Introduction to GIS Methods in Economics

Giorgio Chiovelli Sebastian Hohmann

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Table of contents I.

Table of contents II.

Table of contents III.

Overview

Purpose of these slides

Basic Geoprocessing tools

- Building blocks of most things you do in ArcGIS.
- Take geographical dataset, perform an operation, produce an output.
- These slides cover basic operations with feature data (shapefiles) and raster data as well as tools to output results to standard file formats.
- We will see other tools in sessions 2-5, but these are the basic ones you will always need.
- To make it a bit less boring, we will introduce the tools with practical examples.
- We will not go over these slides in the course, but you may find them useful as a reference.

Maps

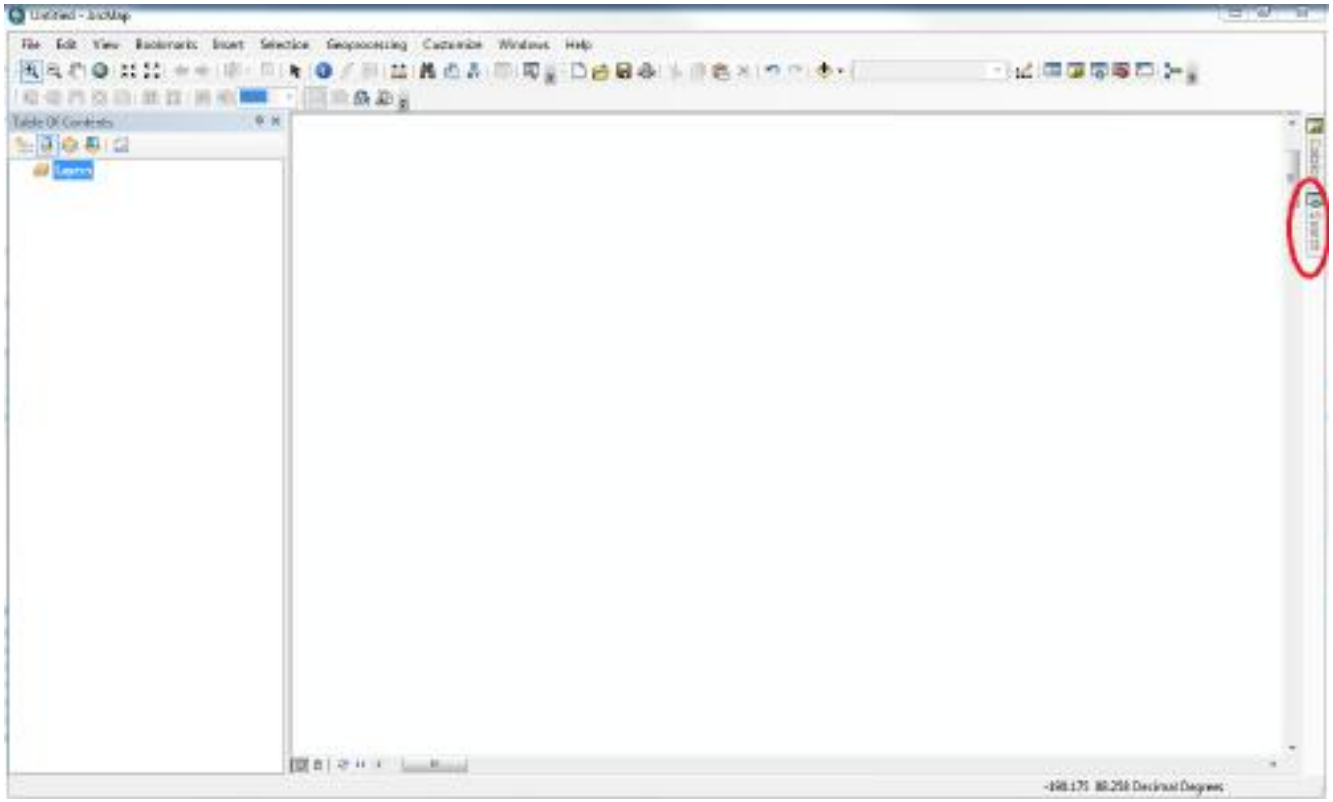
- The final five slides give an example how ArcGIS can be used to make nice looking maps .

Geoprocessing tools

Finding tools

First, a quick aside – the Search function

- Recall the location of the search sidebar from session 1 (if not visible, "Windows" $\rightarrow$ "Search").
- Select "Local Search", type in the name of the tool you want to use, and click on it.



Geoprocessing tools

Simple example: Calculating country areas

Inputs

- go to `http://www.naturalearthdata.com/downloads/10m-cultural-vectors/`
- download "Admin 0 – Countries", save to some directory and unzip

Workflow

- *Copy Features* to create a backup to work on.
- *Project* to project to an equal area projection.
- *Add Field* to an an "area" field.
  - Choose "DOUBLE" for *Field Type*.
- *Calculate Field* to find the area of each country in square kilometres.
  - Choose the area field just created as *Field Name*.
  - Under *Expression*, type *!SHAPE.AREA@SQUAREKILOMETERS!*.
  - For *Expression Type*, select *PYTHON_9.3*.

Geoprocessing tools

Tools for feature data – Make XY Event Layer

What the tool does

- Create layer of points from tabular latitude/longitude data (.csv, .txt etc.)

Setting parameters

- *XY Table*: A table with latitudes/longitudes, e.g. the one we created in Session 1.
- *X Field* and *Y Field*: The longitude and latitude variables; leave blank *Z Field* unless you have data in three dimensions
- *Layer Name or Table View*: Name the layer; if leave blank, default name will be created
- *Spatial Reference*: The Coordinate system for the point features

Output

- Creates *layer* of point features
- A layer (*.lyr*) file is not a shapefile, but just a (temporary) link to the underlying data

Geoprocessing tools

Tools for feature data – Copy features

What the tool does

- Copy input feature class* or layer to new feature class

Setting parameters

- *Input Features*: The layer of shapefile you want to copy
- *Output Feature Class*: The path to the new shapefile, including its name (include the ending *.shp*)
- Leave other parameters as default (read the help if interested in geodatabases etc.)

Output

- A new shapefile with the feature data in the layer or old shapefile.

* homogeneous collections of common features with same spatial representation (points, lines, polygons)

Geoprocessing tools

Tools for feature data – Define Projection

Prep – just for illustration

- Remove the point shapefile just created from the toc, go to the folder that contains the new *.shp* file, delete the *.prj* file containing the spatial reference; re-add the shapefile.

What the tool does

- Overwrites existing dataset spatial reference information; only use when exiting SR incorrect / unknown.

Setting parameters

- *Input Dataset or Feature Class*: The dataset for which we want to define the projection (can be raster)
- *Coordinate System*: The coordinate system. Here, select "Geographic Coordinate Systems" $\rightarrow$ "World" $\rightarrow$ "WGS 1984".

Output

- A Feature Class or raster file with the desired co-ordinate system.

What the tool does

- Takes an existing shapefile with an existing co-ordinate system and creates a copy with a new co-ordinate system.

Setting parameters

- *Input Dataset or Feature Class* and *Output Dataset or Feature Class*: Input at outputs; useful to give file name that indicates the SR
- *Output Coordinate System*: Desired new co-ordinate system. Let's pick a projected equal area system for this example
- Leave other parameters as default

Output

- A copy of an existing shapefile with a new co-ordinate system.

Note: A version of this tool exists for raster data. It is called "Project Raster".

Geoprocessing tools

Tools for feature data – Select

What the tool does

- Extract features from existing feature class using a logical expression and store them in new feature class

Prep: Add the polygon shapefile with the world's countries from session 1.

Setting parameters

- *Input and Output*: Self-explanatory, give a good title to the new shapefile.
- *Expression*: Click on the  -button. This opens the "Query-Builder", which you can use to build logical queries to select features based on their attributes (recall the attribute table attached to feature data).
- Scroll to "ADMIN", double-click to select it, then click on "Get Unique Values" and select the countries you want to include. For example for a shapefile including China, Russia, and the US, we would have:
  `''ADMIN'' = 'China' OR ''ADMIN'' = 'Russia' OR ''ADMIN'' = 'United States of America'`

Output

- A new shapefile containing the selected features.

What the tool does

- Delete one or more field from an (attribute) table.

Setting parameters

- *Input Table*: The fable from which you want to delete
- *Drop Field*: The fields to be deleted. Let's delete all fields except "ADMIN" from the China-Russia-US-shapefile we just created.

Note: You cannot delete identifiers internal to ArcGIS such as "FID" and "Shape". In python (see next session) you can, but this will create trouble.

Output

- A file / table with the deleted fields removed. Note: this tool overwrites the existing data.

Geoprocessing tools

Tools for feature data – Add Field

What the tool does

- Add new (empty) field to a table

Setting parameters

- *Input Table*: and *Field Name*: Self-explanatory, we will pick, "area" for our new field
- *Field Type*: data storage format, can be string, different numerical formats, dates specialized geographical formats. We will pick "FLOAT"
- *Field Precision*, *Field Precision*, *Field Scale*, *Field Length*, *Field Alias*, *Field Domain*: unimportant, leave as default.
- *Field Is Nullable*: Greyed out if not in geodatabase* (but important for python)

Output

- A file / table with the new field added.

*A collection of geographic datasets of various types held in a common file system folder. See session on networks.

Geoprocessing tools

Tools for feature data – Calculate Field

Prep: Project the China-Russia-US-shapefile to a world equal area projection.

What the tool does

- Calculate value of a field based on an expression entered by the user.

Setting parameters

- *Input Table* and *Field Name*: Self-explanatory, pick the "area" field we just created
- *Expression*: Type in "`!shape.area@SQUAREKILOMETERS!`" (without the quotes)
- *Expression Type*: Format the expression will be written in. 64-bit versions of ArcGIS support only Python expressions. Since we will use python later, stick with "PYTHON_9.3" (standard Python).

Note: `http://desktop.arcgis.com/en/arcmap/10.3/manage-data/tables/calculate-field-examples.htm` is an excellent reference for what can be done with calculate field.

Output

- The input file with the field populated according to the calculation performed.

Geoprocessing tools

Tools for feature data – Create Fishnet

What the tool does

- Creates a fishnet of rectangular cells. The output can be polyline or polygon features.

Setting parameters

- *Output-Feature Class*: File name.
- *Template Extent*: Rather than entering the corners of the fishnet manually, can use an existing dataset as a template.
- *Extent*: If don't use a template, enter the extent here. We will use Left = -20, right = 20, Top = 10, Bottom = -10.
- *Origin Coordinate* and *Y-axis Coordinate*: Can use these to pivot / orient the fishnet. Leave as filled out.
- *Cell Size Width / Height*: Self-explanatory. Set to 1.
- *Number of Rows / Columns*: Self-explanatory. Leave blank if filled out Width/Height. Conversely, can leave Width/Height blank and set this.
- *Opposite Corner*: Leave the default.
- *Create Point Labels*: Unticked.
- *Geometry Type*: Set to Polygon.

Output

- A polygon/polyline shapefile with regularly spaced cells.

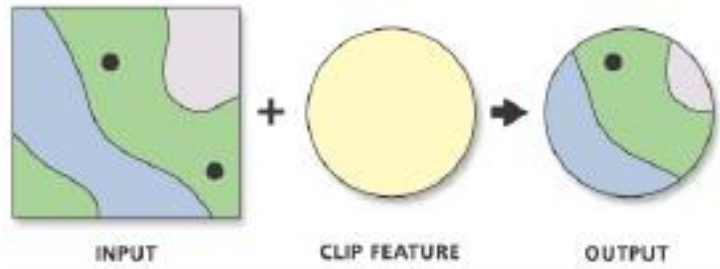
Geoprocessing tools

Tools for feature data – Clip

Prep: Create a single-cell Polygon feature with the following extent: Top = 38, Bottom = -47, Right = 64, Left = -26.

What the tool does

- Extracts input features that overlay clip features. Like a cookie-cutter.



Setting parameters

- *Input Features*: The File to be clipped.
- *Clip Features*: The cookie-cutter, usually a polygon.
- *Output Feature Class*: Self-explanatory
- *XY Tolerance*: Within what tolerance should features be counted as overlaying? Depends on Coordinate system.

Output

- A shapefile with the cut-out features of the Input Shapefile.

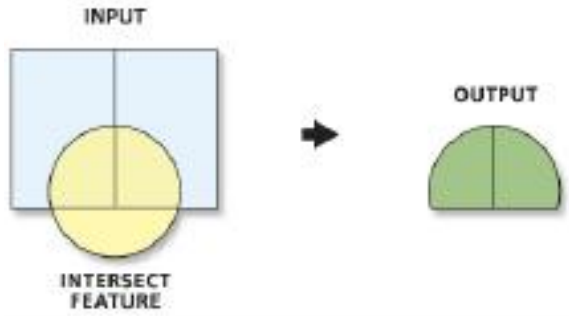
Note: The tool that keeps the part of the input not overlaying the clip feature is called "Erase".

Geoprocessing tools

Tools for feature data – Intersect

What the tool does

- Computes geometric intersection of input features and writes to new shapefile.



Setting parameters

- *Input Features*: List of shapefiles containging the features to be intersected. We will use the fishnet (define Projection first) and the countries.
- *Output Feature Class*: Self-explanatory.
- *JoinAttributes*: What should be part of the new attribute table? All, only the FIDs or everything by the FIDs?
- *XY Tolerance*: How close can features become before they are ruled to be one feature? (unit depends on projection dataset is in), leave blank.
- *Output Type*: Leave as "INPUT" (returns "highest level" geometry possible).

Output

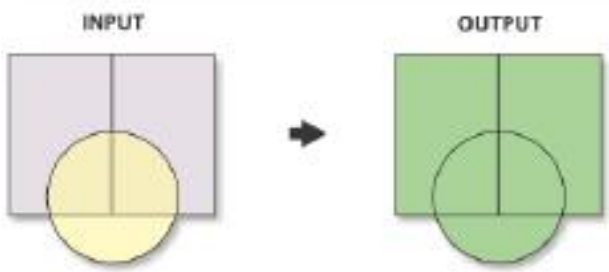
- Shapefile with intersection of the features.

Geoprocessing tools

Tools for feature data – Union

What the tool does

- Computes geometric union of input features and writes to new shapefile.



Setting parameters

- *Input Features*: List of shapefiles containging the features to be intersected. We will use the files *fish*3.*shp* and *fish*4.*shp*.
- *Output Feature Class*: Self-explanatory.
- *JoinAttributes*: What should be part of the new attribute table? All, only the FIDs or everything by the FIDs?
- *XY Tolerance*: How close can features become before they are ruled to be one feature? (unit depends on projection dataset is in), leave blank.
- *Gaps Allowed*: Gaps are areas completely enclosed by other polygons. Unchecking this means creating extra polygons in these areas.

Output

- Polygon shapefile with the union of the input features.

Note: Unlike Intersect, Union only works with Polygons.

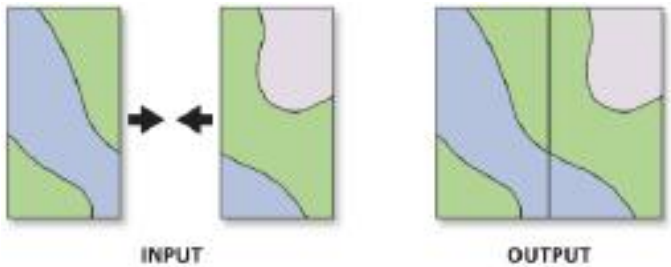
Geoprocessing tools

Tools for feature data – Merge

Prep: Use the single cell polygon once to Clip and once to Erase on the Countries of the World shapefile.

What the tool does

- Combines multiple input datasets **of the same data type** into a single, new output dataset.



Setting parameters

- *Input / Output Dataset(s)*: Self-explanatory.
- *Field Map*: Controls how attribute fields are mapped to the output dataset. Can add, rename, delete output fields and change data type and merge rule. We'll leave the default for now.

Output

- Shapefile with the 2 or more feature classes merged.

Note: A similar tool, "Append", appends one feature to another. Refer to this blog entry for a nice overview on combining datasets:
`https://blogs.esri.com/esri/supportcenter/2014/12/02/combining-spatial-data-in-arcmap/`

Geoprocessing tools

Tools for feature data – Spatial Join

What the tool does

- Joins attributes from one feature to another based on their spatial relationship.

Setting parameters

- *Target Features*: Feature class to which things from the join Features are joined. Capital cities points in our case.
- *Join Features*: See above, countries in our case.
- *Output Feature Class*: Self-explanatory.
- *Join Operation*: Can be JOIN_ONE_TO_ONE or JOIN_ONE_TO_MANY. See the help for discussion. We will use the former in this case.
- *Keep All Target Features*: Keep all the target features (outer join) or just the ones to which something is joined (inner join). We will keep all.
- *Field Map of Join Features*: How will attributes be mapped to the output feature class? Can add, delete, rename fields, and change their properties. See the help. We will leave it as it is.
- *Match Option*: Many options, see the help. We will choose "Intersect" (the most common).
- *Search Radius*: Join features within this distance of a target feature will be considered for the spatial join. Leave blank.
- *Distance Field Name*: The name of a field to be added to the output feature class, which contains the distance between the target feature and the closest join feature. Leave blank.

Output

- Attributes from Join features joined to Target features in new shapefile.

Geoprocessing tools

Tools for feature data – Dissolve

Prep: Download U.S. counties from `http://www.gadm.org/`

What the tool does

- Aggregates features based on specified attributes.

Setting parameters

- *Input / Output Feature*: Self-explanatory.
- *Dissolve_Field(s)*: The field or fields on which to aggregate features. We will use NAME_1 (the State name).
- *Statistics Field(s)*: The fields and statistics with which to summarize attributes. See the options. We will use COUNT only.
- *Create Multipart features*: Whether multi-part features are allowed. If unchecked, create new features instead of multi-part features $\Leftrightarrow$ multi-part polygons won't be dissolved
- *Unsplit lines*: Only applies to line input. See the help.

Output

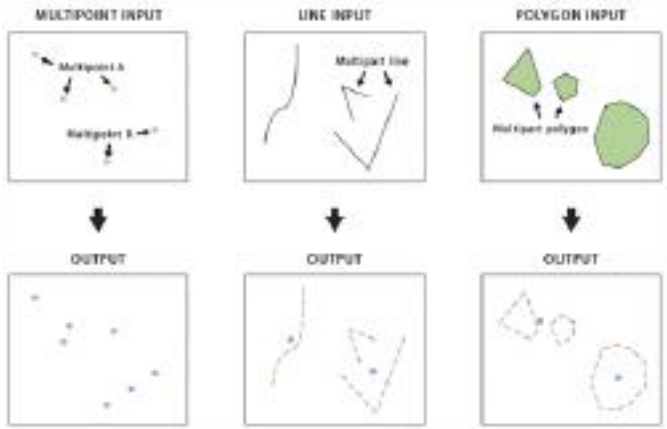
- The dissolved input feature with the desired statistics as attributes.

Geoprocessing tools

Tools for feature data – Feature to Point

What the tool does

- Creates a feature class containing points generated from the representative locations of input features.



Setting parameters

- *Input / Output Feature Class*: Self-explanatory. Use the world's countries.
- *Inside*: If check, force point to lie inside polygon (polygon input), on one of the lines (line input), on one of the points (point input). Useful since polygons often non-convex (Senegal!).

Output

- Shapefile with input feature centroids.

What the tool does

- Adds latitude (POINT_Y) and longitude (POINT_X) to point features depending on coordinate-system.

Setting parameters

- *Input Features*: Self-explanatory

Output

- Point features with latitude and longitude.

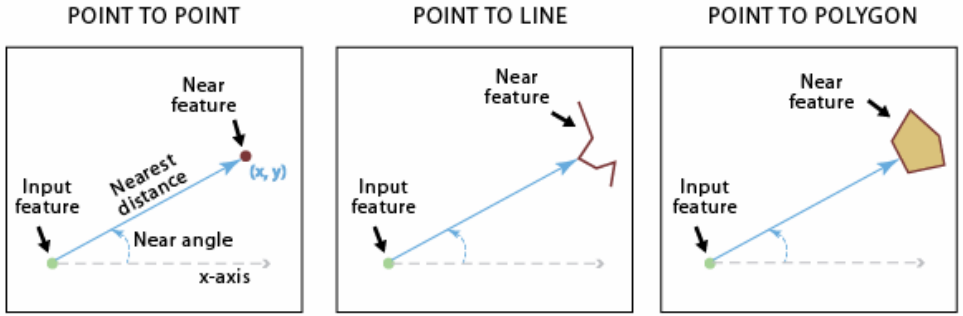
Note: This tool overwrites the input.

Geoprocessing tools

Tools for feature data – Near

What the tool does

- Calculates distance and additional proximity information between the input features and the closest feature in another layer or feature class.



Setting parameters

- *Input Features*: The main feature of interest, in our case country centroids.
- *Near Features*: The features of which we want to find the closest to each main feature of interest. Use rivers from Natural Earth.
- *Search Radius*: Leave blank to consider all features.
- *Location*: If check, tool adds latitude (NEAR_Y) and longitude (NEAR_X) of the closest feature to the attribute table.
- *Angle*: If check, too adds angle of the closest feature to the attribute table.
- *Method*: Can be planar or geodesic. Best to use geodesic if haven't selected appropriate projection first.

Output

- Input Feature with additions to attribute table depending on selected options.

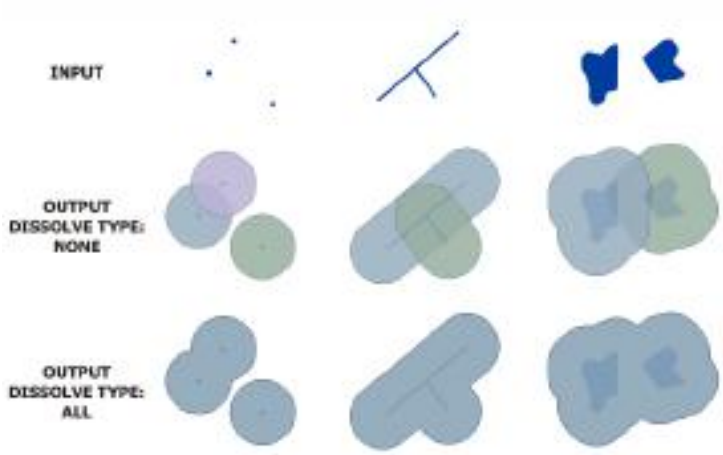
Note: There is another tool called "Generate Near Table", that is similar and much faster (we will use it in the python section of the class).

Geoprocessing tools

Tools for feature data – Buffer

What the tool does

- Creates buffer polygons around input features to a specified distance.



Setting parameters

- *Input Feature / Output Feature class*: Inputs can be all feature types, output will be polygons. Use country centroids as inputs.
- *Distance*: Can specify same distance for every feature or can specify a distance field with different value for each feature. Use 100km.
- *Side Type*: Sides of feature that will be buffered. Leave as FULL.
- *End Type*: Shape of buffer at end of line input. Leave as ROUND.
- *Method*: Since we are in geographic co-ordinate system, use GEODESIC
- *Dissolve Type*: Dissolve overlapping buffers. Select NONE.
- *Dissolve Field(s)*: If Dissolve Type other than NONE, can select fields to dissolve on (see slide on Dissolve tool).

Output

- Polygon buffers.

Before moving on to raster tools, need to activate the "Spatial Analyst" extension

- Esri sells ArcGIS in pieces to make more money.
- If you have bought an extension (the student version has all you need), you can activate them via "Customize" $\rightarrow$ "Extensions" $\rightarrow$ check "Spatial Analyst".
- We will only need Spatial Analyst and Network Analyst (lecture 5).

What the tool does

- Creates a raster of a constant value.

Setting parameters

- *Output Raster*: Choose *.tif* as extension. **Note: raster names cannot be longer than 13 characters!**
- *Constant Value*: Can be integer or decimal. If latter, need to select FLOAT for data type.
- *Output Data type*: See above.
- *Output cell size*: Self-explanatory.
- *Output extent*: Self-explanatory.

Output

- Raster with constant value.

Geoprocessing tools

Tools for raster data – Plus

What the tool does

- Add two rasters cell-by-cell or add a constant to a raster.

Setting parameters

- *Input raster or constant value 1*: The input raster.
- *Input raster or constant value 2*: Can add a second raster, cell by cell, to the first, or add a constant.
- *Output raster*: Self-explanatory.

Output

- A raster that is the sum of the two rasters or the first raster plus a constant.

Note: if the resolution of the raster cells differ, the new raster will have the coarser resolution and the dataset with the finer resolution will first be "re-sampled" . This is somewhat of a black box without setting the specifics of resampling yourself. We therefore recommend to execute the Resample tool (see below) first if resolutions differ.

More simple arithmetic on rasters

Some of the most common operations are

- Divide
- Float (convert integer raster values to float)
- Int (the reverse)
- Minus
- Plus (just seen)
- Times

See here for a full list of raster math tools:

`http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/an-overview-of-the-math-tools.htm`

What the tool does

- Reclassifies (or changes) the values in a raster

Setting parameters

- *Input / Output Raster*: Self-explanatory
- *Reclass Field*: The value field of the raster we want to reclassify.
- *Reclassification*: Set the reclassification rule. For every entry (can delete, add) need to set a range of old values and a new value.
- *Change missing values to NoData*: Determines if any values that are not covered by the Reclassification rule retain their original value or will be set to "No Data".

Output

- A reclassified raster.

What the tool does

- Change the spatial resolution of your raster dataset and set rules for aggregating or interpolating values across the new pixel sizes.

Setting parameters

- *Input / Output Raster*: Self-explanatory.
- *Output Cell Size*: Can either set cell size manually or according to an existing dataset.
- *Resampling Technique*: The crucial parameter. Different techniques appropriate for discrete and continuous data. See here for details: `http://desktop.arcgis.com/en/arcmap/latest/extensions/spatial-analyst/performing-analysis/cell-size-and-resampling-in-analysis.htm`

Output

- A raster dataset with new resolution.

Geoprocessing tools

Tools for raster data – Aggregate

What the tool does

- Generates a reduced-resolution version of a raster. Each output cell contains the Sum, Minimum, Maximum, Mean, or Median of the input cells that are encompassed by the extent of that cell

Aggregating with Maximum rule

Setting parameters

- *Input / Output Raster*: Self-explanatory.
- *Cell Factor*: An integer > 1. Factor by which to increase cell size. Note that each of the new cells will contains $factor^2$ of the old cells.
- *Aggregation technique*: How to aggregate the old to the new raster: can be sum, max, mean, median, min.
- *Expand extent if needed*: Defines how to handle the boundaries of the input raster when its rows or columns are not a multiple of the cell factor, can expand or truncate.
- *Ignore NoData*: If NoData values are ignored, then mean etc. will be calculated just on the basis of the non-missing cells. Otherwise, if a NoData cell falls in the one of the new cells, the new cell will be NoData.

Output

- A raster dataset in coarser resolution with values set from the old values according to the aggregation rule.

Geoprocessing tools

Tools for raster data – Extract Values to Points

What the tool does

- Extracts the cell values of a raster based on a set of point features and records the values in the attribute table of an output feature class

Setting parameters

- *Input / Output point features, Input raster*: Self-explanatory.
- *Interpolate values at the point locations*: Using none, the tool extracts the value of the cell* into which the point falls. Using interpolate, the tool extracts the value of the cells corresponding to the four nearest input cell centers using bilinear interpolation (distance weighted average, see the documentation).
- *Append all the input raster attributes to the output point features*: Whether want to add fields from the raster attribute table besides the value to the output point feature attribute table

Output

- A new shapefile of point features with the extracted cell values as a new field.

* The cell whose center is closest to the point

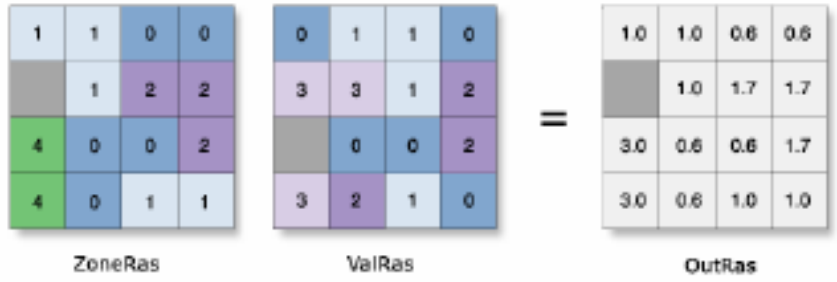
Geoprocessing tools

Tools for raster data – Zonal Statistics

What the tool does

- Calculates statistics on values of a raster within the zones of another dataset

Zonal statistics with Mean rule



Setting parameters

- *Input raster or feature zone data*: Raster or polygons within which the statistics will be calculated. A "zone" is a bunch of areas with a common value (same name for country, same value for raster cell)
- *Zone field*: The field of the zone data file that serves as the ID for the calculation of the statistic.
- *Input value raster*: The raster from which statistics are calculated.
- *Output raster*: This tool outputs a raster dataset. Crucial: don't give file
- *Statistics type*: Self-explanatory.
- *Ingore NoData in calculations*: If unchecked, all zones containing a NoData cell will be assgined NoData.

Output

- A raster dataset with zones

Geoprocessing tools

Tools for raster data – Zonal Statistics as table

What the tool does

- Same as Zonal Statistics, except that it only generates a table, all statistics can be generated at once.

Setting parameters

- *Input raster or feature zone data*: Raster or polygons within which the statistics will be calculated. A "zone" is a bunch of areas with a common value (same name for country, same value for raster cell)
- *Zone field*: The field of the zone data file that serves as the ID for the calculation of the statistic.
- *Input value raster*: The raster from which statistics are calculated.
- *Output raster*: This tool outputs a raster dataset. Crucial: don't give file
- *Statistics type*: Self-explanatory.
- *Ingore NoData in calculations*: If unchecked, all zones containing a NoData cell will be assgined NoData.

Output

- A *.dbf* file with the zonal statistic.

Note: If a zone border splits a cell (always the case with polygon zones), a cell counts towards the zone containing its center. Small zones may not contain any cells. To address this issue, use Resample before ZS.

Geoprocessing tools

Tools for outputting data – Table to Table

What the tool does

- Convert input table to dBASE (*.dbf*), or comma-separated values (*.csv* or *.txt*) tables.

Setting parameters

- *Input Rows*: The input table (can be attribute table from a shapefile or just a .dbf file.
- *Output Location*: The output folder.
- *Output Table*: Self-explanatory.
- *Expression*: Can use the Query-builder to build an SQL expression to select only a subset of rows.
- *Field map*: Export only a subset of the variables, apply merge rules before exporting.

Output

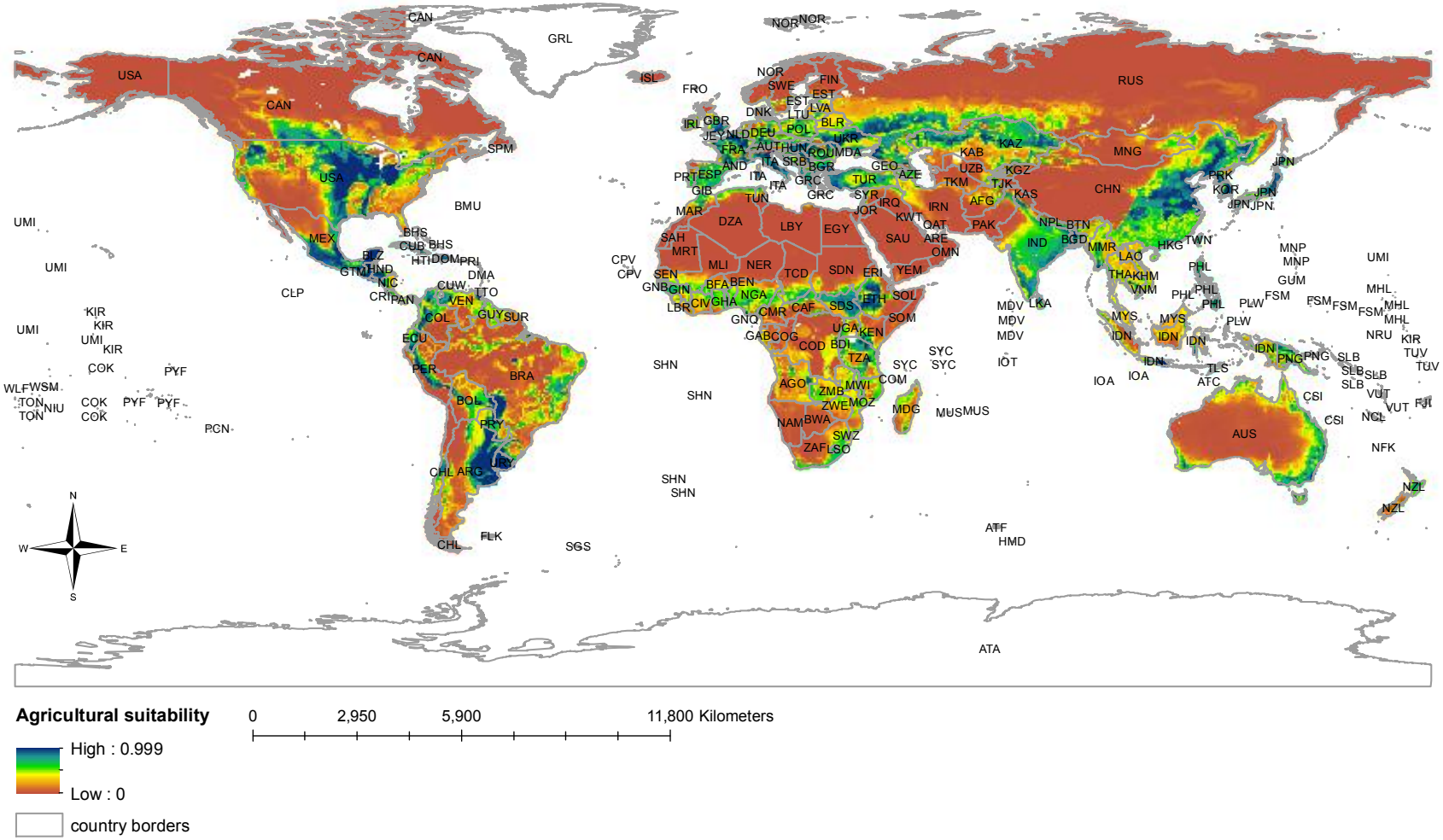
- A table in the specified format containing the data in the input table.

Note: For shorter tables, there is also Table to Excel (Excel 5.0/95 with limits of 16,384 rows. 256 columns). If you have actual feature data and not just a table, you can also use Export Feature Attribute to ASCII.

Maps

Making a nice map – Objective

How do we make something like this?



Maps

Making a nice map – Layer names, labels, symbology

Prep: Add the countries shapefile and the agricultural suitability raster.

Changing layer name

- Currently, the layer with the country borders is called "ne_10m_admin_0_countries". This will look ugly in a legend.
- To change it, right click on the layer → Properties → General tab → change the Layer name to "country borders".

Displaying country labels

- Still in the country border layer properties, choose the Labels tab, → tick Label features in this layer, choose an appropriate label field, and change font and size if desired

Symbology

- Still in the country border layer properties, choose the Symbology tab, → Symbol, change Fill Color to No-Color and change the outline width. Apply all changes.
- Right click the suitability layer → Properties → Symbology → change the Color Ramp.

Maps

Making a nice map – Layout view

Changing to Layout view

- Eventually, we will export your map to *.pdf*, *.png* etc. We want to know how large the "sheet" of virtual paper is on which you get to draw.
- Click on view → Layoutview.
- Click on Change Layout  and choose an appropriate layout.

Resizing the data frame

- Click anywhere on the map and hover over the dotted outline to resize it. Click on  to zoom to fill the page. Pan the data around to move it into the right place.

Setting the coordinate system

- Right click on the data frame → Properties → Coordinate System → choose WGS 1984.

Hiding the frame border

- Still in the Data Frame Properties Menu, choose the Frame tab, → change Border Color to No color.

Maps

Making a nice map – North arrow, scale bar, legend

North arrow and scale bar

- Insert → North arrow, and Insert → scale bar and pick the ones you like. For the latter, have to set the frame co-ordinate system first.*

Legend

- Insert → Legend. Twice, once removing the agricultural suitability from the legend items, once the country borders. Click "Next" until the legend are created.
- Right click the legends → Properties.
- Titles can be changed in the "General" tab (suppress them, change font and size).
- Label font and size can be changed in the "Items" tab.
- Also in the "Items" tab, you can change the Legend style.

* Strictly speaking, we should first have projected the data to a non-length distorting projection to put a scale bar for the entire globe.

Export the map

- Once you are happy, first save what you have done as an ArcMap Document File (*.mxd*) since it is likely that you later discover there are some changes you want to make to the map. File → Save as.
- Then export the map as a *.pdf* or *.png* via File → Export Map.
- Change Resolution and image quality to improve image quality / shrink the map. Maps can weigh down your document, especially if you have more than one.