Defining Imagery
GIS and imagery are synergistic

For professional users, imagery and GIS have been perceived as complementary forms of digital geography, but still largely independent. Users had one system for GIS and another for image processing. An emerging big idea is that the two separate threads are now essentially interwoven within ArcGIS, resulting in a far-reaching and quite sudden expansion of image applications within the world of traditional vector-focused GIS.

A GIS cornerstone
Anatomy of an image

Imagery has long been a cornerstone for GIS that contributed synergistically to a wide range of GIS applications. In a very real sense, the broad and steady adoption of GIS over the decades has been fueled by imagery and remote sensing. Ideal for creating photographic basemaps and a perfect foundation on which to extract, trace, or otherwise digitize geographic features, imagery is the perfect complement to vector GIS, which used points, lines, and polygons to represent geography.

ArcGIS is a comprehensive image integration machine that opens the door to using the thousands of aircraft-, satellite-, drone-, and ground-based image sensors operating around the clock and around the globe. These digitally captured observations fit into geographic space and are time-stamped for temporal applications. The resulting information layers are being continuously added to the collective GIS knowledge of the planet, enabling people who work with geographic information to do more, and to do it faster and with wider impact.

In addition to its traditional GIS capabilities, ArcGIS also incorporates comprehensive image processing system capabilities that support the application, use, and integration of imagery and remote sensing.

This synthesis is founded on a series of key unifying concepts that link imagery to GIS. This chapter reviews these key concepts, reinforcing them with examples that help to communicate the power of imagery in your GIS.

Cell-based imagery

Cell

Every image is composed of a series of rows of cells (aka pixels) that contain a value. The values represented in each cell of an image may be color pixels like you see in any digital photo; a series of observations like the measures in a Landsat scene; or other values that represent thematic categories, surface values such as elevation, or analytical model results.
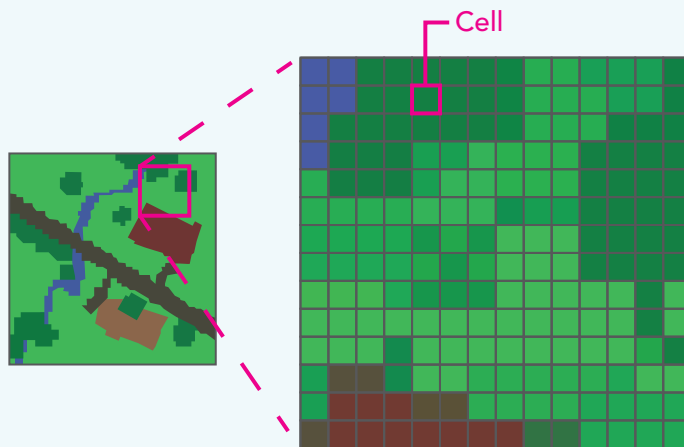
Imagery layers are universal and varied

A raster is a grid of cells in a geographic space. The spaces within the grid are the cells. In a GIS, these cells are referenced to real geography. This cell-based raster structure is used to store and manage all imagery data. This fundamental grid structure makes raster data universal and useful for the representation of virtually any kind of geographic information. This means that all kinds of data can be integrated with imagery for mapping, advanced analysis, and data management.

True color aerial

Imagery along the Pelorus River in Marlborough, New Zealand. This is part of a rich national imagery dataset provided by Land Information New Zealand (LINZ).
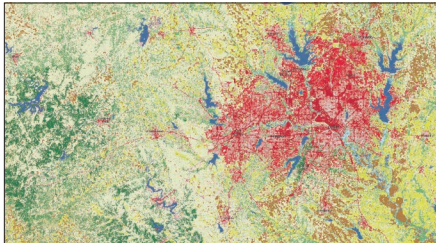
Landsat scene

Landsat 8 scene of the mountains and canyons of Utah. This shortwave infrared image is useful for studying vegetation health, change detection, disturbed soils, and soil types.

Elevation surface
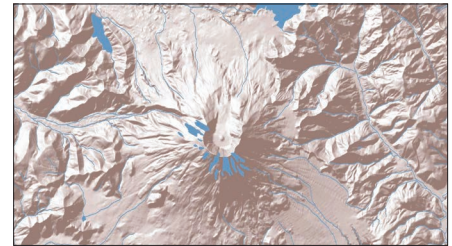
Elevation surface of Mount St. Helens derived from a satellite-acquired digital elevation model (DEM) and used to create a realistic hillshade.

Land cover

Land cover rasters identify different types of developed areas, agricultural lands, forests, and natural vegetation. Each cell represents the predominating value covering that cell.

Precipitation
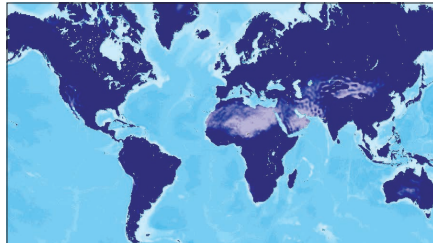
This time series map derived from MODIS satellite imagery contains a historical record showing the volume of precipitation that fell during each month from March 2000 to the present.

Flood inundation zones

This map of Charleston, South Carolina, compares areas that are vulnerable to coastal flooding with the same areas in a US Coast Survey map of the city from 1863.

Under the hood
Imagery contains metadata

Earth observation imagery, like any digital photograph, contains important metadata that enables intelligent use of your information in ArcGIS. Software algorithms use this information to automate many of the once-cumbersome technical steps of georeferencing imagery.

Digital photo metadata

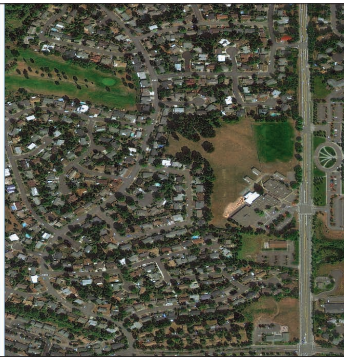| File Name: | IMG_0400.PNG |
File Type:	Portable Network Graphics (*.png)
Location:	N44.95080° W93.36773° Datum: NAD83
Size:	2.58 MB
Created:	Oct 31, 2015 11:22:00 AM
Modified:	Oct 31, 2015 11:22:00 AM
Dimensions:	750 x 1334
Bit Depth:	24

Your digital photos contain metadata about the photo, including the date that the photo was taken, along with the location of the camera—its geotag, which records the GPS coordinates.

Imagery metadata

Similarly, drone, aerial, and satellite imagery contains detailed metadata items that enable more intelligent use—the spatial reference (or location) of your image, creation date, amount of cloud cover, and other properties.

ArcGIS puts this information to work with your imagery, creating automated, intelligent displays and analytics.

Images have a geographic reference

The defining characteristic of GIS data is that all layers are referenced onto the surface of the earth (or other planets, if that's your study area). Imagery data also has a spatial reference that enables it to be overlaid and used with all other GIS layer types. This is what makes ArcGIS a complete image integration platform.

Rasters have a spatial reference that enables them to be registered onto the earth's surface and to be combined with other GIS data layers.

Coordinate system

Coordinates are 300,000 E, 5,900,600 N
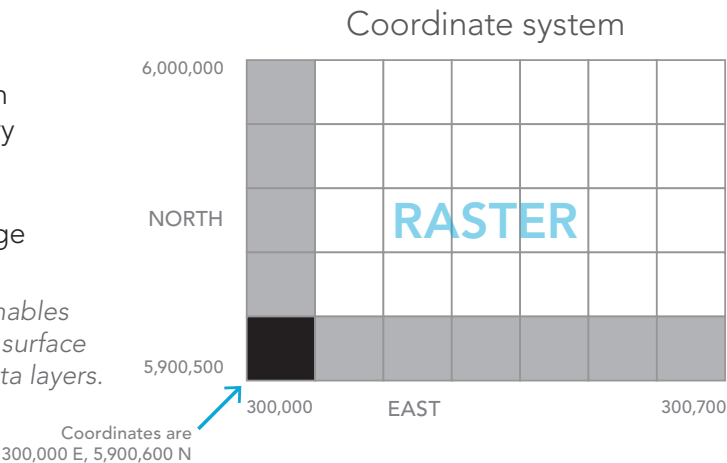
Geography is an organizing key
Imagery aligns with other geographic layers

Images are GIS layers, too. Like all geographic information, they are georeferenced to a location on Earth, which means they are registered with the other geographic layers in the GIS. This overlay capability is the fundamental concept upon which GIS operates. When combined with other mappable data, imagery transcends its status as merely a picture and becomes a true information source—data that can be combined, compared, and analyzed with any other data layers for the same area.

33.746851, -118.321296
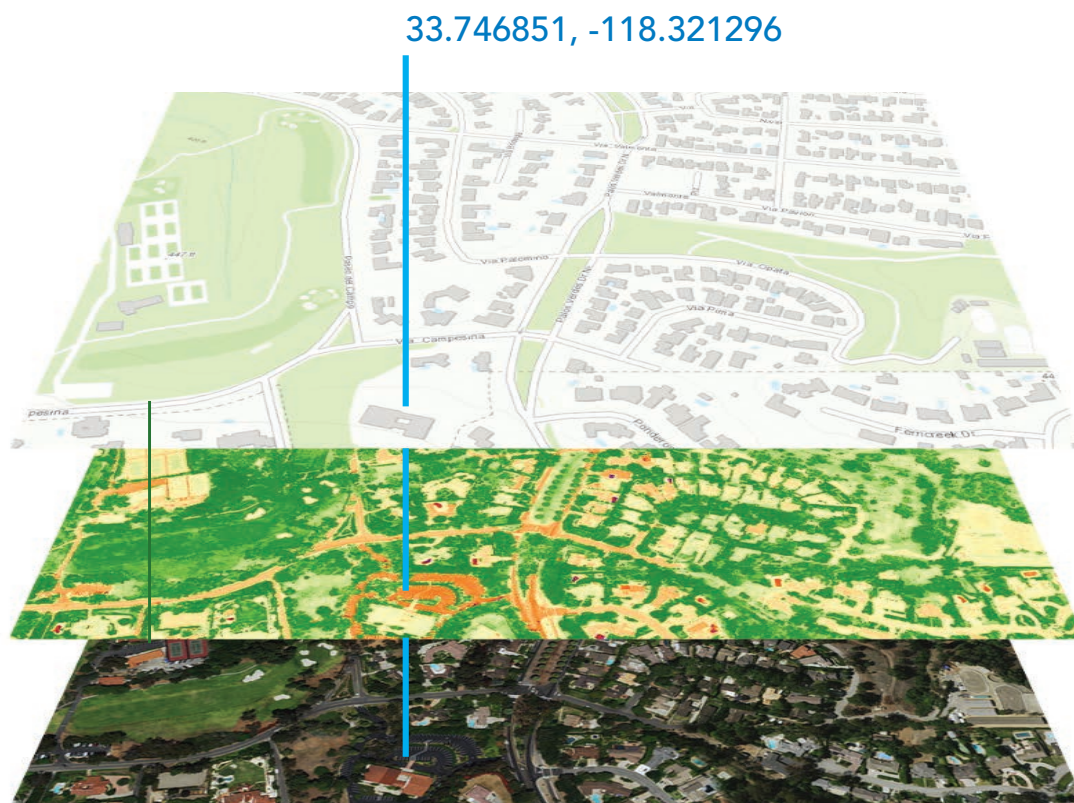
All layers register and align in a GIS, including imagery layers. Georeferencing of information in this way is the hallmark of GIS and allows disparate types of information to be displayed, combined, and analyzed in a common geographic space.

An adaptable format
Any GIS layer can be represented as a raster

Once you realize rasters are just geographically aligned image files, they become the basis for a simple, universally applicable data format. All imagery is managed simply as collections of rasters. In similar ways, virtually any GIS dataset—vector features, continuous surfaces, and time series information—can also be represented using rasters.

In this way, GIS helps to organize and make sense of imagery. Unique datasets for a specific expanse of geography (its scale and extent) form a layer stack (sometimes called a data cube), which enables you to integrate an unlimited collection of independent layers. Consequently, imagery provides many of the layers in every GIS and adds extraordinary power.
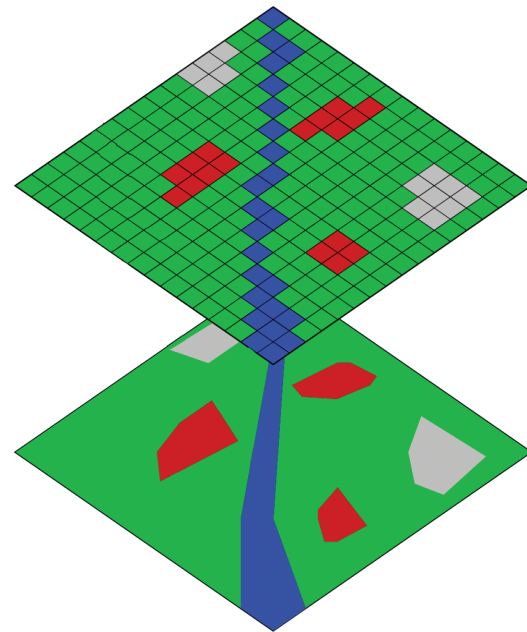
Rasters can represent surfaces
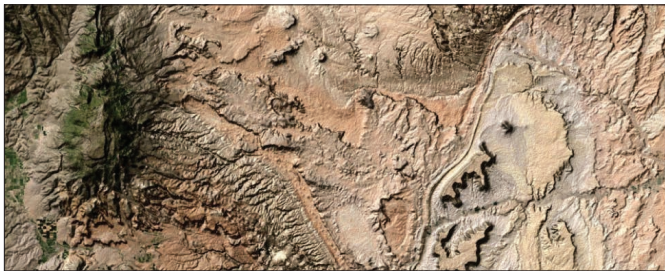
This example shows the extremely variable and dramatic elevation surfaces of southern Utah using the Landsat Shaded Basemap.

Rasters can represent time

This web mapping application is designed to show the monthly average snowpack depth for the year 2014.

Rasters can represent features

This diagram shows a stream segment as a vector (the variable-width blue polygon in the lower view) converted into a raster (along with other features) in the upper view.

Orthorectified imagery
Using elevation to enable accurate image georeferencing

Imagery has an amazing amount of information, but raw aerial or satellite imagery cannot be used in a GIS until it has been processed such that all pixels are in an accurate (x,y) position on the ground. Photogrammetry is a discipline, developed over many decades, for processing imagery to generate accurately georeferenced images, referred to as orthorectified images (or sometimes simply orthoimages). Orthorectified images have been processed to apply corrections for optical distortions from the sensor system, and apparent changes in the position of ground objects caused by the perspective of the sensor view angle and ground terrain.

Raw image | 25 degrees | Rectified | Nadir
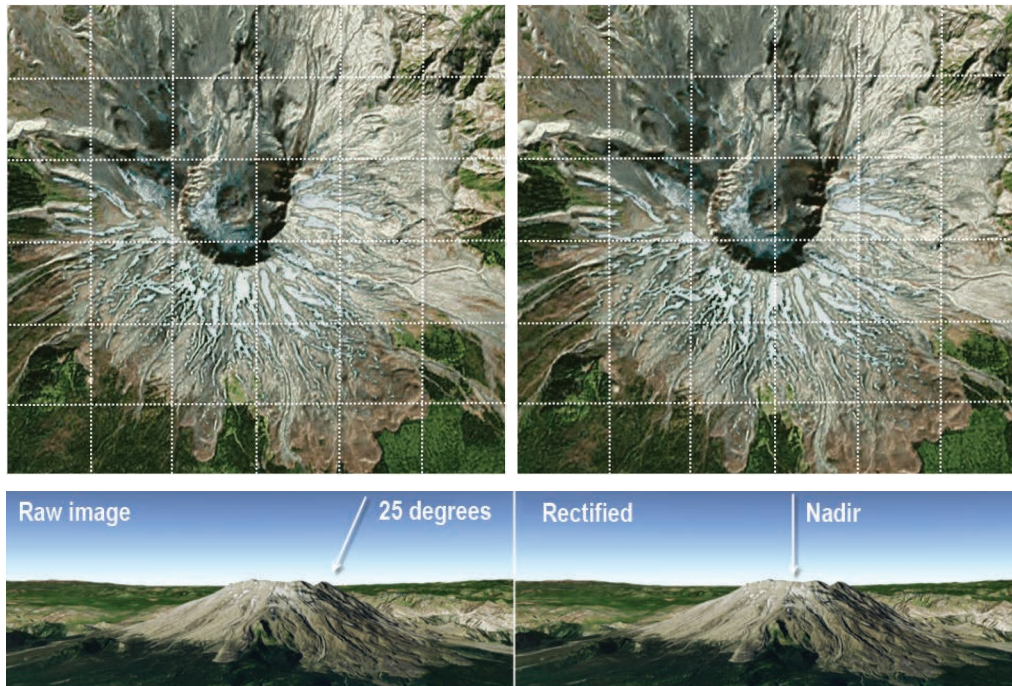
A view captured from an oblique angle (for example, 25°, left) must be corrected for relief displacement caused by terrain to generate the orthorectified view (looking straight down, right). Orthoimagery is produced by calculating the nadir view for every pixel.

The orthorectification process requires: An accurate description of the sensor, typically called the sensor model; detailed information about the sensor location and orientation for every image; and an accurate terrain model, such as the World Elevation service available from ArcGIS Online. After imagery has been orthorectified, it can be used within a GIS and accurately overlaid with other data layers.

Multispectral imagery
Enabling extrasensory perception

One of the most extraordinary types of imagery collected by remote sensing is multispectral imagery. Each image is composed of data from a series of onboard sensors that collect small slices (or bands) across the electromagnetic spectrum. The table below shows the complete list of wavelengths (expressed as bands) that are collected by the Landsat 8 imagery according to what they capture. The images below are examples of what you "see" by combining different bands into red, green, and blue electronic displays or hard-copy prints.

Band 1	Coastal Aerosol	Band 4	Red	Band 7	Shortwave Infrared 2	Band 10	Thermal Infrared
Band 2	Blue	Band 5	Near Infrared			Band 11	Thermal Infrared
Band 3	Green	Band 6	Shortwave Infrared 1	Band 8	Panchromatic		
				Band 9	Cirrus		

Image bands for Landsat 8 can be combined to create a number of scientific data layers used for research and analysis. For details, visit USGS Landsat online.

Natural color

The Natural Color (bands 4, 3, 2) combination of red, green, and blue is well suited for broad-based analysis of both terrestrial and underwater features and for urban studies.

Color infrared

Color infrared photography, often called false color photography because it renders the scene in colors other than those normally seen by the human eye, is widely used for interpretation of natural resources.

Land and water interface

Landsat GLS Land and Water Boundary (bands 4, 5, 3) emphasizes the edges between land and water.

Vegetation analysis
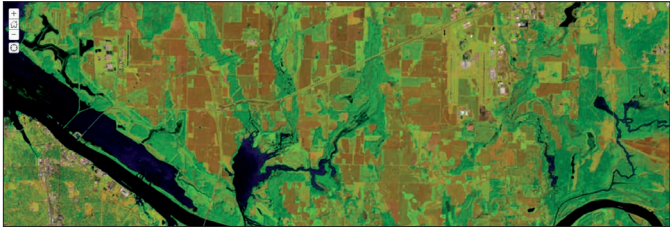
This 6, 5, 4 band combination shows irrigated vegetation as bright green. Soils appear as tan, brown, and mauve.

Mosaic datasets
Collections of images

The recommended data structure within ArcGIS to manage and process imagery is the mosaic dataset. A mosaic structure enables significant big data capabilities for large, even massive, image collections. Each mosaic is composed of a number of related raster datasets, enabling you to keep your original individual image files on disk and to access them as part of a larger, integrated single collection. Mosaics are used to create a continuous image surface across large areas. For example, among other scenarios, you can use mosaics to handle coverage of very high-resolution image files for an entire continent. Or you can manage an entire historical map series for a nation for every year and every map scale. You can even manage huge multidimensional collections of time series information for earth observations and climate forecast modeling (often referred to as 4D). Creating mosaics is straightforward. You can point to a series of source georeferenced image files and automatically assemble a mosaic in minutes where each image acts as a tile within the collection.
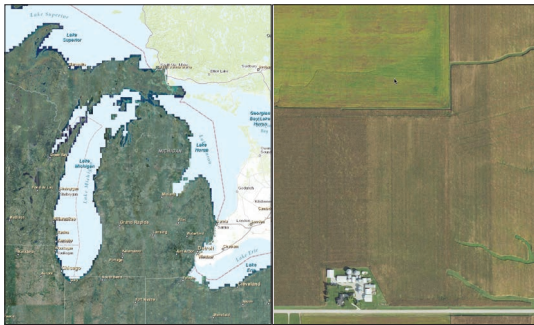

Managing extremely large collections

On the left is a mosaic overview for areas around Michigan, Illinois, and Wisconsin; a rural view of farms is on the right. This mosaic dataset by the National Agriculture Imagery Program (NAIP) contains well over 400,000 individual image tiles and covers the continental US. It includes the full information across multiple bands for each NAIP image as well as overviews for working with imagery at multiple scales.
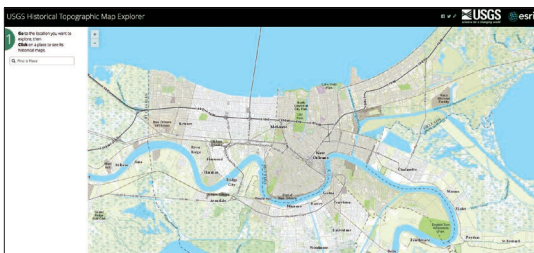
Bringing historical collections to life

Image mosaics can also be made up of scanned historical maps, like the Historical Topographic Map Explorer containing 175,000 historic USGS maps accessible as an image mosaic in ArcGIS Online. You can also georeference your own historic maps and early aerial photographs and assemble them into mosaics.
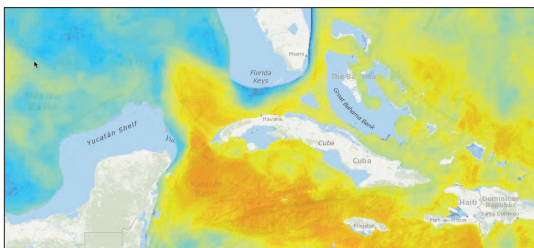
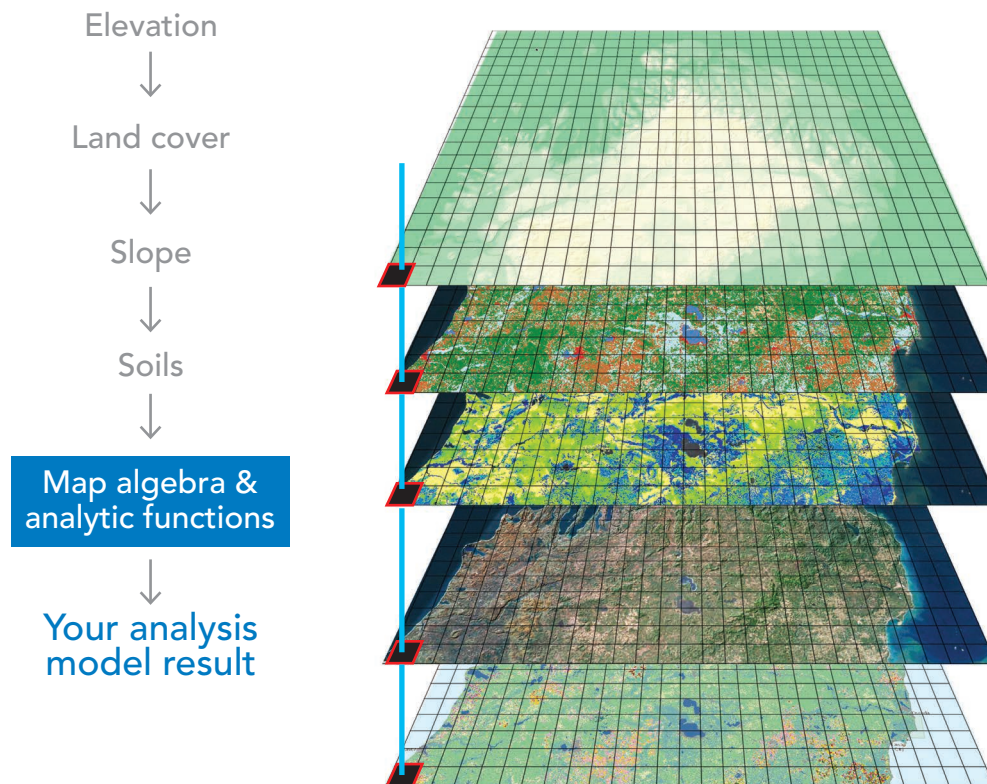### Analyzing multidimensional data

Multidimensional data is captured by location, by ocean depth, and by date. Earth scientists often refer to this data as 4D because it represents location in three dimensions with time as the extra dimension. Mosaic datasets help to manage and apply multidimensional data.

Rasters facilitate analysis

Assembling layer stacks

Rasters facilitate a broad array of sophisticated spatial operations and mathematical functions by providing a simple, universal data format that facilitates virtually any kind of geographic dataset. In turn, these enable simple workflows for performing all types of interesting and complex analytical operations and computations. When raster cells are piled on top of each other, they become a kind of processing-enabled data "stack."

Any GIS data layer can be turned into a gridded dataset, assembled with other datasets, thus creating a stack that can contain many layers, enabling you to combine data in useful analytic models.

Elevation
↓
Land cover
↓
Slope
↓
Soils
↓
**Map algebra &
analytic functions**
↓
**Your analysis
model result**

Rasters enable powerful analytic capabilities. For example, rasters stack on top of one another, enabling integration and useful overlay operations. And neighboring cells within a raster can be used for calculating zonal statistics, proximity to selected features, surface modeling, and flow functions. In addition, both 3D and time can be enabled analytically in significant ways.