

# **CIE5401**

# **GIS and Remote Sensing in**

# **Water Resources Management**

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# **Global Precipitation Measurement Mission**

[https://www.youtube.com/watch?v=iQOsi7Dfi\\_o](https://www.youtube.com/watch?v=iQOsi7Dfi_o)

# Course Introduction: Schedule

<b>Lecture Date</b>	<b>Lecture topic</b>	<b>Assignment Due Date</b>
12 February	Introduction to GIS	19 February
19 February	Spatial Analysis in GIS	26 February
26 February	Watershed delineation	5 March
5 March	Visible RS	12 March
12 March	Thermal IR	19 March
19 March	Microwave remote sensing	26 March

# Course Introduction: Schedule

Lecture Date	Lecture topic	Assignment Due Date
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19 March	Microwave remote sensing	26 March

# Lecture outline

- Review Lecture 1
- Projections
- Spatial Analysis: Vector data in QGIS
- Spatial Analysis: Map Algebra
- Spatial Analysis: Raster data in QGIS
- Introduction to Assignment 2

# Review Lecture 1

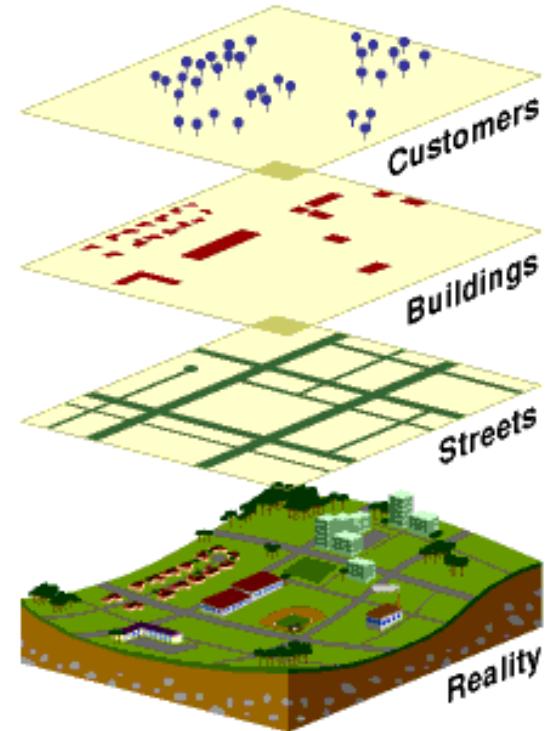
## Introduction to GIS

- What is GIS?
- Data models to represent our world
- Functions of a GIS
- Real applications of GIS in Hydrology and Water Resources Management

# Review Lecture 1

## What is a GIS?

- In a GIS, different types of information are represented as separate map layers
- Each layer is linked to descriptive information
- Layers are combined to make a map

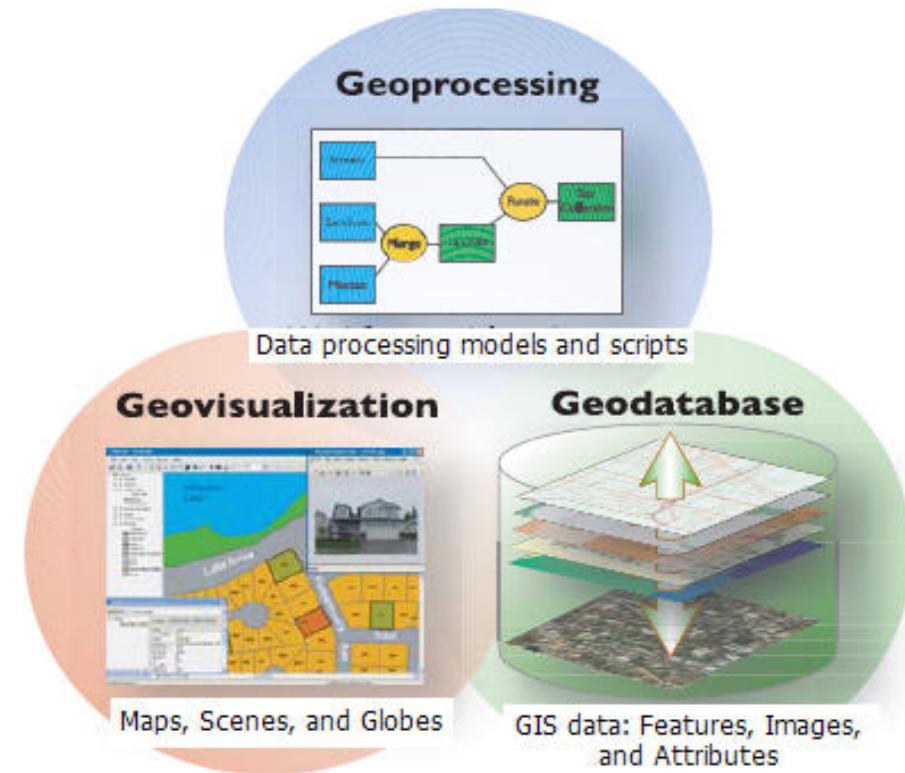


# Review Lecture 1

## Geographical Information Systems

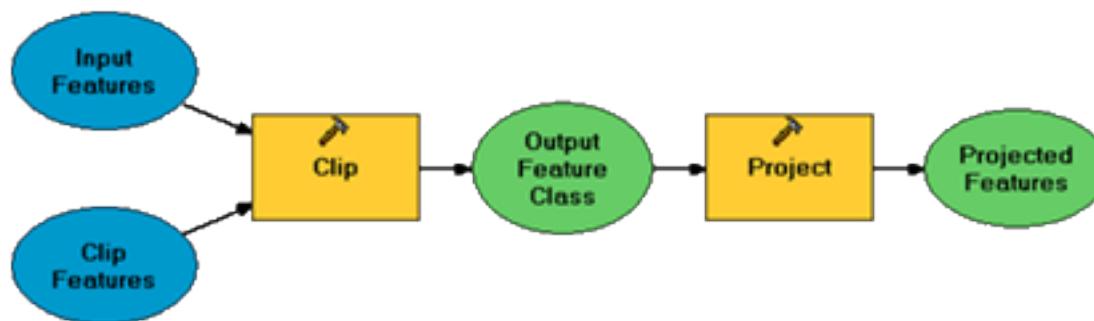
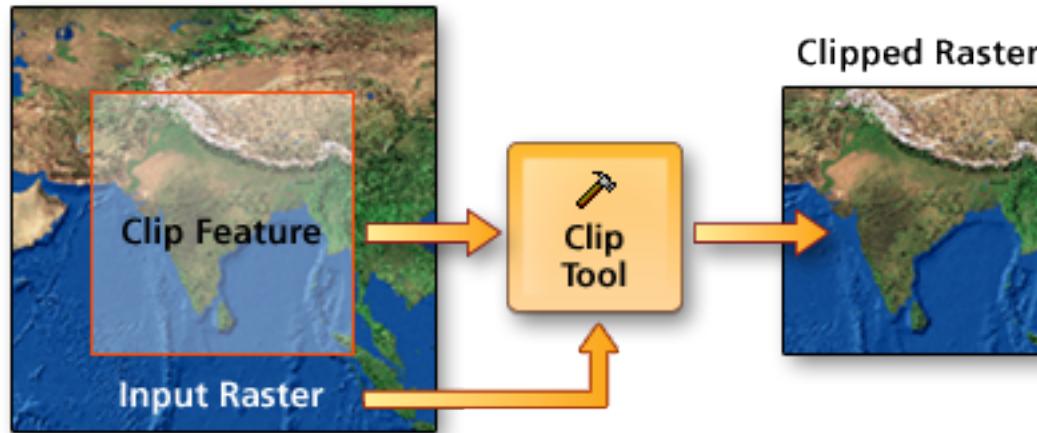
### Key functions of a GIS:

- Data management
- Mapping and Visualization
- Geoprocessing



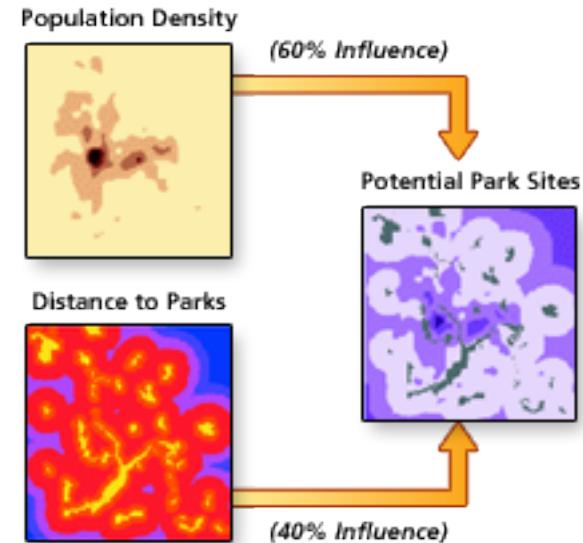
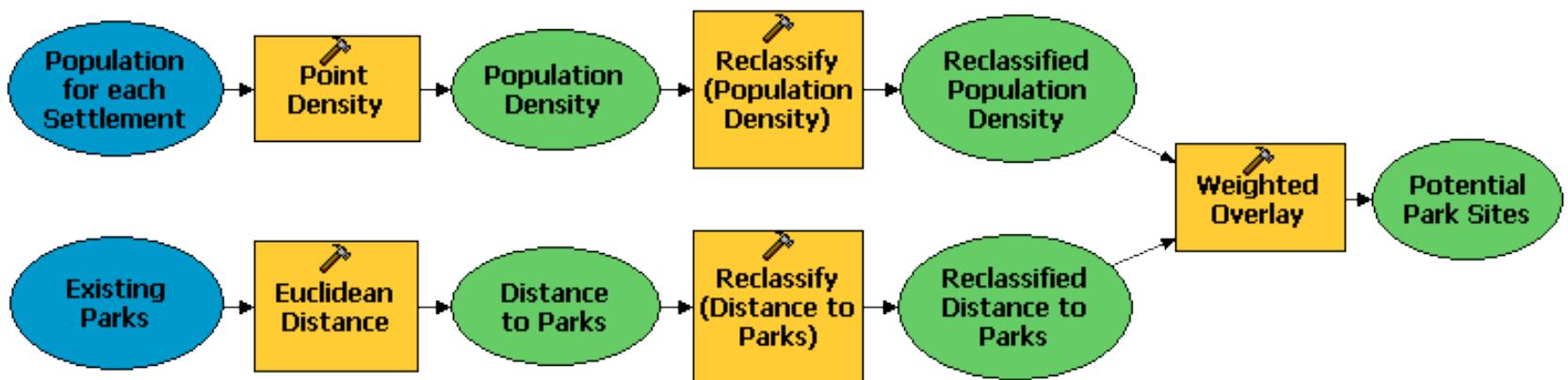
# Review Lecture 1

## Geoprocessing: Automating GIS tasks



# Review Lecture 1: Geoprocessing

## Modeling and analysis



# Review Lecture 1: Assignment 1

## Part 1: Population

- 1) Use Zonal Statistics to calculate the total population of the Volta Basin.

Use QGIS Print Composer to make a map showing the Volta Basin outline overlaying the population count map.

What steps were required?

Problems/pitfalls?

Useful resources?

# Review Lecture 1: Assignment 1

## Part 2: Household water demand

Assume that household water use is 90 liters per person per day in urban areas and 40 liters per person per day in rural areas. Use raster calculator to calculate the total household water demand for the population in the Volta basin.

What steps were required?

Problems/pitfalls?

Useful resources?

# Review Lecture 1: Assignment 1

## Part 3: Transboundary River basin

Use field calculator to calculate the area in km<sup>2</sup> of the Volta Basin.

The Volta basin is shared by six countries: Burkina Faso, Ghana, Togo, Mali, Benin, and Cote d'Ivoire. Calculate the percentage of the total Volta basin area belonging to each of the six countries. Use QGIS Print Composer to make a map showing the Volta Basin outline and the country outlines.

What steps were required?

Problems/pitfalls?

Useful resources?

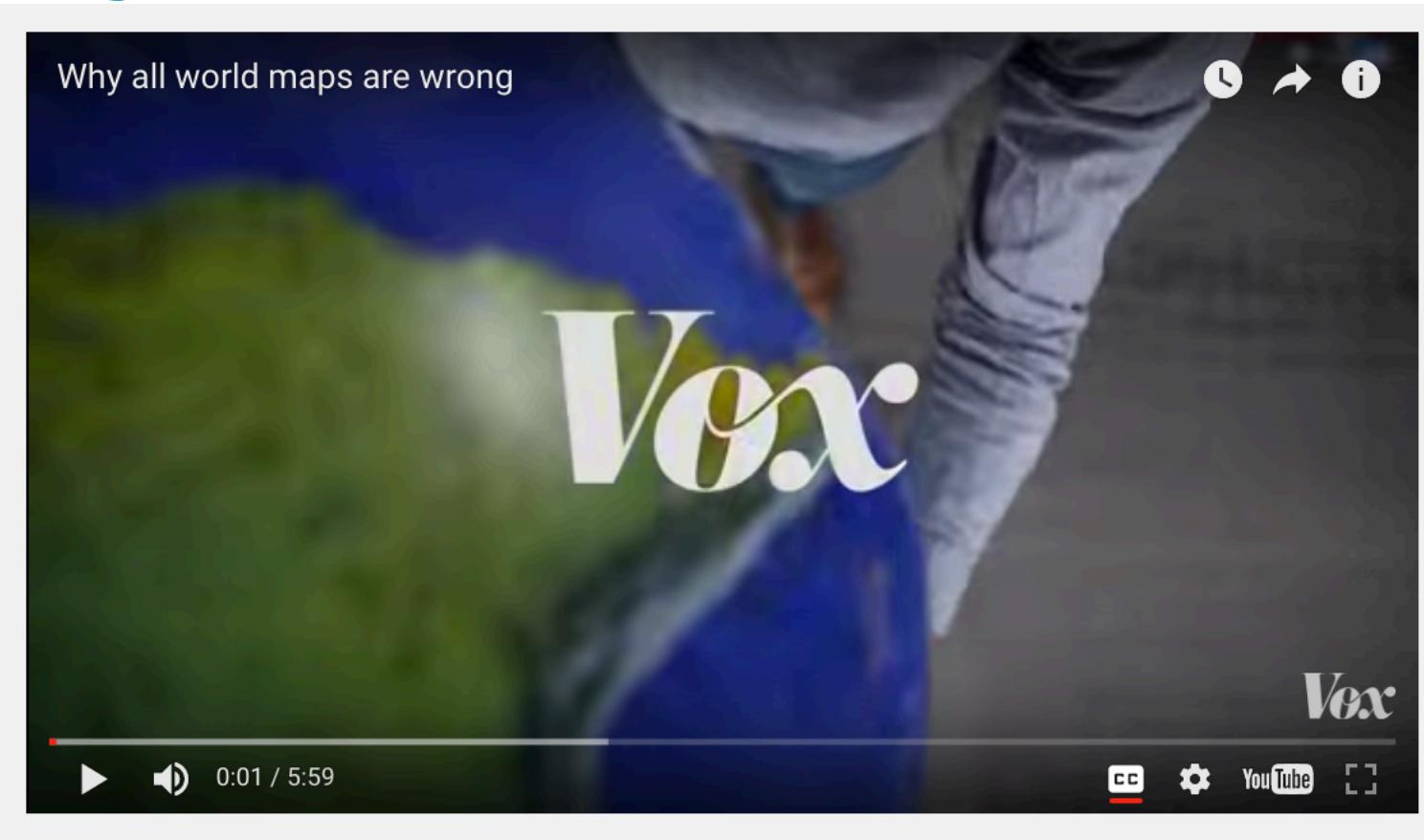
# Lecture outline

- Review Lecture 1
- **Projections**
- Spatial Analysis: Vector data in QGIS
- Spatial Analysis: Map Algebra
- Spatial Analysis: Raster data in QGIS
- Introduction to Assignment 2

# Projection

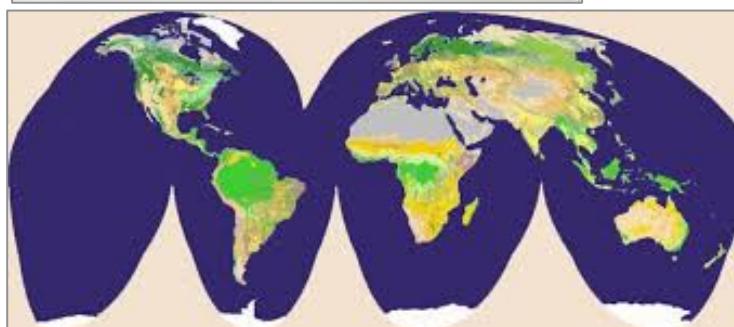


# Projection



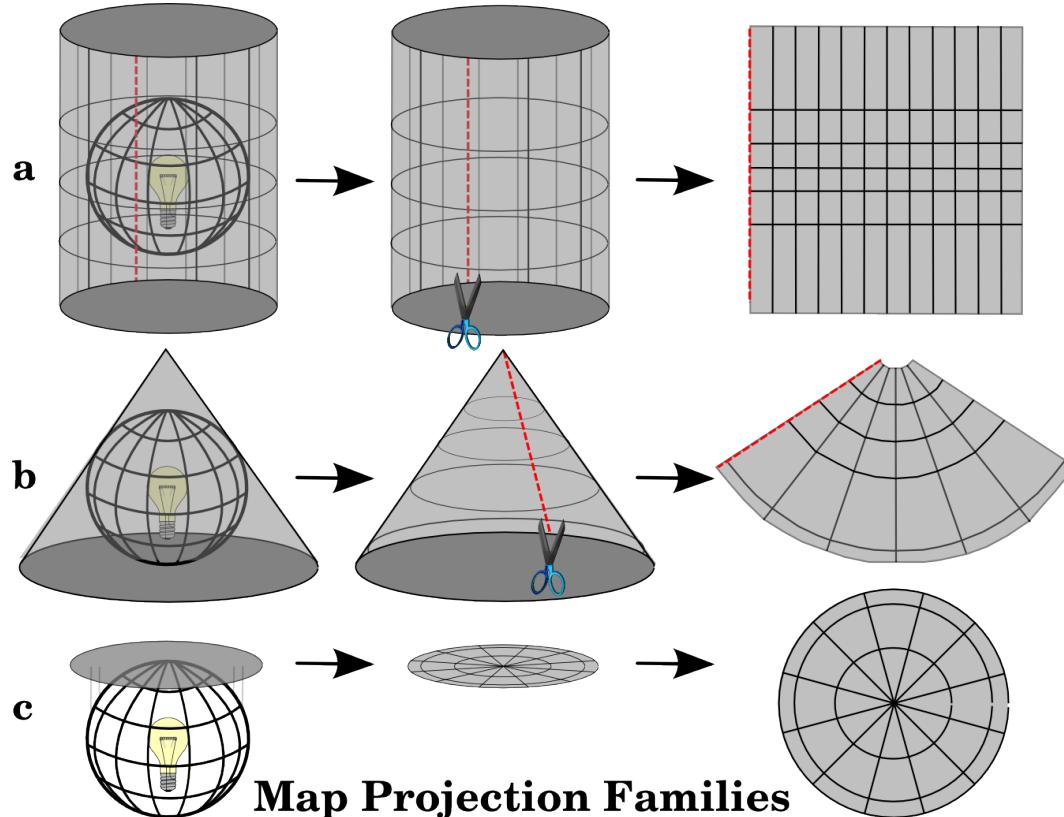
<http://www.vox.com/world/2016/12/2/13817712/map-projection-mercator-globe>

# Projection



# Projection

How can we project a sphere onto a sheet?



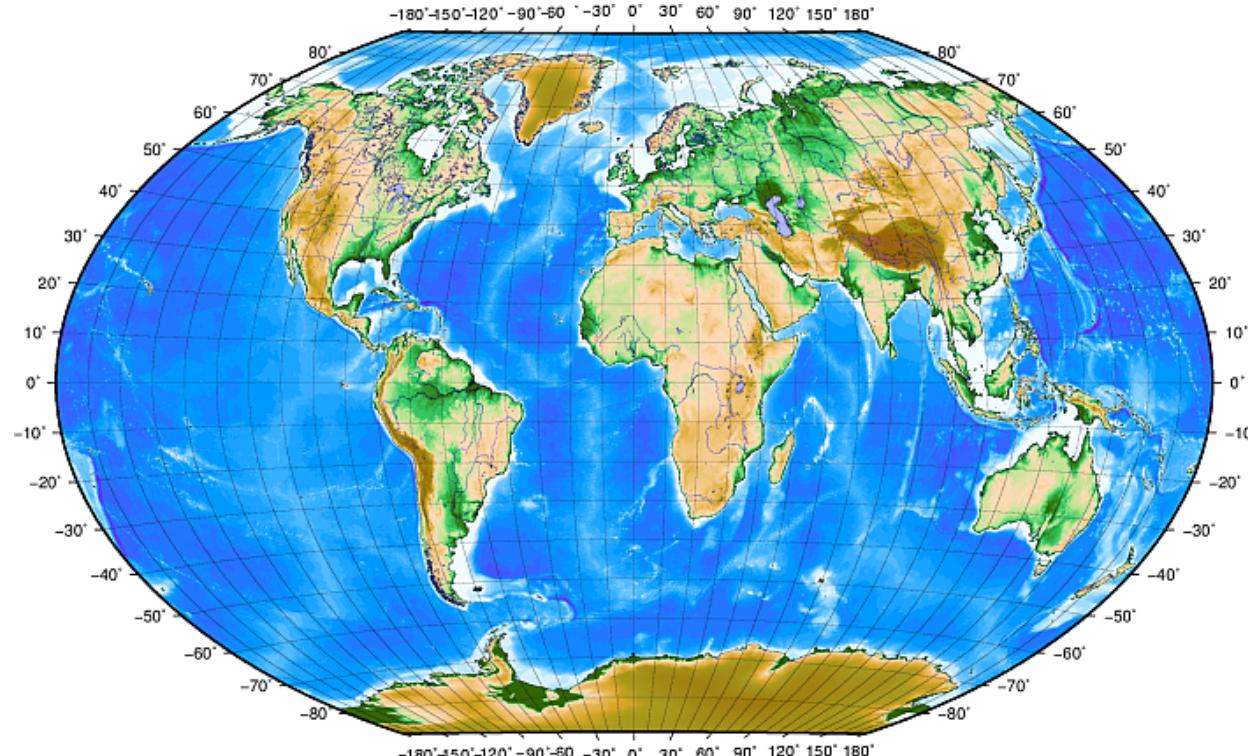
Cylindrical  
Projections

Conical  
Projections

Planar  
Projections

# Projection Coordinate Reference Systems

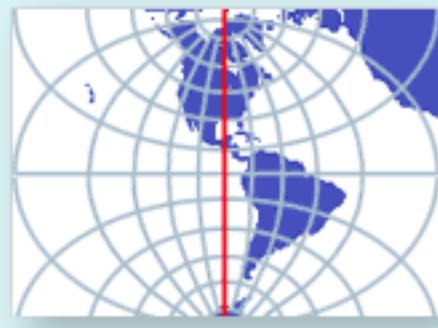
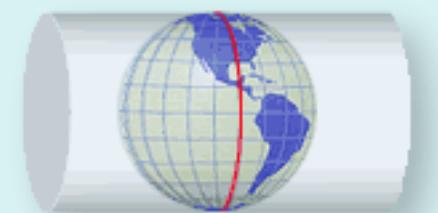
## Geographic Coordinate Reference Systems



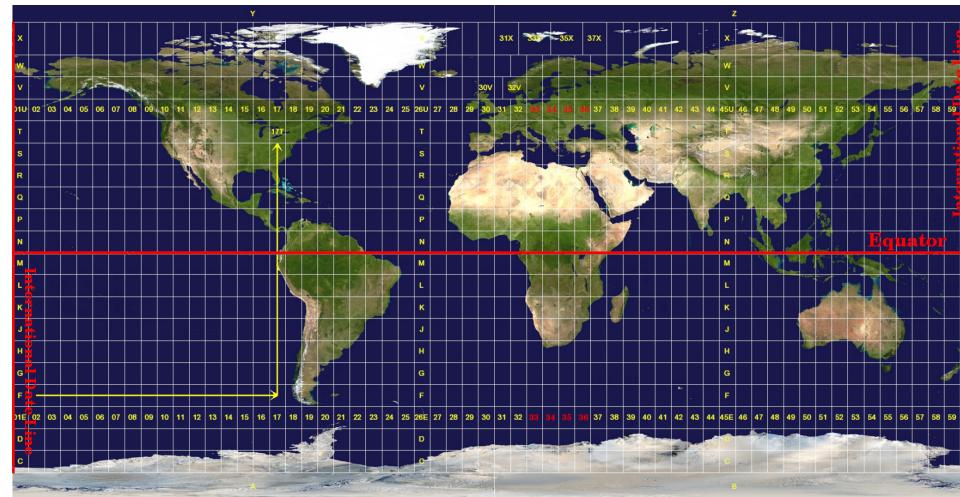
# Projection: Coordinate Reference Systems

## Projected Coordinate Reference Systems

Transverse Mercator



(x,y) coordinates  
(Easting, Northing) coordinates  
e.g. Universal Transverse Mercator

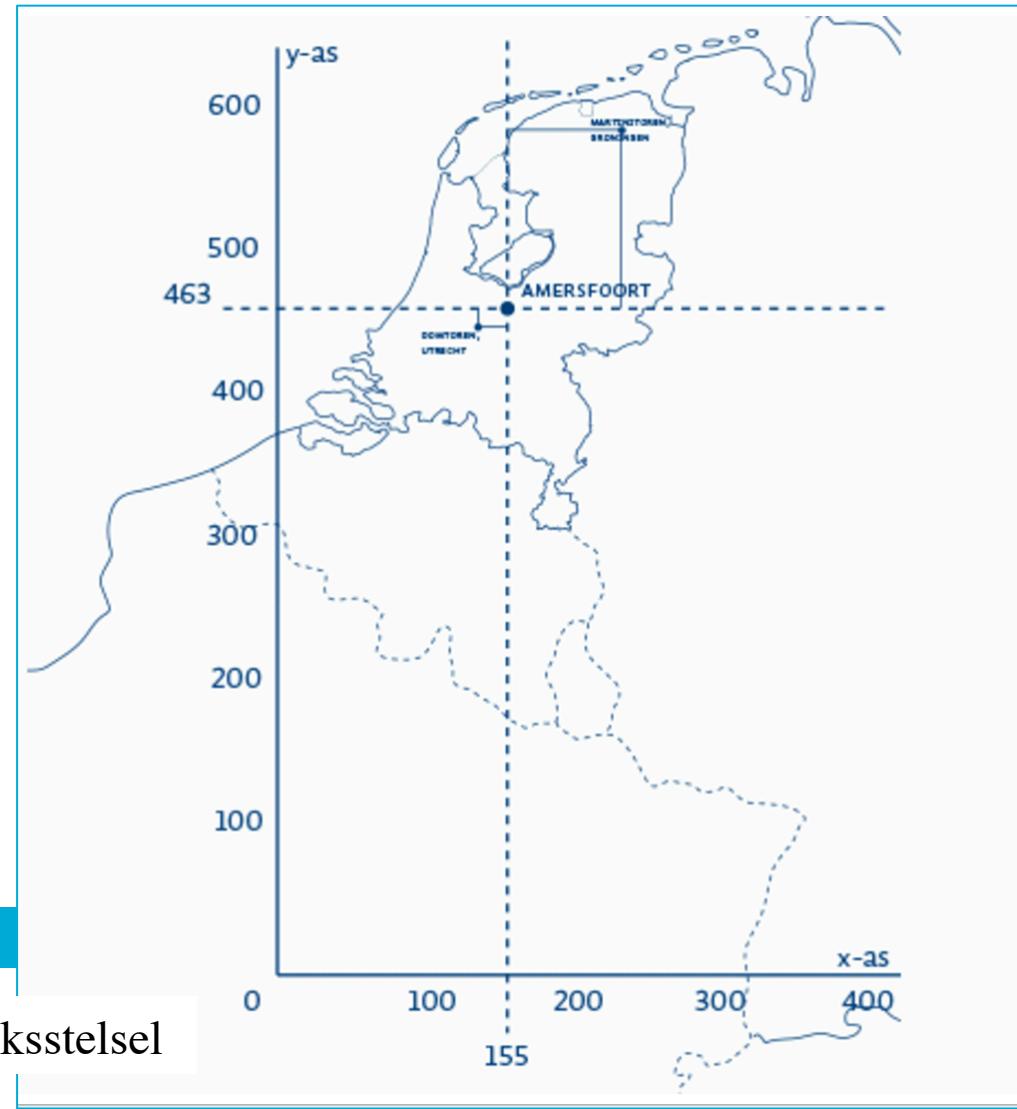


# Projection: Coordinate Reference Systems

## Rijksdriehoeksstelsel

(EPSG) 28992 Amersfoort / RD New.  
Meter units.

Amersfoort heeft coördinaten  
(155000 m, 463000 m)



# Detour: CRS in QGIS

Vector layers: Set CRS v. “Save As ...”

“on the fly”

# Lecture outline

- Review Lecture 1
- Projections
- **Spatial Analysis: Vector data in QGIS**
- Spatial Analysis: Map Algebra
- Spatial Analysis: Raster data in QGIS
- Introduction to Assignment 2

# Spatial Analysis: Vector Data in QGIS

- Spatial Query
- Data Management Tools
- Geoprocessing Tools
- Analysis Tools
- Geometry Tools
- Research Tools

# Spatial Analysis: Vector Data

- Spatial Query
- Data Management Tools
- Geoprocessing Tools
- Analysis Tools
- Geometry Tools
- Research Tools

# Vector data in QGIS: Spatial Query

The screenshot shows the QGIS interface with a spatial query dialog open. The dialog has three main sections: "Select source features from" (set to "regions"), "Where the feature" (operator "Intersects", reference feature "landice"), and "And use the result to" (option "Create new selection"). Below the dialog is a map of Alaska divided into various administrative regions, each colored differently according to a legend. The legend lists 20 regions: Aleutians East, Aleutians West, Anchorage, Bethel, Bristol Bay, Denali, Dillingham, Fairbanks North Star, Haines, Juneau, Kenai Peninsula, Ketchikan Gateway, Kodiak Island, Lake and Peninsula, Matanuska-Susitna, Nome, North Slope, Northwest Arctic, Prince of Wales-Outer Ketchikan, Sitka, Skagway-Yakutat-Anoon, Southeast Fairbanks, Valdez-Cordova, Wade Hampton, Wrangell-Petersburg, and Yukon-Koyukuk. The "regions" layer is selected in the legend.

Region Name	Color
Aleutians East	Brown
Aleutians West	Brown
Anchorage	Brown
Bethel	Brown
Bristol Bay	Brown
Denali	Brown
Dillingham	Brown
Fairbanks North Star	Brown
Haines	Brown
Juneau	Brown
Kenai Peninsula	Brown
Ketchikan Gateway	Brown
Kodiak Island	Brown
Lake and Peninsula	Brown
Matanuska-Susitna	Brown
Nome	Brown
North Slope	Brown
Northwest Arctic	Brown
Prince of Wales-Outer Ketchikan	Brown
Sitka	Brown
Skagway-Yakutat-Anoon	Brown
Southeast Fairbanks	Brown
Valdez-Cordova	Brown
Wade Hampton	Brown
Wrangell-Petersburg	Brown
Yukon-Koyukuk	Brown

<http://qgis.spatialthoughts.com/2011/12/tutorial-performing-spatial-queries-in.html>

# Vector data in QGIS: Spatial Query

Which soil moisture sensors are in Burkina Faso?

The screenshot shows the QGIS interface with a spatial query dialog open. The dialog is titled "Spatial Query" and contains the following settings:

- Select source features from: SMStnsVolta200k
- Where the feature: Within
- Reference features of: AfricanCountries
- And use the result to: Create new selection

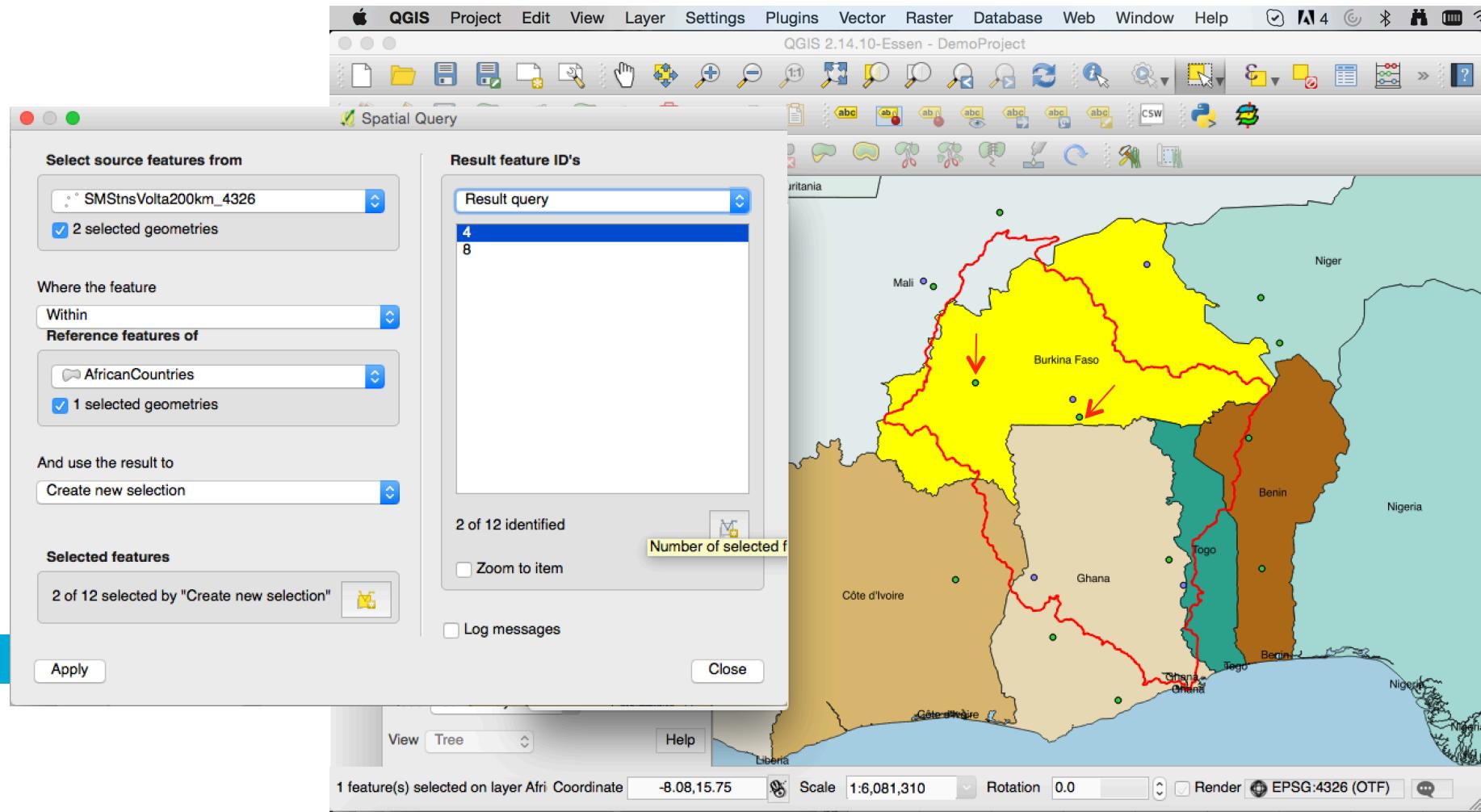
The background map displays the countries of West Africa (Burkina Faso, Mali, Côte d'Ivoire, Ghana, Togo, Benin, Nigeria) in different colors. Burkina Faso is highlighted in yellow. A red polygonal boundary represents the "AfricanCountries" layer. Several green dots are scattered across the map, representing selected features from the "SMStnsVolta200k" layer.

Bottom status bar: 1 feature(s) selected on layer Afri Coordinate -8.08,15.75 Scale 1:6,081,310 Rotation 0.0 Render EPSG:4326 (OTF)

# Vector data in QGIS: Spatial Query

Can make a new layer from selection

Can see selection in attribute table too ...



# Spatial Analysis: Vector Data

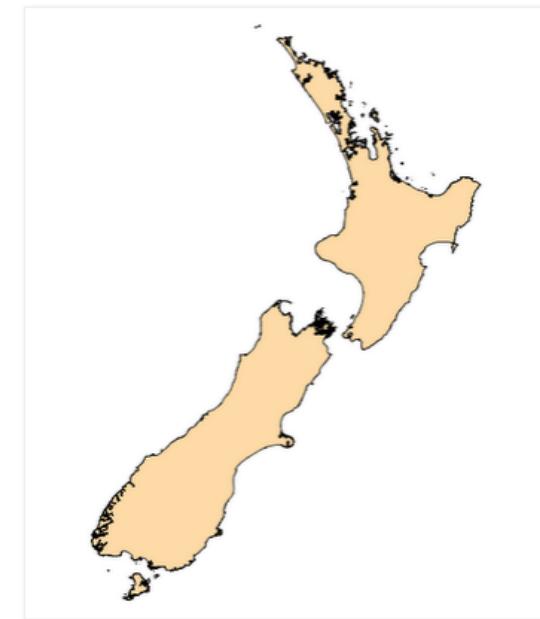
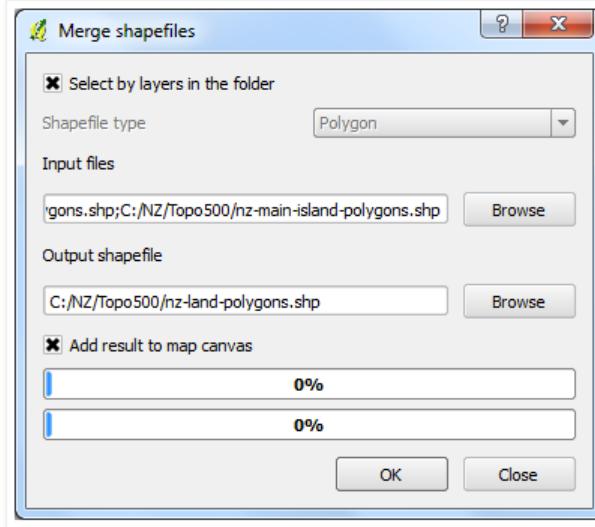
- Spatial Query
- **Data Management Tools**
- Geoprocessing Tools
- Analysis Tools
- Geometry Tools
- Research Tools

# Spatial Analysis: Vector Data

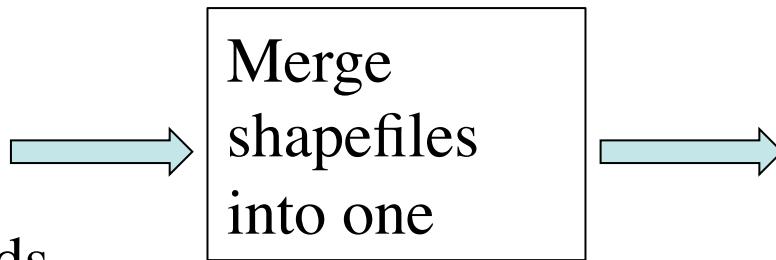
## Data Management Tools

- Merge vector layers
- Split vector layer

# Vector Data Management: Merge



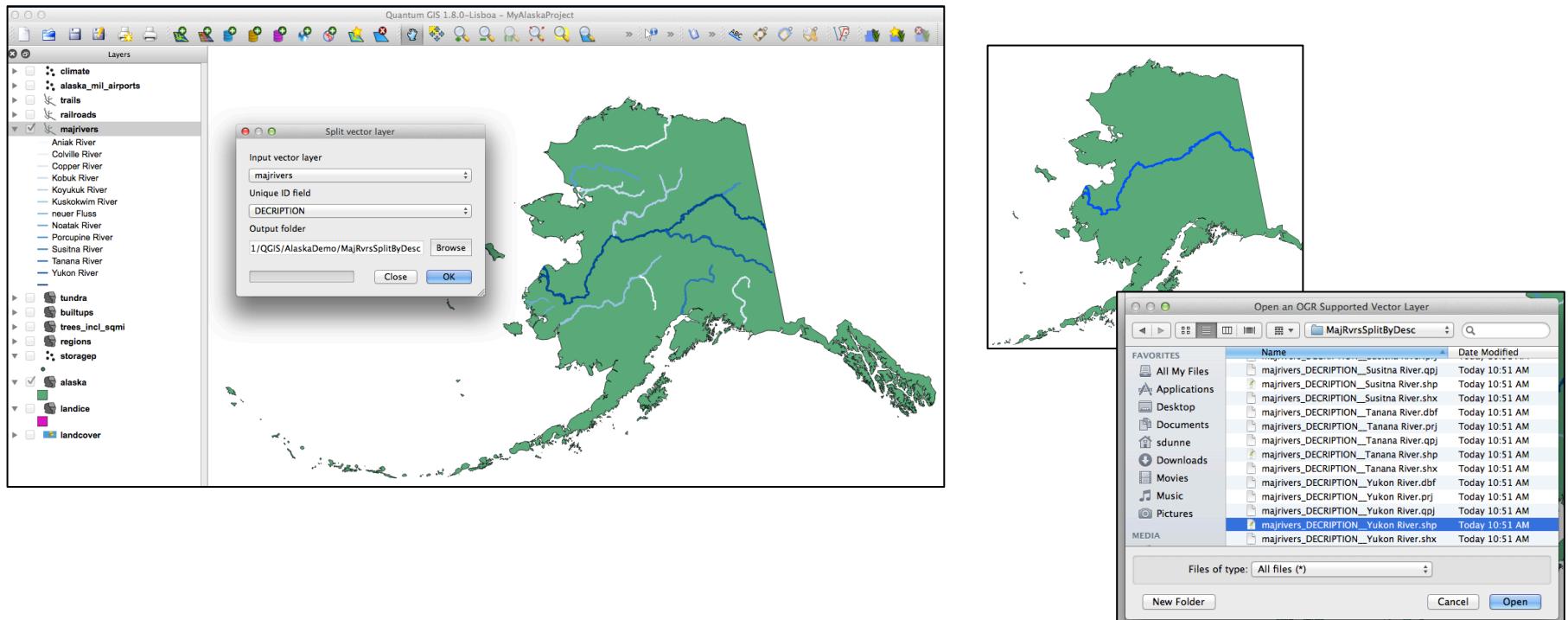
Layer of mainland  
+  
Layer of islands



Single layer of mainland & islands

# Vector Data management: Split

All major rivers → Split vector layer → Layer file for each river



# Spatial Analysis: Vector Data

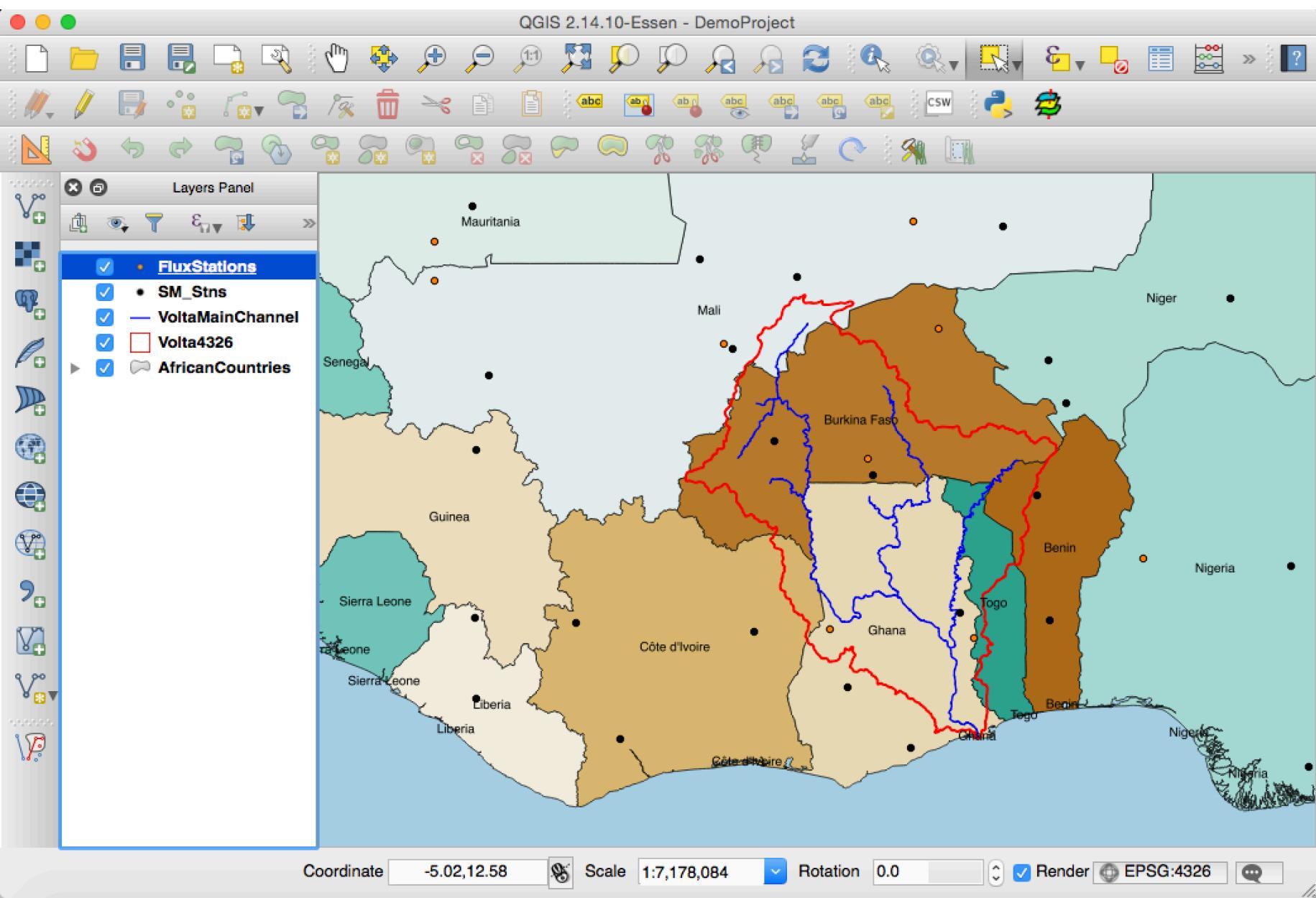
- Spatial Query
- Data Management Tools
- **Geoprocessing Tools**
- Analysis Tools
- Geometry Tools
- Research Tools

# Spatial Analysis: Vector Data

## Geoprocessing Tools:

- Buffers:
  - Fixed distance buffer
  - Variable distance buffer
- Clip & Difference
- Overlay Analysis:
  - Intersection
  - Symmetrical Difference
  - Union
- Dissolve

# Vector Geoprocessing Tools

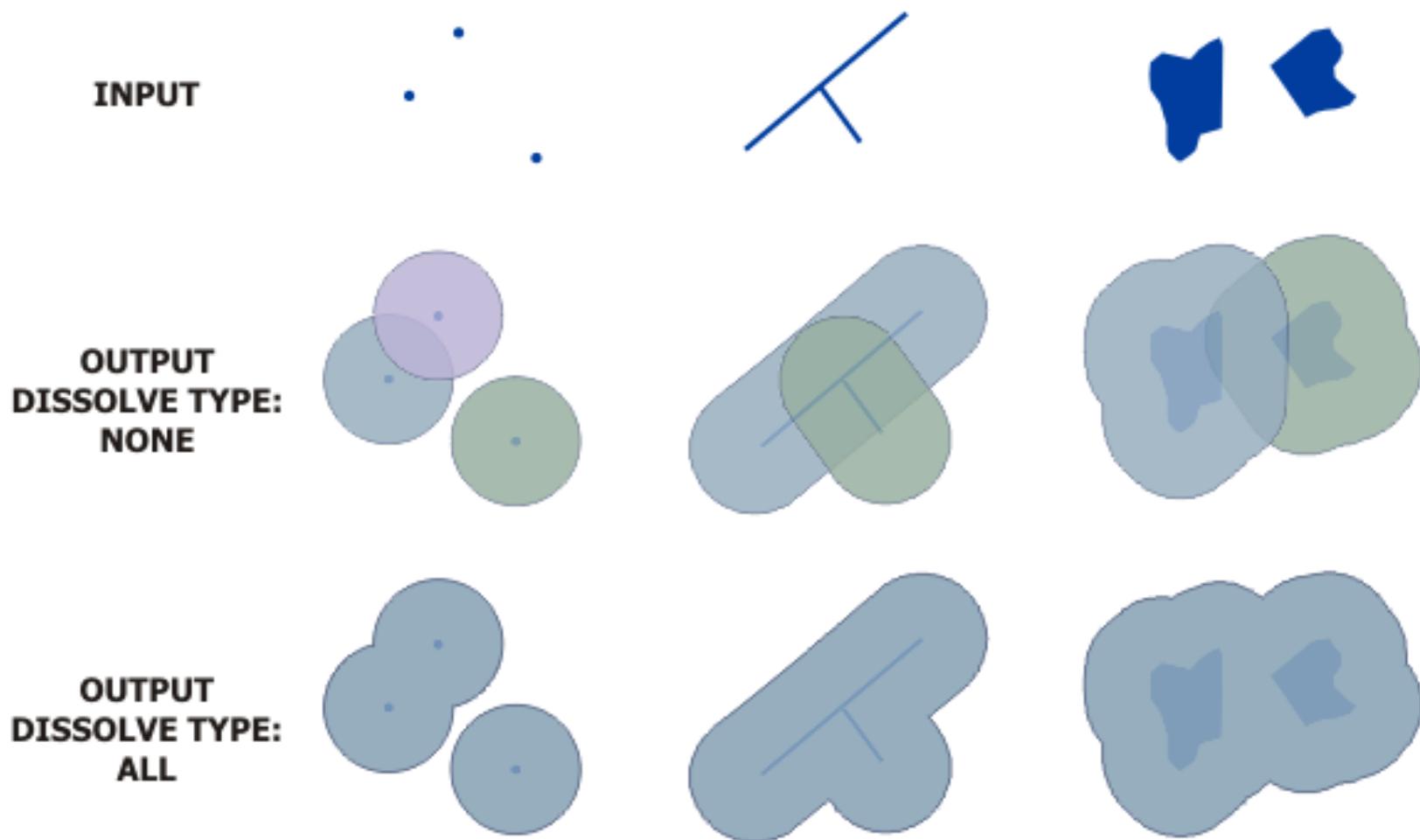


# Vector Geoprocessing Tools

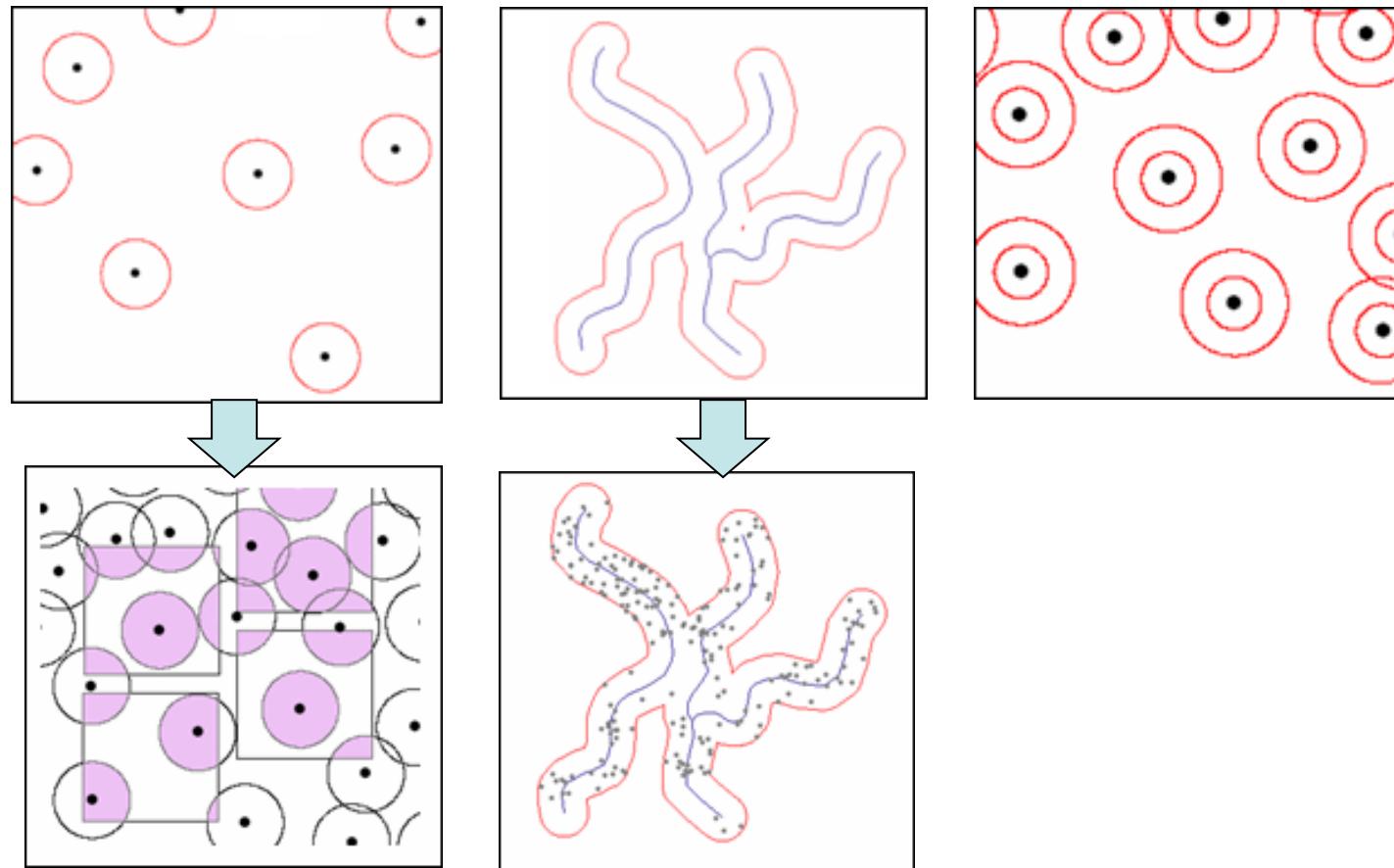
## Geoprocessing Tools:

- **Buffers:**   **Fixed distance buffer**  
                 **Variable distance buffer**
- Clip & Difference
- Overlay Analysis: Intersection  
                 Symmetrical Difference  
                 Union
- Dissolve

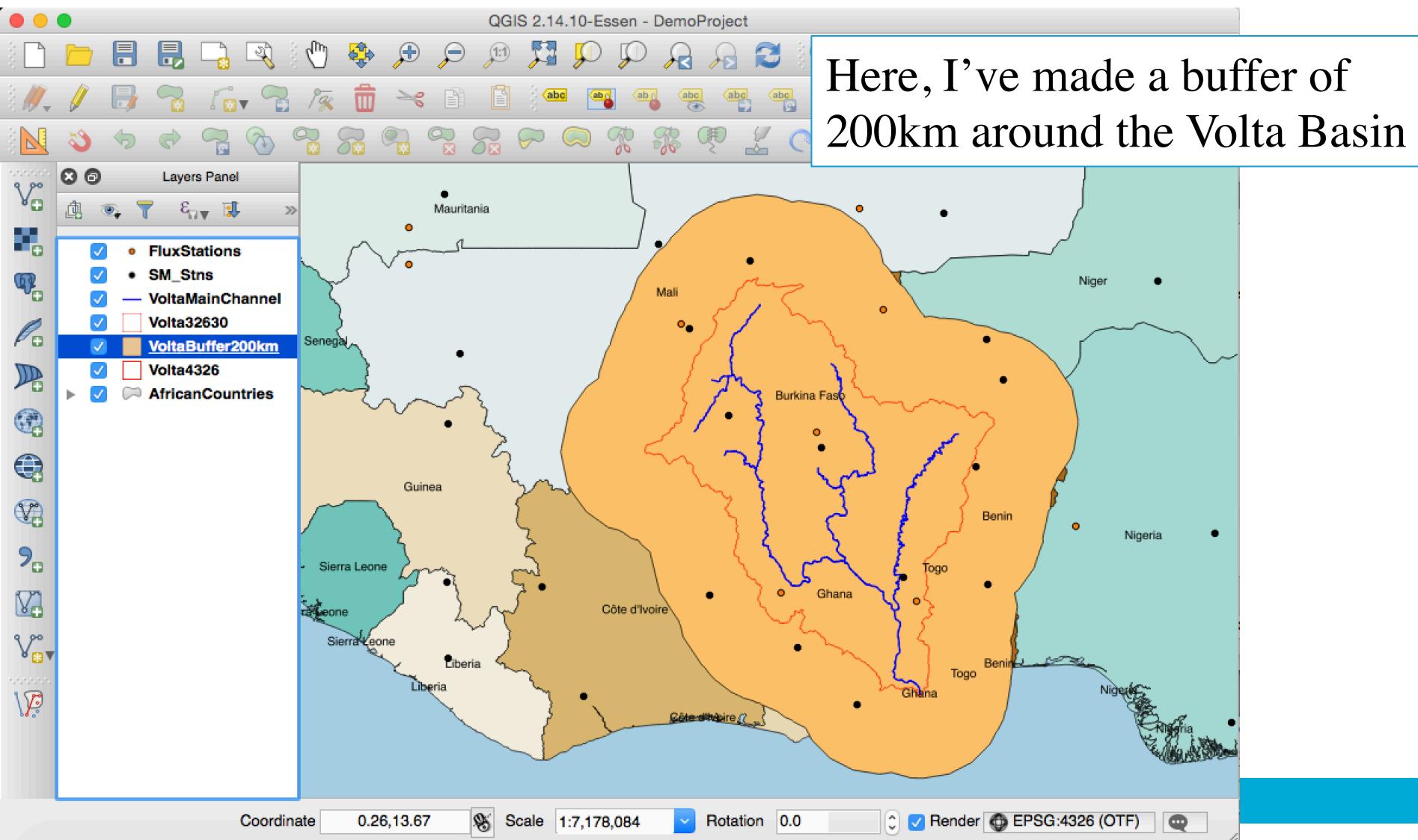
# Vector Geoprocessing Tools: Buffer



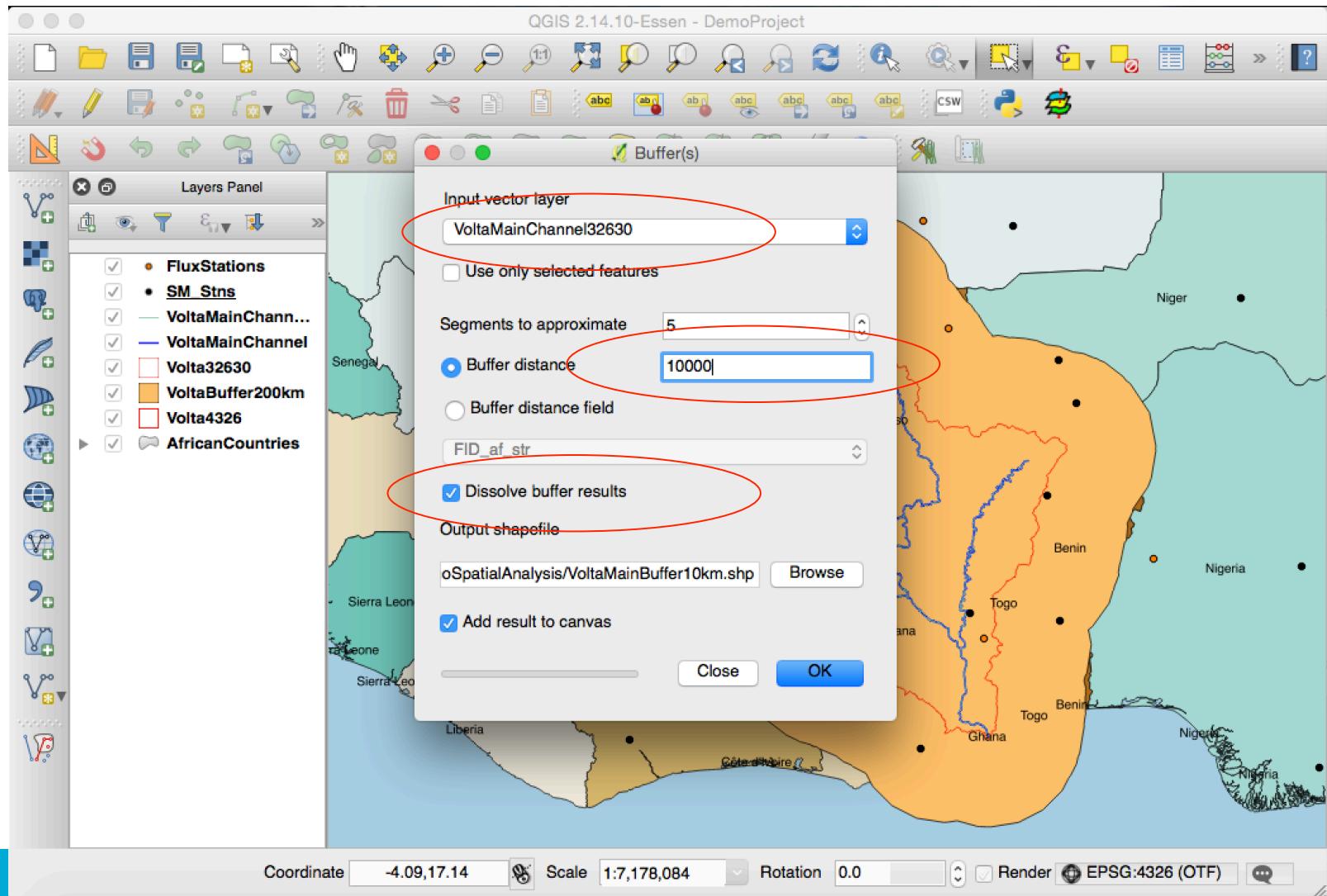
# Vector Geoprocessing Tools: Buffer



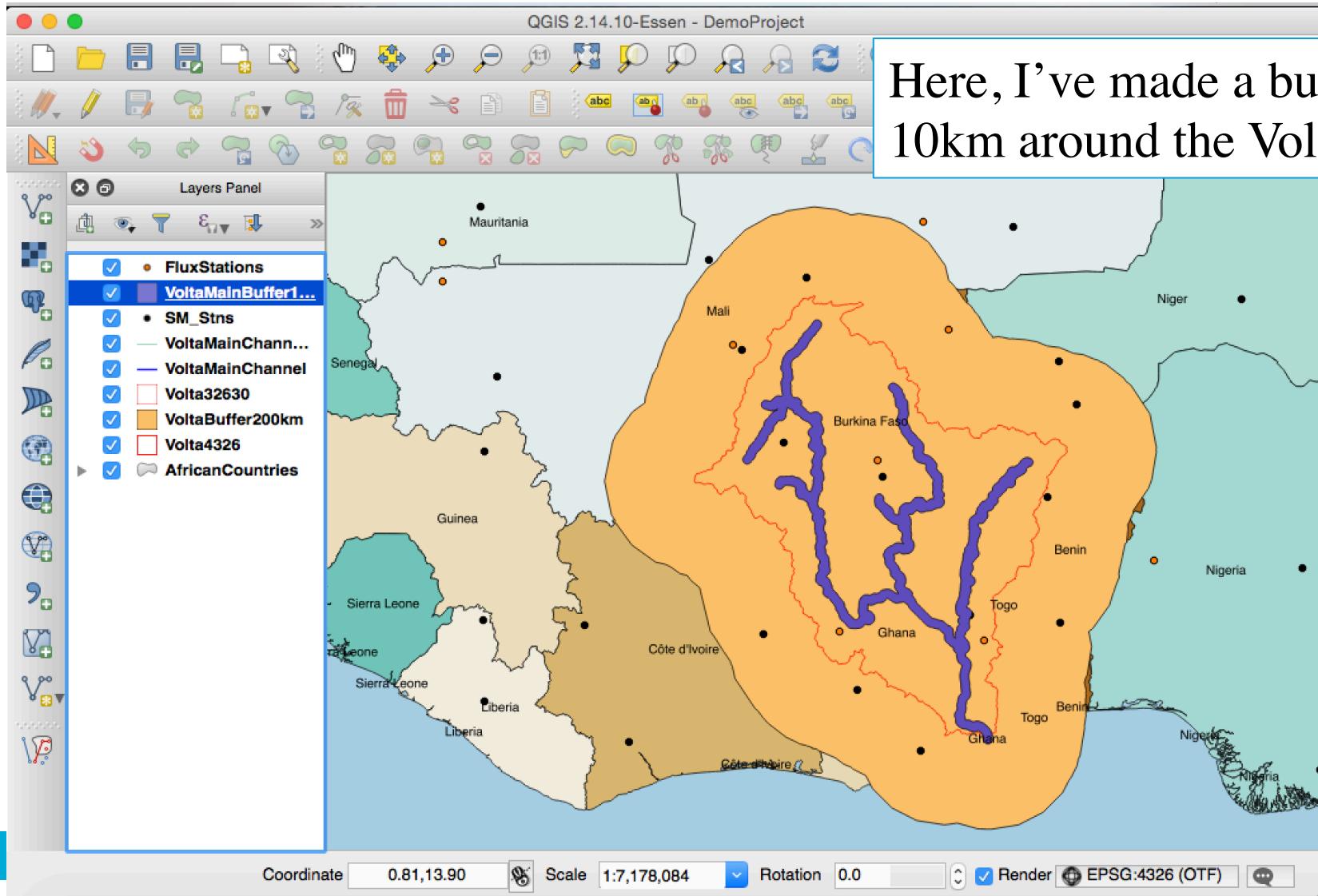
# Vector Geoprocessing Tools: Buffer



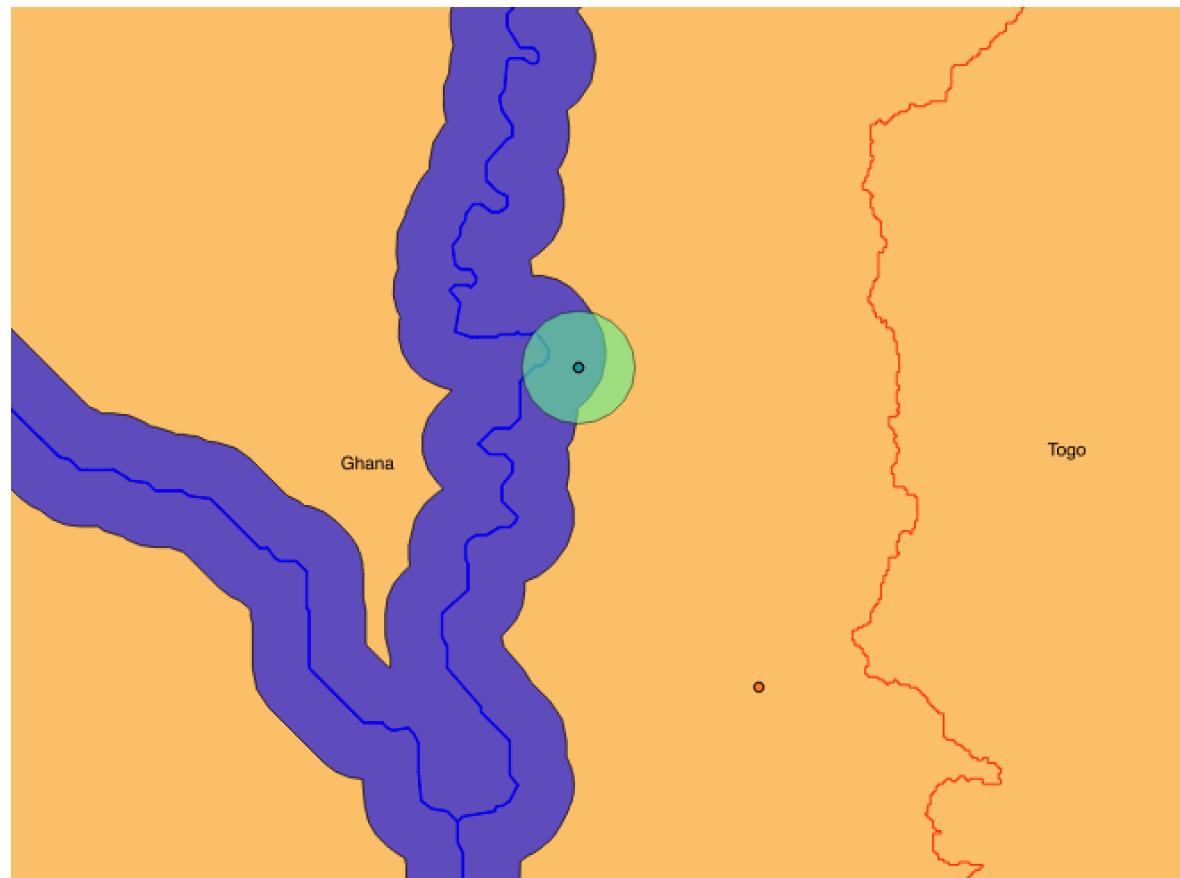
# Vector Geoprocessing Tools: Buffer



# Vector Geoprocessing Tools: Buffer



# Vector Geoprocessing Tools: Buffer

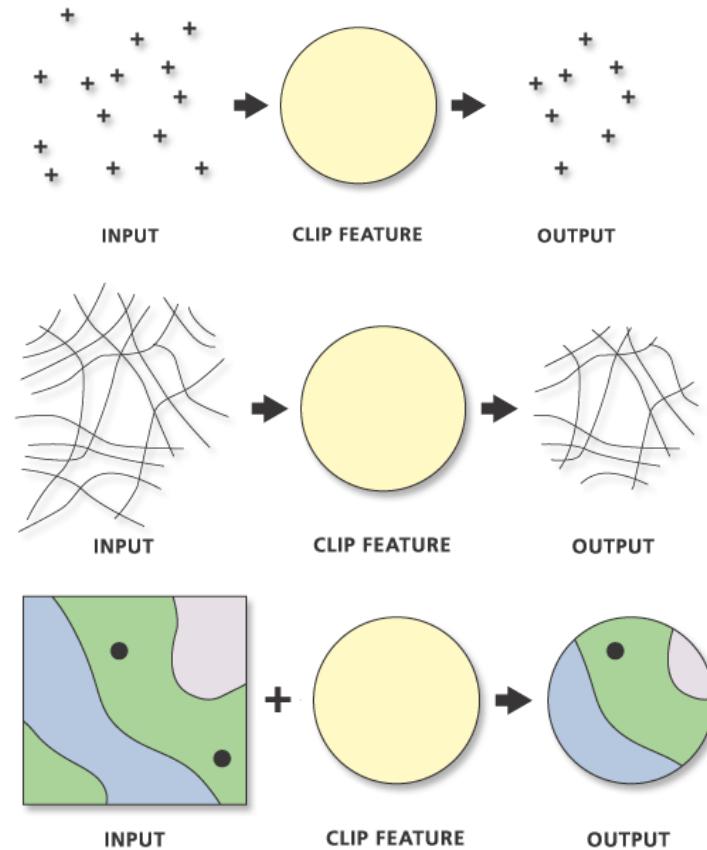


# Spatial Analysis: Vector Data

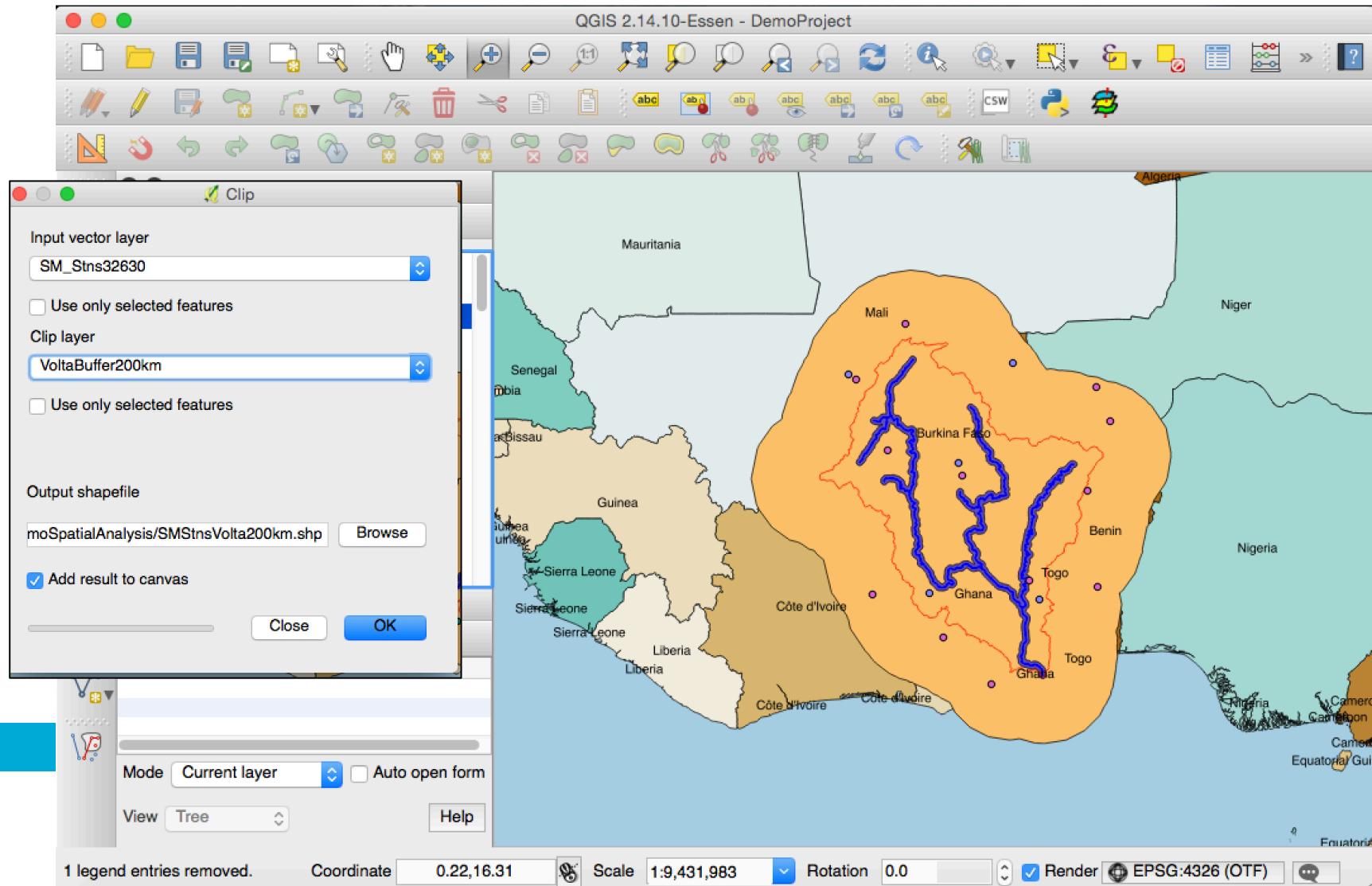
## Geoprocessing Tools:

- Buffers:      Fixed distance buffer  
                    Variable distance buffer
- **Clip & Difference**
- Overlay Analysis: Intersection  
                    Symmetrical Difference  
                    Union
- Dissolve

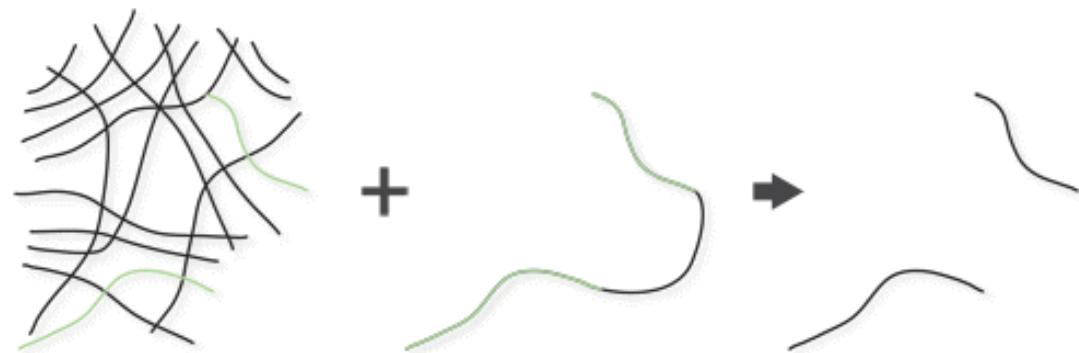
# Vector Geoprocessing Tools: Clip



# Vector Geoprocessing Tools: Clip



# Vector Geoprocessing Tools: Clip



INPUT LINES

CLIP LINE

OUTPUT LINES



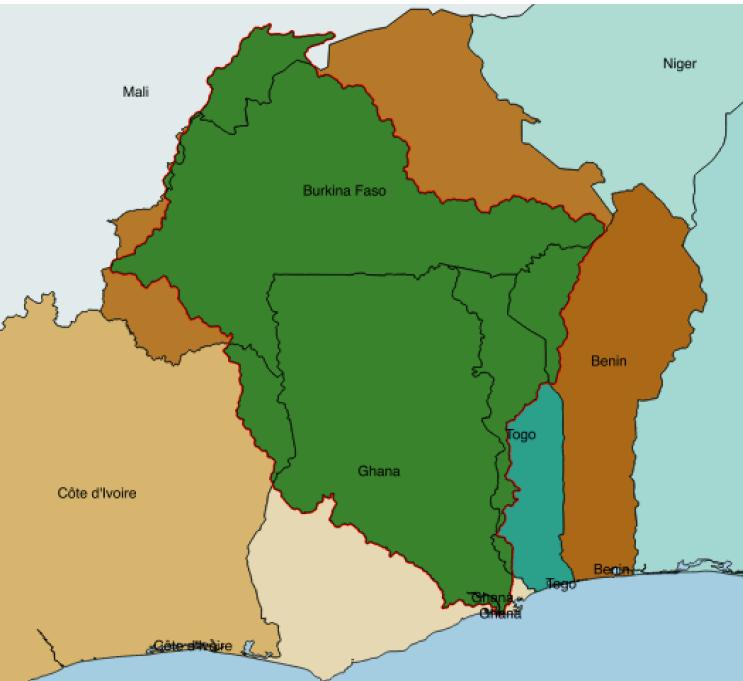
INPUT POINTS

CLIP POINTS

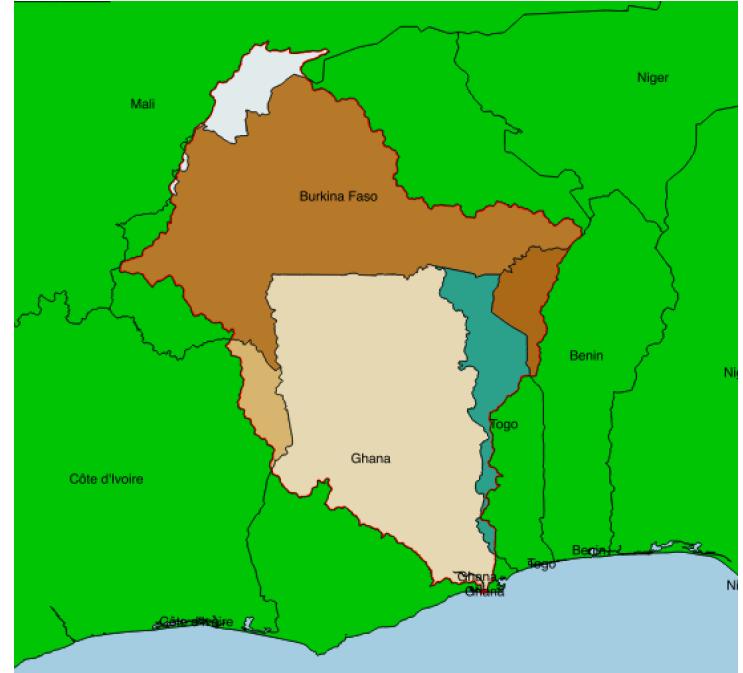
OUTPUT POINTS

# Vector Geoprocessing Tools: Difference

Clip



Difference

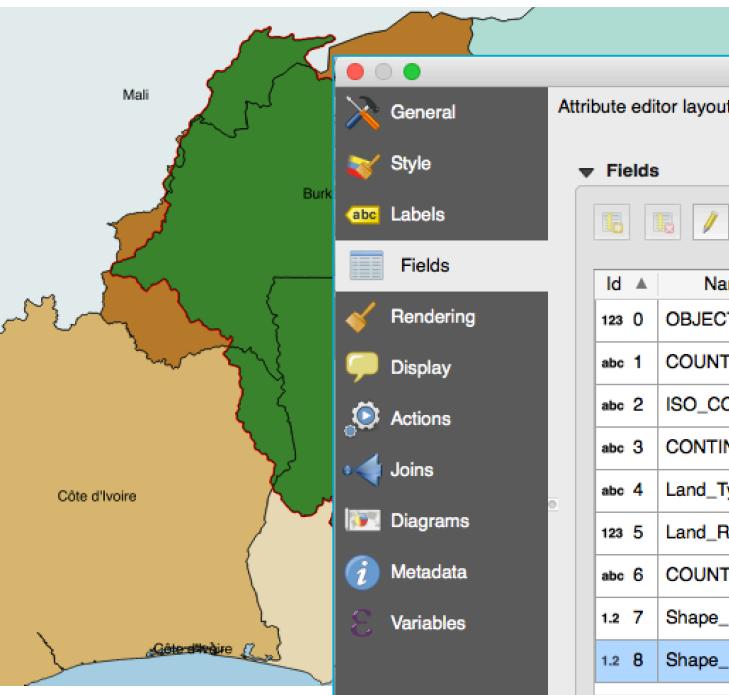


Use Volta to clip countries:  
The parts of the countries layer that  
are within the Volta Basin

Use Volta to get the  
difference:  
The parts of the countries  
layer that are NOT within  
the Volta Basin

# Vector Geoprocessing Tools: Difference

Clip



Difference

Layer Properties - UseVoltaClipCountries | Fields

Attribute editor layout: Autogenerate      Python Init function:

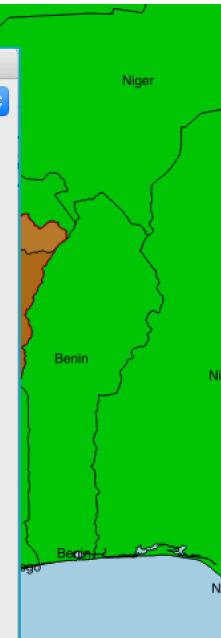
Fields

Id	Name	Type	Type name	Length	Precision	Comment	Edit widget
123 0	OBJECTID	qulonglong	Integer64	10	0		Text Edit
abc 1	COUNTRY	QString	String	50	0		Text Edit
abc 2	ISO_CC	QString	String	2	0		Text Edit
abc 3	CONTINENT	QString	String	13	0		Text Edit
abc 4	Land_Type	QString	String	20	0		Text Edit
123 5	Land_Rank	qulonglong	Integer64	10	0		Text Edit
abc 6	COUNTRYAFF	QString	String	50	0		Text Edit
1.2 7	Shape_STAr	double	Real	18	11		Text Edit
1.2 8	Shape_STLe	double	Real	18	11		Text Edit

Relations

Suppress attribute form pop-up after feature creation: Default

Help      Style      Apply      Cancel      OK



Use Volta to  
The parts of  
are within th

countries  
layer that are NOT within  
the Volta Basin

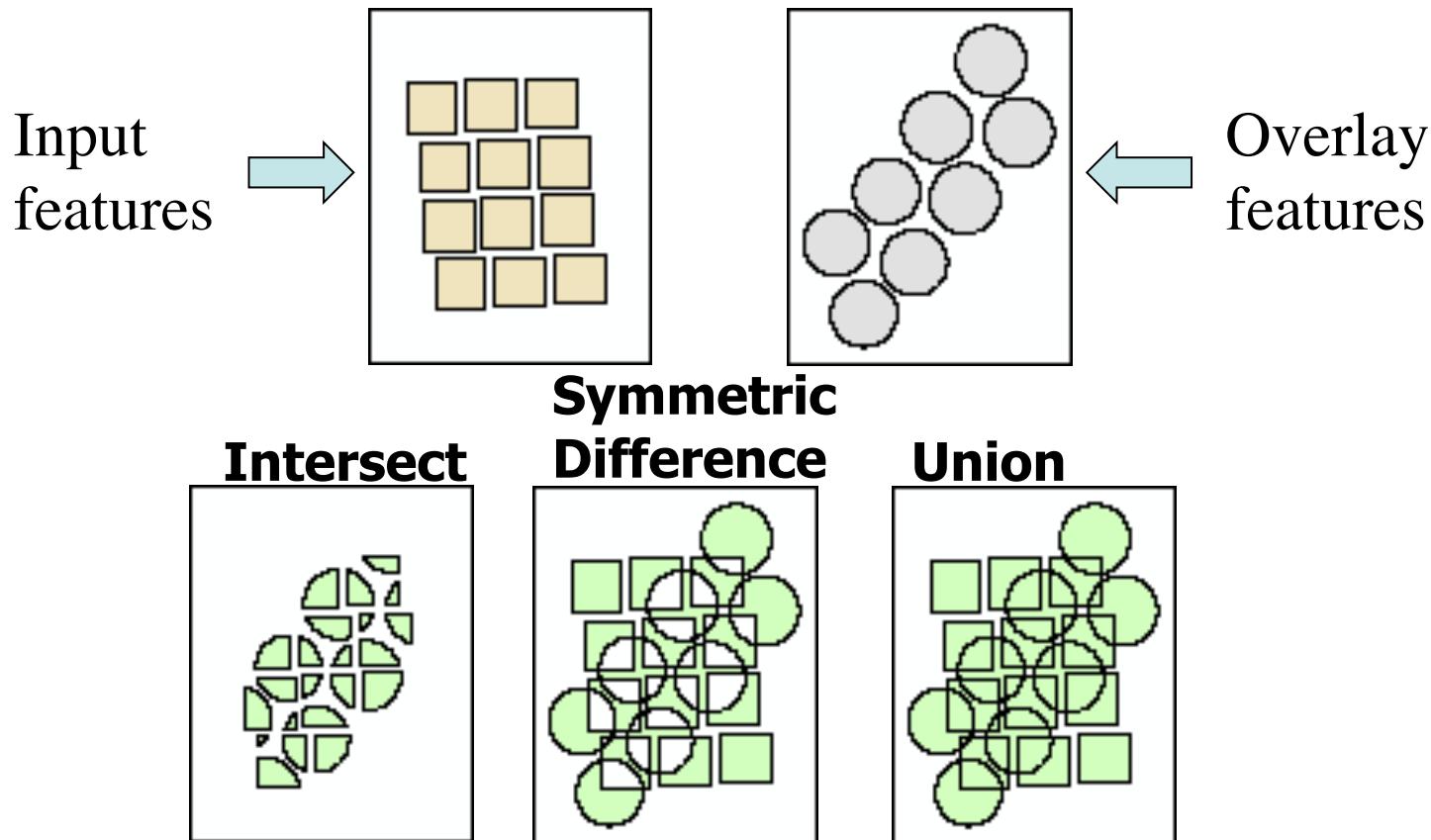
# Spatial Analysis: Vector Data

## Geoprocessing Tools:

- Buffers:
  - Fixed distance buffer
  - Variable distance buffer
- Clip & Difference
- **Overlay Analysis:** **Intersection**  
**Symmetrical Difference**  
**Union**
- Dissolve

# Spatial Analysis: Vector data in QGIS

## Overlay



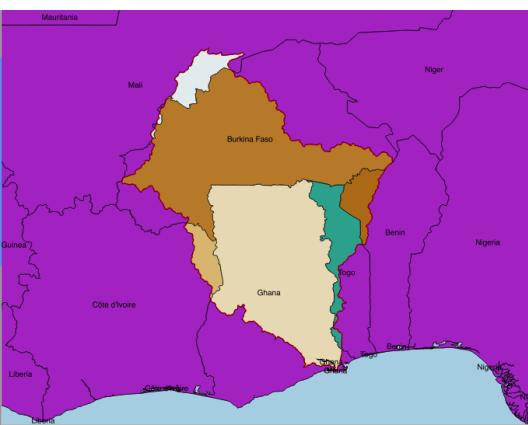
# Spatial Analysis: Vector data in QGIS



Intersect



Symmetrical  
Difference



Union



# Spatial Analysis: Vector data in QGIS

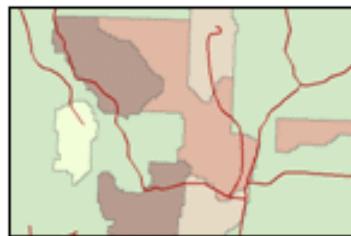
The screenshot shows the QGIS Attribute Editor dialog for a layer named "CtriesIntVolta". The left sidebar contains icons for General, Style, Labels, Fields, Rendering, Display, Actions, Joins, Diagrams, Metadata, and Variables. The main area displays the "Fields" tab, which lists attributes with their names, types, and descriptions. A red box highlights the first four columns: Id, Name, Type, and Type name. The "CONTINENT" and "Land\_Type" fields are highlighted with a red border. A large red callout box with the text "Retains attributes from both layers!!!" is positioned over the highlighted area. The bottom right corner of the dialog shows a small preview map of the joined data.

Id	Name	Type	Type name
abc 3	CONTINENT	QString	String
abc 4	Land_Type	QString	String
123 5	Land_Rank	qlonglong	Integer64
abc 6	COUNTRYAFF	QString	String
1.2 7	Shape_STAr	double	Real
1.2 8	Shape_STLe	double	Real
123 9	SUB_BAS	int	Integer
123 10	TO_BAS	int	Integer
123 11	MAJ_BAS	int	Integer

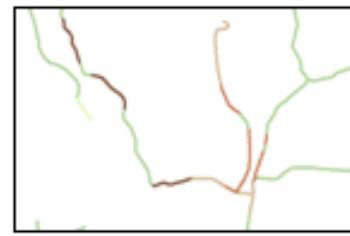
# Spatial Analysis: Vector data in QGIS

## Overlay

What vegetation types are along logging roads?



=



FID	Shape*	LOCALID	RD_TYPE
6	Polyline	222192	1500
7	Polyline	220893	1500
FID	Shape*	LOCALID	RD_TYPE

+

FID	Shape*	VEG_TYPE
6	Polygon	CC
7	Polygon	SO
8	Polygon	SS

FID	Shape*	LOCALID	RD_TYPE	VEG_TYPE
6	Polyline	219378	1500	FC
7	Polyline	219384	1500	FC
8	Polyline	219380	1500	FC
9	Polyline	219380	1500	SO
10	Polyline	224631	1500	FC

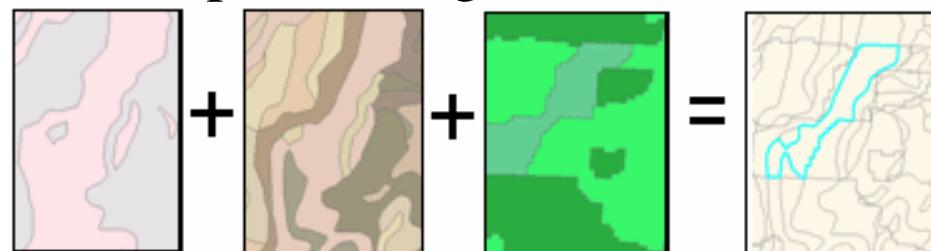
# Spatial Analysis: Vector data in QGIS

## Overlay

### Hydrotopes:

Units that are hydrologically similar.

Similar soil, slope and vegetation?

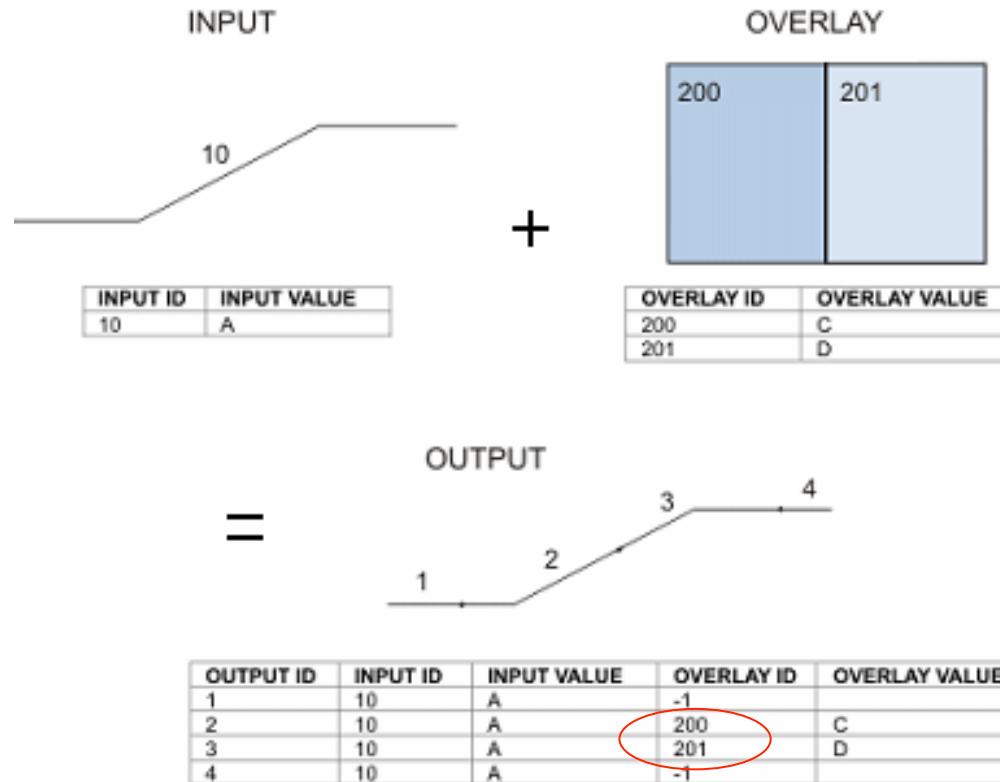


FID	Shape*	FID_soils	CODE	CLASS	FID_si	SLOPE	FID_veg	DET_TYPE
3039	Polygon	508	38F	6	0	60	117	A
3040	Polygon	508	38F	6	0	60	119	SS
3041	Polygon	508	38F	6	0	60	157	U
3042	Polygon	508	38F	6	0	60	158	A
3043	Polygon	508	38F	6	0	60	160	FC

# Spatial Analysis: Vector data in QGIS

## Overlay

(e.g. cost of replacing watermain)



# Spatial Analysis: Vector Data

## Geoprocessing Tools:

- Buffers:
  - Fixed distance buffer
  - Variable distance buffer
- Clip & Difference
- Overlay Analysis:
  - Intersection
  - Symmetrical Difference
  - Union
- Dissolve

# Spatial Analysis: Vector Data

- Spatial Query
- Data Management Tools
- Geoprocessing Tools
- **Analysis Tools**
- Geometry Tools
- Research Tools

# Spatial Analysis: Vector Data

## Analysis Tools

- List unique values
- Count points in polygon
- List unique values
- Nearest neighbour analysis
- Basic statistics:
  - Numeric fields
  - Text fields

# Spatial Analysis: Vector data in QGIS

## Analysis Tools: List Unique Values

QGIS Project Edit View Layer Settings Plugins Vector Raster Database Web Window Help

QGIS 2.14.10-Essen - DemoProject

List unique values

Input Vector Layer: AfricanCountries

Target field: COUNTRY

Unique values:

- Algeria
- Angola
- Benin
- Botswana
- Burkina Faso
- Burundi
- Cameroon
- Canarias
- Cape Verde
- Central African Republic
- Chad

Total unique values: 62

Press Ctrl+C to copy results to the clipboard

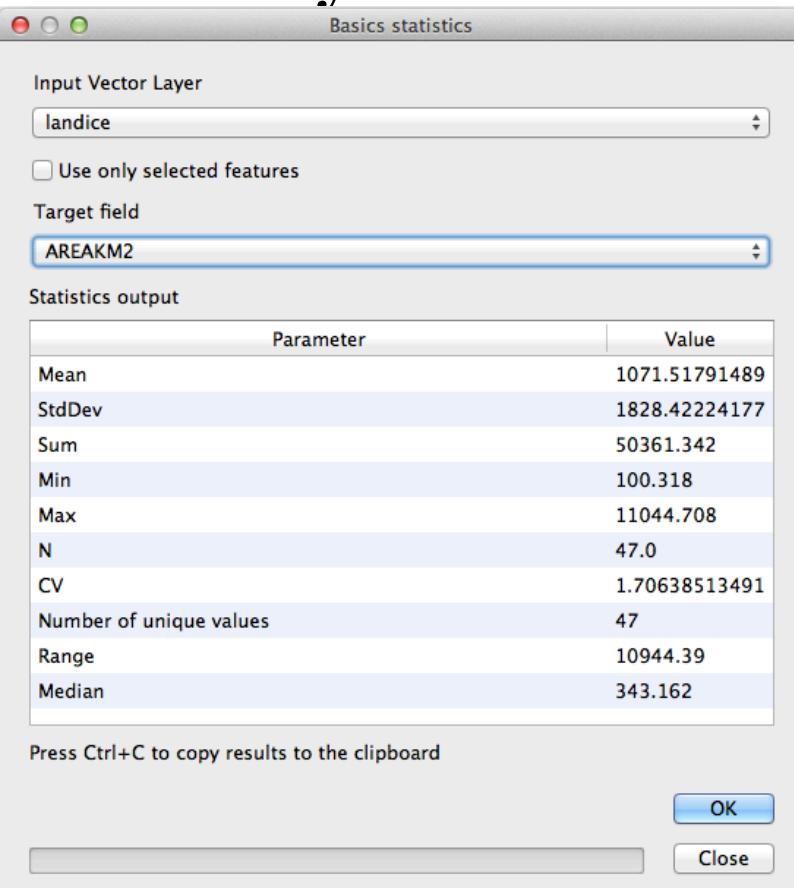
Close OK

There are 62 countries in Africa (!)

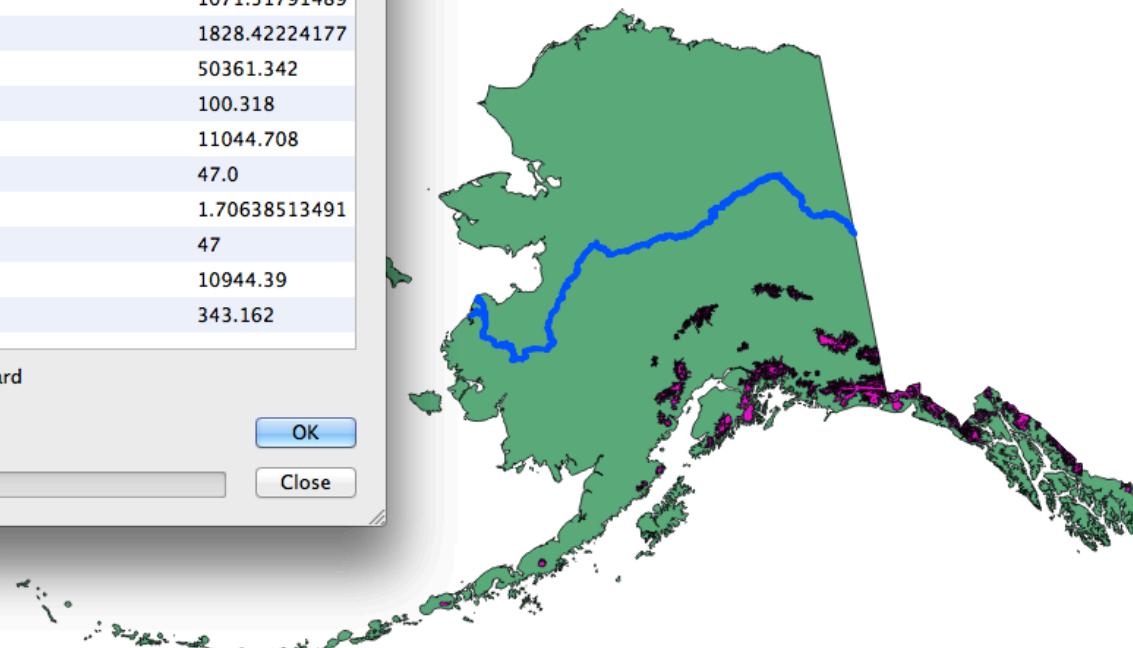
Delft  
Universiteit Delft

# Spatial Analysis: Vector data in QGIS

## Analysis Tools: Basic Statistics



The mean land ice area is  
1071km<sup>2</sup>.



# Spatial Analysis: Vector data in QGIS

**Distance Matrix:**  
How close are the flux towers to the nearest soil moisture sensors?

**Input point layer:** FluxStnsVolta200km

**Input unique ID field:** FluxStn

**Target point layer:** SMStnsVolta200km

**Target unique ID field:** SMStn

**Output matrix type:**

- Linear ( $N \times k$  x 3) distance matrix
- Standard ( $N \times T$ ) distance matrix
- Summary distance matrix (mean, std. dev., min, max)

Use only the nearest ( $k$ ) target points

**Output distance matrix:** s/DemoSpatialAnalysis/DistMatrixFluxSM.csv

**Mode:** Current layer

**View:** Tree

**Coordinate:** -8.08,10.66    **Scale:** 1:6,081,310    **Rotation:** 0.0    **Render:** EPSG:4326 (OTF)

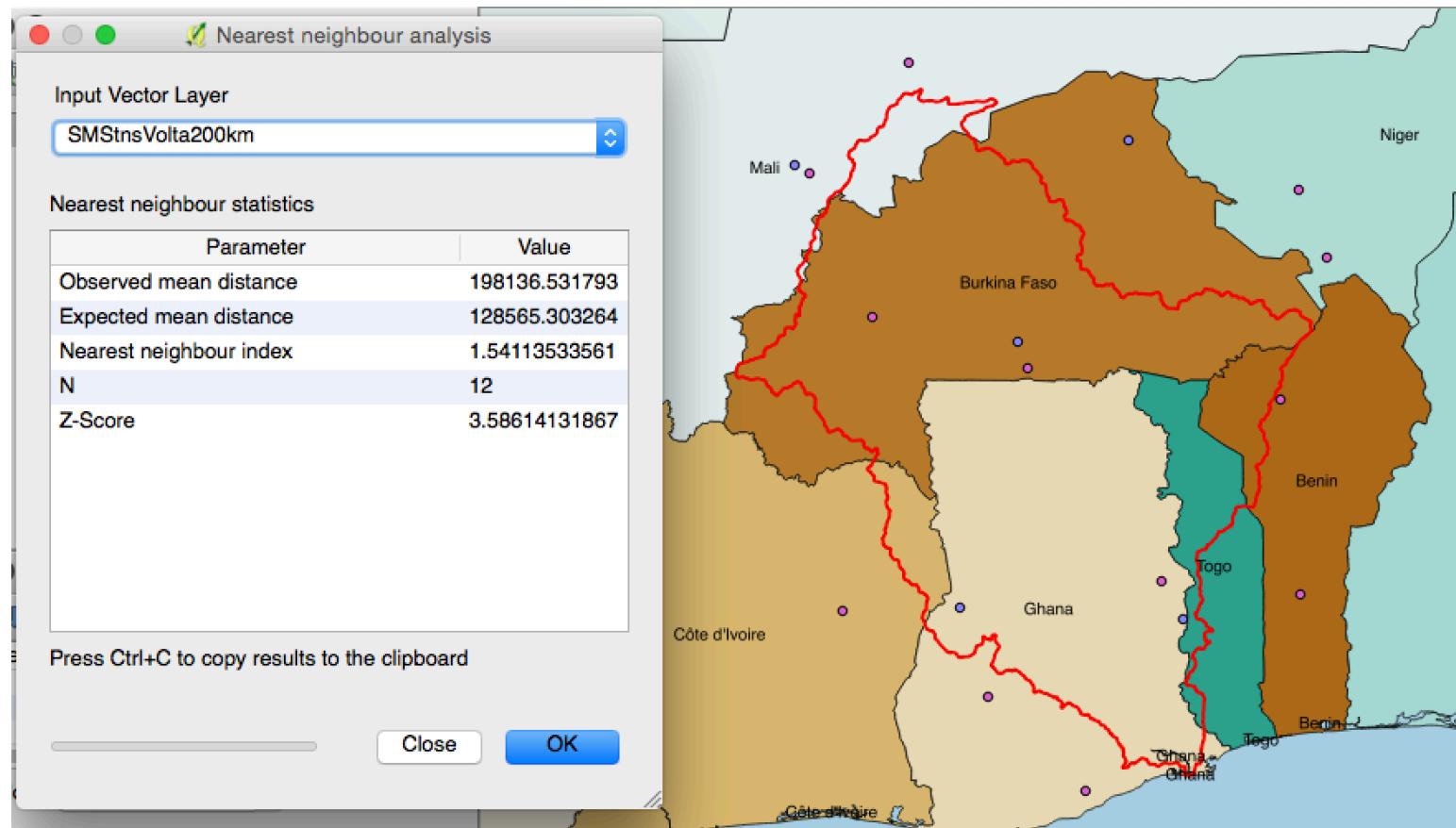
**Table Data:**

	A	B	C	D
1	InputID	TargetID	Distance	
2		1	187	137584.628
3		2	80	253919.576
4		3	127	64866.1135
5		4	152	40222.0768
6	Flux Stn	5	106	23306.8309
7				
8				

**Map View:** A map of West Africa showing the locations of flux towers (blue dots) and soil moisture sensors (purple dots). The map includes borders for Ghana, Togo, Benin, and Nigeria. The distance matrix results are overlaid on the map, showing the distance from each flux tower to its nearest soil moisture sensor.

# Spatial Analysis: Vector data in QGIS

## Analysis Tools: Nearest Neighbour Analysis



# Spatial Analysis: Vector data in QGIS

## Analysis Tools: Points in Polygon

QGIS 2.14.10-Essen - DemoProject

Count Points in Polygon

**Input polygon vector layer:** AfricanCountries

**Input point vector layer:** SMSnsVolta200km\_4326

**Input point vector layer attributes to aggregate:** SMID  
SMSn

**Statistical method for attribute aggregation:** sum

**Output count field name:** PNTCNT

**Output Shapefile:** DemoSpatialAnalysis/CountriesNSMSns.shp

Add result to canvas

**Coordinate:** -0.44,12.43    **Scale:** 1:6,081,310    **Rotation:** 0.0     Render    **EPSG:4326 (OTF)**

The screenshot shows the QGIS 2.14.10-Essen version with a 'DemoProject'. The main window displays a map of West Africa with country boundaries. A specific analysis tool, 'Count Points in Polygon', is open in a dialog box. The 'Input polygon vector layer' is set to 'AfricanCountries'. The 'Input point vector layer' is set to 'SMSnsVolta200km\_4326'. Under 'Input point vector layer attributes to aggregate', 'SMID' and 'SMSn' are selected. The 'Statistical method for attribute aggregation' is set to 'sum'. The 'Output count field name' is 'PNTCNT'. The 'Output Shapefile' is specified as 'DemoSpatialAnalysis/CountriesNSMSns.shp'. The 'Add result to canvas' checkbox is checked. At the bottom of the dialog are 'Close' and 'OK' buttons. The QGIS toolbar and menu bar are visible at the top, and the standard Mac OS X window controls are on the left.

# Spatial Analysis: Vector data in QGIS

## Analysis Tools: Points in Polygon

QGIS 2.14.10-Essen - DemoProject

The screenshot shows the QGIS 2.14.10 interface. The top bar displays the title "QGIS 2.14.10-Essen - DemoProject". The toolbar on the left contains various icons for editing, selection, and analysis. The main window has a table view on the left and a map view on the right. The table view is titled "CountriesNSMStns :: Features total: 150, filtered: 150, selected: 0". It includes columns: \_Type, Land\_Rank, COUNTRYAFF, Shape\_STAr, Shape\_STLe, and PNTCNT. A red box highlights the PNTCNT column. The map view shows a green-shaded map of West Africa with country boundaries and names: Togo, Benin, Nigeria, Ghana, and Côte d'Ivoire.

_Type	Land_Rank	COUNTRYAFF	Shape_STAr	Shape_STLe	PNTCNT
55	5	Ghana	19.57521935...	30.03814686...	3
6	5	Benin	9.493342617...	22.30554119...	2
10	5	Burkina Faso	22.77166245...	33.31664100...	2
77	5	Mali	106.6715525...	72.22929909...	2
93	5	Niger	100.5572074...	53.86371680...	2
26	5	Côte d'Ivoire	26.28829508...	46.22979318...	1
0	5	Algeria	213.0643447...	76.49267842...	0
1	2	Algeria	0.000056916...	0.043855476...	0
2	1	Algeria	0.000168894...	0.316232231...	0
3	5	Angola	103.7695948...	69.70455425...	0
4	2	Angola	0.016628449...	2.854777943...	0
5	1	Angola	0.000625689...	0.856480736...	0
7	2	Benin	0.000140207...	0.107251347...	0

New shape file, identical to “countries” but with an additional field:

**How many SM stations are in each country?**

# Spatial Analysis: Vector Data

- Spatial Query
- Data Management Tools
- Geoprocessing Tools
- Analysis Tools
- **Geometry Tools**
- Research Tools

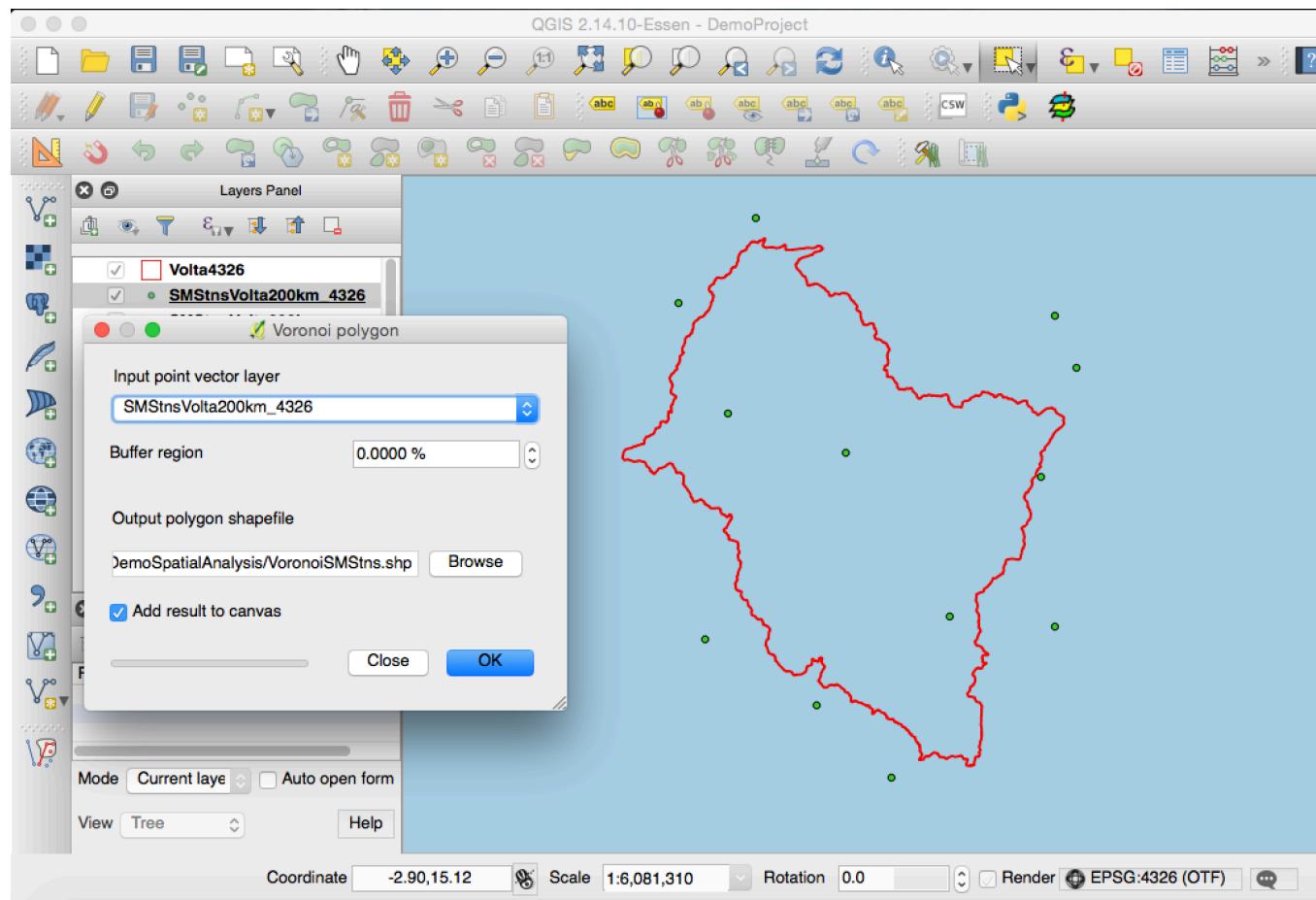
# Spatial Analysis: Vector Data

## Geometry Tools:

- Voronoi polygons
- Multipart  $\leftrightarrow$  singleparts
- Check validity

# Spatial Analysis: Vector data in QGIS

## Geometry Tools: Voronoi Polygons



# Spatial Analysis: Vector data in QGIS

## Geometry Tools: Voronoi Polygons

The image displays two side-by-side screenshots of the QGIS application interface, illustrating the creation of Voronoi polygons.

**Left Screenshot:** Shows the 'Voronoi polygon' dialog box. The 'Input point vector layer' dropdown is set to 'SMSntsVolta200km\_4326'. The 'Buffer region' input field is set to '0.0000 %'. The 'Output polygon shapefile' field contains the path 'DemoSpatialAnalysis/VoronoiSMSnts.shp', with a 'Browse' button next to it. A checkbox 'Add result to canvas' is checked. At the bottom are 'Close' and 'OK' buttons.

**Right Screenshot:** Shows the 'Voronoi polygon' dialog box with identical settings to the left one. The 'Buffer region' input field is now set to '10.0000 %'. The 'Output polygon shapefile' field contains the path 'DemoSpatialAnalysis/VoronoiSMSnts.shp', with a 'Browse' button next to it. A checkbox 'Add result to canvas' is checked. At the bottom are 'Close' and 'OK' buttons. The background map canvas shows a green polygon layer and several red wavy lines representing the Voronoi boundaries.

**Page Number:** 68

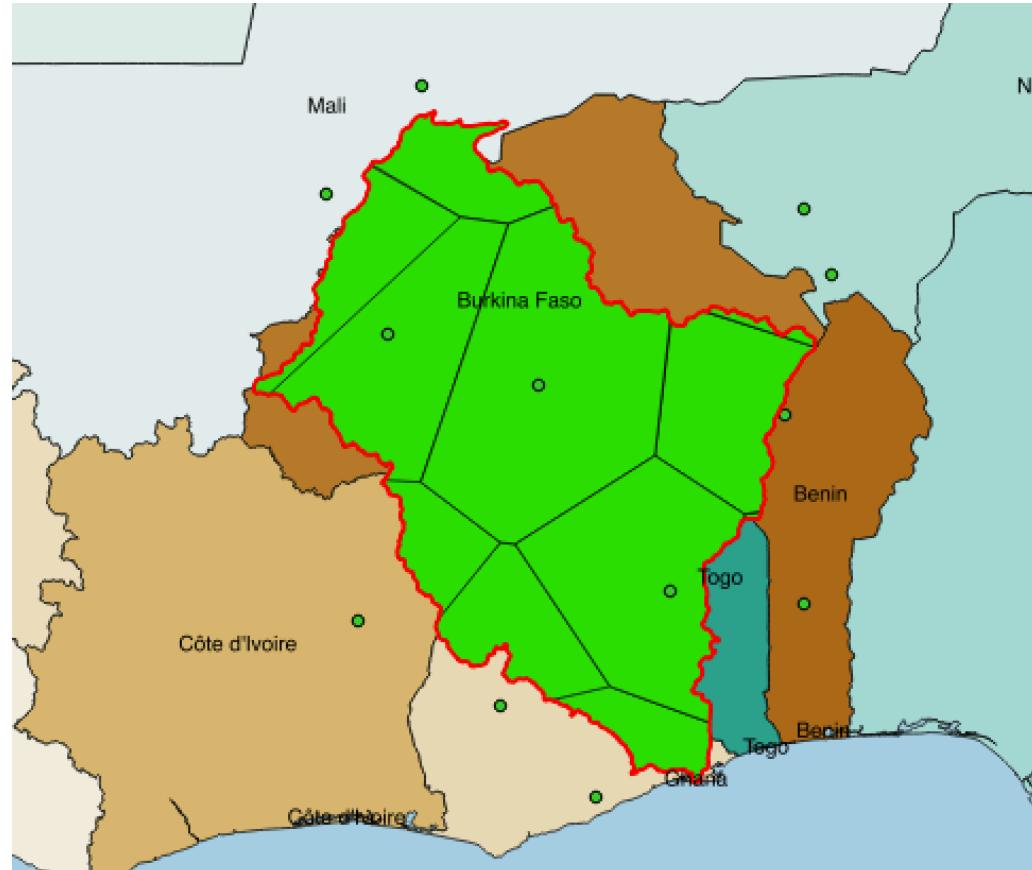
**Delft**

# Spatial Analysis: Vector data in QGIS

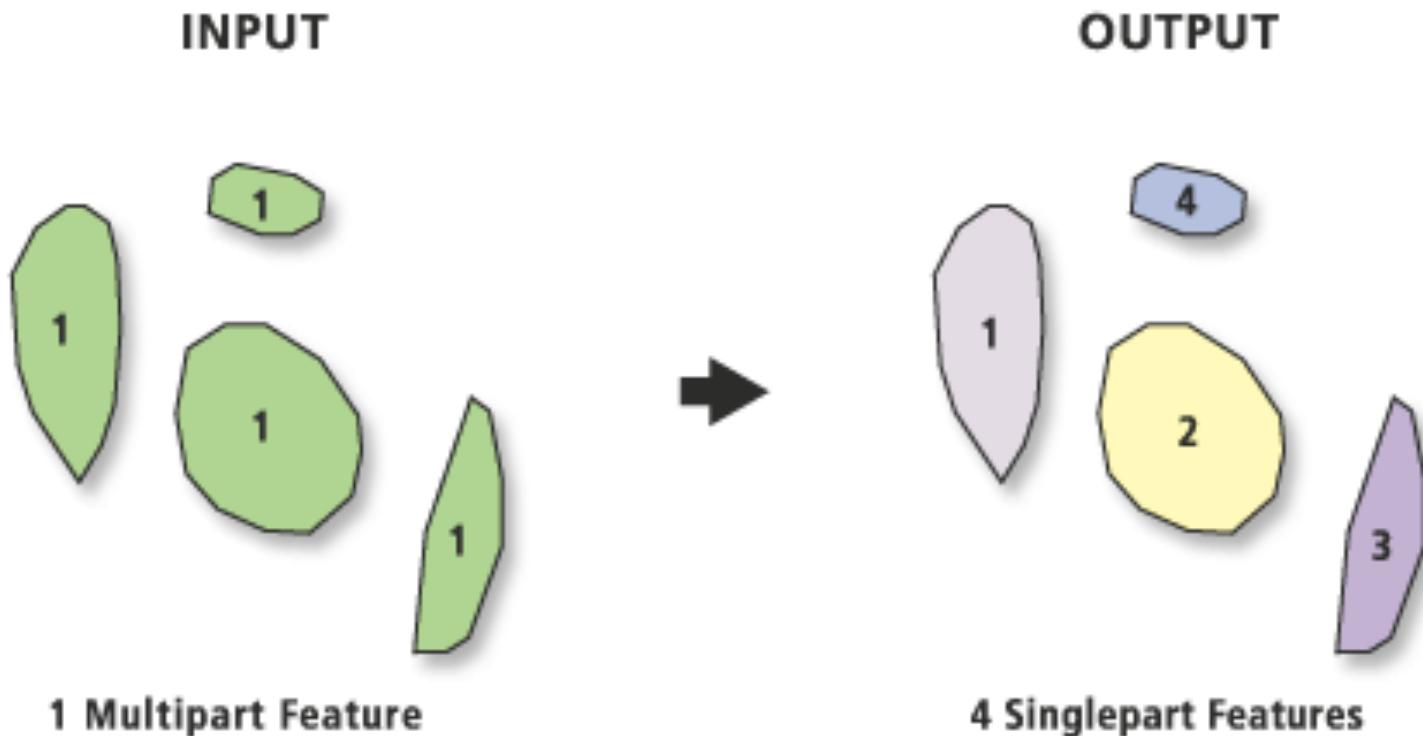
## Geometry Tools: Voronoi Polygons

Clip with Volta  
outline

=> Ready to apply  
for catchment-  
wide calculations!



# Vector Geometry tools: Multipart to Singlepart

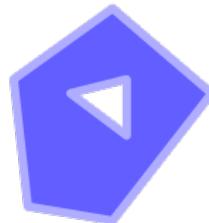


# Vector Geometry tools: Check validity

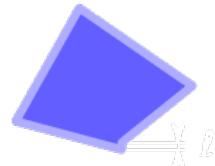
Self intersections   Duplicate nodes



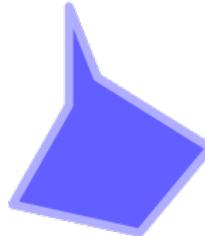
Holes



Segment length



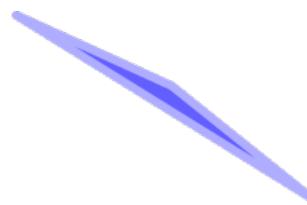
Minimum angle



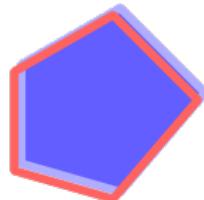
Minimum area



Silver polygons



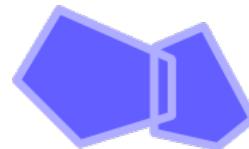
Duplicates



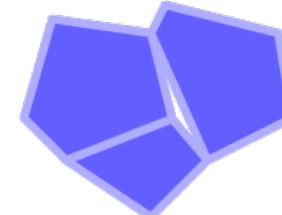
Feature within feature



Overlaps



Gaps



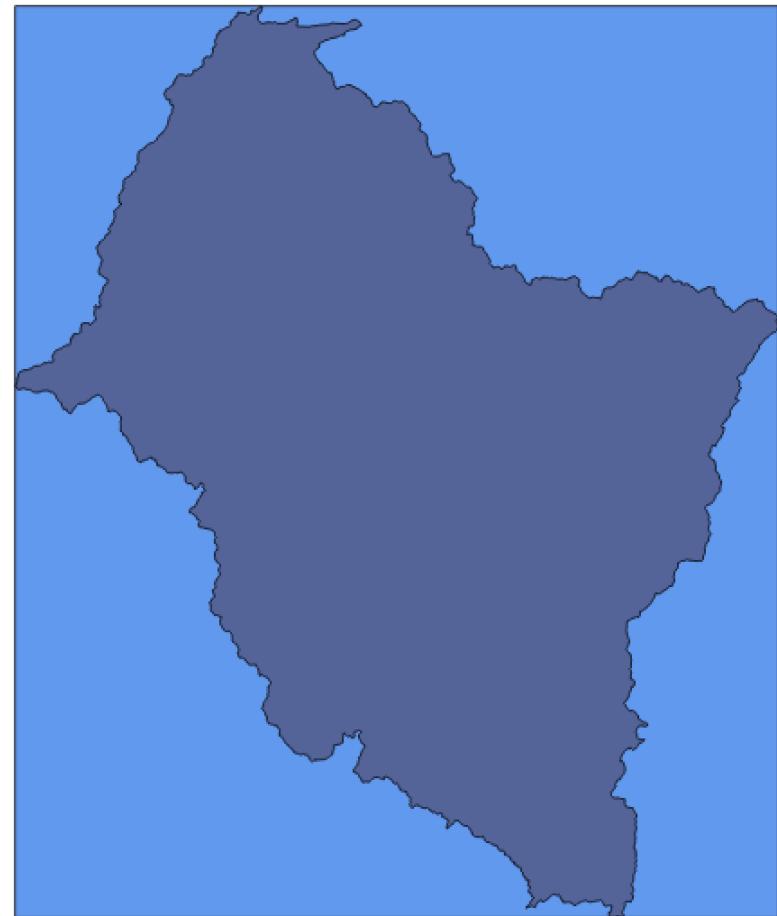
# Spatial Analysis: Vector Data

## Research Tools:

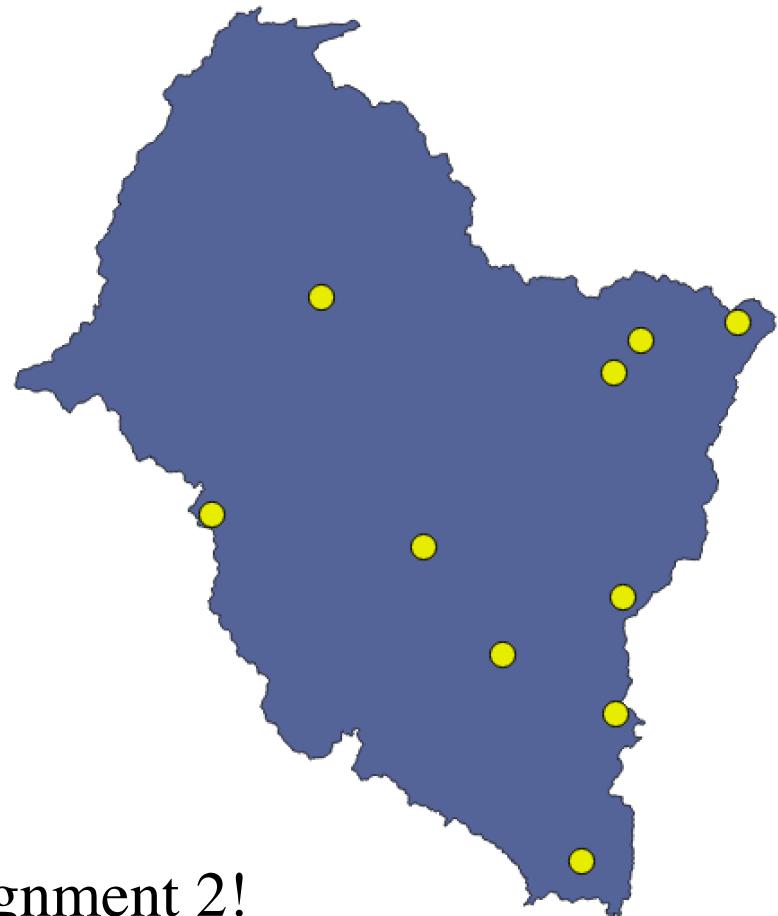
- Select by Location
- Polygon from layer extent
- Random points (inside polygons)

# Vector Research Tools: Polygon from Layer Extent

(Bounding box)



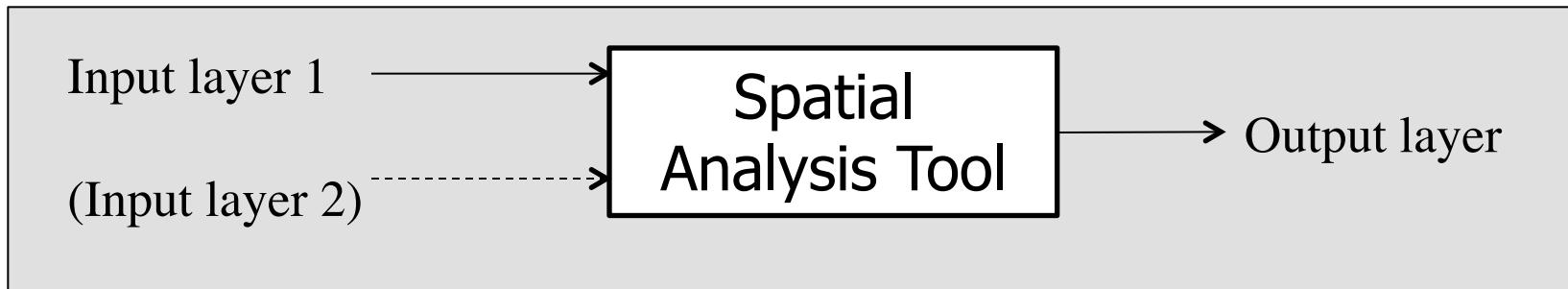
# Vector Research Tools: Random Points in polygon



e.g. Assignment 2!

# Spatial Analysis: Vector data in QGIS

*Things to look out for (1)*



If you find yourself applying a tool repeatedly,  
it's time to revisit **data management** to simplify ...

⇒ Can you combine/reduce the number of layers you need to  
load and run through the tool?

# Spatial Analysis: Vector data in QGIS

*Things to look out for (1), example:*

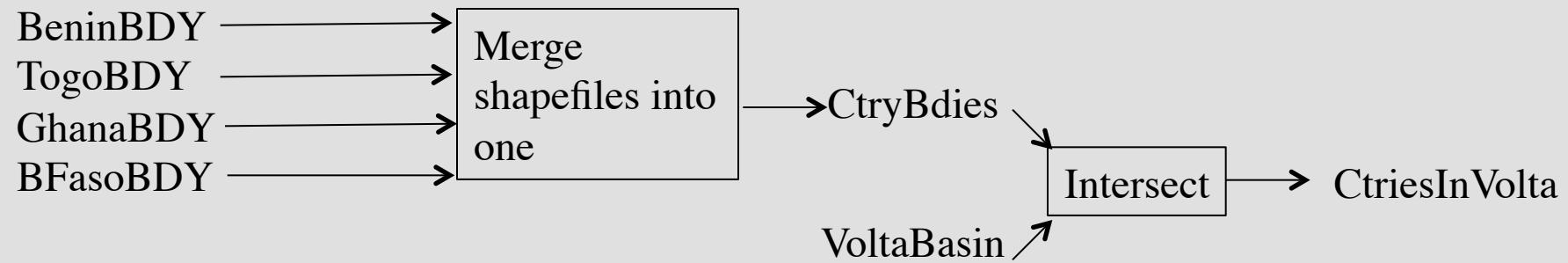
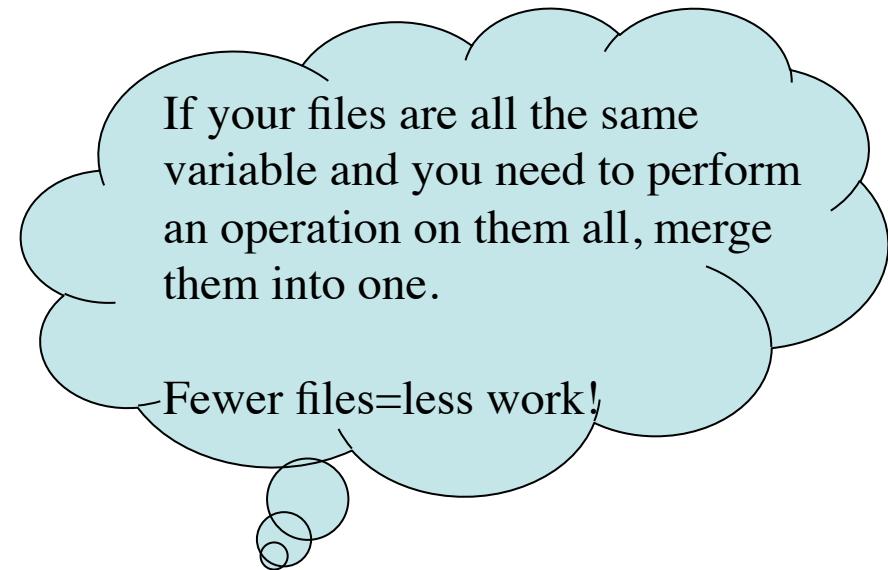


If your files are all the same variable and you need to perform an operation on them all, merge them into one.

Fewer files=less work!

# Spatial Analysis: Vector data in QGIS

*Things to look out for (1), example:*



# Spatial Analysis: Vector data in QGIS

*Things to look out for (2):*

**Are there features I don't need in my feature layer?**

Q: Do I have all countries when I only want European countries?

A: **Select** by attribute & save as new layer.

**Q: Do I have more detail than I need?**

A: **Dissolve** to the level you want, i.e. sub-basin up to basin, province up to country level.

# Coffee

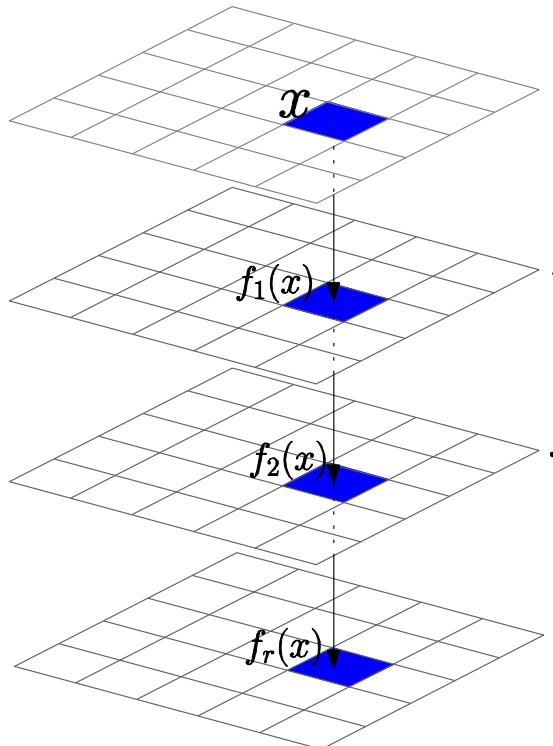
# Lecture outline

- Review Lecture 1
- Projections
- Spatial Analysis: Vector data in QGIS
- **Spatial Analysis: Map Algebra**
- Spatial Analysis: Raster data in QGIS
- Introduction to Assignment 2

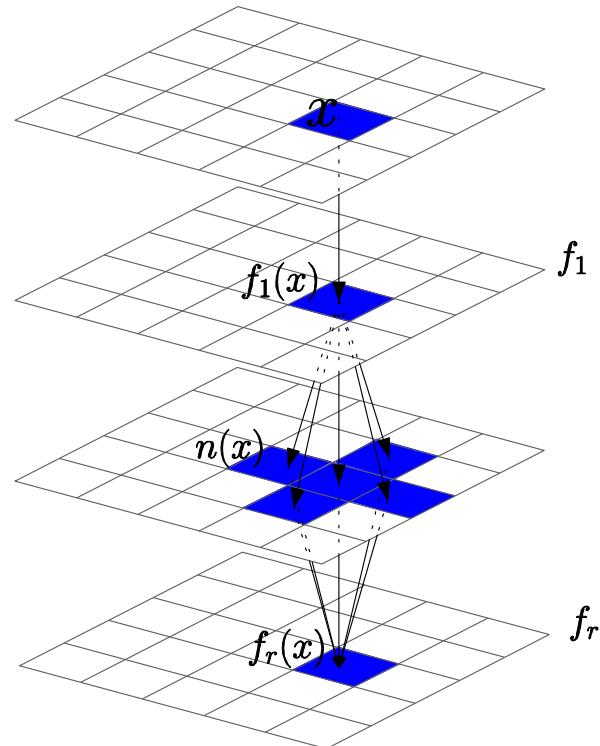
# Spatial Analysis: Map Algebra

- Dana Tomlin (1983)
- “Algebra” because maps are treated as variables and manipulated or combined using algebraic expressions
- Organizes all GIS operations on a **raster** into three types
  - Local operations are determined by the attributes of each cell alone
  - Focal operations are determined by a cell's neighbors
  - Zonal operations apply to all contiguous cells with the same value

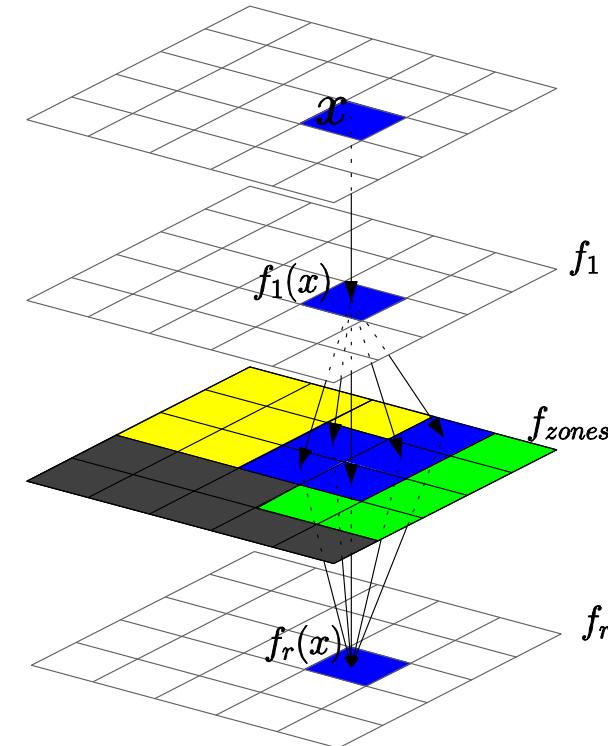
# Spatial Analysis: Map Algebra



Local operation



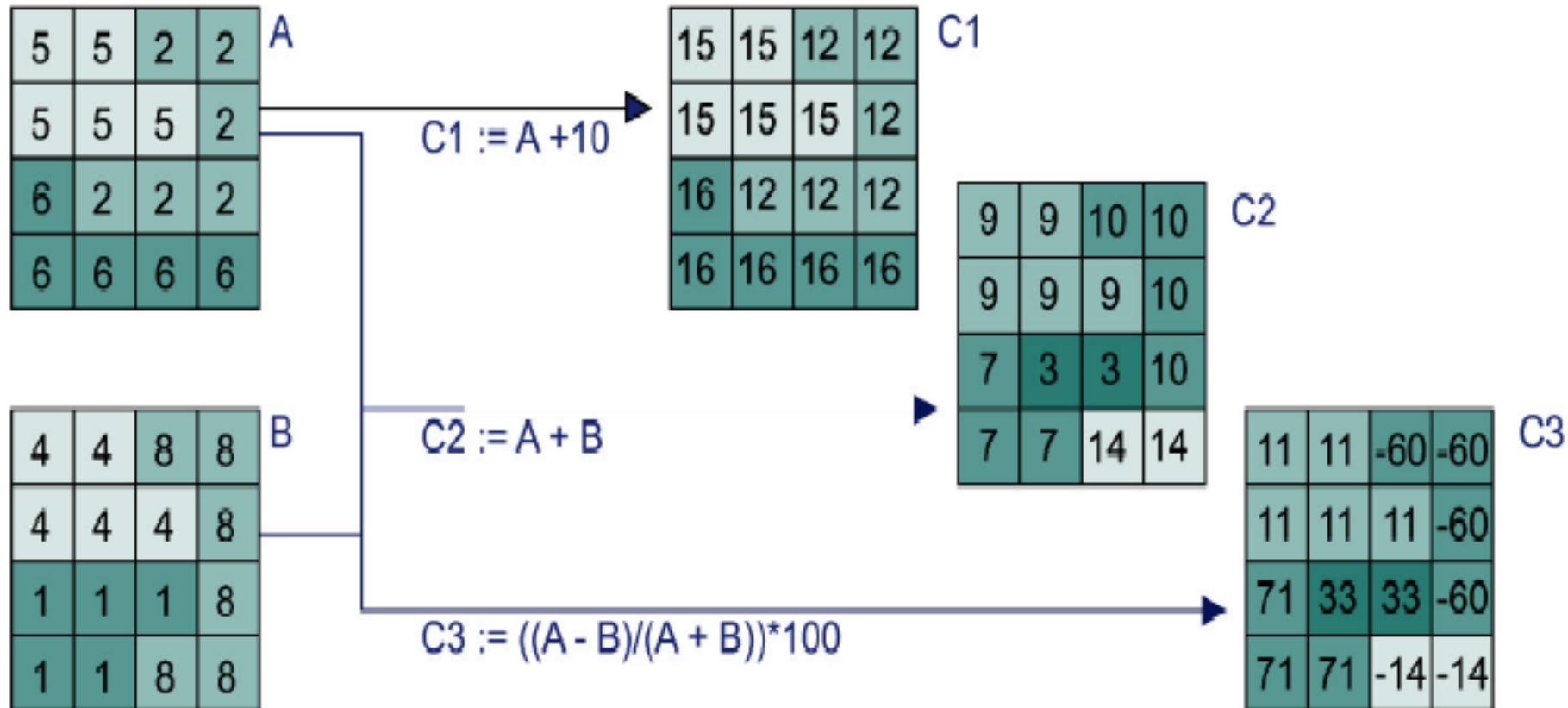
Focal operation



Zonal operation

# Spatial Analysis: Map Algebra

## Local Operations

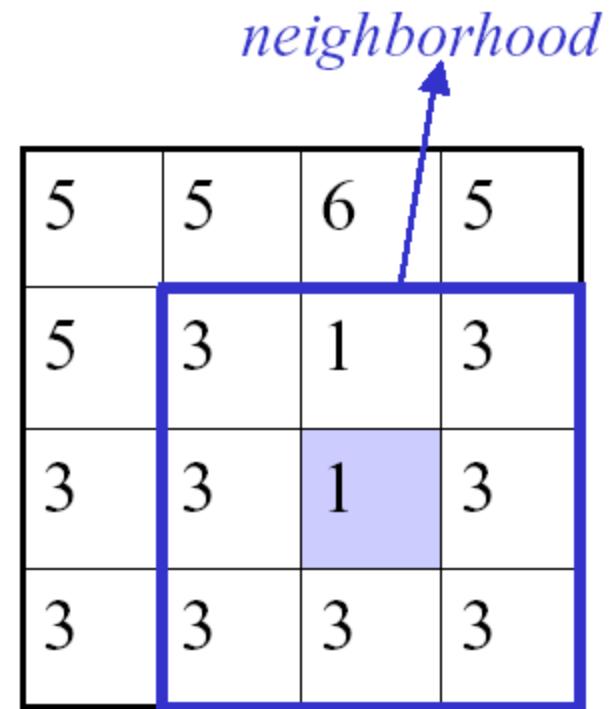


# Spatial Analysis: Map Algebra

## Focal Operations

- Operators:
  - mathematical
  - statistical
- Example  $3 \times 3$  neighborhood:
- $O(i,j) = \text{Function}\{$   
 $I(i-1,j-1), I(i-1,j), I(i-1,j+1),$   
 $I(i,j-1), I(i,j), I(i,j+1),$   
 $I(i+1,j-1), I(i+1,j), I(i+1,j+1)$   
     $\}$

e.g. terrain analysis



# Spatial Analysis: Map Algebra

## Zonal Operations

- Zone:
  - Any two or more connected cells with the same value (e.g. covering the class urban area)
- Neighborhood is the zone to which the target cells belong
- Usually, one layer defines the zones, another layers contains the values on which the operation is carried out

# Spatial Analysis: Map Algebra

## Zonal Operations

### Example

- Calculate for the zone with land use 6 the average height:  
 $O(i,j) = 17.4$

6	5	5
5	6	4
6	6	5

Land use map

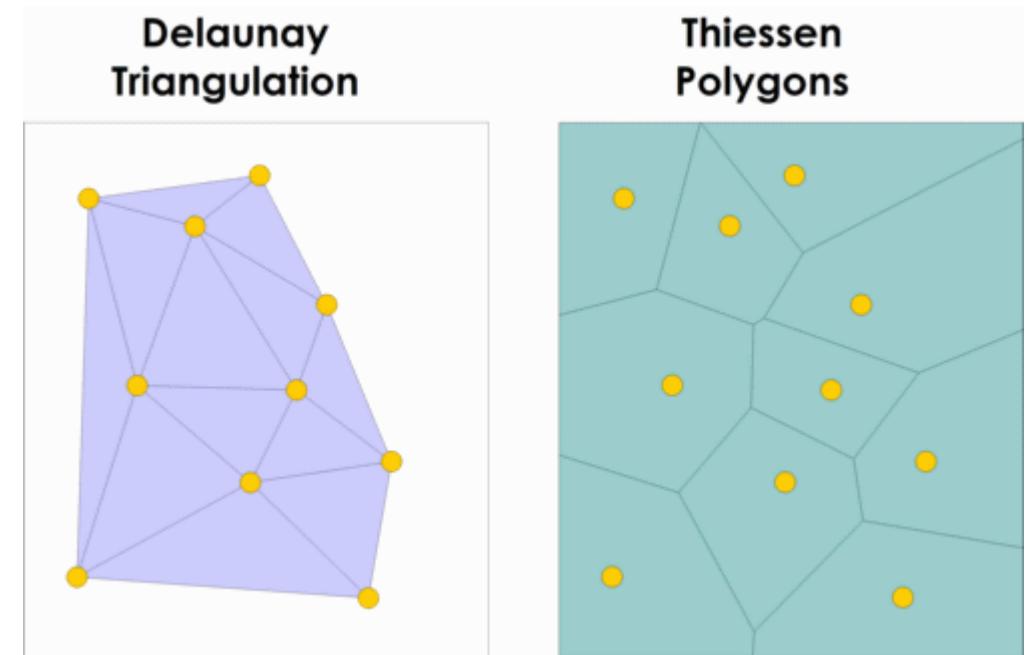
17.2	16.5	16.3
17.5	17.1	16.8
17.7	17.6	17.4

Digital Elevation Model

# Spatial Analysis: Map Algebra

## Global Operations

- Euclidean distance
- Cost distance
- Voronoi polygons, Thiessen polygons



# Spatial Analysis: Map Algebra

	<b>QGIS</b>
Local	Raster Calculator
Focal	e.g. Terrain analysis
Zonal	Raster & polygon layer in zonal statistics. Creative use of Raster Calculator
Global	Proximity (raster distance) Interpolation (of point data)

Many more possibilities when we include GRASS too!

# Lecture outline

- Review Lecture 1
- Projections
- Spatial Analysis: Vector data in QGIS
- Spatial Analysis: Map Algebra
- **Spatial Analysis: Raster data in QGIS**
- Introduction to Assignment 2

# Raster data in QGIS

- Data Management: Merge and Clipper
- Raster Calculator
- Zonal Statistics
- Interpolation
- Warp

# Raster data in QGIS

- **Data Management: Merge and Clipper**
- Raster Calculator
- Zonal Statistics
- Interpolation
- Warp

# Raster data in QGIS: Merge and Clipper

QGIS Project Edit View Layer Settings Plugins Vector Raster Database Web Processing Window Help

QGIS 2.18.15 - SSD\_Assignment1

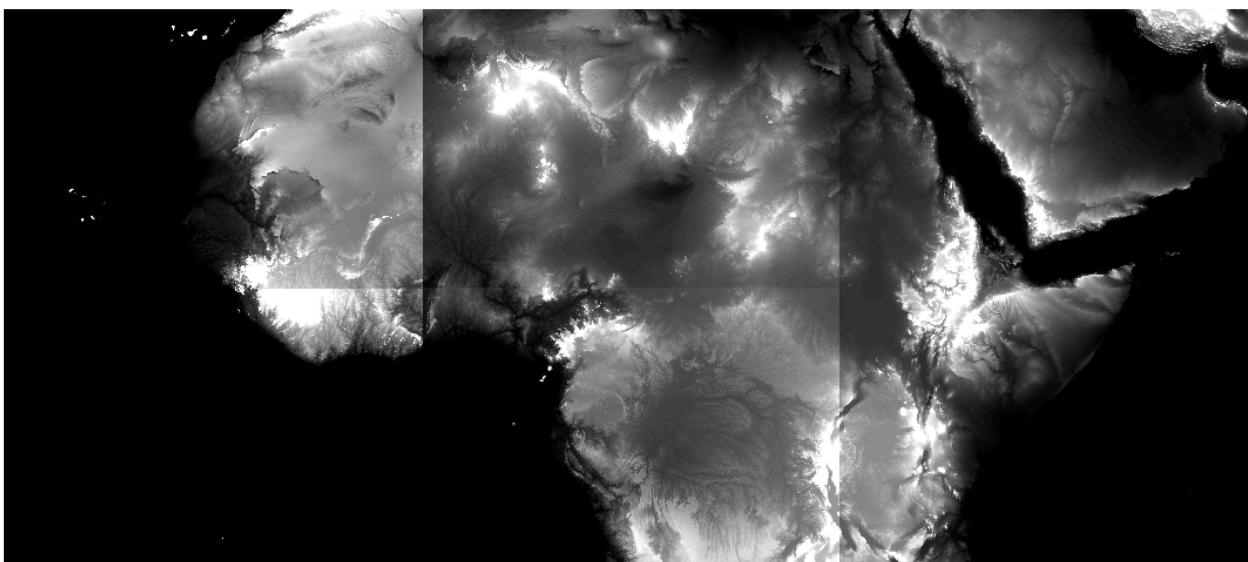
Layers Panel

- 10n030w\_20101117\_gmted\_me300
  - 0
  - 540
- 10s030w\_20101117\_gmted\_me300
  - 0
  - 396
- 10s030e\_20101117\_gmted\_me300
  - 0
  - 2035
- 10s000e\_20101117\_gmted\_me300
  - 0
  - 1263
- 10n030e\_20101117\_gmted\_me300
- 10n000e\_20101117\_gmted\_me300

Browser Panel

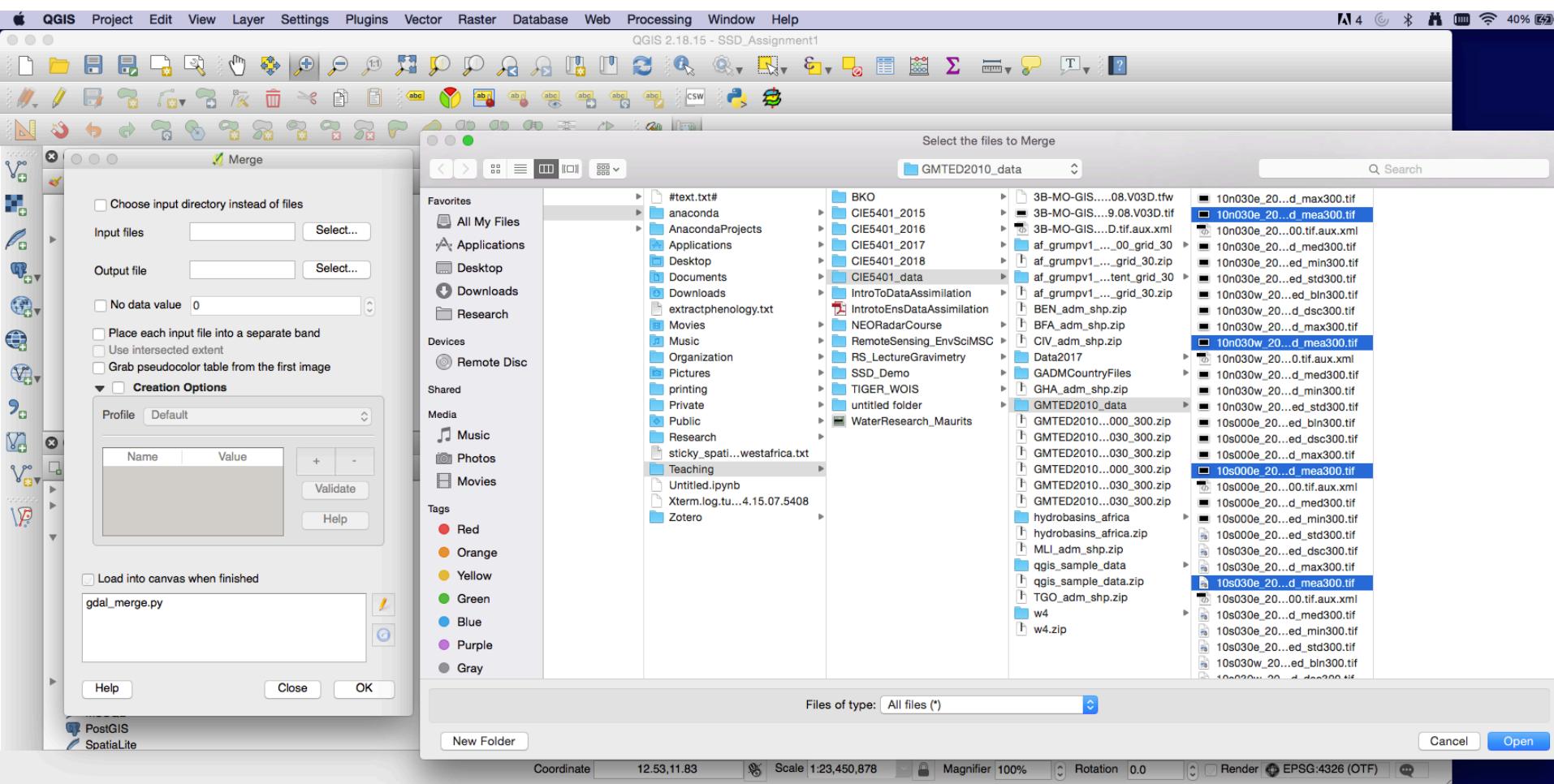
- Project home
- Home
- Favourites
- /
- Applications
- Library
- opt
- System
- Users
  - localadmin
  - sdunne
  - Shared
- Volumes
  - DB2
  - MSSQL
  - PostGIS
  - SpatiaLite

Input: Six DEM files



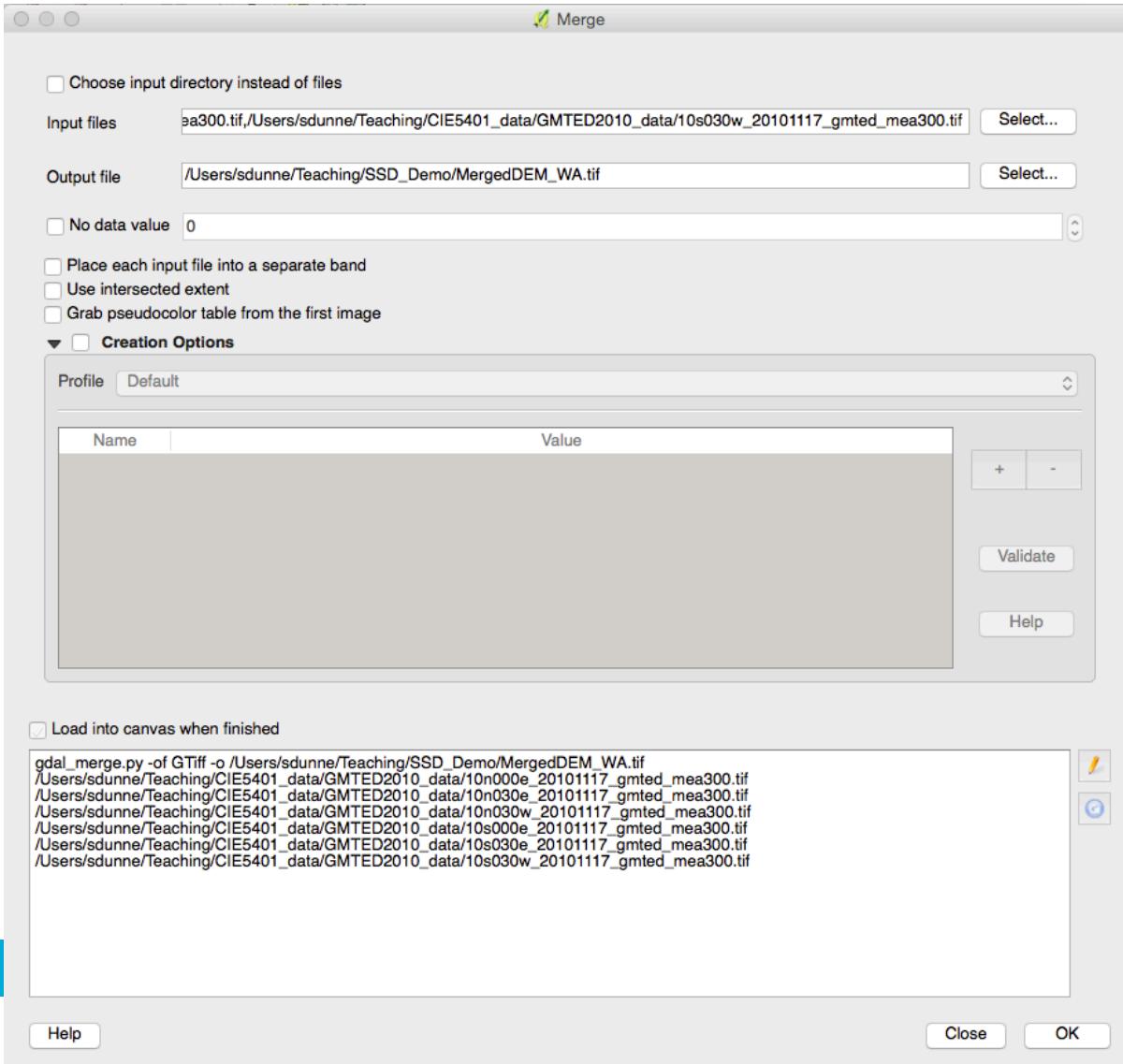
Coordinate 7.98,-3.36 Scale 1:23,450,878 Magnifier 100% Rotation 0.0 Render EPSG:4326 (OTF)

# Raster data in QGIS: Merge and Clipper

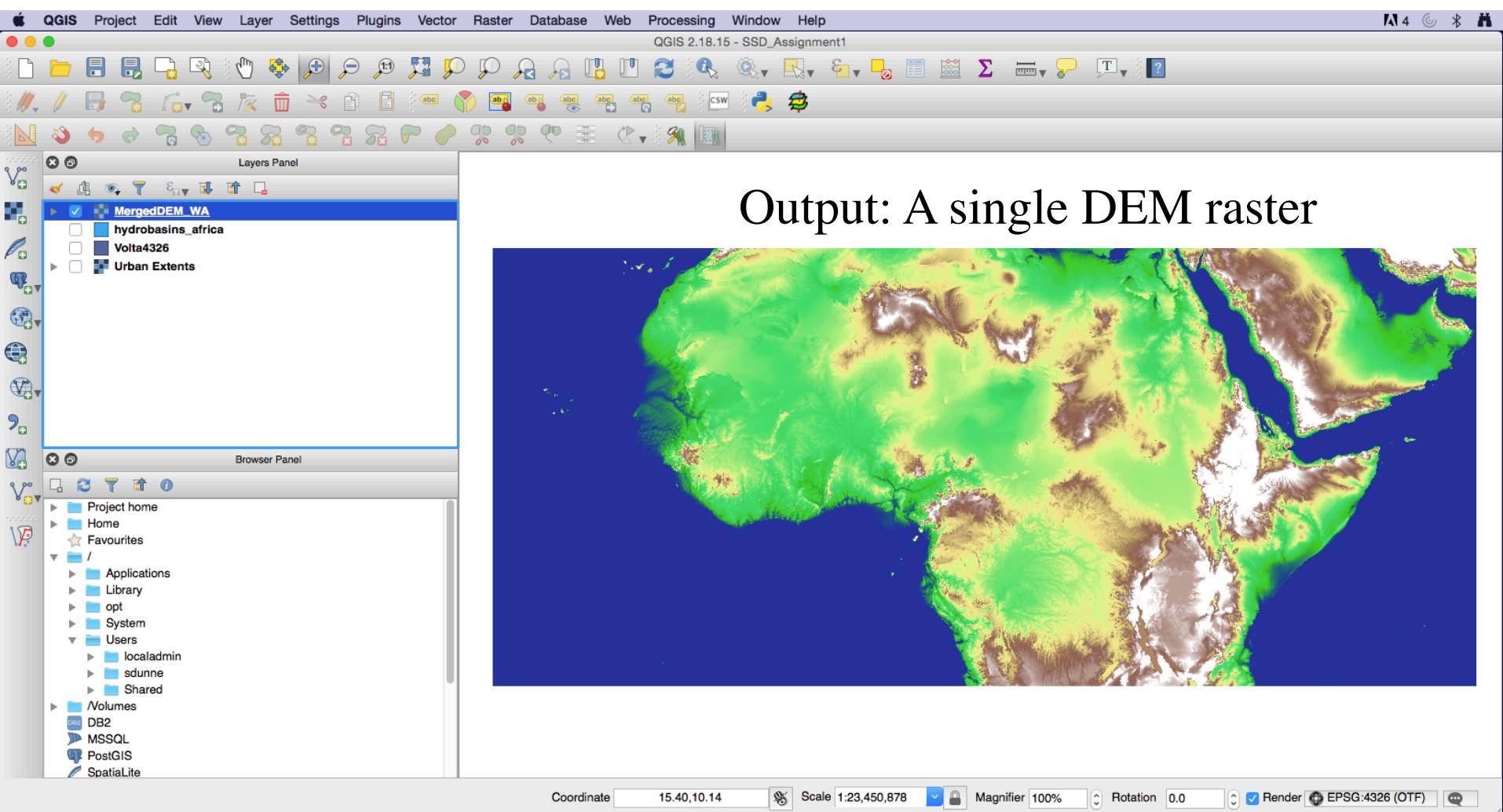


93

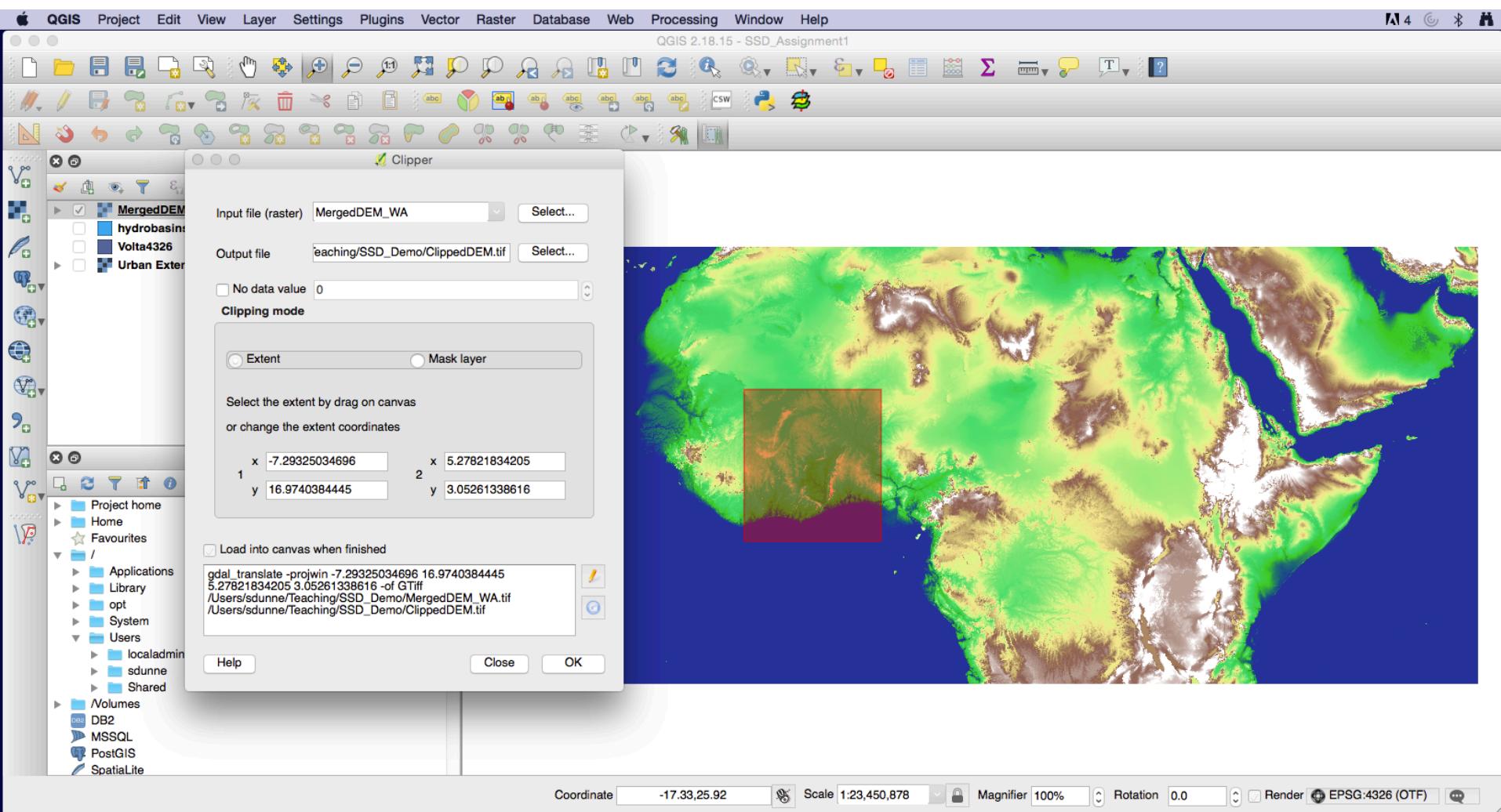
# Raster data in QGIS: Merge and Clipper



# Raster data in QGIS: Merge and Clipper



# Raster data in QGIS: Merge and Clipper



# Raster data in QGIS: Merge and Clipper

QGIS Project Edit View Layer Settings Plugins Vector Raster Database Web Processing Window Help

QGIS 2.18.15 - SSD\_Assignment1

Layers Panel

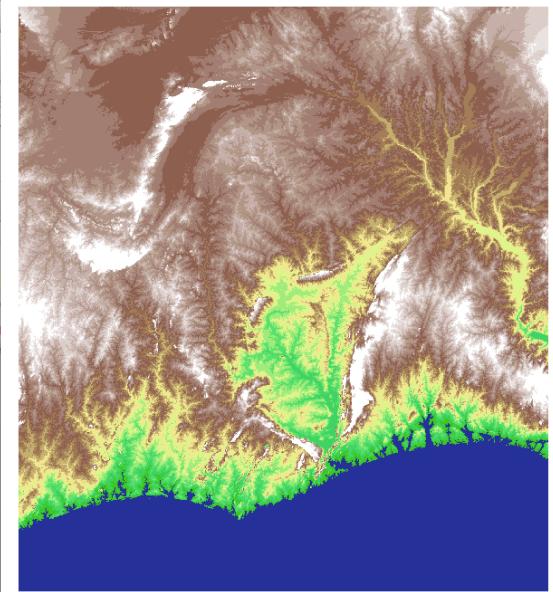
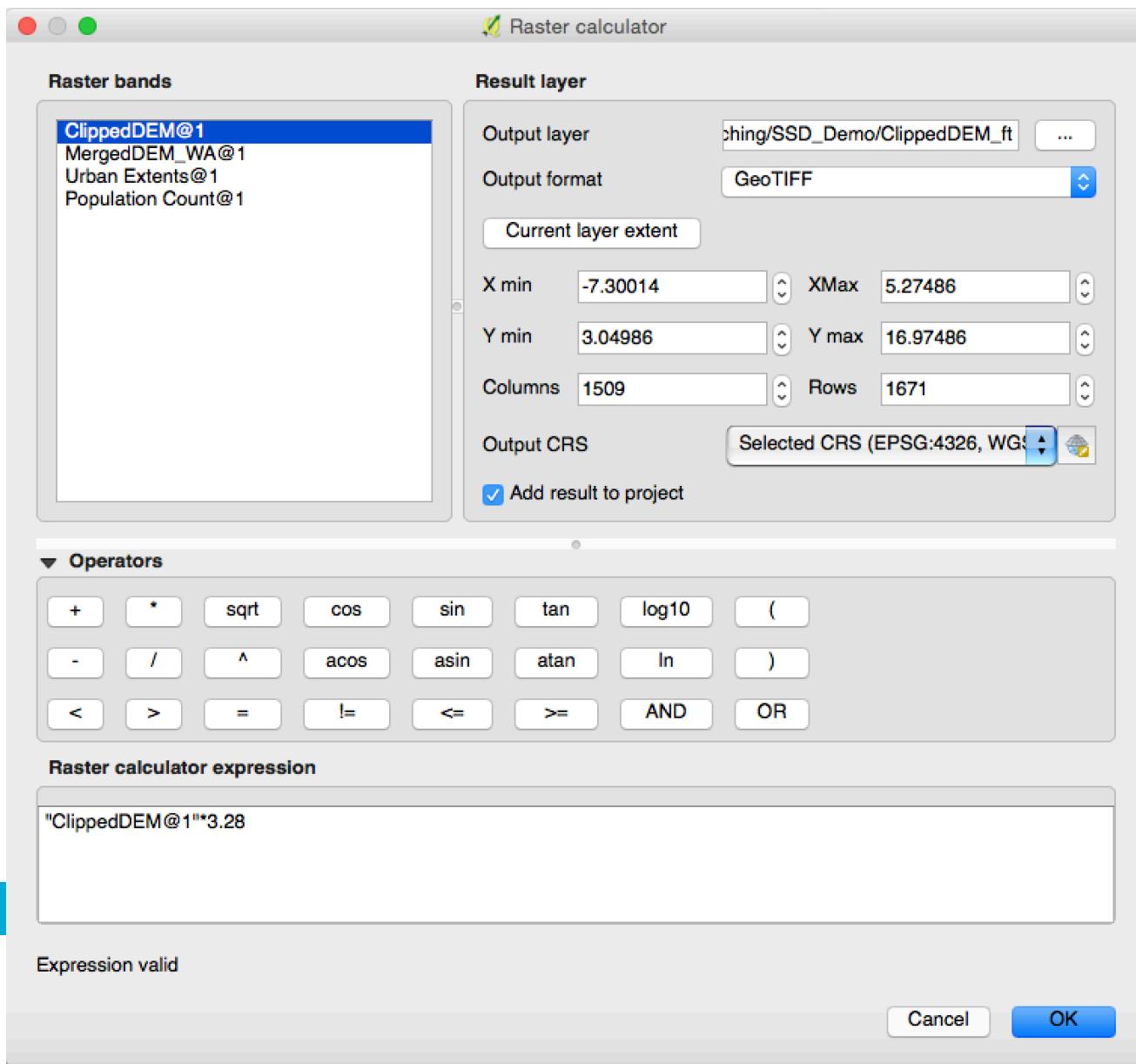
- ClippedDEM
- MergedDEM\_WA
- hydrobasins\_africa
- Volta4326
- Urban Extents

Browser Panel

- Project home
- Home
- Favourites
- /
- Applications
- Library
- opt
- System
- Users
- localadmin
- sdunne
- Shared
- Volumes
- DB2
- MSSQL
- PostGIS
- SpatiaLite

Coordinate -11.61,12.73 Scale 1:6,009,809 Magnifier 100% Rotation 0.0 Render EPSG:4326 (OTF)

# Raster data in QGIS: Raster Calculator



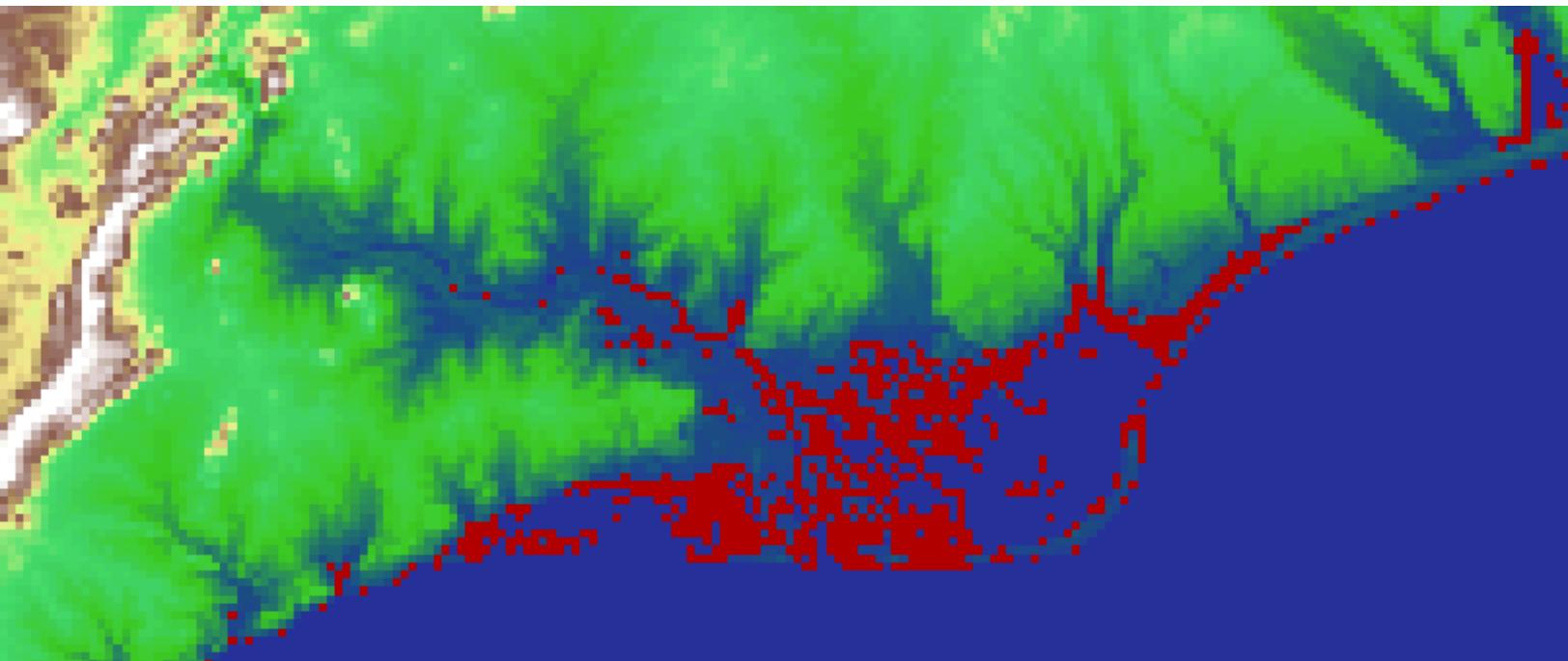
Arithmetic:

e.g. Converting  
from metres to feet

# Raster data in QGIS: Raster Calculator

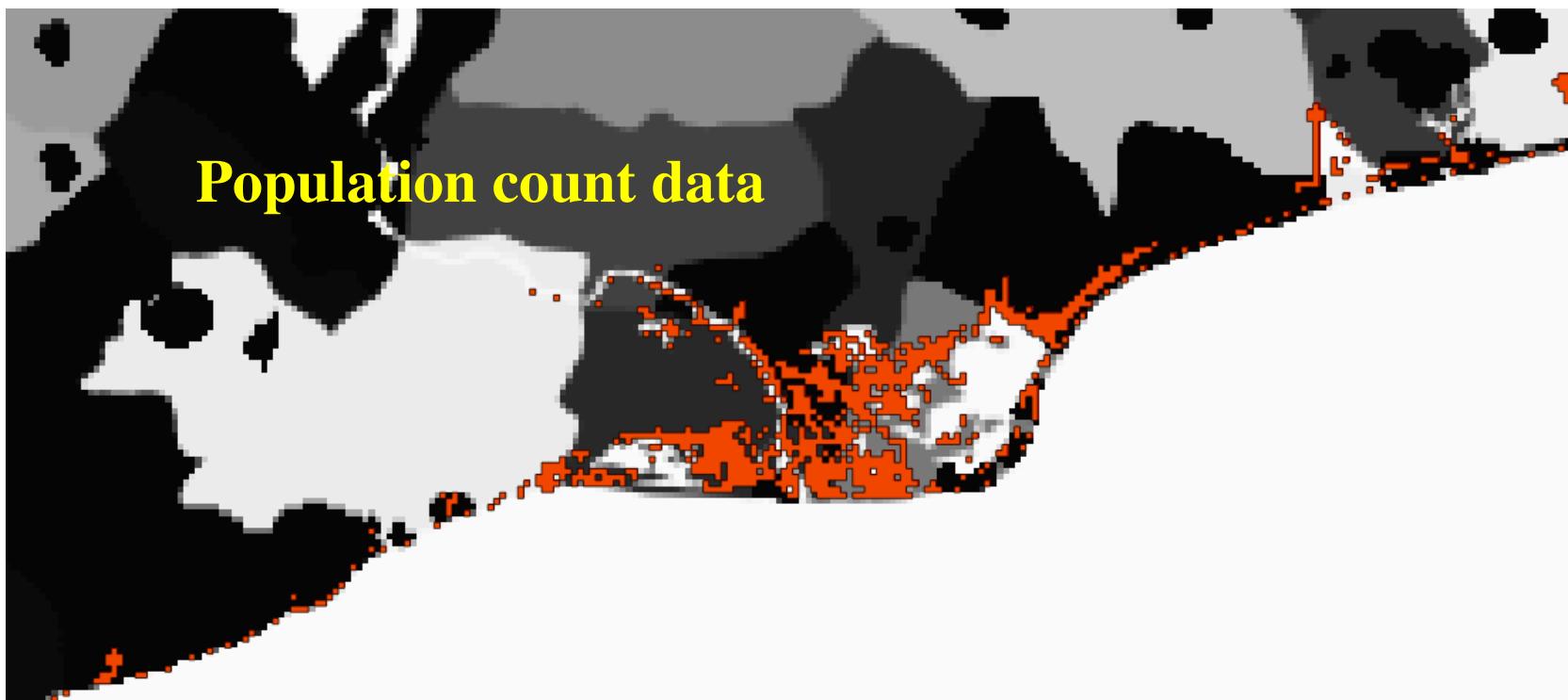
## Masks/Conditions

$("ClippedDEM@1">>0)*("ClippedDEM@1"<3)$

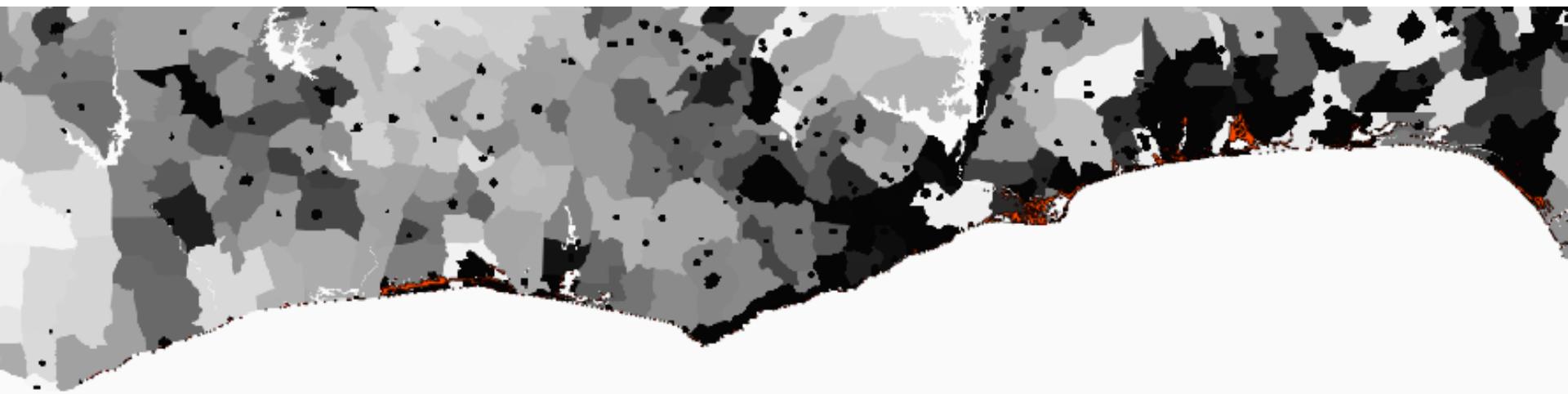


# Raster data in QGIS: Convert

Convert to polygon for overlay analysis or zonal statistics!

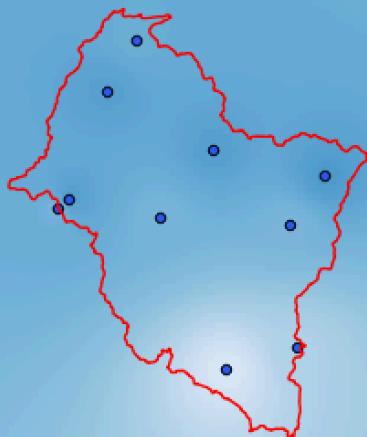


# Raster data in QGIS: Zonal Statistics



**1.17 million people in this area affected if sea level rises by 3m!?**

# Raster data in QGIS: Interpolation

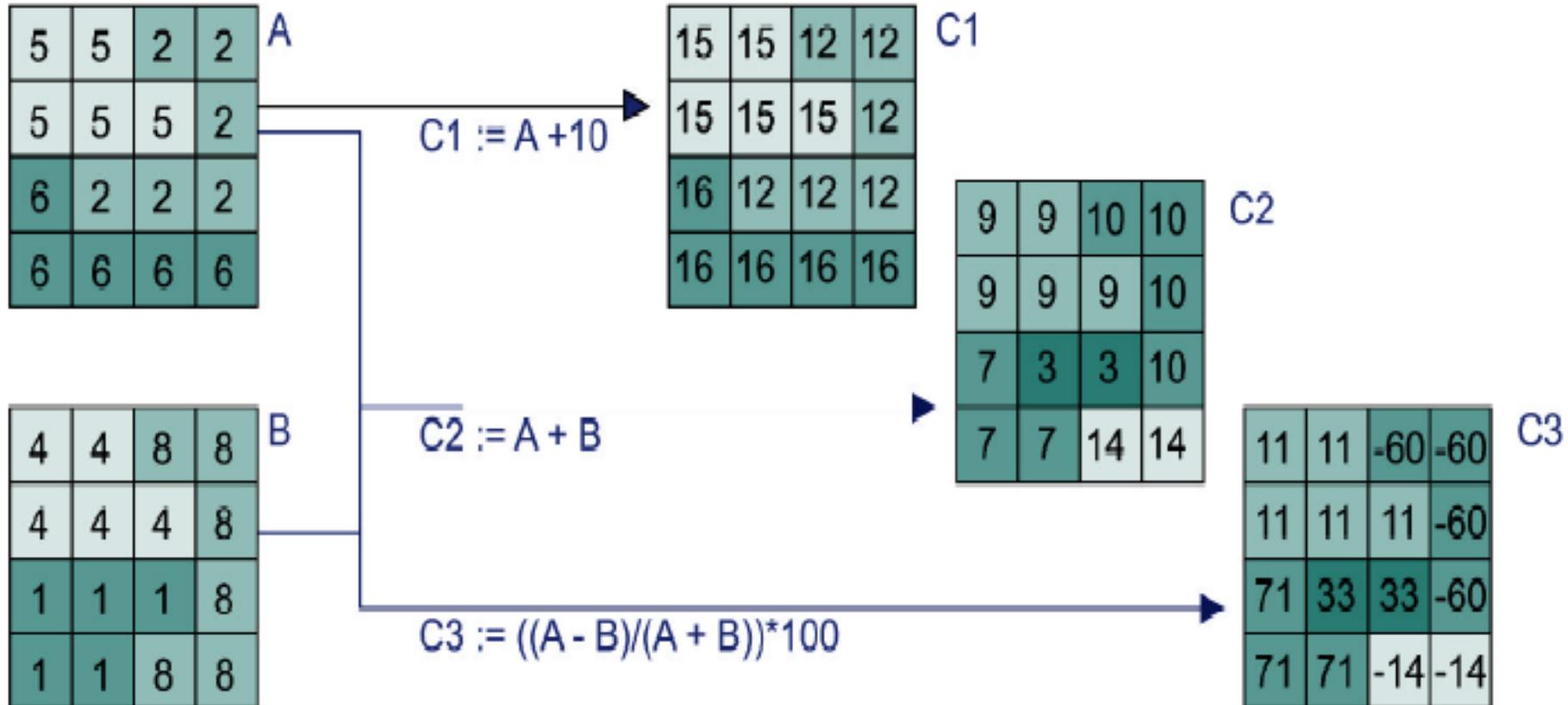


QGIS Raster Interpolation:  
Triangular Interpolation  
**Inverse Distance Weighting**

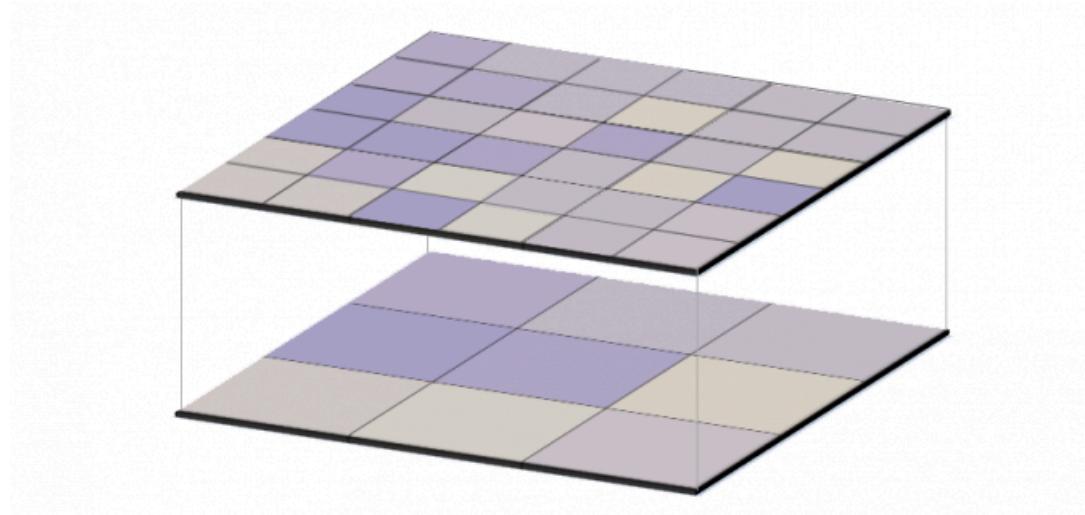
Many more options in  
GRASS, SAGA plug-ins

# Raster data in QGIS: Warp

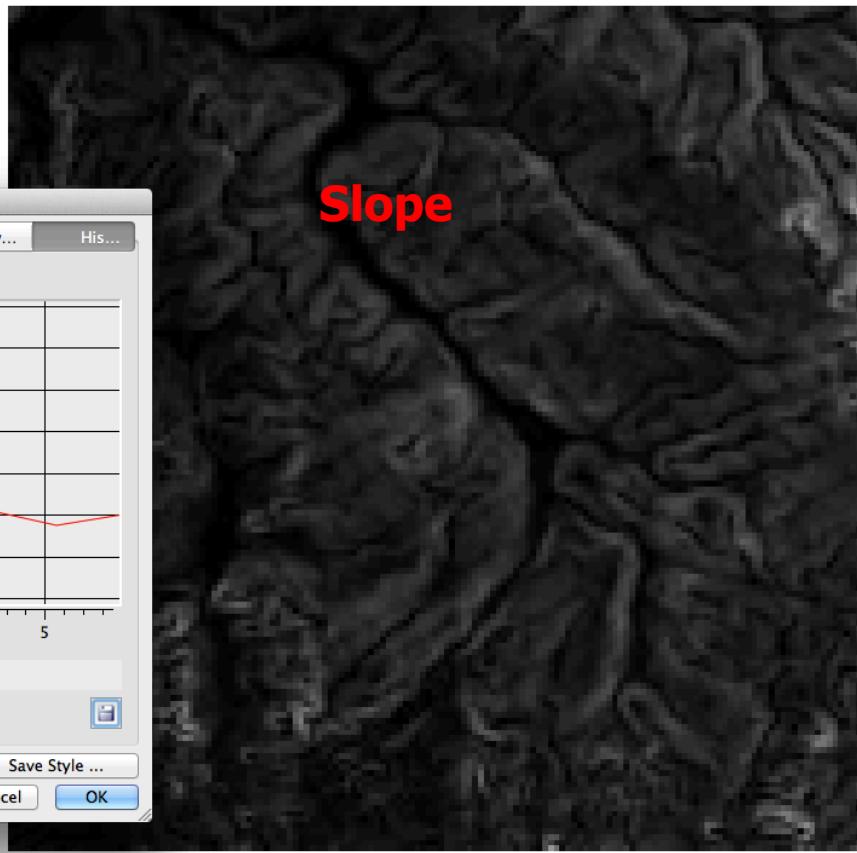
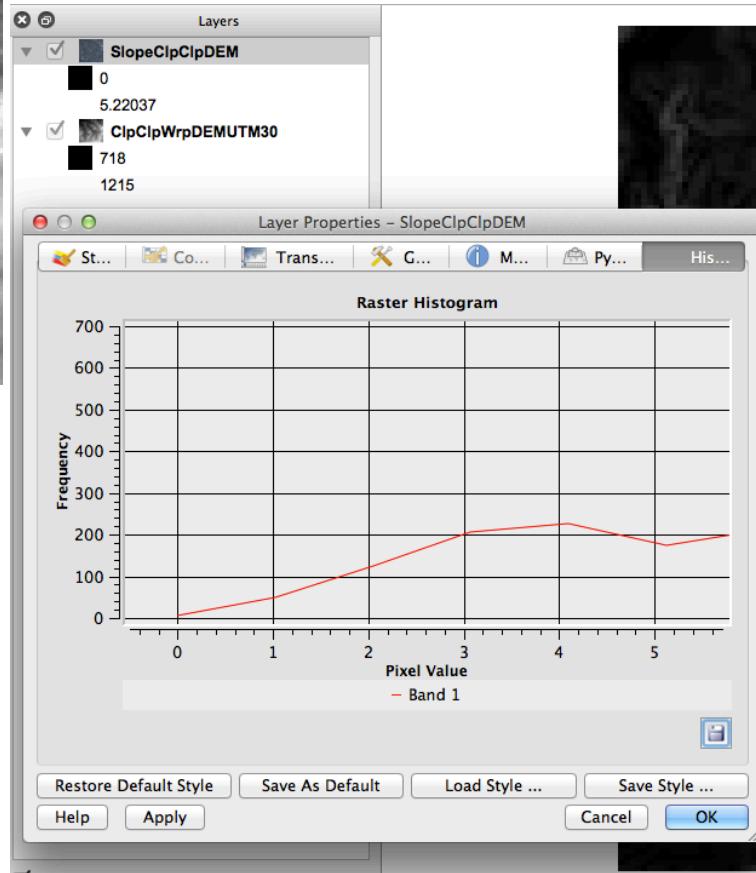
## Why?



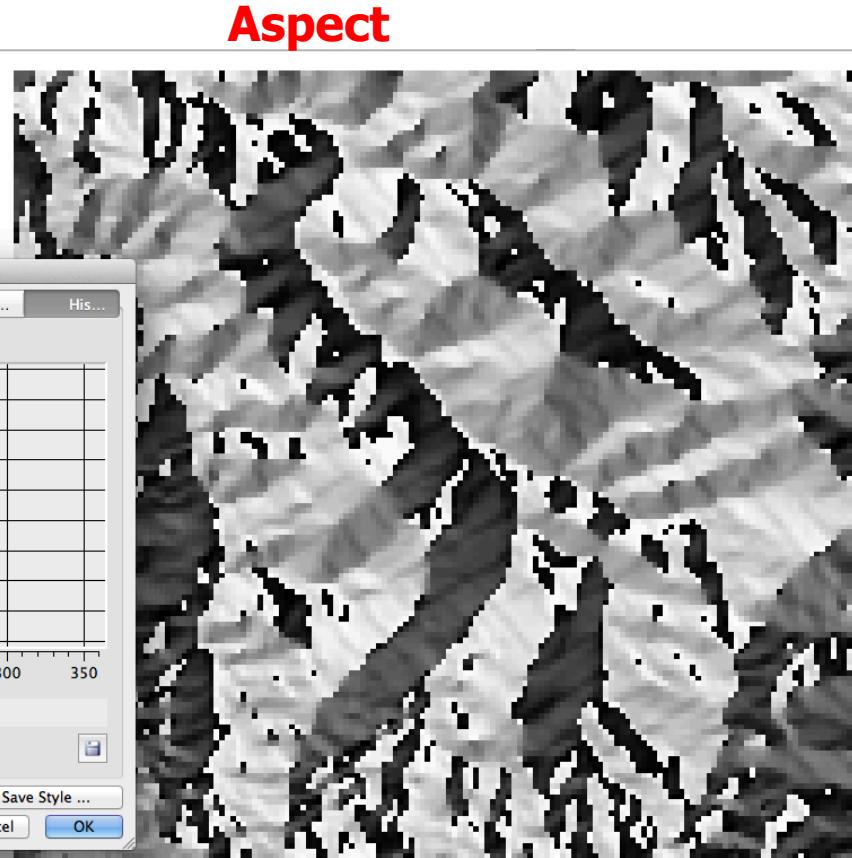
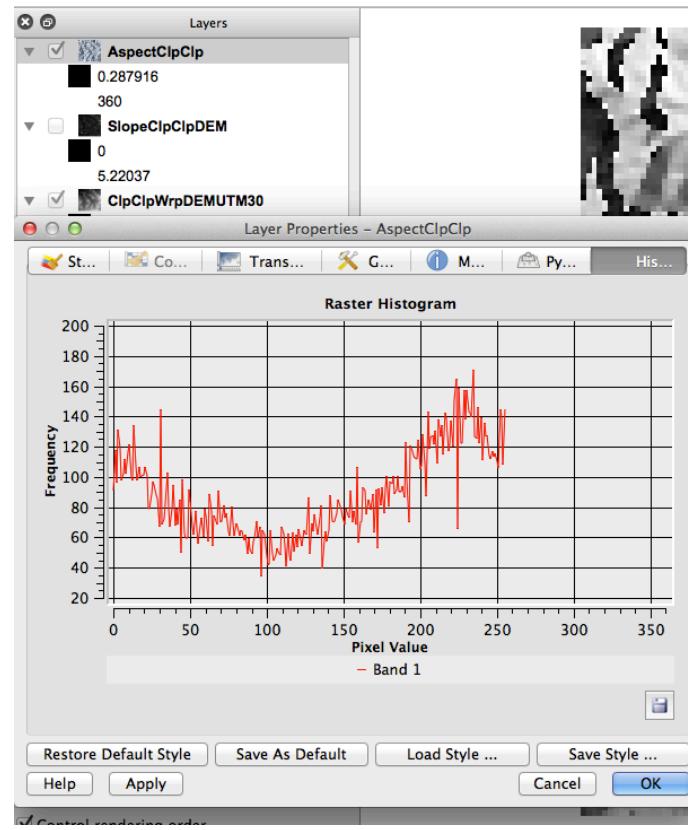
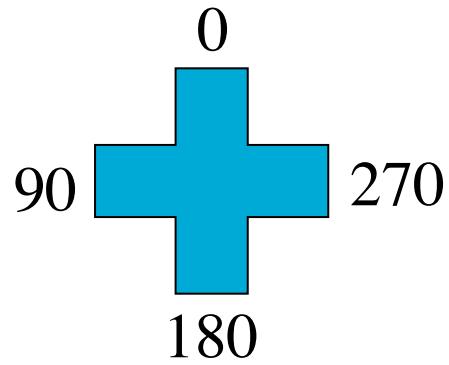
# Raster data in QGIS: Warp



# Raster data in QGIS: Terrain Analysis



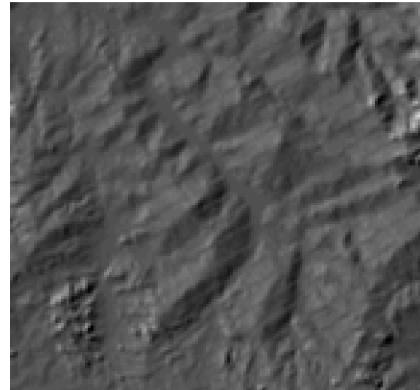
# Raster data in QGIS: Terrain Analysis



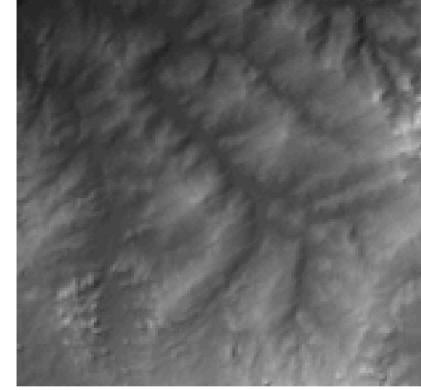
# Raster data in QGIS: Terrain Analysis



DEM



Hillshade

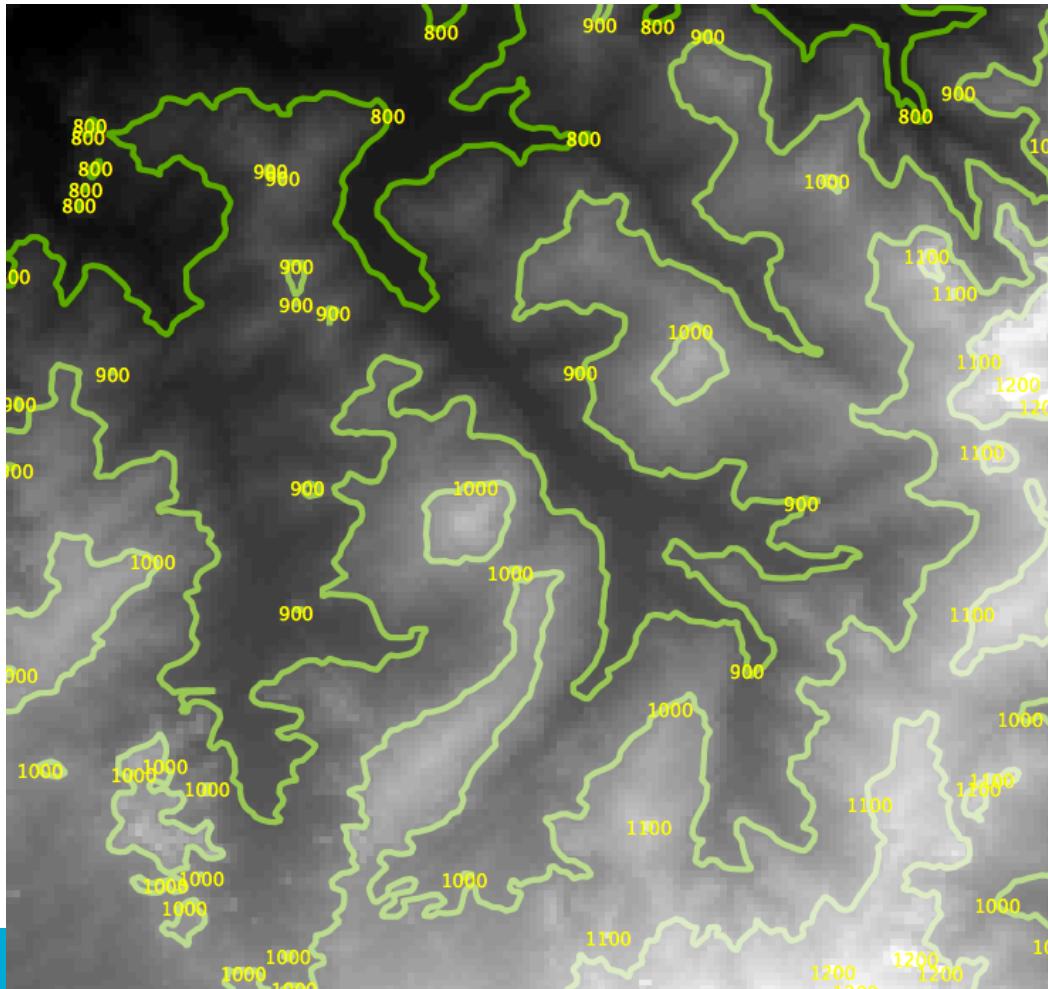


Hillshade + DEM  
=> 3D effect

More later ... even better with GRASS!

# Spatial Analysis: Raster data in QGIS

## Contour



# Lecture outline

- Review Lecture 1
- Projections
- Spatial Analysis: Vector data in QGIS
- Spatial Analysis: Map Algebra
- Spatial Analysis: Raster data in QGIS
- **Introduction to Assignment 2**