PLSCS/NTRES 6200
Spatial Modelling and Analysis

Introduction to Geographic Information Systems (GIS)

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January 3, 2019

What is a GIS?

- **G**eographic **I**nformation **S**ystem
  - GIS also stands for “Geographic Information Science”
- Manages **information** about **geographic entities**, i.e., with defined **spatial location** and **extent**
- Function: **data storage, manipulation and organization**
- Function: **spatial analysis**
- Function: **map composition and display**
- Function: **visualization** (static, dynamic)

Some GIS textbooks

- O'Sullivan, D., & Unwin, D. (2010). Geographic information analysis (2nd ed.). Wiley.
- Burrough, P. A., McDonnell, R., & Lloyd, C. D. (2015). Principles of geographical information systems (3rd edition). Oxford; New York: Oxford University Press.
- Bolstad, P. (2016). GIS fundamentals: a first text on geographic information systems (5th edition.). Acton, MA: XanEdu.
- Campbell, J. E., & Shin, M. (2012). Geographic Information System Basics. Retrieved December 28, 2018, from http://2012books.lardbucket.org/books/geographic-information-system-basics/index.html

Some references using the GI Science term

- Asami, Y., & Longley, P. (2012). Spatial thinking and geographic information science. Environment and Planning B-Planning & Design, 39(6), 975–977. https://doi.org/10.1068/b3906ge
- Blaschke, T., & Merschdorf, H. (2014). Geographic information science as a multidisciplinary and multiparadigmatic field. Cartography and Geographic Information Science, 41(3), 196–213. https://doi.org/10.1080/15230406.2014.905755
- Goodchild, M. F. (2004). The validity and usefulness of laws in geographic information science and geography. Annals of the Association of American Geographers, 94(2), 300–303. https://doi.org/10.1111/j.1467-8306.2004.09402008.x
- O'Sullivan, D. (2005). Geographical information science: time changes everything. Progress in Human Geography, 29(6), 749–756. https://doi.org/10.1191/0309132505ph581pr
- Singleton, A. D., Spielman, S., & Brunsdon, C. (2016). Establishing a framework for Open Geographic Information science. International Journal of Geographical Information Science, 30(8), 1507–1521. https://doi.org/10.1080/13658816.2015.1137579
- Wilson, J. P., & Fotheringham, A. S. (2008). The handbook of geographic information science. Malden, MA: Blackwell Pub. Retrieved from http://catdir.loc.gov/catdir/toc/ecip0712/2007008297.html

Data in a GIS

non-spatial with *no* spatial reference

- example: **attributes** of a soil type (horizon names and depths, particle-size distribution of each horizon . . .)
- example: **attributes** of a census block (total population, median age, proportion female . . .)

spatial *with* spatial (geo-)reference

- example: **location** of a soil profile of a given soil type
- example: **location** of a road centre-line
- example: **location** of a census block: boundary (polygon), centroid (point)

In a GIS, *non-spatial* information is only stored in order to be **linked** to *spatial* information

- e.g., to display a map (polygons) of the soil thickness to bedrock (attribute)
- e.g., to display a road's surface material, maintainer, traffic volume . . .

GIS data types (2D)

vector Exact geographic position given by coördinates for:

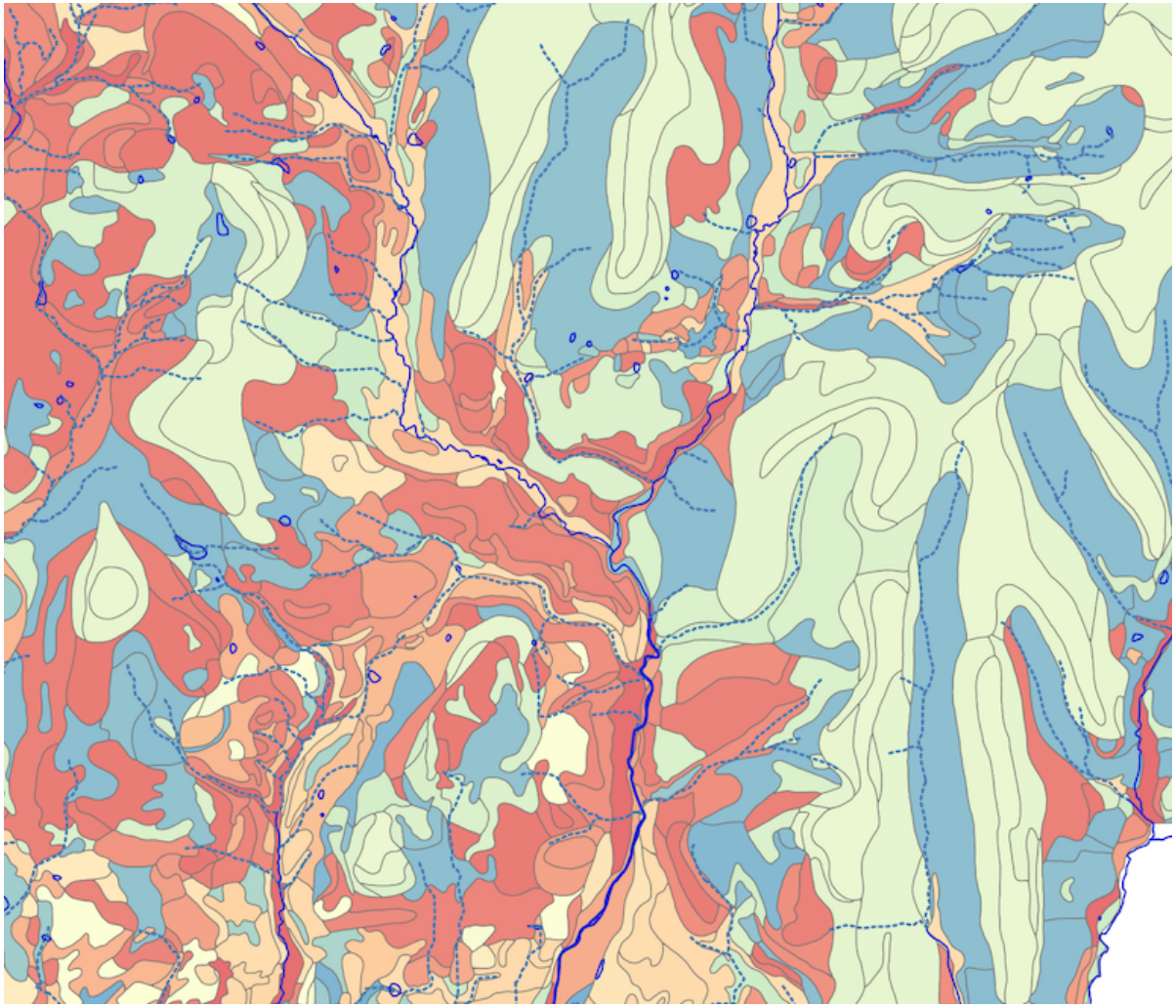
points 0-dimensions
lines 2-dimensions, connecting points
polygons lines enclosing an area
triangular irregular networks (TIN) triangles formed by three lines/points

raster (also called "grid")

grid cells regular tesselation; geographic position of centroid or a corner; fixed dimension
- square, rectangular, hexagonal . . .

pixels "picture elements", grid cells of imagery
- generally processed to be square in some coördinate reference system (CRS)

Example vector layers

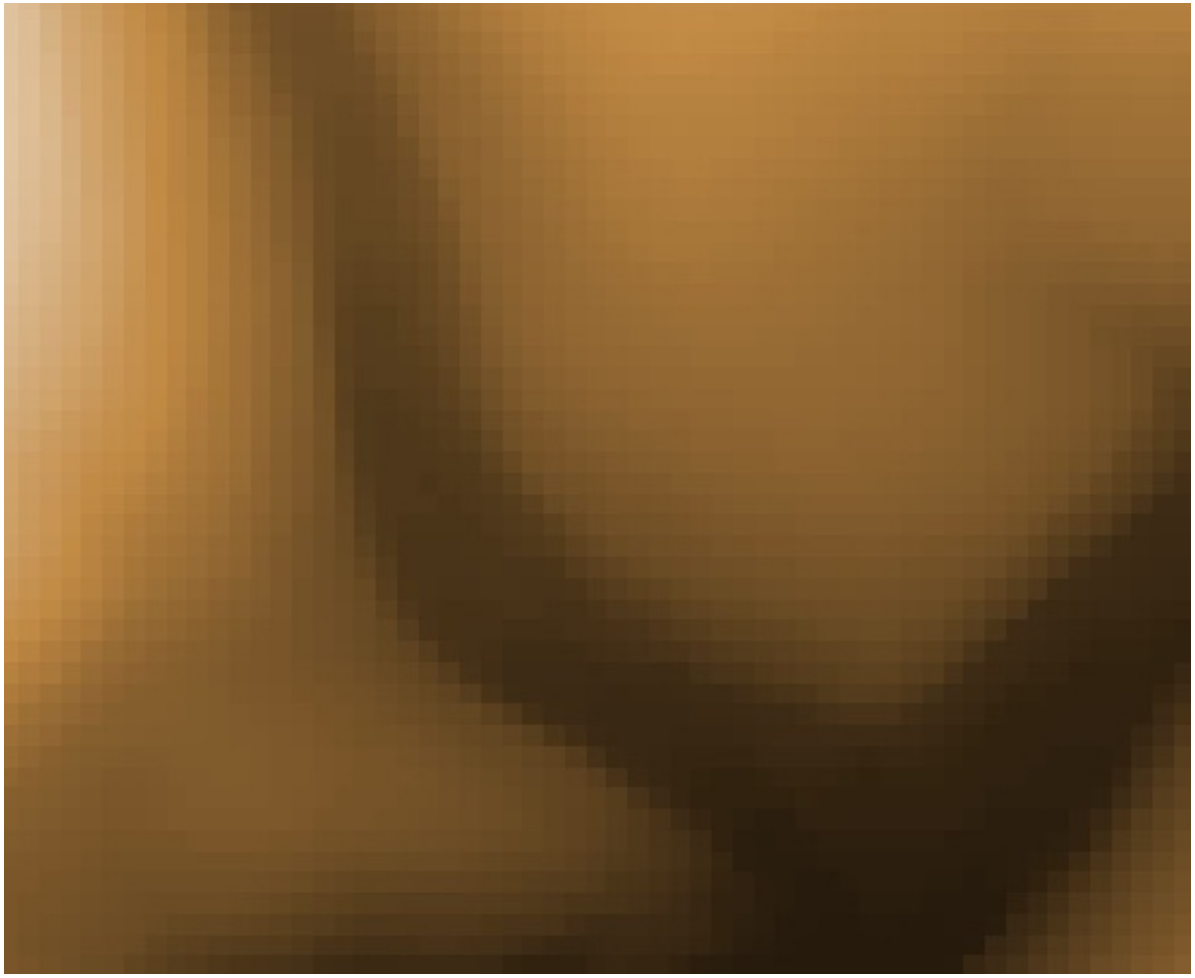


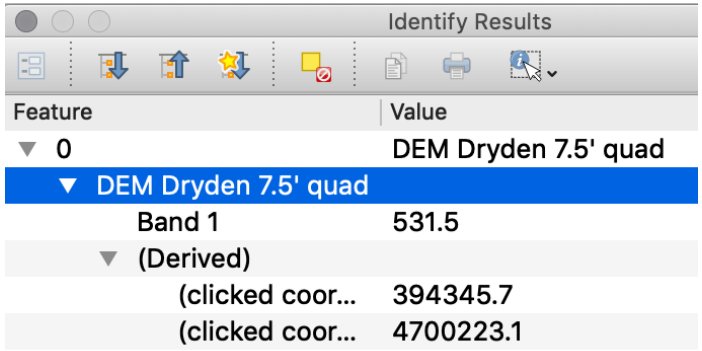
Identify Results

Feature	Value
SSURGO soil map units...	
fid	11936
(Derived)	
Part number	1
Parts	1
Feature ID	11936
Closest verte...	196
Vertices	386
(clicked coor...	391406
Closest X	391540
Closest verte...	391541
Closest Y	4697446
(clicked coor...	4697454
Closest verte...	4697454
Area (Cartesi...	743735.785 m²
Area (Ellipsoi...	744116.438 m²
Perimeter (Ca...	8578.992 m
Perimeter (Elli...	8581.189 m
(Actions)	
SPATIALVER	9
fid	11936
MUKEY	295650
MUSYM	LnE
SSURGO map un...	Lordstown channery silt loam, 25 to 35 percent slopes
SSURGO map un...	Not prime farmland
AREASYMBOL	NY109

soil map units: **polygons**; stream network: **polylines**
each object has **attributes** (feature-space characteristics)

Example raster layer



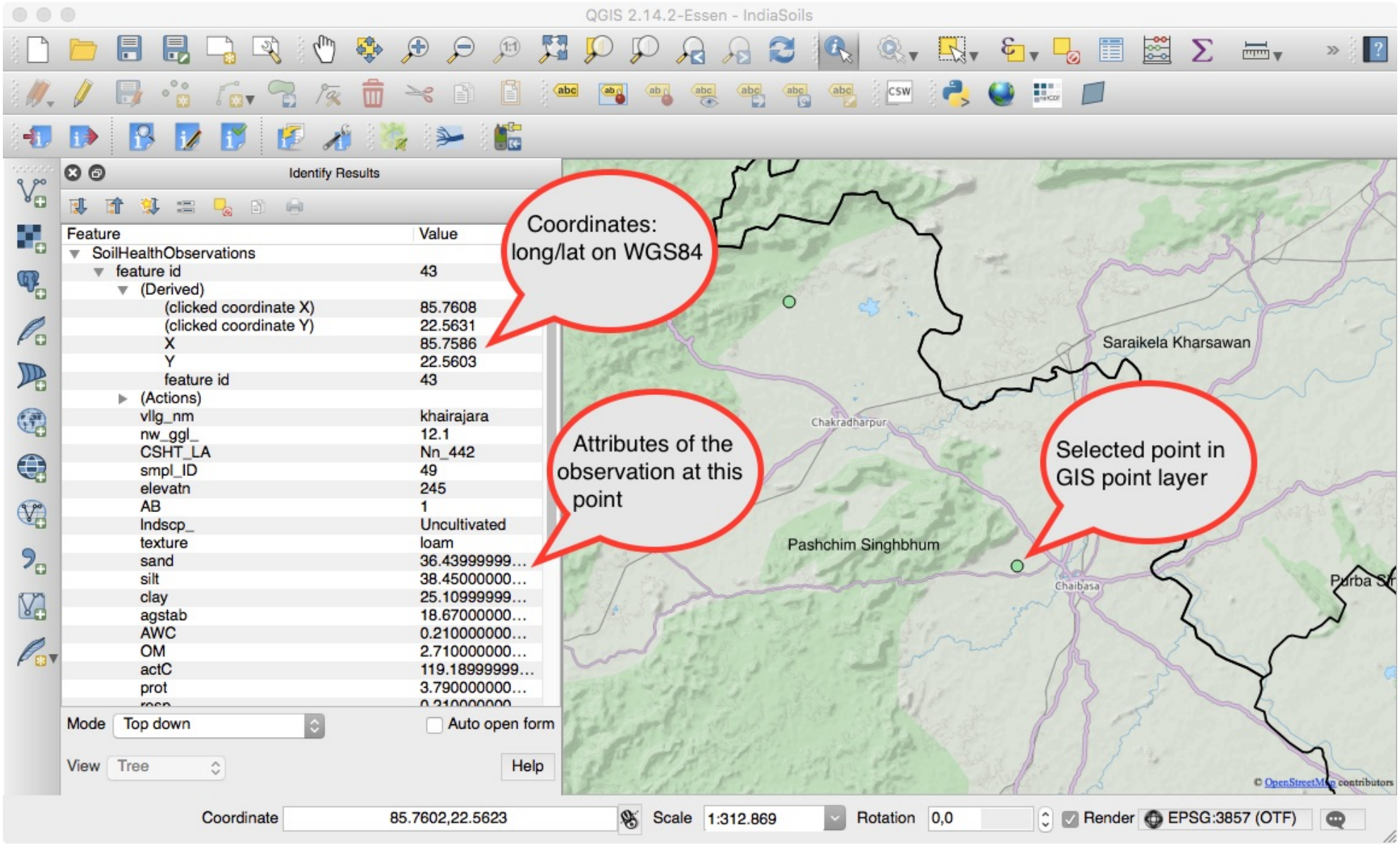


10 x 10 m horizontal resolution

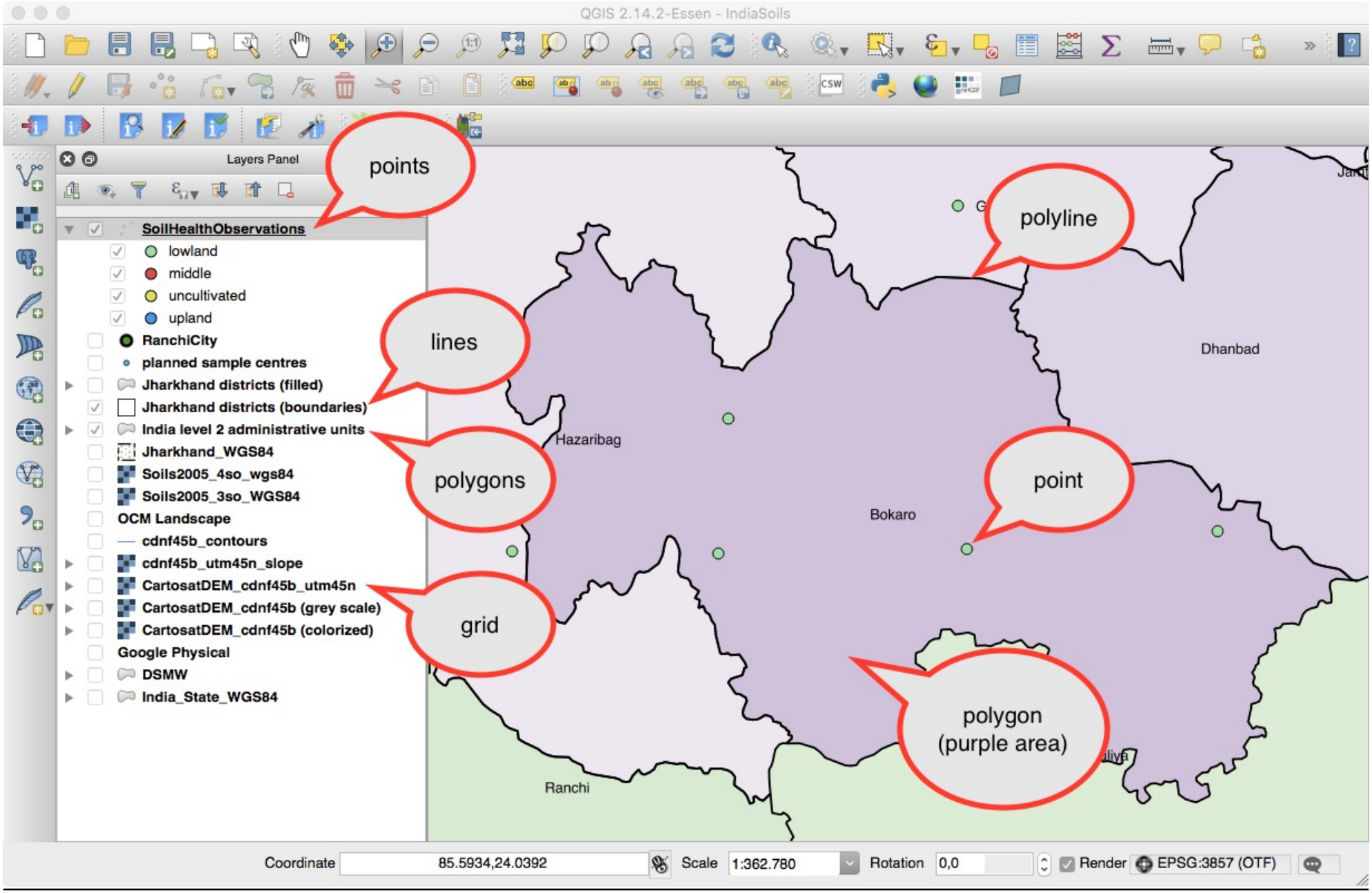
`.dem`: USGS Digital Elevation Model (DEM) data file

Each pixel centroid gives the elevation m.a.s.l.

Spatial objects: location and attributes



Types of spatial objects



GIS data types (3D)

vector positions in 3D

- including height or depth relative to a vertical datum (origin)

raster 3D grid cells or voxels “volume elements”

- centroid has 3D position with respect to a CRS or a grid origin
- note a DEM is 2D, with the elevation as an *attribute*, not a coördinate

(Geospatial) Toplogy

- In **vector** GIS, the rules specifying **valid geometric relationships** between vector objects (points, polylines and polygons)
  - In **raster** GIS the topology is implicit in the grid structure
- Especially, **connecting** or **adjacent** features
- Does not consider the coördinates as such, just their spatial relations
- Enforced by the GIS during operations
- Standards, e.g., Simple Features (ISO 19125), Dimensionally Extended nine-Intersection Model (DE-9IM)

Topology errors

undershoots lines should meet at a point but one line does not reach the point

overshoots lines should meet at a point but one line extends beyond

slivers vertices of polyons that should match (common border) are digitzed separately, so a “ghost” polygon is between them

open polygons boundary does not close

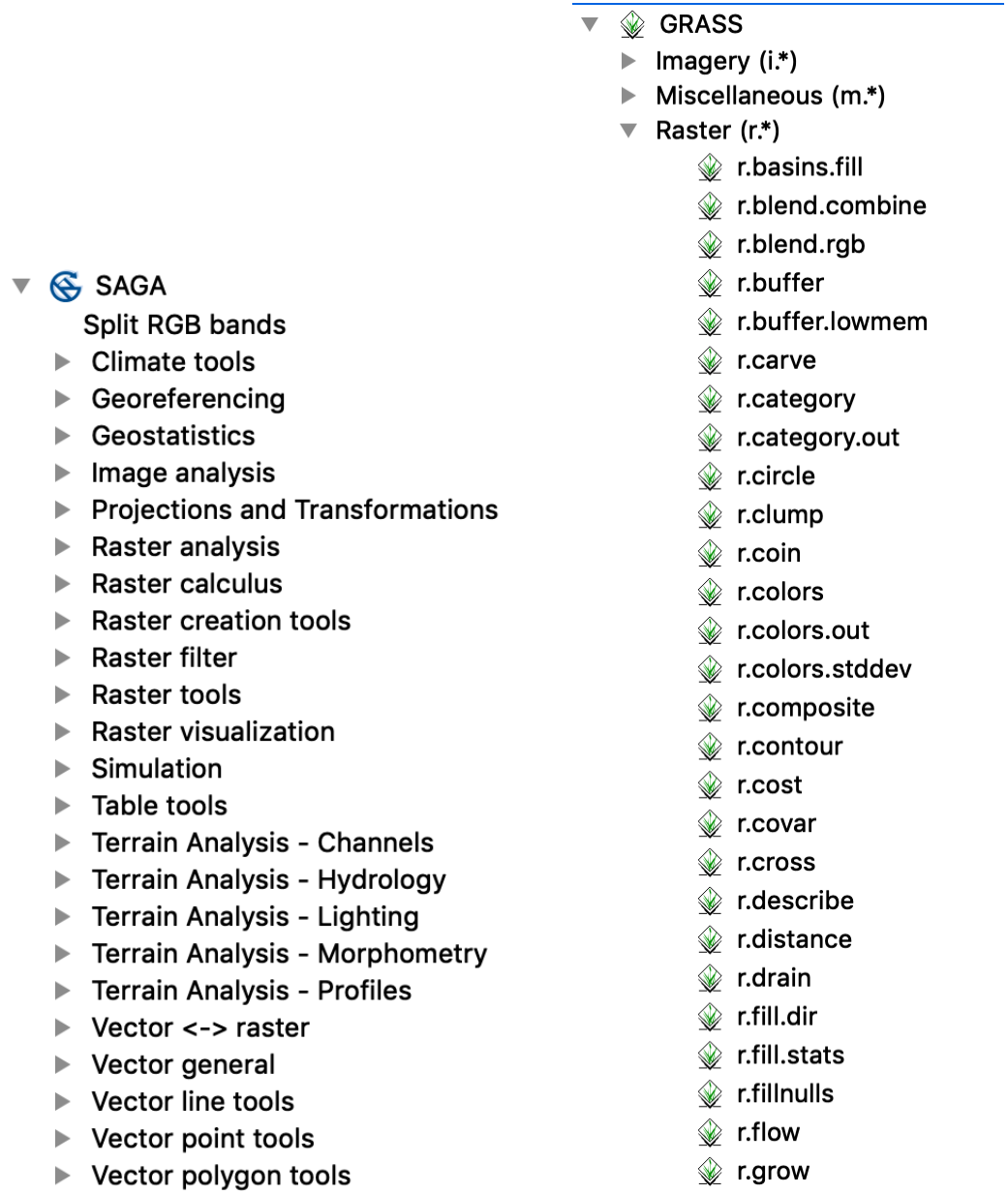
GIS operations – data storage, manipulation and organization

- Vector geometry
  - Add geometry attributes
  - Aggregate
  - Boundary
  - Bounding boxes
  - Buffer
  - Centroids
  - Check validity
  - Collect geometries
  - Concave hull (alpha shapes)
  - Concave hull (k-nearest neighbor)
  - Convert geometry type
  - Convex hull
  - Create layer from extent
  - Create wedge buffers
  - Delaunay triangulation
  - Delete holes
  - Densify by count
  - Densify by interval
  - Dissolve
  - Drape (set z-value from raster)
  - Drop M/Z values
  - Eliminate selected polygons
  - Explode lines
  - Extend lines
  - Extract specific vertices
  - Extract vertices
  - Filter vertices by m value
  - Filter vertices by z value
  - Fix geometries
  - Geometry by expression
  - Interpolate point on line
  - Keep N biggest parts
  - Line substring
  - Lines to polygons
  - Merge lines
  - Minimum bounding geometry
  - Minimum enclosing circles
  - Multi-ring buffer (constant distance)
  - Multipart to singleparts
  - Offset lines
  - Oriented minimum bounding box
  - Orthogonalize
  - Point on surface
  - Points along geometry
  - Points displacement
  - Pole of inaccessibility
  - Polygonize
  - Polygons to lines
  - Project points (Cartesian)
  - Promote to multipart
  - Rectangles, ovals, diamonds (fixed)
  - Rectangles, ovals, diamonds (variable)
  - Remove duplicate vertices
  - Remove null geometries
  - Reverse line direction
  - Rotate
  - Segmentize by maximum angle
  - Segmentize by maximum distance
  - Set M value
  - Set m-value from raster
  - Set Z value
  - Simplify
  - Single sided buffer
  - Smooth
  - Snap geometries to layer
  - Snap points to grid
  - Subdivide
  - Swap X and Y coordinates
  - Tapered buffers
  - Tessellate
  - Transect
  - Translate
  - Variable width buffer (by m-value)
  - Voronoi polygons

GIS operations – spatial analysis (1)

- Vector analysis
  - Basic statistics for fields
  - Count points in polygon
  - DBSCAN clustering
  - Distance matrix
  - Distance to nearest hub (line to hub)
  - Distance to nearest hub (points)
  - Join by lines (hub lines)
  - K-means clustering
  - List unique values
  - Mean coordinate(s)
  - Nearest neighbour analysis
  - Statistics by categories
  - Sum line lengths
- Raster analysis
  - Raster calculator
  - Raster layer statistics
  - Raster layer unique values report
  - Reclassify by layer
  - Reclassify by table
  - Sample raster values
  - Zonal histogram
  - Zonal statistics
- Raster terrain analysis
  - Aspect
  - Hillshade
  - Hypsometric curves
  - Relief
  - Ruggedness index
  - Slope
- Network analysis
  - Service area (from layer)
  - Service area (from point)
  - Shortest path (layer to point)
  - Shortest path (point to layer)
  - Shortest path (point to point)

GIS operations – spatial analysis (2)



GIS operations – map composition and display

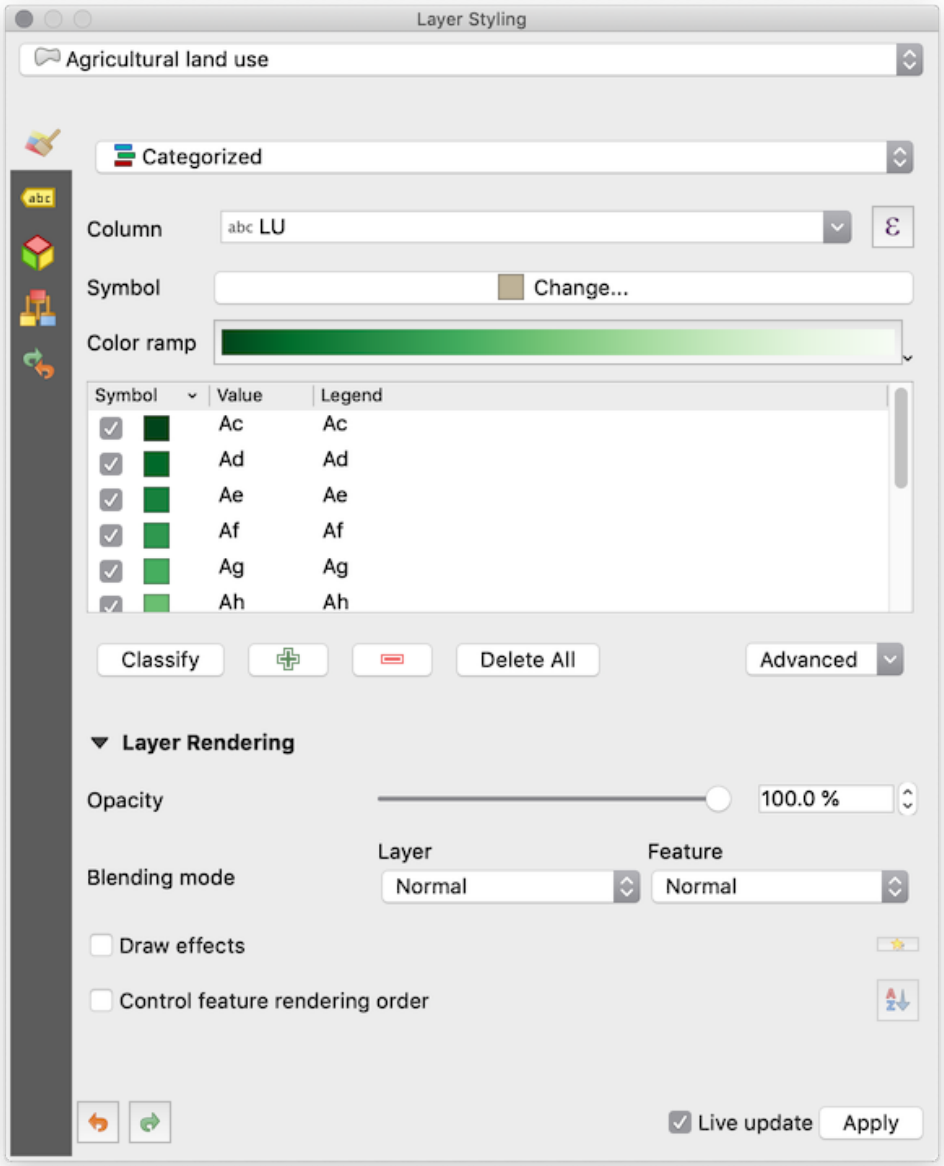
- on-screen (interactive)
- printed (static)
- layers (symbolized), annotations (scale bars, grids, compass . . .)

GIS operations – visualization

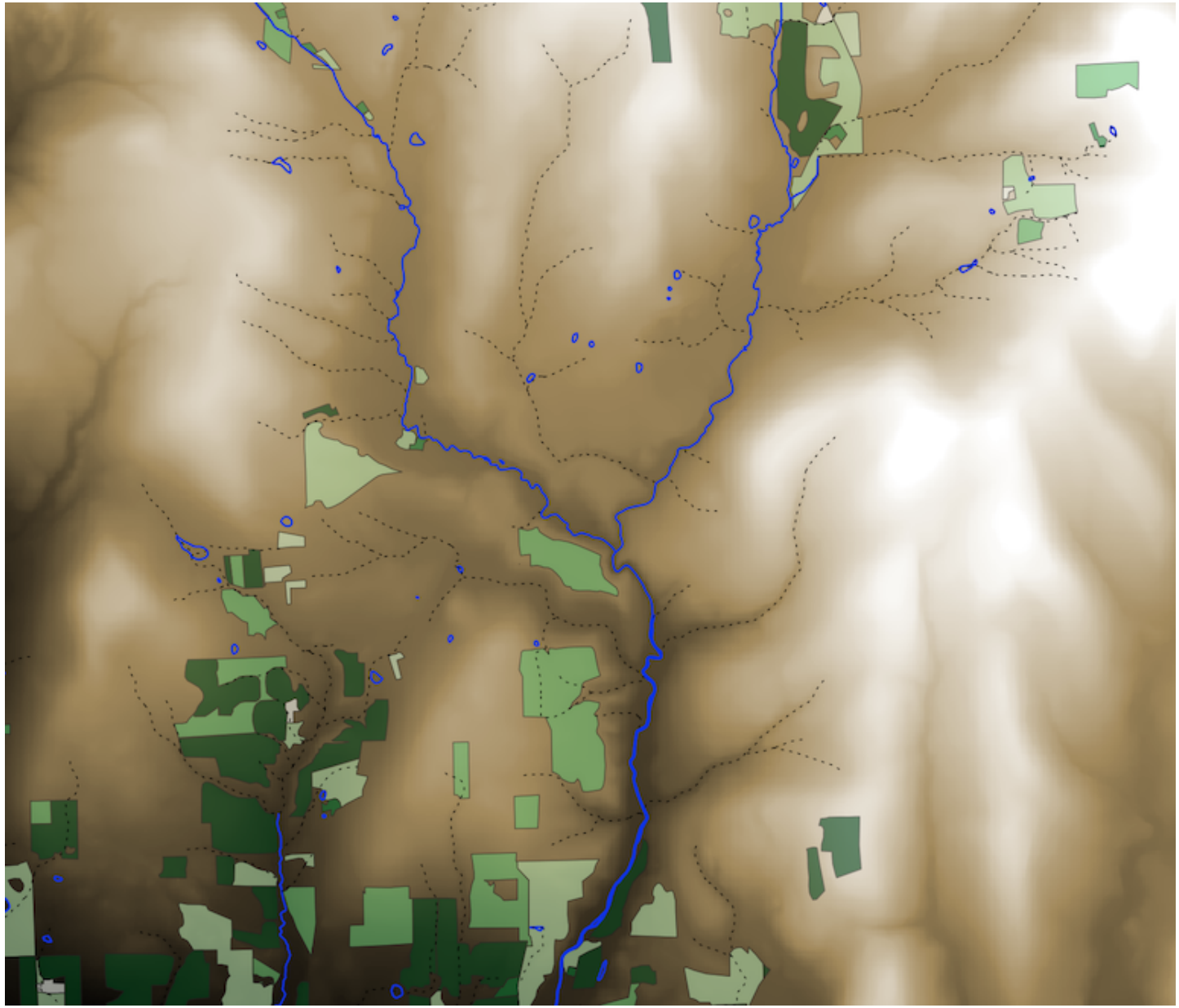
- symbolize a layer
  - colours, line widths, point sizes, point symbols . . .
  - should **communicate the theme to the viewer**
- display several layers together
  - display order, transparency, contrasting colour schemes and symbology
  - should communicate the relation to the viewer
- Reference: Monmonier, M. S. (2018). How to lie with maps (3rd ed.). Chicago: The University of Chicago Press.

  "An instant classic when first published in 1991, . . . reveal[s] how the choices mapmakers make consciously or unconsciously mean that **every map inevitably presents only one of many possible stories** about the places it depicts. . . . Fully updated for the digital age, this new edition . . . examines the myriad ways that **technology offers new opportunities** for cartographic mischief, deception, and propaganda."

Layer symbolization



Relation of agricultural land to stream network and elevation



What is QGIS?

An open-source, community-built GIS:

- a project of the Open Source Geospatial Foundation (OSGeo)[1]
- released under the GNU GPL license: free to use, distribute and modify but not sell
- **cross-platform**: runs on Linux, Unix, Mac OSX, Windows and Android
- **fully programmable** (scripts, Python)
- **plugins** bring the functionality of other popular open-source GIS into QGIS
  - SAGA, GRASS, Tau-DEM, GDAL, R . . .
- On-the-fly transformation of coördinate reference systems
- inclues a **graphical modeler** to build process flow models

[1] http://www.osgeo.org

Why QGIS?

- Attractive and fairly intuitive **user interface**
- Has “all” vector and raster GIS capabilities
- Handles “all” data formats; including ESRI, ERDAS . . .
- **Extensible** via plugins and Python scripts; active user community
- Open-source, **free**, so accessible to anyone (e.g., NGO’s, low-budget organizations)

Why *not* QGIS?

- Employer may have decided for a commercial GIS
- Extensions may be available only for a commercial GIS (e.g., ArcGIS Geostatistical Modeler)

Resources

Several documents are provided by the QGIS project[2]; these are also accessible from the `Help | Help Contents` menu item:

- QGIS User's Guide
- QGIS Training Manual
- A Gentle Introduction to GIS

Another source is the QGIS Tutorials and Tips page[3].

[2] http://qgis.org/en/docs/index.html
[3] http://www.qgistutorials.com/en/index.html

Installing QGIS

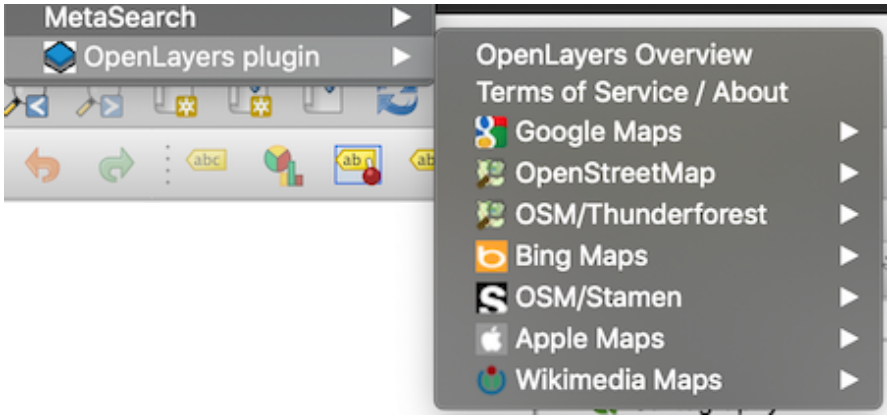
The download page[4] explains how to download for various platforms.

QGIS is installed in Bradfield 108 and some Mann Library clusters.

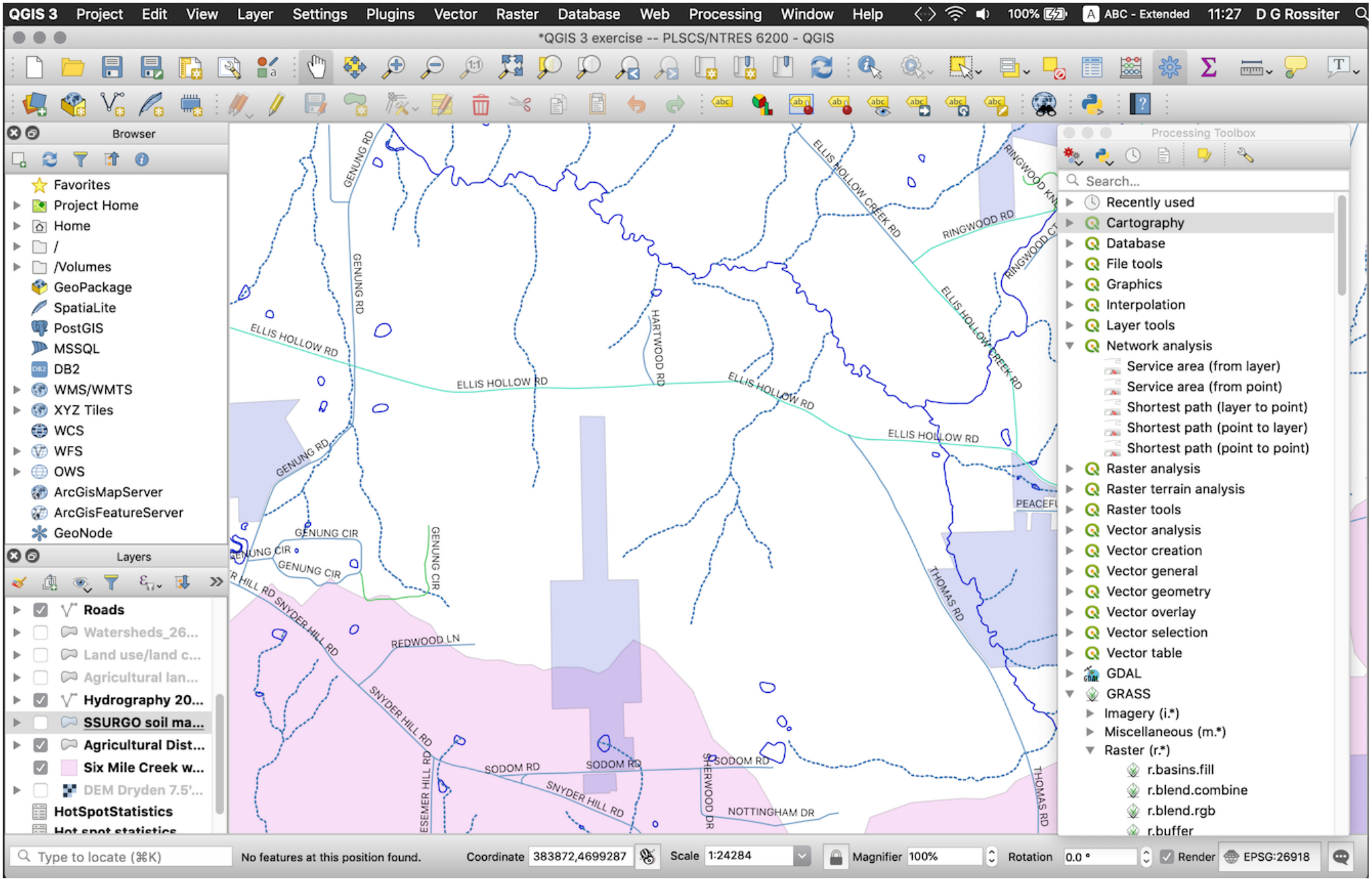
[4] https://qgis.org/en/site/forusers/download.html

User interface components

- Map display with scale, CRS, coördinates of cursor, map query
- Browser; includes access to OWS, WCS, WFS, WMS map servers

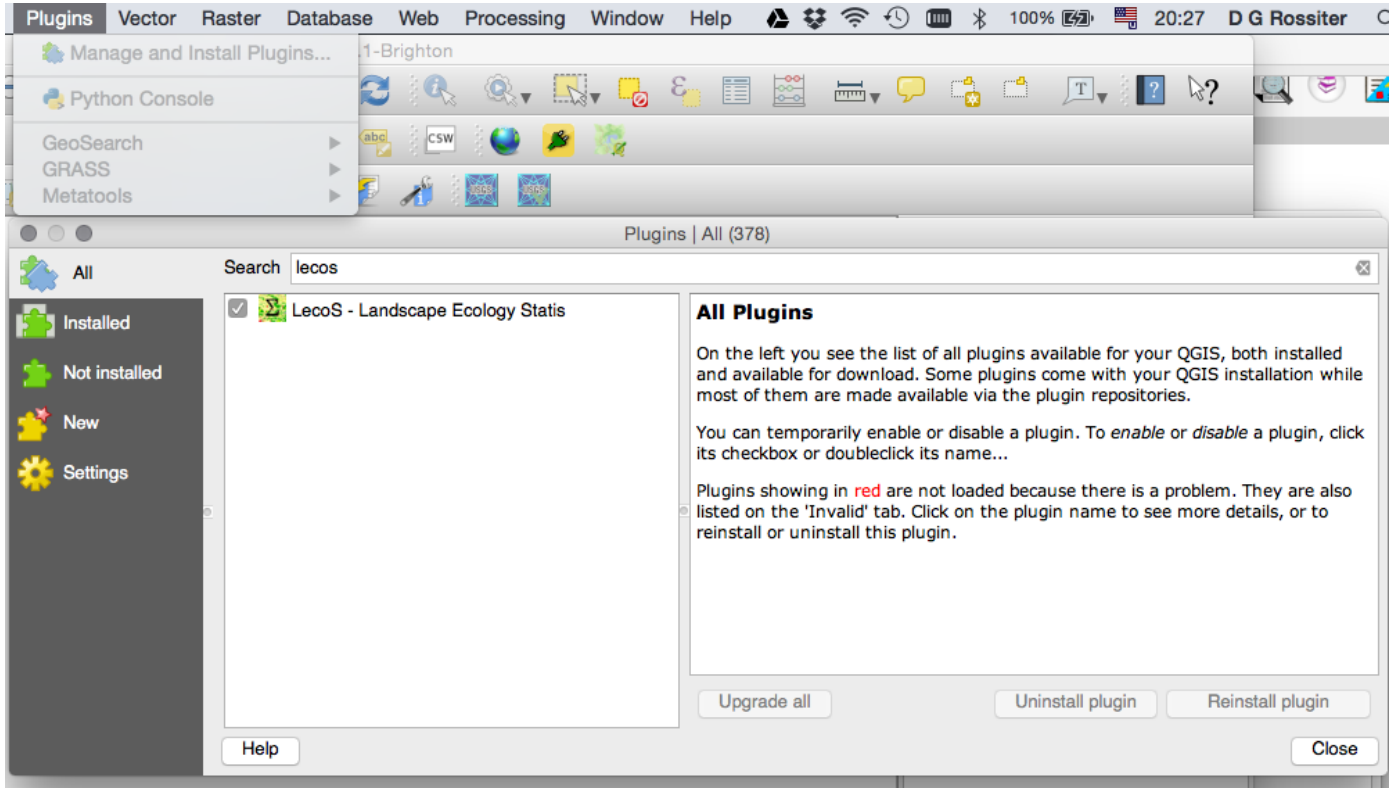


- Layer list (current project)
- Toolbars
- Processing toolbox
- Log


QGIS 3 Project Edit View Layer Settings Plugins Vector Raster Database Web Processing Window Help
*QGIS 3 exercise -- PLSCS/NTRES 6200 - QGIS
Browser
Favorites
Project Home
Home
/
/Volumes
GeoPackage
SpatiaLite
PostGIS
MSSQL
DB2
WMS/WMTS
XYZ Tiles
WCS
WFS
OWS
ArcGisMapServer
ArcGisFeatureServer
GeoNode
Layers
Roads
Watersheds_26...
Land use/land c...
Agricultural lan...
Hydrography 20...
SSURGO soil ma...
Agricultural Dist...
Six Mile Creek w...
DEM Dryden 7.5'...
HotSpotStatistics
Processing Toolbox
Search...
Recently used
Cartography
Database
File tools
Graphics
Interpolation
Layer tools
Network analysis
Service area (from layer)
Service area (from point)
Shortest path (layer to point)
Shortest path (point to layer)
Shortest path (point to point)
Raster analysis
Raster terrain analysis
Raster tools
Vector analysis
Vector creation
Vector general
Vector geometry
Vector overlay
Vector selection
Vector table
GDAL
GRASS
Imagery (i.*)
Miscellaneous (m.*)
Raster (r.*)
r.basins.fill
r.blend.combine
r.blend.rgb
r.buffer
GENUNG RD
ELLIS HOLLOW RD
ELLIS HOLLOW CREEK RD
RINGWOOD RD
HARTWOOD RD
GENUNG CIR
REDWOOD LN
SNYDER HILL RD
SODOM RD
NOTTINGHAM DR
THOMAS RD
Type to locate (⌘K)
No features at this position found.
Coordinate 383872,4699287
Scale 1:24284
Magnifier 100%
Rotation 0.0 °
Render
EPSG:26918

Finding and instaling Plugins

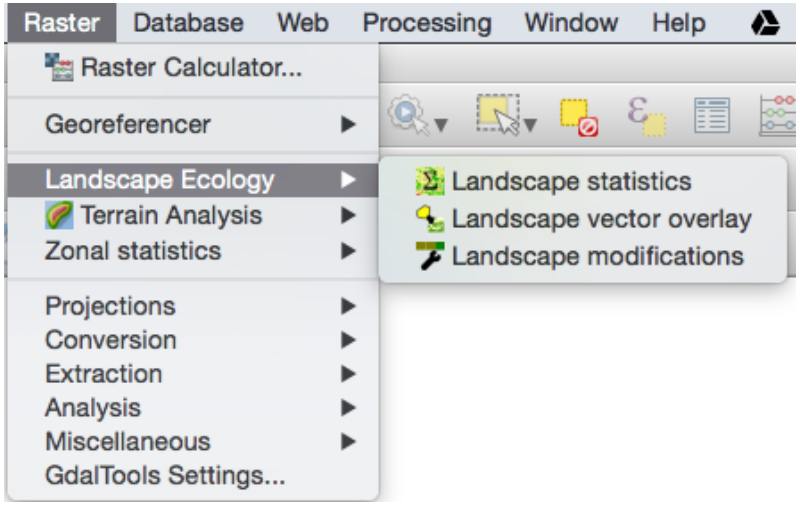
- repository `http://plugins.qgis.org/plugins/`
- access via Menu item `Plugins | Manage and Install Plugins ...`
- search by name or browse, click “Install plugin”



Using a plugin

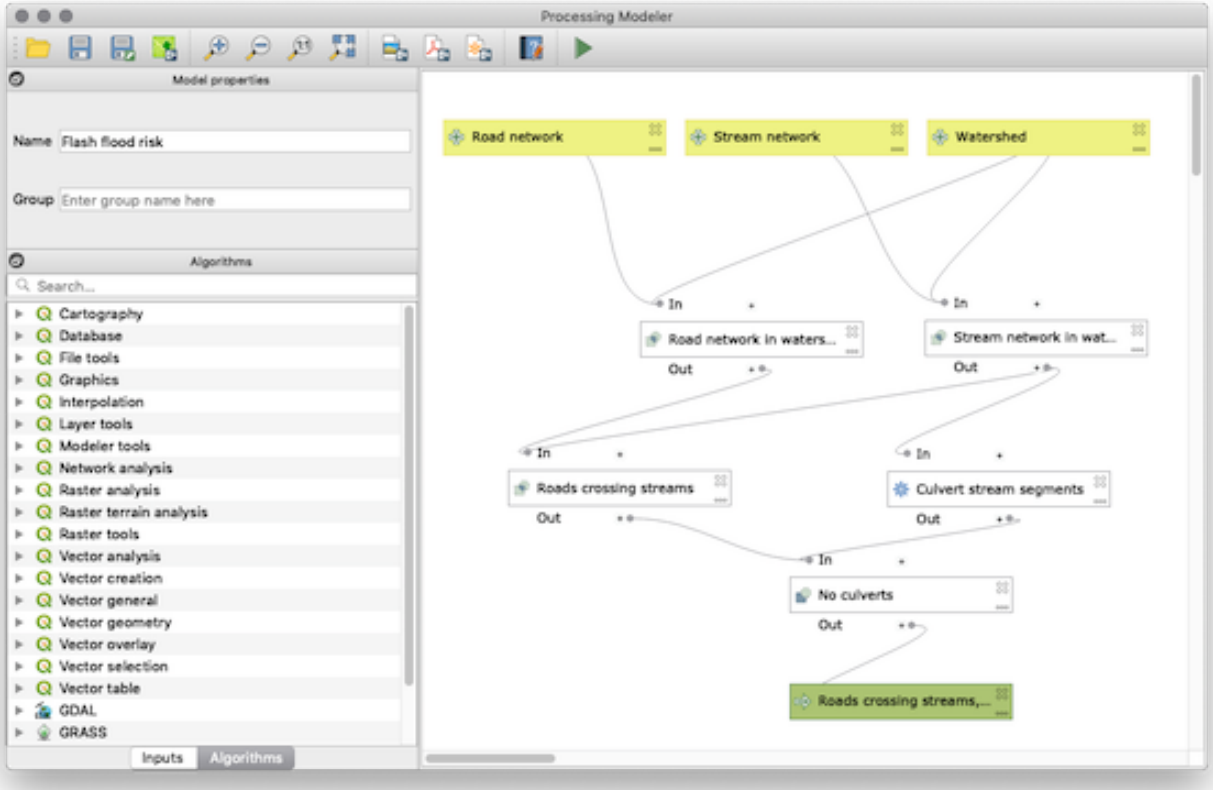
- Each plugin installs new menu items, depending on the kind of data it works on.

- For example, the Landscape Ecology plugin works on rasters, so it installs in the `Raster` menu:



Graphical modeler

- QGIS includes a **graphical modeler**:
  - define a **workflow**, i.e., a set of linked procedure
  - run it to produce one or more outputs.
  - also run as a **batch** to process several of inputs of the same type.



End