# Integrating GIS in the Inquiry of Historical Comparative Development

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# Outline

- Why GIS in economics?
- Examples of research
- Spatial Data Types
- Coordinate Systems

# Why GIS in Economics?

- Without GIS the unit of analysis is limited to:
  - countries
  - administrative districts in some developed countries (NUTS in Europe, counties in the US)
  - some villages in developing countries
- The unit of analysis can be **any** level of spatial aggregation:
  - administrative units across **all** countries
  - all populated territories globally
  - locations of ethnic/linguistic groups
  - old kingdoms
  - artificial units

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- More credible identification strategies. Examples include:
  - account for a plethora of geographic covariates
  - Come up with instruments (distance from certain locations, like Mainz (spread of the printing press) from Wittemberg (spread of Protestantism)
  - Conduct spatial RD-design exploiting historical accidents (MIta in Peru, colonial border drawing in Africa, extent of historical empires in Europe, etc..).
  - Explore the level at which the pattern uncovered prevails. Invariance to spatial aggregation?
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# Examples of Data

- Satellite images of:
  - Annual Nighttime Lights
  - Fires
  - Annual changes in forest cover
- Modern/Historical Maps
  - Roads, trade routes, empires, kingdoms, administrative units
  - Group Boundaries, suitability for various crops (FAO-GAEZ)
- Geocoded Data:
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- => Each district govt official engages in Cournot competition in selling (illegal) logging permits
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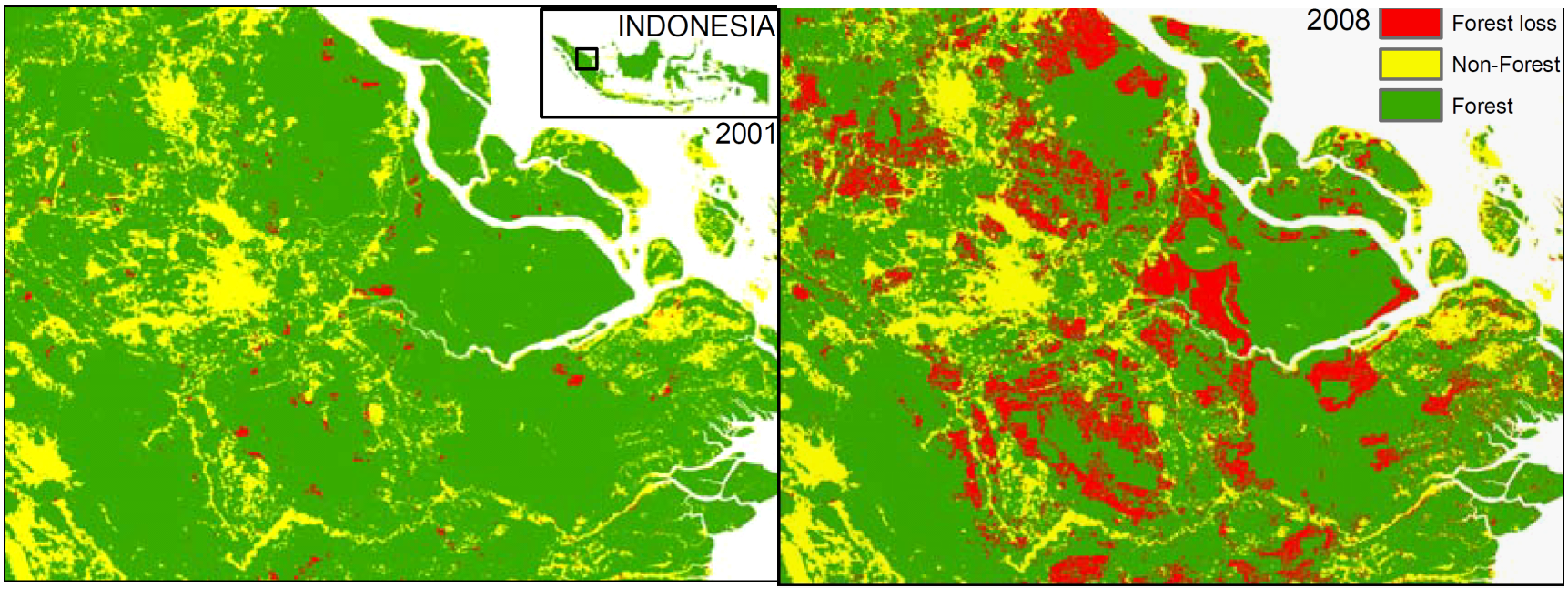
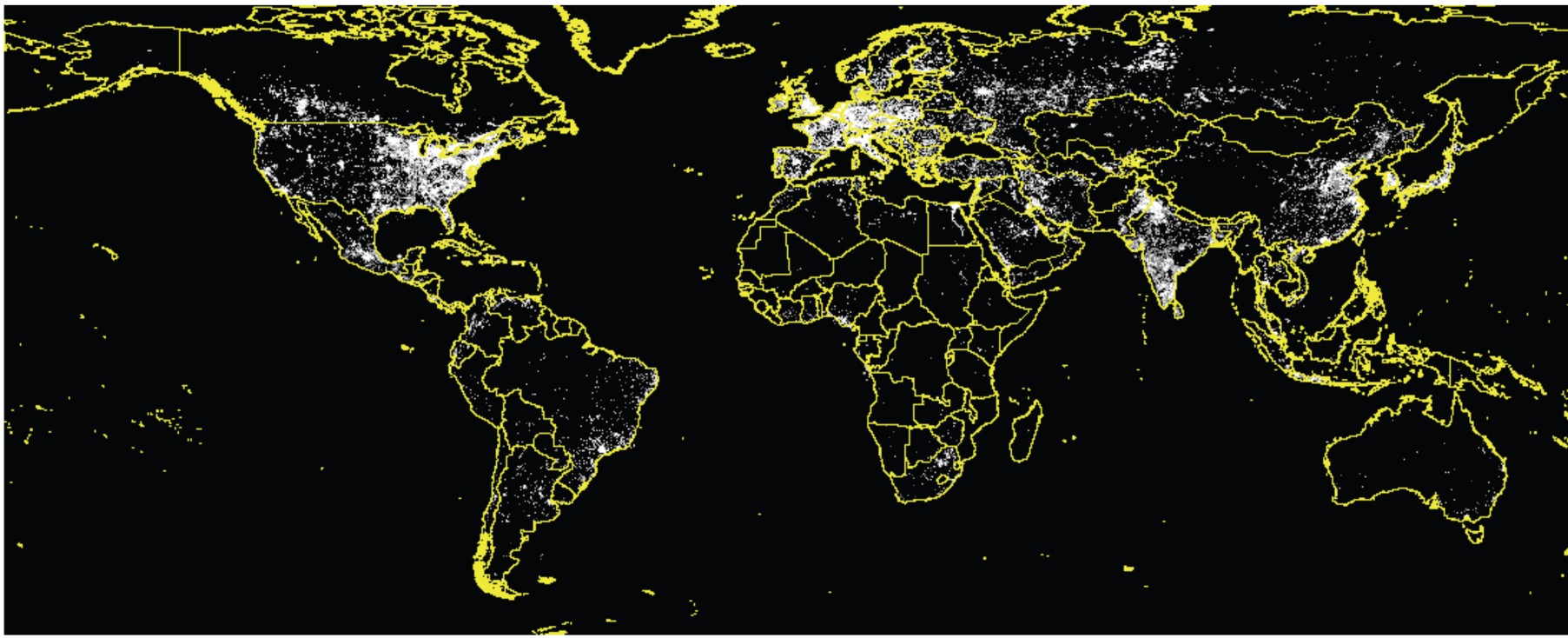
# Novelty of Deforestation Paper

- Getting official data on deforestation is both practically and politically infeasible
- Use satellite image of 250m x 250m pixels images of electromagnetic radiation strength in 36 bands of spectrum
- Develop algorithm to convert radiation patterns to forest coverage

# Deforestation in Indonesia



# Global Map of Luminosity



# Where all Hope is Lost Follow the Light!

- Usually the more interesting questions and certainly the least understood phenomena concern regions where economic indicators range from limited to fabricated to simply unavailable. Examples include:
  - conflict-prone regions,
  - non-democratic regimes manufacturing the published statistics,
  - low state capacity countries where aggregating information capabilities are non-existent
- Henderson et al (2012), Michalopoulos and Papaioannou (2013, 2014), Pinkovskiy (2013), Pinkovskiy and Sala-i-Martin (2014), Depetris Chauvin (2014), etc.

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# Ethnic Homelands At Colonization - Murdock 1959

# First Uses of Murdock Map

- Nunn (2008)
  - Number of slaves exported from each ethnic homeland aggregated at the country level and current economic performance
- Nunn and Wantchekon (2012)
  - Trust and the number of slaves per ethnic homeland, using as instrument the distance of one's ancestral homeland from historic slave ports and looking at individuals no longer residing in their ethnic homeland
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  - Digitize Michelin maps for Kenya since 1961 and track road network expansion over time to see if the president's ethnic group sees more roads built than other groups
- Alsan (2014)
  - Uses historic climate data to construct pre-colonial Tse-Tse suitability for each homeland
  - Groups on Tse-Tse prone regions had little use of domesticated animals => low degree of pre-colonial centralization and low dependence on intensive agriculture.
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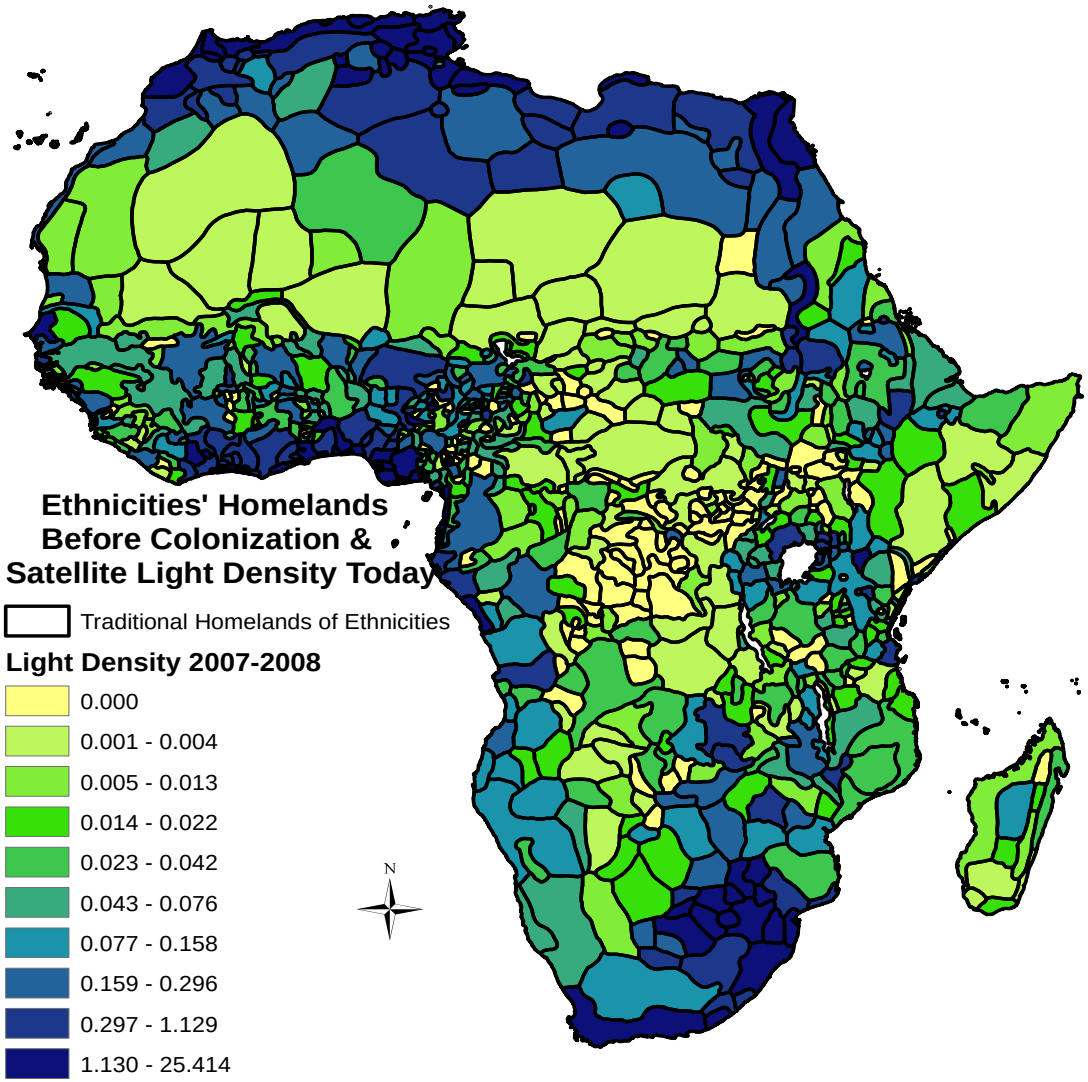
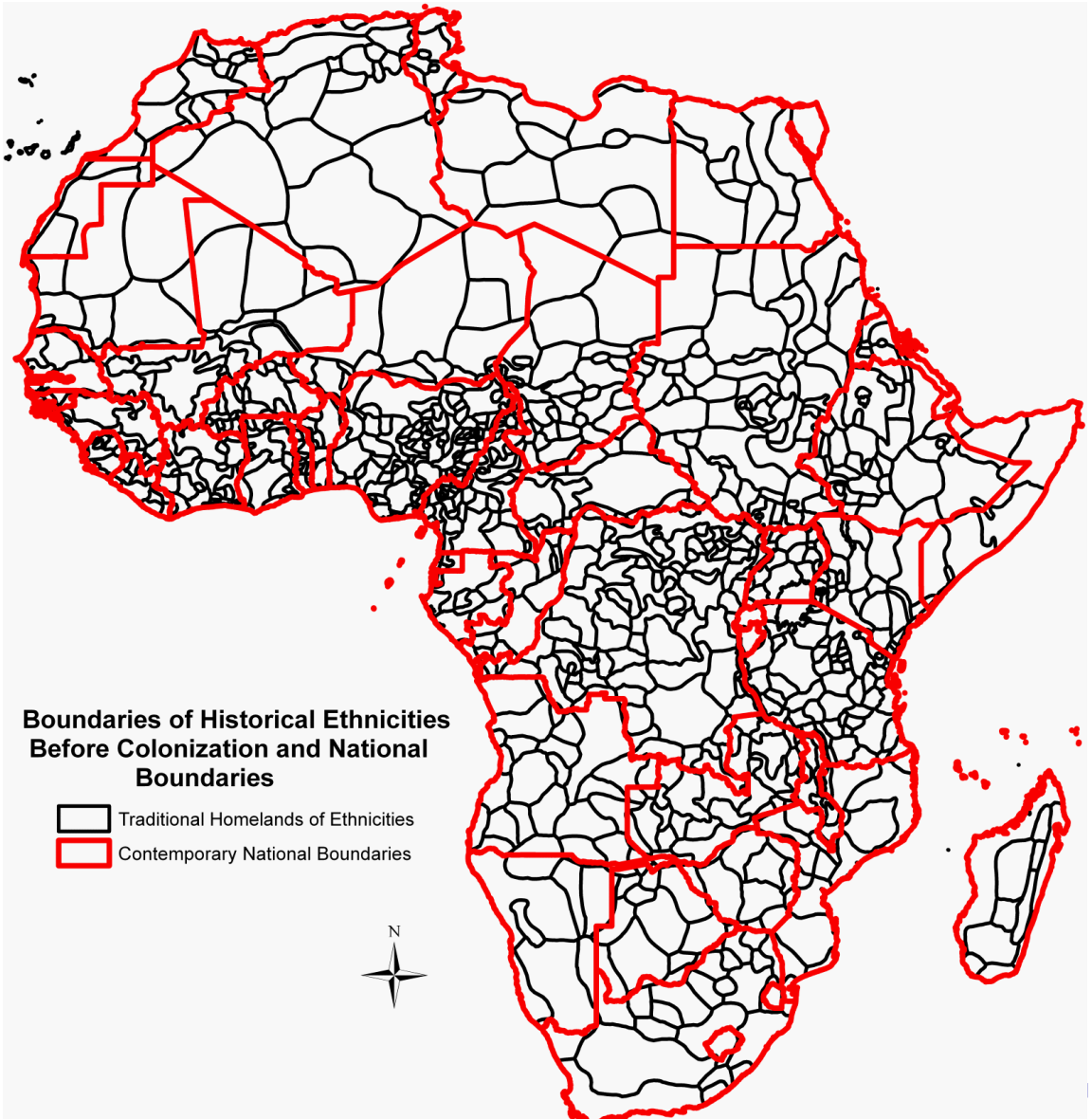
- Michalopoulos and Papaioannou (2013, 2014a, 2014b)

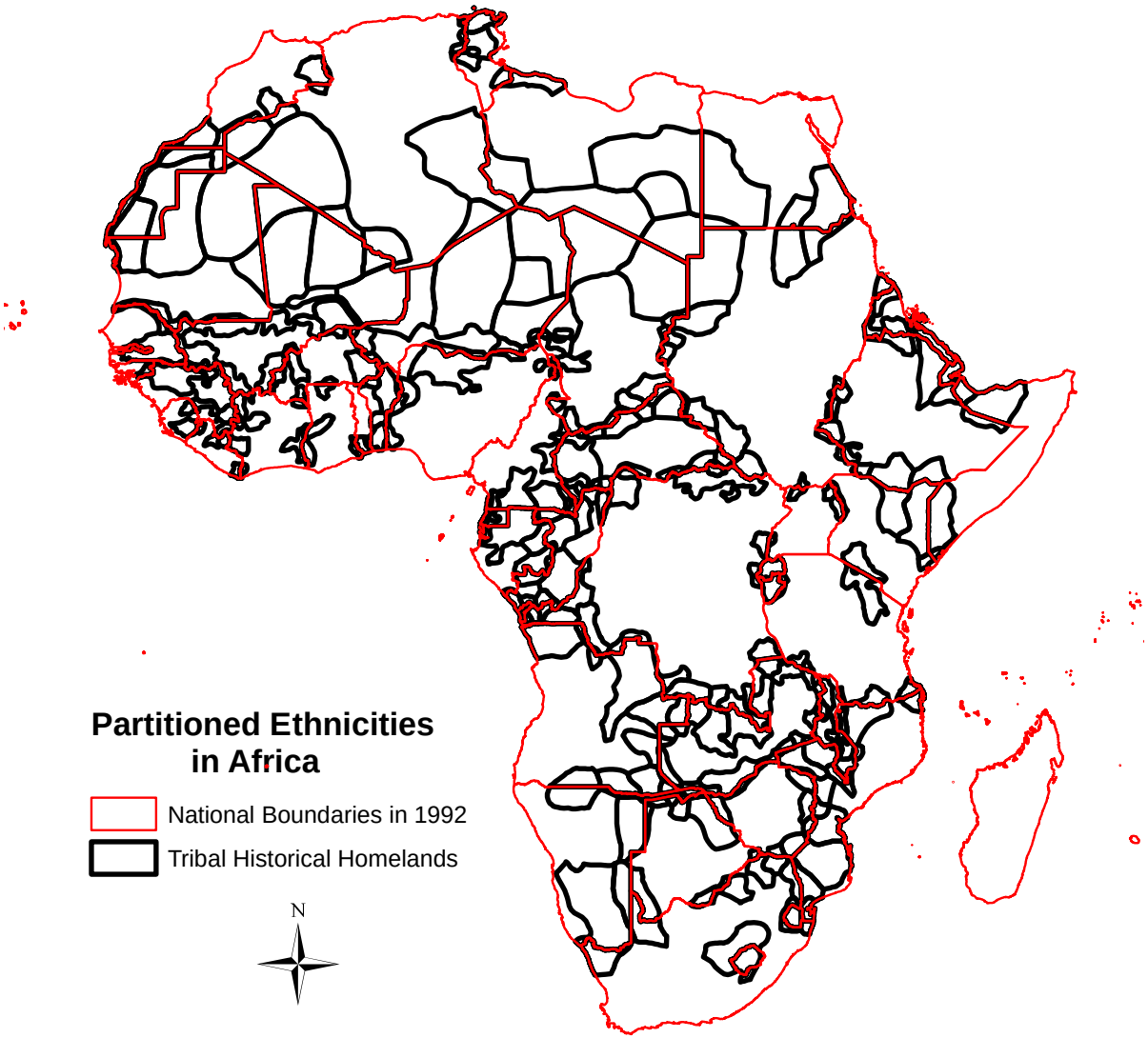
# Precolonial Ethnic Homelands - Light Density 2008



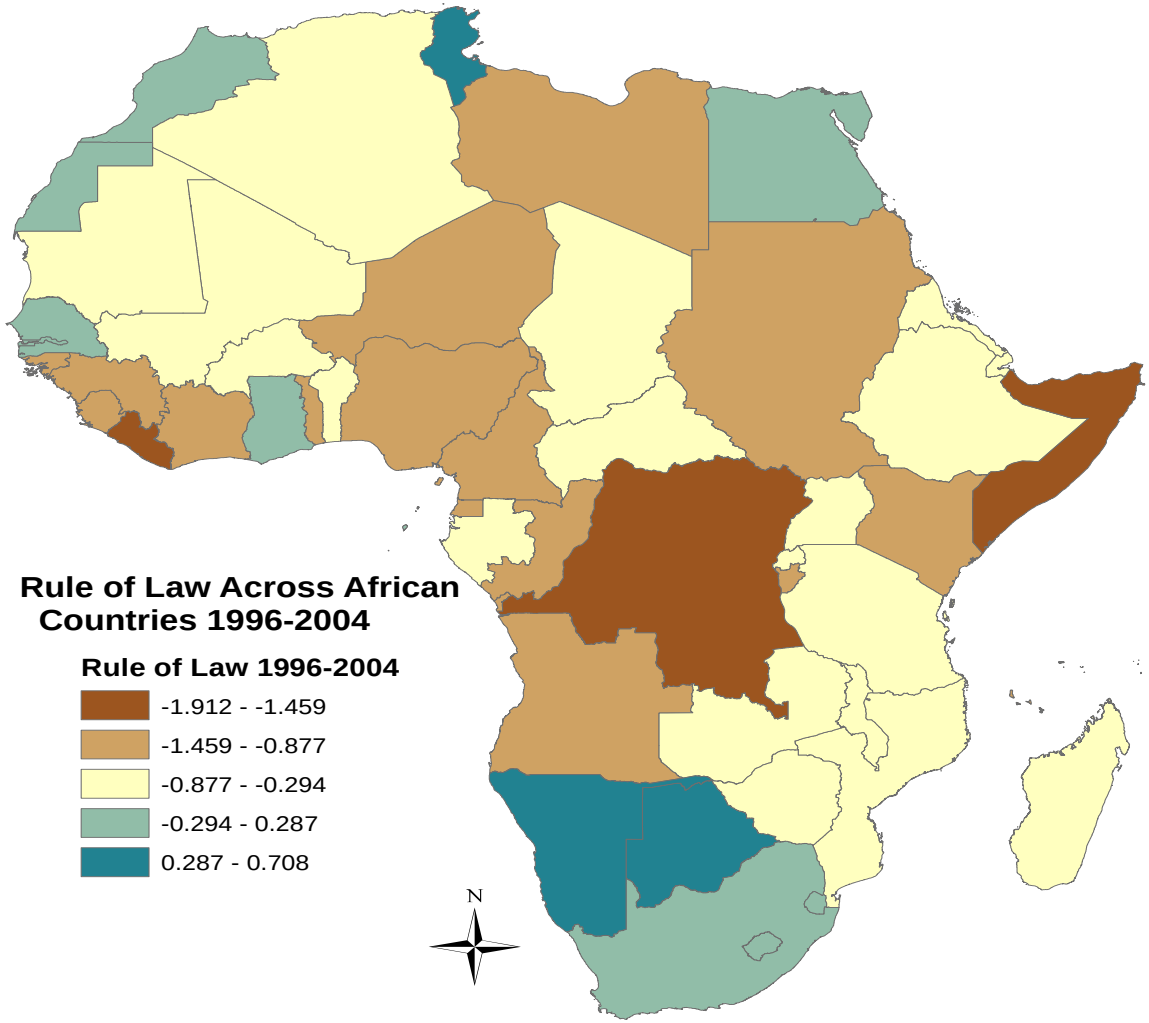
# Current National Boundaries and Ethnic Homelands



# Partitioned Groups



# Contemporary National Institutions across Africa



# Digitizing a Map Can be Rewarding!

- As you see digitizing a historical map can take you a very long way...
- Yes it is time consuming but the rewards can be tremendous
- Will spend last half hour of the lectures digitizing a map from scratch.

# Coordinate Systems

- Earth is a sphere approximately (oblate spheroid)
- But we need to represent its surface on a plane
- Various ways to do so. Each way corresponds to a coordinate system.
- Very important to know what are the properties of your coordinate system

# Coordinate Systems

- Why important?
  - Properly merge different spatial datasets
    - the iOS 6 application got this wrong
- Properly calculate distances and areas
- Two types: Geographic / Projected

# Coordinate Systems

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- Properly calculate distances and areas
- Two types: Geographic / Projected

# Geographic Coordinate Systems

- Each location is coded by decimal degrees
  - e.g., Mexico City
    - Latitude: 19.4284700
    - Longitude: -99.1276600
- Not suitable for calculating distances/areas
- 1 degree of latitude: 110.6km at equator, 111.7km at the poles
- 1 degree of longitude: 111.3km at equator, 55.8km at 60 degrees N/S, 0km in the poles

# Geographic Coordinate Systems

- For calculating long distances between two point locations, however, it is useful:
  - Formula for great circle distance uses degrees in latitude/longitude
  - Implemented by Stata ado GLOBDIST
- Many spatial datasets adopt WGS 1984, the most popular geographic coordinate system

# Projected Coordinate Systems

- Earth surface is projected on a flat plane
- Each location: coded in meters from a certain origin on the projected surface
- Various projection methods: cylindrical, conic, azimuthal, etc.

# Which Coordinate System?

- Depends on what you want to calculate. (There's no definite answer. Here's my suggestion)
- WGS 1984 (or any other geographic coordinate system)
  - distance between two locations in large study areas
- UTM good for calculating
  - length of polyline features
  - distance / area in small regions (within 6 degrees in longitude)
- Any of the "equal area" projections
  - such as Sinusoidal, Lambert, Cylindrical, Albers Conic good for calculating area of large regions
    - cf. Which equal area projection to be used only changes the way the world is shown on a map; all give you the correct area calculation.

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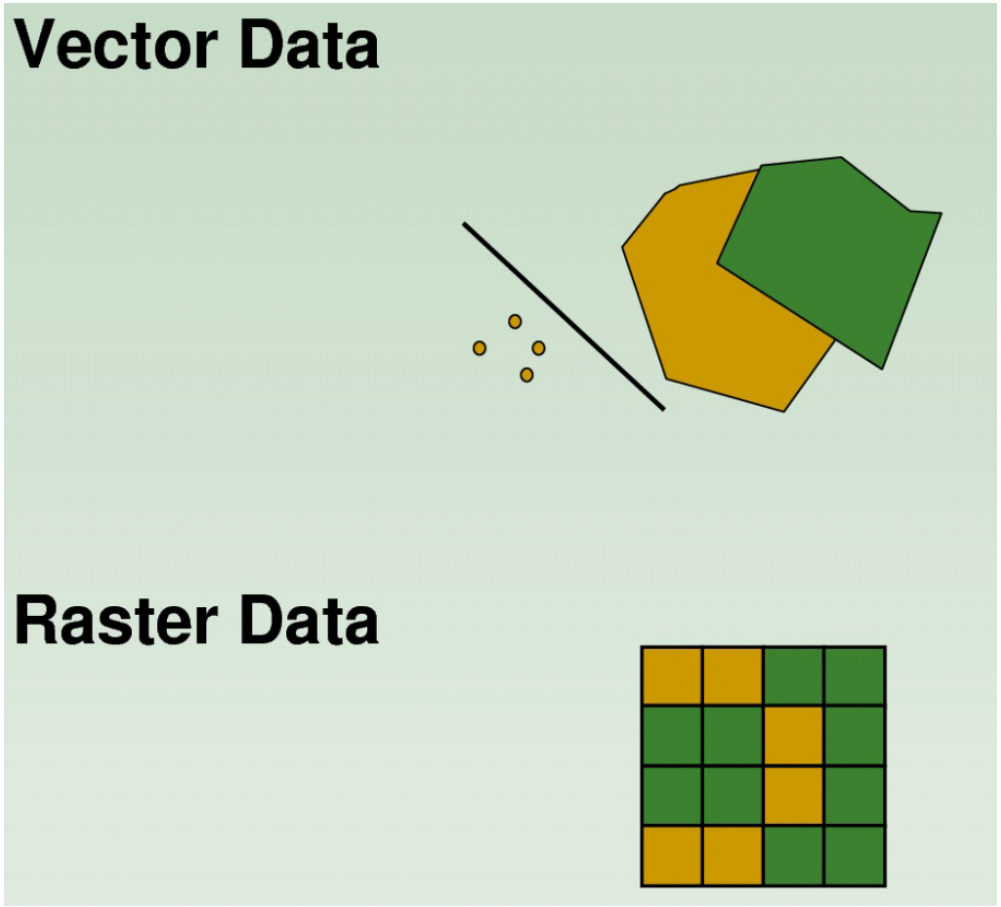
# Data Types in GIS

- Spatial data comes in two different types: Vector & Raster



# Data Types in GIS

- The way to edit data differs a lot between vector and raster.
- Below we read, browse, and intersect spatial datasets in ArcGIS while learning these different types of spatial data

# Vector Data

- Each spatial unit in vector data is called a feature
- Three types of a feature:
  - polygon
  - polyline
  - point
- A set of features of the same type: a feature class
- File format in ArcGIS: Shapefile (.shp)

# Vector Data: Polygons

- Represent geographic zones
- Examples include:
  - Countries
  - Sub-national districts
  - Areas in which a certain language is spoken
  - Lakes, Islands, etc.

# Let's Play with Vector Data in ArcMap

- Read Polygons in GIS
- First, launch ArcMap
- Second, drag the shapefiles from Catalog Window to Data Frame.
- If you don't see Catalog Window, click "Windows" in the menu bar.
- If you don't see the data directory, right-click "Folder Connections" and click "Connect Folder..."
- Bring in the African countries polygons and the Murdock Map polygon.

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# Polylines

- Represent networks / routes
- Examples:
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# More Polygons

- Bring in the rivers and lakes shapefile
- Change the color of permanent water bodies to blue.
- Click the symbol (in this case, colored line) just below the data name in Table of Contents
- Choose the preferred color.
- If you read the river data first and then the national boundary data, the river data will be hidden below the national boundary data.
- In the Table of Contents window (the one on the left), drag the river data and drop it above the national boundary data. Then rivers will show up

# Checking Coordinate System

- We can check whether (or what) coordinate system is assigned to each data by:
  - Right-click the data
  - Click "Properties..."
  - Click the "Source" tab
  - Scroll down to "Spatial Reference"
  - If it's not assigned yet, it says "<Undefined>"

# Assigning Coordinate System

- If you get an alert message "Unknown Spatial Reference" This means the coordinate system is not assigned to these data.
- When the coordinate system is missing then need to define it.
- Read at the documentation of spatial data you use (usually comes with metadata that specify the coordinate system used when the data is created).
- use the Define Projection tool

# Changing Projection

- If defined and I want to change the projection
  - for vector data, use the Project tool
  - for raster data, use the Project Raster tool

# Remember

- You cannot overlay data with different coordinate systems
- ArcMap cannot display all the data if they are in different coordinate systems
- To read a data with a different coordinate system, open a new map document.

# What is a Map Document?

- It saves the way you overlay, color-code, & symbolize different spatial datasets
- The file extension is ".mxd"
- This file DOES NOT contain spatial data. It just has links to them.
- Make sure setting the relative path to refer to each data

# What is a Map Document?

- Set relative paths as the default
  - In the menu bar, click Customize => ArcMap Options => Check "Make relative paths the defaults for new map documents.
- Click the save icon in the Standard Toolbar
  - This icon is NOT for saving the data
- Choose the location in which you save the map document
  - best to save in the parent folder for spatial data files

# Point Features

- Represent point location
- Plots, Schools, Surveyed communities, Cities, Centroid of polygons
- Can be created from XY data

# What is XY Data?

- XY data: a table in which
- Each row: point feature
- Column 1: longitude (x value) ranges from -180 to 180.
- Column 2: latitude (y value) ranges from -90 to 90.
- Other columns: attributes of point feature (name, statistics, etc.)

# Read XY Data

- Read ACLED data; open excel and see the data.

# Point Features

- XY data format in ArcGIS: tab delimited text file or a worksheet in an Excel file
  - Comma delimited text files sometimes work, sometimes don't
- For the Stata data file (.dta), use the "outsheet" command
  - Use the "format" command so that Stata won't round off longitude & latitude values (see Stata help format)
  - If longitude and latitude are string, first use the "destring" command to make them numerical

# Point Features

- You can create XY data on your own
  - During your survey, use a GPS receiver
  - If location names are available, use an online gazetteer:
    - www.fallingrain.com/world
    - geonames.nga.mil

# Model Builder

- To create a point feature class from an XY data, we will use geoprocessing tools.
- We do this by using the Model Builder
  - Model Builder helps us write a Python script (which is the coding language for GIS)

# Read XY Data with Model Builder

- Convert the ACLED dataset.xlsx into a point feature class in the shapefile format (.shp).
- Geoprocessing tools to be used:
  - Data Management Tools => Layers and Table Views => Make XY Event Layer
  - Data Management Tools => Features ==> Copy Features
- *Alternatively can add XY directly. By File => Add Data => Add XY data*

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# Read XY Data with Model Builder

- Open a Model Builder window by clicking in the Standard Toolbar.
- In Search Window, type the name of the geoprocessing tool and search.
- If you don't see Search Window, click "Windows" in the menu bar.
- Drag the tool from Search Window to Model Builder
- Double-click the tool to set inputs, outputs, options etc.

# Read XY Data with Model Builder

- To understand what needs to be filled in for each item:
- Click "Show Help" on the bottom right.
- Then click the item you don't understand. The help document appears on the right column.

# Read XY Data with Model Builder

- This tool (make XY data event) creates a temporary layer file out of XY data.
- But the layer file often doesn't properly work with other tools.
- We also want to save the point feature class in the disk.
- => Use the Copy Features tool to make it a shapefile data

# Read XY Data with Model Builder

- Input Features: the output from the Make XY Event Layer
- Output Feature Class: ***.shp
- It's a good idea to save all the newly created spatial data in a folder different from the one the original data is saved
- In our case, let's save outputs in C:/warwick/

# Read XY Data with Model Builder

- To save the model, do the following:
  - Click the save icon
  - Navigate to the directory in which you will save the model
  - Click the toolbox icon (red box at top-right)
  - Create a new toolbox (name it, say, warwick1.tbx)
  - Then click this toolbox
  - Type the file name for the model
- **A model can only be saved inside a toolbox.**

# Save Your Work Often

- ArcGIS often crashes. It's always a good idea to save the Model frequently while editing it.

# How to use Model Builder

- To edit an existing model...
  - Locate the model in Catalogue Window
  - If you cannot see a folder you just created, right-click the parent directory and "Refresh".
- Right-click the model
- Click "Edit" (NOT "Open")
- Now run the Model.
  - Click the triangle icon at top right.
  - the conflict events across African territories should appear

# Vector Data cont.

- One more thing about vector data...
- Comes with attributes table in the dBASE format (.dbf)
- Attributes table contains fields (i.e., variables) which can take a different value for each feature
- To see in ArcMap, right-click the data in Table of Contents and click "Open Attribute Table..."

# How to Zoom in Attributes?

- Method 1: Selection by Attributes
- In the menu bar, click “Selection => Select By Attributes”
- Select the shape file (“name”)
- Double-click the name of a field based on which the selection is conducted (“COUNTRY" in this case)
- Click “=”
- Click “Get Unique Value”
- Double-click “the country you wan to select”
- In the bottom, now you should see “COUNTRY” = ‘X name’

# How to Zoom in Attributes?

- Method 1 (cont.)
- Click OK. Now "country X" is selected on the map
- Right-click the shapefile ("DCW_Africa")
- Click "Selection > Zoom To Selected Features"
- To go back to the whole world, click the Full Extent icon in the Tools Toolbar.

# How to Zoom in Attributes?

- Now clear the selection
- In the menu bar, click "Selection > Clear Selected Features"
- If you forget doing this and conduct geoprocessing, the outputs will be only for these selected features.

# How to Zoom in Attributes?

- Method 2: use the Zoom-In tool
- Click the Zoom-in Tool icon in the Tools Toolbar
- Drag a box that encloses the country of interest
- Play around with other tools in the Tools Toolbar

# Let's Make a Map!

- We would like to generate a map of conflict incidents in Zambia
- First, make a polygon shapefile with Zambia only
- Second, clip the Conflict point file by the Zambia polygon
- Now we have both a polygon for Zambia and the conflicts in Zambia
- Let's distinguish between the types of conflicts

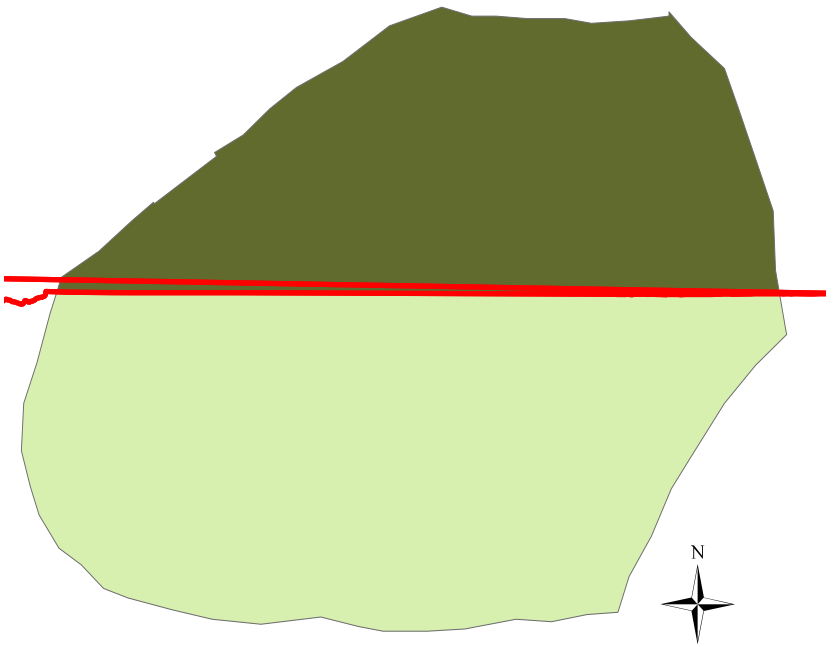
# Create Your Own Unit of Analysis

- Data Management => Feature Class => Create Fishnet
- Intersect the resulting Fishnet with the country shapefile
  - this way I will have a unique cell in each country
- add coordinates as fields to this newly constructed dataset

# Calculating Area of Polygon Features

- Let's calculate the area of each virtual country we generated
  - Change the projection of the map on the fly
    - Table of Contents Window => Layers => Coordinate System => choose projected Sinusoidal => ok
  - Add field in the attribute Table of the "virtual" shapefile
  - Right click on the new field and calculate geometry
    - after finishing bring the projection back to the original one

# Creating Cells within the Original Unit

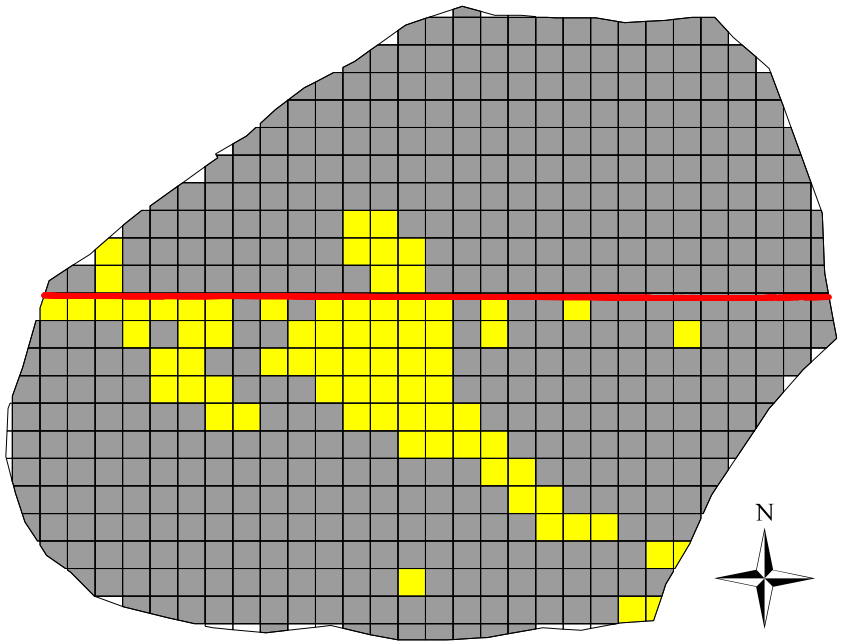



**Ambo Group Partitioned Between Angola and Namibia**

**Light Density in 2007-2008**

Mean Luminosity for Ambo's partition in Angola: 0.0504

Mean Luminosity for Ambo's partition in Namibia: 0.162



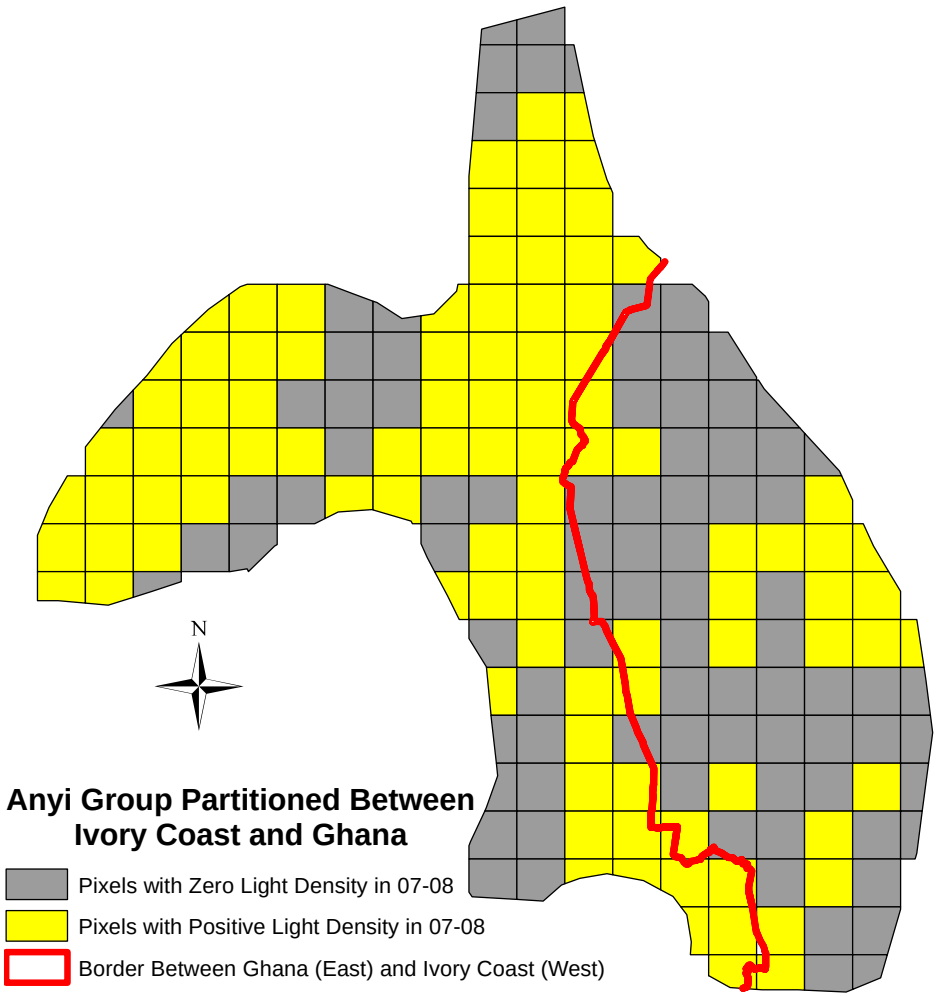

**Ambo Group Partitioned Between Angola and Namibia**

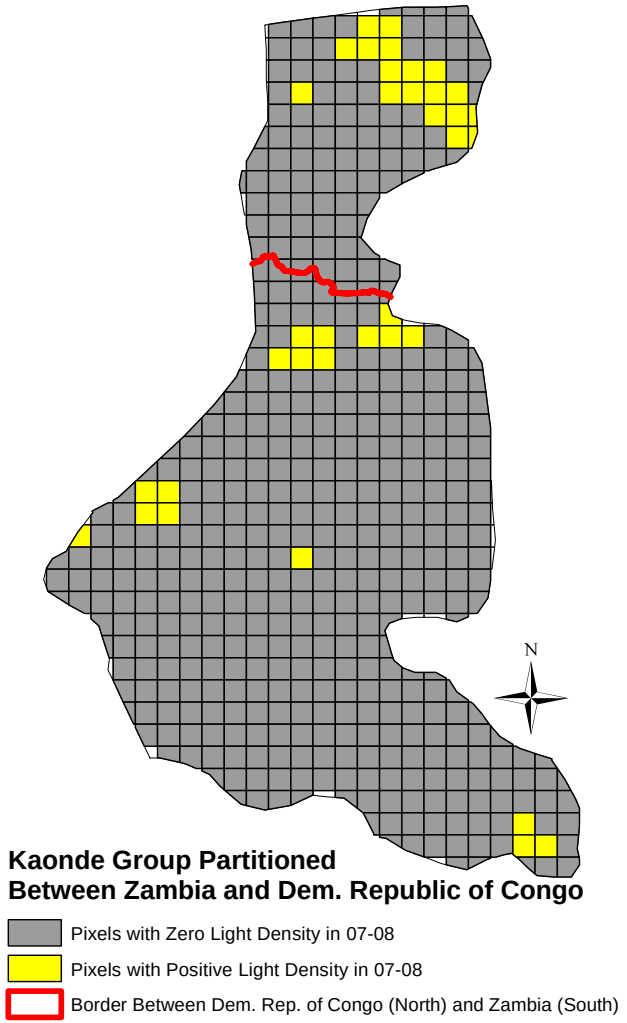
Pixels with Zero Light Density in 07-08

Pixels with Positive Light Density in 07-08

Border Between Angola (North) and Namibia (South)

# Cells within Partitioned Groups



# Raster Data

- Divides the earth surface into many "square" cells (or pixels)
- **Each cell contains a single value**
- Often created from satellite images

# Raster Data

- Examples
  - Elevation, Suitability for agriculture, Population density, Forest coverage, Nighttime light
  - Can be used to assign a new variable to features in the vector data (sse below)
- File format in ArcGIS: ESRI grid
  - Some other formats (e.g., TIFF) can also be read in ArcGIS
  - Geoprocessing raster datasets is quicker if in ESRI grid $\Longrightarrow$ Better to convert to ESRI grid format
  - If it comes in the ASCII format (.asc), you need to convert (use the Ascii to Raster tool)

# File Name for ESRI Grid Format

- A file name for ESRI grid format raster cannot be longer than 13 characters.
- No extension needed

# Bring in Some Rasters

- Let's bring in the raster files for luminosity and agricultural suitability

# How do GIS Data Files Look Like?

- Browse the spatial data in Windows
- You see many, many files
- Shapefile: .shp + .sbx + .sbn + .dbf + .prj
- Raster: the info folder + the data folder + .aux + .rdd + .prj
- dbf: the attributes table (dBASE format)
- prj: projection

# Use the Catalogue for Movinf Data Around

- **Never** use Windows Explore to browse, move, copy, or delete spatial data
- **Always use the Catalogue Window** in ArcMap.

# Spatial Analyst

- How can I derive the statistics on light density, suitability for agriculture etc.. per unit of analysis, i.e., country, homeland etc.?
- Use Spatial Analyst extension. In particular, the Zonal Statistics.
- Since we have many polygons and many raster files it is much easier to use model builder to automate the process.

# Spatial Analyst

- Now that we have the Tables with information on the suitability for agriculure and light density for each polygon.
  - join this information to the respective shapefile and
  - generate a map of average light density across homelands.

# Useful References

- Let's digitize a historical map!!

# Useful References

- The Yale GIS Workshops
- Dell 2009 (http://scholar.harvard.edu/files/dell/files/090110combined_gis_notes
- Special thanks to Masayuki Kudamatsu http://people.su.se/~mkuda/gis_lecture.html