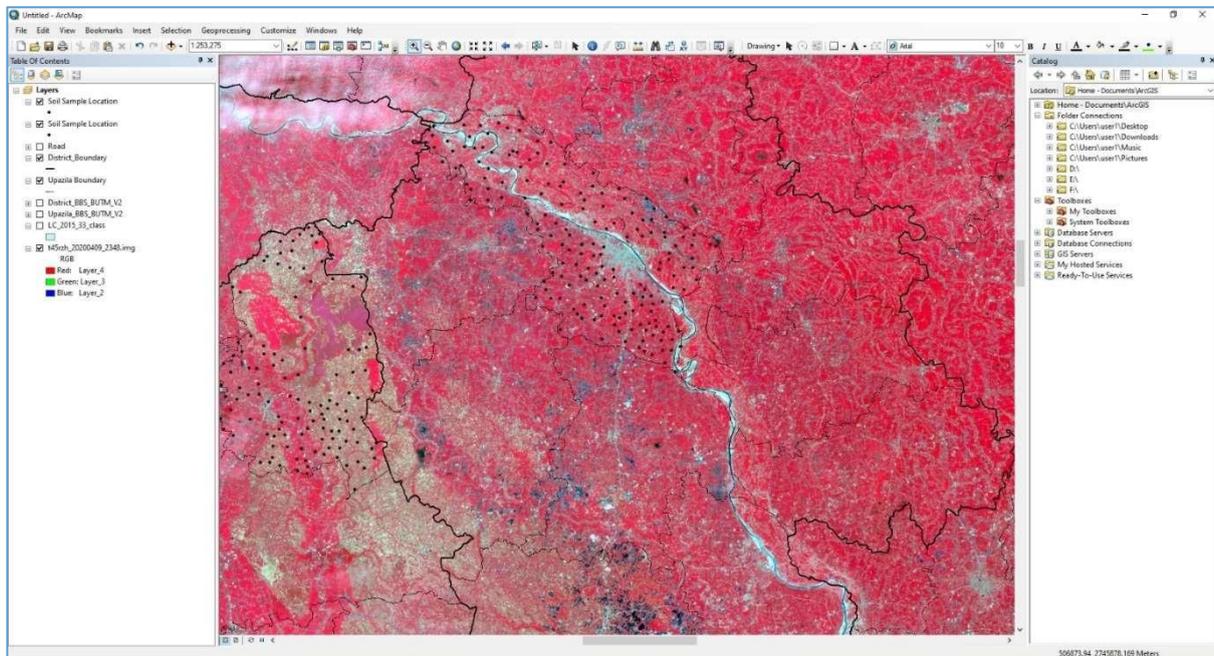
ArcMap represents geographic information as a collection of layers and other elements in a map. ArcMap is where you display and explore GIS datasets for your study area, where you assign symbols, and where you create map layouts for printing or publication. ArcMap is also the application you use to create and edit datasets.

ArcMap is one of the primary desktop GIS applications included in the ArcGIS Desktop suite. It is used to perform a wide range of common GIS tasks as well as specialized, user-specific tasks. Here is a list of some common workflows you can perform:

- Work with maps
- Print maps
- Compile and edit GIS datasets
- Use geo-processing to automate work and perform analysis
- Organize and manage your geodatabases and ArcGIS documents
- Publish map documents as map services



- Share maps, layers, geo-processing models, and geodatabases with other users
- Document your geographic information
- Customize the user experience

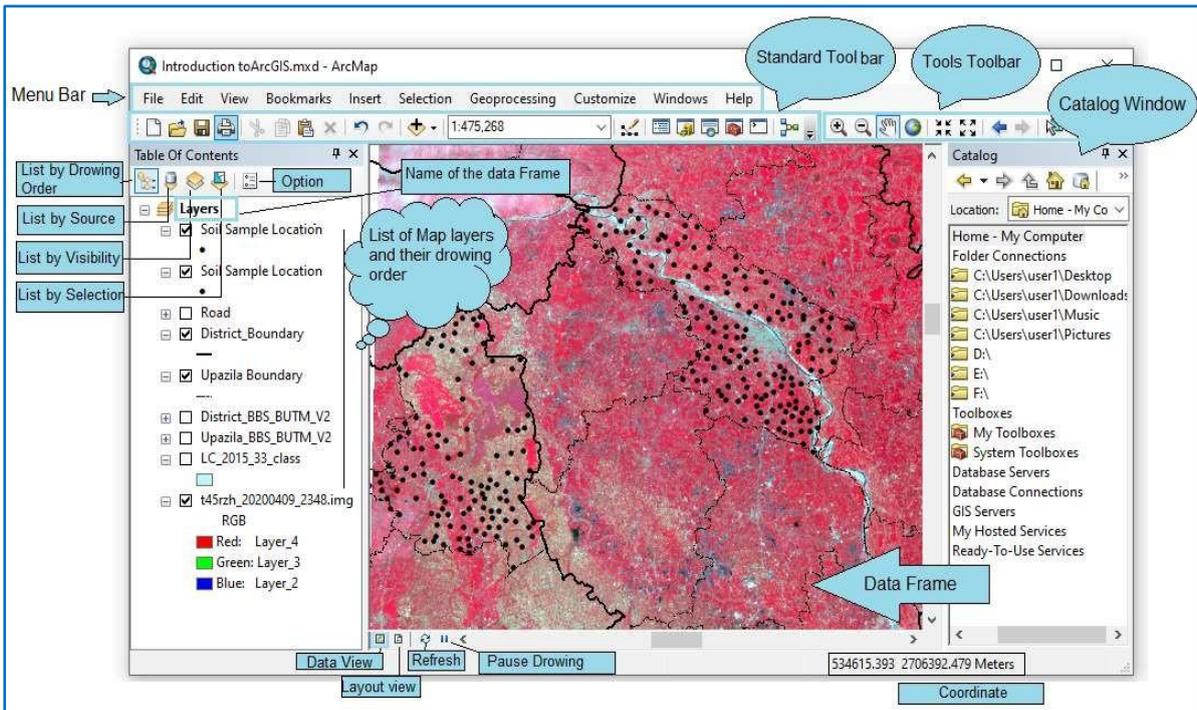


When you save a map, you have created in ArcMap, it will be saved as a file on disk. This is an ArcMap document and is referred to as a map document or mxd since the file name extension (.mxd) is automatically appended to your map document name. You can work with an existing .mxd file by double-clicking the document to open it. This will start an ArcMap session for that .mxd file.

Map documents contain display properties of the geographic information that you work with in the map—such as the properties and definitions of your map layers, data frames, and the map layout for printing—plus any optional customizations and macros that you add to your map.

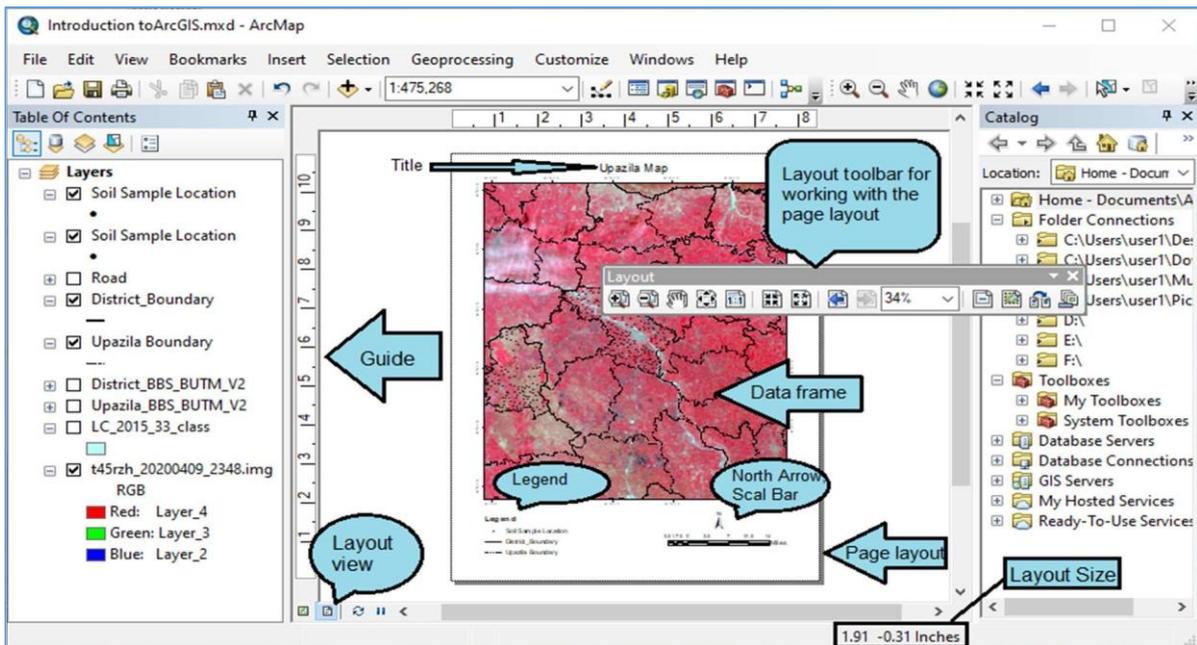
ArcMap represents geographic information as a collection of layers and other elements in a map view. There are two primary map views in ArcMap: the **data view** and the **layout view**.

In ArcMap data view, the map is the data frame. The active data frame is presented as a geographic window in which map layers are displayed and used. Within a data frame, you work with GIS information presented through map layers using geographic (real-world) coordinates. These will typically be ground measurements in units such as feet, meters, or measures of latitude-longitude (such as decimal degrees). The data view hides all the map elements on the layout, such as titles, north arrows, and scale bars, and lets you focus on the data in a single data frame, for instance, editing or analysis.



When you're preparing your **map's layout**, you'll want to work with your map in page layout view. A page layout is a collection of map elements (such as a data frame, map title, scale bar, north arrow, and a symbol legend) arranged on a page. Layouts are used for composing maps for printing or export to formats such as PDF.

The Layout view is used to design and author a map for printing, exporting, or publishing. You can manage map elements within the page space (typically, in inches or centimeters), add new map elements, and preview what your map will look like before exporting or printing it.



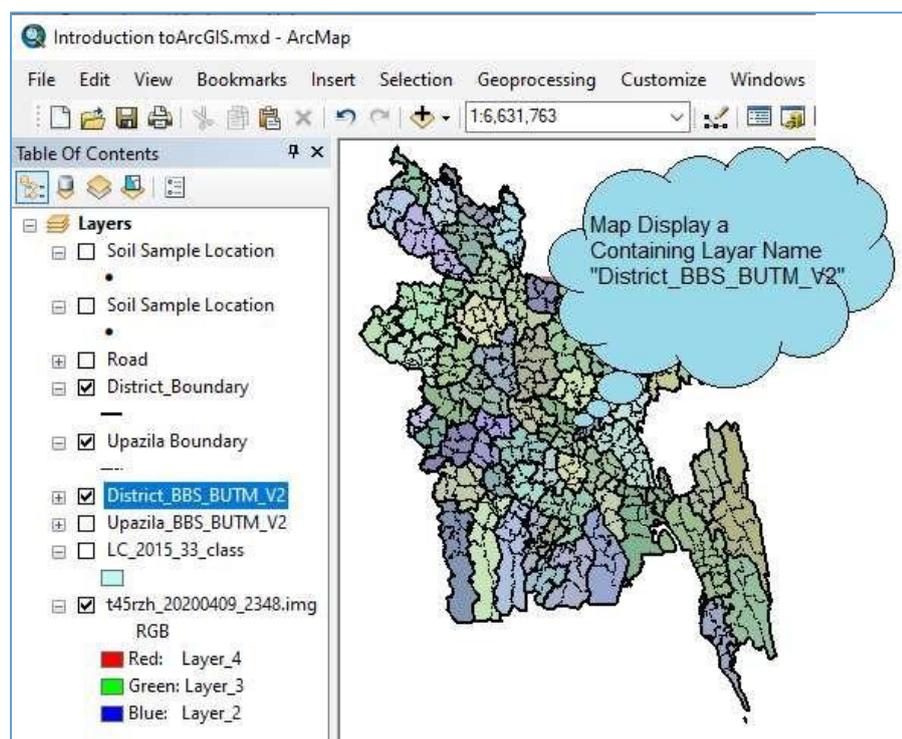
Common map elements include data frames with map layers, scale bars, north arrows, symbol legends, map titles, text, and other graphic elements.

Within the data frame, you display geographic datasets as layers, where each layer represents a particular dataset overlaid in the map. Map layers help convey information through:

- Discrete feature classes such as collections of points, lines, and polygons.
- Continuous surfaces, such as elevation, which can be represented in a number of ways. For example, as a collection of contour lines and elevation points or as shaded relief.
- Aerial photography or satellite imagery that covers the map extent

Example map layers include streams and lakes, terrain, roads, political boundaries, parcels, building footprints, utility lines, and orthophoto imagery

In addition to representing geographic information, each layer's map symbols, colors, and labels help describe the objects in the map. You can interact with the layers displayed in each data frame to query each feature and see its attributes, perform analytical operations, and to edit and add new features to each dataset.



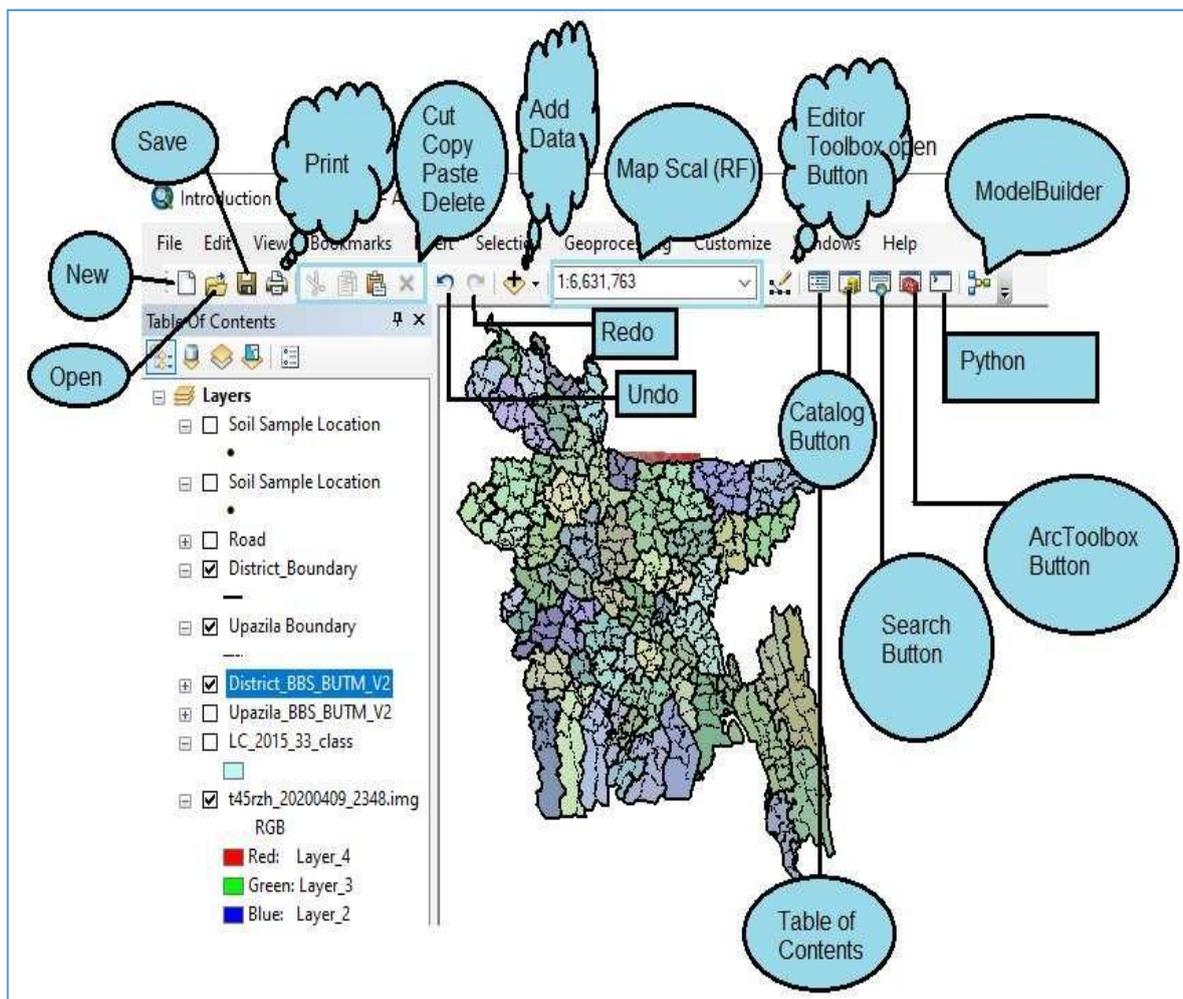
A layer doesn't store the actual geographic data. Instead, it references a dataset, such as a feature class, an image, a raster, and so on. Referencing data in this way allows the layers on a map to automatically reflect the most up-to-date information in your GIS database.

In ArcMap, you specify properties for each map layer, such as its map symbols and labeling rules, by right-clicking the layer in the table of contents and clicking Properties or by double-clicking on the layer name.

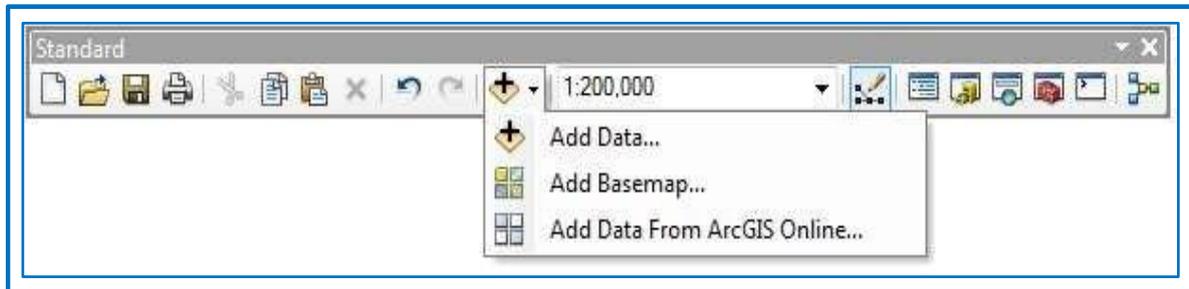
The **Table of Contents** window lists all the layers on the map and shows what the features in each layer represent. The check box next to each layer indicates whether its display is currently turned on or off. The order of layers within the Table of Contents window specifies their drawing order in the data frame.

The map's table of contents helps you manage the display order of map layers and symbol assignment, as well as to set the display and other properties of each map layer.

A typical map might have an image or a terrain base (such as shaded relief or elevation contours) near the bottom. Above that layer are a basemap; polygon, line, and point features; and annotation and other reference information.

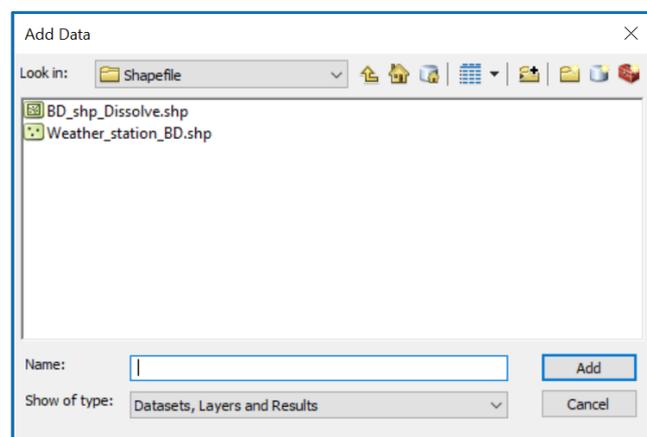


The **Standard toolbar** most typically appears at the top of the ArcMap application window and is used for map printing, creating a new map, opening an existing map, saving your map, starting related ArcGIS applications, and more.



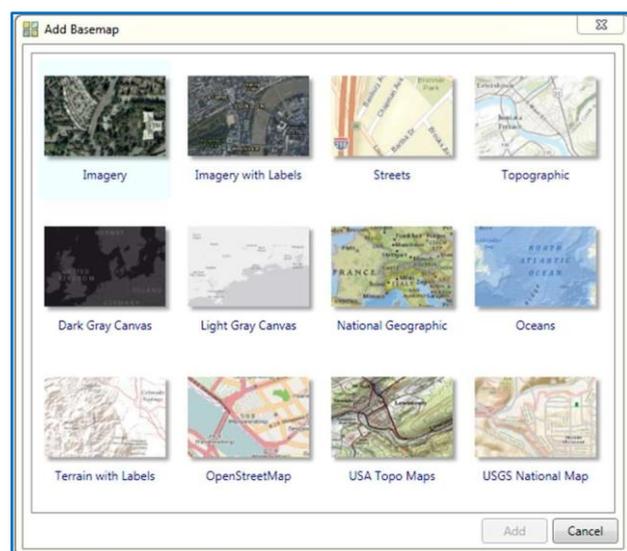
Clicking ‘Add Data’ Button Opens the ‘Add Data’ Dialog box for adding data of all compatible types to ArcMap.

- Double-click to open items that house other items, such as a folder or feature dataset.
- You will know what items are data and what items are “containers” for other data based upon the icon
- Review File Icons
- Control+Click or Shift+Click to select multiple items.



“Add Basemap” option opens the dialog box to add one of many basemaps available from ArcGIS Online.

- These maps are streaming over the Internet; thus, the speed of drawing will be based upon your internet speed.
- These basemaps are in **WGS 84 Web Mercator**, and unless your project is in the same projection, take care when digitizing and georeferencing data to streaming basemaps. You may be affecting you overall accuracy and precision.

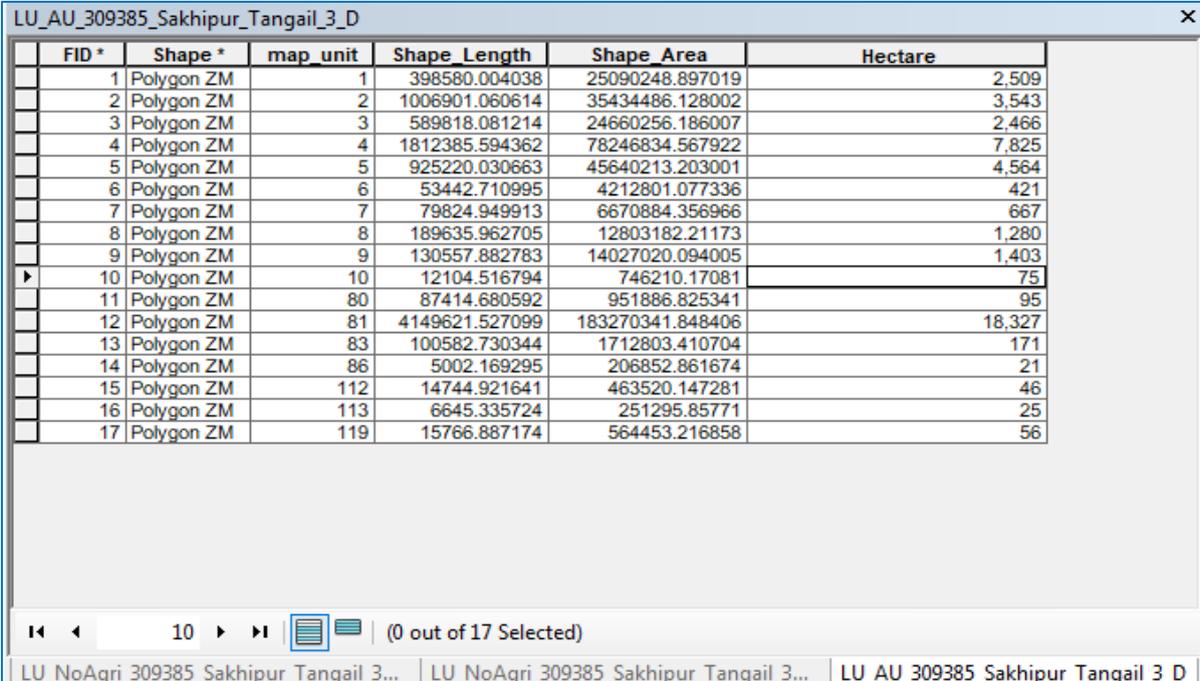


Working with Attribute Table

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Editing Attributes

Attributes are descriptions of a geographic feature in a GIS, usually stored as a row in a table. For example, attributes of a river might include its name, length, and average depth. You can enter new attribute values when you create features, and you can edit existing values. When you create a feature, it starts with only the default attribute values as specified in the template used to create the feature. You input attributes after you create a feature. There are two main ways of adding or updating attributes in ArcMap: the Attributes window and the table window.

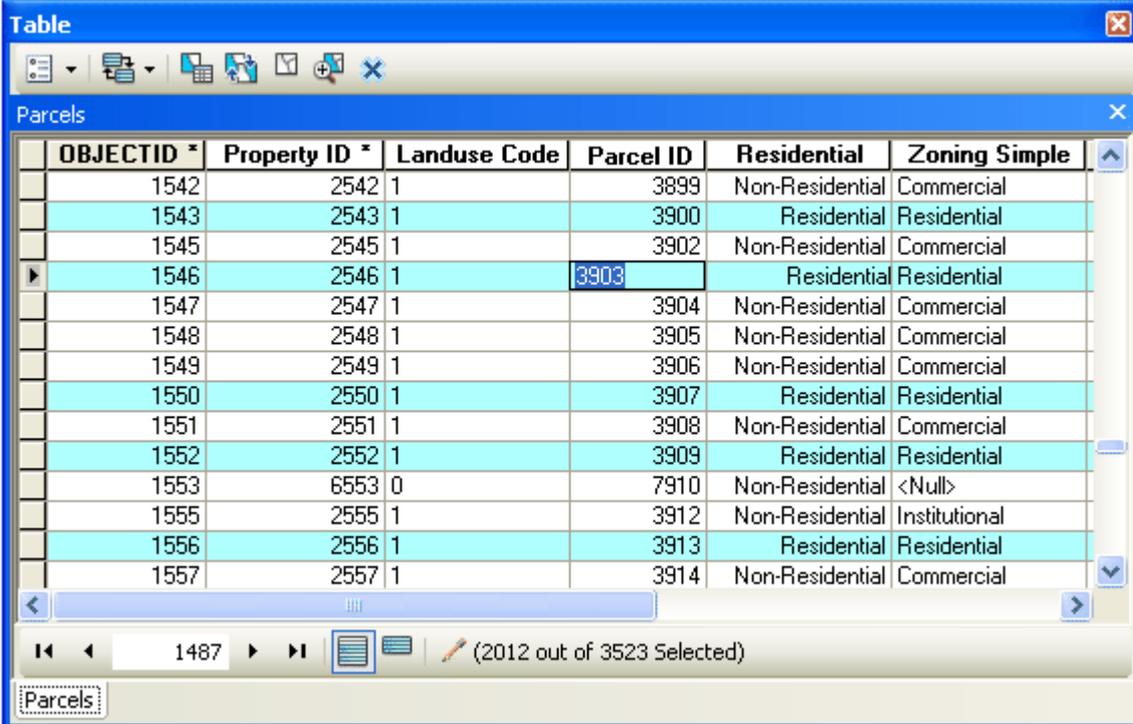


FID*	Shape*	map_unit	Shape_Length	Shape_Area	Hectare
1	Polygon ZM	1	398580.004038	25090248.897019	2,509
2	Polygon ZM	2	1006901.060614	35434486.128002	3,543
3	Polygon ZM	3	589818.081214	24660256.186007	2,466
4	Polygon ZM	4	1812385.594362	78246834.567922	7,825
5	Polygon ZM	5	925220.030663	45640213.203001	4,564
6	Polygon ZM	6	53442.710995	4212801.077336	421
7	Polygon ZM	7	79824.949913	6670884.356966	667
8	Polygon ZM	8	189635.962705	12803182.21173	1,280
9	Polygon ZM	9	130557.882783	14027020.094005	1,403
10	Polygon ZM	10	12104.516794	746210.17081	75
11	Polygon ZM	80	87414.680592	951886.825341	95
12	Polygon ZM	81	4149621.527099	183270341.848406	18,327
13	Polygon ZM	83	100582.730344	1712803.410704	171
14	Polygon ZM	86	5002.169295	206852.861674	21
15	Polygon ZM	112	14744.921641	463520.147281	46
16	Polygon ZM	113	6645.335724	251295.85771	25
17	Polygon ZM	119	15766.887174	564453.216858	56

Figure: Attribute table

Editing values in the table window

Once you begin an edit session, you'll notice a pencil icon next to the Table Options button Table Options on the Table window, indicating that the table can be edited. In addition, those fields that you can edit will have a white background in the field heading. You can make any of the attribute changes you need by clicking a cell and typing a new attribute value.



OBJECTID *	Property ID *	Landuse Code	Parcel ID	Residential	Zoning Simple
1542	2542	1	3899	Non-Residential	Commercial
1543	2543	1	3900	Residential	Residential
1545	2545	1	3902	Non-Residential	Commercial
1546	2546	1	3903	Residential	Residential
1547	2547	1	3904	Non-Residential	Commercial
1548	2548	1	3905	Non-Residential	Commercial
1549	2549	1	3906	Non-Residential	Commercial
1550	2550	1	3907	Residential	Residential
1551	2551	1	3908	Non-Residential	Commercial
1552	2552	1	3909	Residential	Residential
1553	6553	0	7910	Non-Residential	<Null>
1555	2555	1	3912	Non-Residential	Institutional
1556	2556	1	3913	Residential	Residential
1557	2557	1	3914	Non-Residential	Commercial

Figure: Editing Attribute table

Data Queries in GIS

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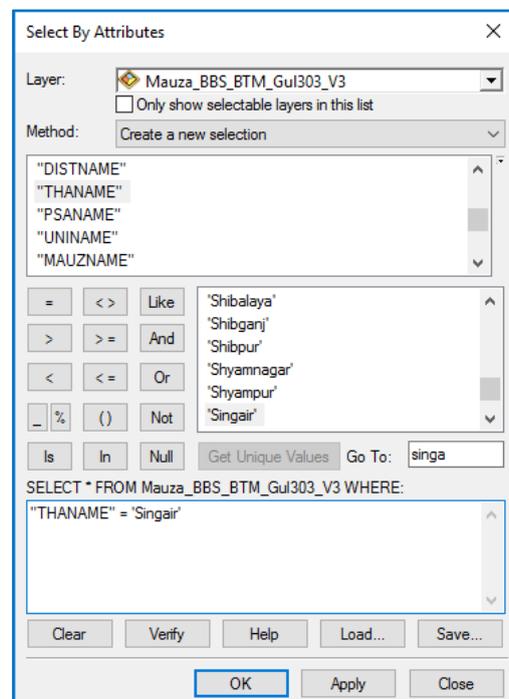
In GIS, **Data Queries** help you **select**, **filter**, and **analyze** records based on attribute information. ArcMap uses a Structured Query Language (SQL)-like syntax for queries.

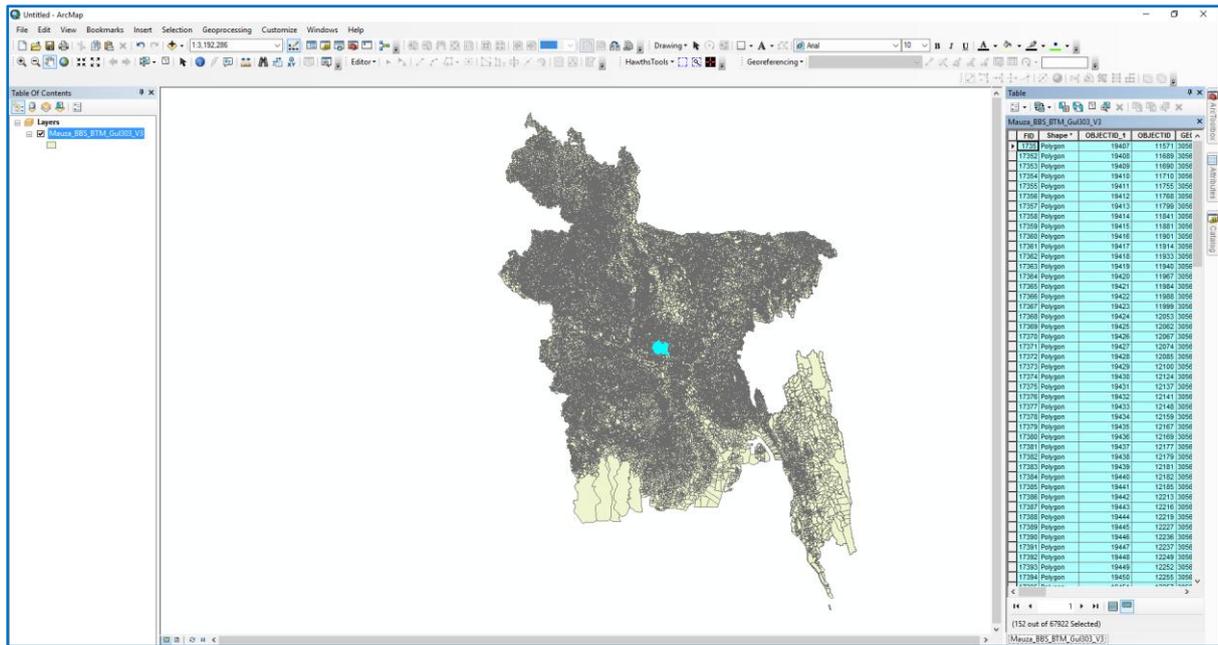
Basic Query Logic

Logical Operator	Meaning	Example	Purpose
AND	Both conditions must be true	District = 'Dhaka' AND Population > 500000	Find areas in Dhaka with population > 500,000
OR	Either condition can be true	District = 'Dhaka' OR District = 'Chittagong'	Select features in either Dhaka or Chittagong
LIKE	Pattern matching (wildcards)	District LIKE 'D%'	Select districts starting with 'D'
NOT	Exclude specific values	NOT District = 'Barisal'	Select everything except Barisal
IS NULL	Field has no data	Population IS NULL	Find features with missing population data

How to Perform a Query in ArcMap

- Open Attribute Table**
 - ❖ Right-click the layer > Open Attribute Table.
- Select by Attributes**
 - ❖ Click Table Options (top left) > Select by Attributes.
- Build Your Query**
 - ❖ Double-click a field, select an operator, and type your value.
 - ❖ Example:
 City = 'Dhaka' AND
 Population > 1000000





4. Apply the Query

- ❖ Click **Apply** or **OK** to see selected features highlighted.

Data Joining: Spatial Join and Attribute Join

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ArcMap provides two primary methods for joining data: **Attribute Join** and **Spatial Join**.

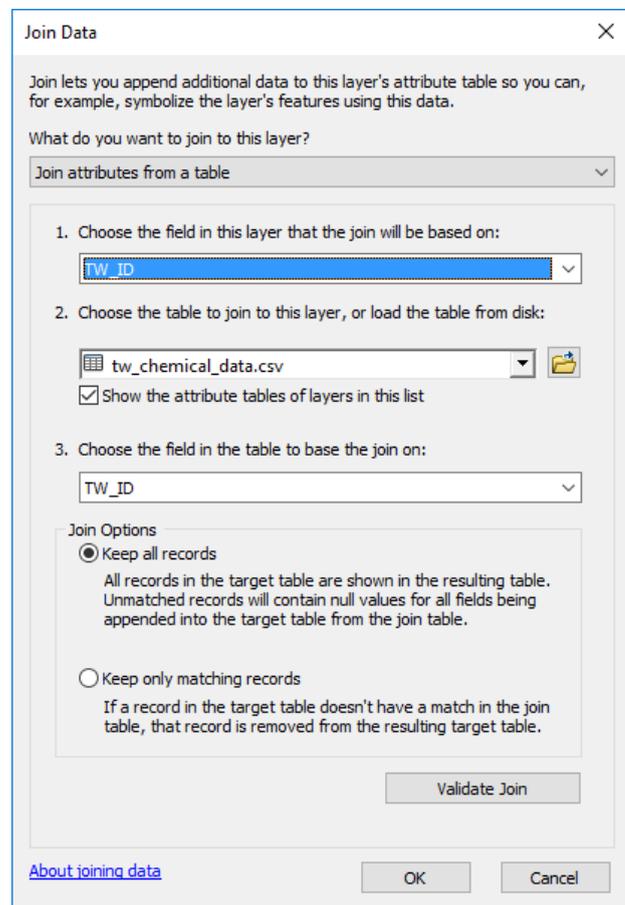
1. Attribute Join

Purpose: Combine a table of data with spatial features based on a common attribute.

Example Scenario: Joining a CSV file containing soil chemical data to a shapefile of districts using the 'TW_ID' field.

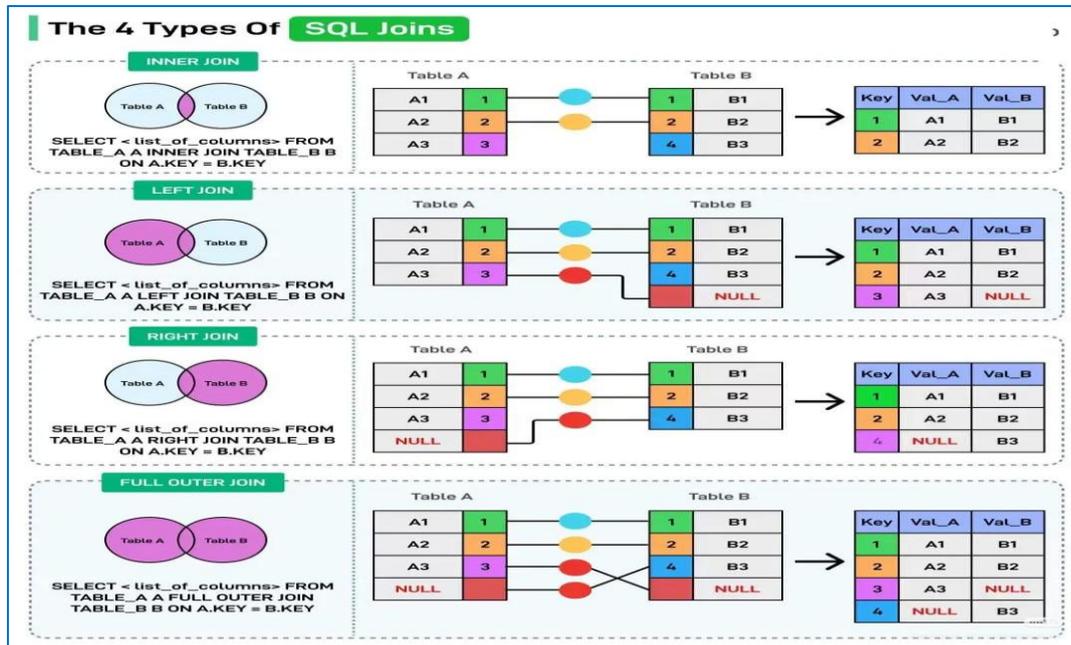
Steps:

1. **Right-click** on the target layer (e.g., Districts) in the Table of Contents.
2. Select **Joins and Relates > Join**.
3. In the Join Data dialog:
 - o Choose **Join attributes from a table**.
 - o Select the field in the layer that matches the field in the table.
 - o Browse and select the table to join.
 - o Choose the matching field in the table.
4. Click **OK**. The attributes from the table are now associated with the spatial features.

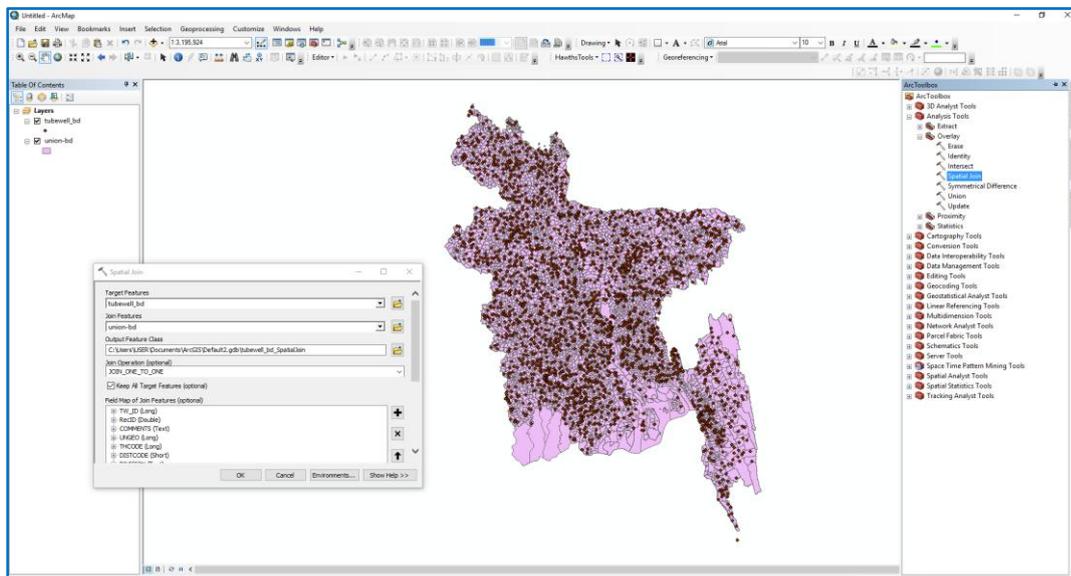


2. Spatial Join

Purpose: Combine attributes from one layer to another based on their spatial relationship.



Example Scenario: Assigning the number of tubewells within each union.



Steps:

1. **Right-click** on the target layer (e.g., Union, Upazilla, District).
2. Choose **Joins and Relates > Join**.
3. In the Join Data dialog:
 - o Select **Join data from another layer based on spatial location**.
 - o Choose the layer to join (e.g., Tubewell, Schools, Farmers).
 - o Specify the spatial relationship (e.g., features that intersect).
4. Click **OK**. A new layer is created with combined attributes.

Basic Geoprocessing Tools

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Geoprocessing refers to a collection of operations used to manipulate, analyze, and manage spatial data in GIS. These operations take geographic data as input, apply a process or transformation, and generate new datasets as output.

Geoprocessing is essential for:

- Spatial analysis
- Data extraction
- Overlay and proximity operations
- Data cleaning and preparation
- Creating new datasets based on analysis needs

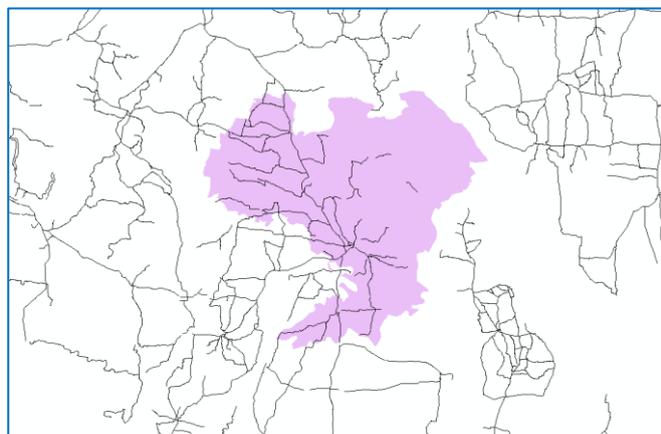
Common concepts:

- **Input Data:** Feature class, shapefile, raster.
- **Parameters:** Buffer distance, clipping boundary, dissolve field, etc.
- **Output Data:** New feature class/shapefile with modified geometry/attributes.
- **Coordinate Systems:** Very important for distance-based operations (e.g., buffer).
- **Environment Settings:** Extent, output coordinate system, snapping, XY tolerance.

In ArcMap, geoprocessing tools are available through **ArcToolbox**, ModelBuilder, Python script, or the Geoprocessing menu.

Clip

Clip is an extraction tool used to cut out features from an input layer based on the boundary of a clip polygon. Only those features (or parts of features) lying inside the clip polygon will be included in the output. It preserves the attributes of the input layer.



Used for:

- Extracting study area
- Cutting national layers to district/Upazila level
- Focusing analysis on a specific boundary

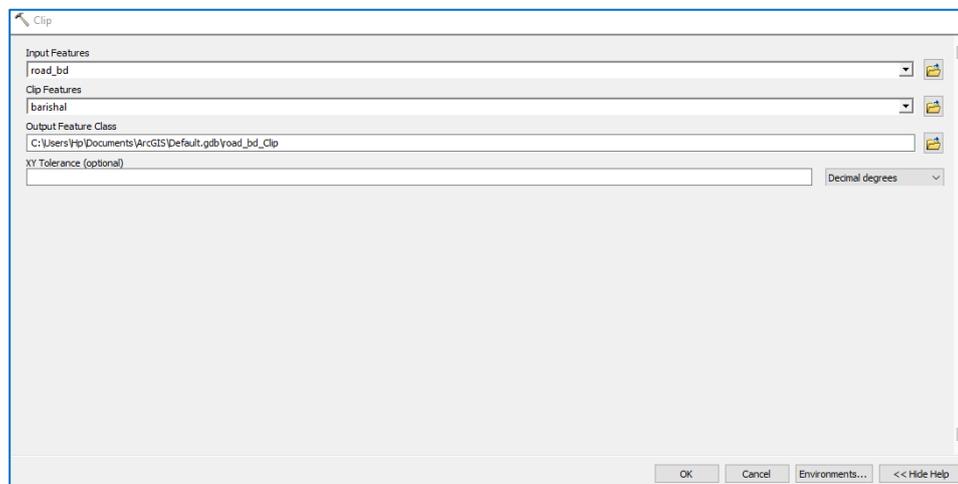
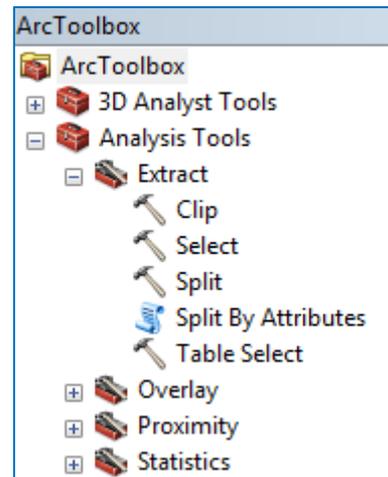
Requirements:

- Input Features: Point, line, or polygon
- Clip Features: Must be polygon

Steps:

1. Open ArcMap and add both **Input Layer** and **Clip Polygon Layer**.
2. Ensure both layers use the same coordinate system or projection.
3. Open: **ArcToolbox** → **Analysis Tools** → **Extract** → **Clip**
4. Set parameters:

- **Input Features:** Choose the layer you want to extract
- **Clip Features:** Choose the polygon boundary
- **Output Feature Class:** Choose location + name



5. Click **OK**.
6. Review the output layer. Check geometry and attribute table.

Buffer

Buffer is a proximity analysis tool that creates a zone around input features at a specified distance. The result is always a polygon, regardless of whether the input is point, line, or polygon.

Used for:

- Identifying influence zones (e.g., 100 m around roads)
- Creating safety zones
- Environmental protection or planning

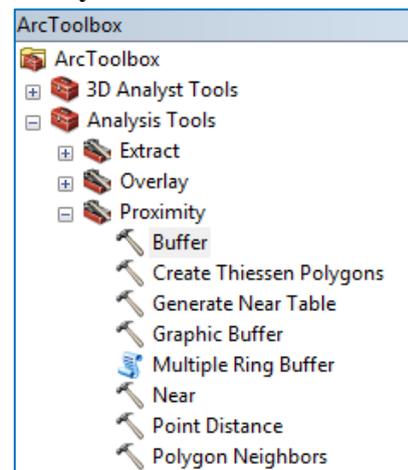
Important:

Always use a **projected coordinate system** (meters or feet). Degrees (Lat/Long) produce wrong distances.

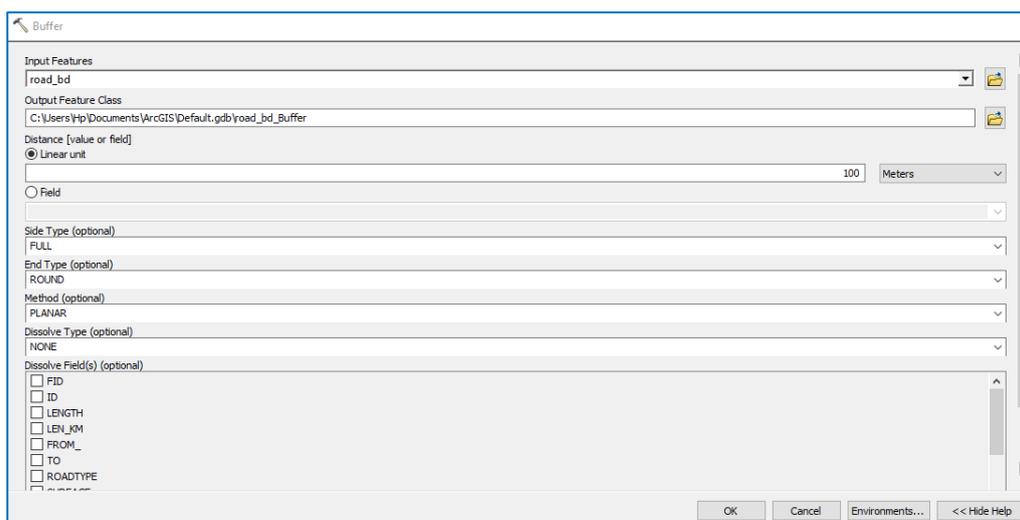
Steps:

1. Add the input layer (point/line/polygon).
2. Reproject to a projected CRS if needed.
3. Open: **ArcToolbox** → **Analysis Tools** → **Proximity** → **Buffer**
4. Set parameters:

- **Input Features:** Select input layer
- **Output Feature Class:** Provide location + name
- **Distance:** e.g., 100 Meters, 500 Meters, 0.5 Kilometers
- **Side Type** (for lines): Full, Left, Right
- **End Type** (for lines): Round or Flat
- **Dissolve Type:**
 - NONE – individual buffers
 - ALL – merge overlapping buffers
 - LIST – dissolve using fields



5. Click **OK**.
6. Verify buffer distance using the Measure Tool.



Intersect

Intersect combines multiple layers and returns only the areas where all input layers overlap. It keeps the attribute fields of all input layers, creating a detailed output table.

Works with:

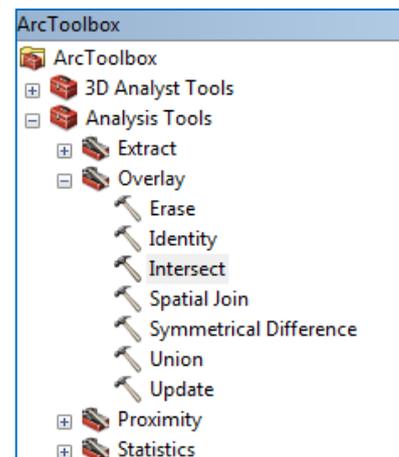
- Points
- Lines
- Polygons

Common usage:

- Finding roads inside flood zones
- Identifying agricultural land inside a project area
- Extracting common areas from multiple thematic layers

Steps:

1. Load the input layers (two or more).
2. Confirm they overlap spatially and have consistent CRS.
3. Open: **ArcToolbox** → **Analysis Tools** → **Overlay** → **Intersect**
4. Set parameters:
 - **Input Features:** Select the layers
 - **Output Feature Class:** Provide location + name
 - **Output Type:** Usually **INPUT**
5. Click **OK**.
6. Review output geometry and combined attribute table.



Common Issues

- Large attribute table due to combined fields
- Empty output if layers do not overlap
- Sliver polygons due to small misalignments

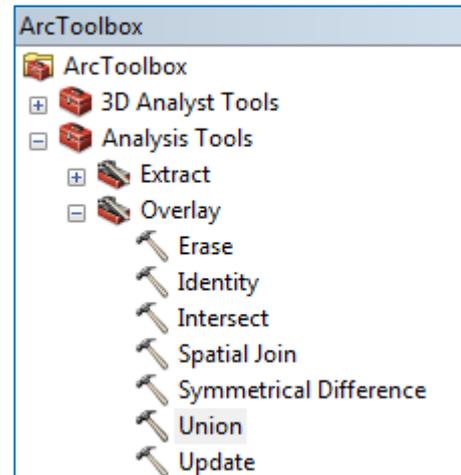
Union

Union overlays two or more polygon layers and creates a new layer containing all areas from all layers. It preserves full spatial extent and attributes of every input.

Union tool only works with polygon layers.

Steps:

1. Add two or more polygon layers.
2. Ensure projections match.
3. Open: **ArcToolbox** → **Analysis Tools** → **Overlay** → **Union**
4. Set parameters:
 - **Input Features:** Select polygon layers
 - **Output Feature Class:** Provide location + name
 - **Gaps Allowed:** Leave checked unless you want to remove small gaps
5. Click **OK**.
6. Inspect new subdivided polygons and attributes.



Dissolve

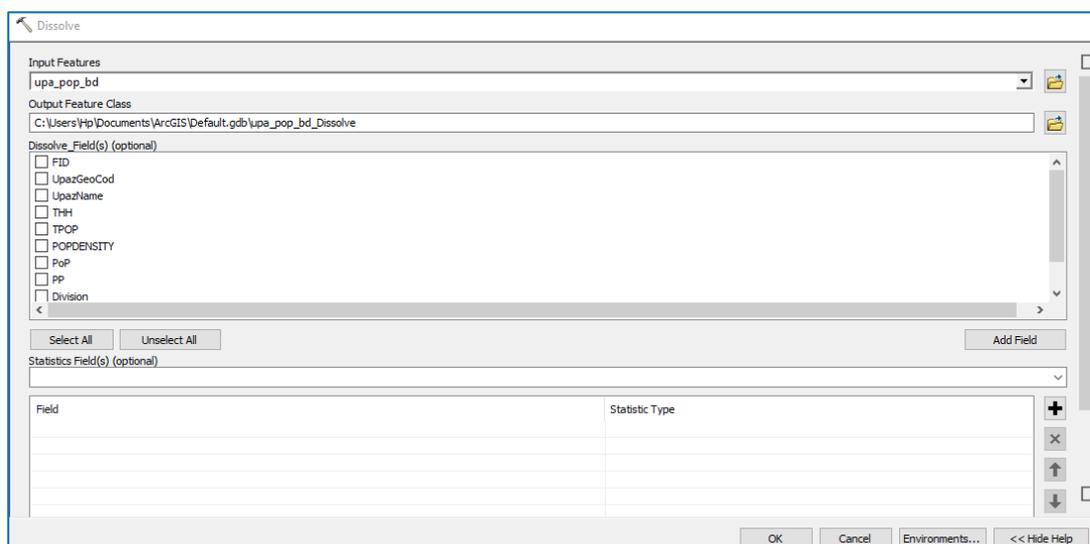
Dissolve merges polygon features that share a common attribute value. Internal boundaries are removed and a simplified feature is created. Numeric fields can be aggregated.

Used for:

- Creating district boundaries from Upazilas
- Simplifying map layers
- Aggregating area/length statistics

Steps

1. Add polygon layer.
2. Open: **ArcToolbox** → **Data Management Tools** → **Generalization** → **Dissolve**
3. Set parameters:
 - **Input Features:** Select polygon layer
 - **Output Feature Class:** Provide name
 - **Dissolve Fields:** Choose attributes for grouping
 - **Statistics Fields** (optional): Choose numeric fields + statistic types (Sum, Mean, Min, Max)
4. Click **OK**.
5. Inspect output layer for simplified geometry.



GIS Visualization and Map Layout

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A **page layout** (often referred to as a layout) is a collection of map elements organized on a virtual page, designed for map printing. Common map elements that are arranged in the layout include one or more data frames (each containing an ordered set of map layers), a scale bar, north arrow, map title, descriptive text, and a symbol legend.

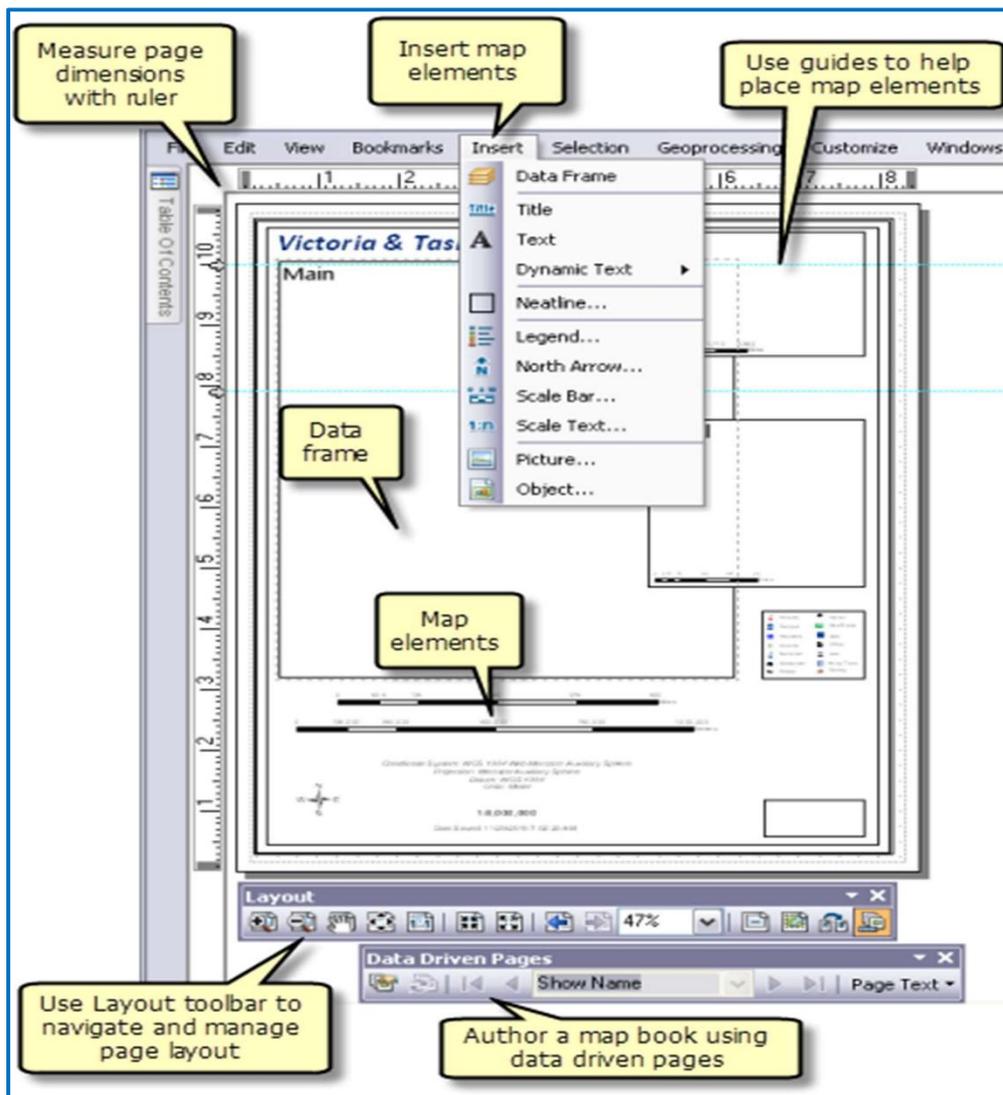


FIGURE: KEY ELEMENTS OF THE PAGE LAYOUT USER INTERFACE

In Layout view we can add map elements such as north arrows, legends, and scale bars, as well as, frames that contain the geographic data or the maps themselves. Other finishing touches can be added to a Layout using a full suite of graphics and graphic editing tools. Rulers and guides can be used in the Layout View to help accurately measure and organize the elements on the page. What we see on the layout is what we get if we print or export the map to

the same page size.

Creating a New Page Layout

The first step in ArcMap is to change your map view to layout—either by selecting Layout View from the View menu or by clicking the Layout View button on the lower left of the map display



In order to save time, we may want to consider using a template to preconfigure your layout. When starting a new document, we can use one of the templates included with ArcMap or create your own.



FIGURE: LAYOUT TEMPLATES

Using a template is optional.

Once we are working in layout view, we can set up your page orientation and dimensions using the Page and Print Setup dialog box.

When we create a new document from a template, an untitled map is opened based on the selected template. These templates are listed under the My Templates node under New Maps.

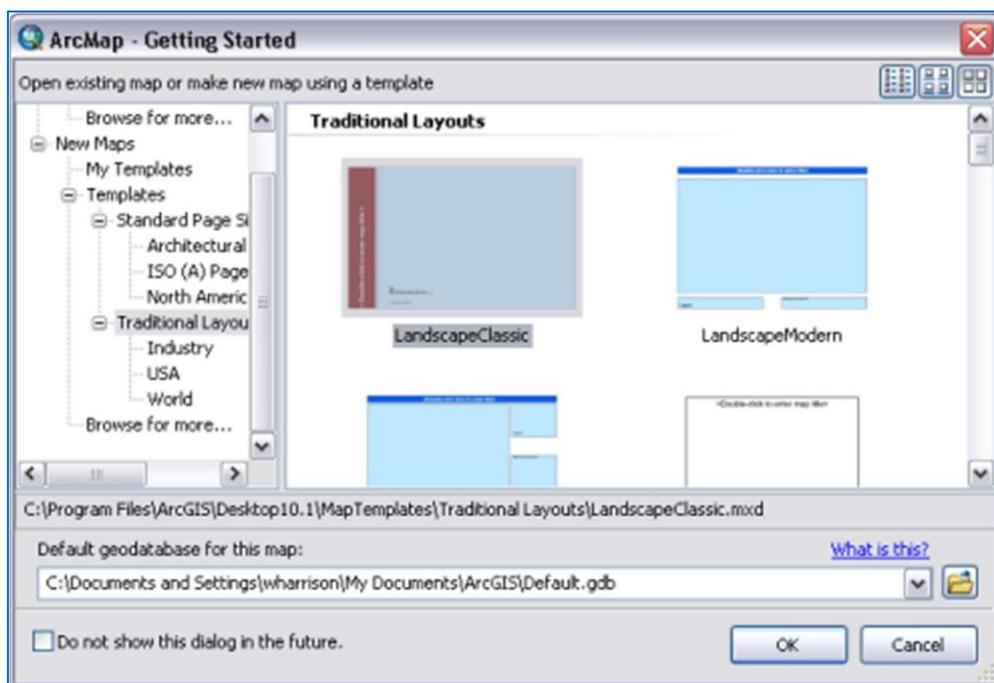


Figure: Open existing maps or create new

The Select Template dialog box

User and system templates are also available when changing your page layout in the Select Template dialog box. New templates are available in the Select Template dialog box from the same user profile and system location used by the Getting Started dialog box.

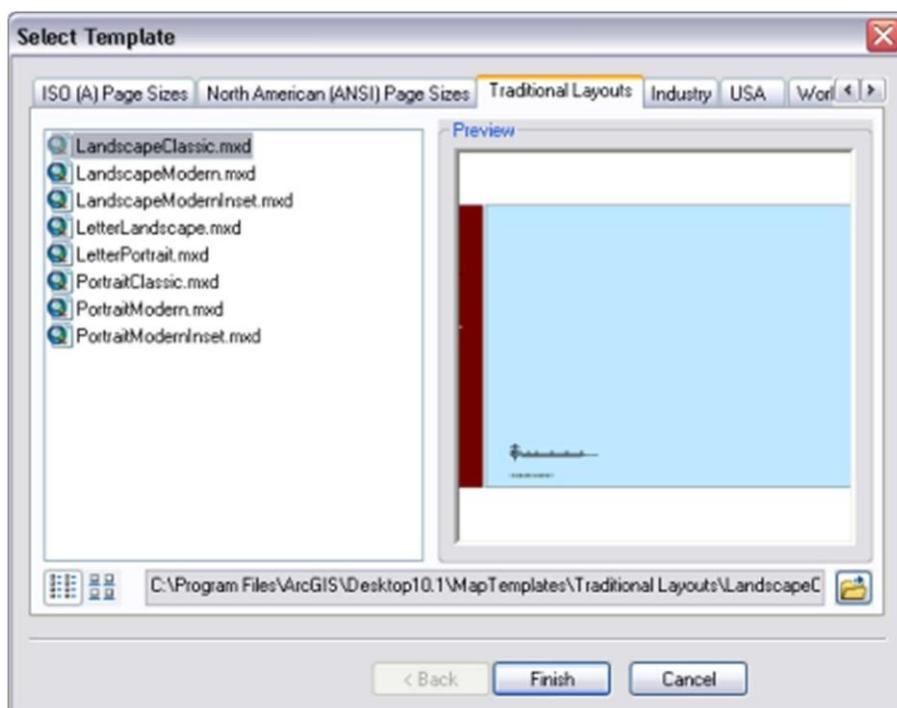


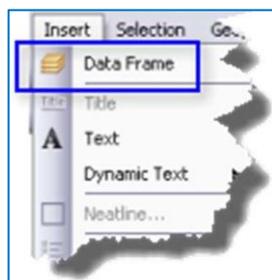
Figure: Change page layout with a user-defined template under My Templates or a system template from Templates

Change your page layout with a user-defined template under My Templates or a system template from Templates.

To open the Select Template dialog box, click the Change Layout button  on the Layout toolbar.

Adding a data frame to the page layout

The data frame displays a collection of layers drawn in a particular order for a given map extent and map projection. We can add a data frame to the page layout using the Insert menu.

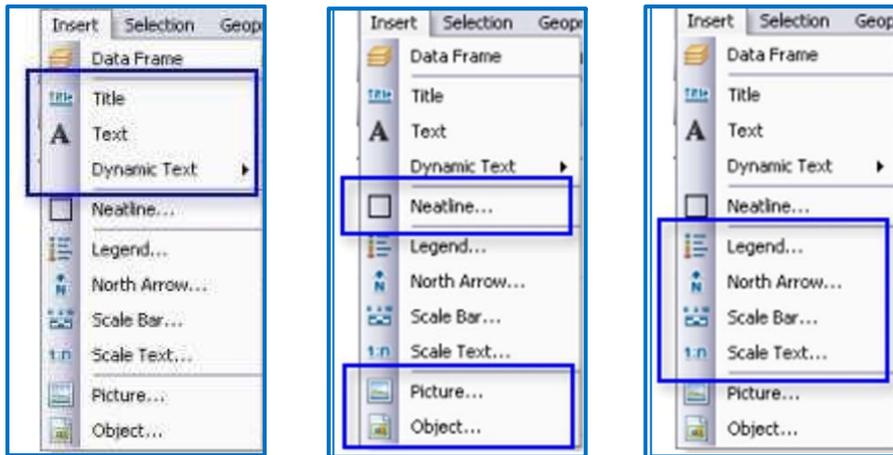


From this menu, we can insert additional data frames. These additional data frames may be for locator or detail maps. If we are using multiple data frames we may want to consider using extent indicators to show the extent of one data frame within another data frame. A good locator map will also contain an indicator, such as an outline, showing where the extent of the detail map fits within a larger extent. For example, your locator map might show the location of a state within a country.

When your map document contains more than one data frame, only one will be the active data frame, that is, the one with which we are actively working. The active data frame name is shown in bold in the table of contents and the frame will be highlighted on the page with a dashed outline. To make a data frame active, right-click on its name in the table of contents and select Activate or single-click the data frame on the page layout.

Adding Other Map Elements to Page Layout

Use the Insert menu to select other map elements to add to your layout. We can use this menu to add a Title to the page. The added text will be the same as the text entered for the title in the Map Document Properties dialog box. Along with a title we can add (static) Text and Dynamic Text.



We can use the Insert menu to add a Legend, North Arrow, Scale Bar, and Scale Text. Clicking any of these options opens an appropriate wizard or dialog box where we can set properties for each map element.

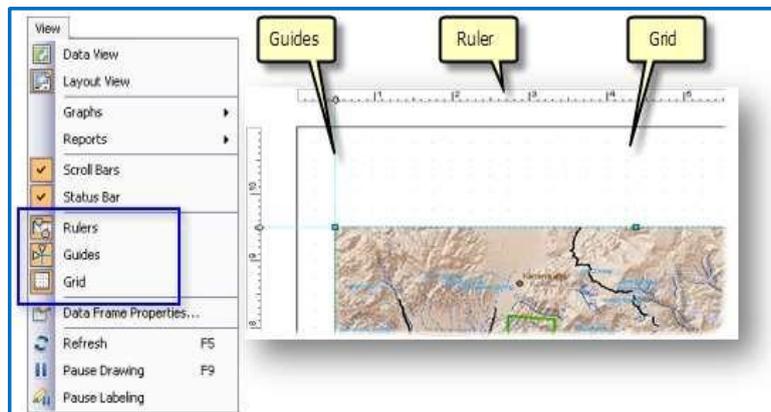
We can also add Neatlines, pictures, and objects from the Insert menu.

The **Draw toolbar** can be used to add graphic shapes such as rectangles, lines, and points. We can also add graphic text and edit text properties.



Working with Map Elements

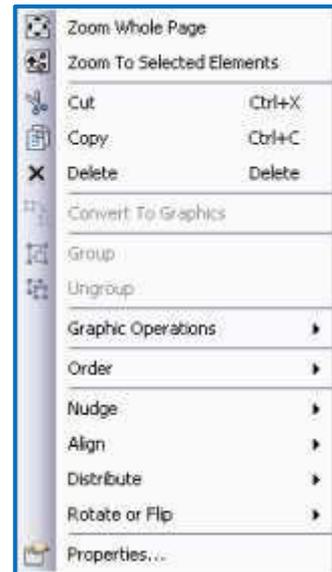
As we add map elements, we can edit their properties, size, position, and appearance, and arrange them on the page with other map elements. From the View menu we can toggle on Rulers, Guides, and a Grid to aid in positioning elements on the page. We can also access placement aids in the layout view context menu. Open this menu by right-clicking the page layout.



We can set properties for these placement tools using the Layout View tab of the ArcMap Options dialog box, which is available from the Customize menu. Here, we can set the units and division values for the page ruler, and set the spacing for the grid.

Options on the Layout View tab also include ways to manage the appearance of the layout view. We can choose to stretch the contents of the view when the window is resized.

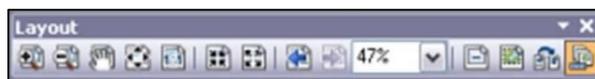
To work with individual elements, select the element or elements we want to work with and right-click to open the **element context menu**. Here we can zoom to, Cut, Copy, or Delete the selected element or elements from the page layout. In some cases we may want to convert a dynamic element, such as a legend or scale bar, to graphics in order to apply greater control over their display. The menu provides options to Group or Ungroup elements. Grouping elements is a good way of managing a page layout with many elements.



This menu also provides commands to further manipulate graphics through Graphic Operations and placement commands. Placement commands include the ability to place elements in a specified drawing Order, Nudge, or move the element in a particular direction, Align, and Distribute multiple elements on the page. We can also Rotate or Flip an element.

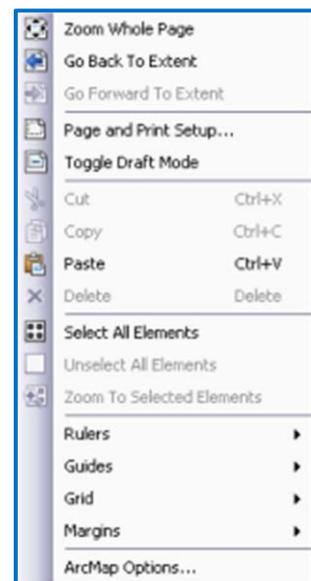
We can change the size of map elements by selecting them and dragging the selection handles. Dragging a handle in either direction will resize the element. We can also use the element's properties dialog box—Size and position tab—to position the element.

Working with a Page Layout



The Layout toolbar is used to navigate the page layout. It is enabled when we are in layout view. We can pan and zoom in/out on the page. We can also jump back and forth to previous page extents or specify a zoom percentage based on the page size. Other options for navigating in the page layout include the Layout View context menu, changing the active tool into a navigation tool by using the keyboard, and using the mouse wheel to zoom in and out.

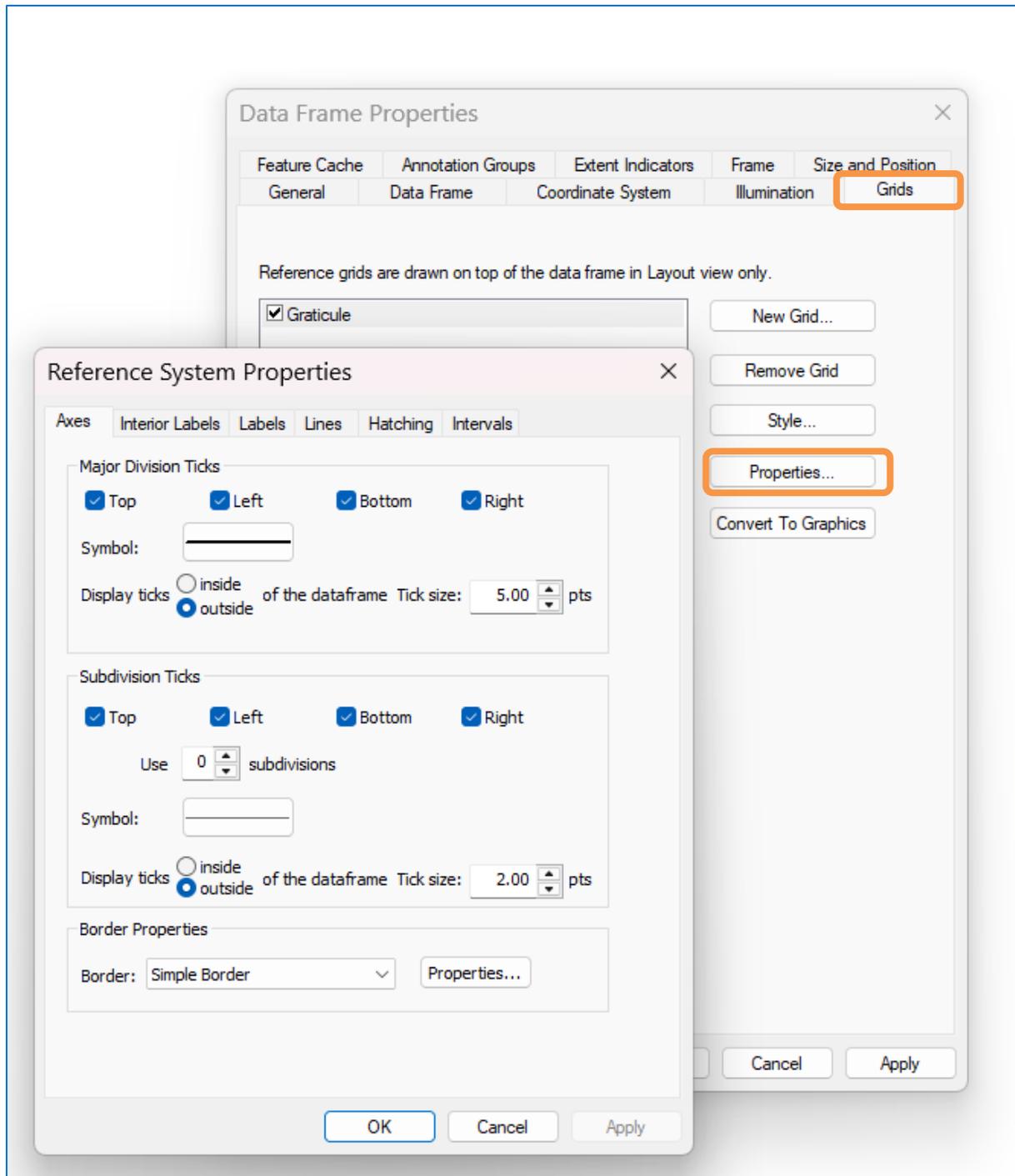
We can access the **layout context menu** by right-clicking in any open area on the page. The layout context menu offers ways to work with the page layout. Along with access to the placement aids (Rulers, Guides, Grid, and Margins), this context menu provides a few commands to quickly change the view of the page, access the Page and Print Setup dialog box, Toggle Draft Mode, and work with selected elements.



When in draft mode, using Toggle Draft Mode, the contents of the page elements are not drawn. Instead, only the bounding box of the frame and a label showing its name are drawn. We can control draft mode for individual elements through the Frame tab of the element's Properties dialog box.

Grids and Graticules

Grids and graticules are used to display coordinate positions on the earth. Graticules show lines of latitude and longitude for the earth, while grids show measured locations based on a coordinate system or can be used as a reference system for a grid index. For example, we can place a grid that divides a map into a specified number of rows and columns by choosing the reference grid type.



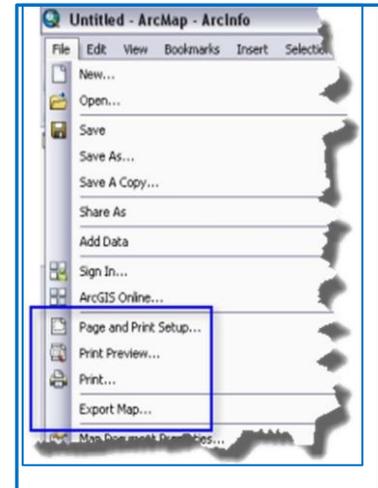
ArcMap has three ways in which we can add grids and graticules to your map

- Grids and Graticule Wizard
- Custom overlay reference grids
- Grid and Graticule layers

Deciding which option to use depends on the requirements of the grid or graticule used in the map.

Printing and Exporting Layout

Once we have completed this work on your layout, we can print your map or create other types of output formats—PDF files, PostScript files, or Illustrator files. Under the file menu we have the options to open the Page and Print Setup dialog box, Print Preview, Print the page, or to Export Map.



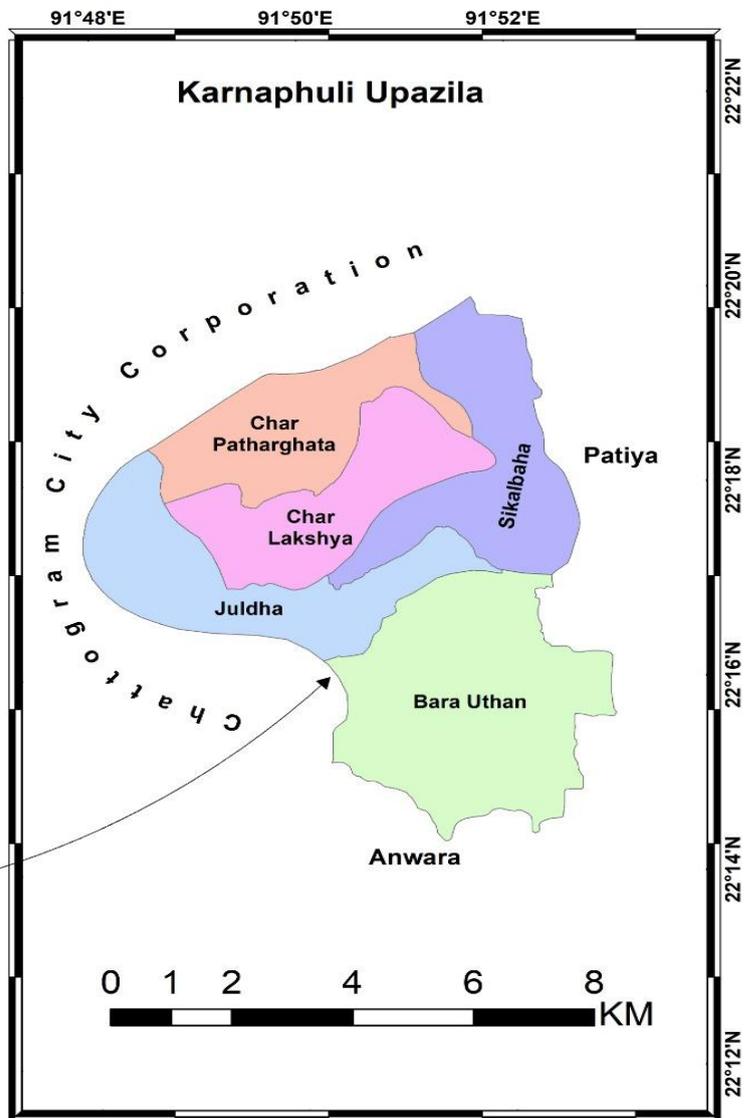
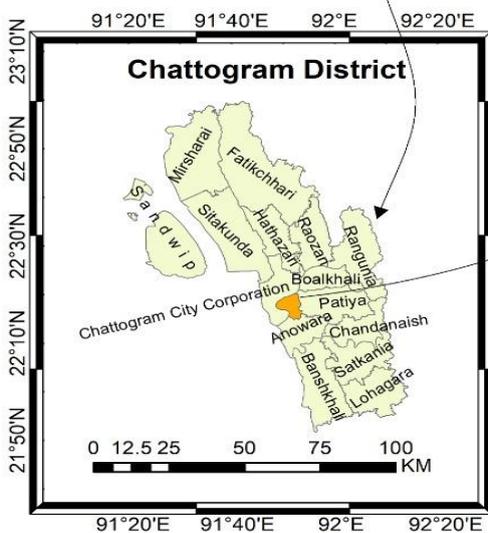
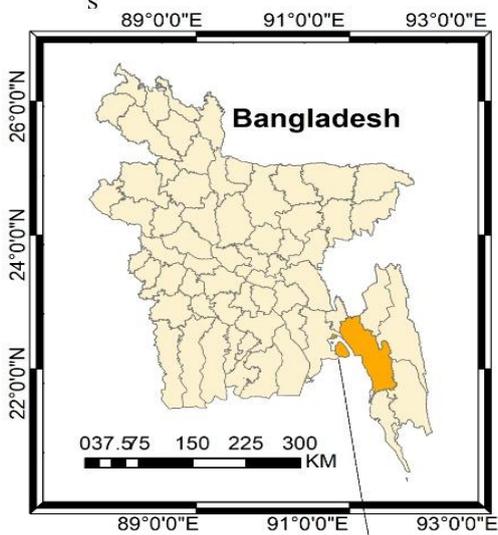
Reference:

Esri. 2023. Using map templates

<https://desktop.arcgis.com/en/arcmap/latest/map/page-layouts/using-mxd-templates.htm>

Exercise

Study Area Map - Karnaphuli



Author: Bangladesh Agricultural Research Council (BARC)

Creation Date: 26-Nov-25

Basic Concepts of Remote Sensing Technology

Hasan Mahmud, Senior System Analyst, Computer & GIS Unit
Bangladesh Agricultural Research Council
Email: hasan.mahmud@barc.gov.bd

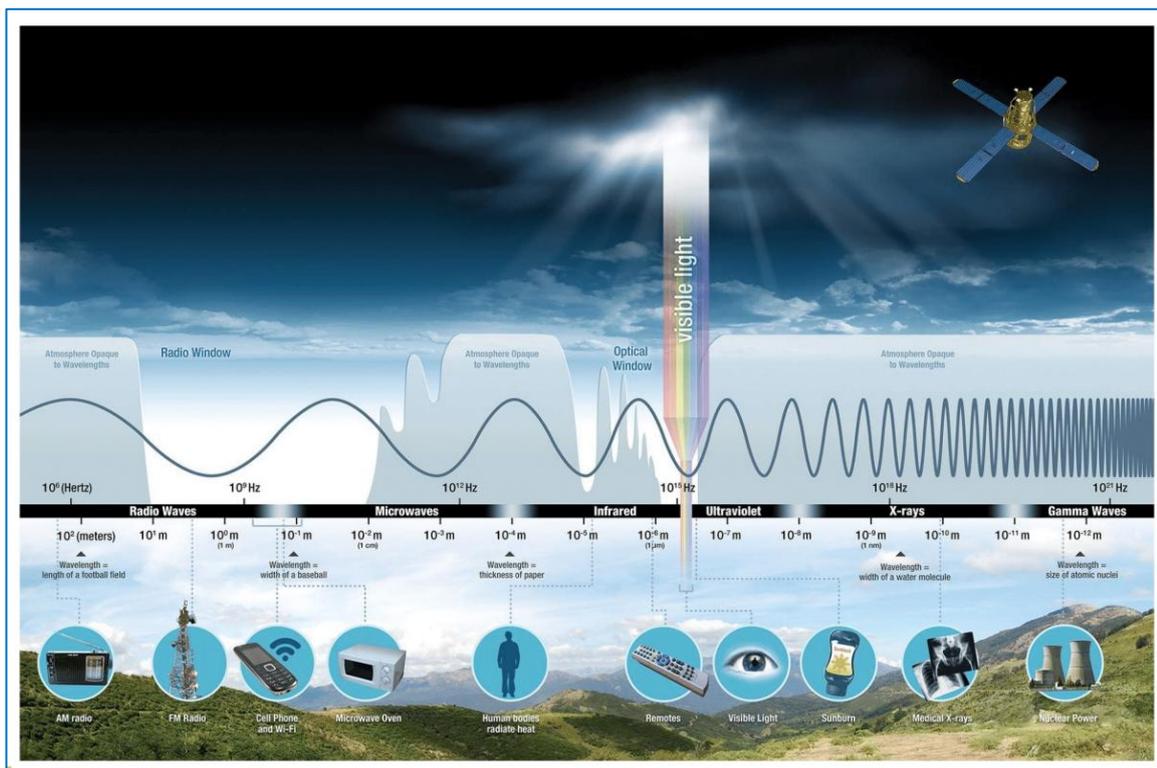
1. Introduction to Remote Sensing

Remote sensing is the science of obtaining information about objects or areas from a distance, typically using satellite or aerial sensor technologies. It plays a crucial role in monitoring and managing natural resources, urban planning, agriculture, disaster response, and climate studies. The technology leverages electromagnetic radiation to gather data without direct contact with the subject.

A formal definition:

"Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information."

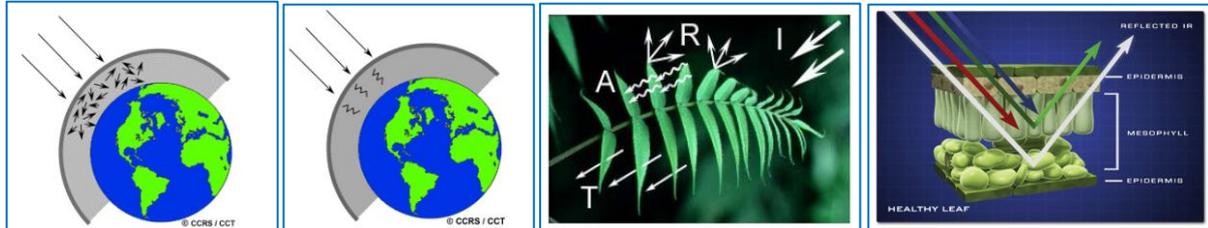
2. Electromagnetic Spectrum and Radiation Principles



Remote sensing relies on electromagnetic radiation (EMR), which is emitted or reflected by objects. The EM spectrum includes various wavelengths from gamma rays to radio waves. Different materials reflect, absorb, or emit EM radiation uniquely, allowing remote sensors to identify and analyze them through their spectral signatures.

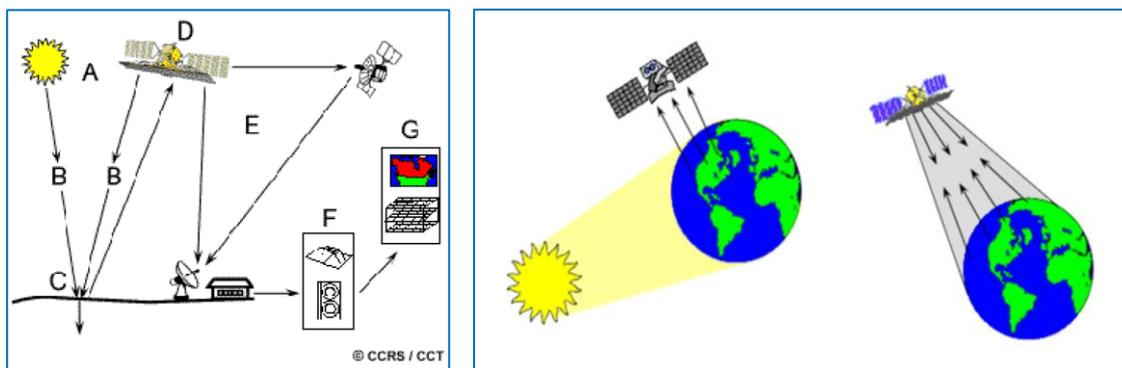
3. Interactions with Atmosphere and Earth's Surface

Before reaching sensors, radiation interacts with the atmosphere through scattering and absorption. Upon striking the Earth, radiation may be absorbed, transmitted, or reflected, depending on surface characteristics. Vegetation, water, and soil each exhibit distinct reflectance patterns across wavelengths.



4. Remote Sensing Systems: Passive and Active

Remote sensing systems can be classified as passive or active. Passive systems detect natural energy (typically from the sun) reflected by the surface, while active systems emit their own signal and measure its reflection. Examples include optical sensors (passive) and radar systems (active).



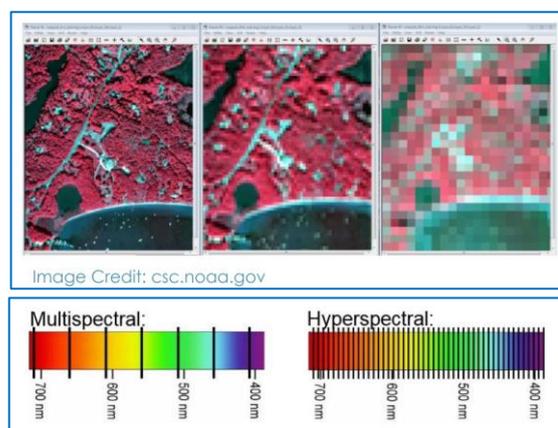
5. Types of Resolutions

Resolution in remote sensing defines the level of detail. The four primary types are:

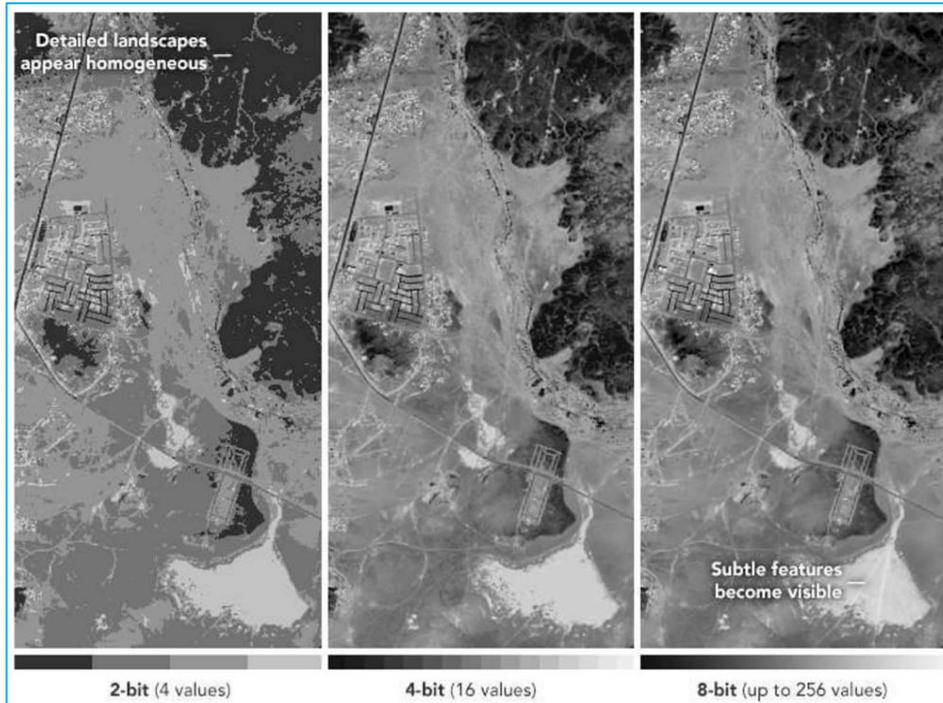
Spatial: Size of the smallest object detectable.

Spectral: Number and width of spectral bands.

Temporal: Frequency of data acquisition.



Radiometric: Sensitivity to differences in signal strength. Represented as how many bits are used to represent a reflectance value.



6. Satellites, Orbits, and Sensors

Satellites operate in various orbits - geostationary, polar, or sun-synchronous - each serving different observation purposes. Sensors onboard these satellites, such as MODIS, Landsat OLI, and Sentinel-1 SAR, differ in design and application. Key satellite parameters include orbit type, swath width, and revisit time.

Parameter	Sentinel-1	Sentinel-2	Landsat-8	Landsat-9	MODIS (Terra/Aqua)
Orbit	Sun-synchronous, Near-polar				
Altitude	~693 km	~786 km	~705 km	~705 km	~705 km
Repeat Cycle	12 days (6 days A+B)	10 days (5 days A+B)	16 days	16 days (8 days Landsat-8)	1-2 days (near-global daily)
Sensor	C-SAR	MSI	OLI & TIRS	OLI-2 & TIRS-2	MODIS
Resolution	5-20 m	10 m, 20 m, 60 m	15 m (pan), 30 m (MS), 100 m (Thermal)		250 m, 500 m, 1 km
Swath Width	80-400 km	290 km	185 km	185 km	2330 km
Spectral Bands	HH, VV, HV, VH	13	9 (Vis, NIR, SWIR, Pan) + 2 (Thermal)		36 (Visible to Thermal IR)

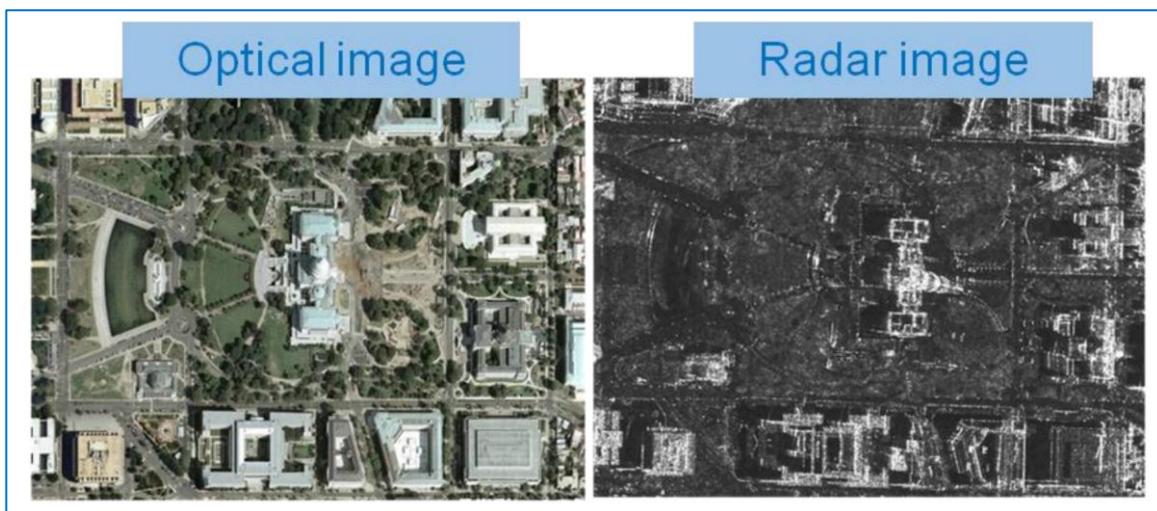
Data Type	Radar Backscatter (Intensity & Phase)	TOA Reflectance	TOA Reflectance, Thermal Radiance	Radiance, Reflectance, Temperature, Indices, etc.
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7. Data Processing Levels

Satellite data is processed in levels:

- Level 0/1: Raw Sensor Data.
- Level 2: Geophysical Variables (e.g., surface temperature).
- Level 3: Gridded, Calibrated data, Quality Controlled Data.
- Level 4: Model-assimilated products.

8. Optical Vs Radar



Feature	Optical Imagery	Radar Imagery (SAR)
Sensor Type	Passive (detects reflected/emitted light)	Active (emits and receives microwaves)
Illumination	Sun (mostly), thermal emission	Self-illuminated (microwaves)
Weather	Affected by clouds, fog, smoke	Can penetrate clouds, fog, smoke
Day/Night	Primarily daytime	Day and night
Penetration	Limited	Can penetrate vegetation, some ground
Data Captured	Spectral reflectance (color, vegetation health, composition)	Surface roughness, dielectric properties, geometry

Image Look	Visually intuitive (photo-like)	Grayscale, textural, requires specific interpretation
Resolution	Can be very high	High (with SAR processing)

9. Important Indices

NDVI, NDWI, NDSI, and EVI are key vegetation and land surface indices derived from multispectral satellite data. NDVI uses red and NIR bands to assess vegetation greenness, while NDWI (using NIR and SWIR) monitors vegetation water content and open water. NDSI (using green and SWIR) is designed for snow detection. EVI is an enhanced vegetation index utilizing blue, red, and NIR bands to minimize atmospheric and soil noise and reduce saturation in dense vegetation, offering a more robust measure compared to NDVI in certain environments. The Leaf Area Index (LAI) is a crucial biophysical parameter that quantifies the amount of leaf material present in a plant canopy or ecosystem. Defined as one-half of the total green leaf area per unit horizontal ground surface area (for broadleaf canopies) or a related measure for coniferous canopies. Each index provides specific insights into surface characteristics but has limitations related to atmospheric conditions, background influences, and the specific properties they aim to measure.

$$\text{NDVI} = (\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red})$$

$$\text{NDWI (Common)} = (\text{NIR} - \text{SWIR}) / (\text{NIR} + \text{SWIR})$$

$$\text{NDSI} = (\text{Green} - \text{SWIR}) / (\text{Green} + \text{SWIR})$$

$$\text{EVI} = G * ((\text{NIR} - \text{Red}) / (\text{NIR} + C1 * \text{Red} - C2 * \text{Blue} + L))$$

(where G, C1, C2, and L are adjustment factors)

10. Advantages and Challenges

Advantages:

- Provides data where ground access is limited
- Offers global coverage and consistent observations
- Supports real-time and historical analysis
- Information on non-visible regions of the spectrum

Challenges:

- Balancing resolution parameters
- Data volume and complexity
- Need for calibration and validation
- Costly high resolution Imagery

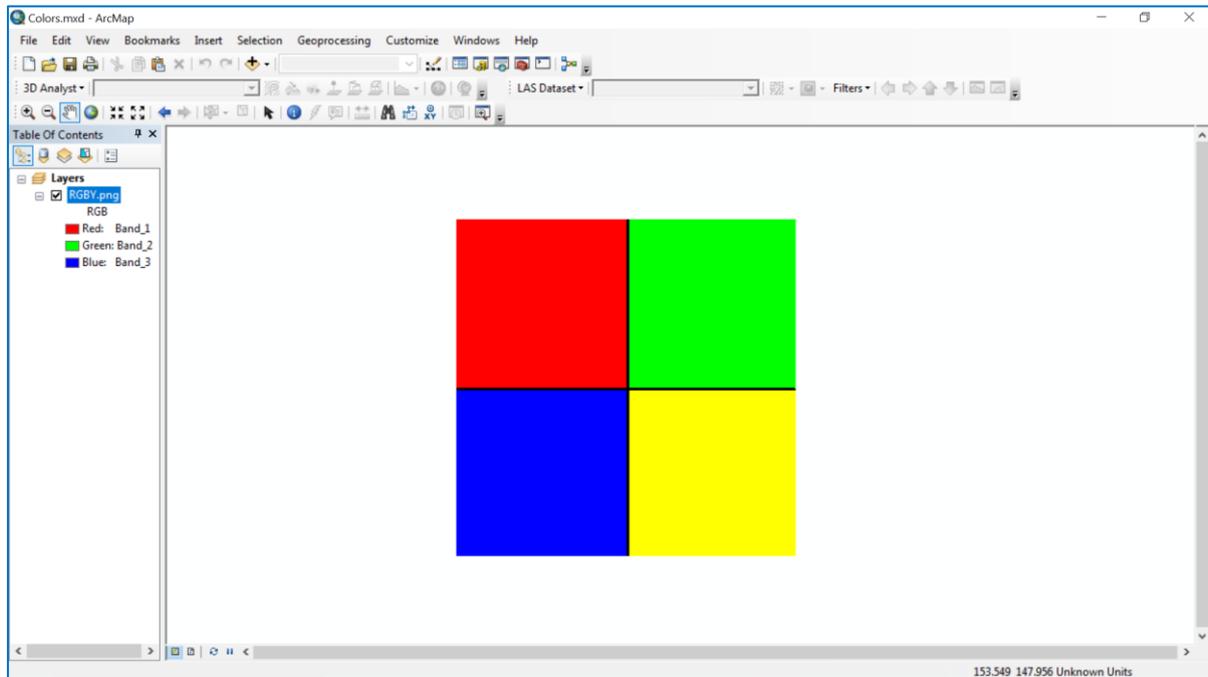
References:

- ❖ NASA's Applied Remote Sensing Training Program
- ❖ Canada Centre for Remote Sensing Remote Sensing Tutorial
- ❖ Tutorial by TELECAN on Fundamentals of Remote Sensing

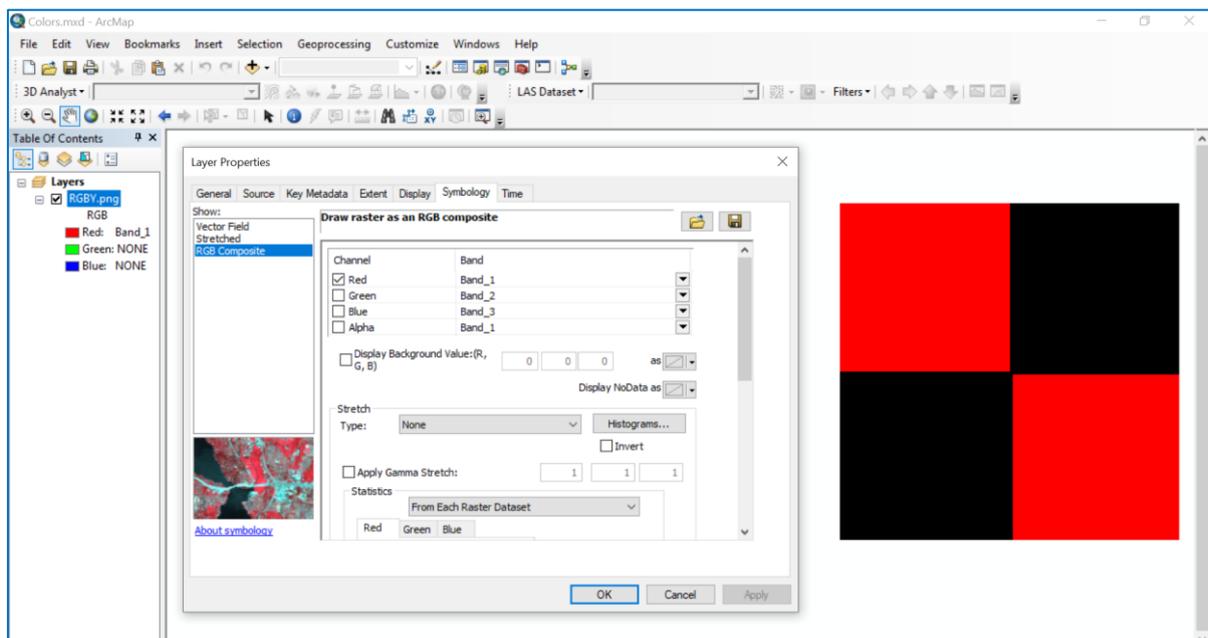
A Simple Illustration of Bands (Practical)

In this exercise we will check how do the individual channels/bands (RGB) looks that are present in our standard jpg, png images.

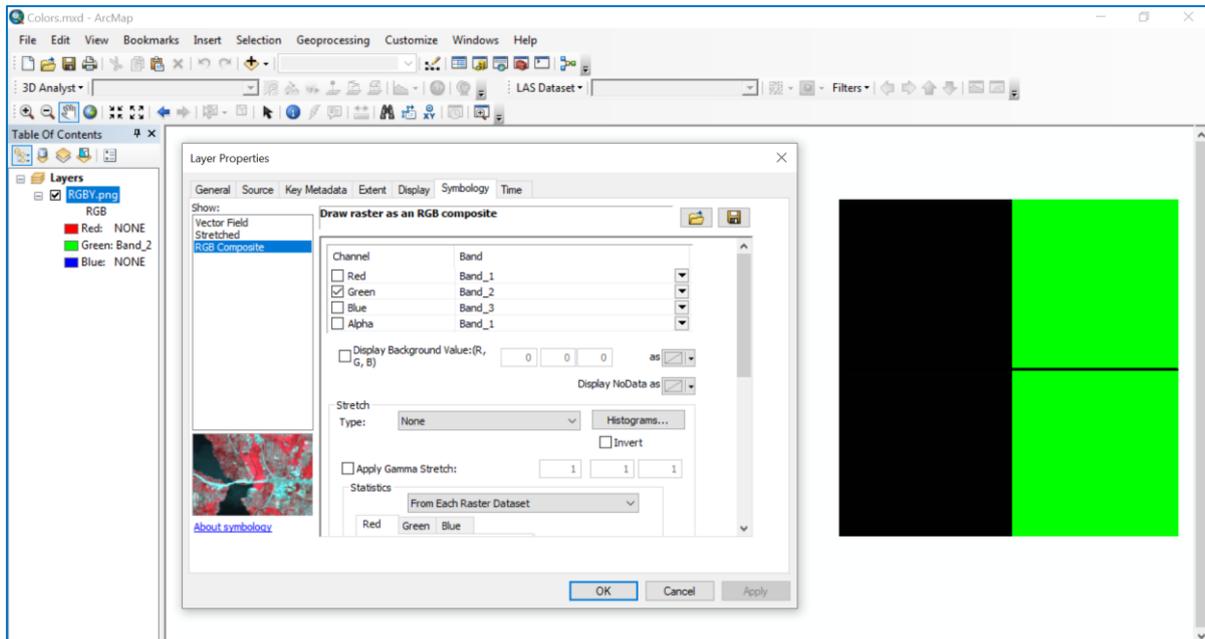
All 3 Channels Composite



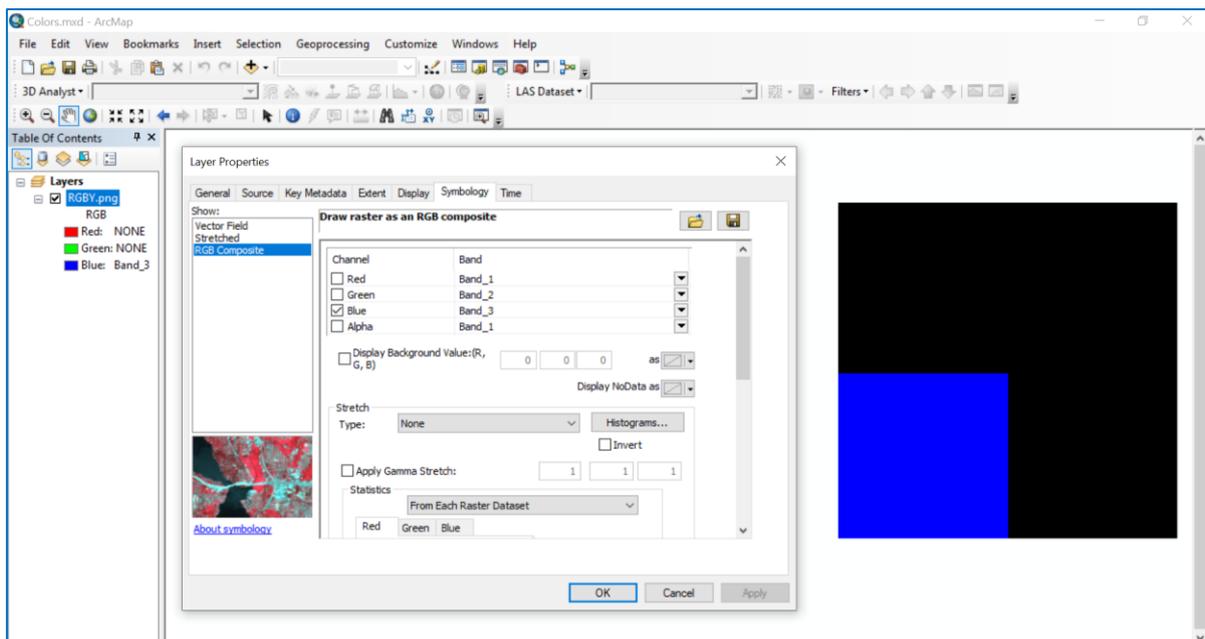
Only Red Channel



Only Green Channel



Only Blue Channel



For True Color Composite:

Red => Band_1

Green => Band_2

Blue => Band_3

Try assigning any others bands (except Band-1) to Red channel. Observe the effects.
This is the foundation of **false-color composite**.

Introduction to LiDAR Remote Sensing

Dr. Md. Golam Mahboob, PSO (Forestry), NRM Division
Bangladesh Agricultural Research Council
Email: golam.mahboob@barc.gov.bd

Overview

LiDAR (Light Detection And Ranging) is a remote sensing technology that uses laser pulses to measure distances and create precise 3D representations of the Earth's surface. It is widely used in forestry, agriculture, environmental monitoring, urban planning, and geological studies.

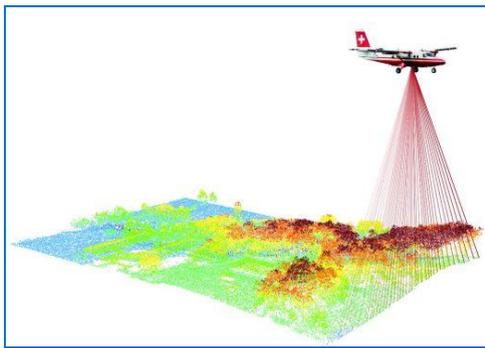


Figure-1: LiDAR Data Acquisition

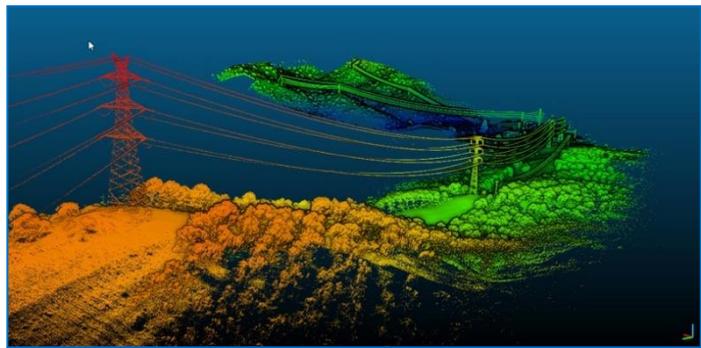


Figure- 2: 3D Point Cloud

Principles of LiDAR

The basic principle of laser ranging is the measurement of the time it takes for a laser signal to travel from the transmitter to the reflecting surface of a target and back to the receiver.

$$D = c \times \frac{t}{2}$$

Here, D is the measured distance
c is the speed of light (3×10^8 m/s)
t is the pulse travel time

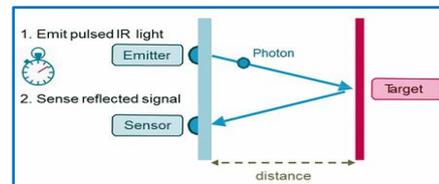


Figure-3: LiDAR Measurement

Types of LiDAR



Figure-4: Types of LiDAR

- Satellite LiDAR**
Used in global mapping applications.
- Airborne LiDAR**
Mounted on aircraft or drones to map large areas.
- Terrestrial LiDAR**
Fixed or mobile ground-based systems for detailed mapping.

Components of LiDAR System

- *Laser Scanner*
 - Emits laser pulses
- Laser receiver
 - Records reflected energy
- *GNSS Receiver*:
 - Provides positional accuracy
- *Inertial Measurement Unit (IMU)*
 - Tracks movement and orientation.
- *High-precision clock*
 - Synchronizes all sensors
- *Onboard software*
 - Manage systems and store data
- *Optical/infra-red camera*
 - Optional, for photograph or video capture

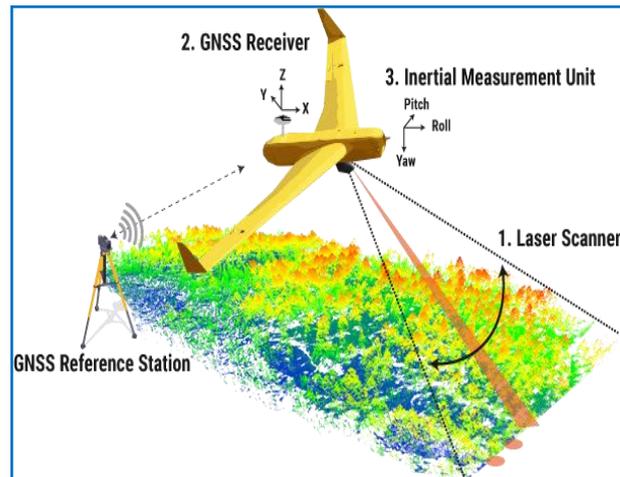


Figure-5: Key Components of LiDAR System

Applications in Environmental Science

Forestry: Measuring tree height, biomass estimation, and canopy structure analysis.

Agriculture: Precision farming and land-use classification.

Hydrology: Monitoring water flow, flood modeling, and watershed management.

Geology: Terrain mapping, fault detection, and slope stability assessment.

Advantages of LiDAR

- ✓ High spatial accuracy
- ✓ Rapid data acquisition
- ✓ Works in varying light conditions
- ✓ Suitable for large-scale mapping

Limitations

- ✗ High cost of equipment
- ✗ Requires specialized data processing skills
- ✗ Laser penetration affected by water bodies

Prospects

LiDAR technology is advancing with improved sensors, AI-driven data processing, and integration with satellite imaging for enhanced environmental analysis.

Bibliography

- Mallet, C., & Bretar, F. (2009). Full-waveform topographic LiDAR: State-of-the-art. *ISPRS Journal of Photogrammetry and Remote Sensing*, 64(1), 1-16. [doi:10.1016/j.isprsjprs.2008.09.002](https://doi.org/10.1016/j.isprsjprs.2008.09.002)
- Mandlbürger, G., et al. (2020). Topographic LiDAR: Data, processing, and applications. *Remote Sensing*, 12(20), 3340. [doi:10.3390/rs12203340](https://doi.org/10.3390/rs12203340)
- NOAA (2012) "Lidar 101: An Introduction to Lidar Technology, Data, and Applications." Revised. Charleston, SC: National Oceanic and Atmospheric Administration (NOAA), Coastal Services Center. <https://coast.noaa.gov/data/digitalcoast/pdf/lidar-101.pdf>
- Vierling, L. A., et al. (2008). Lidar: shedding new light on habitat characterization and modeling. *Frontiers in Ecology and the Environment*, 6(2), 90-98. <https://doi.org/10.1890/070001>
- Wang, C., et al. (2024). *Introduction to LiDAR Remote Sensing*. CRC Press. [doi:10.1201/9781032671512](https://doi.org/10.1201/9781032671512)
- Wehr, A., & Lohr, U. (1999). Airborne laser scanning—An introduction and overview. *ISPRS Journal of Photogrammetry and Remote Sensing*, 54(2-3), 68-82. [doi:10.1016/S0924-2716\(99\)00011-8](https://doi.org/10.1016/S0924-2716(99)00011-8)

Applications of LiDAR Remote Sensing in Natural Resources Management

1. Introduction to LiDAR Remote Sensing

LiDAR (**L**ight **D**etection and **R**anging) is an advanced remote sensing technology that uses laser pulses to measure distances and generate high-resolution 3D representations of the Earth's surface. It is widely used in natural resources management due to its ability to provide precise and detailed spatial data.

Key Features of LiDAR:

- High-resolution topographic mapping
- Ability to penetrate vegetation canopy
- Precise elevation measurements
- Generation of 3D models for environmental analysis

2. Applications in Forestry Management

LiDAR plays a crucial role in forestry by offering detailed insights into forest structure, health, and biomass estimation.

Forestry Applications:

- Tree Height & Density Mapping**
Helps estimate forest canopy height and tree distribution.
- Biomass & Carbon Stock Assessment**
Measures forest biomass for carbon sequestration studies.
- Forest Inventory & Species Classification**
Identifies tree species and assesses forest composition.
- Deforestation & Habitat Monitoring**
Tracks forest loss and its impact on biodiversity.

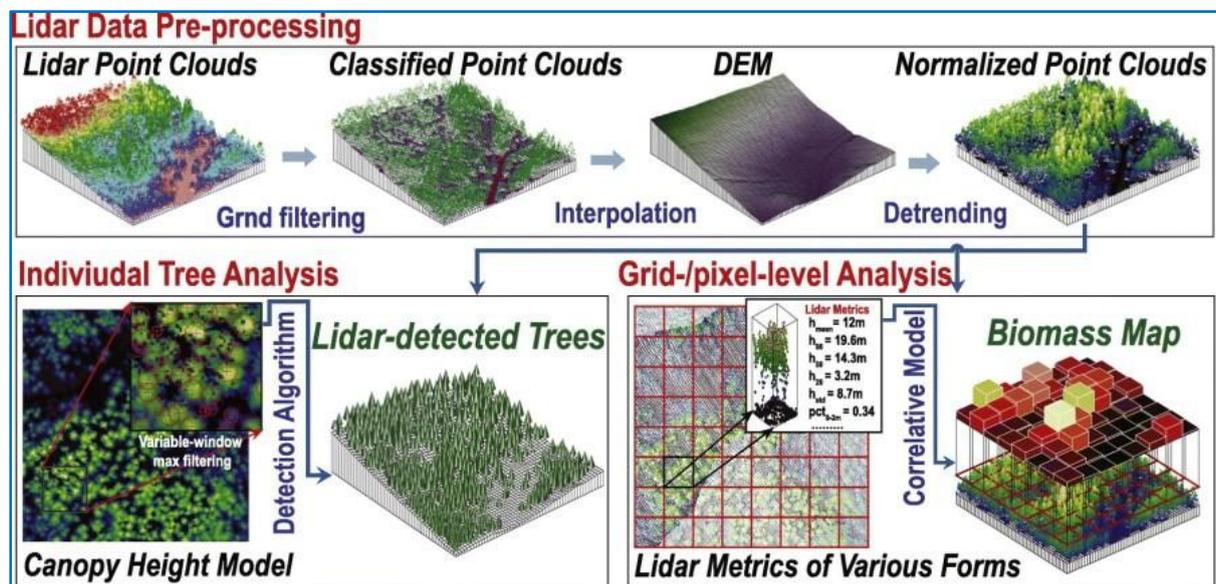


Figure-1: Forest Biomass Mapping from LiDAR Data

3. Applications in Watershed & Hydrology Management

LiDAR data significantly enhances hydrological studies by improving terrain analysis and flood modeling.

Hydrological Applications

- Watershed Delineation**

Defines drainage basins and water flow paths.

- Flood Risk Assessment**

Creates accurate floodplain maps for disaster preparedness.

- Riparian Zone Analysis**

Identifies vegetation along rivers, improving conservation planning.

- Groundwater & Surface Water Interaction Studies**

Assists in evaluating water movement and storage.

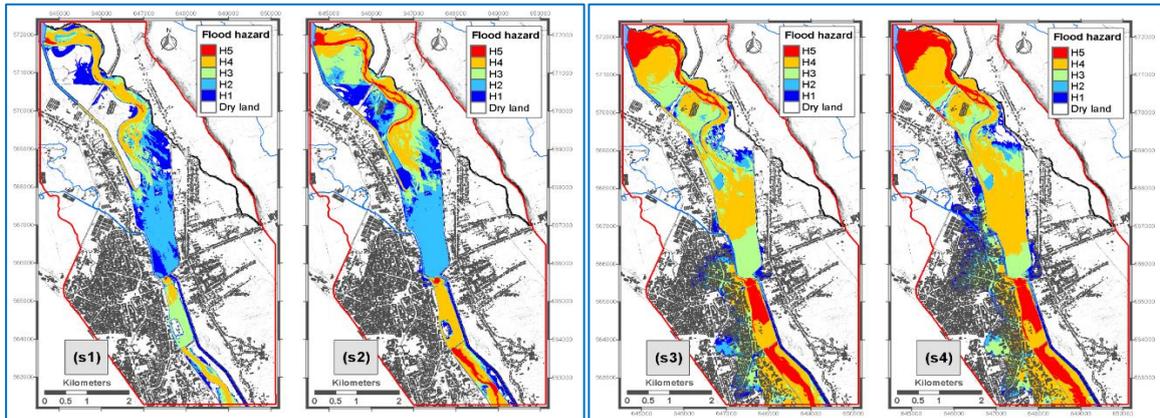


Figure-2: Urban Flood Hazard Maps, doi: <https://doi.org/10.3390/w11091832>

4. Applications in Agriculture & Land Use Planning

LiDAR supports precision agriculture and sustainable land use management.

Agricultural Applications:

- Soil Erosion & Terrain Mapping**

Assesses landforms to mitigate soil degradation.

- Crop Health & Yield Prediction**

Analyzes plant growth patterns for precision farming.

- Irrigation Planning**

Optimizes water distribution based on terrain slope and elevation.

- Land Use Classification**

Differentiates agricultural, urban, and natural landscapes.



Figure-3: a. LiDAR Scanner, b. Mobile LiDAR System, c. Collected Point Clouds from Crop Field

5. Applications in Biodiversity & Wildlife Conservation

LiDAR contributes to ecological studies by enhancing habitat mapping and species monitoring.

Conservation Applications:

- Habitat Suitability Analysis**
Identifies critical habitats for endangered species.
- Vegetation Structure Assessment**
Evaluates forest canopy for biodiversity conservation.
- Wildlife Corridor Planning**
Supports strategic conservation for species movement.
- Mapping Invasive Species Spread**
Detects vegetation changes to manage invasive species.

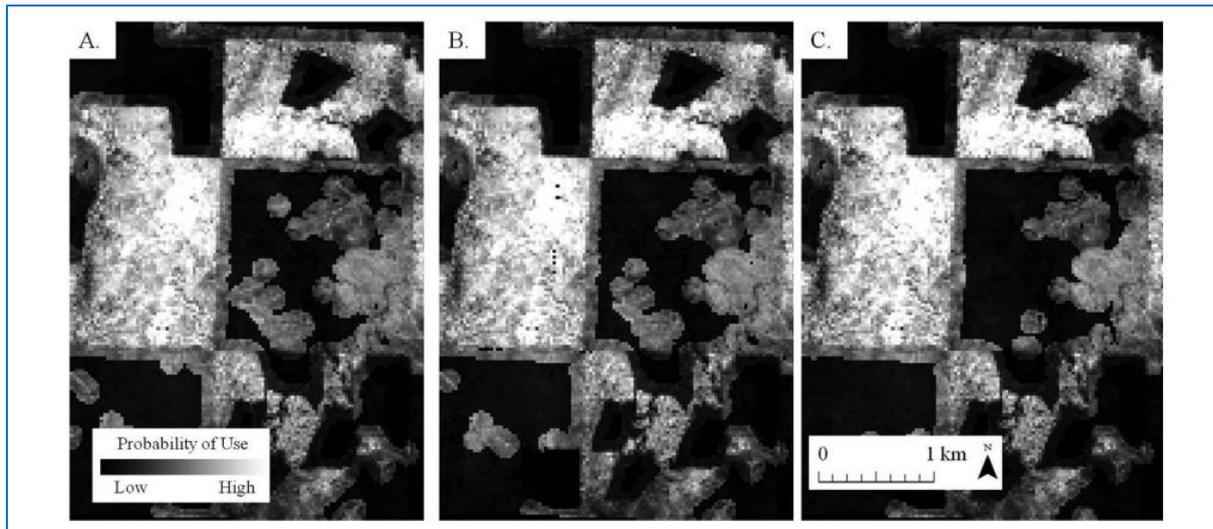


Figure-4: Habitat suitability maps for red tree voles derived from airborne LiDAR at (A) full (10.36 pulses/m²) and reduced point densities of (B) 4 points/m² and (C) 1 point/m² in southwestern Oregon, USA, [doi: 10.1002/jwmg.21173](https://doi.org/10.1002/jwmg.21173)

6. Future Prospects & Emerging Applications

- Integration with AI & Machine Learning**
Enhances automated feature detection.
- LiDAR for Coastal & Marine Studies**
Expands applications to underwater ecosystems.
- Advancements in Drone-Based LiDAR**
Increases accessibility for localized monitoring.
- Climate Change Impact Studies**
Supports long-term environmental assessments.

Conclusion:

LiDAR remote sensing is revolutionizing natural resources management by providing high-precision data for environmental monitoring, conservation, and sustainable development. Its integration with GIS and AI offers promising advancements for future applications.

Open-Source Satellite Imagery

Md. Zohir Uddin Omor
Manager, GIS & IM, Care Bangladesh
Email: zohiruddin.omor@care.org

There are several open-source and publicly available satellite imagery sources that provide coverage of Bangladesh. These are useful for monitoring agriculture, urban growth, flooding, deforestation, and more. Here's a list of some of the best platforms and datasets:

1. Sentinel Hub (European Space Agency - ESA)

- **Satellites:** Sentinel-1 (radar), Sentinel-2 (optical)
- **Resolution:** 10–20 meters (Sentinel-2), all-weather radar (Sentinel-1)
- **Update frequency:** Every 5 days (Sentinel-2)
- **Use cases:** Land use, vegetation, flood mapping
- **Access:** <https://apps.sentinel-hub.com/eo-browser>

2. NASA Earthdata (via LP DAAC and Earthdata Search)

- **Satellites:** MODIS (Terra & Aqua), Landsat, VIIRS
- **Resolution:**
MODIS: 250m–1km (daily)
Landsat: 30 meters (16-day revisit)
- **Use cases:** Climate monitoring, long-term land change
- **Access:** <https://search.earthdata.nasa.gov/>

3. USGS Earth Explorer

- **Satellites:** Landsat series, others
- **Resolution:** 30 meters (Landsat), 10 meters (Sentinel-2)
- **Use cases:** Historical land cover change, hydrology, urban planning
- **Access:** <https://earthexplorer.usgs.gov/>

4. Google Earth Engine (GEE)

- **Type:** Cloud-based geospatial processing
- **Data:** Landsat, Sentinel, MODIS, many more
- **Use cases:** Custom time-series analysis, deforestation, flood mapping
- **Access:** <https://earthengine.google.com/>

Note: Requires an application for access (free for research, NGOs, and developers)

5. OpenAerialMap

- **Type:** Open aerial imagery contributed by users and organizations
- **Use cases:** Post-disaster mapping, infrastructure
- **Access:** <https://openaerialmap.org/>

6. Radiant Earth Foundation

- **Type:** Open ML-ready earth observation data
- **Use cases:** Agriculture, humanitarian response, ML models
- **Access:** <https://radiant.earth/>

Steps to download sentinel 2 data from Copernicus sentinel hub

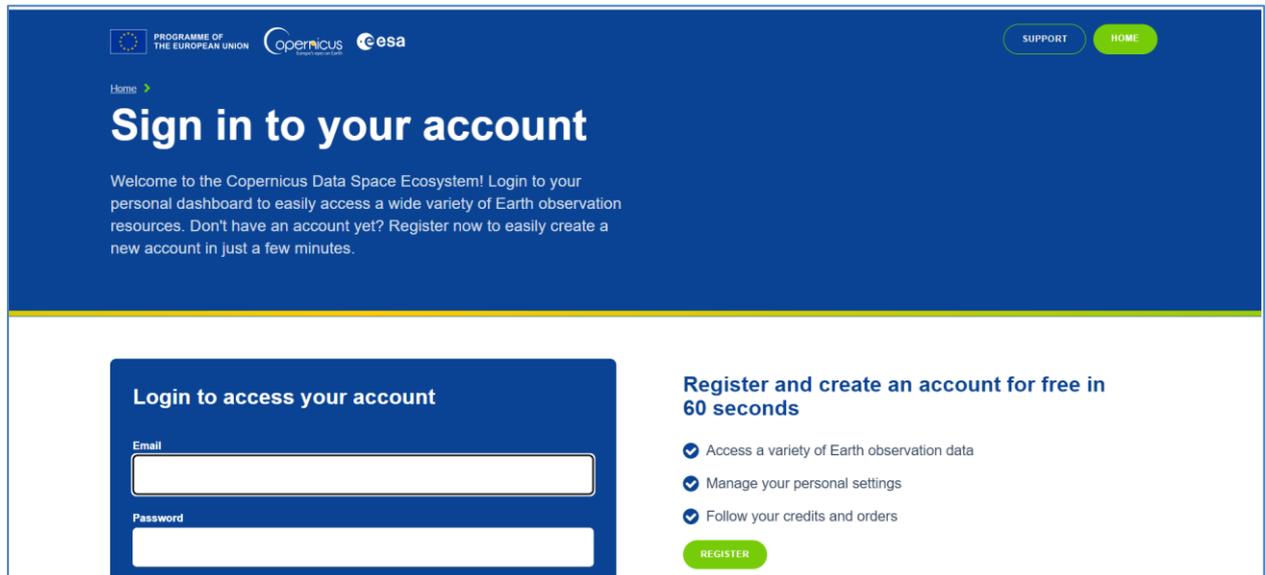
Sentinel-2:

To download Sentinel-2 data from the Copernicus Sentinel Hub (ESA), you can follow these steps. There are two main ways: via the EO Browser (user-friendly interface)

Open EO Browser:

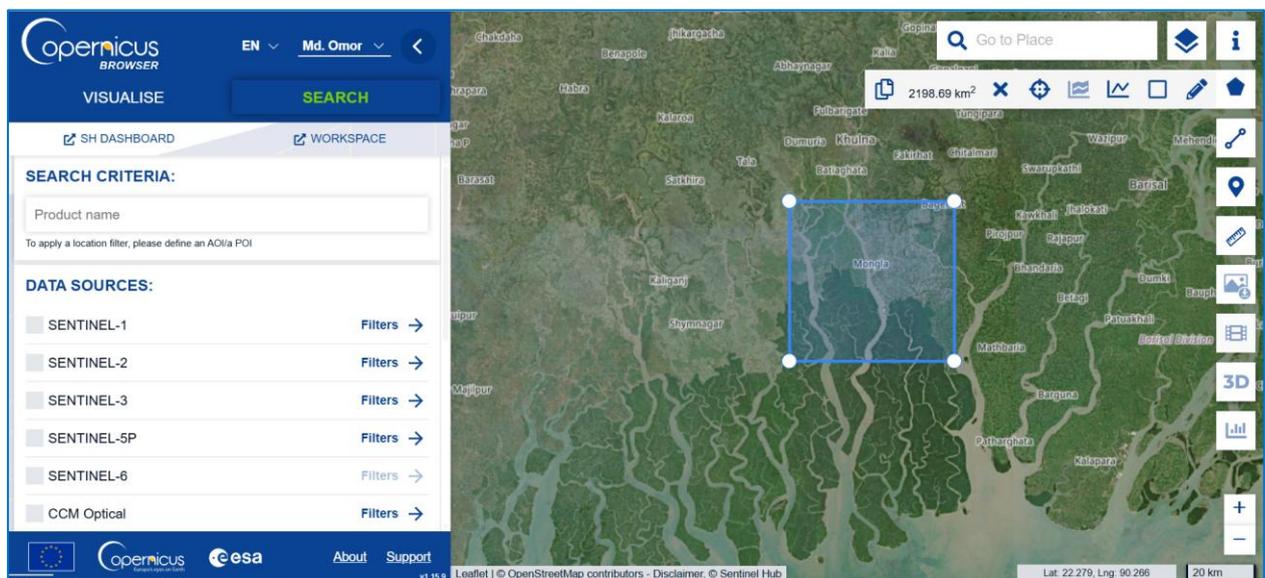
Create a (free) account:

- Click “Log in” or “Sign up” (free for public and research use).
- You need an account to download high-resolution imagery.



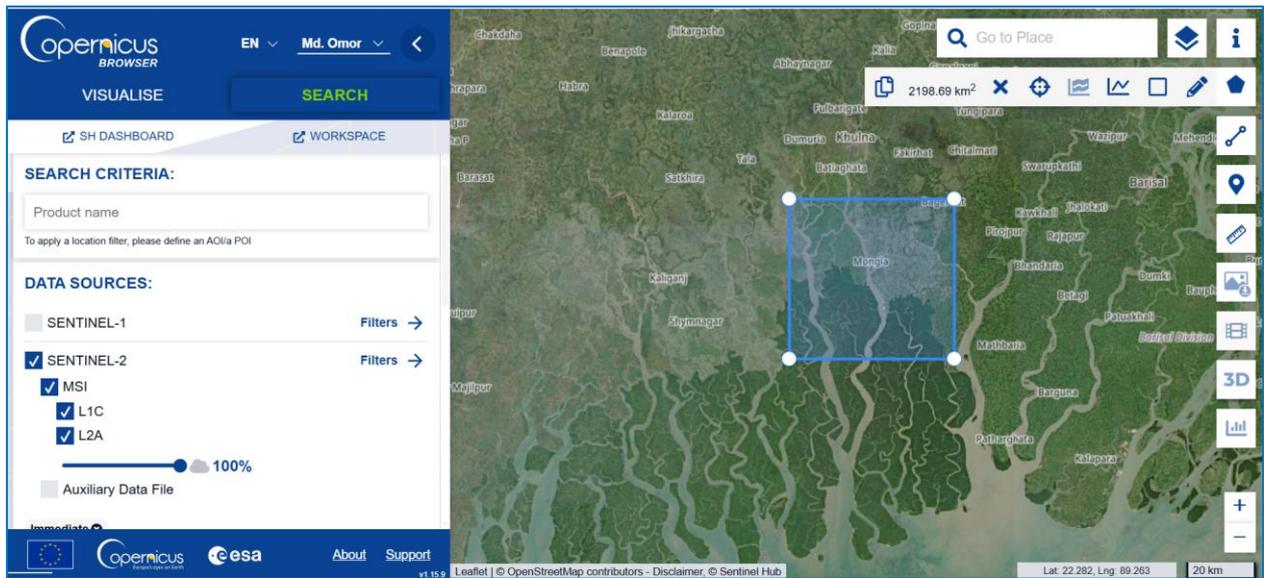
Select Area of Interest (AOI):

- Use the search bar or draw a polygon/rectangle on the map to define your area.



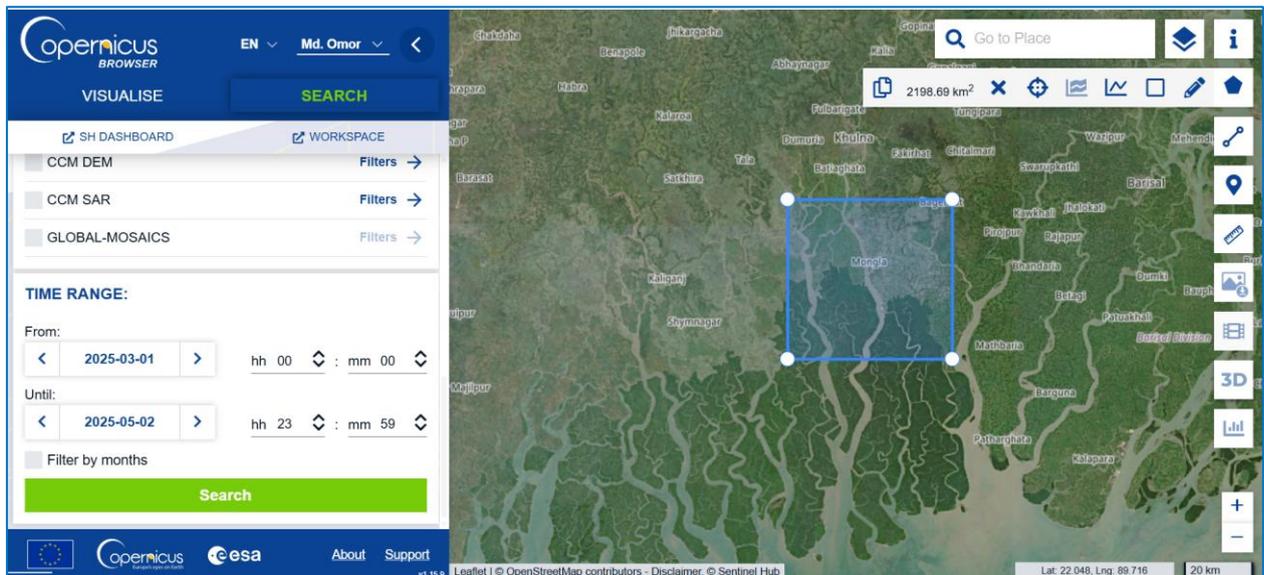
Select Satellite and Data Source:

- Choose Sentinel-2 L1C (Top-of-atmosphere reflectance)
- Or Sentinel-2 L2A (Surface reflectance, atmospherically corrected)



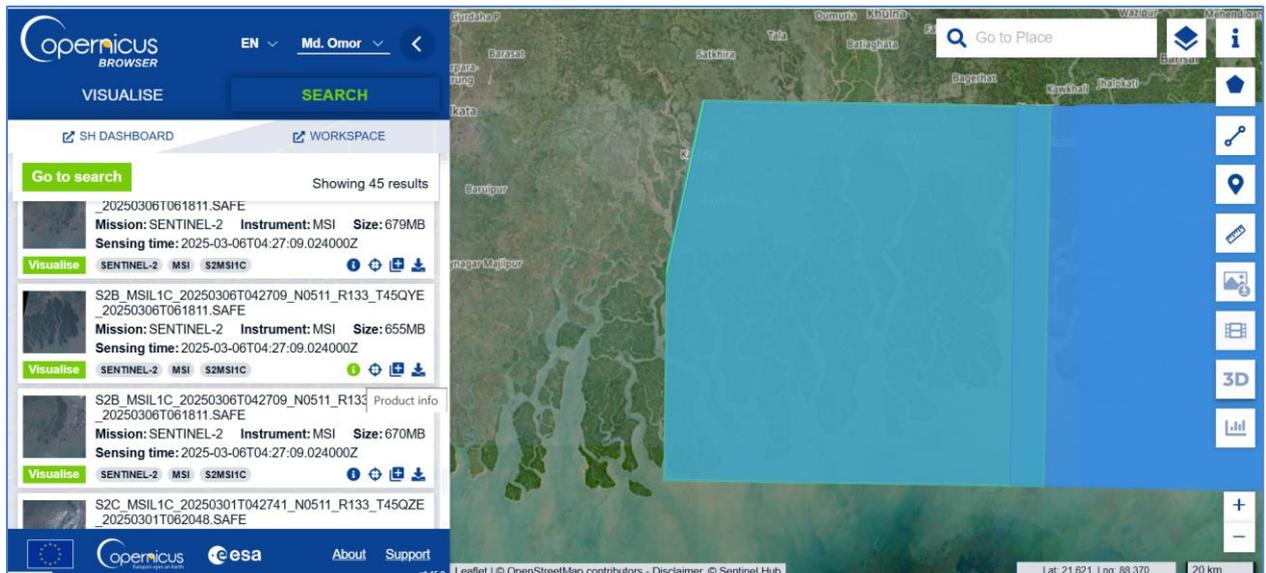
Choose Time Range:

- Select a date range in the top-left panel to filter available scenes.



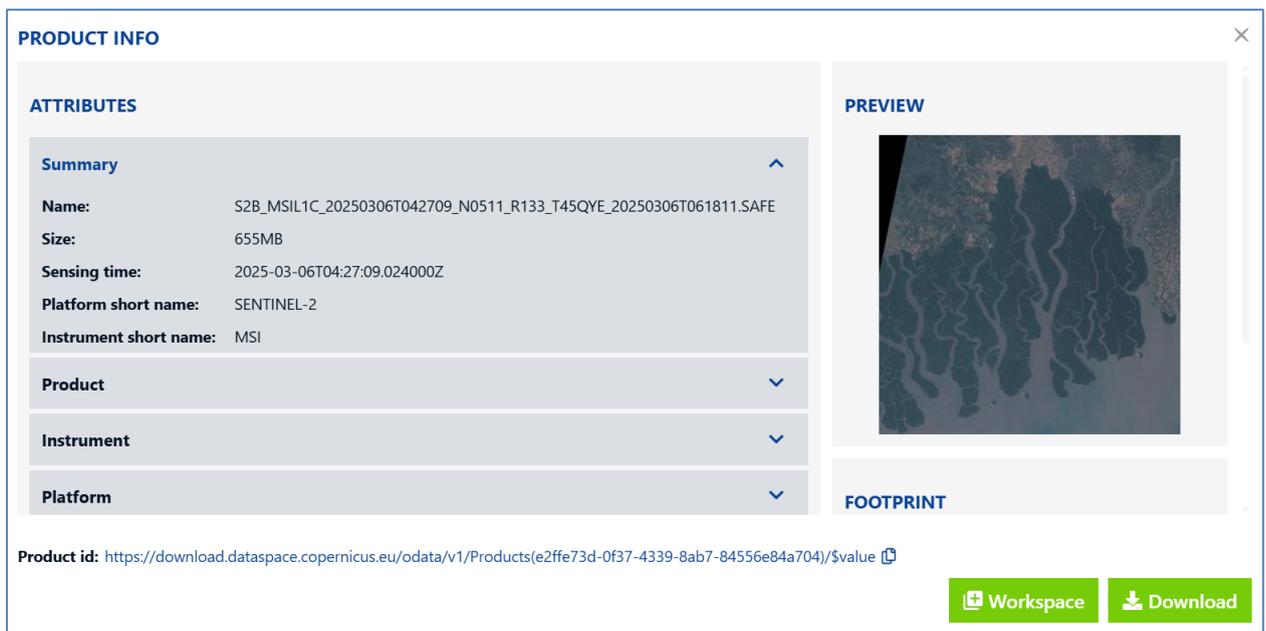
Browse and Preview Data:

- Click on a result to preview the scene.
- Use the drop-down to choose band composites (e.g., True color, NDVI, etc.)



Download the Image:

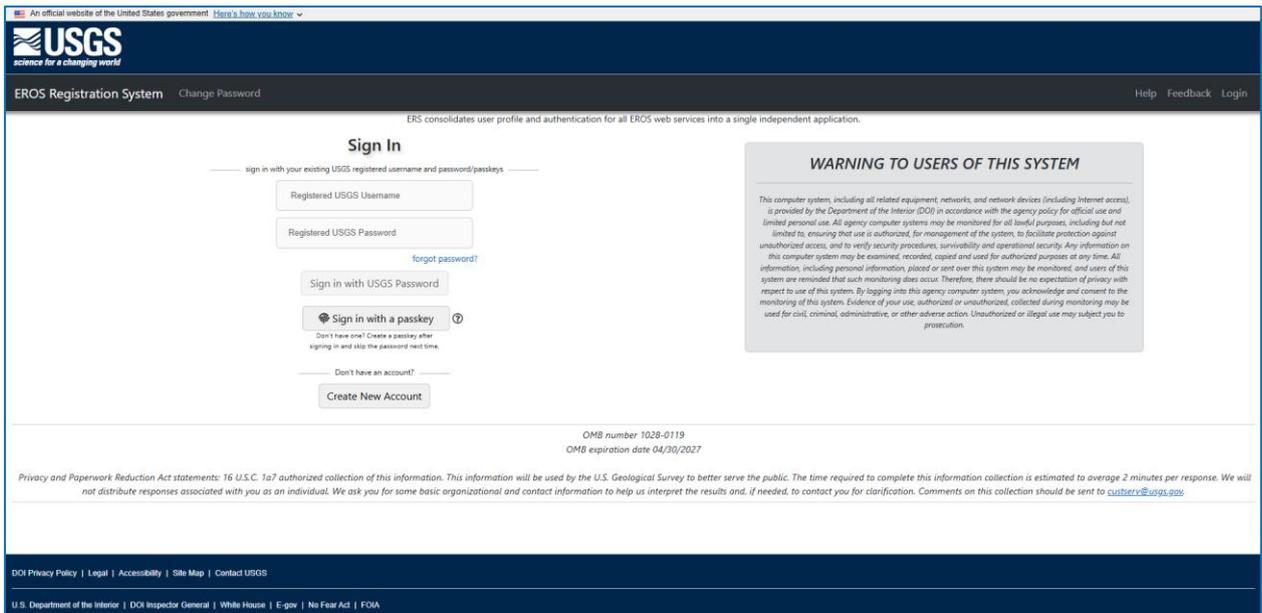
- Click "Download" (bottom right).
- Set resolution and bands to export (e.g., B2, B3, B4, B8)



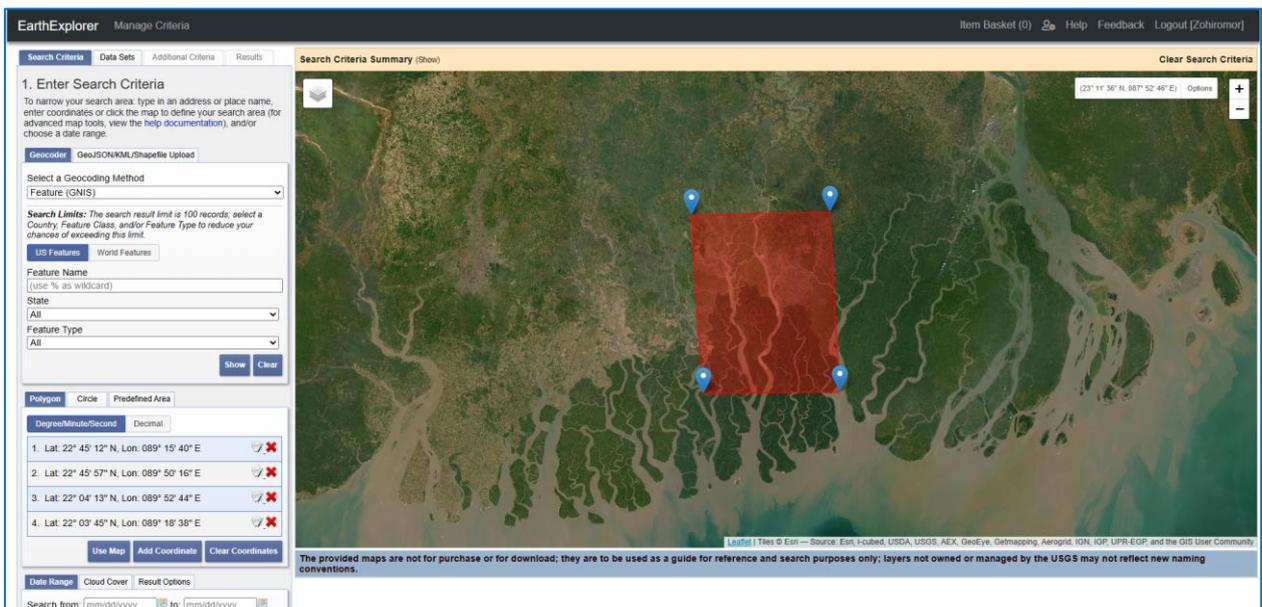
Landset 8/9

Create a (free) account:

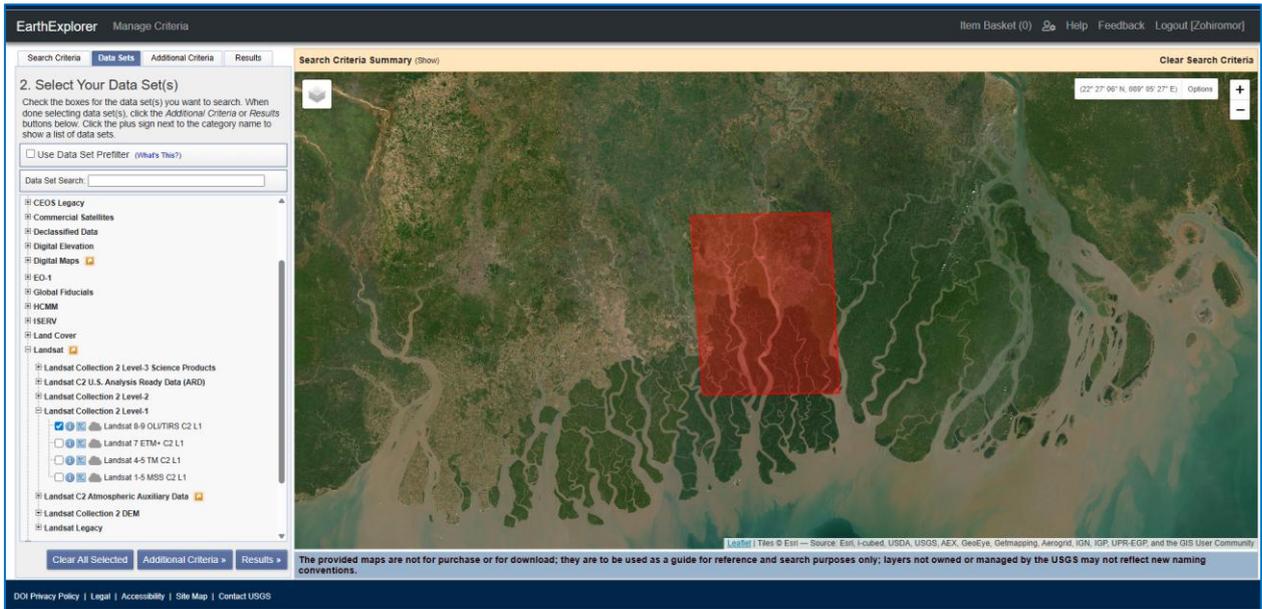
- Click “Log in” or “Sign up” (free for public and research use).
- You need an account to download high-resolution imagery.



Select Area of Interest (AOI):
 Use the search bar or draw a polygon/rectangle on the map to define your area.

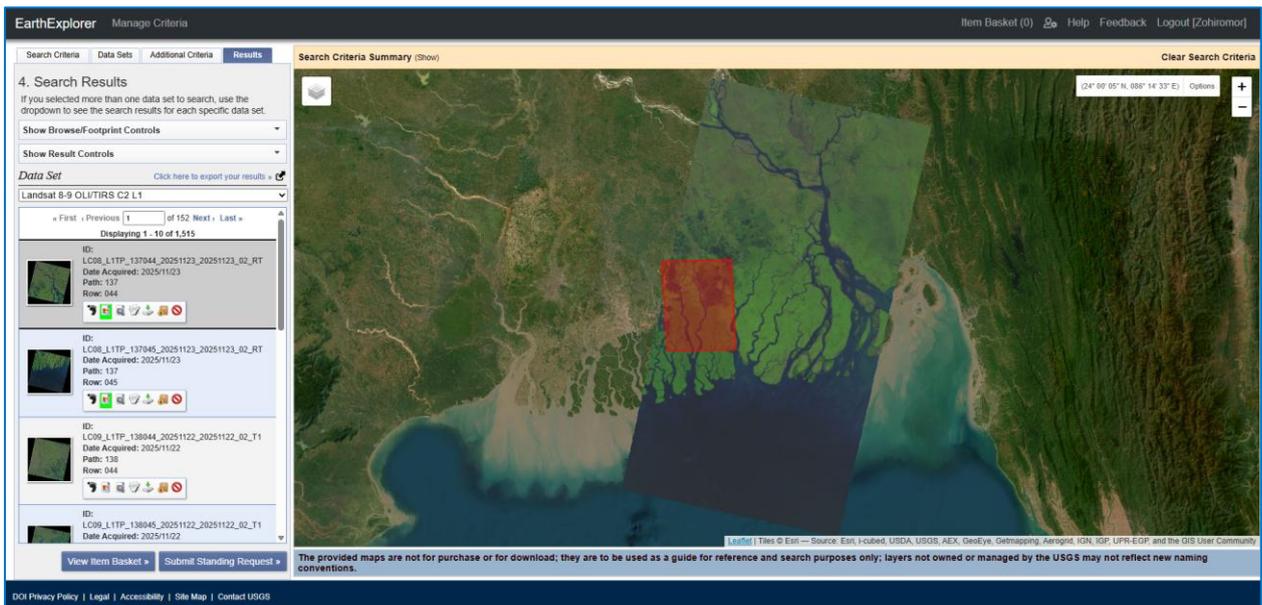


Data Set Selection:
 From the second button all data set can view in the list and select Landsat data.



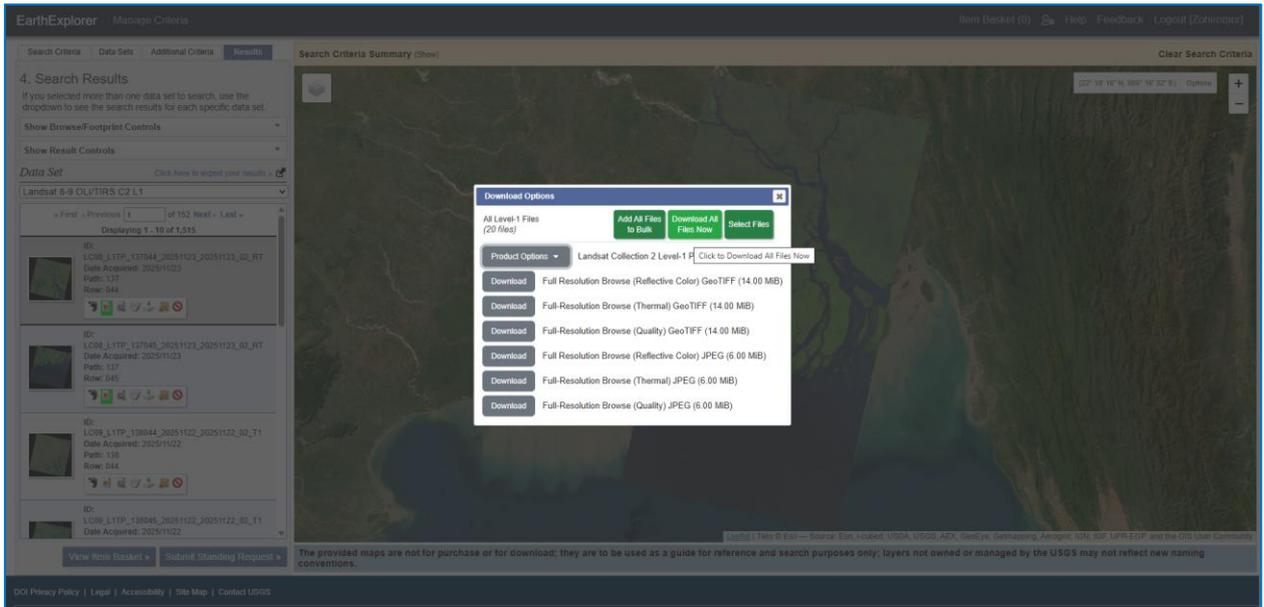
Browse and Preview Data:

Click on a result to preview the scene and use the drop-down to choose band composites.

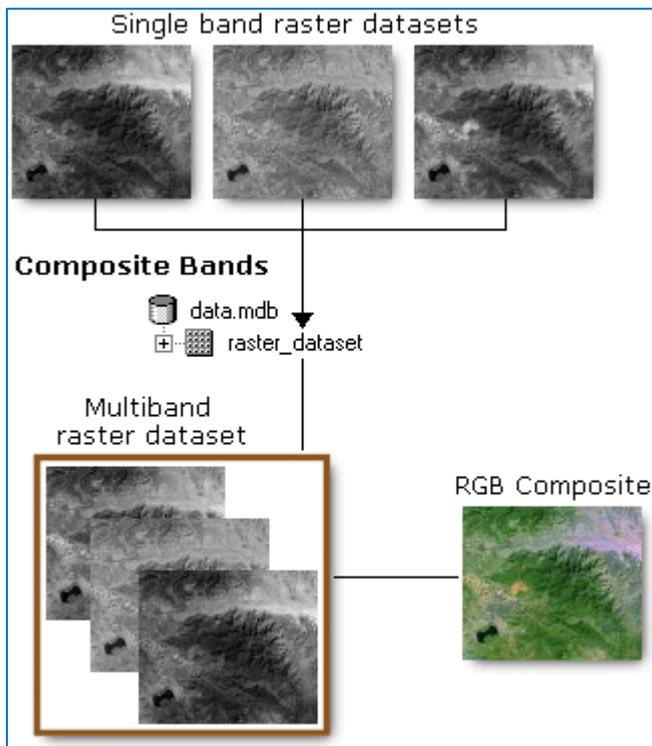


Download the Image:

Click "Download" from the pop-up box for need or purpose basis.



Creates a single raster dataset from multiple bands.



Source: ESRI

Uses of Band Composite:

- This tool can also create a raster dataset containing subset of the original raster dataset bands. This is useful if you need to create a new raster dataset with a specific band combination and order.
- The order that the bands are listed in the Multi-value Input control box will determine the order of the bands in the output raster dataset.
- This tool can only output a square cell size.
- You can save your output to BIL, BIP, BMP, BSQ, DAT, Esri Grid , GIF, IMG, JPEG, JPEG 2000, PNG, TIFF, MRF, CRF, or any geodatabase raster dataset.
- The output raster dataset takes the cell size from the first raster band in the list.
- By default, the output raster dataset takes the extent and the spatial reference of the first raster band with a spatial reference in the list. You can change this by setting the output extent and output coordinate system in the Environment Settings.

The following are some examples of why you would want to combine single raster datasets into multiband raster datasets:

- You may have received some satellite data where each band of data is contained in a single file—for example, band1.tif, band2.tif, and band3.tif. To render these raster datasets together to create a color composite, each band needs to be contained within a single raster dataset (for example, allbands.tif).
- You may have several raster datasets of the same area captured at various times. By displaying these raster datasets as a color composite, you can detect change in the area, such as urban growth or cut forests. To create this color composite, each raster dataset needs to be contained as individual bands within a single raster dataset.
- In some cases, the output of an analysis operation is a single-band raster dataset. To do further visual analysis, you may need to combine the outputs by rendering your data as a color composite.
- Combining bands into one raster dataset can help you organize many related single-band rasters.

Layer Stack/Composite Bands of Satellite Image

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Composite bands in satellite imagery refer to combining multiple spectral bands (channels) into a single image to highlight specific features or patterns on Earth's surface. Different band combinations (also called "band composites") are used to visualize and analyze different land cover types, vegetation, water bodies, urban areas, etc.

Common Types of Band Composites

1. True Color Composite

- **Bands Used (e.g., Sentinel-2):** Red (B4), Green (B3), Blue (B2)
- **What It Shows:** Similar to what the human eye sees
- **Use Case:** General visualization, urban mapping

2. False Color (Infrared) Composite

- **Bands Used:** NIR (B8), Red (B4), Green (B3)
- **What It Shows:** Vegetation appears red; healthy vegetation is very bright
- **Use Case:** Vegetation health, crop analysis

3. Shortwave Infrared (SWIR) Composite

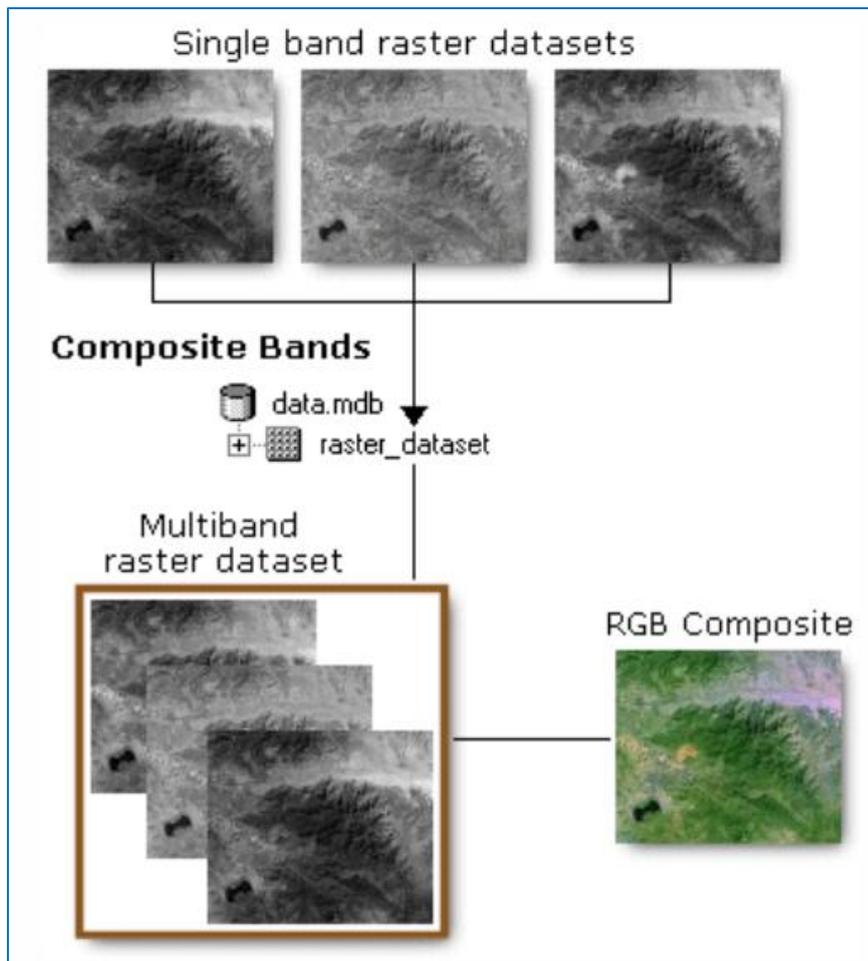
- **Bands Used:** SWIR1 (B11), NIR (B8), Red (B4)
- **What It Shows:** Useful for distinguishing water, snow, burn scars, and soil moisture
- **Use Case:** Flood detection, burn area mapping

4. Urban/Man-Made Feature Composite

- **Bands Used:** SWIR (B12), NIR (B8A), Red (B4)
- **What It Shows:** Enhances man-made structures; urban areas appear distinct
- **Use Case:** Urban growth monitoring

Composite Bands in ArcMap 10.8

Creates a single raster dataset from multiple bands.



Source: ESRI

Usage

- This tool can also create a raster dataset containing subset of the original raster dataset bands. This is useful if you need to create a new raster dataset with a specific band combination and order.
- The order that the bands are listed in the Multi-value Input control box will determine the order of the bands in the output raster dataset.
- This tool can only output a square cell size.
- You can save your output to BIL, BIP, BMP, BSQ, DAT, Esri Grid , GIF, IMG, JPEG, JPEG 2000, PNG, TIFF, MRF, CRF, or any geodatabase raster dataset.
- The output raster dataset takes the cell size from the first raster band in the list.
- By default, the output raster dataset takes the extent and the spatial reference of the first raster band with a spatial reference in the list. You can change this by setting the output extent and output coordinate system in the Environment Settings.
- The following are some examples of why you would want to combine single raster datasets into multiband raster datasets:

- ✓ You may have received some satellite data where each band of data is contained in a single file—for example, band1.tif, band2.tif, and band3.tif. To render these raster datasets together to create a color composite, each band needs to be contained within a single raster dataset (for example, allbands.tif).
- ✓ You may have several raster datasets of the same area captured at various times. By displaying these raster datasets as a color composite, you can detect change in the area, such as urban growth or cut forests. To create this color composite, each raster dataset needs to be contained as individual bands within a single raster dataset.
- ✓ In some cases, the output of an analysis operation is a single-band raster dataset. To do further visual analysis, you may need to combine the outputs by rendering your data as a color composite.
- ✓ Combining bands into one raster dataset can help you organize many related single-band rasters.

Example Steps by Steps

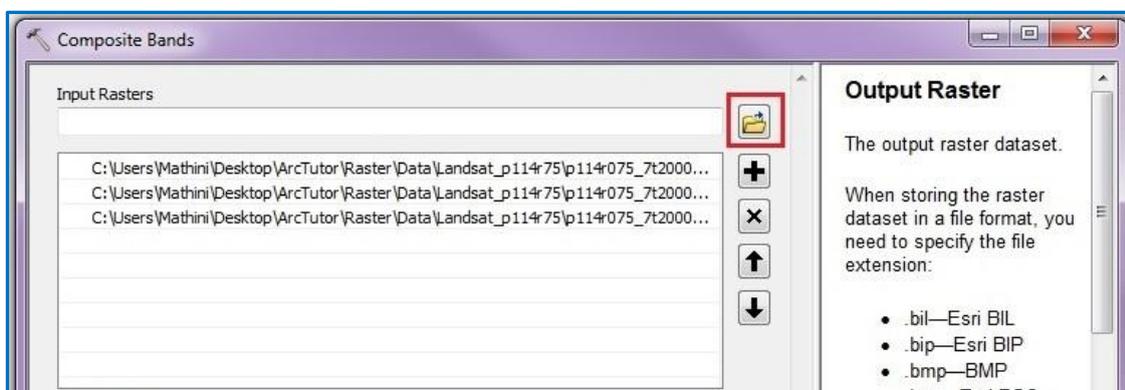
A multiband raster from Landsat 8 band images can be created in ArcMap, either by using the Composite Bands (Data Management) tool or the Composite Bands button in the Image Analysis window.

The instructions provided describe how to create a multiband raster from Landsat 8 band images.

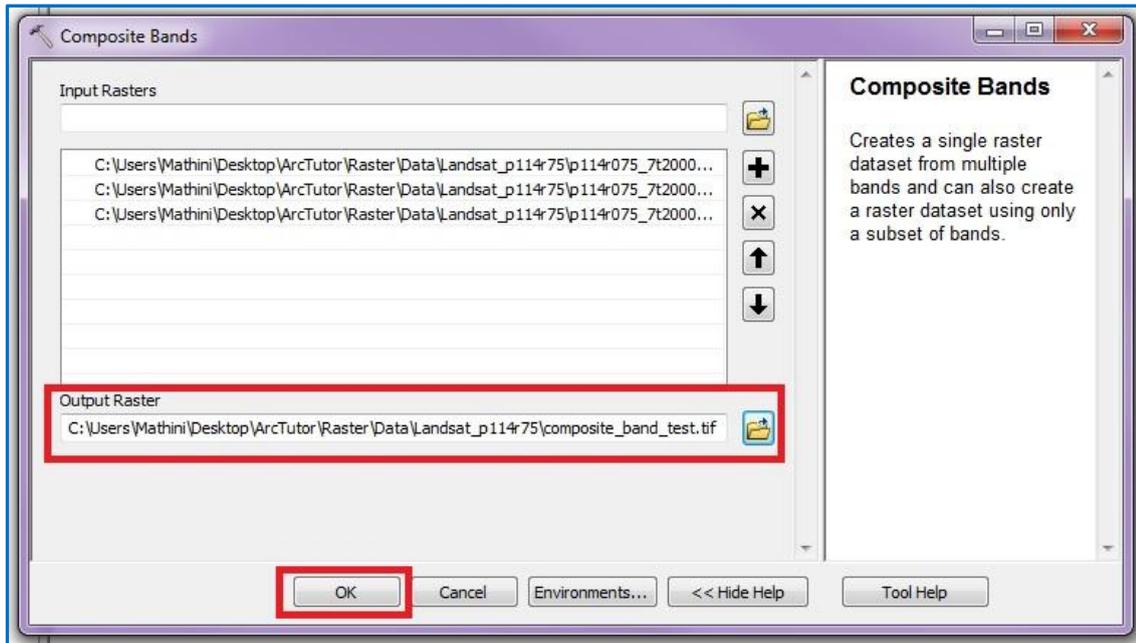
Option A:

Use the Composite Bands (Data Management) tool.

1. In ArcMap, navigate to Geoprocessing > ArcToolbox > Data Management Tools > Raster > Raster Processing > Composite Bands.
2. Click the browse button, and search for the desired input raster.



3. Specify the name and location of the output raster, and click OK.



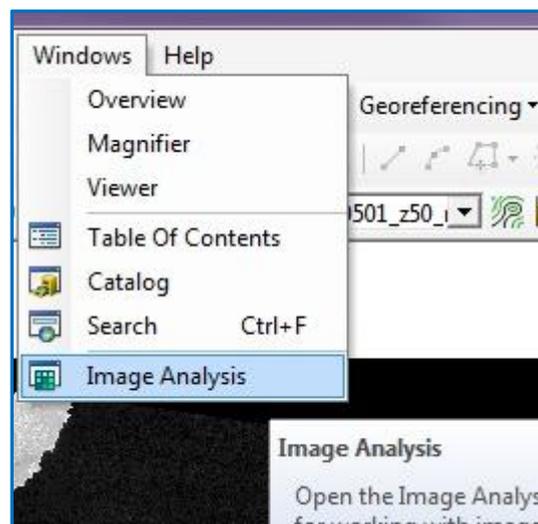
Note:

If working outside a geodatabase, specify the extension of the output raster.

Option B:

Use the Composite Bands button in the Image Analysis window.

1. In ArcMap, add the raster bands to the map document.
2. Navigate to Windows > Image Analysis.
3. In the Image Analysis window, hold down the shift key and select the band images.
4. Click the Composite Bands button.

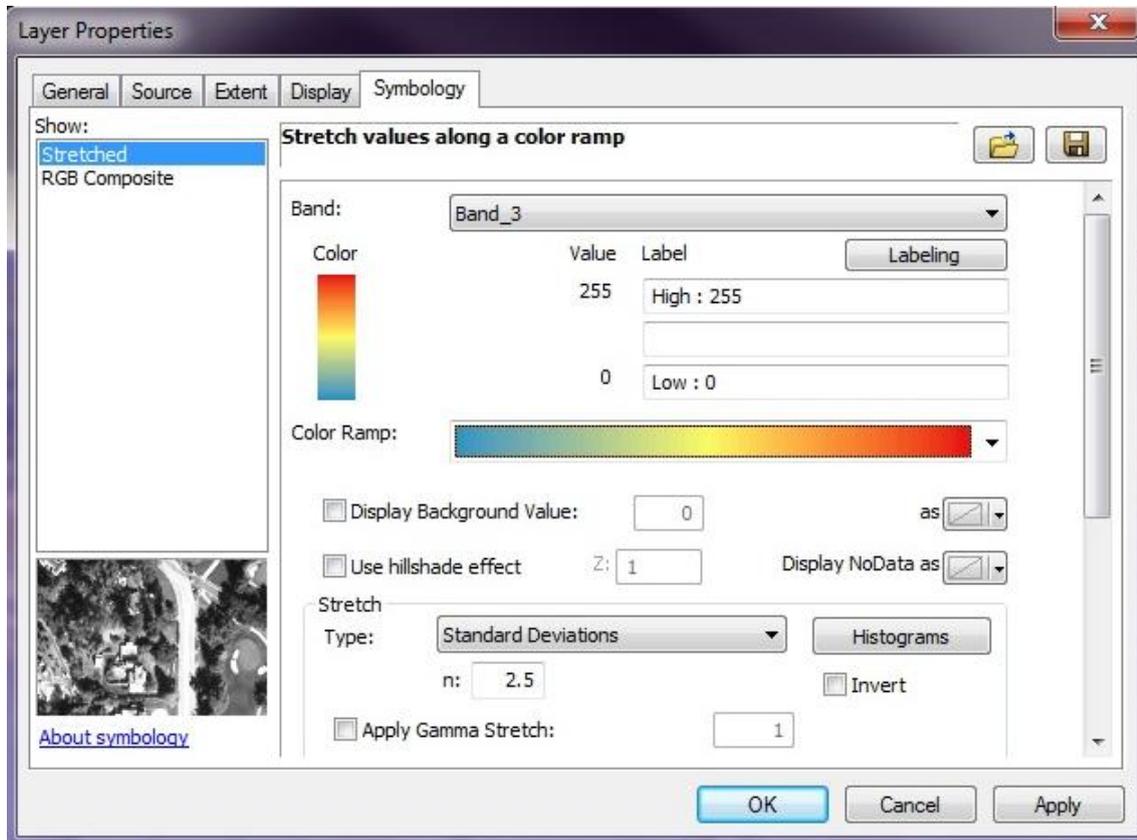


Note:

The output of the Image Analysis window is added to the map document as a temporary layer. To save the output layer as a raster dataset, click the Export button on the Image Analysis window and specify the output location of the raster dataset.

Note:

The output raster of both options is generated as an RGB composite. To change it to a Stretched value composite, right-click the layer > Properties > Symbology. Under the Show section, select the 'Stretched' option, and specify the band to be used for the stretch values. Input the desired parameters, and click OK.



Satellite Image Processing

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Satellite Image Processing

Satellite image processing involves analyzing and interpreting data captured by satellites to extract meaningful information. This field combines remote sensing, computer vision, and image processing techniques to monitor and manage natural and man-made environments.

1. Key Steps in Satellite Image Processing:

1. Image Acquisition

- Obtaining images from satellite sensors (e.g., Landsat, Sentinel, MODIS).
- Images may come in various bands (visible, infrared, thermal, etc.).

2. Preprocessing

- **Radiometric Correction:** Adjusting pixel values to account for sensor noise and lighting.
- **Geometric Correction:** Aligning images to a known coordinate system.
- **Atmospheric Correction:** Removing atmospheric effects like haze or clouds.
- **Resampling:** Adjusting image resolution or grid alignment.

3. Image Enhancement

- Contrast stretching, filtering, and edge enhancement to improve visual interpretability.

4. Image Classification

- **Supervised** (e.g., SVM, Random Forest, CNN): Uses labeled training data.
- **Unsupervised** (e.g., K-means, ISODATA): Clusters based on pixel similarities.

5. Change Detection

- Comparing images from different time periods to detect environmental or structural changes.

6. Feature Extraction

- Identifying objects like roads, buildings, vegetation, or water bodies using pattern recognition or deep learning.

7. Analysis and Visualization

- Using GIS software (like QGIS, ArcGIS) or programming tools (Python, MATLAB) to interpret results and create visual outputs.

Tools and Libraries:

- **Software:** ENVI, ERDAS Imagine, SNAP (for Sentinel), QGIS, ArcGIS
- **Programming Libraries:**
 - Python: rasterio, gdal, numpy, scikit-image, opencv, tensorflow, pytorch, earthpy
 - R: raster, rgdal, sf, terra

2. Satellite Image Processing in ArcGIS

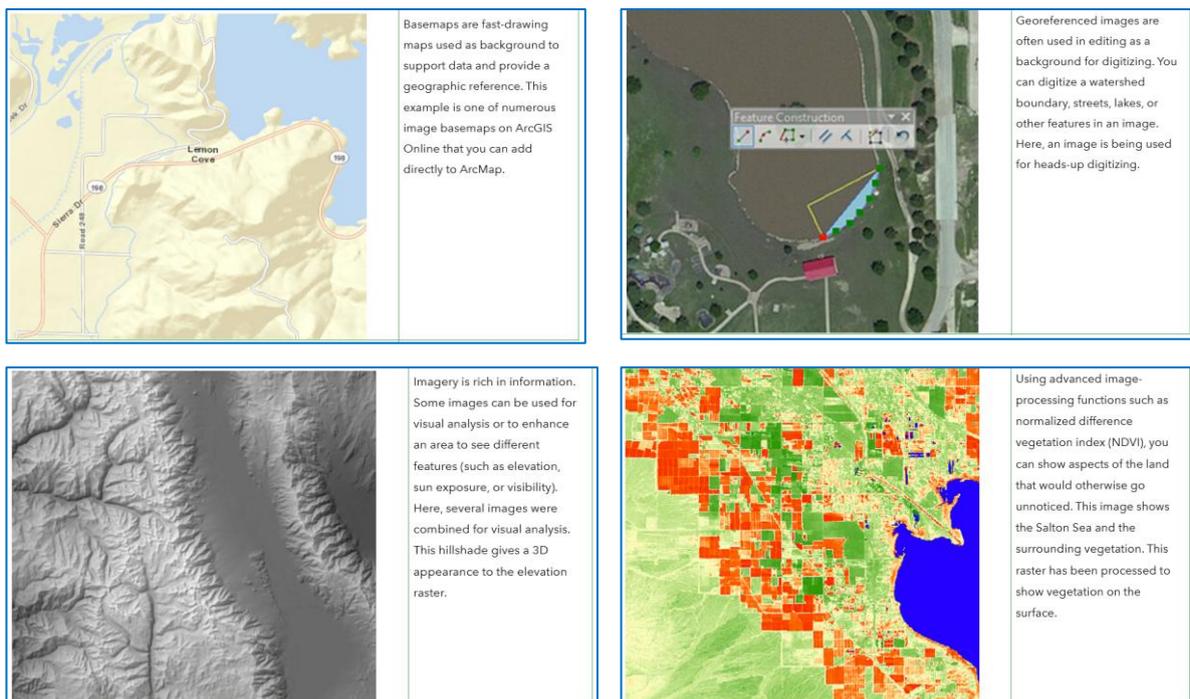
Imagery is processed and used for a wide variety of geospatial applications, including geographic context, visualization, and analysis. You may want to apply processing techniques on image data, visually interpret the data, use it as a background to aid interpretation of other data, or use it for analysis. In this course, you will use tools in ArcGIS to perform basic image processing. You will learn how to dynamically modify properties that enhance image display, visualize surface features, and create multiple products.

The role of imagery in GIS

Images and rasters are used in ArcGIS for various reasons:

- As background to provide reference to geographic data
- For heads-up digitizing while editing
- For visually interpreting a site
- For advanced analysis

Image processing allows you to see information about your data that would have been otherwise difficult to extract. Imagery and raster data are integrated into all aspects of ArcGIS. Imagery can be used to enhance other geographic data or to provide reference in editing, or it can be processed to provide powerful data that is necessary for answering complex analysis questions.

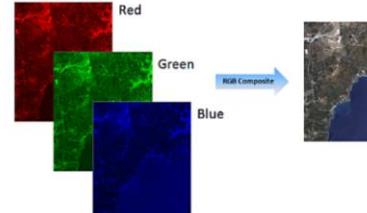


What is image processing?

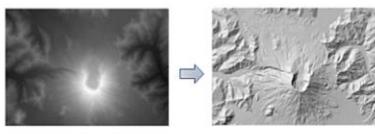
How would you identify where healthy vegetation is growing in a city? How can you combine bands to visualize imagery in natural color? Can you combine a low-resolution natural color image and a high-resolution grayscale image in a single image? Image processing can help you answer questions like these.

Types of image processing

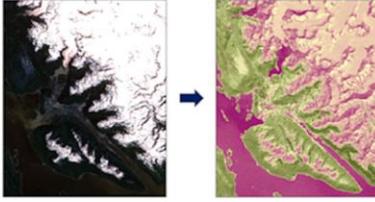
ArcGIS provides many options for image processing. The image-processing techniques described in this graphic allow you to use ArcGIS to extract answers from imagery for analysis.



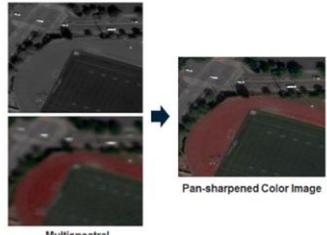
Composite bands create a single raster from multiple bands, allowing the image to be viewed as a multispectral image in ArcGIS.



A hillshade is an alternative representation of a three-dimensional surface, intended to make it easier to visualize the terrain. The hillshade image on the right is derived from elevation data (in this case, the digital elevation model, or DEM, on the left).



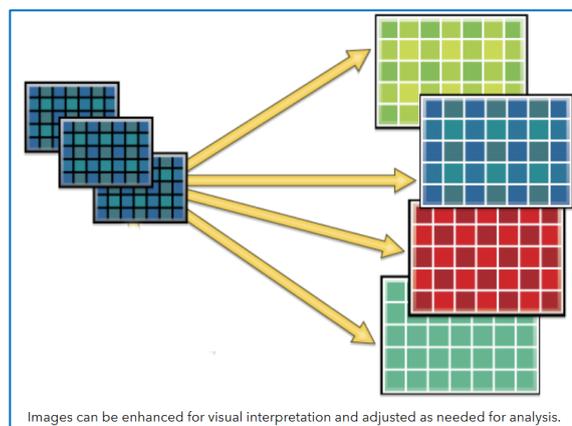
The normalized difference vegetation index (NDVI) is a standardized index that allows you to generate an image displaying greenness (relative biomass). Based on the difference in brightness between the red band and the near-infrared band, NDVI can be used to assess the absence or presence of live green vegetation, determine types of vegetation, and assess the overall health of vegetation.



Panchromatic sharpening fuses a high-resolution panchromatic image and a lower-resolution multiband image to produce a multiband raster with the resolution of the panchromatic. This allows a high-resolution image to have the capabilities of a multispectral image.

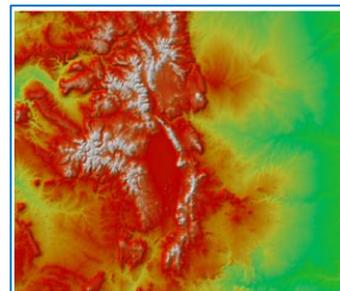
Accessing and enhancing imagery

You can employ numerous types of image formats in ArcGIS for display purposes. Several of these format types can be used for image processing. It is important to know about these formats - and to understand which image-processing operations you can perform on them -before you start your analysis. You can also enhance imagery for visual interpretation. Knowing which options you can use to change and improve the display can help answer questions about your data.



Common imagery types used in processing

Image processing can be applied to a variety of raster types. This graphic illustrates three commonly used types: aerial imagery, satellite imagery, and elevation data.



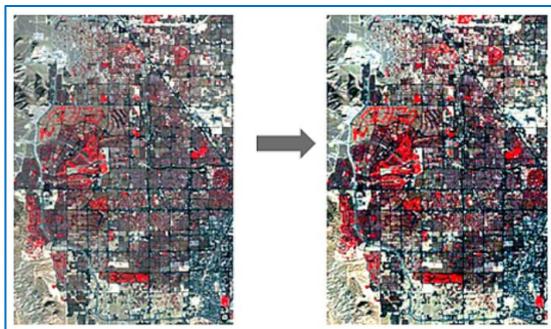
Aerial images are photographs of the earth's surface, usually taken from an aircraft using film or digital camera. These images are often used for image-processing functions like pan-sharpening, NDVI, and composite.

Satellite images often consist of multiple spectral bands, some of which are invisible (such as infrared). In this Landsat 7 image, bands 5, 4, and 1 are represented. A Landsat is an earth-orbiting satellite that gathers imagery for land-use inventory, geological exploration, crop assessment, and similar activities. Satellite images can be subjected to a variety of image-processing functions (pan-sharpening, NDVI, and composite etc.).

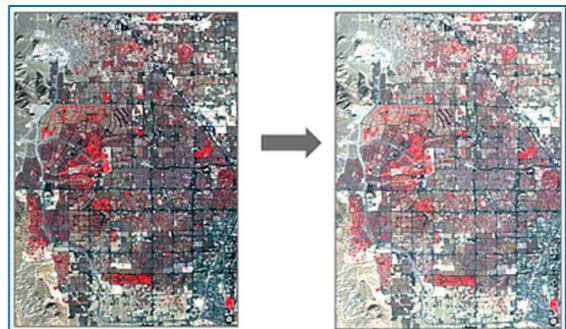
Elevation data represents the ground (bare earth) or surface of the earth (including buildings and other structures). This image is a digital elevation model (DEM) representing the earth's surface. A common image-processing function applied to elevation data is hillshade. Here, the result is a tinted hillshade.

Enhancing Image Display

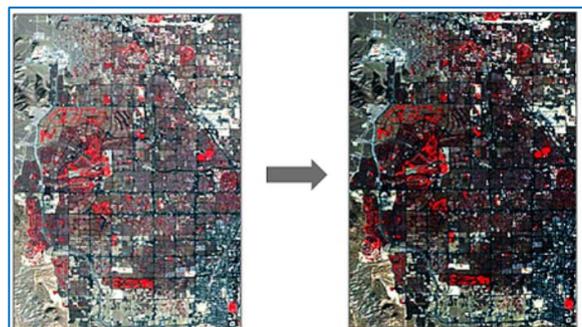
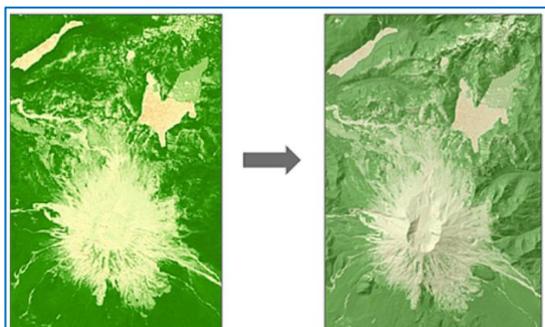
Changing display properties can enhance an image to either prepare it for additional processing or answer questions about your data through visual interpretation. You can easily access these display options through the Image Analysis window and apply them on the fly to avoid altering the original image.



The contrast slider adjusts the displayed contrast characteristics of the selected image. The image on the right has been enhanced to increase contrast.

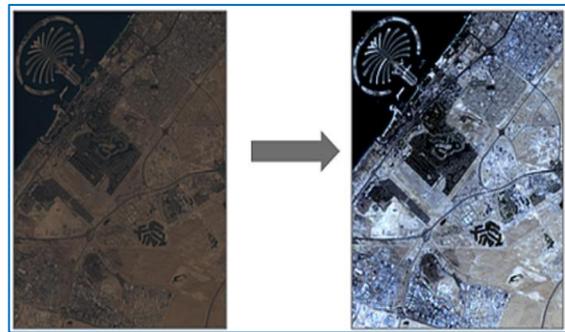


The brightness slider adjusts the displayed brightness characteristics of the selected image. The image on the right has been enhanced to increase brightness.



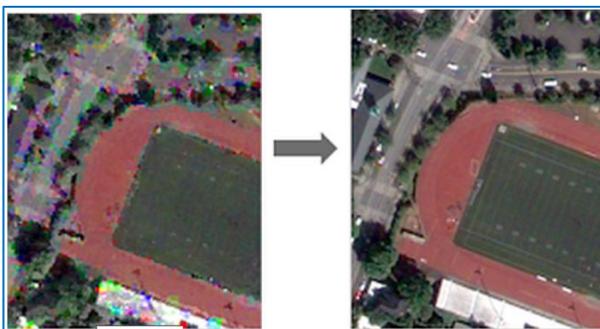
The transparency slider adjusts the transparency of the selected image, allowing for visualization of data under the image. The image on the right has been made partially transparent to allow the hillshade image (another image below the green image) to show through.

The gamma slider adjusts the gamma transformation of the selected image. The gamma refers to the degree of contrast between the mid-level gray values of a raster dataset. Gamma does not affect the black or white values in a raster dataset, only the middle values. The image on the left has 0, whereas the image on the right has .48 applied.



The DRA check box refers to "dynamic range adjustment." This allows the brightness and contrast of the image display to be adjusted based only on the data and contained within the data frame extent. That means dark areas will automatically brighten, and bright areas will automatically darken. The image on the left does not have the option checked, whereas the image on the right does.

The stretch adjusts the stretch applied to the selected image. There are six stretch options available: None, Minimum-maximum (Min-max), Standard deviation (Std-dev), Histogram equalization (Hist-eq), Percent clip, and Esri. Different stretches will produce different results in the raster display. The image on the left has no stretch applied (None), whereas the image on the right has standard deviation (Std-dev).



The resample selection chooses which resampling method to apply when you pan and zoom to view the selected image. Resampling is the process of interpolating the pixel values to fit your raster dataset to the desired resolution. Resampling methods include nearest neighbor, bilinear, cubic convolution, and majority.

Common Image Processing Techniques

Image processing can make imagery more useful and informative. Using image-processing techniques allows you to extract information for use in analysis. ArcGIS offers many options for image processing. Now, you will learn about four specific examples of image-processing functions: hillshade, composite, NDVI, and pan-sharpening.

Image Classification

Image Classification in remote sensing is the process of assigning land cover or land use classes (e.g., water, vegetation, urban) to each pixel in a satellite image based on its spectral characteristics. Image classification refers to the task of extracting information classes from a multiband raster image. The resulting raster from image classification can be used to create thematic maps. Depending on the interaction between the analyst and the computer during classification, there are two types of classification: supervised and unsupervised.

With the ArcGIS Spatial Analyst extension, there is a full suite of tools in the Multivariate toolset to perform supervised and unsupervised classification (see An overview of the Multivariate toolset). The classification process is a multi-step workflow, therefore, the Image Classification toolbar has been developed to provide an integrated environment to perform classifications with the tools. Not only does the toolbar help with the workflow for performing unsupervised and supervised classification, it also contains additional functionality for analyzing input data, creating training samples and signature files, and determining the quality of the training samples and signature files. The recommended way to perform classification and multivariate analysis is through the Image Classification toolbar.

Supervised Classification

Supervised classification uses the spectral signatures obtained from training samples to classify an image. With the assistance of the Image Classification toolbar, you can easily create training samples to represent the classes you want to extract. You can also easily create a signature file from the training samples, which is then used by the multivariate classification tools to classify the image.

Unsupervised Classification

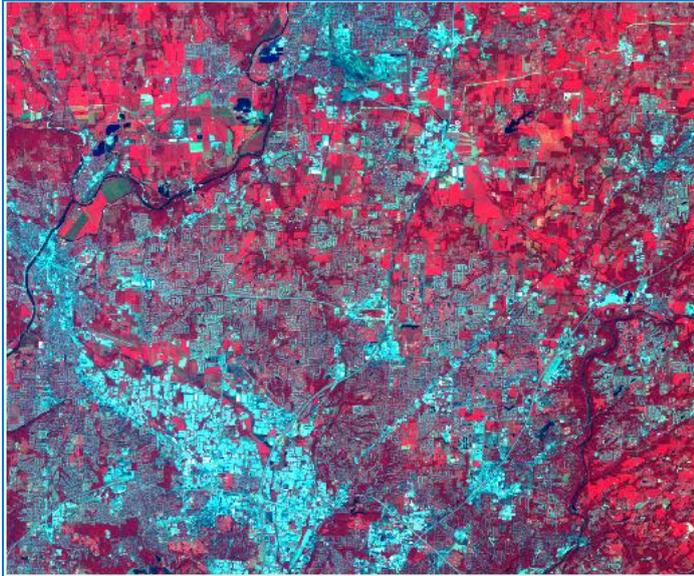
Unsupervised classification finds spectral classes (or clusters) in a multiband image without the analyst's intervention. The Image Classification toolbar aids in unsupervised classification

by providing access to the tools to create the clusters, capability to analyze the quality of the clusters, and access to classification tools.

Example

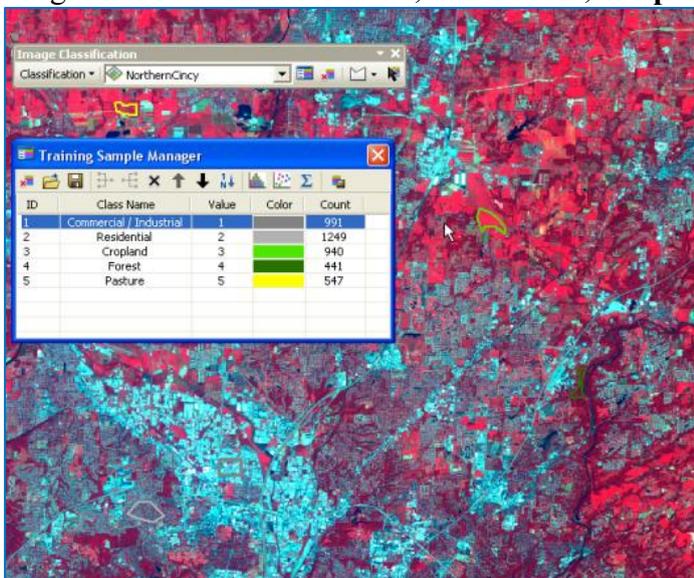
In the following example, the **Image Classification** toolbar was used to classify a Landsat TM satellite image.

The following raw satellite image is a four-band Landsat TM image of the northern area of Cincinnati, Ohio.



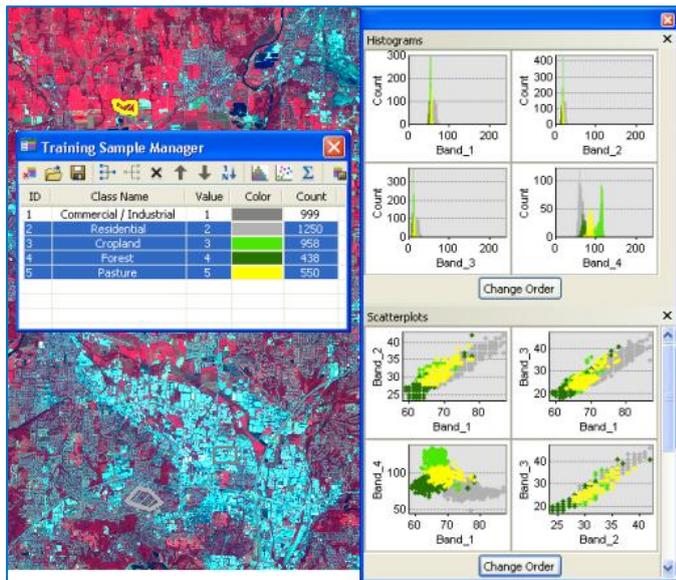
Input Landsat TM image

Using the toolbar, five land-use classes were defined from the satellite image: **Commercial/Industrial**, **Residential**, **Cropland**, **Forest**, and **Pasture**.



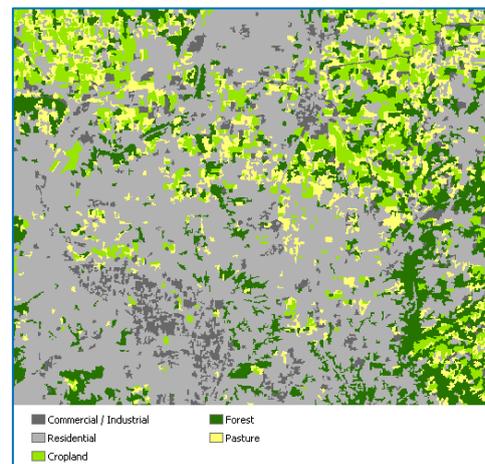
Training Samples

The quality of the training samples was analyzed using the training sample evaluation tools in **Training Sample Manager**.



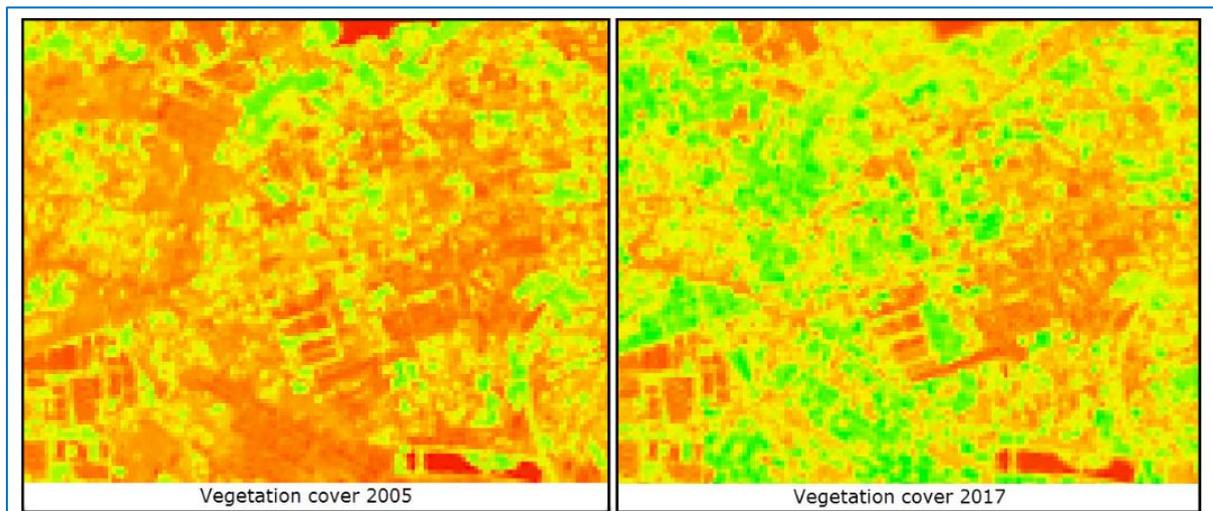
Evaluating Training Samples

Using the **Image Classification** toolbar and **Training Sample Manager**, it was determined the training samples were representative for the area and statistically separate. Therefore, a maximum likelihood classification was performed from the toolbar. The classified image was then cleaned to create the final land-use map as shown below.



Output Classified Land Use Map Change Detection

Temporal change detection can be performed by comparing two rasters from a different time, such as detecting changes in vegetation cover, or land use over a specified period. This can be done with the Raster Calculator in ArcMap, which gives results that allow further interpretation and classification for quantifying areas of change. The images below show vegetation cover for years 2005 and 2017. The instructions provided describe how to detect and quantify vegetation cover changes from 2005 to 2017 using the Raster Calculator tool.



Procedure

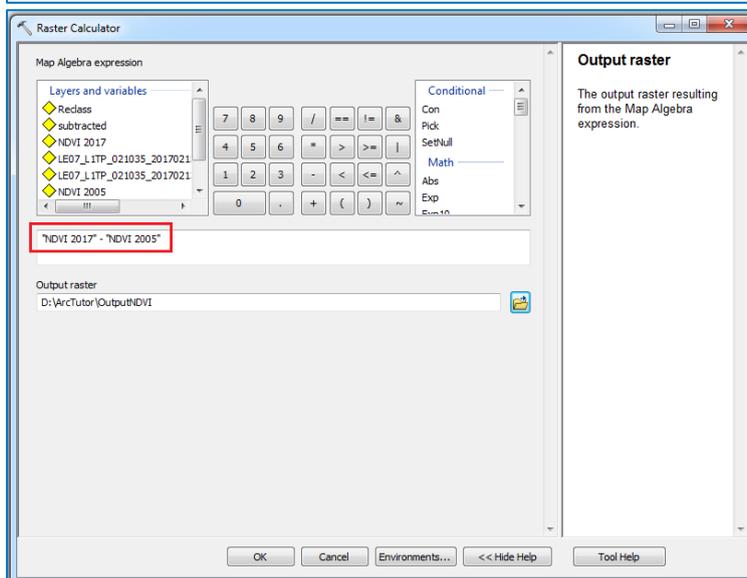
1. Subtract NDVI rasters for the difference in pixel values over time.

Note:

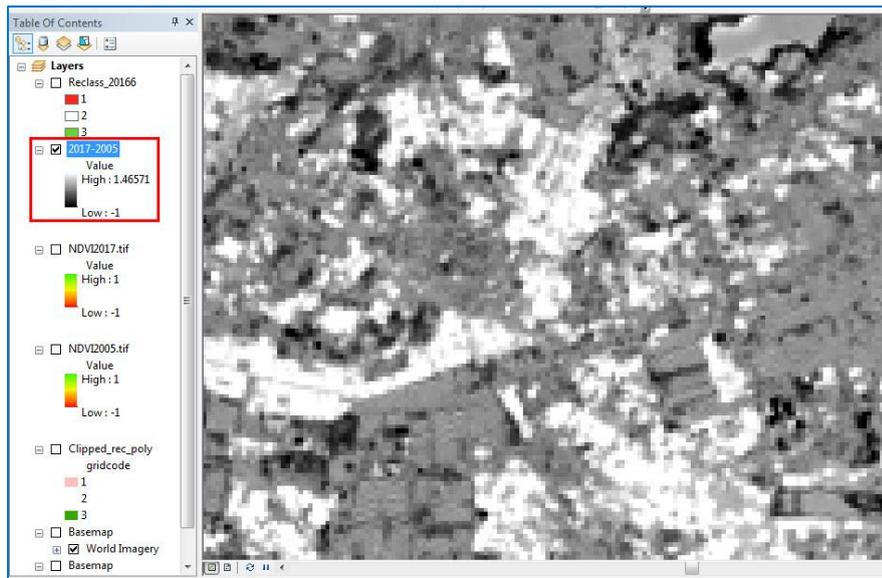
The NDVI rasters must cover the same spatial extent, and the pixels must be perfectly aligned. Additionally, to detect annual changes, acquire NDVI rasters calculated for the same window of the year. Otherwise, NDVI rasters calculated in different seasons reflect vegetation changes over seasons, and not years.

- a. Navigate to **Spatial Analyst Tools > Map Algebra > Raster Calculator**.
- b. In the **Raster Calculator** dialog box, type the expression required to subtract the raster of a previous time from the raster of a later time. For example:

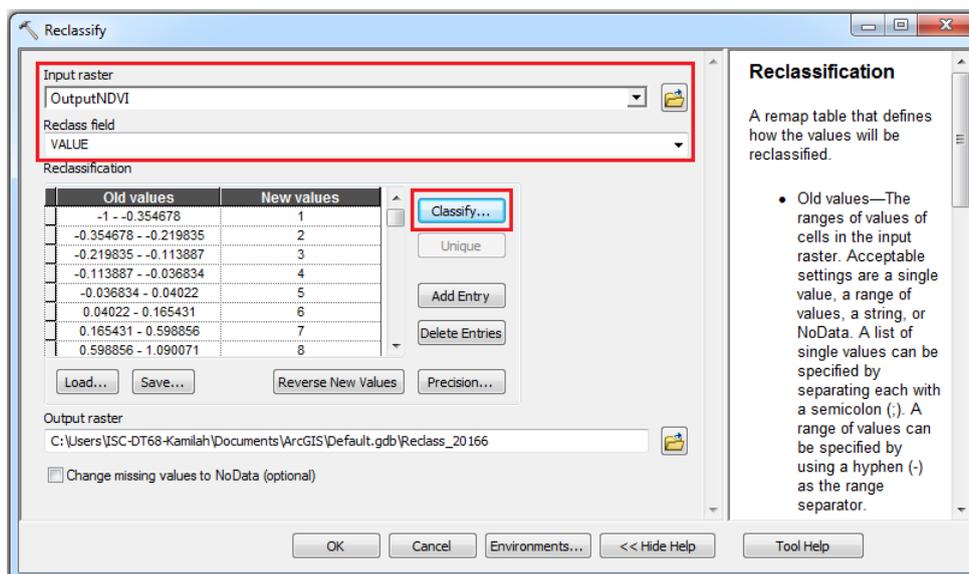
"NDVI 2017" - "NDVI 2005"



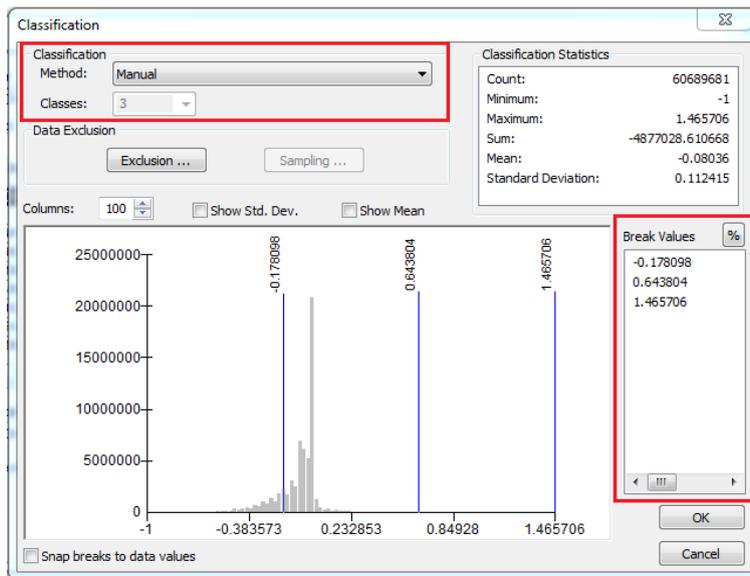
- c. Set a name and location for the **Output raster**.
- d. Click **OK**. The output raster contains the subtracted cell values. Negative values indicate losses while positive values indicate gain. Zero '0' indicates unchanged vegetation cover.



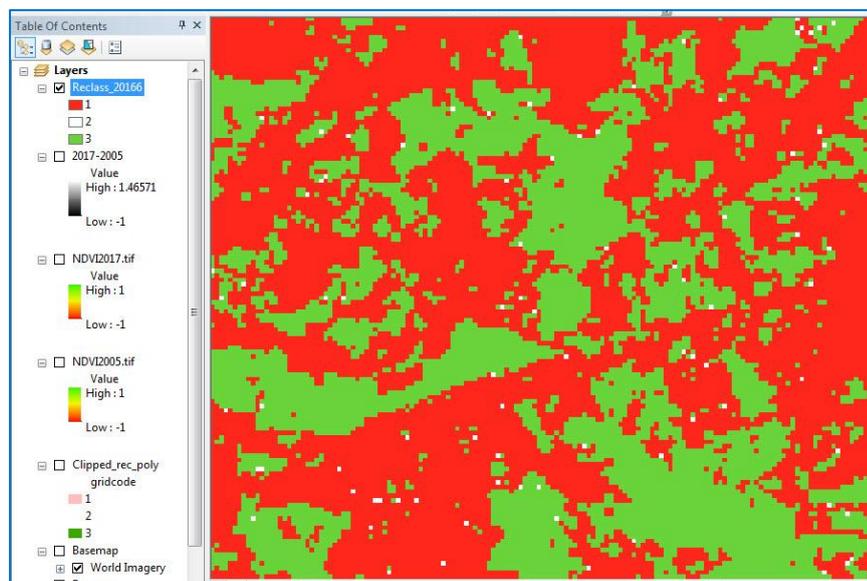
2. The raster generated in Step 1 can be classified into multiple classes to reflect vegetation change direction and extent. For example, (a) Vegetation loss; (b) No change, and (c) Vegetation gain, or (a) Significant loss; (b) Loss; (c) No change; (d) Gain, and (e) Significant gain.
 - a. Navigate to **Spatial Analyst Tools > Reclass > Reclassify**.
 - b. Select the output raster from Step 1 for **Input raster**.
 - c. Select **VALUE** for **Reclass field**.
 - d. Under **Reclassification**, click **Classify...**



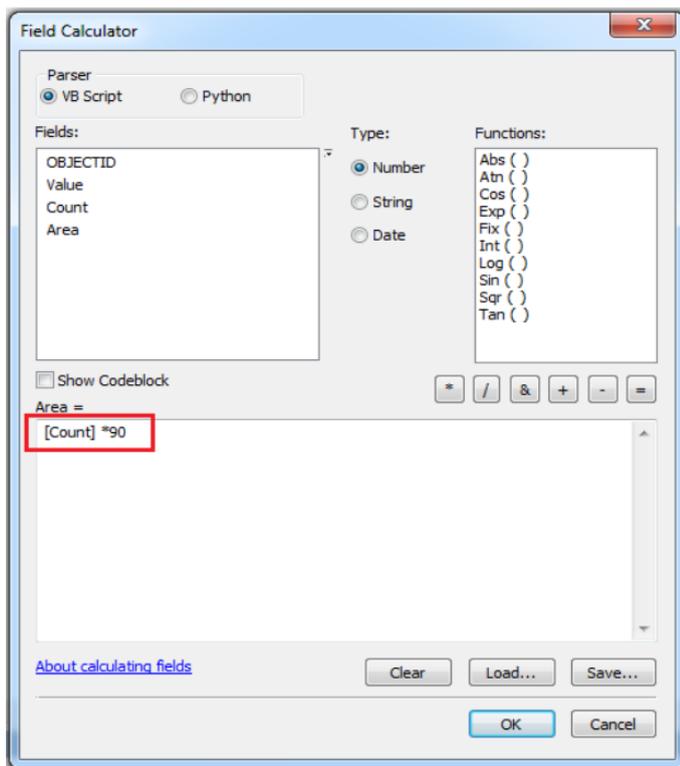
- e. In the **Classification** dialog box, select a method for the classification in the **Method** drop-down list, and select the desired number of classes in the **Classes** drop-down list.
- f. Set the **Break Values** manually, if necessary.



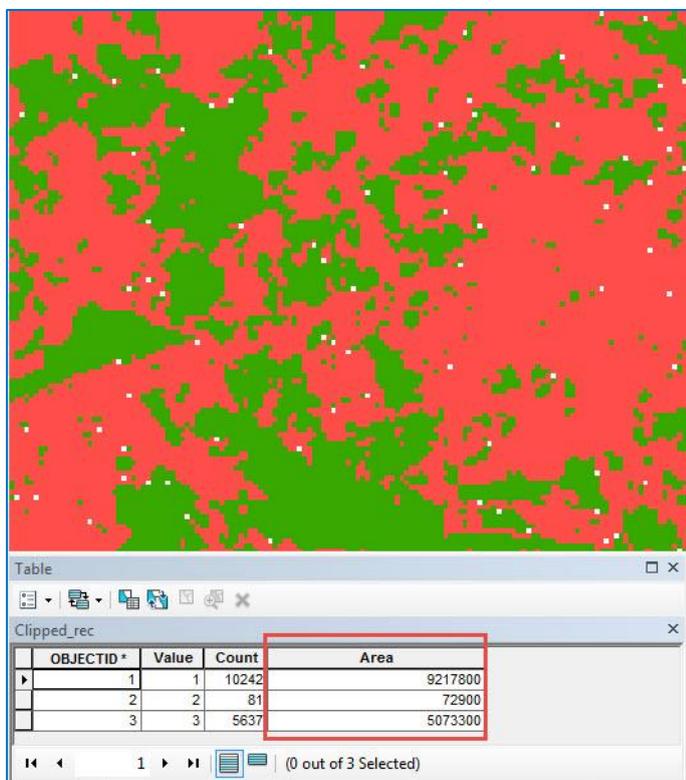
- g. Click **OK** to exit the **Classification** dialog box.
- h. In the **Reclassify** dialog box, set a name and location for **Output raster**.
- i. Click **OK**. A reclassified raster is generated with pixel values indicating the vegetation change classes. A **Count** field is added to the attribute table of the reclassified raster containing the number of cells falling into each class.



3. Quantify the changes by creating a new field, and calculate the area of each class by multiplying the Count field with the pixel size of the raster layer.
 - a. Open the attribute table of the output in Step 2. Right-click the layer and click **Open Attribute Table**.
 - b. Click **Table Options > Add Field**.
 - c. In the **Add Field** dialog box, type a name for the new field. Select **Double** as the field type. Leave other settings at default, and click **OK**.
 - d. Right-click the new field > **Field Calculator**. Click **Yes** if a prompt dialog displays.
 - e. In the **Field Calculator** dialog box, multiply the **Count** field by the pixel size of the raster layer. For example, this raster's pixel size is 90.



- f. Click **OK**. The area for each class is calculated in the new field. The unit of the calculated area is the unit of the raster's coordinate system.



GIS and Remote Sensing Works in Crop Zoning Project

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Background

- Bangladesh Agricultural Research Council (BARC) has been developing the crop zoning system for maintaining a sustainable agricultural production system in order to ensure long-term food security for the people.
- The government of Bangladesh put emphasis on crop zoning based land use planning in 8th five year plan policies and strategies of the crop sub-sector.
- On February 4, 2021, at the unveiling ceremony of “The 100 Agro Technologies Atlas” published by BARC, the Honorable Prime Minister of Bangladesh mentioned the necessity for crop zoning and requested to take action in this regard.

Basic Information

- **Implementing Organization:**
Bangladesh Agricultural Research Council (BARC)
- **Partner Organizations:**
 1. Soil Resource Development Institute (SRDI)
 2. Institute of Water Modeling (IWM)
- **Focal Point Organizations:**
 1. Department of Agriculture Extension (DAE)
 2. Bangladesh Agricultural Research Institute (BARI)
 3. Bangladesh Rice Research Institute (BRRI)
 4. Bangladesh Institute of Nuclear Agriculture (BINA)
 5. Bangladesh Wheat & Maize Research Institute (BWMRI)

Objectives

The overall objective is to develop crop zoning in support of GoB’s strategy to facilitate a more efficient and sustainable agricultural production systems in the context of food and nutritional security of the country. More specifically the objectives are:

- Provide crop zoning information to agricultural policy planners/ decision makers in creating a “farm friendly” policy framework to sustain an economically viable agriculture sector through conserving and protecting farmland for current and future generations;
- Facilitate and strengthen farmers and other stakeholders’ access to information on suitable crop, fertilizer recommendation and others related to increased agricultural productivity and farm income;
- Awareness building on the utility and use of crop zoning information system to help farmers, extension personnel, policy makers’ transition to more sustainable agricultural system.

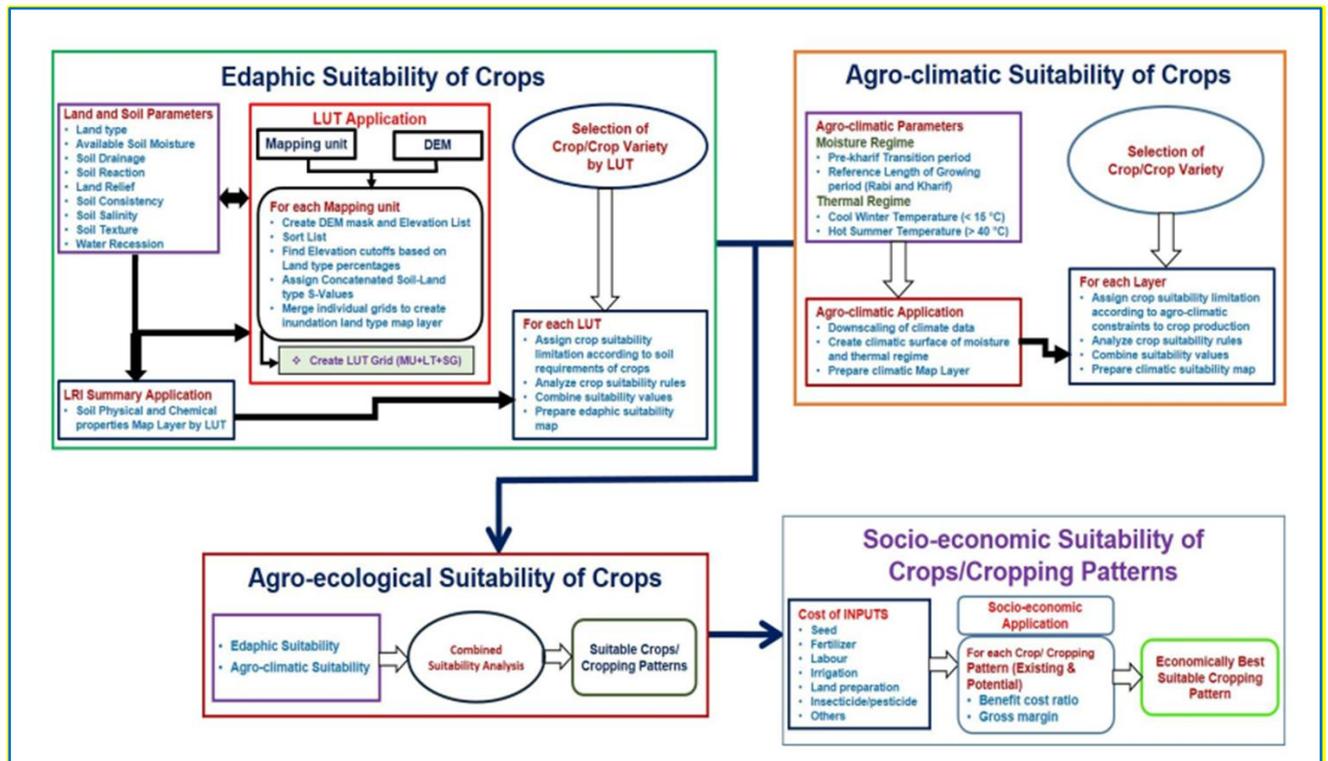
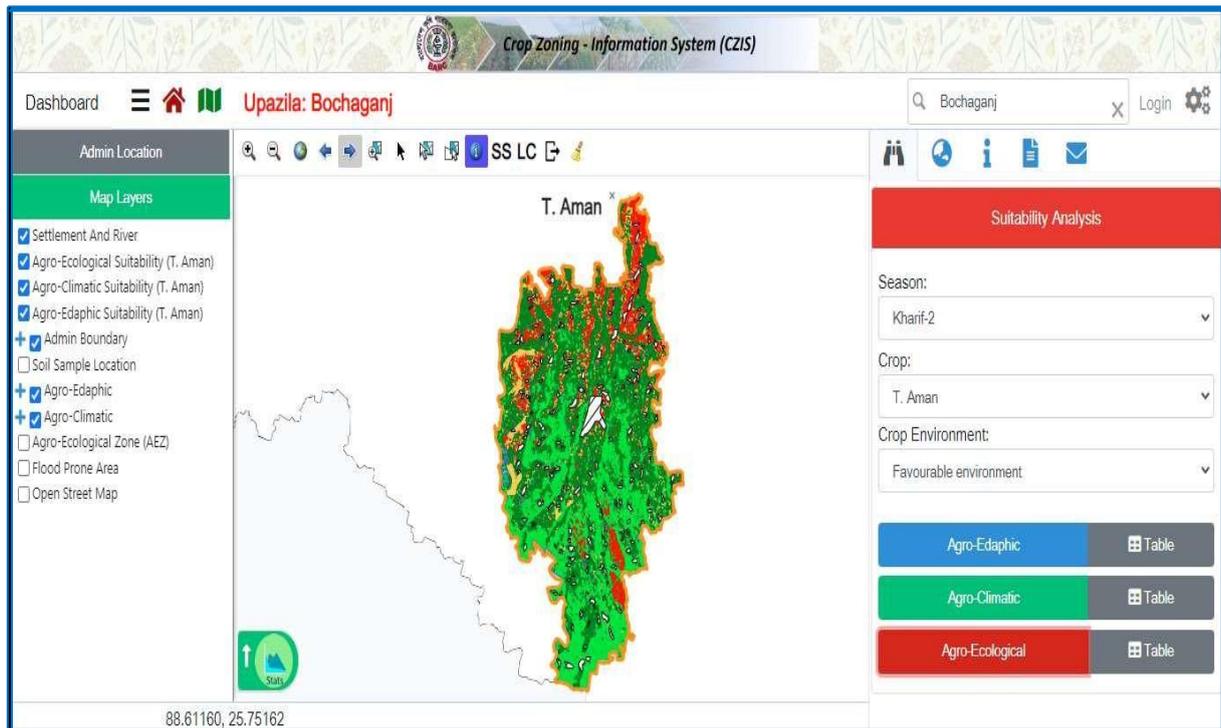


Figure: Crop Suitability Assessment Framework

Data used in Crop Zoning

- ❑ Upazila wise land and soil characteristics, soil chemical properties and soil and topography maps.
- ❑ 30 years (1988-2017) of weather data (daily temperature, precipitation, humidity, sunshine, wind speed, cloud cover).
- ❑ Information on crop-based land and soil requirements, agro climate requirement etc.
- ❑ Limitation rating made on the basis of requirement of crop based
- ❑ land and soil, agro climate, etc. in determining crop suitability.
- ❑ Information on variety information, yield, life span of 76 crops.
- ❑ Information on determining crop-based fertilizer recommendations and application methods.
- ❑ Socio-Economic Data and Indicators for Assessing Financial Benefits in supporting the Introduction of Sustainable Crop Production Systems.
- ❑ Upazila wise land type, roughness, soil texture, soil firmness, extractable juice status, water recession status, drainage status, soil reaction, salinity map.
- ❑ Pre-Kharif, Kharif and Rabi production periods and cold and hot temperature zone map.
- ❑ Upazila-wise administrative map (union and mauza boundaries, settlements, water bodies, rivers, pastures, etc.).
- ❑ Digital Elevation Model (DEM), Satellite Imagery.
- ❑ Existing land use map.

Crop Zoning Information System



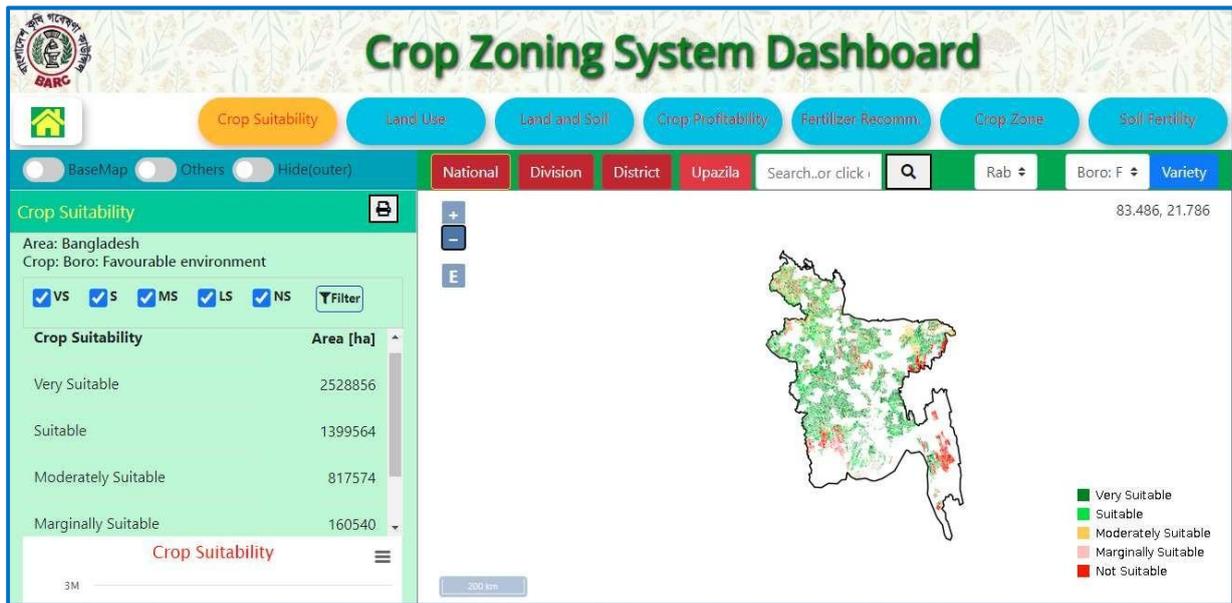
- Edaphic Suitability Assessment of Crop
- Agro-climatic Suitability Assessment of Crop
- Bio-physical Suitability Assessment of Crop
- Potential Crops and their Extents
- Cropping Patterns with GM and BCR
- Fertilizer Recommendation

Khamari Mobile App



- Location based Crop Suitability
- Location based Soil Fertility Status
- Location based Fertilizer Recommendation
- Cropping Patterns with GM and BCR
- Crop Zones
- Saved Information for Offline Viewing

Crop Suitability, Land Use, Crop Profitability, Fertilizer Recommendation



Agri-advisory Portal

AGRI-ADVISORY PORTAL
Bangladesh Agricultural Research Council (BARC)
Ministry Of Agriculture

Navigation: Home, About Portal, Crop INFO, Innovative Agriculture, Pest Management, Post Harvest Management, Agri Mechanization, Gallery, FAQ, Feedback

Crop Production Technology

Sidebar: Maize Sheller, Potato planter, Potato Harvester, Power Tiller Seeder, Cereal

Rice (Boro)

Variety: Iratom-24, BRR1 hybrid dhan7, BRR1 hybrid dhan5, BRR1 hybrid dhan3, BRR1 hybrid dhan2, BRR1 hybrid dhan1, BRR1 dhan99, BRR1 dhan97, BRR1 dhan96, BRR1 dhan92, BRR1 dhan89, BRR1 dhan88, BRR1 dhan86, BRR1 dhan84, BRR1 dhan81, BRR1 dhan74, BRR1 dhan69, BRR1 dhan68, BRR1 dhan67, BRR1 dhan64, BRR1 dhan63, BRR1 dhan61, BRR1 dhan60, BRR1 dhan59, BRR1 dhan58, BRR1 dhan55, BRR1 dhan50 (Banglamati), BRR1 dhan47, BRR1 dhan45, BRR1 dhan36, BRR1 dhan35, BRR1 dhan29, BRR1 dhan28, BR9 (Sufala), BR8 (Asa), BR7 (BRR1 Balam), BR6, BR3 (Biplob) Boro variety, BR2, BR1 (Chandina), BR19 (Mongal), BR18 (Shahjalal), BR17 (Hasi), BR16 (Shahibalam), BR15 (Mohini), BR14 (Gazi), BR12 (Mayna), Binadhan-8, Binadhan-6, Binadhan-5, Bina Dhan-24, Binadhan-18, Binadhan-14, Binadhan-10, Bangobondhu dhan100.

Land and Soil: Loamy, clay and clay loam soils with irrigation facilities are suitable for BRR1 dhan29 cultivation.

Seed rate: 22 kg /hectare

Navigation: Crop INFO / Crop Production Technology

Future Plan

- Develop National Crop Production Planning Tool using AI
- Develop Khamari app as an integrated platform (one stop solution)
- Updating of Land Use and Land Cover for all Upazila.
- Capture LiDAR data for precise land height
- Develop Satellite based crop monitoring and yield estimation
- Institutionalize Demonstration Trial of Khamari app (through DAE).
- Capacity Building of Manpower
- Initiate Crop Modelling for Assessing Future Scenario of Crop Zoning

Applied GIS & Remote Sensing Techniques

Instructor: Md. Abdus Shaker
ICT, GIS & Remote Sensing Division (ICT), IWM

1. Introduction to Applied GIS & Remote Sensing

GIS and Remote Sensing are critical components of digital agriculture. These technologies support:

- Crop monitoring & agricultural planning
- Land suitability assessment
- Spatial decision-making
- Web-based information dissemination
- Real-time data visualization for planners, scientists, and farmers

This session focuses on modern GIS workflows, web GIS technologies, and an important national case study implemented in Bangladesh.

2. GIS Data Types & Structure

2.1 Vector Data

Represents discrete features:

- Points: tube-wells, sampling points, farm locations
- Lines: canals, river networks, roads
- Polygons: field boundaries, unions/upazilas, crop zones

Used for administrative mapping, crop zoning, land parcels.

2.2 Raster Data

Represents continuous surfaces:

- Satellite imagery
- Soil moisture
- Elevation (DEM)
- Temperature/rainfall surfaces

Used in suitability analysis, terrain evaluation, crop health studies.

2.3 Coordinate Systems Used in Bangladesh

- WGS84 Geographic (EPSG:4326): GPS, satellite-based data
- UTM Zone 46N / 47N: accurate measurement & analysis

3. Remote Sensing Fundamentals

Remote Sensing provides regularly updated satellite-based information for agriculture.

Key parameters:

- Spatial resolution: how detailed (10m, 30m)
- Spectral resolution: number of bands—crucial for vegetation, soil, water features
- Temporal resolution: revisit time—important for crop monitoring
- Radiometric resolution: sensitivity to brightness changes

Applications in agriculture:

- Crop growth stage detection
- Flood and drought impact mapping
- Seasonal monitoring
- Crop type identification
- Land use and land cover changes

4. Land Use / Land Cover (LULC) Mapping & Classification

Types of Classification

- Unsupervised: K-means, ISODATA
- Supervised: SVM, Random Forest, Maximum Likelihood

Uses in Agriculture

- Mapping cultivated vs. fallow land
- Monitoring encroachment
- Crop type and cropping intensity
- Seasonal land use trend analysis

Web GIS Integration

- Online LULC viewers
- Change detection dashboards
- Downloadable geospatial layers

5. Spatial Interpolation Techniques

Used to create continuous surfaces from point data (soil, rainfall, elevation).

IDW

- Simple and fast
- Best for uniformly distributed samples

Kriging

- Statistical model for high accuracy
- Used in groundwater and soil nutrient mapping

Spline

- Smooth surface generation
- Elevation & moisture gradients

Agricultural Use

- Soil nutrient maps
- Salinity interpolation
- Rainfall surfaces
- Groundwater depth mapping

6. Crop Zoning & Land Suitability Assessment

Suitability analysis integrates multi-layer datasets to determine the best zones for crop cultivation.

Key parameters used:

- Soil properties (pH, OM, texture)
- Topographic factors (slope, elevation)
- Climate variables (rainfall, temperature)
- Hydrological conditions
- LULC and cropping patterns
- Flood, drought, salinity risk

7. Land Type Development

Step-1: Spot Height With Map Unit

- Collect spot heights
- Apply interpolation (IDW)
- Overlay map units
- Extract elevation per unit
- Generate elevation table & curve

Step-2: Area Elevation

- Sort by elevation
- Calculate cumulative area
- Determine cut-off thresholds
- Assign Land Type (LL, MLL, MHL, HL)

This supports flood depth analysis, cropping pattern selection, and land productivity planning.

8. Web GIS Technologies

8.1 What is Web GIS?

A system that allows users to:

- Access geospatial data online
- View and analyze maps in real-time
- Integrate multi-source datasets
- Use interactive dashboards
- Support multi-user decision-making

8.2 Technologies Commonly Used for Smart Agriculture Systems

Backend & GIS Server

- PHP Laravel – API logic, business rules
- GeoServer – publishing spatial data as WMS/WFS/WMTS
- PostgreSQL + PostGIS – spatial database engine

Frontend Web GIS

- OpenLayers – map rendering, advanced GIS tools
- Leaflet – lightweight map viewer
- Mapbox GL JS – high-performance vector rendering

Mobile GIS Components

- Android Native (Java/Kotlin) – Khamari Android
- React Native – Khamari iOS
- GPS-based data collection
- Push notification support

8.3 Typical Web GIS Architecture

1. Client: Browser or mobile app
2. Web Server: Laravel/PHP
3. GIS Server: GeoServer
4. Database: PostgreSQL/PostGIS
5. Front-end Map Engine: OpenLayers

Produces:

- Maps
- Charts & Reports
- Suitability advisory

9. Case Study: Development of Upazila Land Suitability Assessment and Crop Zoning System of Bangladesh

(CZIIS – real national GIS application)

9.1 Objective

To provide crop suitability information to:

- Farmers
- Planners
- Researchers
- Policy makers

To ensure:

- Higher food production
- Optimized crop rotation
- Sustainable agricultural planning
- Improved farmer income

9.2 GIS and RS Components of the Project

1. Web GIS–based Upazila-level Crop Suitability Assessment System

- Crop suitability maps
- Multi-criteria analysis
- Layer-based spatial comparison
- Crop zoning advisory
- Flood/salinity/drought risk overlays
- Dynamic statistics and charts

2. Mobile App Development – “খামারি”

- Android version: Native (Java/Kotlin)
- iOS version: React Native
- Features:
 - Farmer location-based advisory
 - Crop recommendation
 - Weather info
 - Suitability by union/upazila
 - Notifications

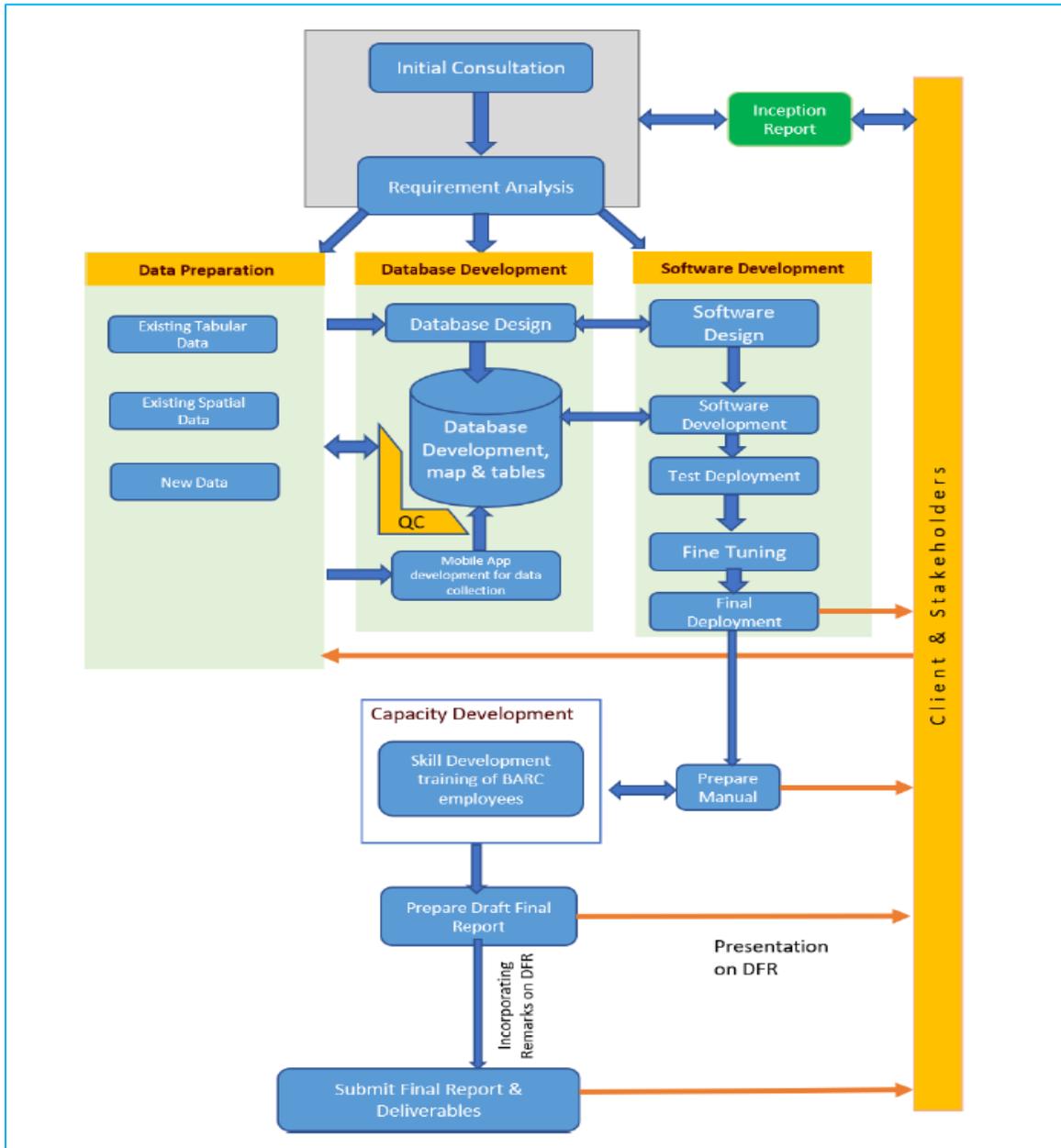
3. Agricultural Portal Development

- Integrated dashboard
- Geospatial data browsing
- Suitability reports
- LULC and soil data access
- Administrative tools for DAE/BARC stakeholders

9.3 Technology Stack (Open-Source)

- PHP Laravel – application logic
- PostgreSQL + PostGIS – spatial DB
- GeoServer – geospatial data publishing
- OpenLayers – interactive map interface
- Android Native – field-level dissemination
- React Native – iOS application
- GEE (for preprocessing) – used in some RS workflows

9.4 Methodology



Land Type Development

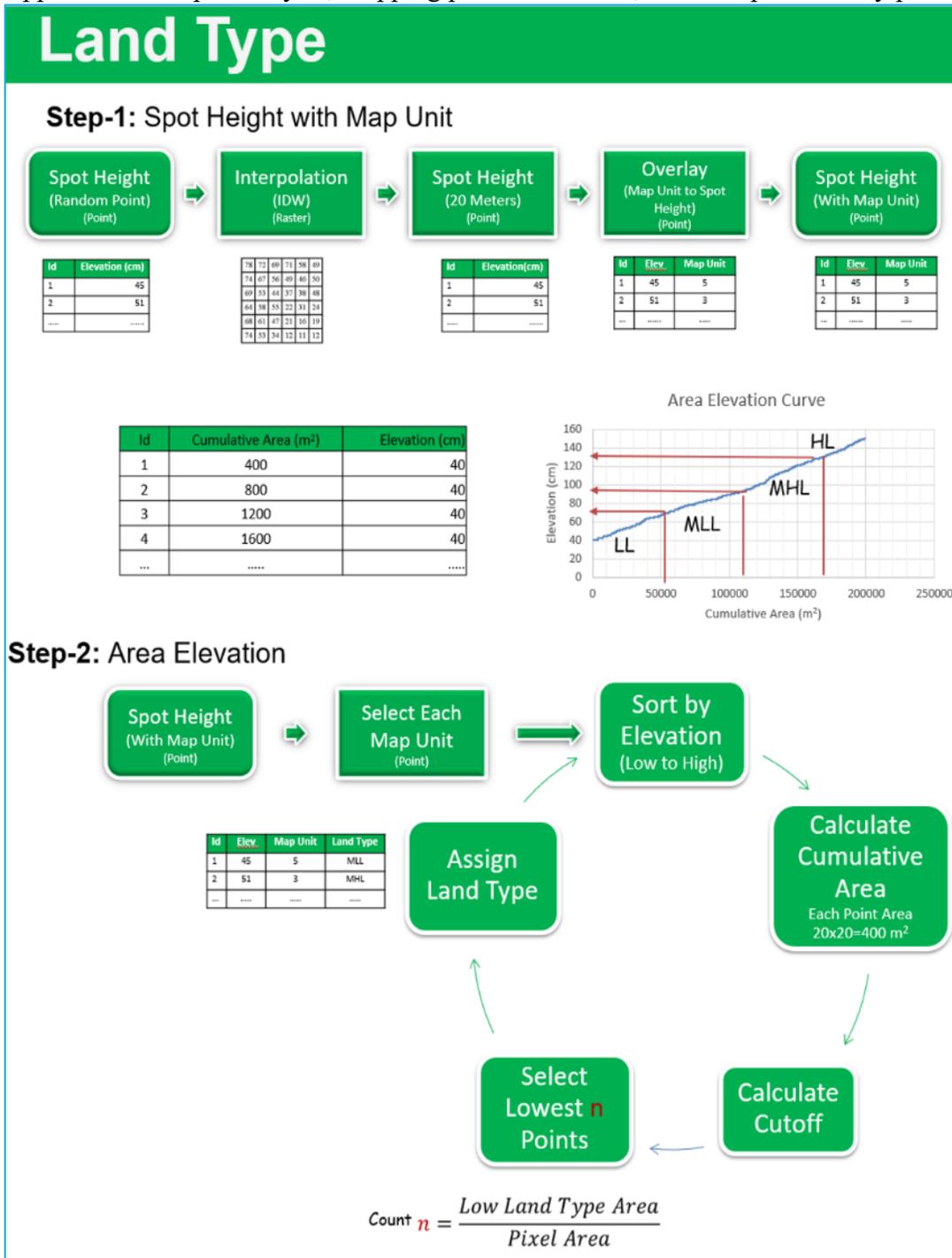
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- Determine cut-off thresholds
- Assign Land Type (LL, MLL, MHL, HL)

This supports flood depth analysis, cropping pattern selection, and land productivity planning.



Backend System

- Collect spatial and non-spatial datasets
- Build centralized geodatabase
- Preprocess layers (slope, LULC, soil, climate)
- Generate suitability layers
- Publish via GeoServer (WMS/WFS/WMTS)
- Integrate into Web GIS portal

Web Application Workflow

1. User requests crop suitability
2. Laravel processes request
3. API requests map data from GeoServer
4. OpenLayers displays map
5. System generates reports/charts
6. Mobile app fetches advisory

Communication & Integration

- SMS / Email integration for BARC
- Mobile notification services
- Downloadable reports: PDF, Excel, Maps

10. Conclusion

Participants gain:

- Understanding of modern GIS & RS techniques
- Clear idea of Web GIS technology
- Insights into a national-level operational GIS system (CZIIS)
- Practical knowledge on suitability, zoning, interpolation, LULC
- Awareness of how GIS and RS support digital agriculture