Training Manual
on
Remote Sensing (RS) & Geographic Information System (GIS)

Compiled and Edited by

Hasan Md. Hamidur Rahman

Course Director & Director, Computer and GIS Unit

Hasan Mahmud

Course Coordinator & Senior System Analyst, Computer and GIS Unit

Al-Helal

Programmer, Computer and GIS Unit

Rashedul Islam

Asst. Programmer, Computer and GIS Unit

Computer & GIS Unit
Bangladesh Agricultural Research Council

Computer & GIS Unit
Bangladesh Agricultural Research Council

TABLE OF CONTENTS

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

Md. Abeed Hossain Chowdhury, Project Manager, Crop Zoning Project
Bangladesh Agricultural Research Council
Email: abeedchowdhury@gmail.com

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.

GIS and Remote Sensing Works in Crop Zoning Project

Hasan Md. Hamidur Rahman, Director (Computer & GIS Unit)
Bangladesh Agricultural Research Council
Email: h.rahman@barc.gov.bd

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 agriculturalsystem.

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.

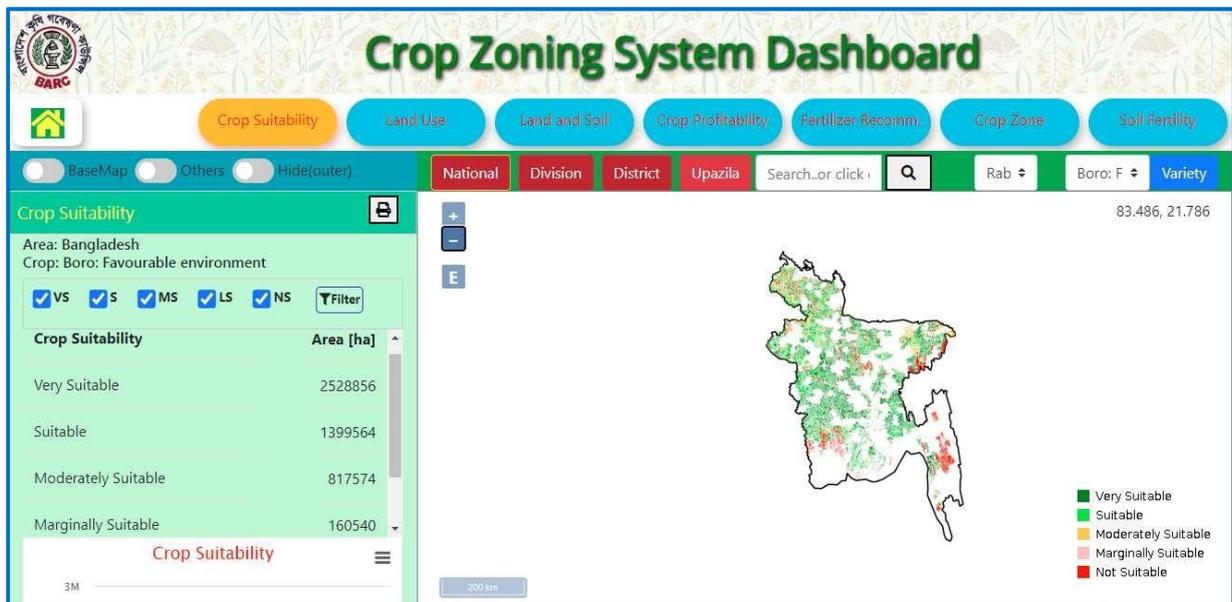# Crop Zoning Information System
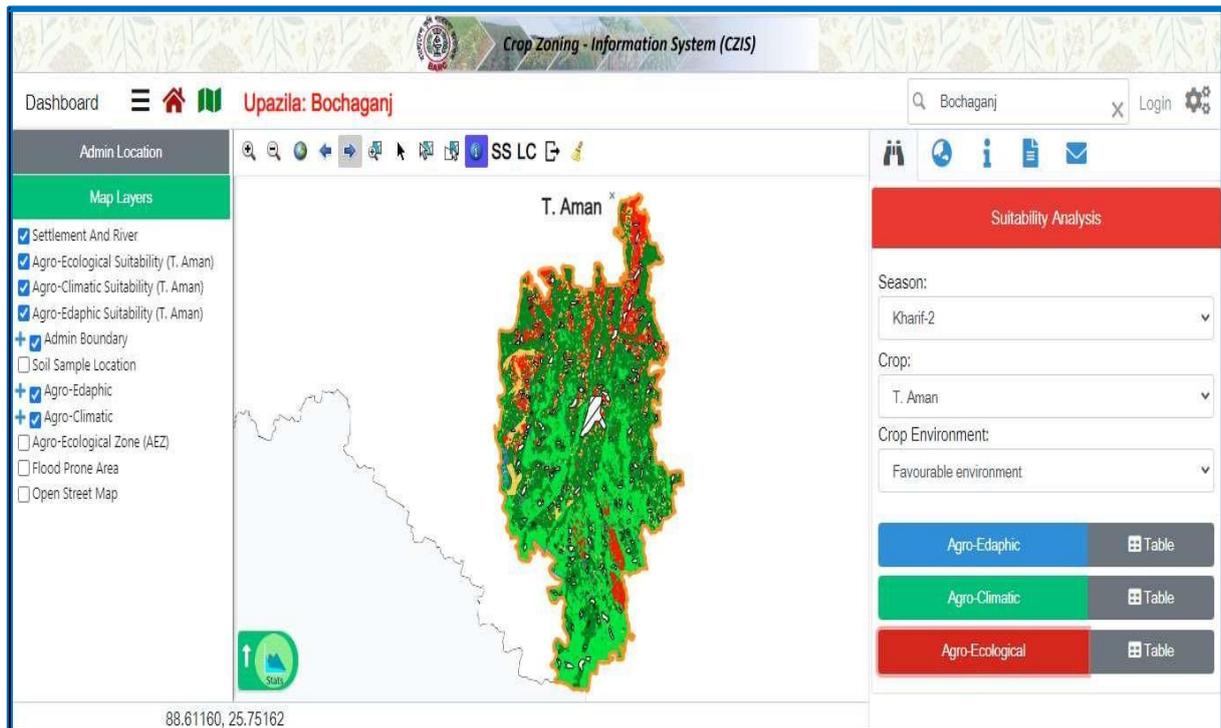
- ➢ Edaphic Suitability Assessment of Crop
- ➢ Agro-climatic Suitability Assessment of Crop
- ➢ Bio-physical Suitability Assessment of Crop
- ➢ Potential Crops and their Extents
- ➢ Cropping Patterns with GM and BCR
- ➢ Fertilizer Recommendation

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

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

Basic Concepts of GIS Technology

Abid Kamal
GIS Analyst, Crop Zoning Project
Bangladesh Agricultural Research Council
Email: geoabid38@gmail.com

Introduction

- ➢ GIS stands for Geographic Information System.
- ➢ It is a system designed to capture, store, analyze, and display spatial or geographic data.
- ➢ GIS combines hardware, software, and data to provide powerful tools for understanding and visualizing location-based information.

Benefits of GIS

Improved Decision-Making:

- ➢ GIS provides valuable insights by visualizing complex data in a spatial context.
- ➢ It enables better-informed decision-making by integrating multiple layers of information.

Enhanced Efficiency:

- ➢ GIS automates tasks, streamlines workflows, and reduces manual effort.
- ➢ It saves time and resources by optimizing processes like route planning or data analysis.

Increased Collaboration:

- ➢ GIS facilitates data sharing and collaboration among individuals and organizations.

➢ It enables stakeholders to work together, contributing to better planning and decision-making.
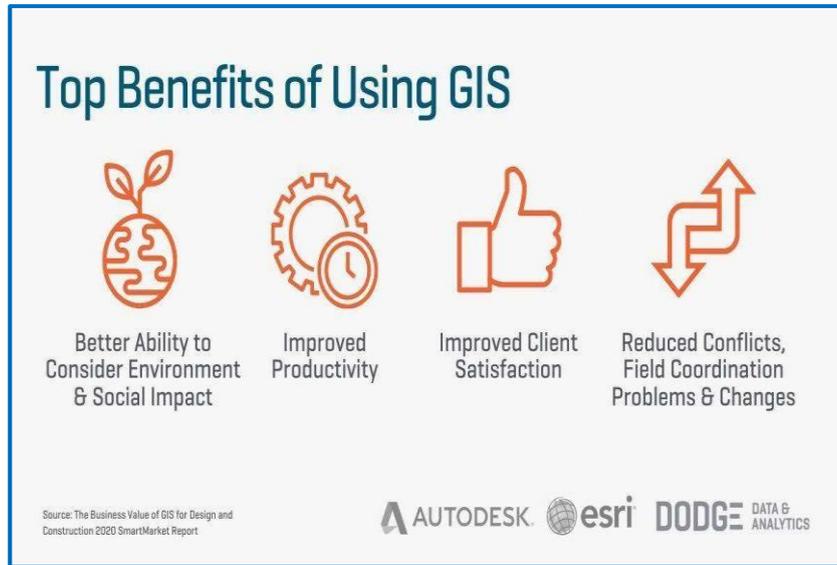
Components of GIS Hardware:
➢ Computers, servers, scanners, printers, GPS devices, and other physical equipment used to collect and process data.

Software:
➢ GIS software provides the tools and functionalities to manage, analyze, and visualize spatial data.
➢ Examples: ArcGIS, QGIS, Google Earth, and many others.
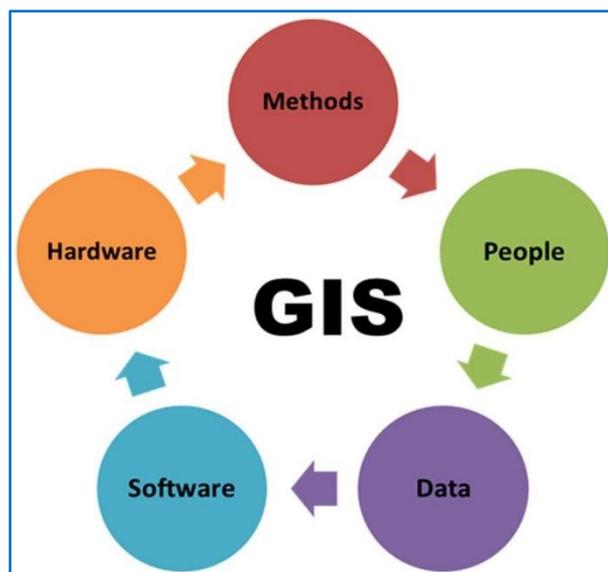
Figure: Components of GIS

Data:

➢ Geographic data is the foundation of GIS.

➢ It includes both spatial data (e.g., maps, satellite images) and attribute data (e.g., population, temperature).

➢ Data can be collected from various sources, such as surveys, remote sensing, or existing datasets.

GIS Data Types and Data Sources Data Types:

➢ Spatial data: maps, satellite imagery

➢ Attribute data: population, temperature, land use

➢ Importance of integrating spatial and attribute data

Data Sources:

➢ Data collection methods: surveys, remote sensing, GPS

➢ Open data sources: government agencies, research institutions

➢ Data quality considerations

GIS Data Management

➢ Data storage and organization

➢ Data formats: raster vs. vector

➢ Database management systems (DBMS)
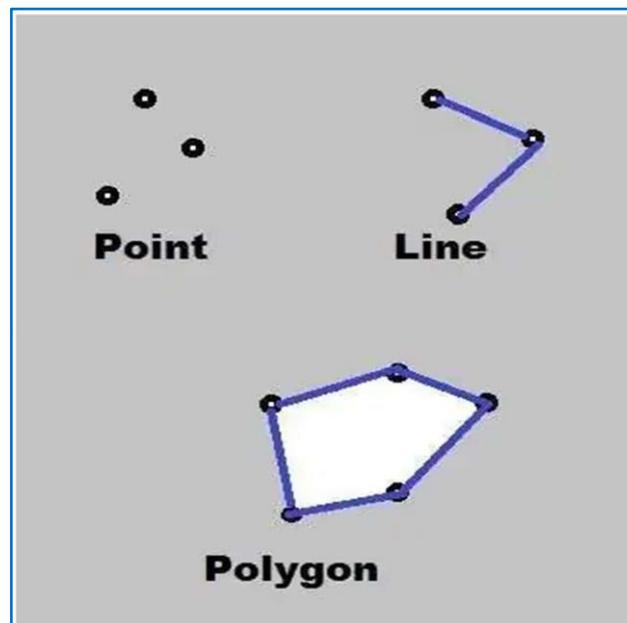
GIS Analysis

➢ Spatial analysis techniques: buffering, overlay, proximity analysis

➢ Geoprocessing tools and operations

➢ Modeling and simulation capabilities

GIS Visualization

- ➢ Maps and cartography
- ➢ Symbolization and thematic mapping
- ➢ 3D visualization and fly-throughs

GIS Applications in Agriculture

1. Crop Monitoring and Management
- Use satellite imagery and drones to monitor crop health.
- Identify areas with stress due to pests, diseases, or lack of nutrients.
- Apply fertilizers or pesticides only where needed (site-specific management).

2. Soil Mapping and Analysis
- Map soil types, textures, pH, and moisture levels.
- Support land suitability analysis for different crops.
- Optimize tillage and irrigation plans.

3. Precision Farming
- Combine GPS with GIS for precision planting, fertilizing, and harvesting.
- Reduce waste and maximize yield by analyzing spatial variability in fields.

4. Irrigation Management
- Map irrigation zones based on crop needs and soil moisture data.
- Improve water use efficiency using remote sensing and real-time sensors.

5. Yield Prediction and Mapping
- Analyze historical yield data spatially to forecast future output.
- Create yield maps that guide decisions for upcoming seasons.

6. Climate and Weather Analysis
- Integrate weather data for forecasting and crop planning.
- Identify areas prone to droughts, floods, or frost.

7. Pest and Disease Mapping
- Map and monitor outbreaks of pests or diseases across regions.
- Plan and implement targeted intervention strategies.

8. Farm Planning and Land Use Management
- Plan crop rotations, buffer zones, and farm infrastructure using spatial data.
- Ensure sustainable use of land and natural resources.

Water Resource Management Applications

- ➢ Watershed modeling
- ➢ Flood risk assessment
- ➢ Water quality monitoring

GIS in Water Research

Other Applications:

- • Urban Planning
- • Disaster Management
- • Environmental Management
- • Education and Research
- • Archeology
- • Real Estate
- • Healthcare
- • Many More ……
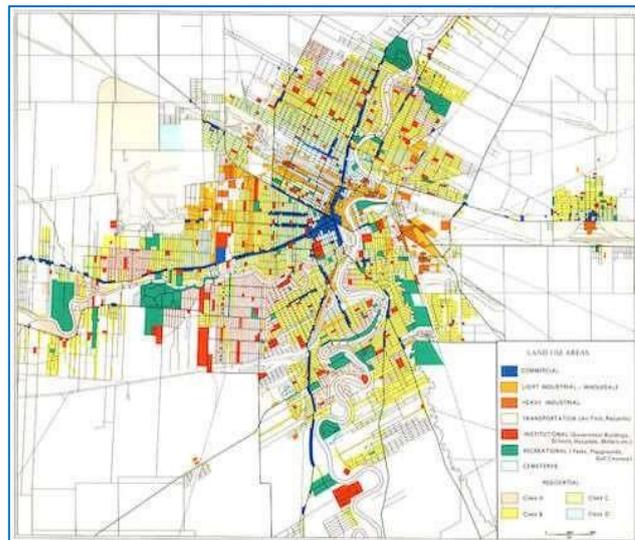
Conclusion

GIS is a powerful tool for managing and analyzing spatial data. Its applications span across diverse fields, including urban planning, environmental management, emergency response, public health, and transportation. With its ability to integrate data from various sources and provide visualizations, GIS helps in making informed decisions and solving complex problems.

Overview of ArcGIS

Al-Helal
Programmer, Computer & GIS Unit
Bangladesh Agricultural Research Council
Email: al.helal@barc.gov.bd

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
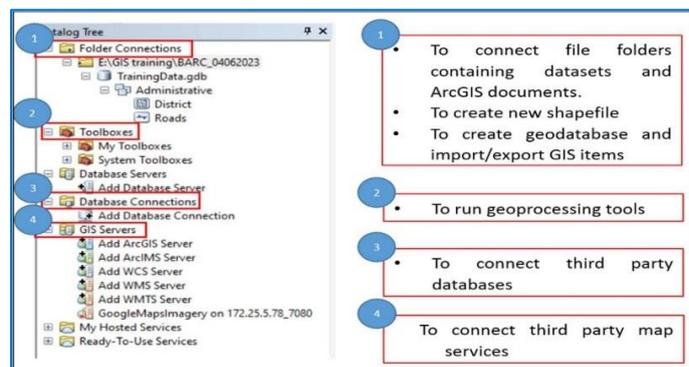
- Share maps, layers, geo-processing models, and geodatabases with other users
- Document your geographic information
- Customize the user experience
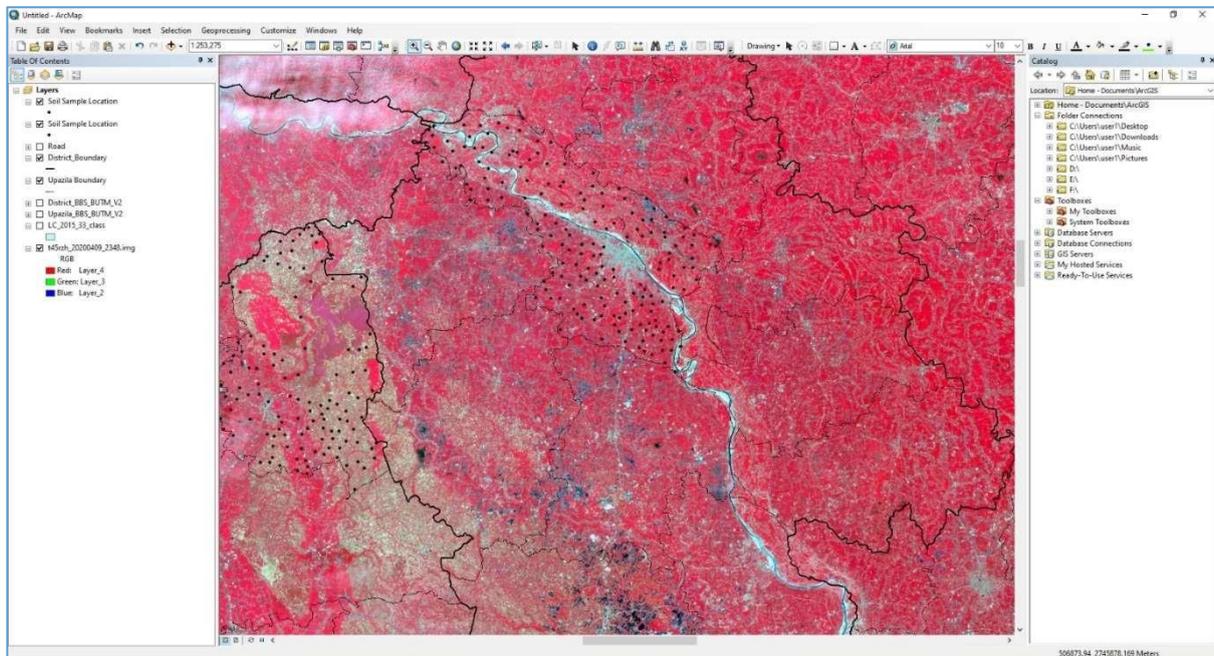
When you save a map, you have created in ArcMap, it will be saved as a file on disk. This is an ArcMap document and is referred to as a map document or mxd since the file name extension (.mxd) is automatically appended to your map document name. You can work with an existing .mxd file by double-clicking 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.
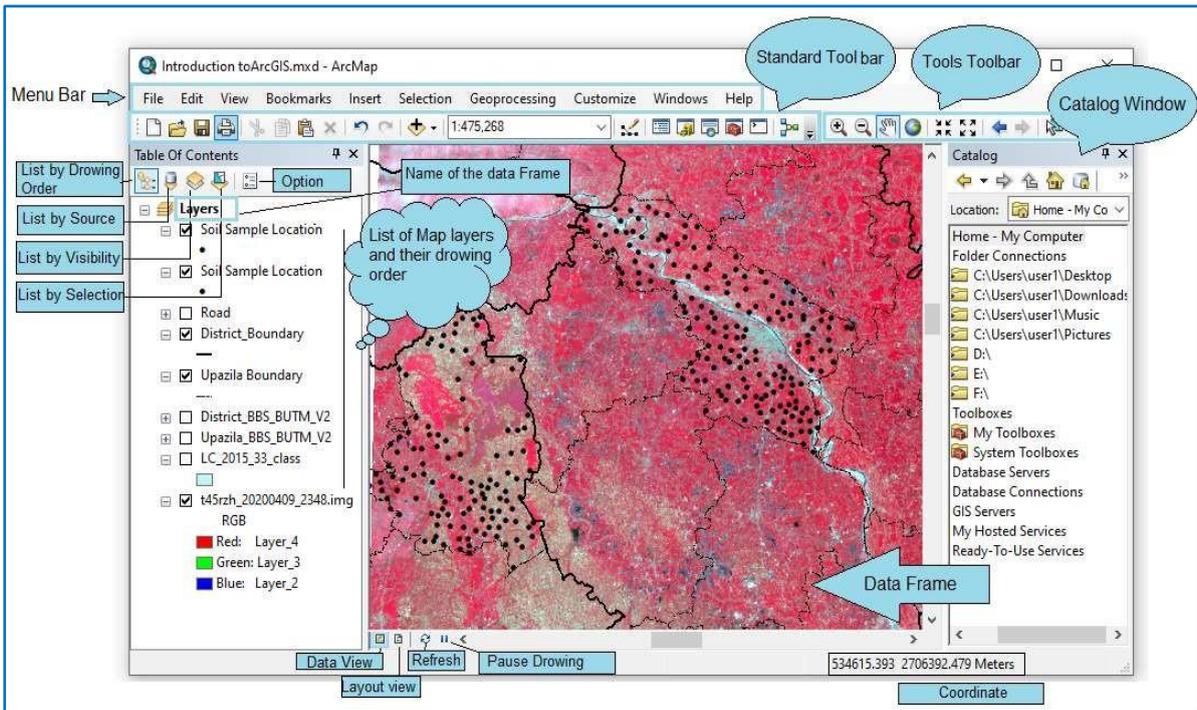
When you're preparing your **map's layout**, you'll want to work with your map in page layout view. A page layout is a collection of map elements (such as a data frame, map title, scale bar, north arrow, and a symbol legend) arranged on a page. Layouts are used for composing maps for printing or export 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.
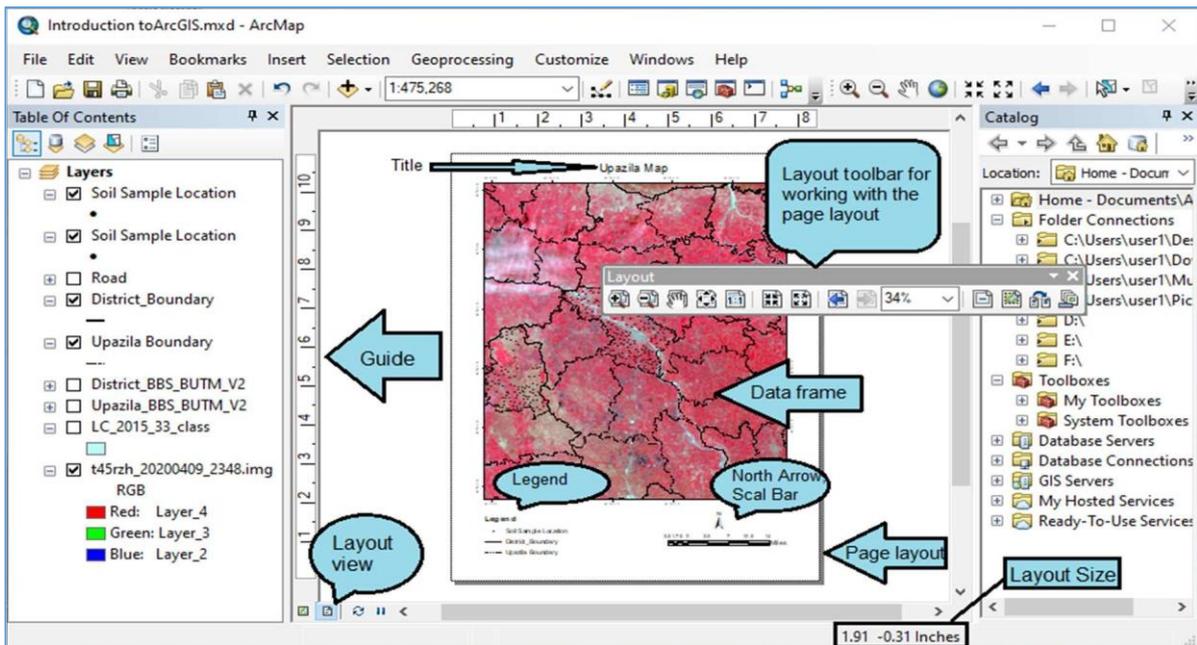
Common map elements include data frames with map layers, scale bars, north arrows, symbol legends, map titles, text, and other graphic elements.

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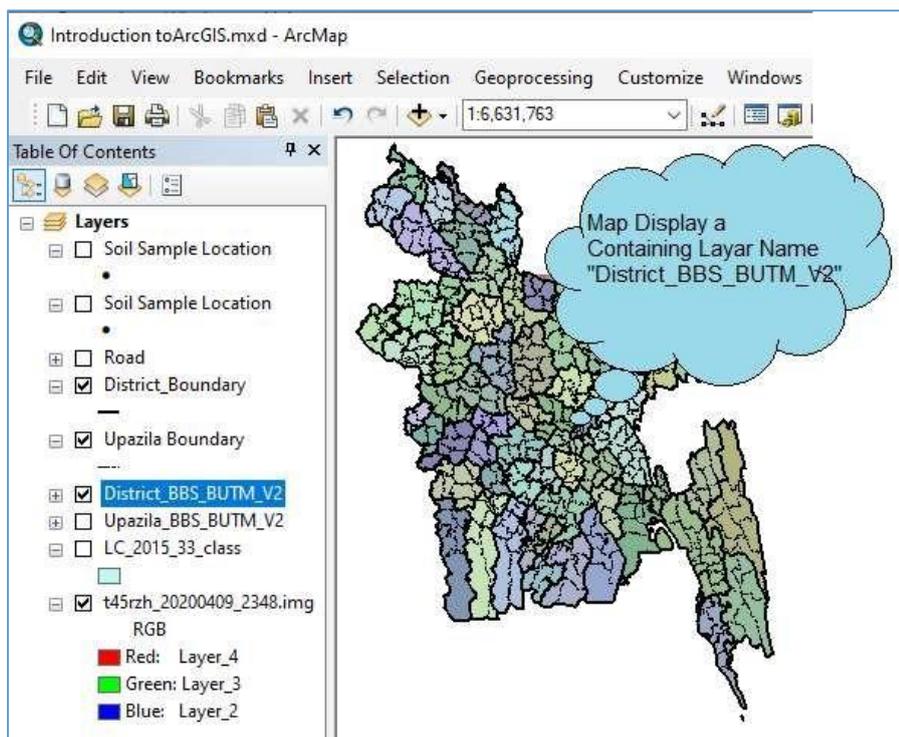
A layer doesn't store the actual geographic data. Instead, it references a dataset, such as a feature class, an image, a raster, and so on. Referencing data in this way allows the layers on a map to automatically reflect the most up-to-date information in your GIS database.

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.
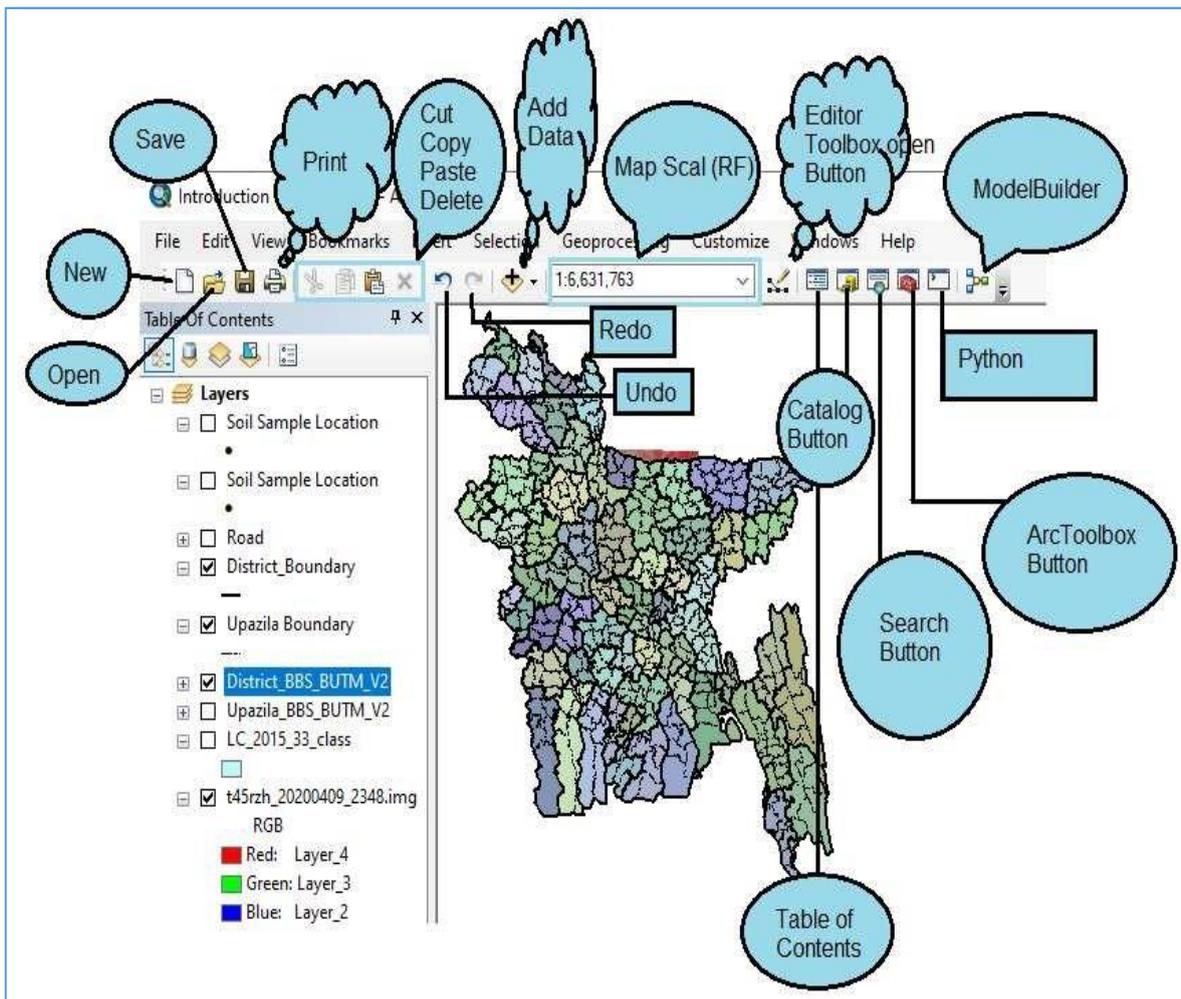
The Standard toolbar most typically appears at the top of the ArcMap application window andis used for map printing, creating a new map, opening an existing map, saving your map, starting related ArcGIS applications, and more.
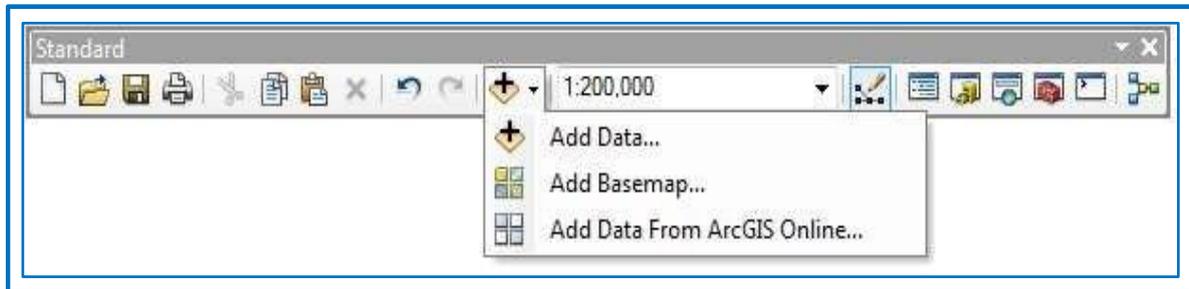
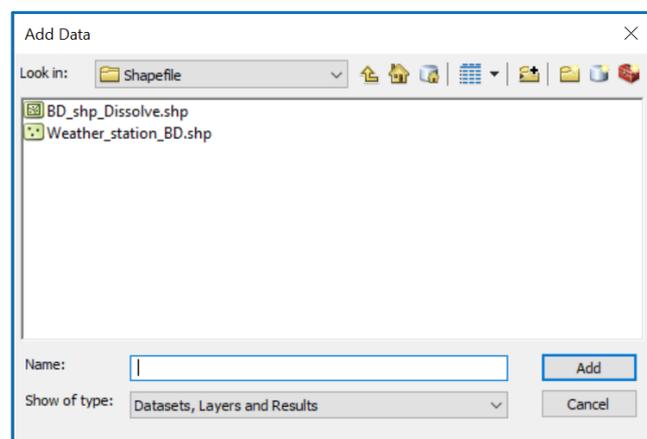Clicking **'Add Data'** Button Opens the 'Add Data' Dialog box for adding data of all compatible types to ArcMap.

- 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.
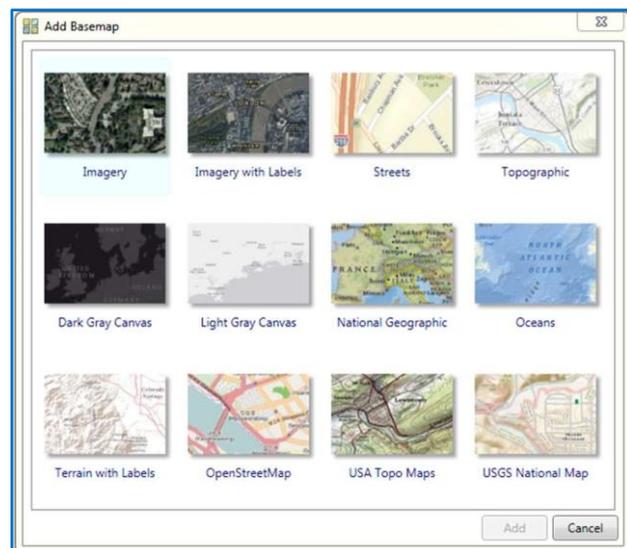
Geo-Referencing Techniques

Mustafa Atikul Mazid,
Remote Sensing Analyst, Crop Zoning Project
Bangladesh Agricultural Research Council
Email: tushar060401@gmail.com

Add Image to ArcGIS

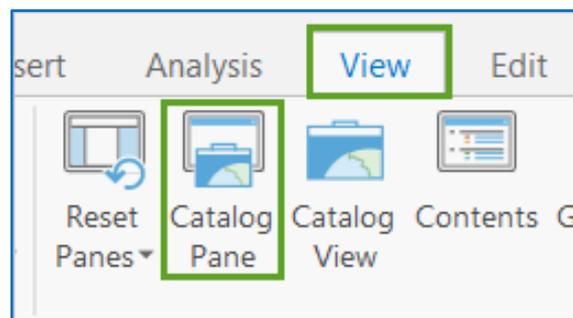You will add an image to your map that does not have statistics or georeferencing data. You will use tools in ArcGIS Pro to calculate the statistics so the image will load more smoothly as you work with it and identify where the map was placed without its georeferencing data.

1. On the ribbon, click the View tab, and in the Windows group, click Catalog Pane.

2. In the Catalog pane, click the arrows to expand provided data folder, Georeferencing. Right- click AOI and choose Add To Current Map.

The Calculate statistics for AOI window appears notifying you that the image you are adding does not have statistics and prompting you to calculate them. You will accept and calculate statistics for your image.

1. In the Calculate statistics for AOI window, click Yes.

AOI appears in the Contents pane, but for now, you don't see it on the map. A message in the upper right corner warns you that the image does not have coordinate system information. This is expected because the image you added did not contain any spatial reference information. Before you remedy this, you'll locate the image on the map.
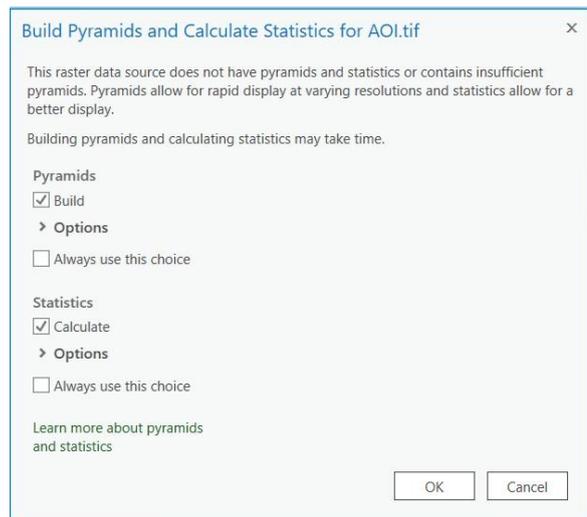
2. In the Contents pane, right-click AOI and choose Zoom To Layer.
3. The map now shows the image of the area you have downloaded. However, since it is not georeferenced, the application cannot locate it and displays it near the latitude and longitude (0,0), as you can see indicated in the lower part of the map view.

Create Control Points and Apply a Transformation

You'll add control points to the image and apply a transformation to complete the georeferencing process.

When you georeference an image, you define its location using map coordinates and assign the coordinate system of the map frame to the image. You do this by adding control points that identify a location in the image and its corresponding location in the reference basemap. In this section, you will identify and add several control points.

On the Georeference tab, in the Adjust group, click Auto Apply once to turn it off.
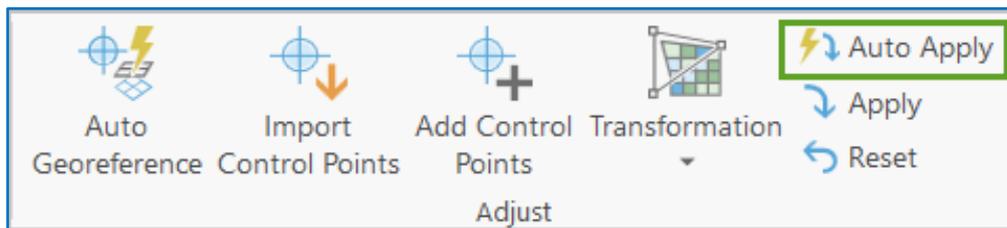
When Auto Apply is active, it automatically applies a transformation to the source layer and updates the display as control points are added, removed, or modified. For the purpose of this exercise, you want Auto Apply to be off to be able to observe your control points in their original location. You'll apply the transformation in the next section.

1. In the map extent zoom to the location for the first control point.

2. Click the Georeference tab, and in the Review group, click Control Point Table. Reposition the table below the Map view.

3. Click Fit to Display to add image in the current map extent
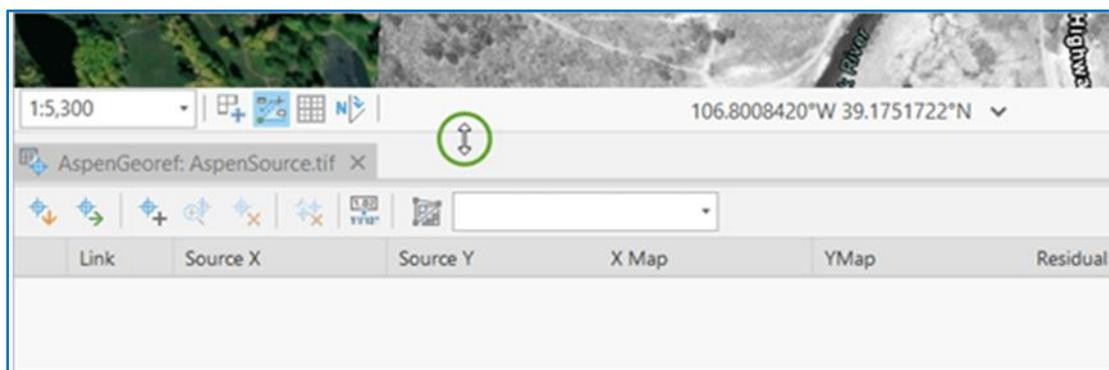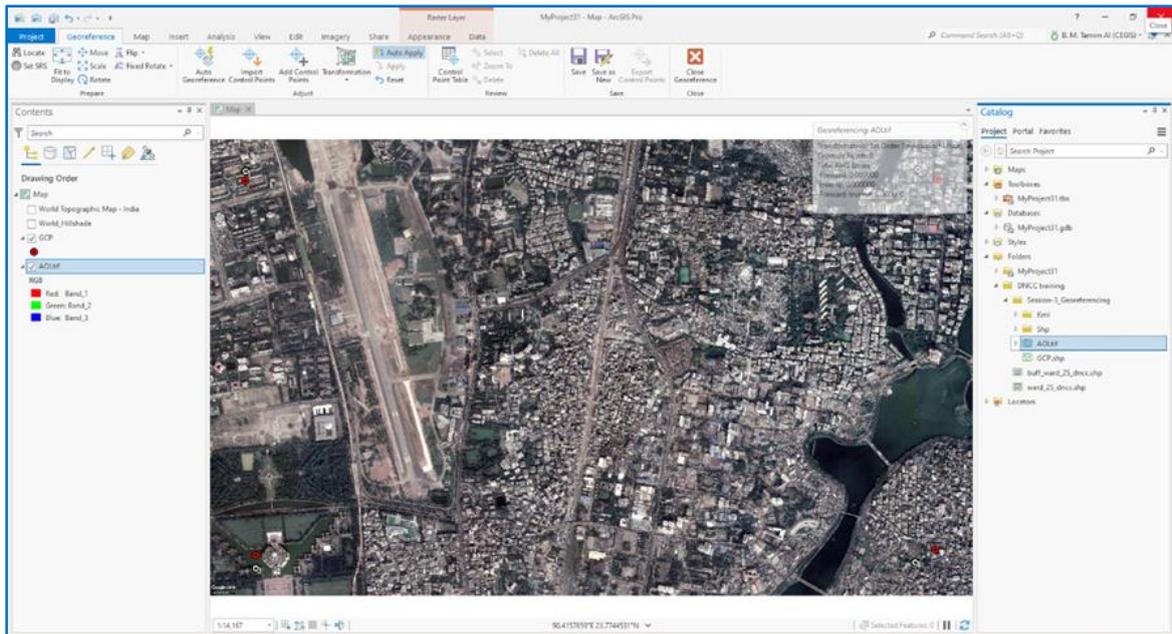
On the Georeference tab, in the Adjust group, click Add Control Points.
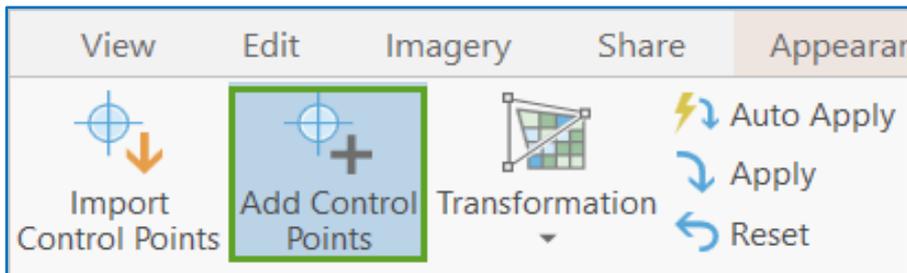
To add a control point, you'll first left click a location and then right click in the corresponding location. Provide the X, Y coordinate in Decimal Degree.

Review the control point table.

The first control point is now listed. The Source X and Source Y values represent the coordinates for the From point, and the X Map and Y Map values represent the coordinates for the To point.

	Link	Source X	Source Y	X Map	YMap	Residual X	Residual Y	Residual
☑	2	7.986411	-14.844630	89.625000	24.500000	81.638589	39.344630	90.624826

In a similar procedure add more three control points.

Apply a Transformation

In this section, the default transformation to the image based on the four control points will be applied.

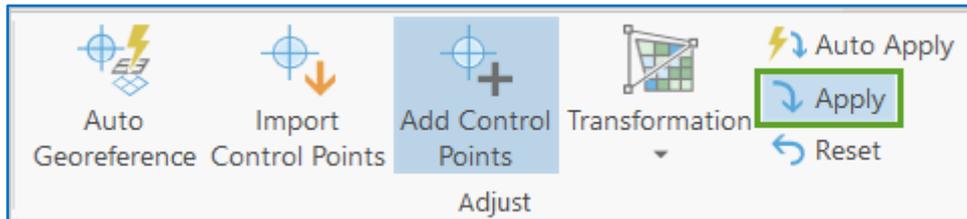1. With the mouse scroll wheel, zoom out until you can see the entire historical image.
2. On the Georeference tab, in the Adjust group, click Apply.

The source image is automatically shifted, scaled, and rotated to make every source and target control point pair coincide as much as geometrically possible.

3. If necessary, refine the adjustment by adding additional control points and clicking Apply again.
4. Review the control point table.
5. In the control point table, verify the transformation method applied is 1st Order Polynomial (Affine).

Source X	Source Y	X Map
1.722976	30.493312	89.625000
21.665050	30.500143	89.750000
21.682684	8.702835	89.750000
1.720551	8.696528	89.625000

6. In the control point table, click the 1st Order Polynomial (Affine) drop-down arrow.

There are various transformation types available in the list. You only see five of them, because other transformations require a higher number of control points to be created.

For now, you'll keep the 1st Order Polynomial (Affine) transformation.

7. In the control point table, review the individual residual values associated with each control point.

The residual value of a control point is the difference between where the source point and the target point display on the map. Residuals closer to zero are considered more accurate.

8. At the top of the map, expand and review the on-screen georeferencing details.

For each control point, the residual is the difference between where the From point displays in the map and the actual location that was specified. The total error is computed by taking the root mean square (RMS) sum of all the residuals to compute the RMS error. The value describes how accurately the selected transformation method is able to fit all of the control points to their specified location. When the error is particularly large, you can remove and add control points to adjust the error. However, a large error may also mean that the selected transformation method is unable to accurately fit the points to their specified location. However, if the points are all properly selected and a large error is reported, it typically means that a different transformation is required.

The forward residual shows you the error in the same units as the data frame spatial reference. The inverse residual shows you the error in the pixel units. The forward-inverse residual is a measure of how close your accuracy is, measured in pixels. Residuals closer to zero are considered more accurate.

9. In the map view, zoom out to display the full image.

10. Review the transformed image. If the result is reasonably satisfactory, we can save it.

11. On the Georeference tab, in the Save group, Click Save.
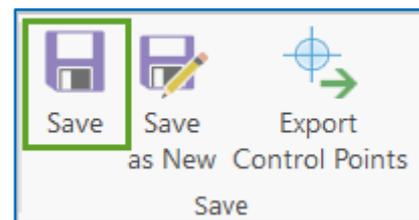
Saving the image writes the georeferencing information in an associated auxiliary file. This information includes where the image should be positioned and how much it should be shifted, scaled, and rotated.

12. On the Quick Access Toolbar, click Save to save the project.

References

❏ Datums, Ellipsoids, Grids and Grid Reference Systems. Washington, D.C.: NIMA,1990. Technical Manual 8358.1, www.nima.mil/GandG/pubs.html.

❏ Department of Defense World Geodetic System 1984. Third Edition. Washington,D.C.: NIMA, 1997. Technical Report 8350.2, www.nima.mil/GandG/pubs.html.

❏ ESRI, 2023. GIS Dictionary. https://support.esri.com/en-us/gis-dictionary/coordinate-system

❏ European Petroleum Survey Group, EPSG Geodesy Parameters, 2000. v4.5. www.ihsenergy.com/?epsg/epsg.html.

❏ Snyder, John P., and Philip M. Voxland, An Album of Map Projections. USGS Professional Paper 1453. Washington, D.C.: USGS, 1989.

Creating & Editing Shapefiles

Mustafa Atikul Mazid,
Remote Sensing Analyst, Crop Zoning Project
Bangladesh Agricultural Research Council
Email: tushar060401@gmail.com

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.
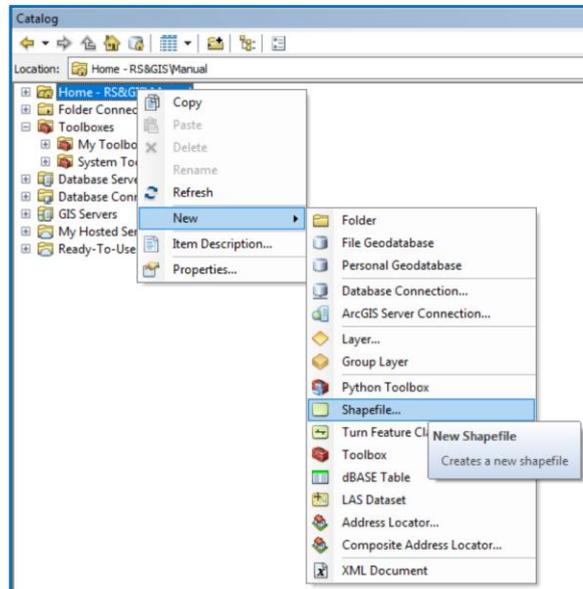
The new shapefile appears in the folder's contents.

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. Templatesalso have a name, description, and tags that help you to find and organize them. If templatesare 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 thetoolbar, but additional ones are available on the Snapping menu.
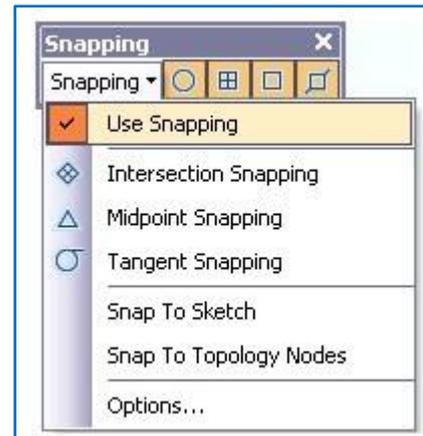

Figure: Snapping tools

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.
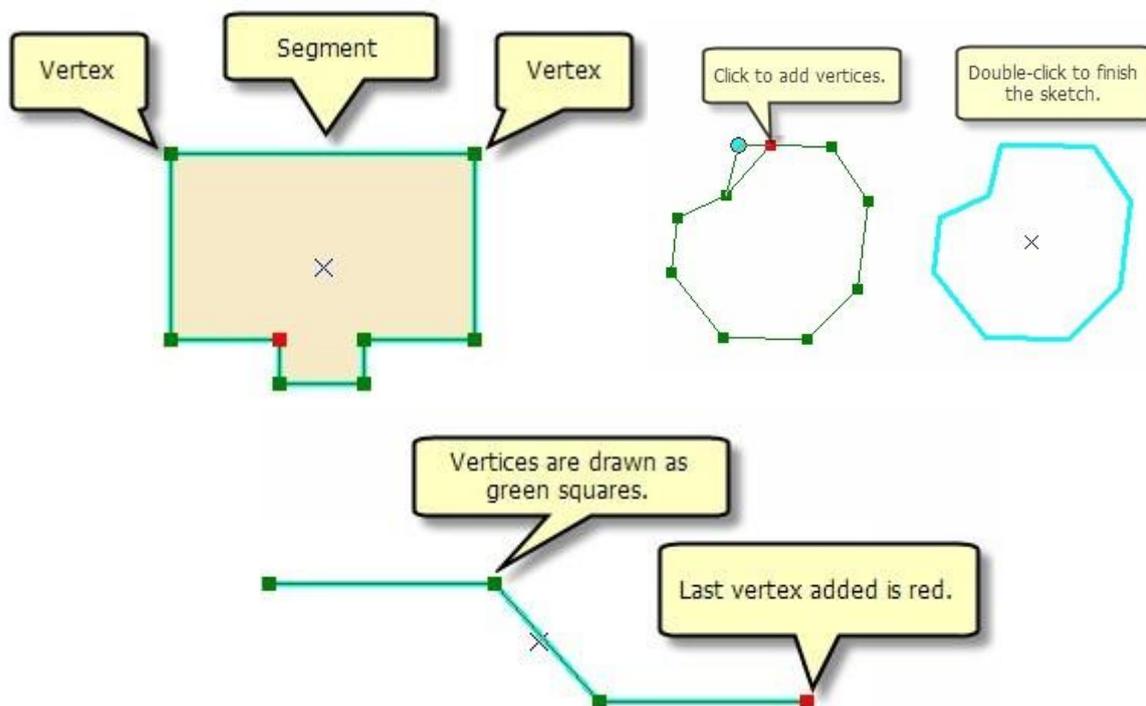

Figure: Creation of points, line polygon

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 not formally associated with features in the geodatabase. For example, you might have a piece of standard annotation that represents a mountain range, an ocean, or an administrative boundary-the annotation simply marks the general area on the map.

Another kind of annotation, feature-linked annotation, is associated with the feature it is describing through a relationship class. The text reflects the value of a field or fields from the feature to which it is linked. You might use feature-linked annotation to identify features suchas parcels, streets, rivers, roads, or cities. With feature-linked annotation, as you create parcelsor street features, for example, using the editing tools in ArcMap, annotation is created automatically.
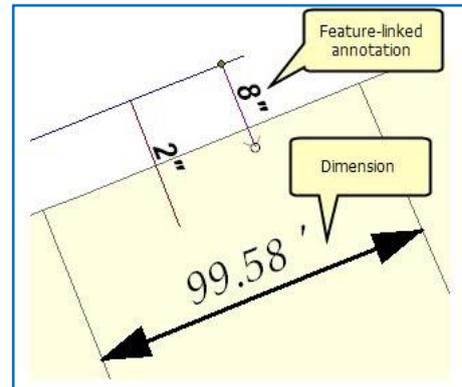
Defining New Types of Features to Create

Sometimes, you may want to create features of a certain type in an existing layer, but the layer is not set up to capture those features. For example, you want to add features to a roads layer to represent an unpaved road, but you currently 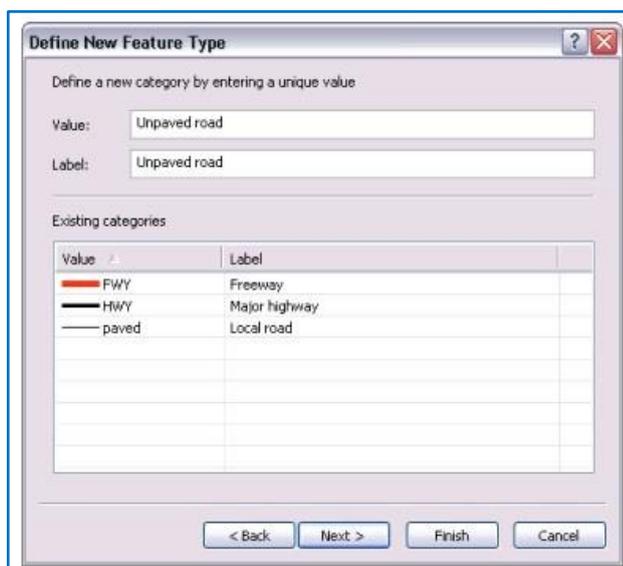only have categories in your data for freeway, major highway, and local road. Through a wizard, you can define everything about the unpavedroad category at one time—making it easy to prepare your data to display and store the new types of features. ArcMap automatically adds a symbol for the new category, any required geodatabase information (such as subtype value or coded domain value) for that layer, and a feature template to use when creating an unpaved road. The wizard saves you from having to stop your work to open multiple dialog boxes to set up the data on your own.

Figure: Define new feature type wizard

Editing existing features

Once you have created features, you can also edit their shapes with the tools on the Editor Toolbar. For example, to split a polygon into two polygons, select the feature, click the Cut Polygons tool on the Editor Toolbar, then draw a line where you want to split the feature. To draw in a new shape for a line or polygon, select it, click the Reshape Feature tool on the EditorToolbar, and sketch in how you want the feature to appear.
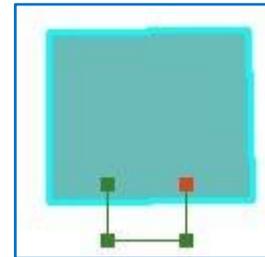
Advanced Editing

To use additional or more specialized editing tools, you must add other editing toolbars to ArcMap. These include Advanced Editing.

Working with Attribute Table

Mustafa Atikul Mazid,
Remote Sensing Analyst, Crop Zoning Project
Bangladesh Agricultural Research Council
Email: tushar060401@gmail.com

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.
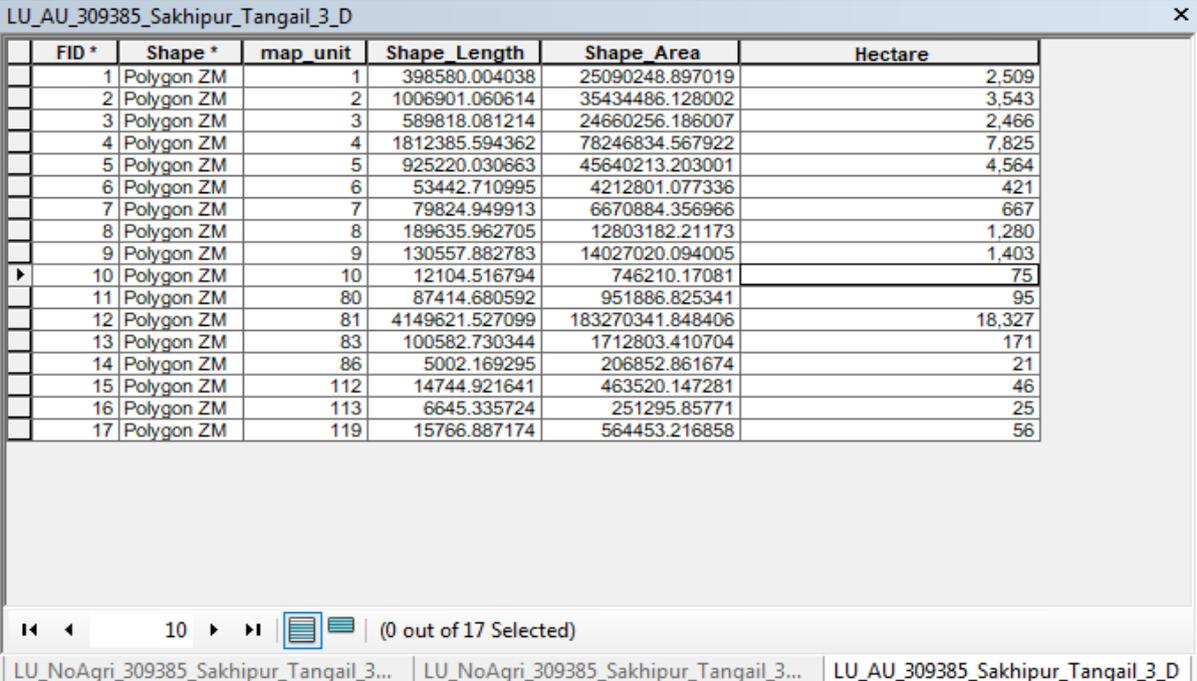
FID *	Shape *	map_unit	Shape_Length	Shape_Area	Hectare
1	Polygon ZM	1	398580.004038	25090248.897019	2,509
2	Polygon ZM	2	1006901.060614	35434486.128002	3,543
3	Polygon ZM	3	589818.081214	24660256.186007	2,466
4	Polygon ZM	4	1812385.594362	78246834.567922	7,825
5	Polygon ZM	5	925220.030663	45640213.203001	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

LU_AU_309385_Sakhipur_Tangail_3_D

10   (0 out of 17 Selected)

LU_NoAgri_309385_Sakhipur_Tangail_3...   LU_NoAgri_309385_Sakhipur_Tangail_3...   LU_AU_309385_Sakhipur_Tangail_3_D

Figure: Attribute window and 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.

Table

Parcels

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

◄◄ ◄ 1487 ► ►◄ (2012 out of 3523 Selected)

Parcels

Data Queries in GIS

Abid Kamal
GIS Analyst, Crop Zoning Project
Bangladesh Agricultural Research Council
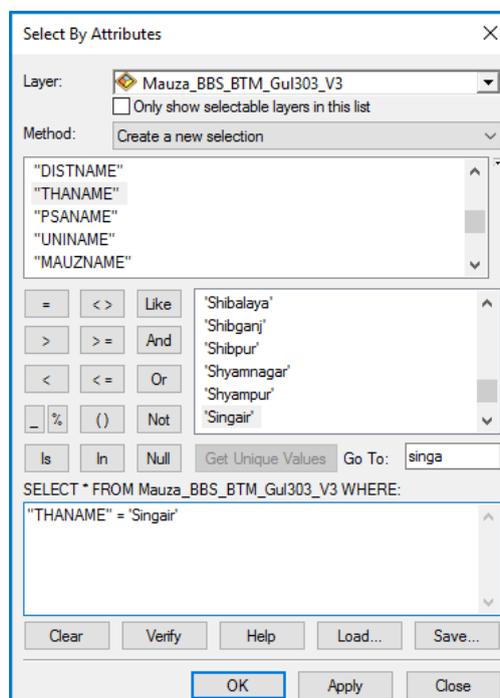Email: geoabid38@gmail.com

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

1. **Open Attribute Table**
   - ❖ Right-click the layer > Open Attribute Table.
2. **Select by Attributes**
   - ❖ Click `Table Options` (top left) > `Select by Attributes`.
3. **Build Your Query**
   - ❖ Double-click a field, select an operator, and type your value.
   - ❖ Example:
     `City = 'Dhaka' AND Population > 1000000`
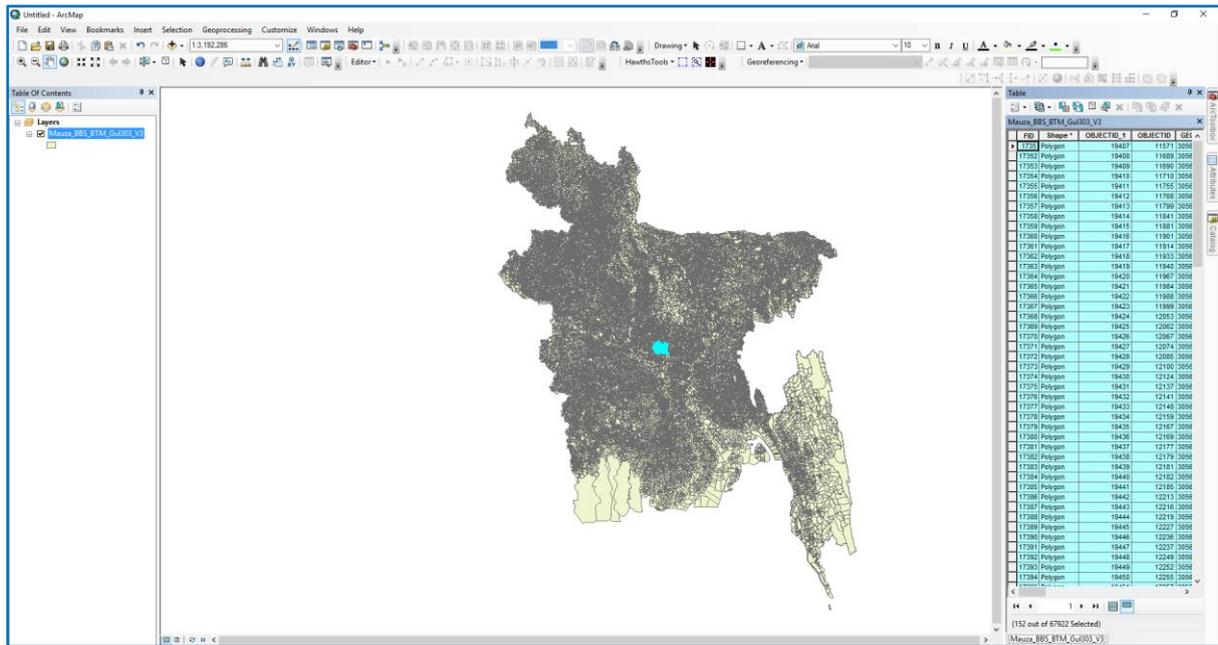
4. **Apply the Query**
   ❖ Click **Apply** or **OK** to see selected features highlighted.

Data Joining: Spatial Join and Attribute Join

Abid Kamal
GIS Analyst, Crop Zoning Project
Bangladesh Agricultural Research Council
Email: geoabid38@gmail.com

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:
   - Choose **Join attributes from a table**.
   - Select the field in the layer that matches the field in the table.
   - Browse and select the table to join.
   - Choose the matching field in the table.
4. Click **OK**. The attributes from the table are now associated with the spatial features.
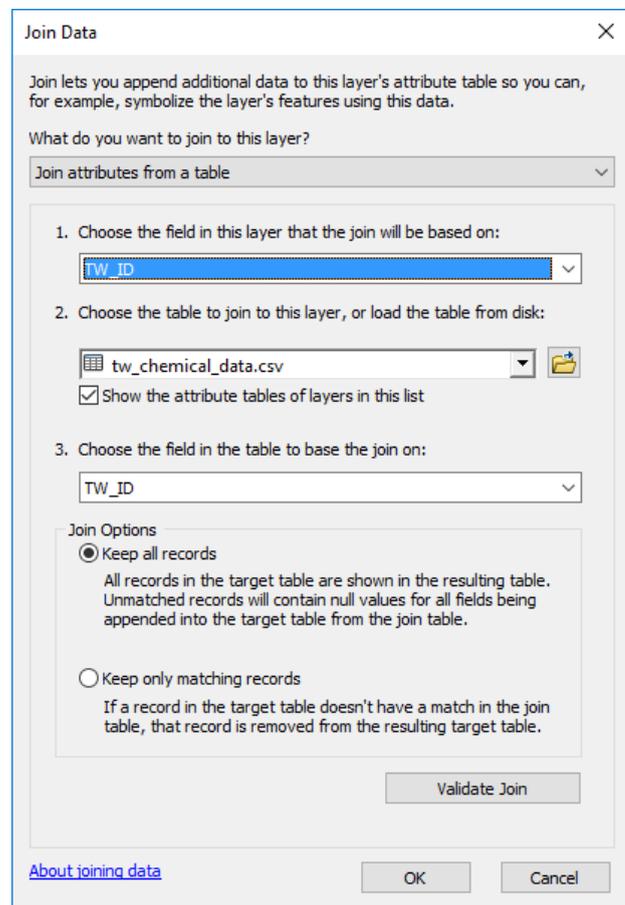
2. Spatial Join

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

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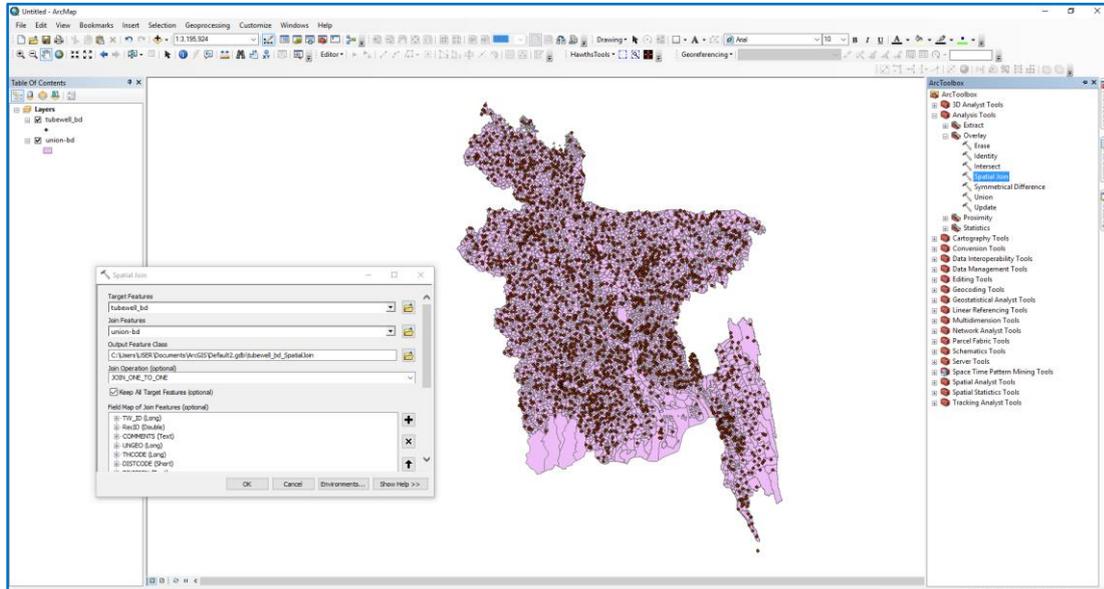
Steps:

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

4. Click **OK**. A new layer is created with combined attributes.

Basic Geoprocessing Tools

Abid Kamal
GIS Analyst, Crop Zoning Project
Bangladesh Agricultural Research Council
Email: geoabid38@gmail.com

Step 1: Start ArcMap

Step 2: Add data to ArcMap

       Add **Road_bd.shp**
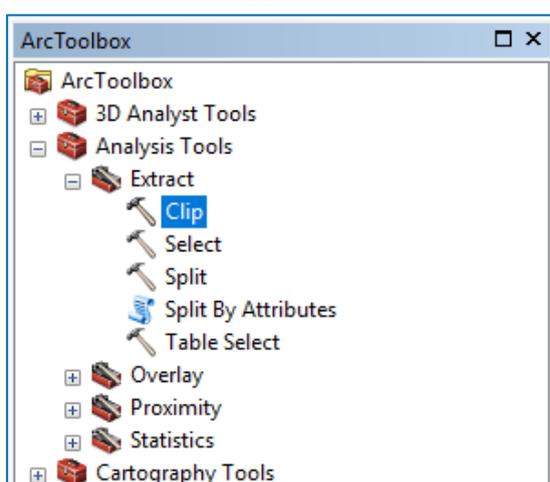   Add **Barishal.shp**

Step 3: Clip Operation
       Road Clip by Barishal District
       Click on **ArcToolbox** button
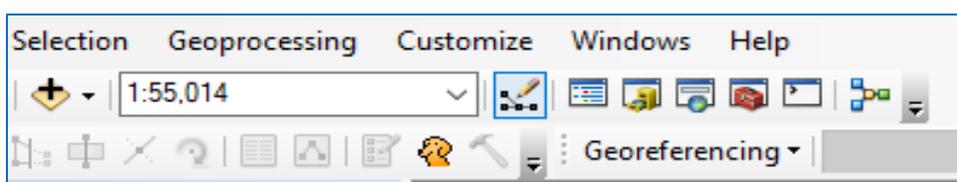
ArcToolbox will appear.

From ArcToolbox, Expand **Analysis Tools > Extract >** Double-click on **Clip**
Clip Wizard will be displayed.
Select as follows:
       Input features: Road_bd.shp
       Clip Features: Barishal.shp
       Output Feature Class: Road_Barishal.shp

       Click OK

Step 4: Buffer Operation

Click on **Geoprocessing** menu > **Buffer**
Buffer window will be opened.
Select as follows:
 Input features: Road_Barishal.shp
 Output Feature Class: Road_buff
 Linear unit: 40 ft
 Dissolve type: All

Click OK

Step 5: 'Dissolve Feature' Operation based on an Attributes

Add **mauza_Laksam_upz** (mauza boundary of Laksam upazila)
Right-Click on **mauza_Laksam_upz > Zoom to Layer**
Click on **Geoprocessing** menu > **Dissolve**
Dissolve window will be opened.

Select as follows:
 Output Feature Class: Laksam_unions
 Check on UNINAME as Dissolve Fields

Click OK

Step 6: Intersect Operation

Click on **Insert** Menu > **Data Frame** to create a new data frame

A new blank data frame will be appeared.
Add **Union_Barishal.shp**
Add **Road_Barishal.shp**

Click on **Geoprocessing** menu > **Intersect**
Intersect window will be opened.
Select **Union_Barishal** and **Road_Barishal** as input features

Click OK

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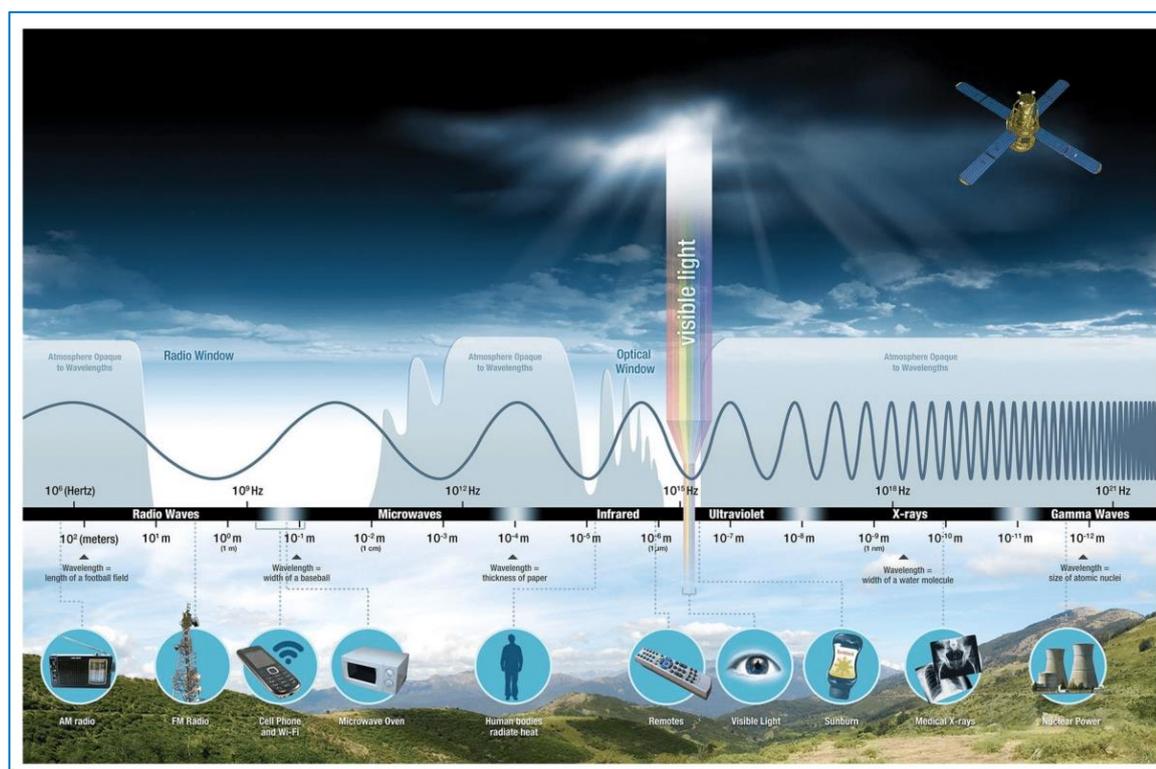
Remote sensing relies on electromagnetic radiation (EMR), which is emitted or reflected by objects. The EM spectrum includes various wavelengths from gamma rays to radio waves. Different materials reflect, absorb, or emit EM radiation uniquely, allowing remote sensors to identify and analyze them through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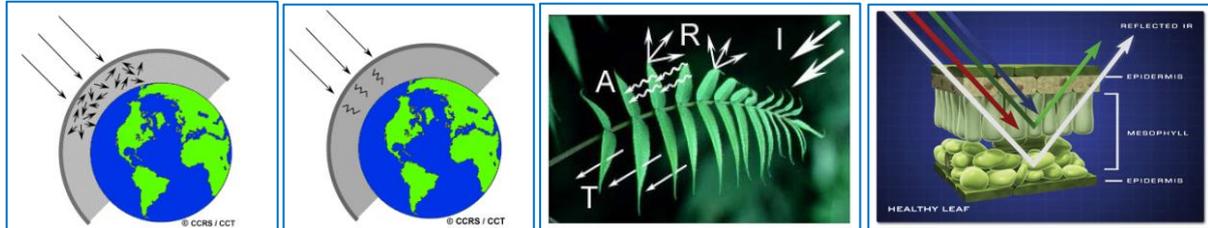
4. Remote Sensing Systems: Passive and Active

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).
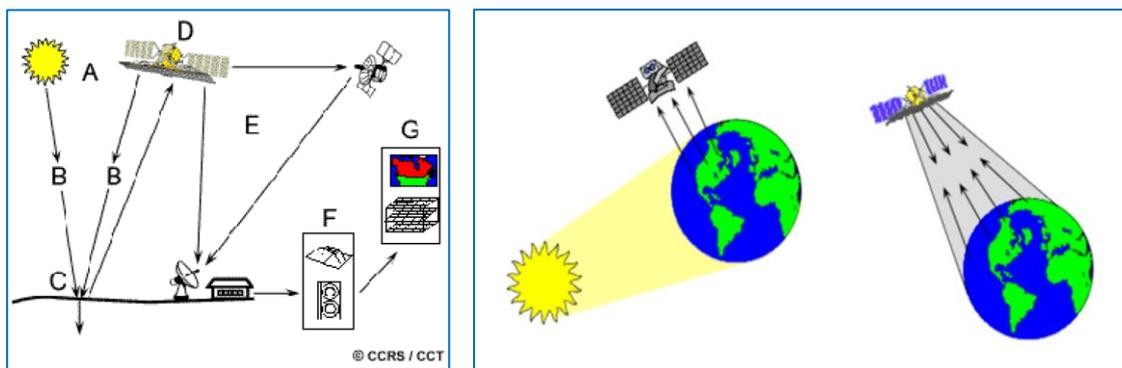
5. Types of Resolutions

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.

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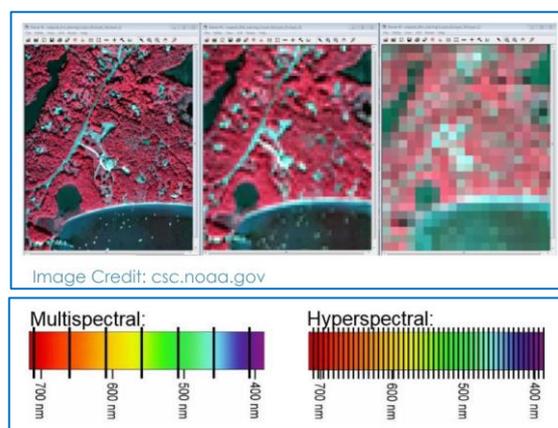
Radiometric: Sensitivity to differences in signal strength. Represented as how many bits are used to represent a reflectance value.

2-bit (4 values)   4-bit (16 values)   8-bit (up to 256 values)
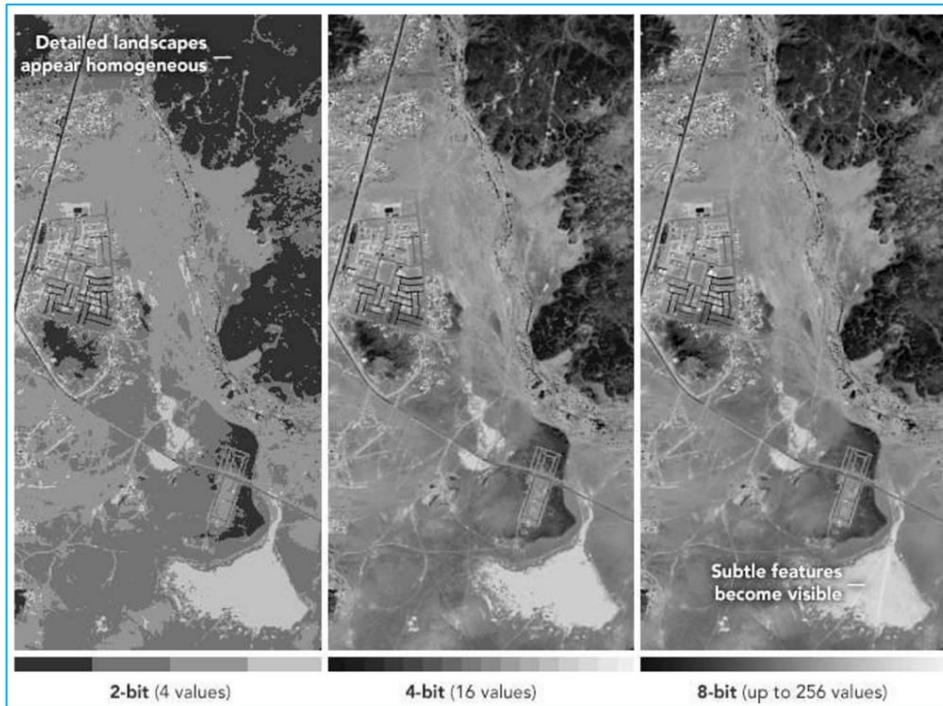
6. Satellites, Orbits, and Sensors

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.

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
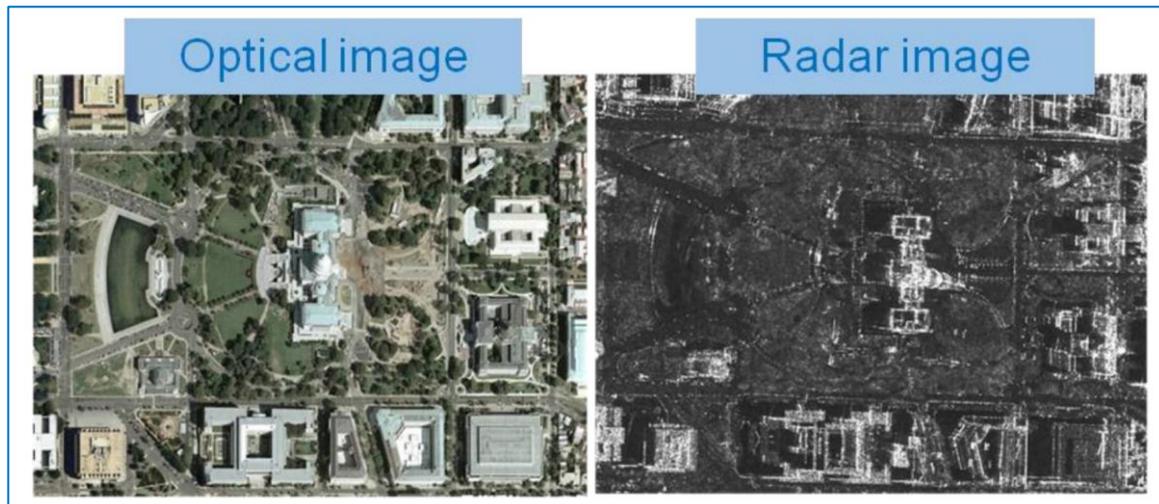
Feature	Optical Imagery	Radar Imagery (SAR)
Sensor Type	Passive (detects reflected/emitted light)	Active (emits and receives microwaves)
Illumination	Sun (mostly), thermal emission	Self-illuminated (microwaves)
Weather	Affected by clouds, fog, smoke	Can penetrate clouds, fog, smoke
Day/Night	Primarily 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.

NDVI = (NIR - Red) / (NIR + Red)

NDWI (Common) = (NIR - SWIR) / (NIR + SWIR)

NDSI = (Green - SWIR) / (Green + SWIR)

EVI = G * ((NIR - Red) / (NIR + C1 * Red - C2 * 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
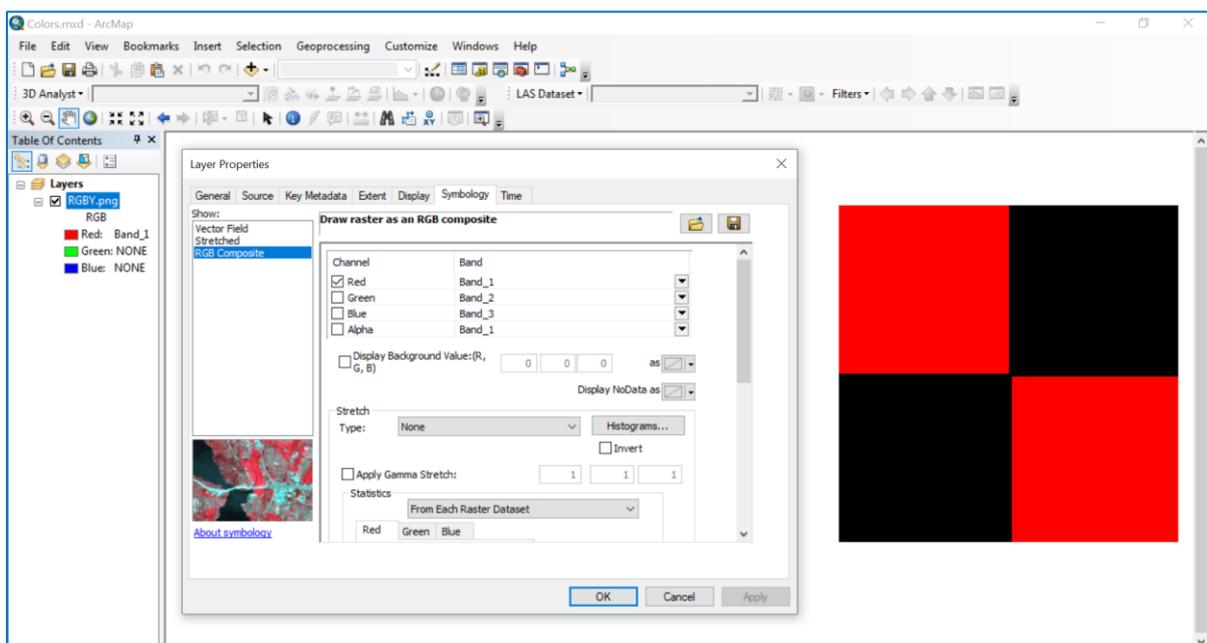- ❖ Tutorial by TELECAN on Fundamentals of Remote Sensing

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.
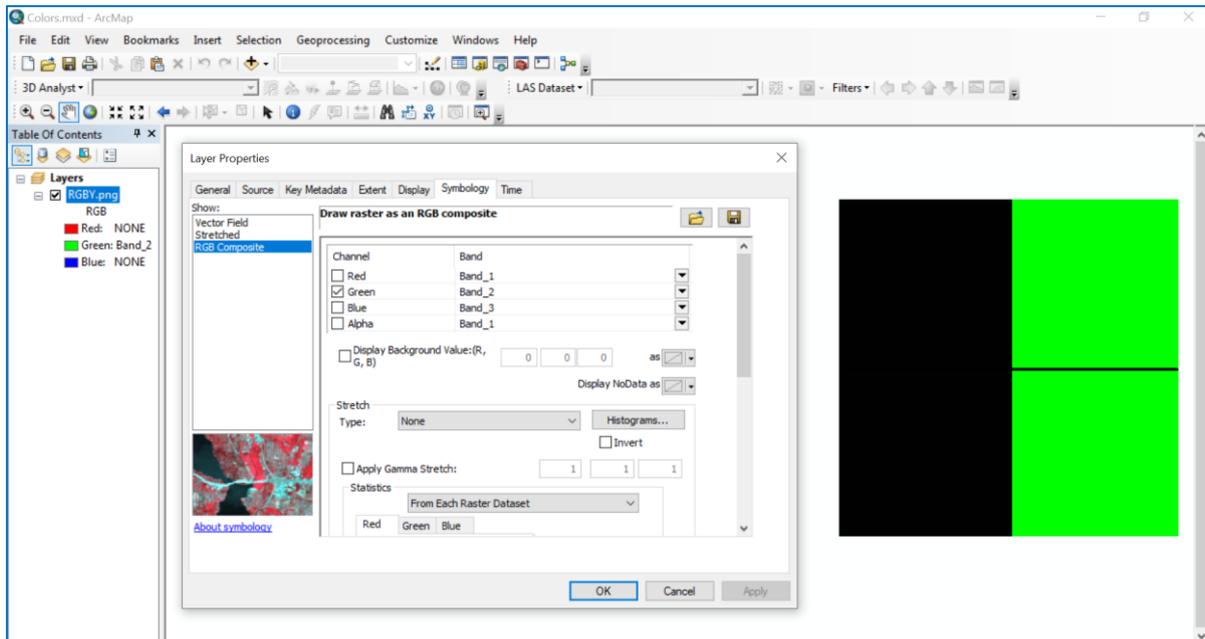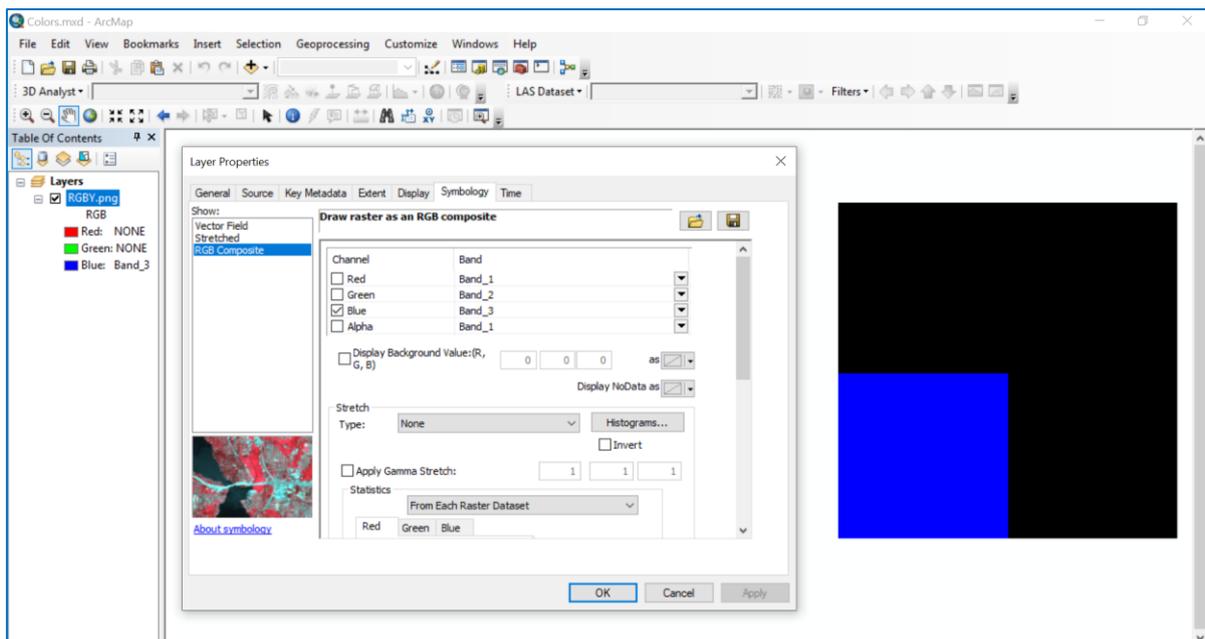
All 3 Channels Composite
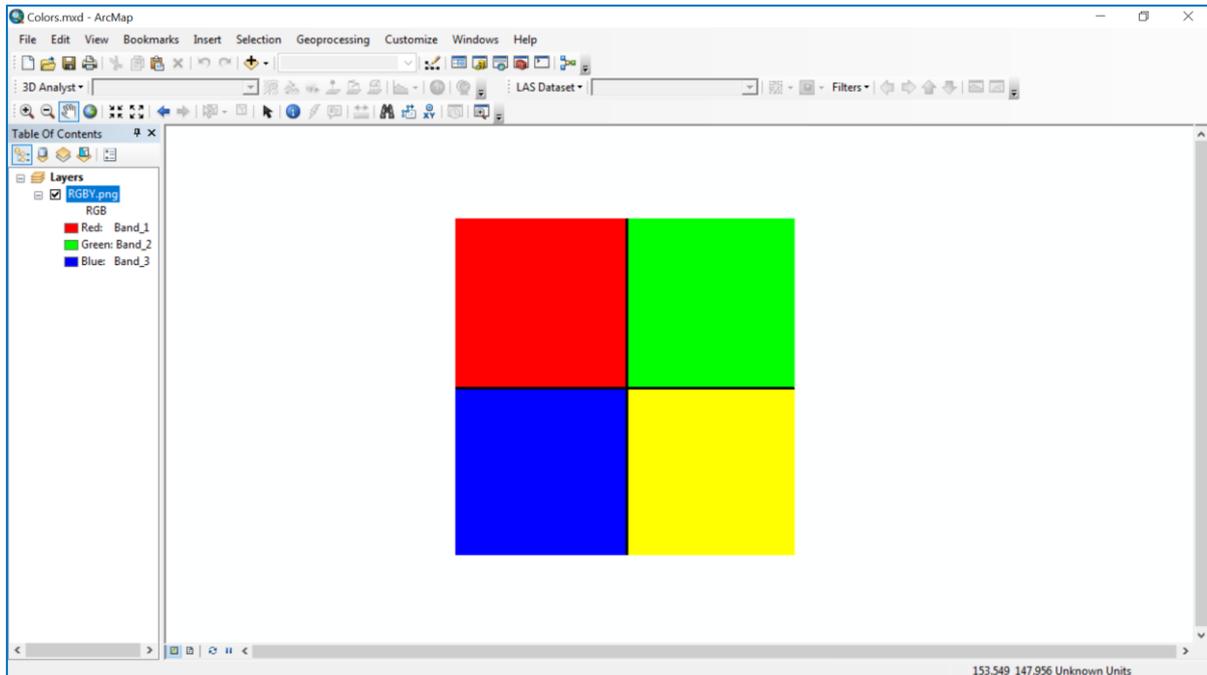
Only Red Channel

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.
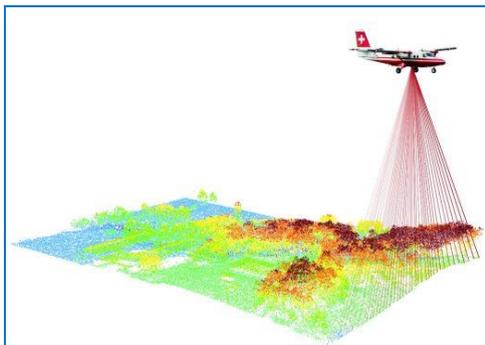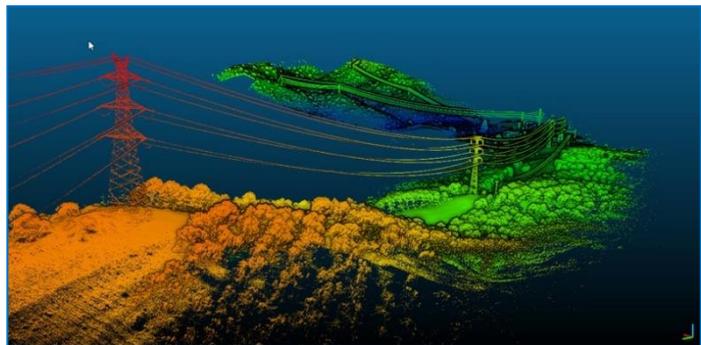

Figure-1: LiDAR Data Acquisition

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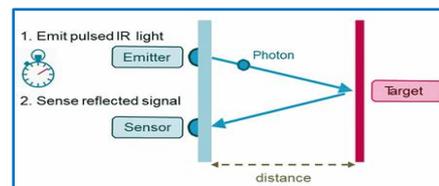c is the speed of light (3×10^8 m/s)
t is the pulse travel time

Figure-3: LiDAR Measurement

Types of LiDAR

☐ **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.

Figure-4: Types of LiDAR

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
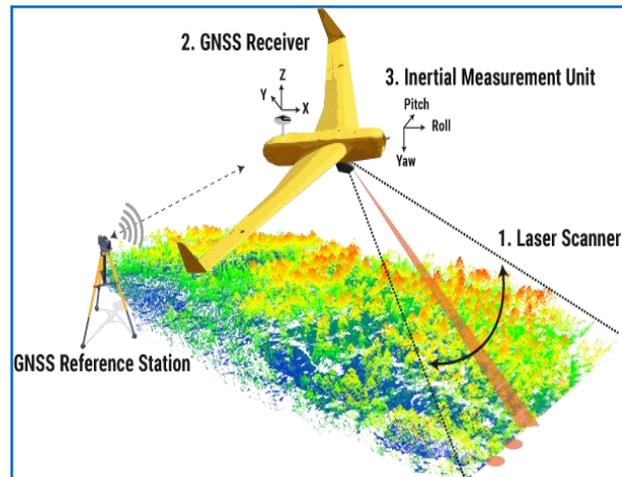- *Optical/infra-red camera*
  Optional, for photograph or video capture

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

Mandlburger, G., et al. (2020). Topographic LiDAR: Data, processing, and applications. *Remote Sensing, 12*(20), 3340. doi: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

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

Applications of LiDAR Remote Sensing in Natural Resources Management

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

1. Introduction to LiDAR Remote Sensing

LiDAR (Light Detection and Ranging) 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**
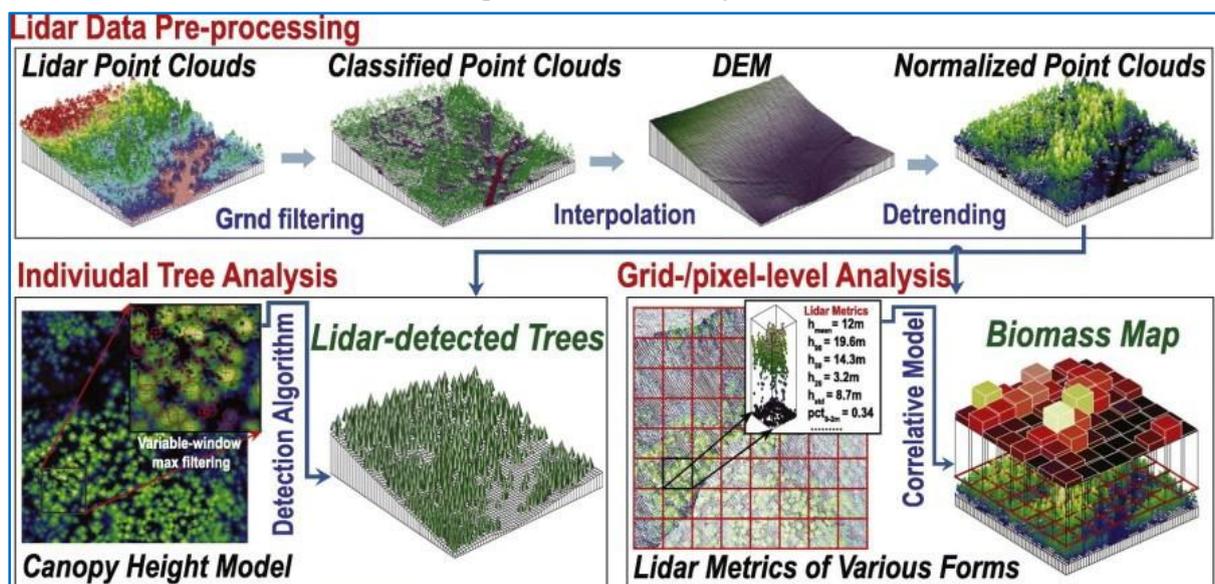 Tracks forest loss and its impact on biodiversity.

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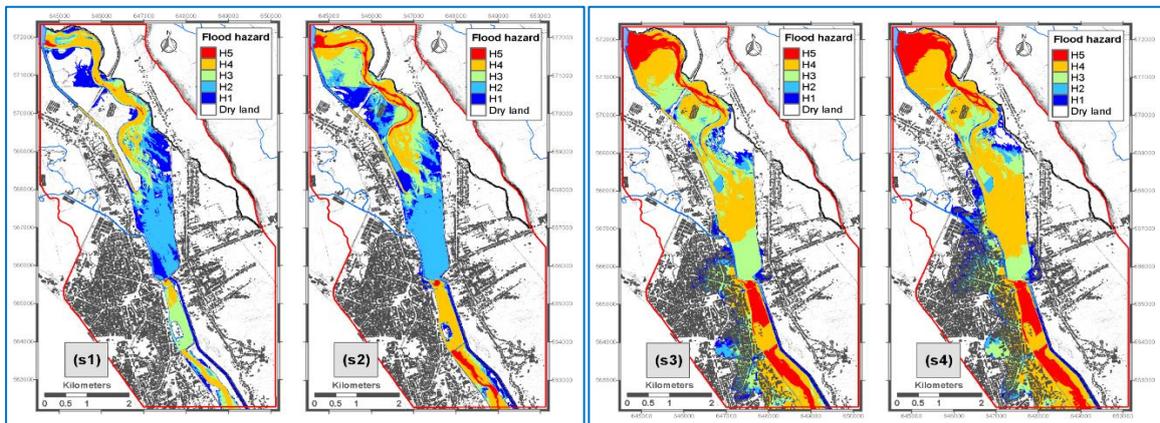
Figure-2: Urban Flood Hazard Maps, doi: https://doi.org/10.3390/w11091832

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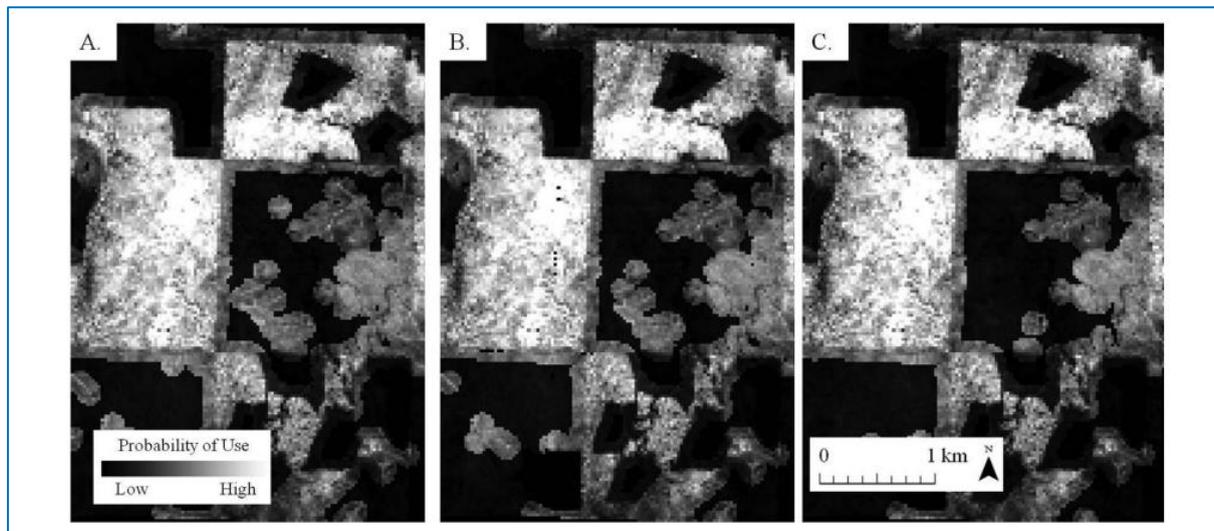
Figure-4: Habitat suitability maps for red tree voles derived from airborne LiDAR at (A) full (10.36 pulses/m2) and reduced point densities of (B) 4 points/m2 and (C) 1 point/m2 in southwestern Oregon, USA, doi: 10.1002/jwmg.21173

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, Sentinel-2, 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
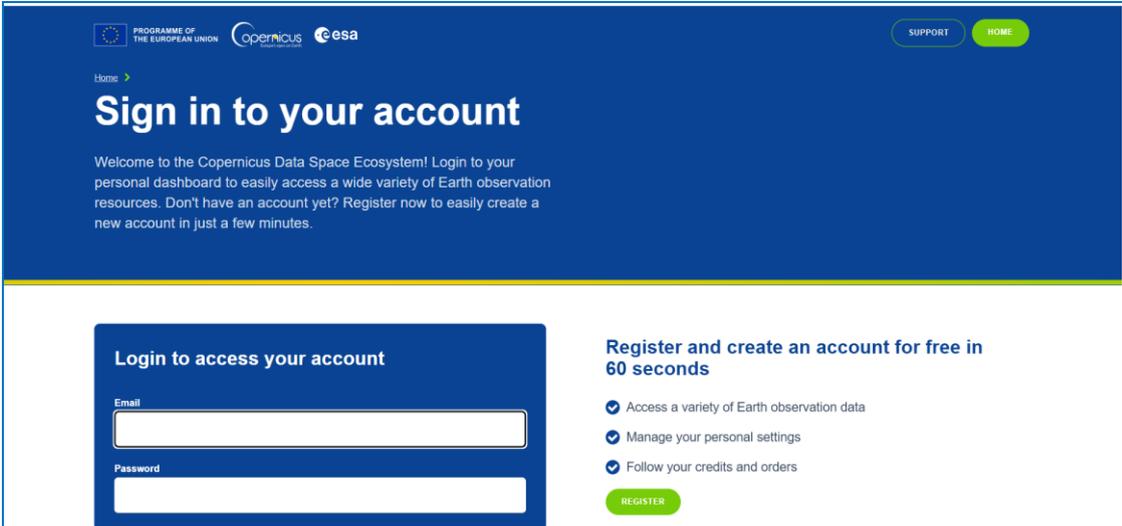   - **Use cases:** Agriculture, humanitarian response, ML models
   - **Access:** https://radiant.earth/

Steps to download sentinel 2 data from Copernicus Sentinel Hub

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)
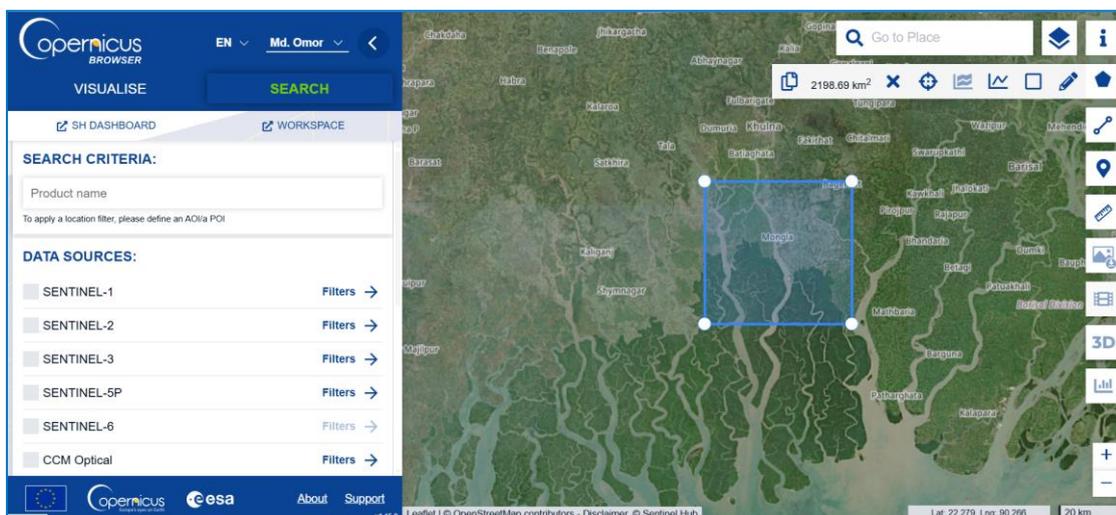
Open EO Browser:

Create a (Free) Account:
   - Click "Log in" or "Sign up" (free for public and research use).
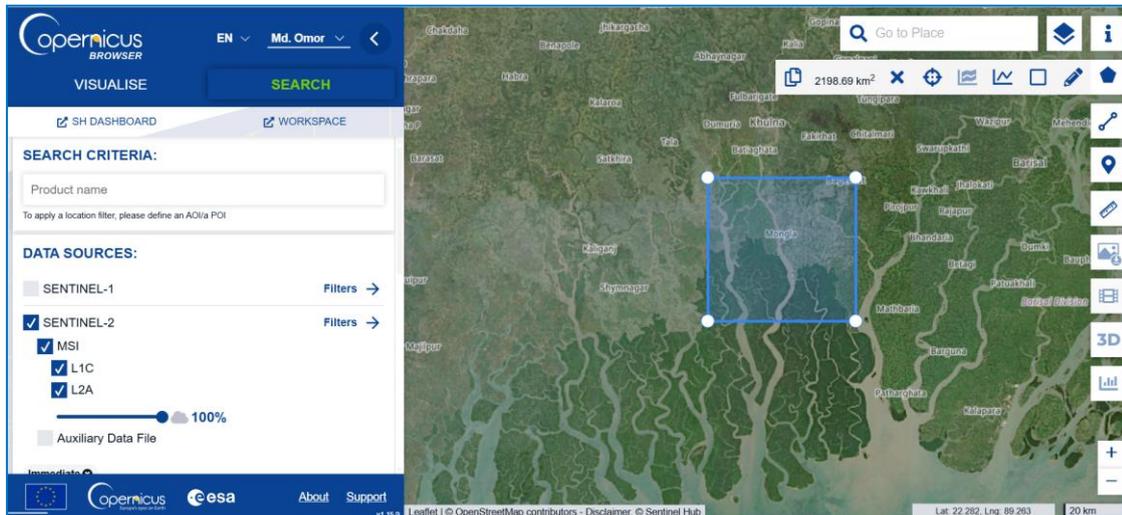   - You need an account to download high-resolution imagery.

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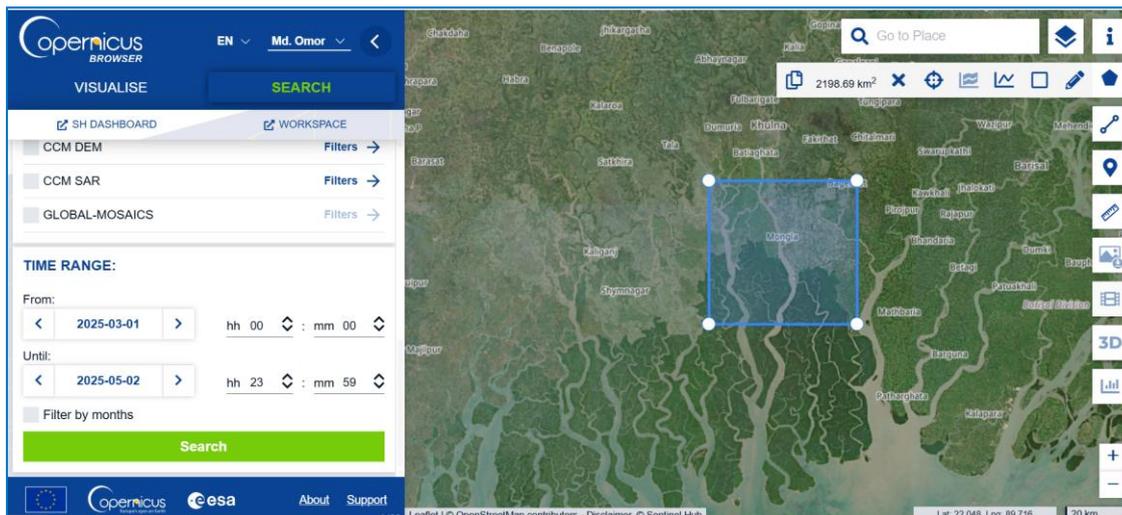   - Use the search bar or draw a polygon/rectangle on the map to define your area.

Select Satellite and Data Source:

- Choose Sentinel-2 L1C (Top-of-atmosphere reflectance)

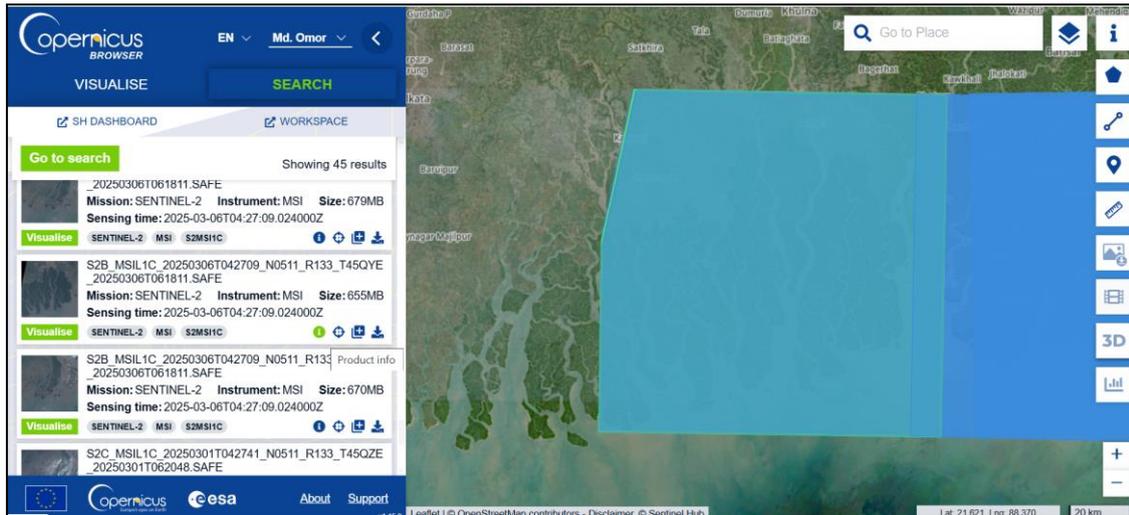- Or Sentinel-2 L2A (Surface reflectance, atmospherically corrected)

Choose Time Range:

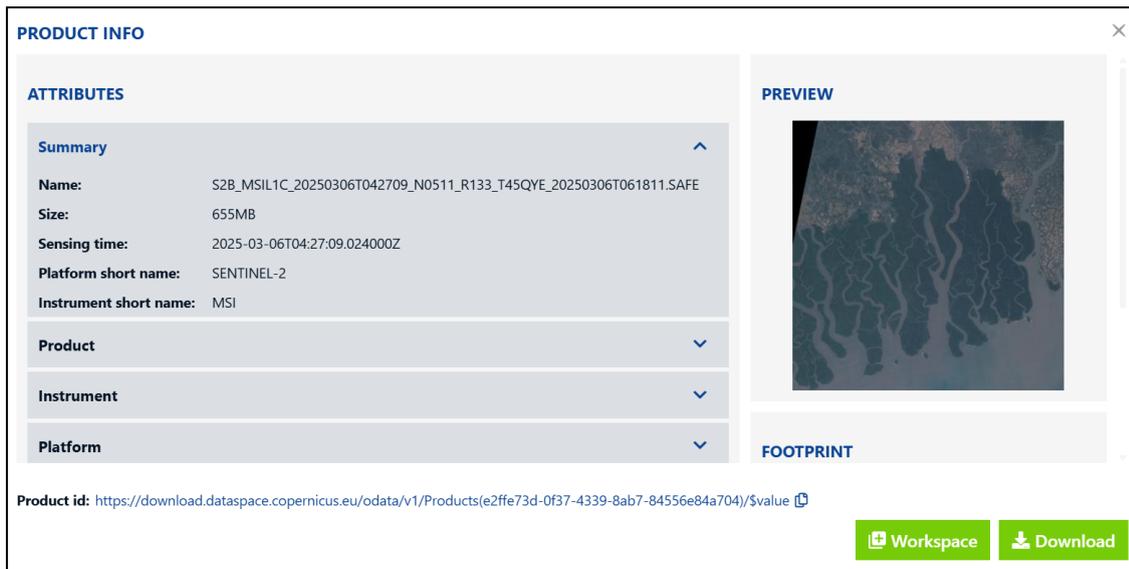- Select a date range in the top-left panel to filter available scenes.

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)

Layer Stack/Composite Bands of Satellite Image

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

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.
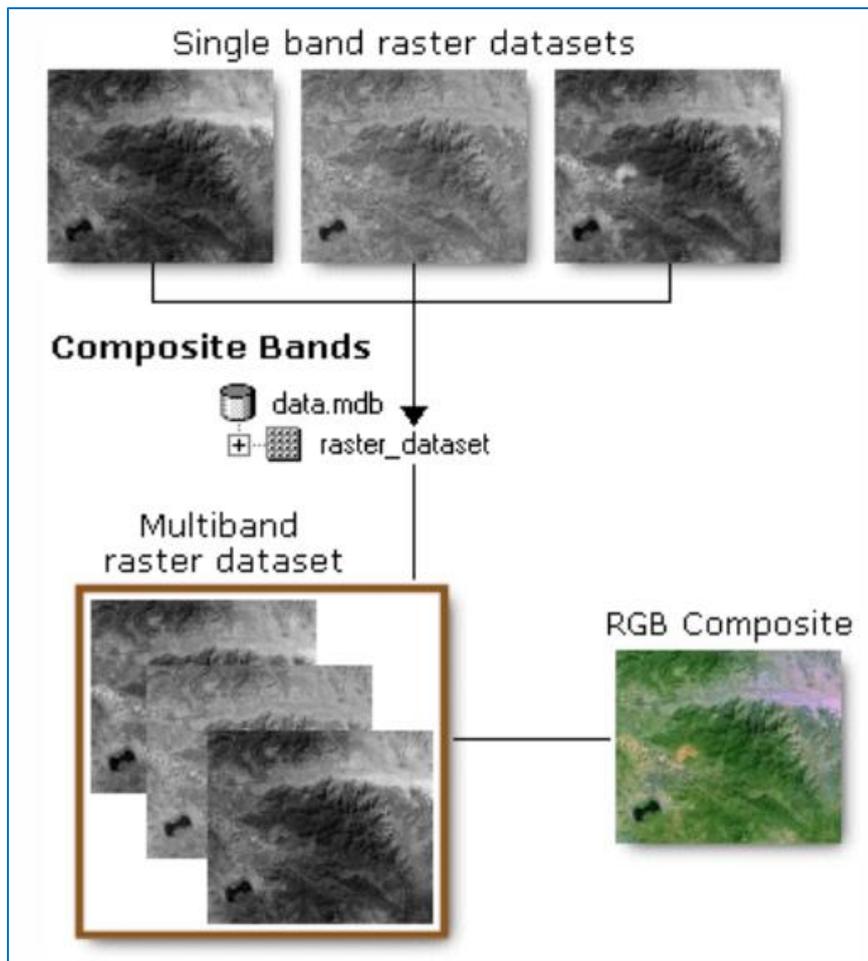
Source: ESRI

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.
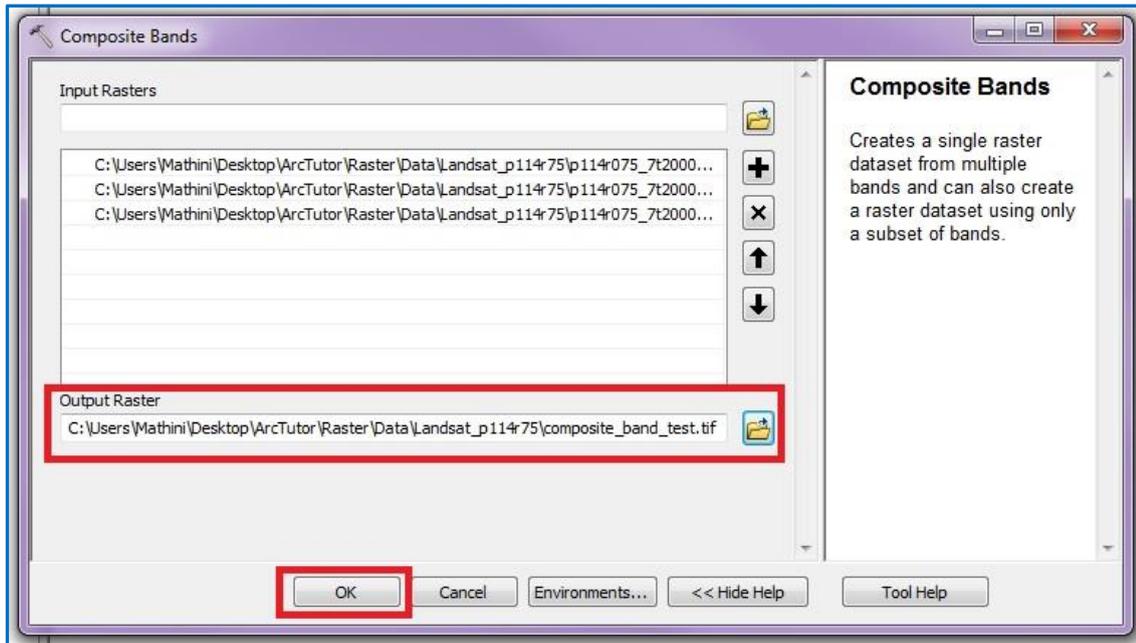
Option A:

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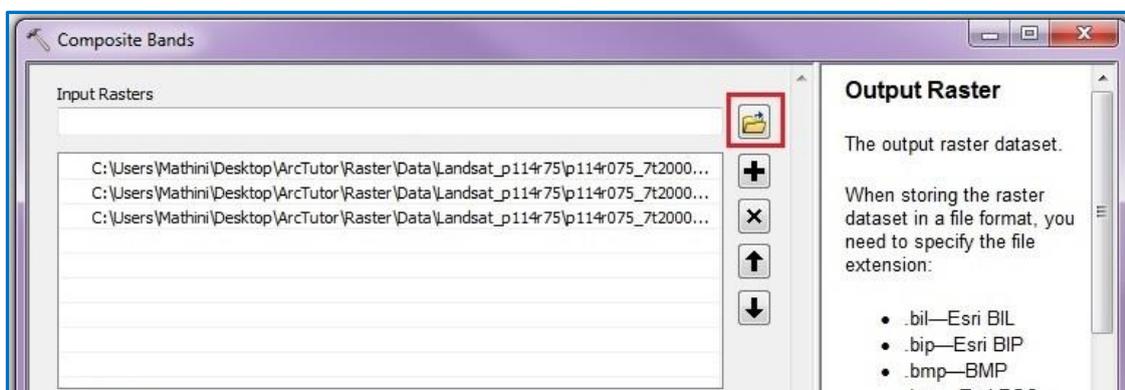
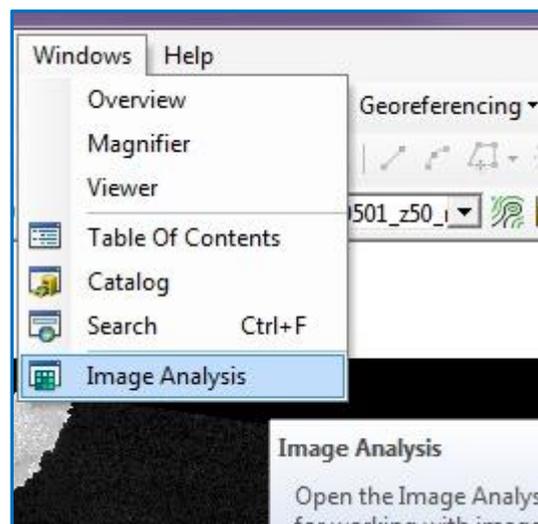3. Specify the name and location of the output raster, and click OK.

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.
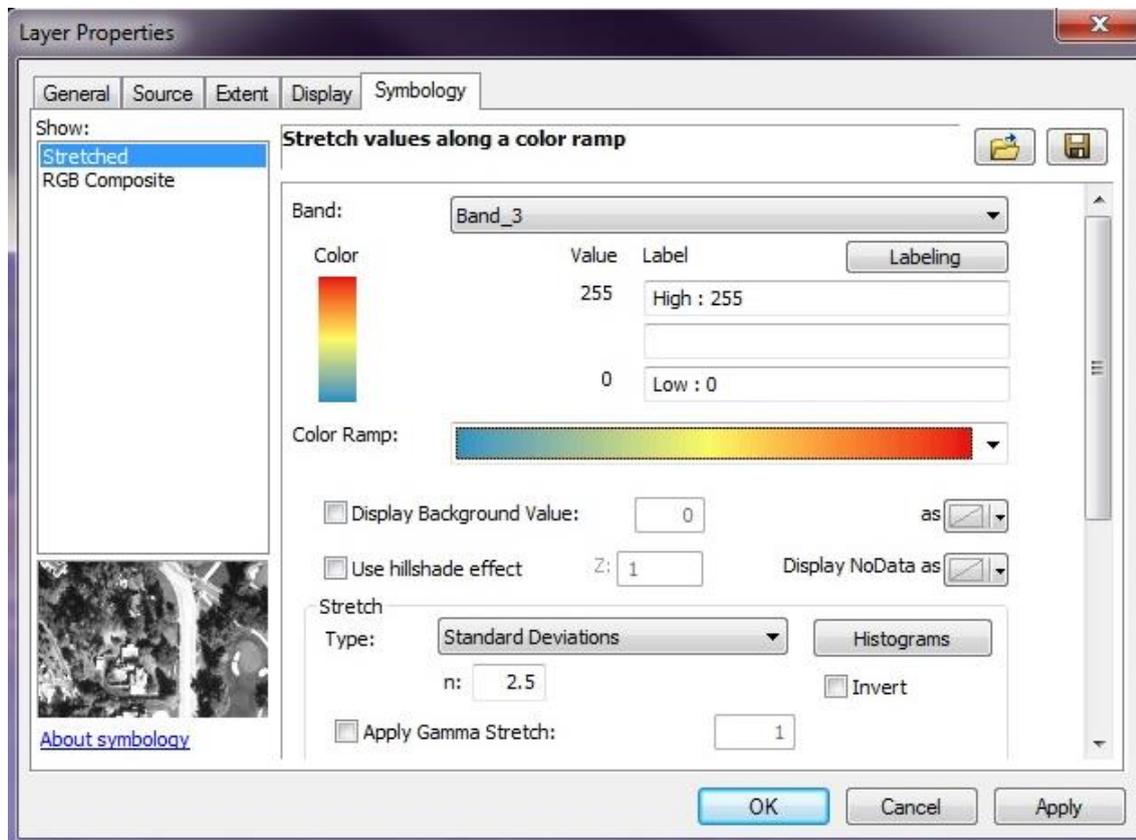
Satellite Image Processing

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

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.
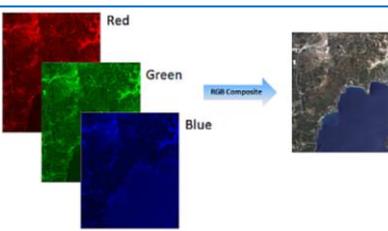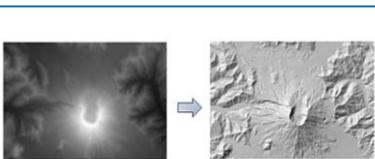

Basemaps are fast-drawing maps used as background to support data and provide a geographic reference. This example is one of numerous image basemaps on ArcGIS Online that you can add directly to ArcMap.

Georeferenced images are often used in editing as a background for digitizing. You can digitize a watershed boundary, streets, lakes, or other features in an image. Here, an image is being used for heads-up digitizing.
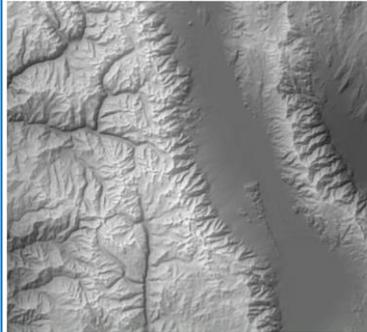
Imagery is rich in information. Some images can be used for visual analysis or to enhance an area to see different features (such as elevation, sun exposure, or visibility). Here, several images were combined for visual analysis. This hillshade gives a 3D appearance to the elevation raster.
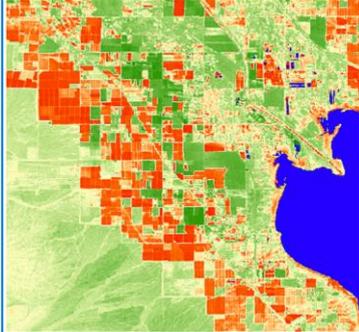
Using advanced image-processing functions such as normalized difference vegetation index (NDVI), you can show aspects of the land that would otherwise go unnoticed. This image shows the Salton Sea and the surrounding vegetation. This raster has been processed to show vegetation on the surface.
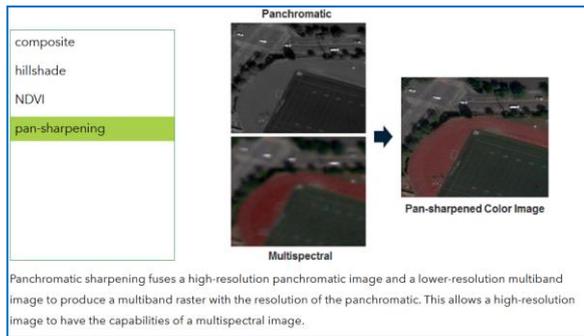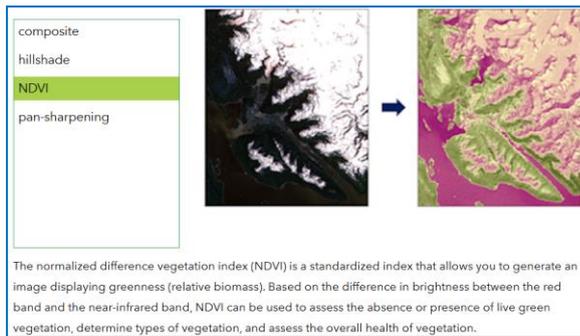
What is image processing?

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.


Images can be enhanced for visual interpretation and adjusted as needed for analysis.
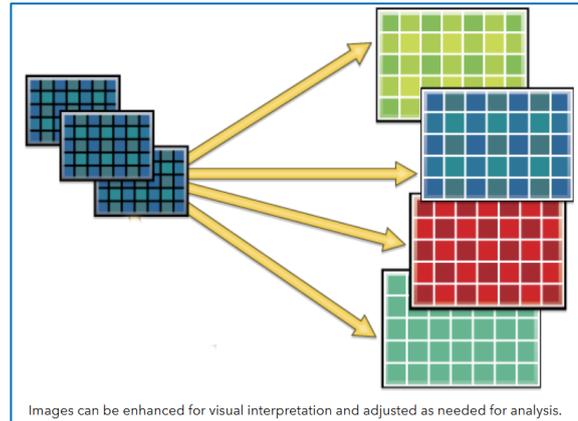
Common imagery types used in processing

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.
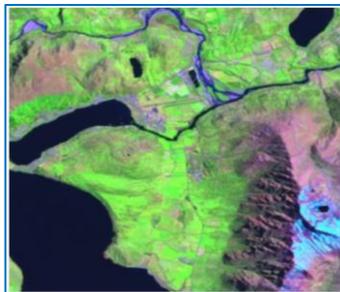
Satellite images often consist of multiple spectral bands, some of which are invisible (such as infrared). In this Landsat 7 image, bands 5, 4, and 1 are represented. A Landsat is an earth-orbiting satellite that gathers imagery for land-use inventory, geological exploration, crop assessment, and similar activities. Satellite images can be subjected to a variety of image-processing functions (pan-sharpening, NDVI, and composite etc.).
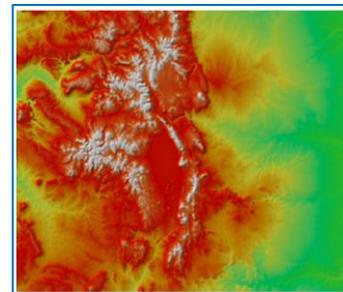
Elevation data represents the ground (bare earth) or surface of the earth (including buildings and other structures). This image is a digital elevation model (DEM) representing the earth's surface. A common image-processing function applied to elevation data is hillshade. Here, the result is a tinted 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.
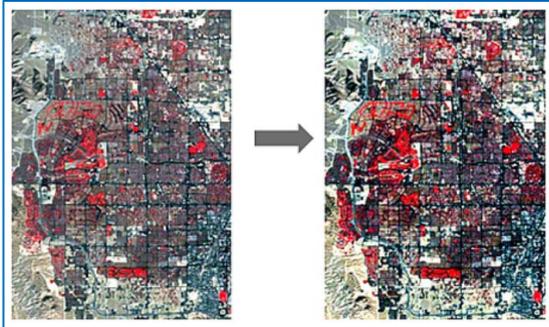
The contrast slider adjusts the displayed contrast characteristics of the selected image. The image on the right has been enhanced to increase contrast.
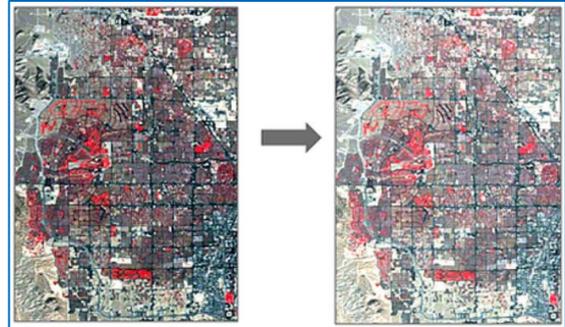

The brightness slider adjusts the displayed brightness characteristics of the selected image. The image on the right has been enhanced to increase brightness.
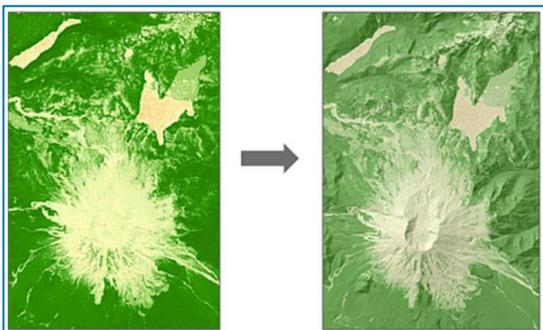

The transparency slider adjusts the transparency of the selected image, allowing for visualization of data under the image. The image on the right has been made partially transparent to allow the hillshade image (another image below the green image) to show through.


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.
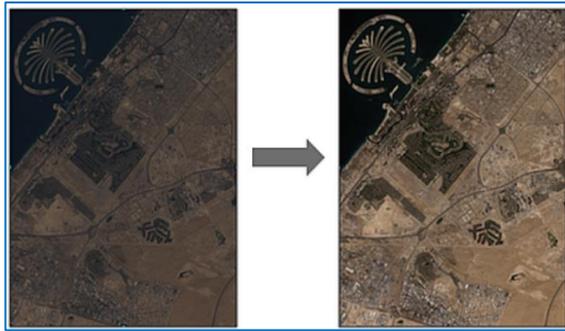
The DRA check box refers to "dynamic range adjustment." This allows the brightness and contrast of the image display to be adjusted based only on the data and contained within the data frame extent. That means dark areas will automatically brighten, and bright areas will automatically darken. The image on the left does not have the option checked, whereas the image on the right does.
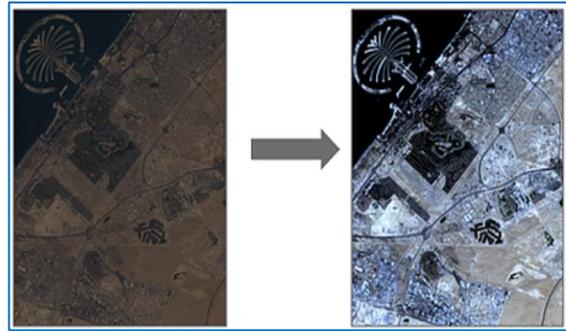
The stretch adjusts the stretch applied to the selected image. There are six stretch options available: None, Minimum-maximum (Min-max), Standard deviation (Std-dev), Histogram equalization (Hist-eq), Percent clip, and Esri. Different stretches will produce different results in the raster display. The image on the left has no stretch applied (None), whereas the image on the right has standard deviation (Std-dev).
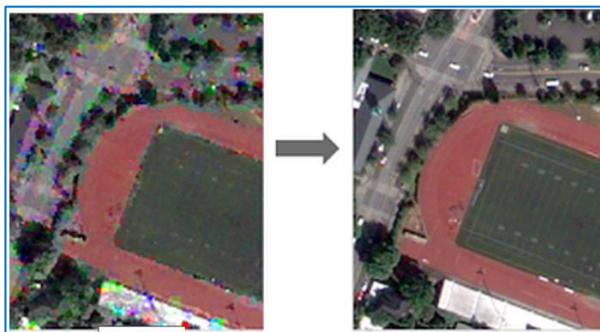
The resample selection chooses which resampling method to apply when you pan and zoom to view the selected image. Resampling is the process of interpolating the pixel values to fit your raster dataset to the desired resolution. Resampling methods include nearest neighbor, bilinear, cubic convolution, 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 provided 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.
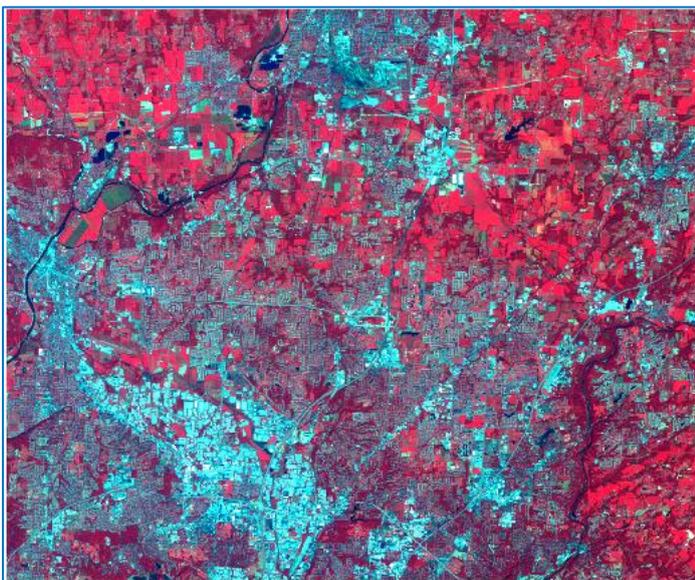
Input Landsat TM image

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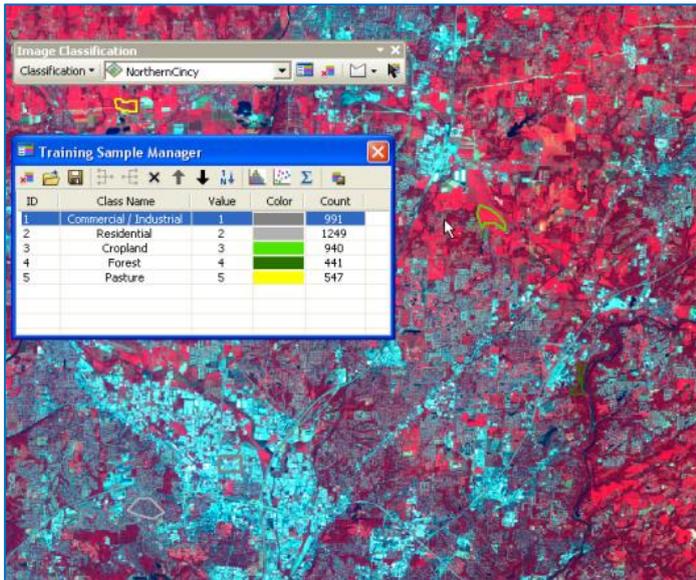
Training Samples

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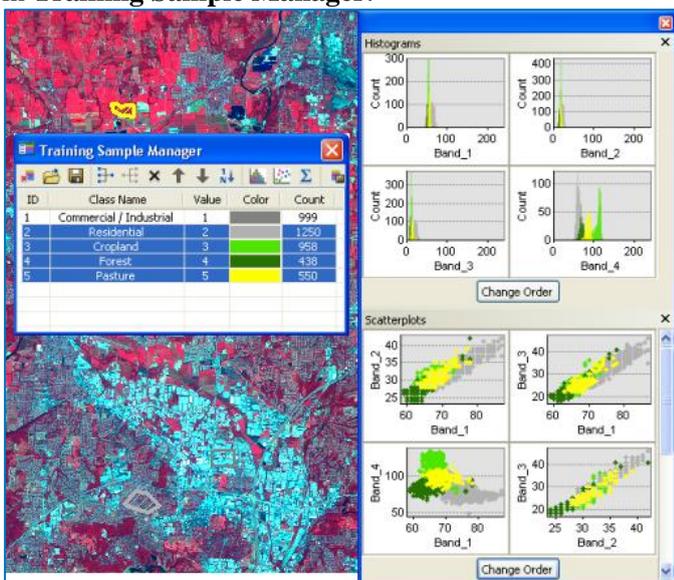

Evaluating Training Samples

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.
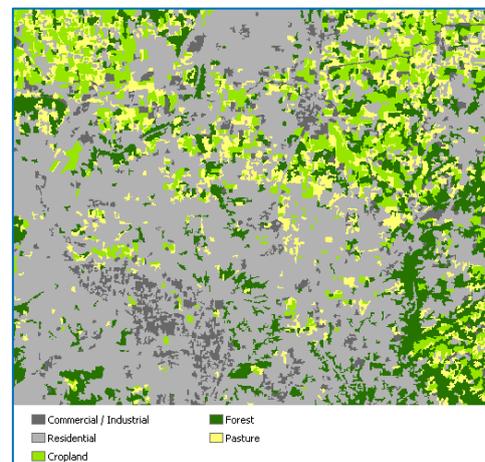
The images below show vegetation cover for years 2005 and 2017. The instructions provided describe how to detect and quantify vegetation cover changes from 2005 to 2017 using the Raster Calculator tool.
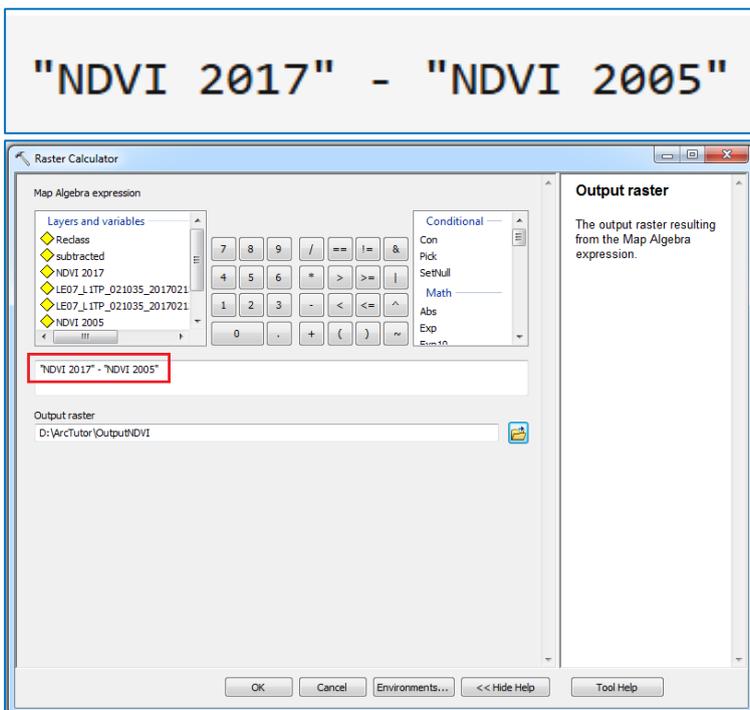

Vegetation cover 2005

Vegetation cover 2017
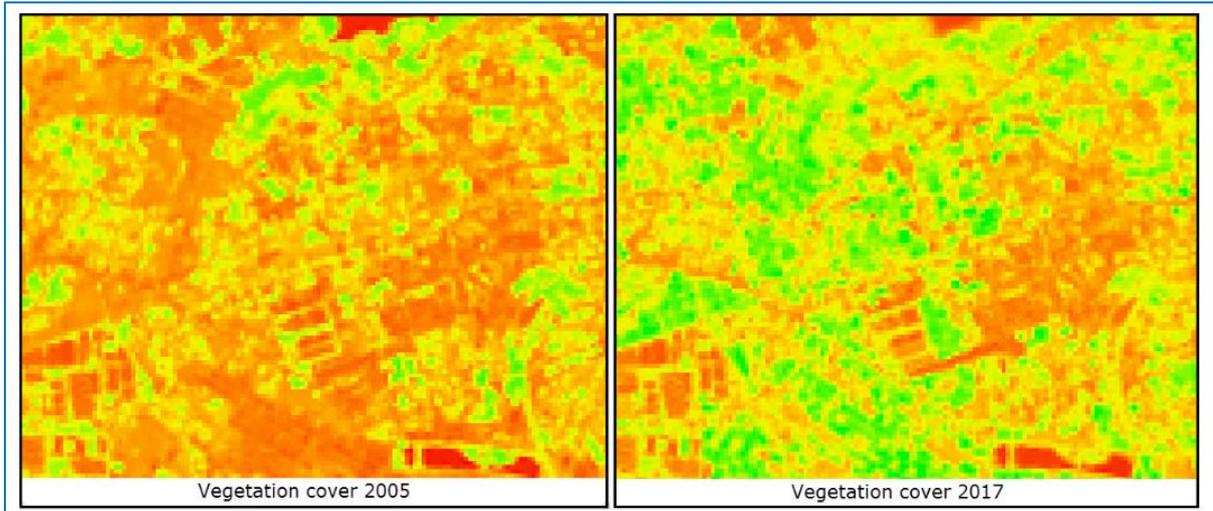
Procedure

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:

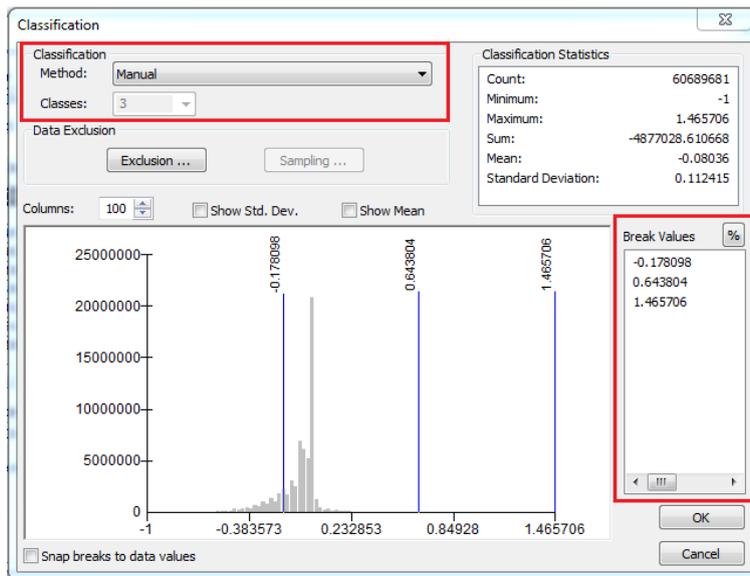   c. Set a name and location for the **Output raster**.
   d. Click **OK**. The output raster contains the subtracted cell values. Negative values indicate losses while positive values indicate gain. Zero '0' indicates unchanged vegetation cover.
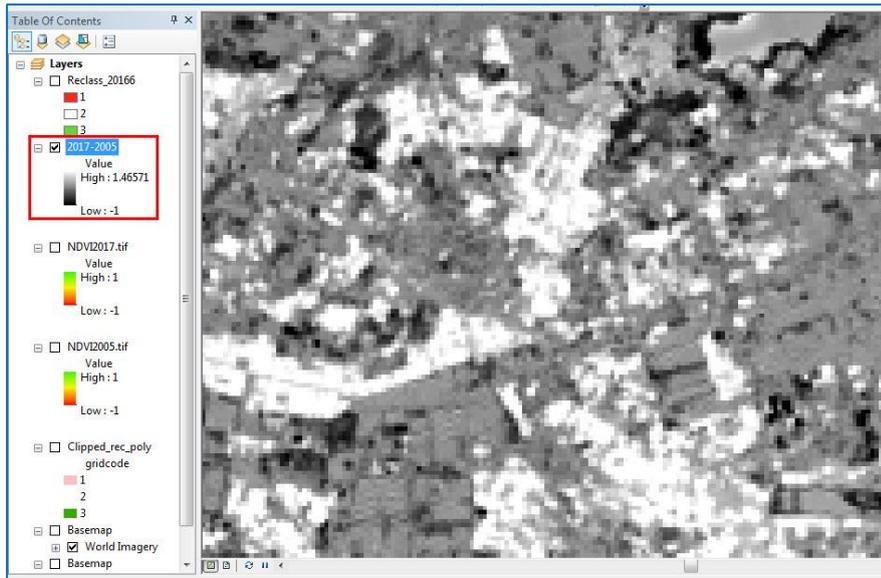
2. The raster generated in Step 1 can be classified into multiple classes to reflect vegetation change direction and extent. For example, (a) Vegetation loss; (b) No change, and (c) Vegetation gain, or (a) Significant loss; (b) Loss; (c) No change; (d) Gain, and (e) Significant gain.

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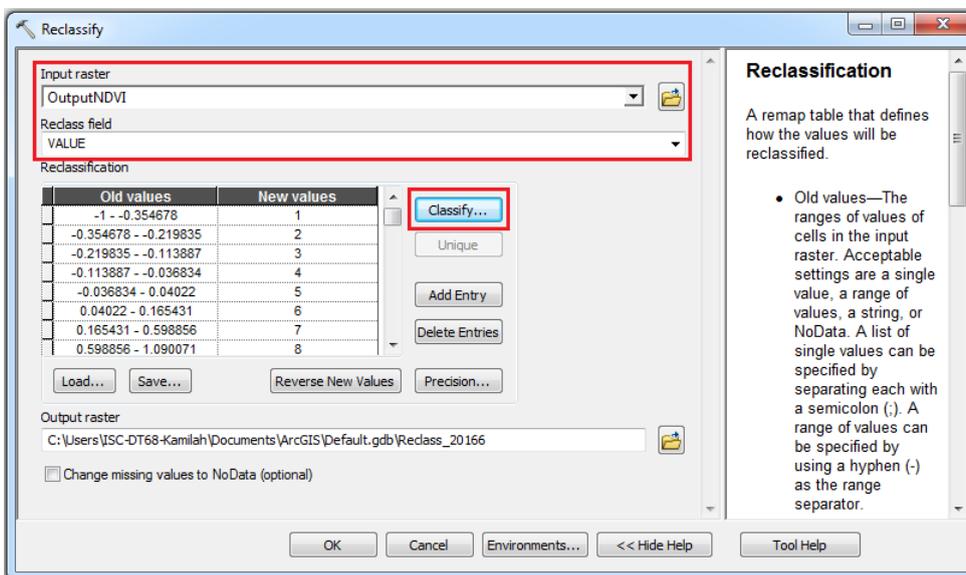
   e. In the **Classification** dialog box, select a method for the classification in the **Method** drop-down list, and select the desired number of classes in the **Classes** drop-down list.
   f. Set the **Break Values** manually, if necessary.

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.
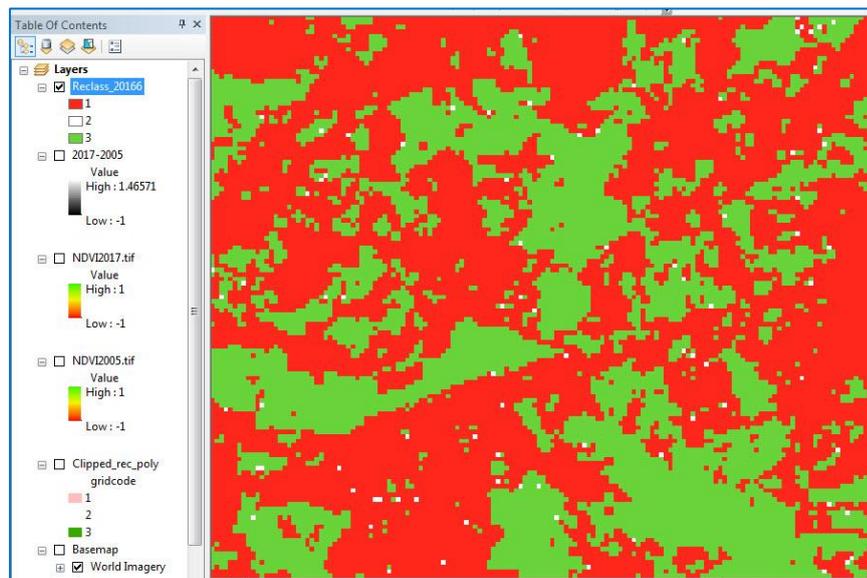
3. Quantify the changes by creating a new field, and calculate the area of each class by multiplying the Count field with the pixel size of the raster layer.

   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.
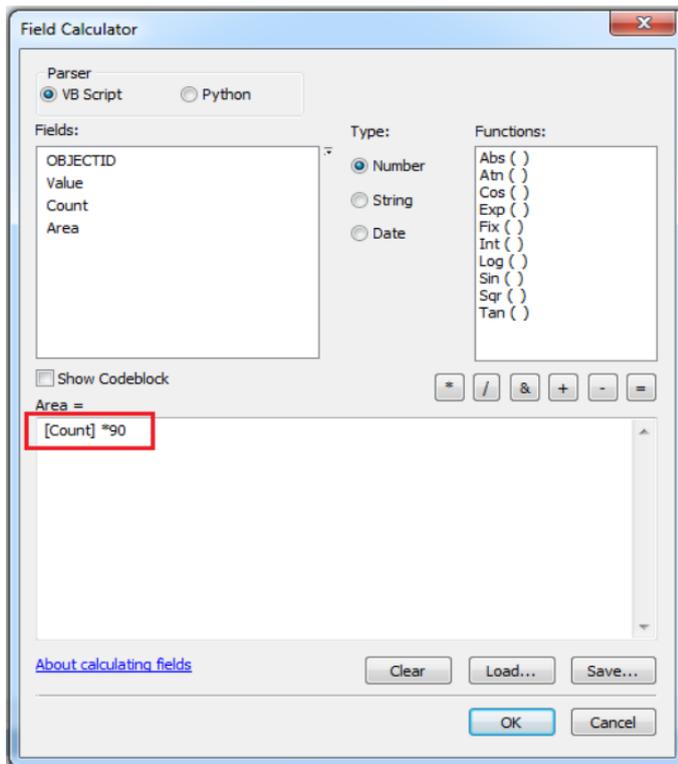
f. Click **OK**. The area for each class is calculated in the new field. The unit of the calculated area is the unit of the raster's coordinate system.
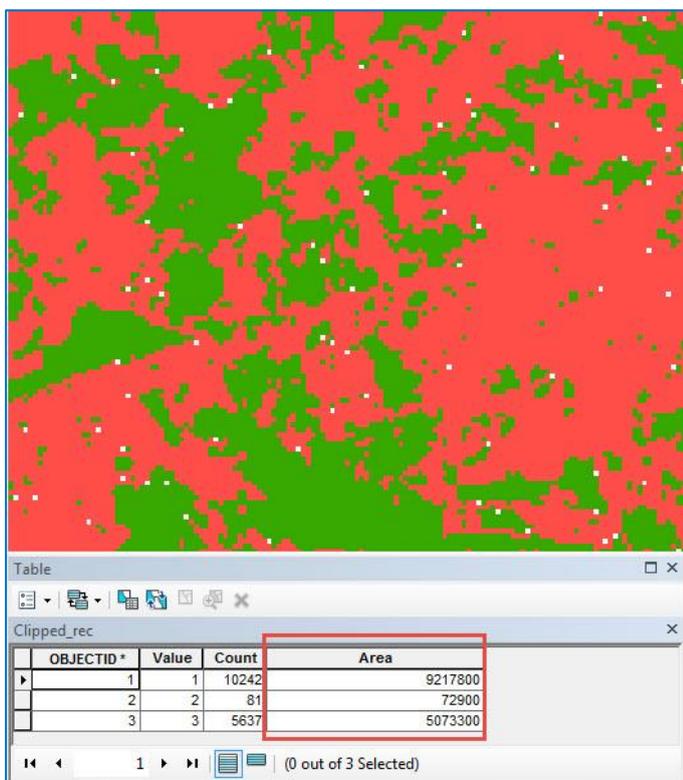
GIS Visualization and Map Layout

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

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.
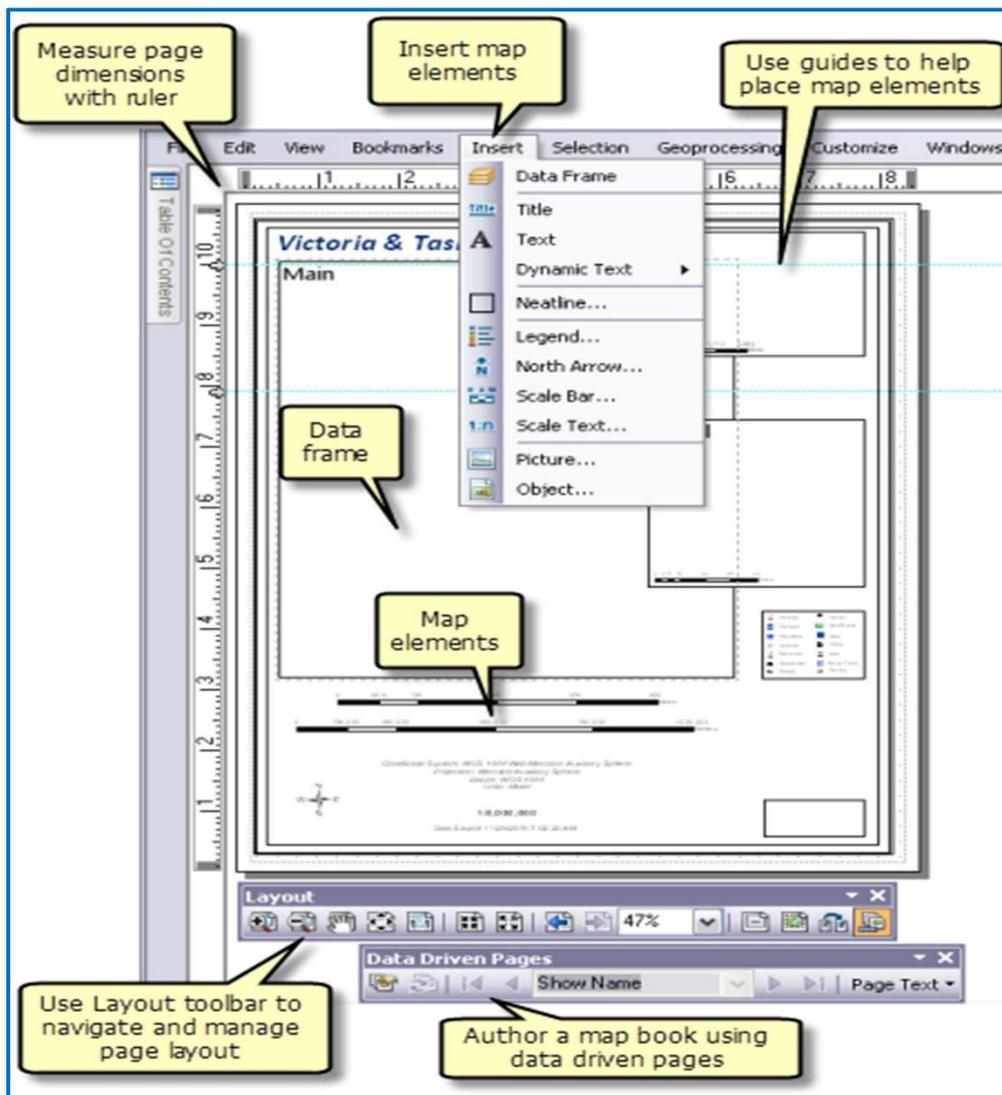
FIGURE: KEY ELEMENTS OF THE PAGE LAYOUT USER INTERFACE

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 mapto 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.
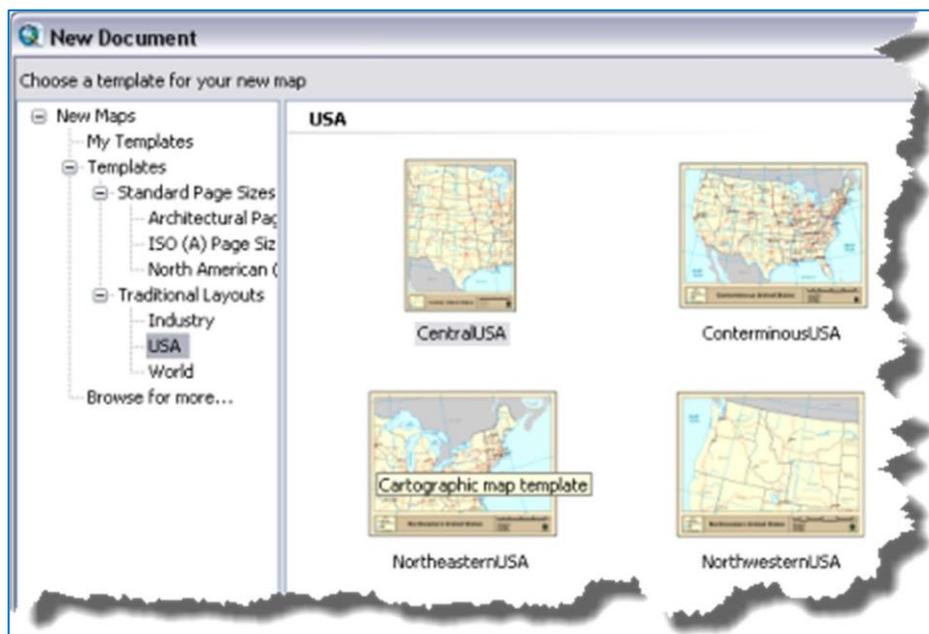
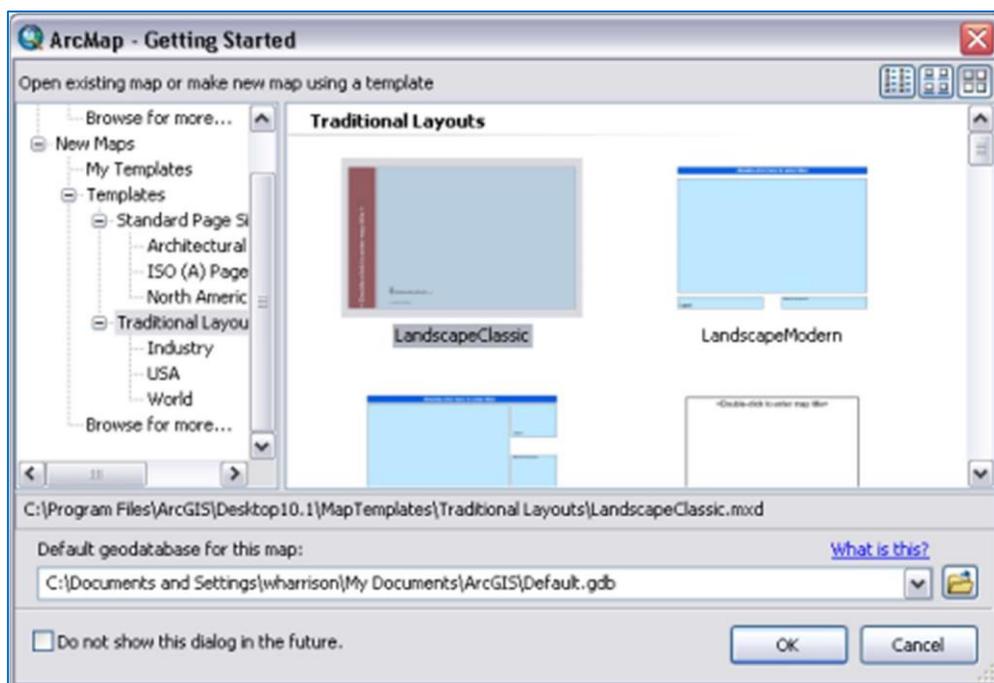

FIGURE: LAYOUT TEMPLATES

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.
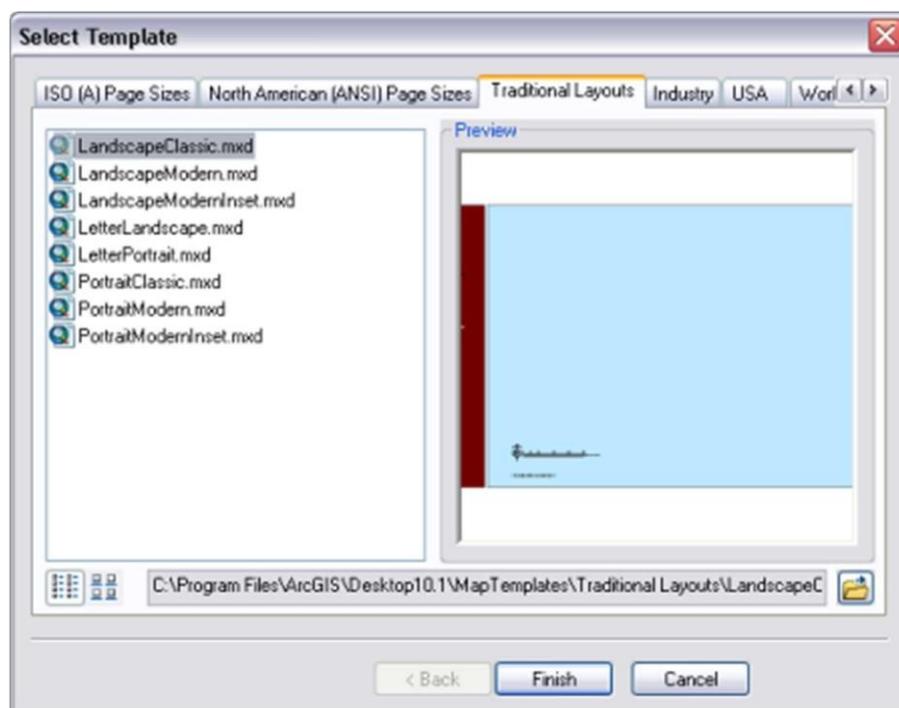
Figure: Change page layout with a user-defined template under

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 ![icon] 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.
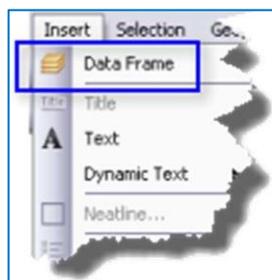

From this menu, we can insert additional data frames. These additional data frames may be for locator or detail maps. If we are using multiple data frames we may want to consider usingextent indicators to show the extent of one data frame within another data frame. A good locatormap will also contain 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.
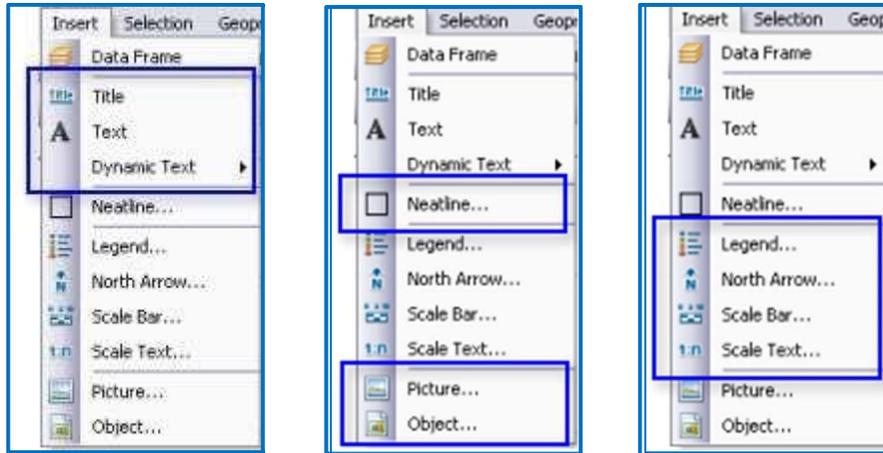
We can use the Insert menu to add a Legend, North Arrow, Scale Bar, and Scale Text. Clickingany of these options opens an appropriate wizard or dialog box where we can set properties for each map element.

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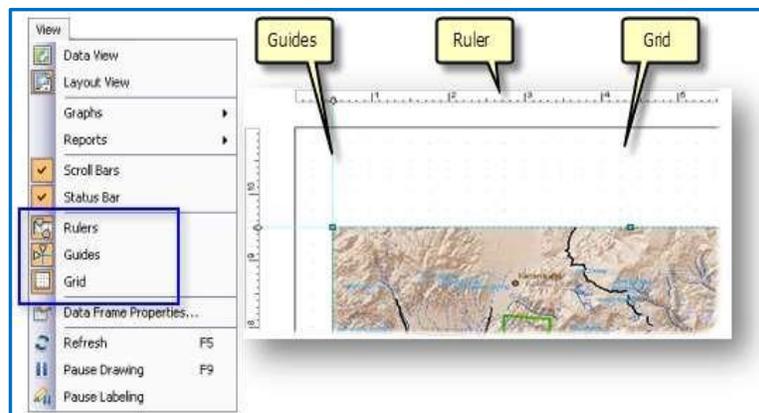
We can set properties for these placement tools using the Layout View tab of the ArcMap Options dialog box, which is available from the Customize menu. Here, we can set the units and division values for the page ruler, and set the spacing for the grid.

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 optionsto Group or Ungroup elements. Grouping elements is a good way of managing a page layout with many elements.
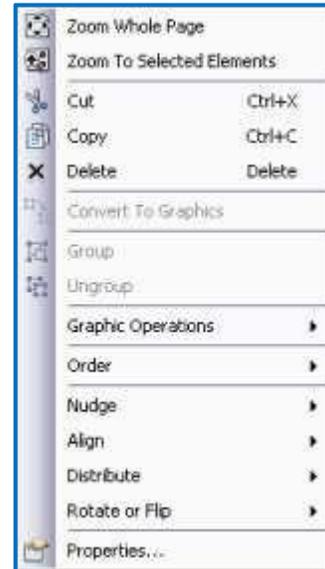
This menu also provides commands to further manipulate graphics through Graphic Operationsand placement commands. Placement commands include the ability to place elements in a specified drawing Order, Nudge, or move the element in a particular direction, Align, and Distribute multiple elements on the 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
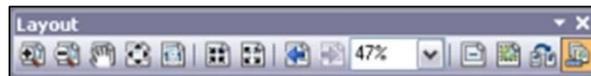
The Layout toolbar is used to navigate the page layout. It is enabled when we are in layout view. We can pan and zoom in/out on the page. We can also jump back and forth to previouspage extents or specify a zoom percentage based on the page size. Other options for navigatingin the page layout include 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.
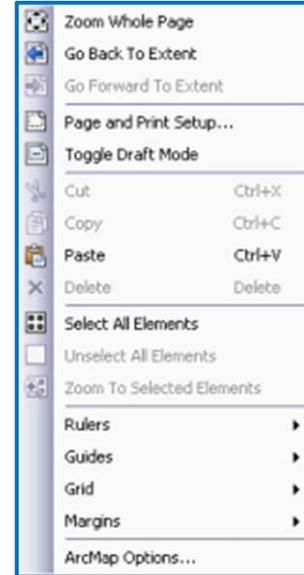
When in draft mode, using Toggle Draft Mode, the contents of the page elements are not drawn. Instead, only the bounding box of the frame and a label showing its name are drawn. We can control draft mode for individual elements through the Frame tab of the element's Properties dialog box.

Grids and Graticules

Grids and graticules are used to display coordinate positions on the earth. Graticules show linesof 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 canplace 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.
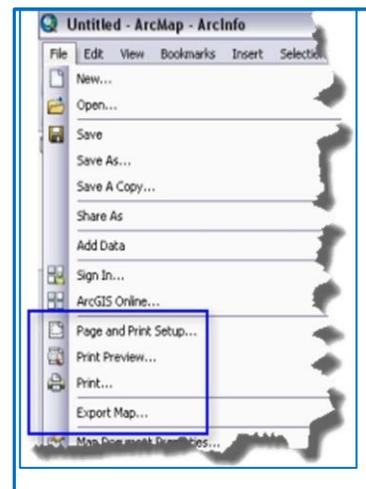
Reference:

Esri. 2023. Using map templates

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

Google Earth Engine (GEE) Basics

Mahmudul Hasan
Geo-Data Specialist, ESRI Bangladesh
Email: mhasanbd08@gmail.com

Google Earth Engine combines a multi-petabyte catalog of satellite imagery and geospatial datasets with planetary-scale analysis capabilities. Scientists, researchers, and developers use Earth Engine to detect changes, map trends, and quantify differences on the Earth's surface. Earth Engine is now available for commercial use and remains free for academic and research use.
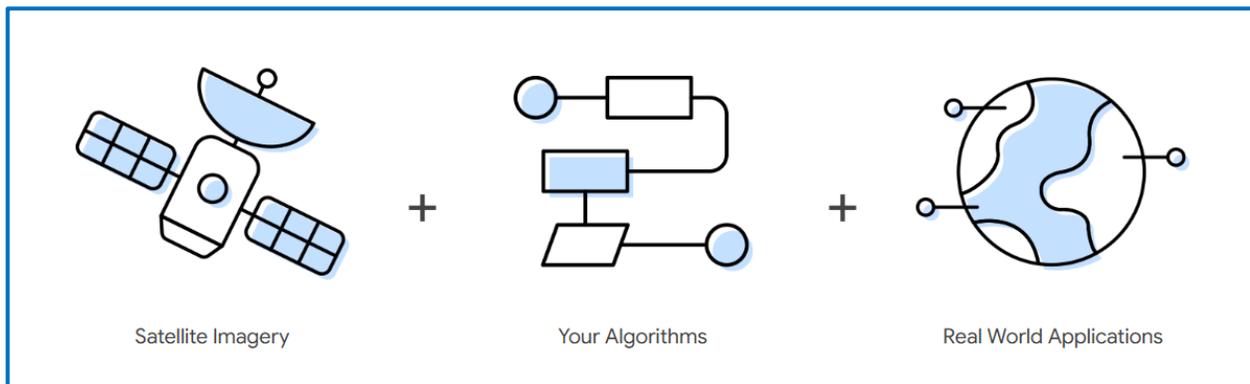
Sign-up for Google Earth Engine

If you already have a Google Earth Engine account, you can skip this step or visit (**https://courses.spatialthoughts.com/gee-sign-up.html**) for step-by-step instructions.

01. Introduction

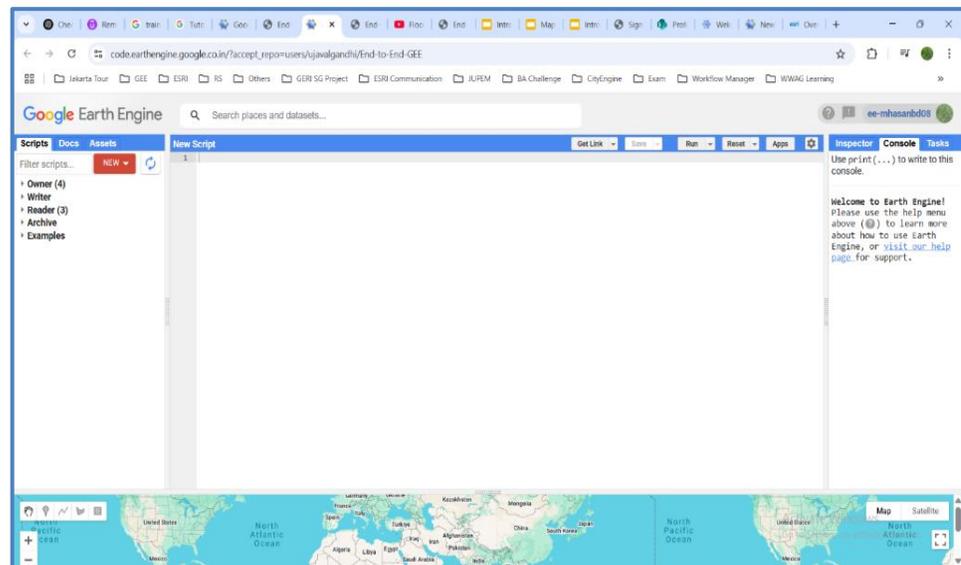The Code Editor is an Integrated **Development** Environment (IDE) for Earth Engine Javascript API. It offers an easy way to type, debug, run and manage code. Type the code below and

click Run to execute it and see the output in the Console tab.

02. Working with Image Collections

Most datasets in Earth Engine come as a ImageCollection. An ImageCollection is a dataset that consists of images takes at different time and locations - usually from the same satellite or data provider.

03. Filtering Image Collections

The collection contains all the imagery ever collected by the sensor. The entire collections are not very useful. Most applications require a subset of the images. We use filters to select the appropriate images. There are many types of filter functions.

We will learn about 3 main types of filtering techniques,

Filter by metadata: You can apply a filter on the image metadata using filters such as ee.Filter.eq(), ee.Filter.lt() etc. You can filter by PATH/ROW values, Orbit number, Cloud cover etc.

Filter by date: You can select images in a particular date range using filters such as ee.Filter.date().

Filter by location: You can select the subset of images with a bounding box, location or geometry using the ee.Filter.bounds(). You can also use drawing tools to draw geometry for filtering.
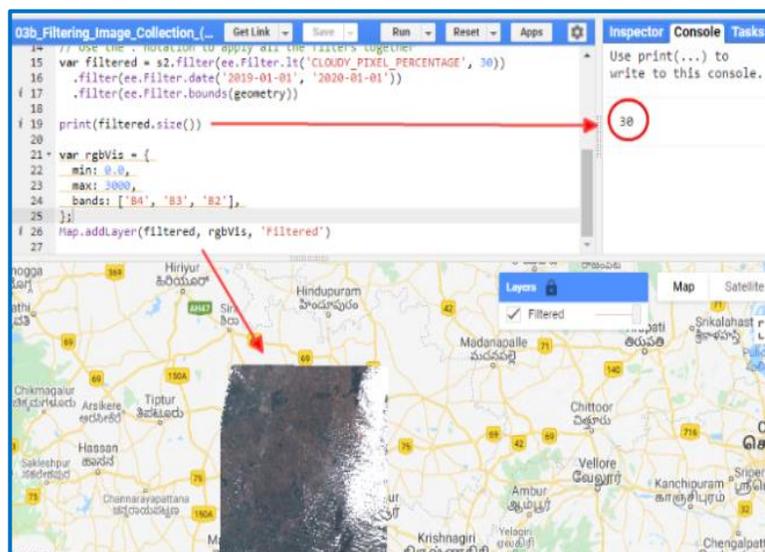
04. Creating Mosaics and Composites from ImageCollections

The default order of the collection is by date. So, when you display the collection, it implicitly creates a mosaic with the latest pixels on top. You can call. mosaic () on an ImageCollection to create a mosaic image from the pixels at the top. We can also create a composite image by applying selection criteria to each pixel from all pixels in the stack. Here we use the median () function to create a composite where each pixel value is the median of all pixels from the stack.

05. Working with Feature Collections

Feature Collections are like Image Collections - but they contain Features, not images. They are equivalent to Vector Layers in a GIS. We can load, filter and display Feature Collections using similar techniques that we have learned so far.
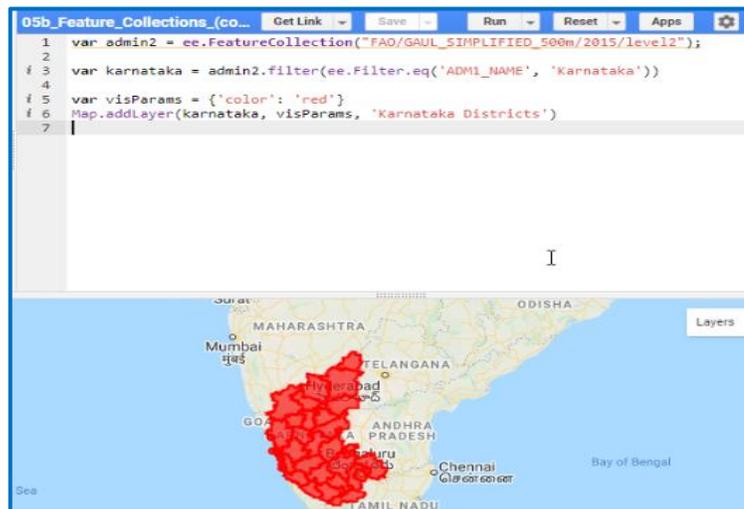
06. Importing Data

You can import vector or raster data into Earth Engine.

07. Clipping Images

It is often desirable to clip the images to your area of interest. You can use the clip () function to mask out an image using a geometry.
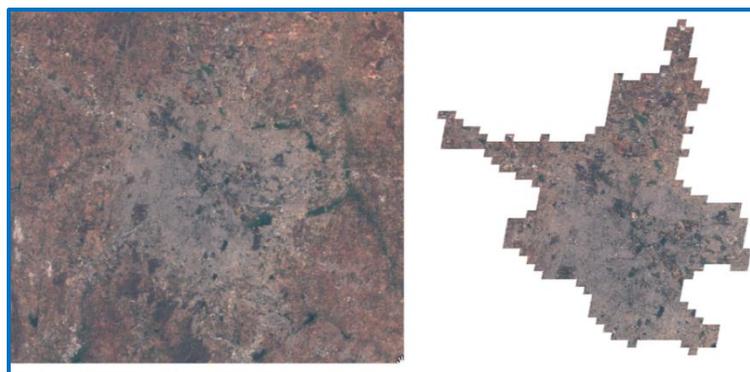
08. Exporting Data

Earth Engine allows for exporting both vector and raster data to be used in an external program. Vector data can be exported as a CSV or a Shapefile, while Raster can be exported as GeoTIFF files. We will now export the Sentinel-2 Composite as a GeoTIFF file.

Image Analysis on GEE

Mahmudul Hasan
Geo-Data Specialist, ESRI Bangladesh
Email: mhasanbd08@gmail.com

01. Earth Engine Objects

This script introduces the basics of the Earth Engine API. When programming in Earth Engine, you must use the Earth Engine API so that your computations can use Google Earth Engine servers.

02. Calculating Indices

Spectral Indices are central to many aspects of remote sensing. Whether you are studying vegetation or tracking fires - you will need to compute a pixel-wise ratio of 2 or more bands. The most used formula for calculating an index is the Normalized Difference between 2 bands. Earth Engine provides a helper function normalized Difference() to help calculate normalized indices, such as Normalized Difference Vegetation Index (NDVI). For more complex formulae, you can also use the expression () function to describe the calculation

03. Computation on ImageCollections

So far, we have learnt how to run computation on single images. If you want to apply some computation - such as calculating an index - to many images, you need to use map (). You first define a function that takes 1 image and returns the result of the computation on that image. Then you can map () that function over the ImageCollection which results in a new ImageCollection with the results of the computation. This is like a for-loop that you may be familiar with - but using a map () allows the computation to run in parallel.

04. Cloud Masking

Masking pixels in an image makes those pixels transparent and excludes them from analysis and visualization. To mask an image, we can use the update Mask () function and pass an image with 0 and 1 values. All pixels where the mask image is 0 will be masked.
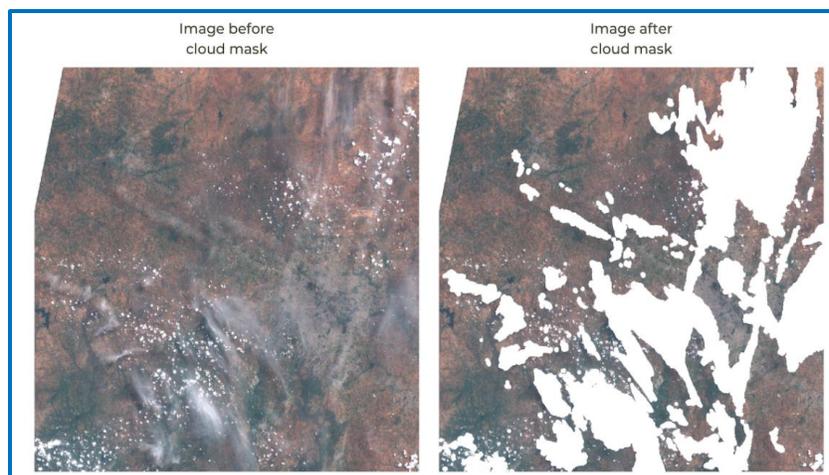
05. Reducers

When writing parallel computing code, a Reduce operation allows you to compute statistics on many inputs. In Earth Engine, you need to run reduction operations when creating composites, calculating statistics, doing regression analysis etc. The Earth Engine API comes with many built-in reducer functions (such as ee.Reducer.sum (), ee.Reducer.histogram (), ee.Reducer.linearFit () etc.) that can perform a variety of statistical operations on input data. You can run reducers using the reduce () function. Earth Engine supports running reducers on all data structures that can hold multiple values, such as Images (reducers run on different bands), ImageCollection, FeatureCollection, List, Dictionary etc.

06. Time-Series Charts

Now we can put together all the skills we have learnt so far - filter, map, reduce, and cloud-masking - to create a chart of average NDVI values for a given location over 1 year. Earth Engine API comes with support for charting functions based on the Google Chart API. Here we use the ui.Chart.image.series () function to create a time-series chart.
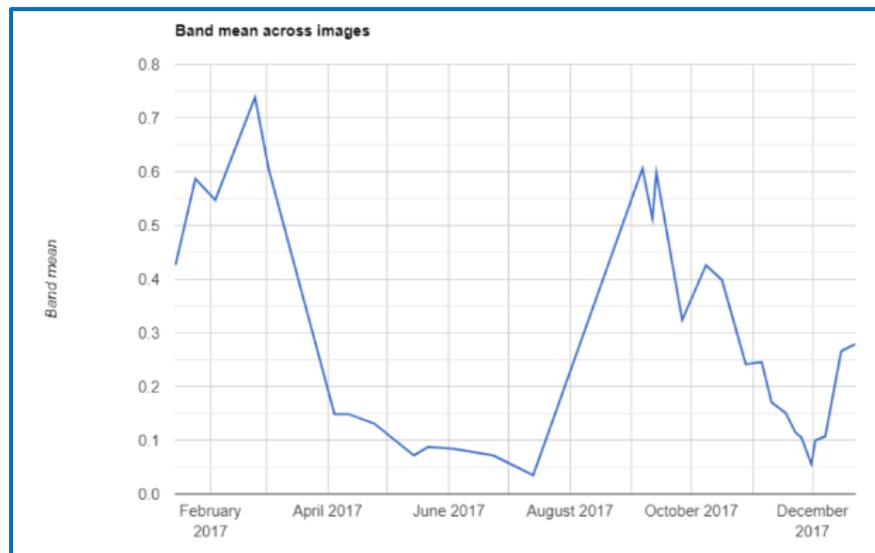
Boro Rice Area Estimation with Google Earth Engine (GEE)

Hasan Md. Hamidur Rahman, Director (Computer & GIS Unit)
Bangladesh Agricultural Research Council
Email: h.rahman@barc.gov.bd

Steps for Boro Rice Area Estimation

Flowchart of Boro rice area delineation:

GEE Data Archive

Sentinel-2 images from GEE platform

a) Defining the RoI as whole Bangladesh
b) Stack creation and spatio-temporal filtering of boro rice, Dec 2020-Mar 2021

c) Filter out cloud above 20%

Field data collection of Boro rice and non-rice signature using handheld GPS

Apply Machine Learning (ML) model CART, k-NN, RF and SVM for classification

Compare the accuracy of the ML algorithms from confusion matrix and compare the area from all ML classification with BBS data and choose CART as the best one.

Area coverage of boro rice

Field/ Signature Data Collection and Processing

1. Field Data Collection through GPS device
2. The field data collected during boro seasons are compiled into an Excel sheet. The validated data is then saved as a CSV file, which serves as the attribute file.
3. Simultaneously, the GPX file from the handheld GPS devices is downloaded and imported into Google Earth Pro to verify the survey locations.
4. Polygons are drawn using the GPS points and digital photos for most of the fields.
5. The file is exported in KML format and opened in QGIS, where it is converted into a shapefile.
6. The shapefile is then joined with the attribute file (CSV) to merge the land types and other parameters.
7. Non-rice land types are generalized into a single class called 'non-rice'. In the shapefile, there are two columns named 'id' and 'feature_name', where the value '0' represents 'non-rice' and '1' represents 'rice' features.
8. The generalized shapefile is imported into the Google Earth Engine (GEE) asset, where it is used as the signature data in the machine learning (ML) model.
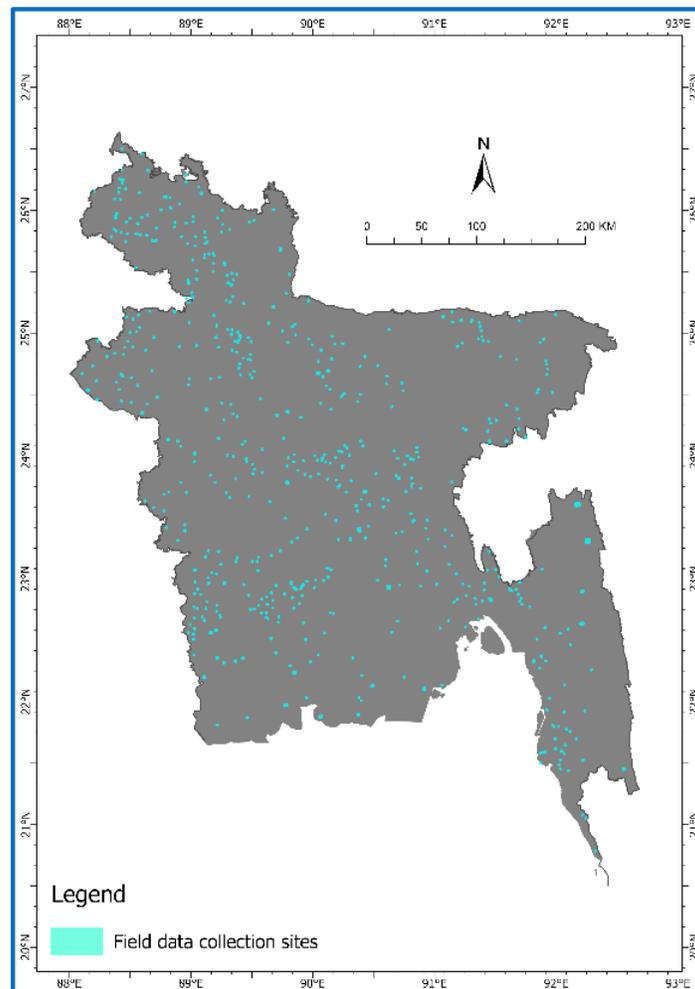
Screenshot of Boro Rice Classified GEE Raster Data (CART)
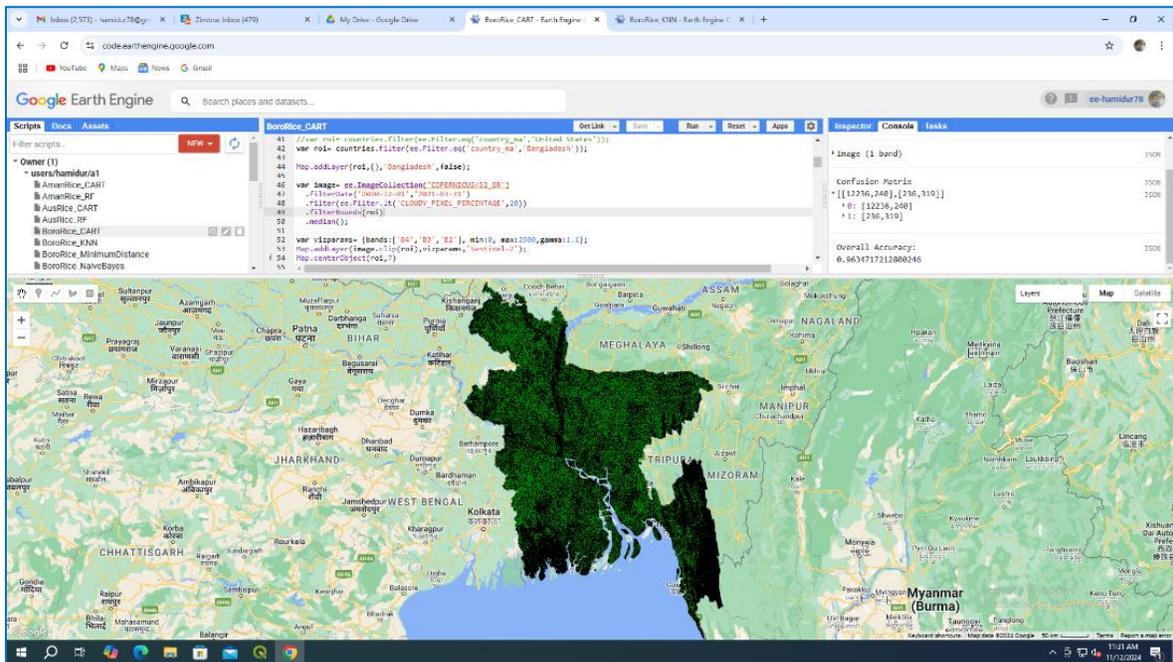
**Screenshot of Boro Rice Classified GEE Raster Data (k-NN)**
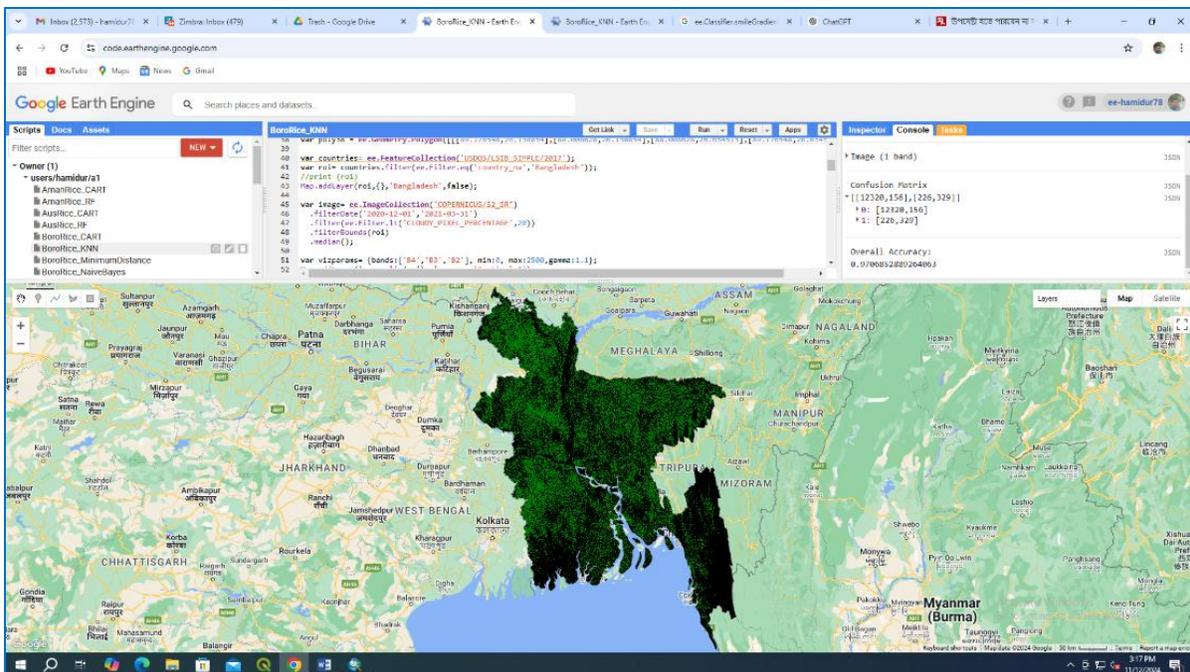
Steps to Process Data in ArcGIS

1. Boro Classified GEE Raster Data
2. Boro Reclassified Mosaiced Raster Data
3. Resampled Raster Data
4. Boro Final Area Result.

ArcGIS Tool for Raster Data Processing:

- Arc Tool Box-> Spatial Analysis Tools->Reclass->Reclassify
- Arc Tool Box-> Data Management Tools->Raster->Raster Dataset->Mosaic to New Raster
- Arc Tool Box-> Data Management Tools->Raster->Raster Processing->Resample

Boro Rice Area Map
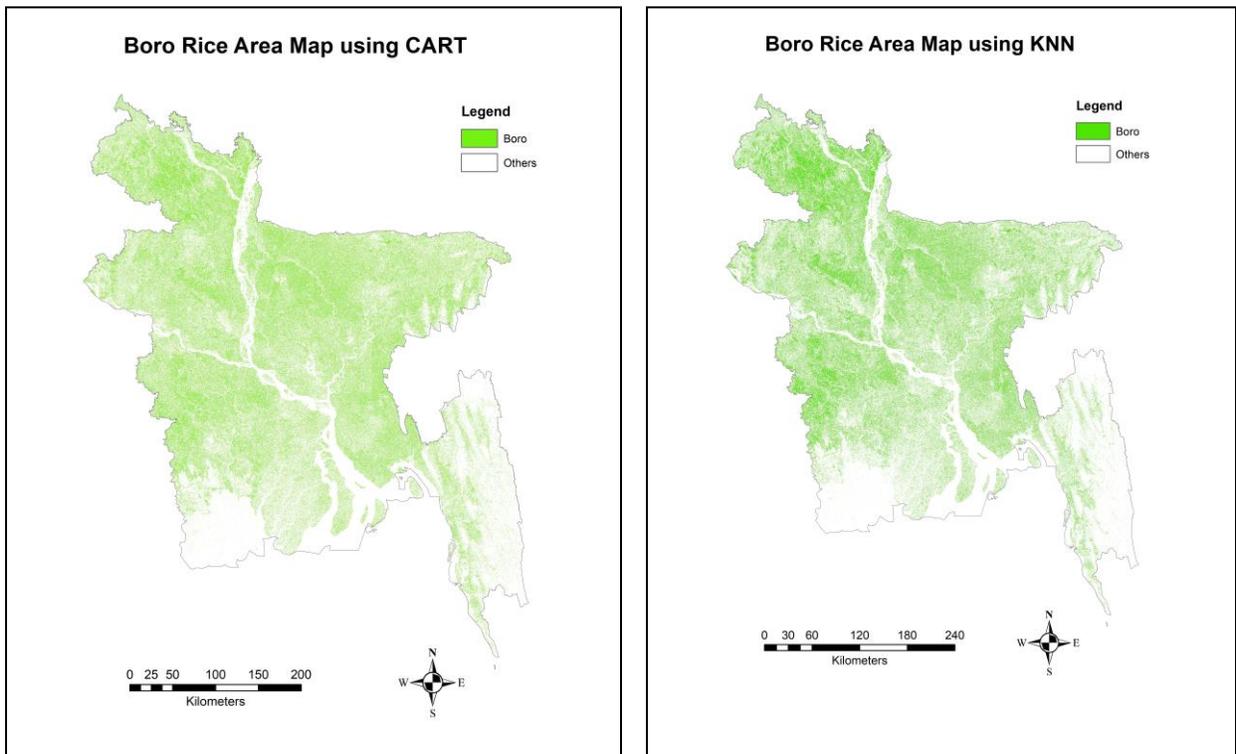
Boro Rice Area Comparison

Sl.	Classification Algorithm	Pixel count (10m x 10m)	Area in Sq. Meter	Area in Sq. km	Area in Ha	Classification Accuracy of Algorithm (%)	Area Accuracy with respect to BBS (%)
1	**CART**	419957945	41995794500	41996	**4,199,579**	**96**	**88**
2	**k-NN**	384058603	38405860300	38406	**3,840,586**	**97**	**80**
			BBS Statistics 2020-21:		**4,786,621**	-	-

Future Applications of GIS and Remote Sensing in Bangladesh Agriculture

Md. Abeed Hossain Chowdhury Project Manager, Crop Zoning Project
Bangladesh Agricultural Research Council
Email: abeedchowdhury@gmail.com

Introduction

Bangladesh's agriculture sector, which contributes 14.23% to GDP and employs 40.6% of the workforce (BBS 2023), faces challenges like climate change, soil degradation, and food security. Geographic Information Systems (GIS) and Remote Sensing (RS) offer transformative solutions by enabling data-driven, precision farming.

Current Challenges in Bangladesh Agriculture

- Climate change impacts (floods, droughts, salinity intrusion)
- Land degradation and soil health issues
- Low productivity and food security concerns
- Need for data-driven decision-making

Role of GIS & RS in Agriculture

GIS Applications:
- Crop suitability and Crop zoning
- Land use/land cover mapping
- Soil fertility analysis
- Irrigation planning
- Disaster management (flood, drought, salinity) and mitigation

RS Applications:
- Crop health monitoring (NDVI)
- Drought/flood forecasting
- Yield prediction

1. Precision Agriculture & Smart Farming

Applications:
- **Soil Health Monitoring:** GIS maps soil nutrient levels, enabling site-specific fertilizer application (Crop Zoning, Khamari app).
- **Crop Health Assessment:** Drones and satellites (e.g., Sentinel-2, Landsat) track NDVI (Normalized Difference Vegetation Index) to detect diseases early.
- **Automated Irrigation:** Soil moisture sensors + GIS optimize water use, crucial for drought-prone regions.

Future Potential:
- **AI-powered Drones** for real-time pest detection.
- **Blockchain-integrated GIS** for transparent supply chains.

2. Climate Resilience & Disaster Management

Applications:
- **Flood & Drought Forecasting:** RS tracks water levels (using SAR data) and predicts impacts on crops.
- **Salinity Intrusion Mapping:** Coastal areas (e.g., Satkhira, Khulna) use GIS-based salinity models to recommend salt-tolerant crops.
- **Early Warning Systems:** Integrating NASA's MODIS and Bangladesh Meteorological Department (BMD) data for cyclone alerts.

Future Potential:
- **Machine Learning models** to predict climate-induced yield losses.
- **Satellite-based crop insurance** for farmers.

3. Crop Yield Prediction & Food Security

Applications:
- **Satellite-Based Yield Models:** Using Sentinel-1 (radar) to estimate rice production before harvest.
- **Supply Chain Optimization:** GIS maps storage facilities to reduce post-harvest losses (currently **15-20%** in Bangladesh).

Future Potential:
- **AI + Big Data Analytics** for real-time yield forecasting.
- **Integration with IoT sensors** in fields for hyper-local data.

4. Land Use Planning & Policy Support

Applications:
- **Crop Zoning:** GIS identifies best-suited crops for specific regions (e.g., mangoes in **Chapai Nawabganj**).
- **Urban Encroachment Monitoring:** RS detects illegal farmland conversions.

Future Potential:
- Digital Twin Technology for virtual farm simulations.
- Policy Dashboards for the Ministry of Agriculture to track subsidies and schemes.

5. Challenges & Recommendations

Key Challenges:
- High costs of satellite/drone technology.
- Limited technical expertise among farmers.
- Data accessibility issues in rural areas.

Recommendations:
- ✓ Training Programs for Farmers and officials: Mobile apps (e.g., "Khamari Mobile App") with GIS insights.
- ✓ Public-Private Partnerships (PPP): Collaborate with Google Earth Engine, NGO, FAO.
- ✓ Government Initiatives: Expand Agricultural projects with AI-based GIS and RS (Satellite/Drone technology) tools.

Conclusion

GIS and RS are transformative for Bangladesh's agriculture. The future of Bangladesh's agriculture lies in scaling GIS and RS technologies to enhance productivity, sustainability, and climate resilience. With government support, private sector innovation, and farmer training, Bangladesh can become a leader in smart agriculture in South Asia.