Zonal Analysis:

A GIS lecture tutorial

Prof. Yuji MURAYAMA, PhD.
Mr. Ronald C. ESTOQUE, MSc.

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Contents, Data & Software Used

Contents

Data & Software

1. Built-up/developed area map, slope maps, road distance map, erosion potential map, and municipal boundary map.
2. ArcGIS software

1. Introduction

Background

- Zonal analysis is one of the most important analysis tools in ArcGIS under its spatial analyst extension.
  - It is useful for GIS-related studies or activities such as environmental monitoring (e.g., erosion potential estimation), urban studies (e.g., urban development pattern analysis), land management (e.g., land suitability analysis), among others.
  - In ArcGIS, several zonal tools are available such as tabulate area, zonal fill, zonal geometry, zonal statistics as table, among others.

- In this lecture tutorial, two of the most commonly used zonal tools will be explored. These are "tabulate area" and "zonal statistics as table".

Objective

- The aim of this lecture tutorial is to explain two zonal tools available in ArcGIS software, namely "tabulate area" and "zonal statistics as table", and give examples of how these tools are used in actual analysis.

2. Basic concepts & definitions

Zonal analysis

- is the creation of an output raster (or statistics table) in which the desired function is computed on the cell values from the input value raster that intersect or fall within each zone of a specified input zone dataset. *Source: ESRI*

An input zone

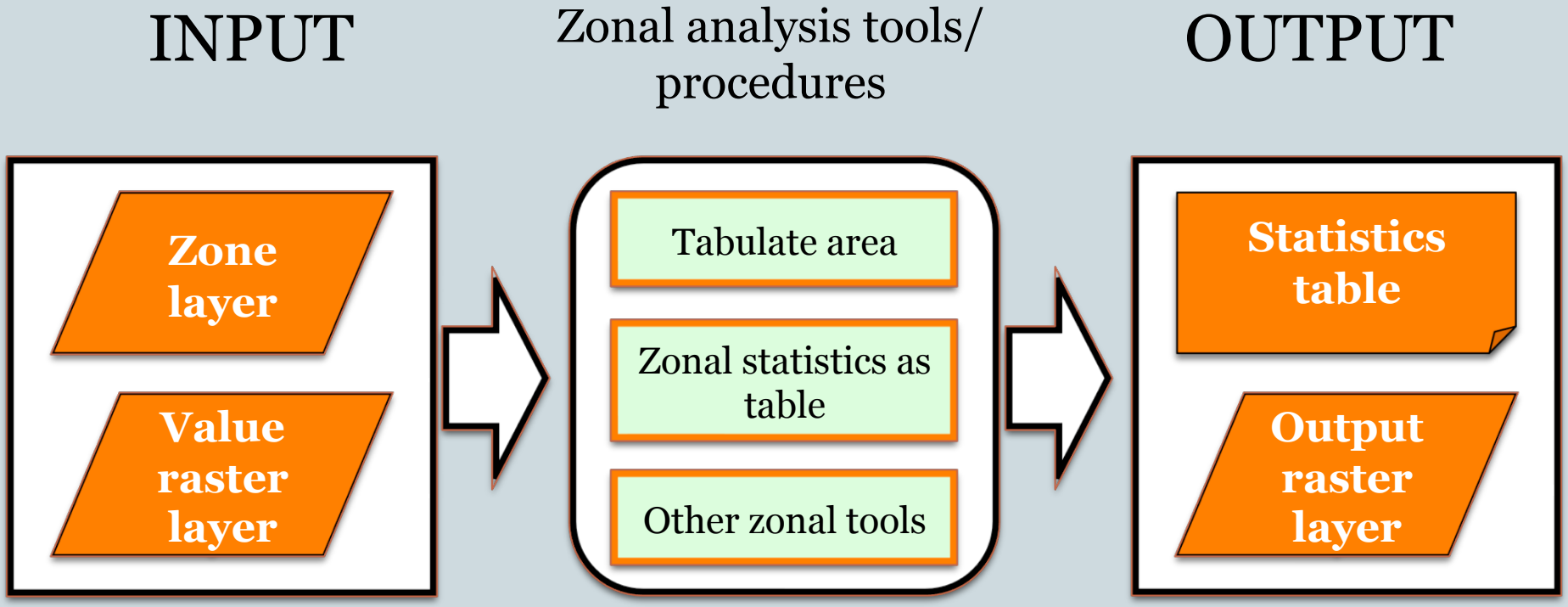
- can be a vector file or an integer raster file.
- Examples of an input zone include but not limited to the following: administrative or political boundary, buffer zones, slope or elevation values or classes, areas of interests with defined boundaries, among others.

An input value raster

- includes any raster file that contains values that can be analyzed visually and statistically.
- Examples of an input value raster include but not limited to the following: built-up/ developed area map, erosion potential map, land suitability map, among others.

The input zone dataset is only used to define the size, shape, and location of each zone, while the input value raster contains the values to be used in the evaluations within the zones. *Source: ESRI*

3. Zonal analysis workflow



Note: The main outputs of the examples illustrated in this lecture tutorial are tables, which can be further analyzed statistically. These tables can also be linked (using the "Join and Relates" function) to the zone layer and used to visualize the results of the zonal analysis.

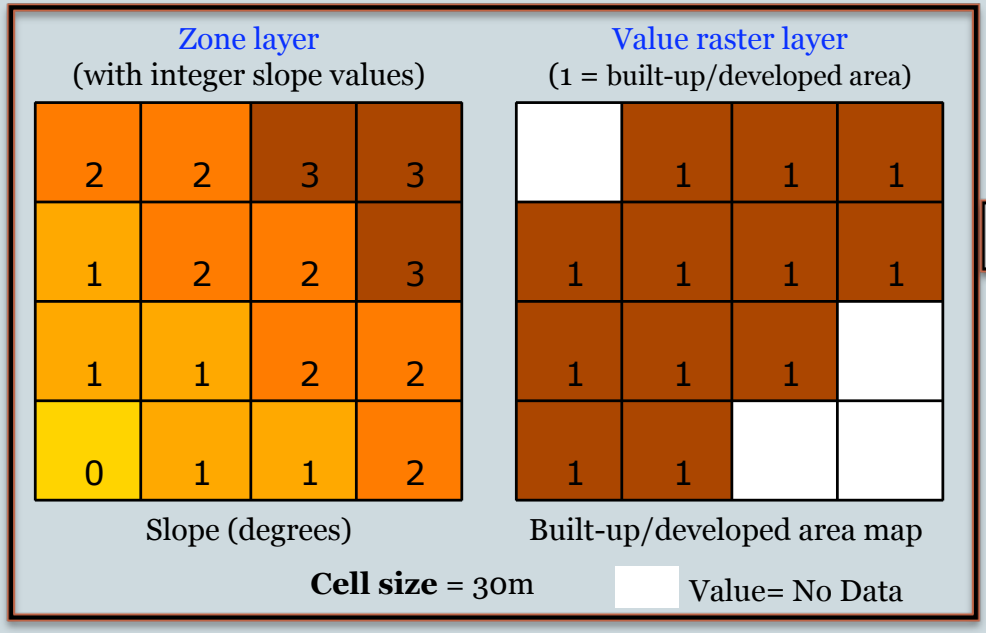
4. Zonal tool – Tabulate area

6

4.1. How does it work?

Goal: *To determine the area of built-up/developed areas for each slope value.*

INPUT layers



OUTPUT table

Rowid	VALUE	VALUE_1
1	0	900
2	1	3600
3	2	3600
4	3	2700

- The "VALUE" column contains the integer slope values.
- The "VALUE_1" column contains the area (m^2) of built-up/developed areas for each integer slope value.

Note:

- Zones are defined as areas that have identical values.
- If the zone input is a raster, it must be integer.
- If the zone input is a feature class, the zone field must be integer, though a character field is also acceptable.

Reference: ESRI

4. Zonal tool – Tabulate area

4.2. Example

- Background
  - In this example, we will try to illustrate how to use the "tabulate area" zonal tool using data from a study focusing on urban development pattern analysis.
  - The study was conducted in Baguio, a hill station and summer capital of the Philippines. (*See* Estoque & Murayama, 2011 for more details).

- Objective of this example:
  - To explore the distribution of built-up/developed area relative to slope and the distance from the roads.

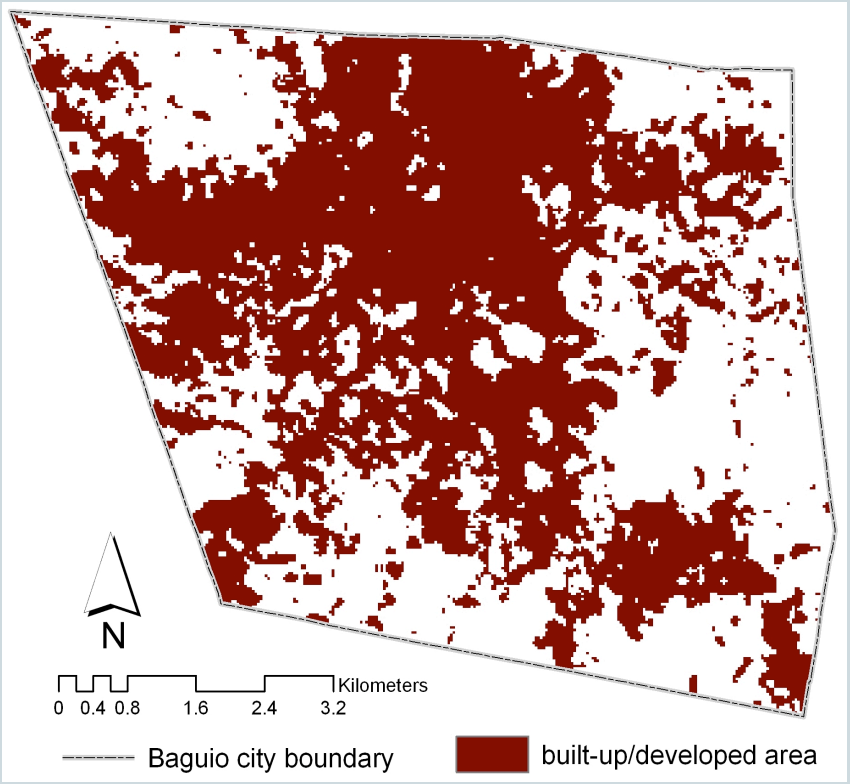
4. Zonal tool – Tabulate area

Example – List of data inputs

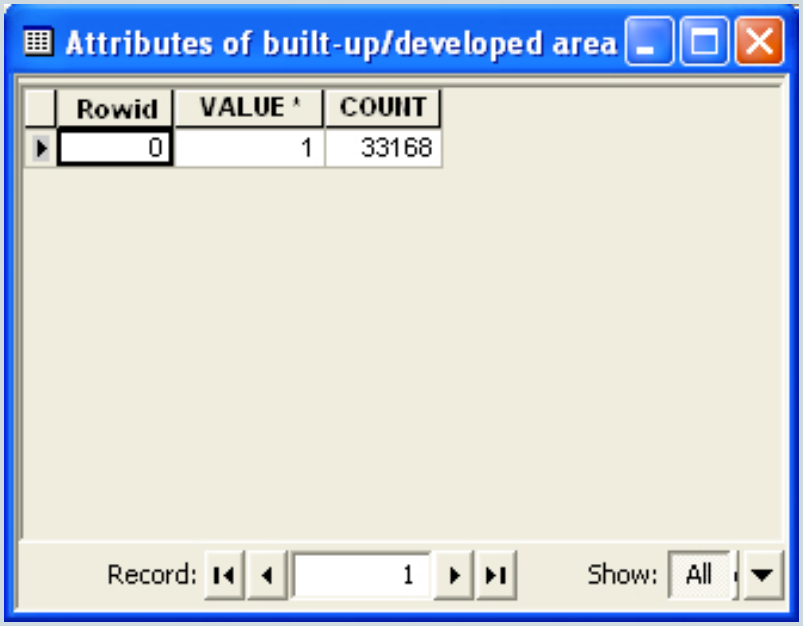
- map of built-up/developed area (value raster layer)
  - this map was extracted from a land use/cover map classified from an ALOS AVNIR-2 image captured in 2009. (*Source:* Estoque & Murayama, 2011)
- slope map (raster zone layer)
  - the slope values, expressed as integers, range from about 0 – 60 degrees
- road map (vector zone layer)
  - contains buffer zones (around the roads) with a zone size of 200m created using the multiple ring buffer method
  - the farthest distance from the road is about 2000 meters

4. Zonal tool – Tabulate area

Example – Input maps



2009 built-up/developed area map (*raster file*)

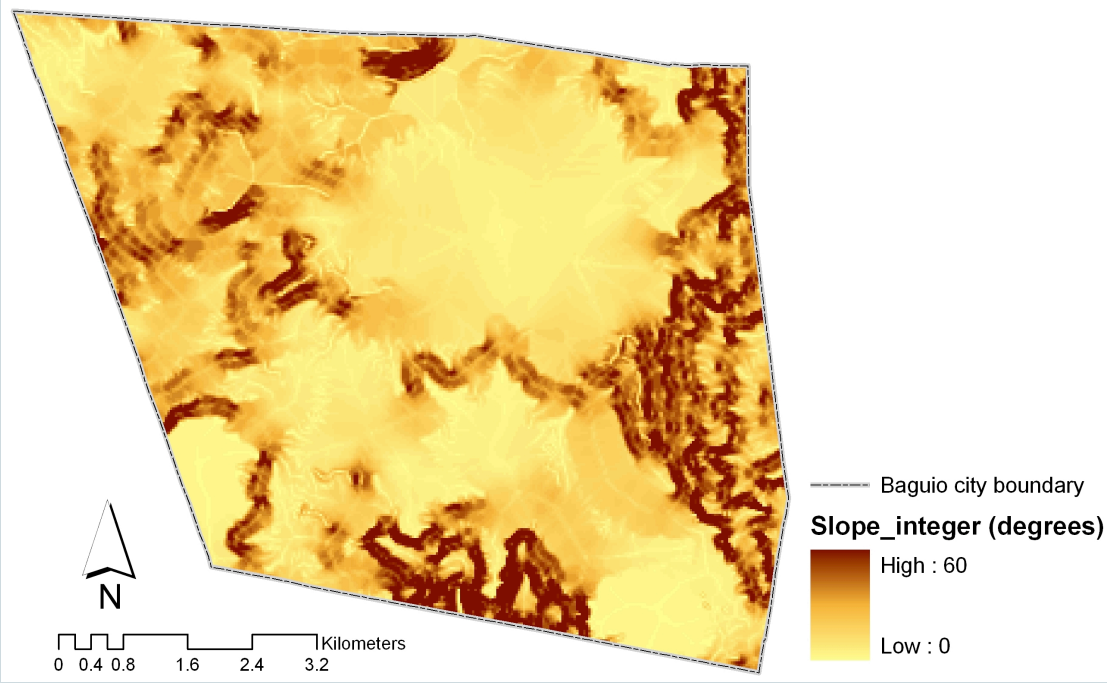


Note:

- The "COUNT" column contains the number of pixels with a value of 1 (built-up/developed area).
- The pixel or cell size is 30m.

4. Zonal tool – Tabulate area

Example – Input maps



Slope map (with integer slope values)
(*raster file*)

Attributes of Slope_integer (degrees)

Rowid	VALUE	COUNT
0	0	915
1	1	4332
2	2	7151
3	3	6204
4	4	4450
5	5	3523
6	6	3026
7	7	2803
8	8	3104
9	9	2717
10	10	2492

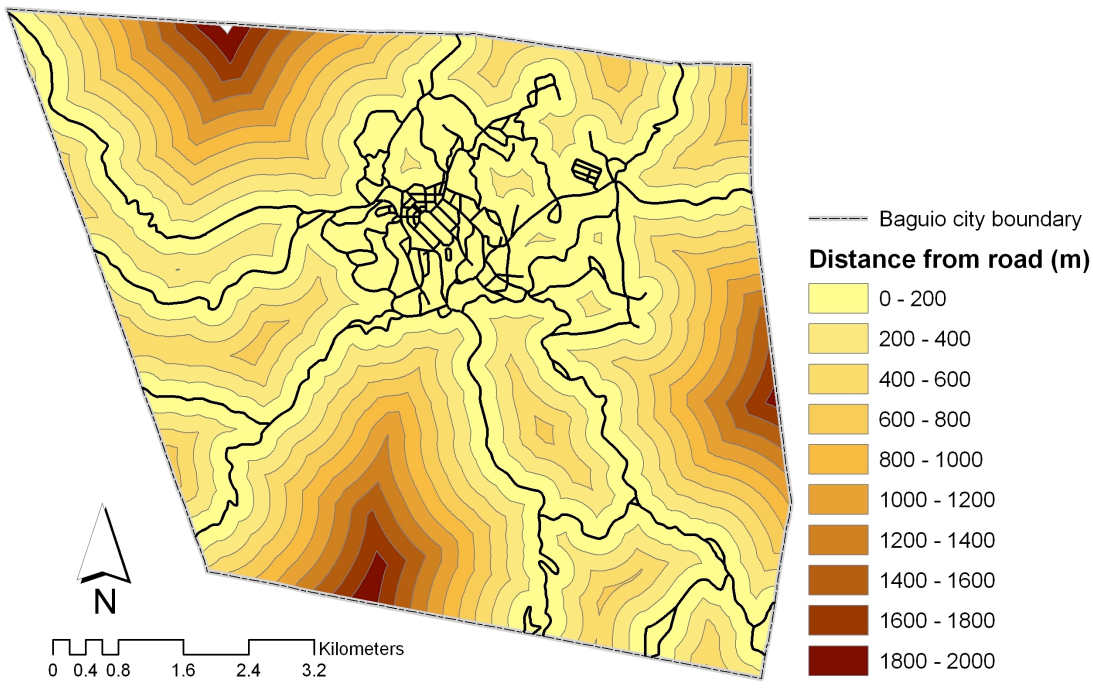
Record: 1 Show: All

Note:

- The "VALUE" column contains the integer slope values, while the "COUNT" column contains the number of pixels that correspond to each integer slope value.
- The pixel or cell size is 30m.

4. Zonal tool – Tabulate area

Example – Input maps



Buffer zones from the roads (m)
(*vector file*)

Attributes of Distance from road (m)

FID	Shape *	distance	Value
0	Polygon	200	200
1	Polygon	400	400
2	Polygon	600	600
3	Polygon	800	800
4	Polygon	1000	1000
5	Polygon	1200	1200
6	Polygon	1400	1400
7	Polygon	1600	1600
8	Polygon	1800	1800
9	Polygon	2000	2000

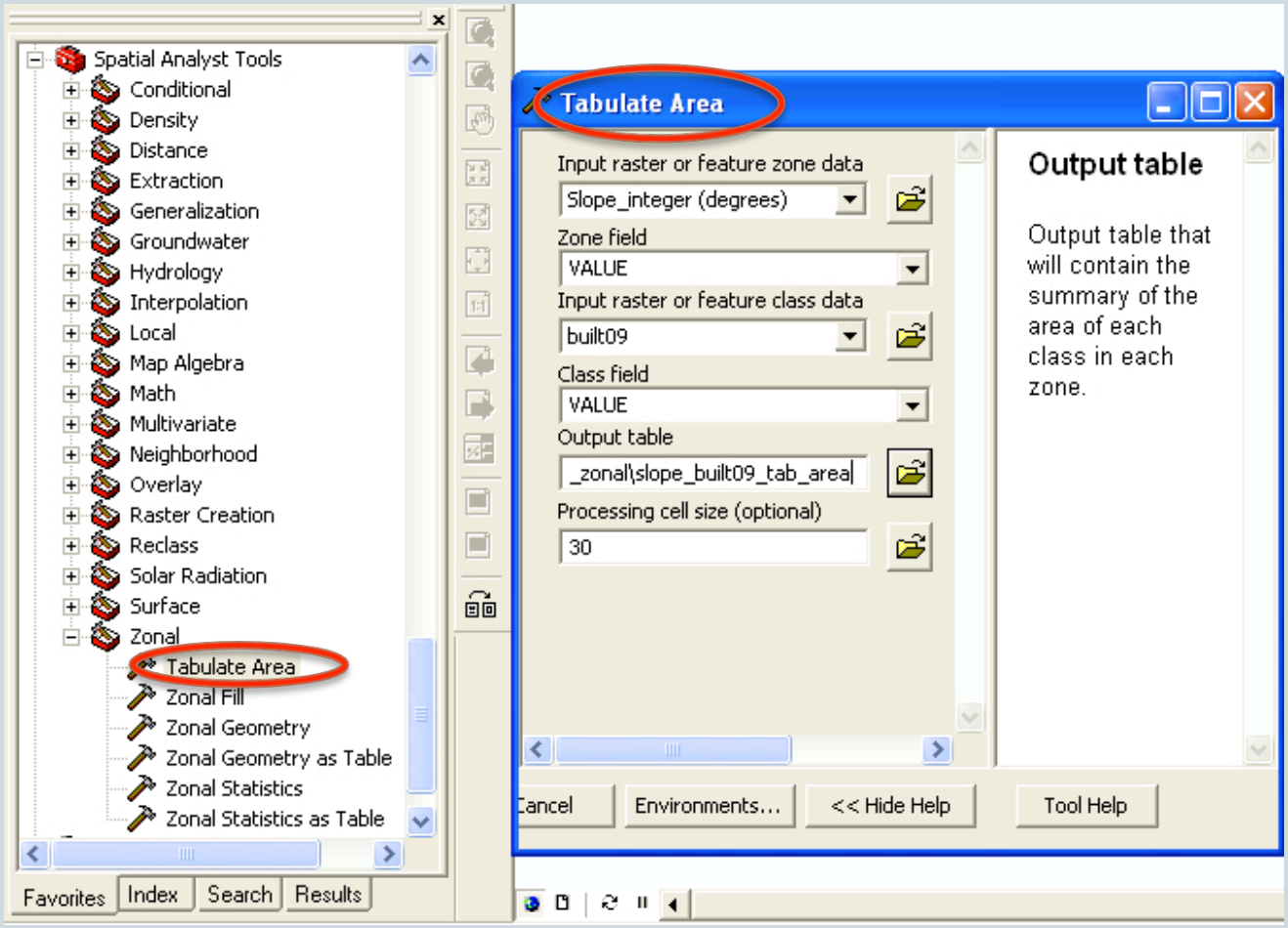
Record: 1 Show: All

Note:

- The "distance" column was automatically created during the buffering process using the multiple ring buffer method.
- A separate column (Value) containing the distance from road integer values was created.
- The zone size is 200 meters.

4. Zonal tool – Tabulate area

Procedure – Built-up/developed area and Slope



Inputs:

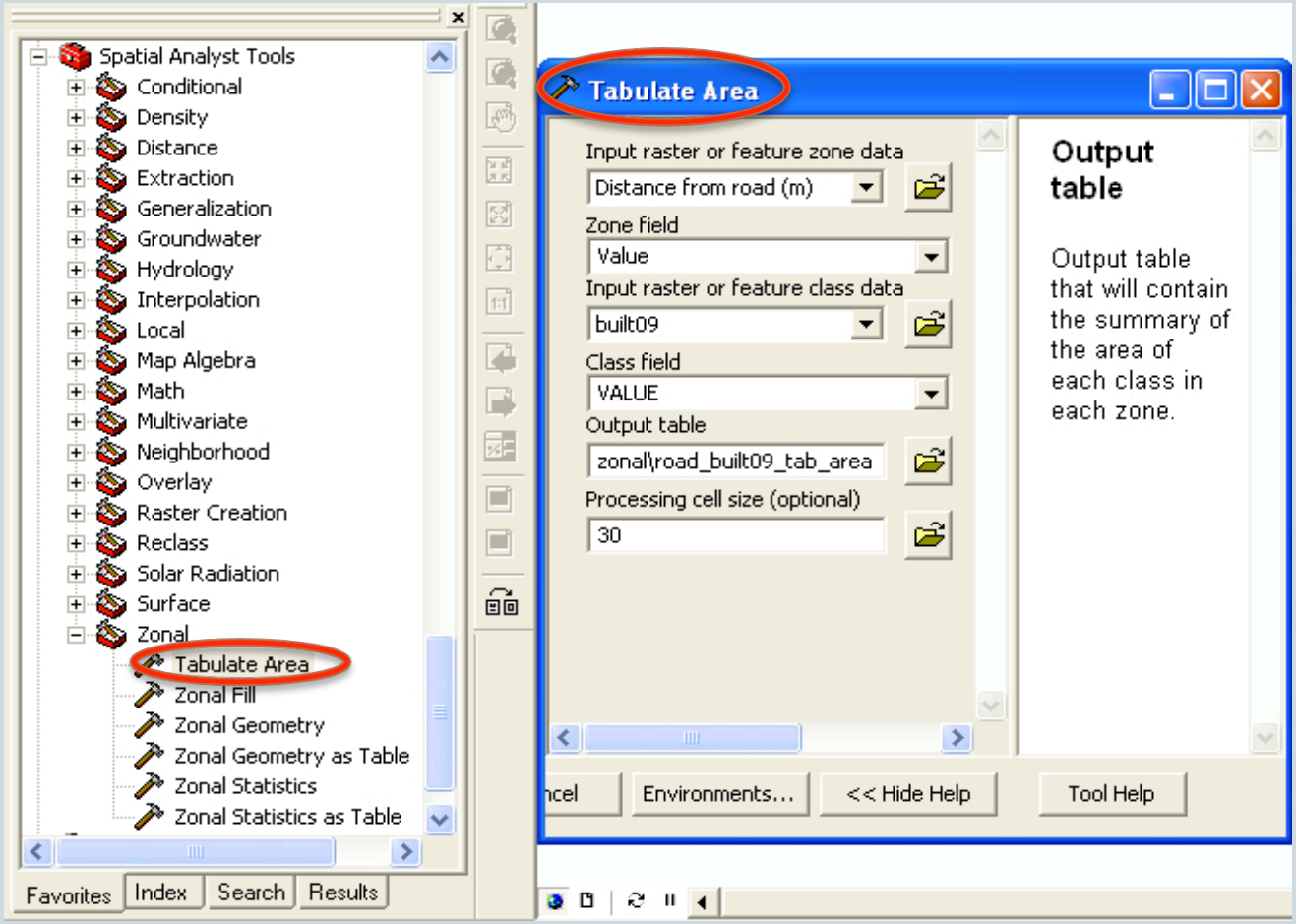
Zone layer (raster)
- Slope map (integer)
- Zone field = VALUE

See slide 10 for the details of the zone field "VALUE".

Value raster layer
- Built-up/developed area map
- Class field = VALUE

4. Zonal tool – Tabulate area

Procedure – Built-up/developed area and Distance from road



Inputs:

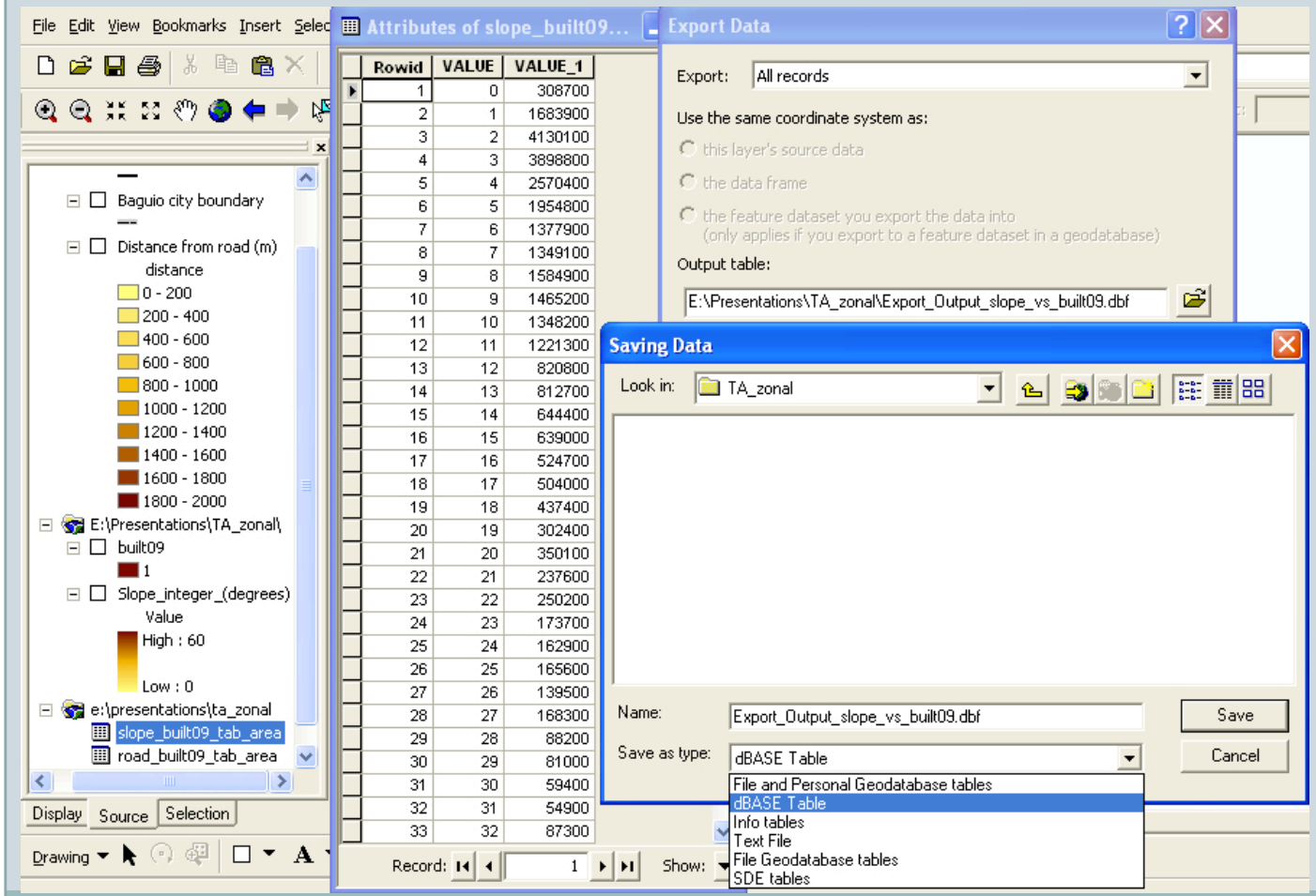
Zone layer (vector)
- Road distance map (buffer zones)
- Zone field = VALUE

See slide 11 for the details of the zone field "VALUE"

Value raster layer
- Built-up/developed area map
- Class field = VALUE

4. Zonal tool – Tabulate area

Output – Built-up/developed area and Slope

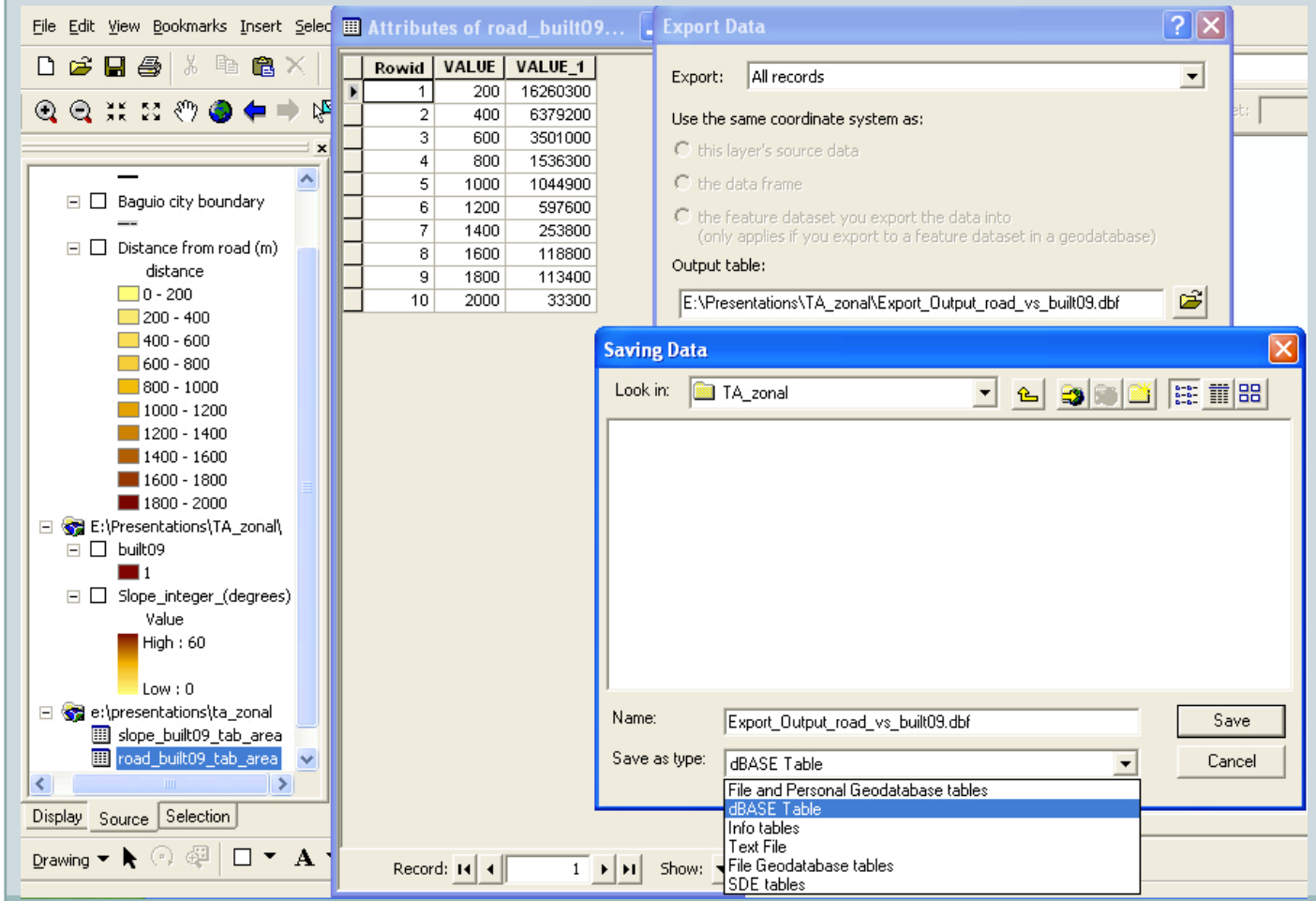


- The result (table) can be accessed from the "Source" window and can be exported and saved as dbf, text file, etc.

- The "VALUE" column contains the integer slope values, while the "VALUE_1" column contains the corresponding area (m^2) of built-up/ developed areas.

4. Zonal tool – Tabulate area

Output – Built-up/developed area and Distance from road

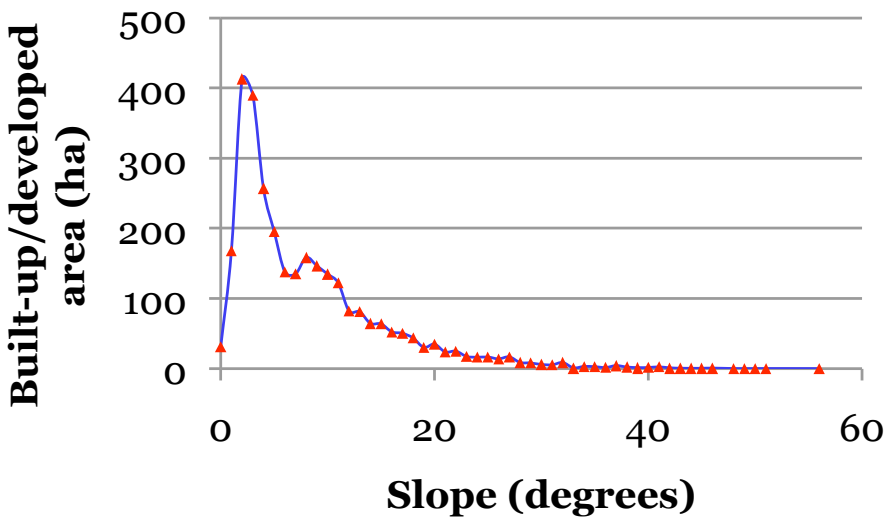


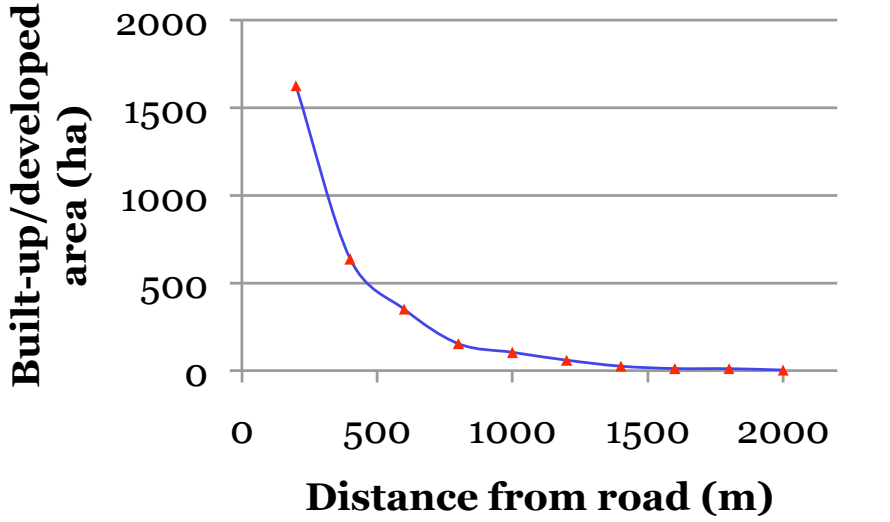
- The result (table) can be accessed from the "Source" window and can be exported and saved as dbf, text file, etc.

- The "VALUE" column contains the distance from road integer values, while the "VALUE_1" column contains the corresponding area (m^2) of built-up/ developed areas.

4. Zonal tool – Tabulate area

Analysis





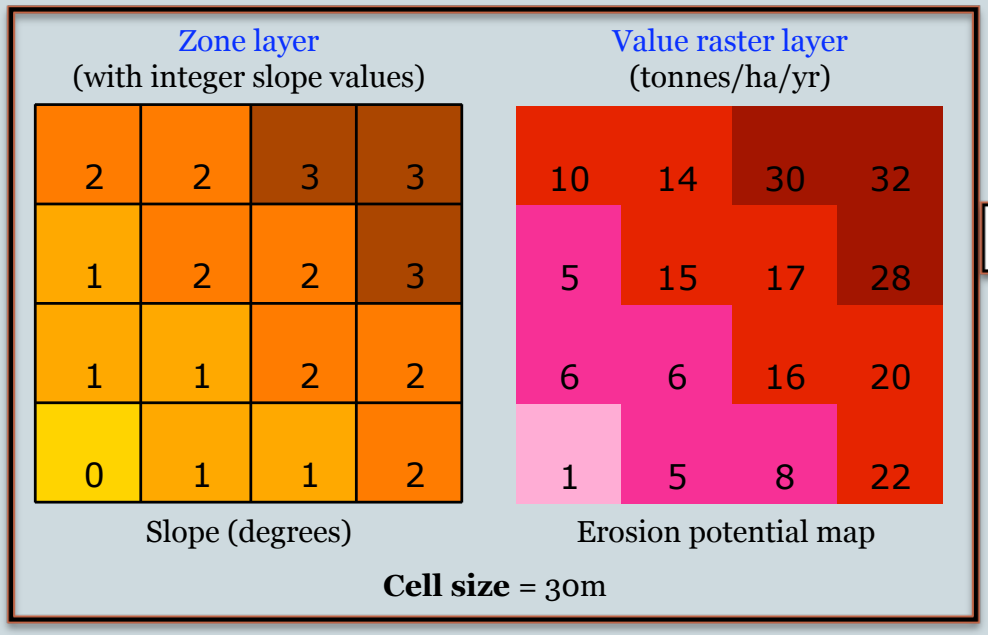
- The results of the zonal analysis show that built-up/developed area increases rapidly then decreases gradually as the slope gets steeper.
- Furthermore, the results show that built-up/developed area is relatively higher in locations closer to the roads and decreases gradually as the distance from the roads goes farther.

5. Zonal tool – Zonal statistics as table

5.1. How does it work?

Goal: *To determine the maximum and mean erosion potential for each slope value.*

INPUT layers



OUTPUT table

Rowid	VALUE	MAX	MEAN
1	0	1.00	1.00
2	1	8.00	6.00
3	2	22.00	16.29
4	3	32.00	30.00

- The "VALUE" column contains the integer slope values.
- The "MAX" and "MEAN" columns contain the maximum and mean erosion potential rates for each integer slope value, respectively.
- Note that "zonal statistics as table" produces a lot of information and is not limited only to "MAX" and "MEAN" (see slide 25).

Reference: ESRI

Note:

- Zones are defined as areas that have identical values.
- If the zone input is a raster, it must be integer.
- If the zone input is a feature class, the zone field must be integer, though a character field is also acceptable.

5. Zonal tool – Zonal statistics as table

5.2. *Example*

- Background
  - In this example, we will try illustrate how to use the "zonal statistics as table" zonal tool using data from a study focusing on erosion potential estimation.
  - The study was conducted in the province of La Union in the Philippines. (*See* Estoque et al., 2006 for more details).

- Objective of this example:
  - To explore the distribution of erosion potential relative to slope and calculate the maximum and mean erosion potential rates per municipality.

5. Zonal tool – Zonal statistics as table

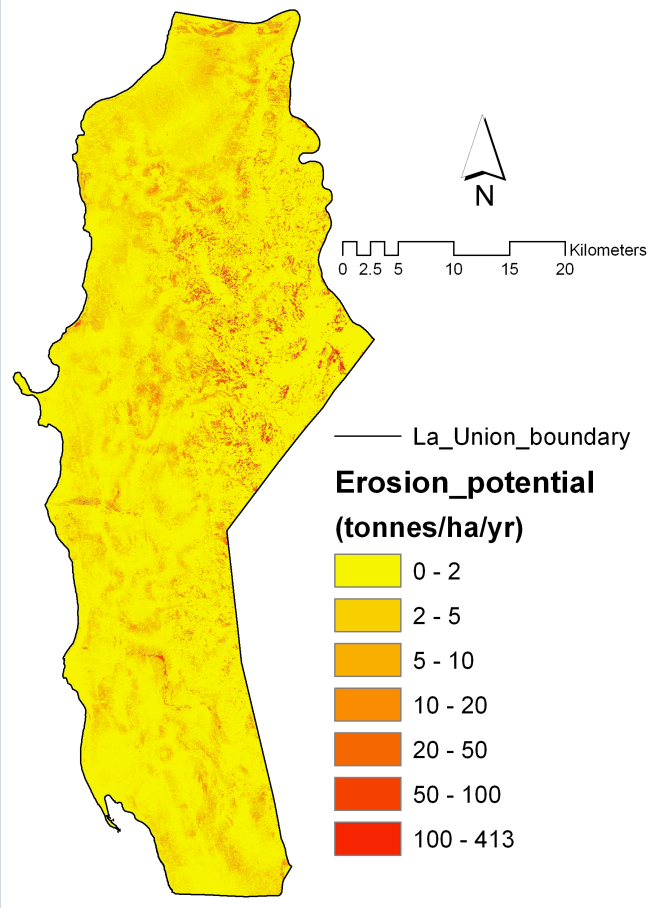
Example – List of data inputs

- erosion potential map (value raster layer)
  - this erosion potential map was empirically developed following the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997). (*Source:* Estoque et al., 2006)
- slope map (raster zone layer)
  - the slope values, expressed as integers, range from about 0 – 71 degrees
- municipal boundary map (vector zone layer)
  - the province of La Union is composed of 19 municipalities and 1 city

5. Zonal tool – Zonal statistics as table

Example – Input maps

Erosion potential map (*raster file*)



Attributes of Erosion_potential

Rowid	VALUE	COUNT
0	0	936545
1	1	151875
2	2	116445
3	3	94145
4	4	68419
5	5	47711
6	6	34222
7	7	24800
8	8	17417
9	9	12120
10	10	8845

Record: 1 Show: All Selected

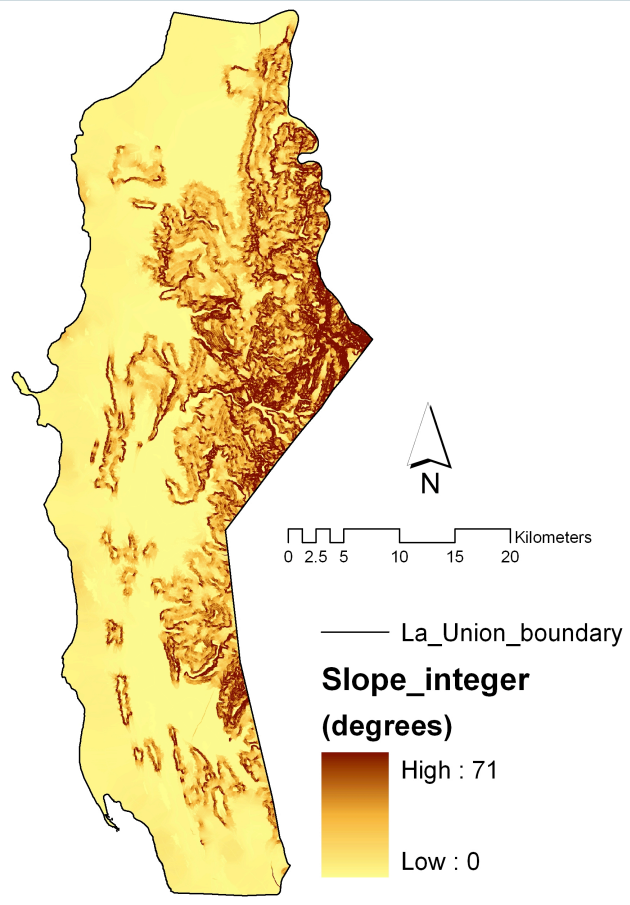
Note:

- The column "VALUE" contains the erosion potential rates, while the column "COUNT" contains the number of pixels that correspond to each erosion potential rate.
- The pixel or cell size is 30m.

5. Zonal tool – Zonal statistics as table

Example – Input maps

Slope map
(with integer slope values)
(*raster file*)



Attributes of slope_integer

Rowid	VALUE	COUNT
0	0	468045
1	1	313574
2	2	97654
3	3	46549
4	4	35219
5	5	30687
6	6	29132
7	7	29735
8	8	31165
9	9	31883
10	10	32254

Record: 1 Show: All Selected

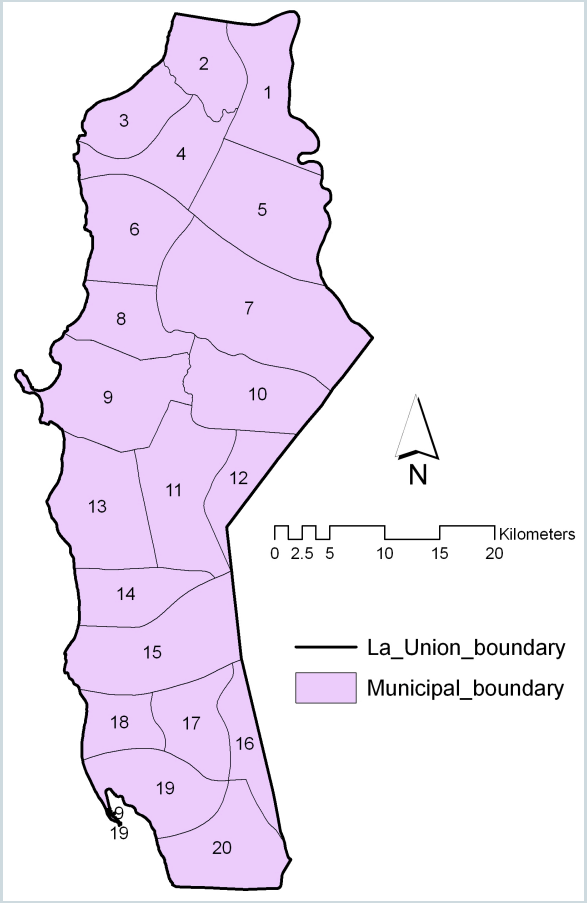
Note:

- The "VALUE" column contains the integer slope values, while the "COUNT" column contains the number of pixels that correspond to each integer slope value.
- The pixel or cell size is 30m.

5. Zonal tool – Zonal statistics as table

Example – Input maps

Municipal boundary map (*vector file*)



Attributes of Municipality

FID	Shape *	CITY_MUNI	Area_m2	Code
0	Polygon	SUDIPEN	70141687	1
1	Polygon	BANGAR	48707659	2
2	Polygon	LUNA	47700004	3
3	Polygon	BALAOAN	58845836	4
4	Polygon	SANTOL	105194757	5
5	Polygon	BACNOTAN	74856227	6
6	Polygon	SAN GABRIEL	158817765	7
7	Polygon	SAN JUAN	50952709	8
8	Polygon	SAN FERNANDO	99664263	9
9	Polygon	BAGULIN	76056556	10
10	Polygon	NAGUILIAN	91637563	11
11	Polygon	BURGOS	38203093	12
12	Polygon	BAUANG	87962841	13
13	Polygon	CABA	49334544	14
14	Polygon	ARINGAY	106342878	15
15	Polygon	PUGO	35860587	16
16	Polygon	TUBAO	49604284	17
17	Polygon	AGOO	35467398	18
18	Polygon	SANTO TOMAS	65670806	19
19	Polygon	ROSARIO	73238072	20

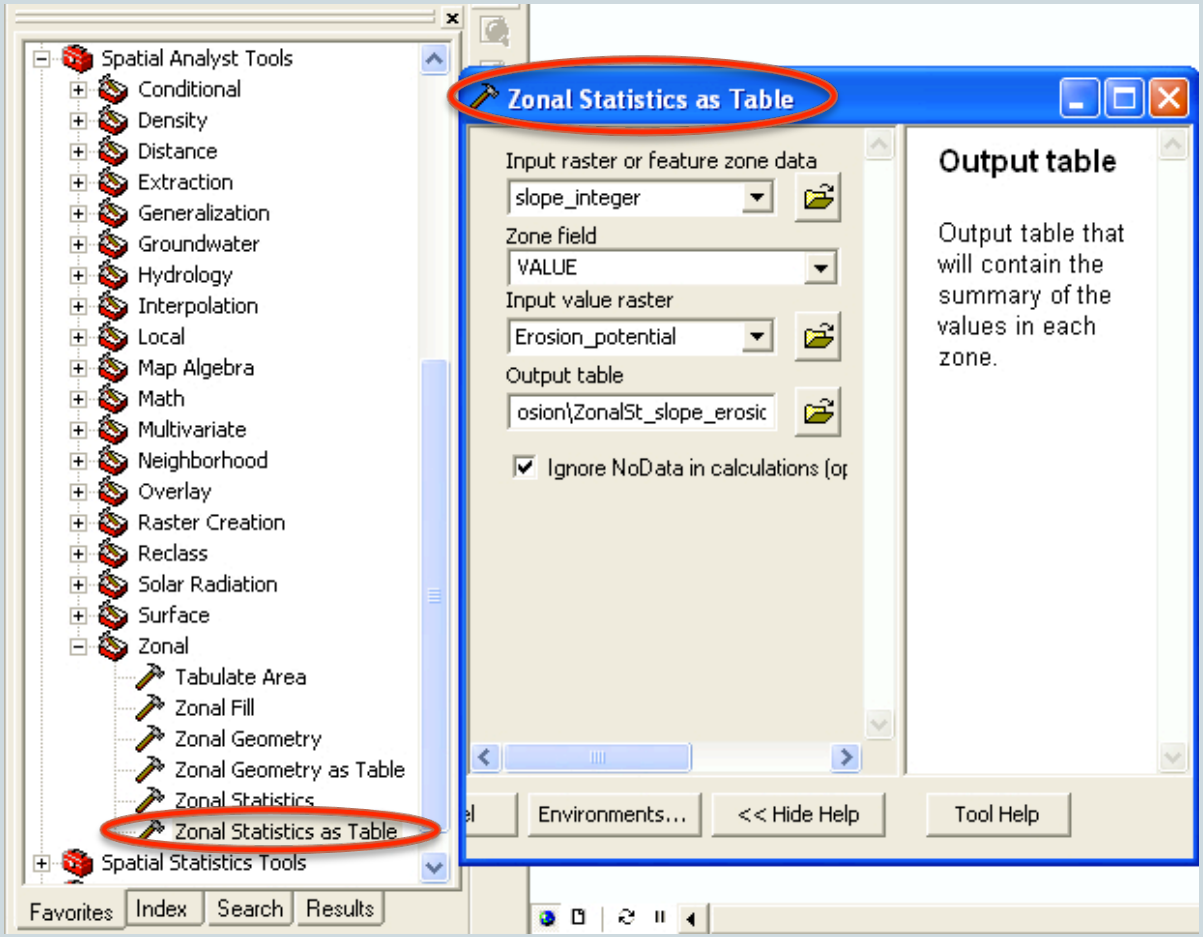
Record: 1 Show: All Selected Records (0 out of 22

Note:

- The province of La Union is composed of 19 municipalities and 1 city (San Fernando).
- For the names of the municipalities, refer to the attribute table (above).

5. Zonal tool – Zonal statistics as table

Procedure – Erosion potential and Slope



Inputs:

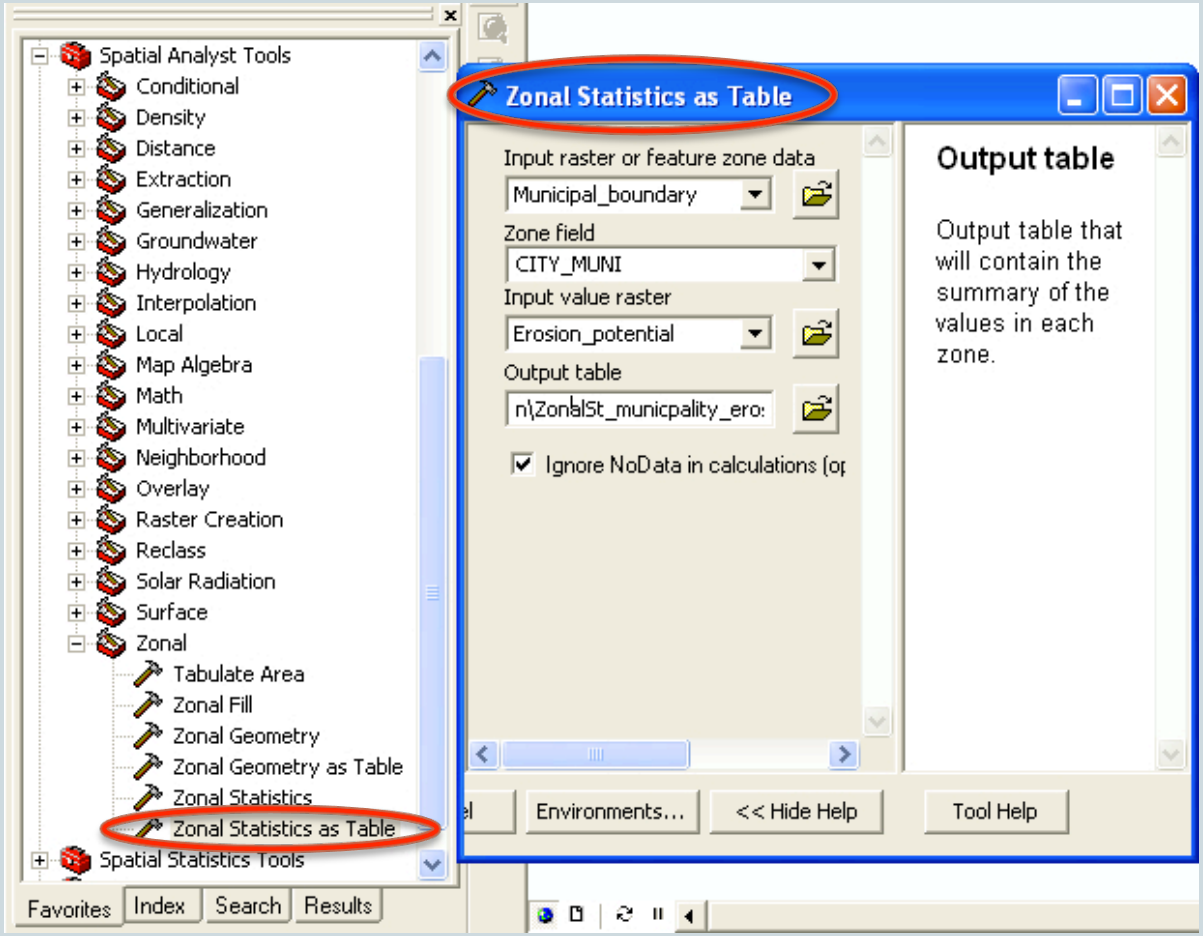
Zone layer (raster)
- Slope map (integer)
- Zone field = VALUE

See slide 21 for the details of the zone field "VALUE".

Value raster layer
- Erosion potential map

5. Zonal tool – Zonal statistics as table

Procedure – Erosion potential and Municipality



Inputs:

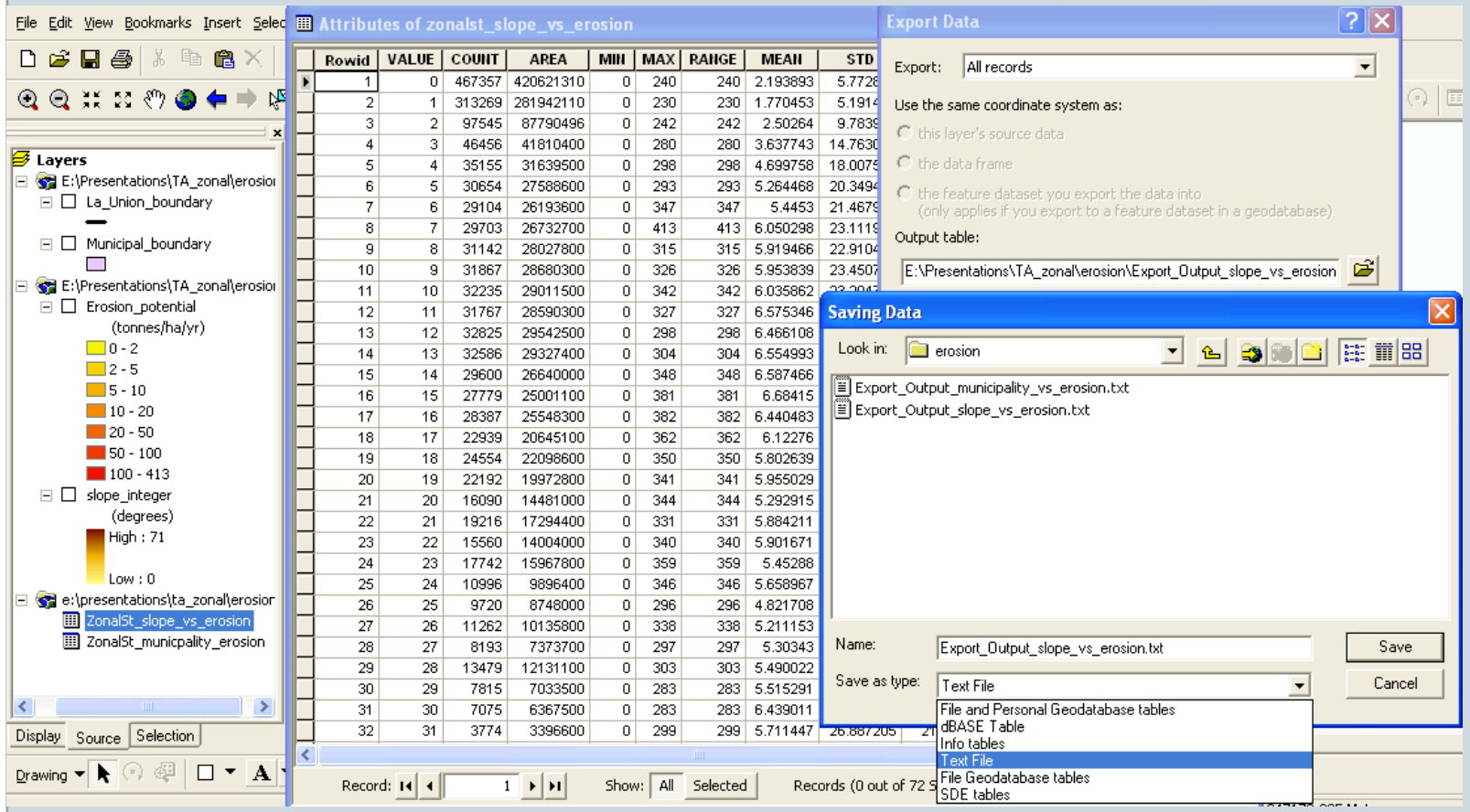
Zone layer (vector)
- Municipal boundary map
- Zone field = CITY_MUNI

See slide 22 for the details of the zone field "CITY_MUNI".

Value raster layer
- Erosion potential map

5. Zonal tool – Zonal statistics as table

Output – Erosion potential and Slope



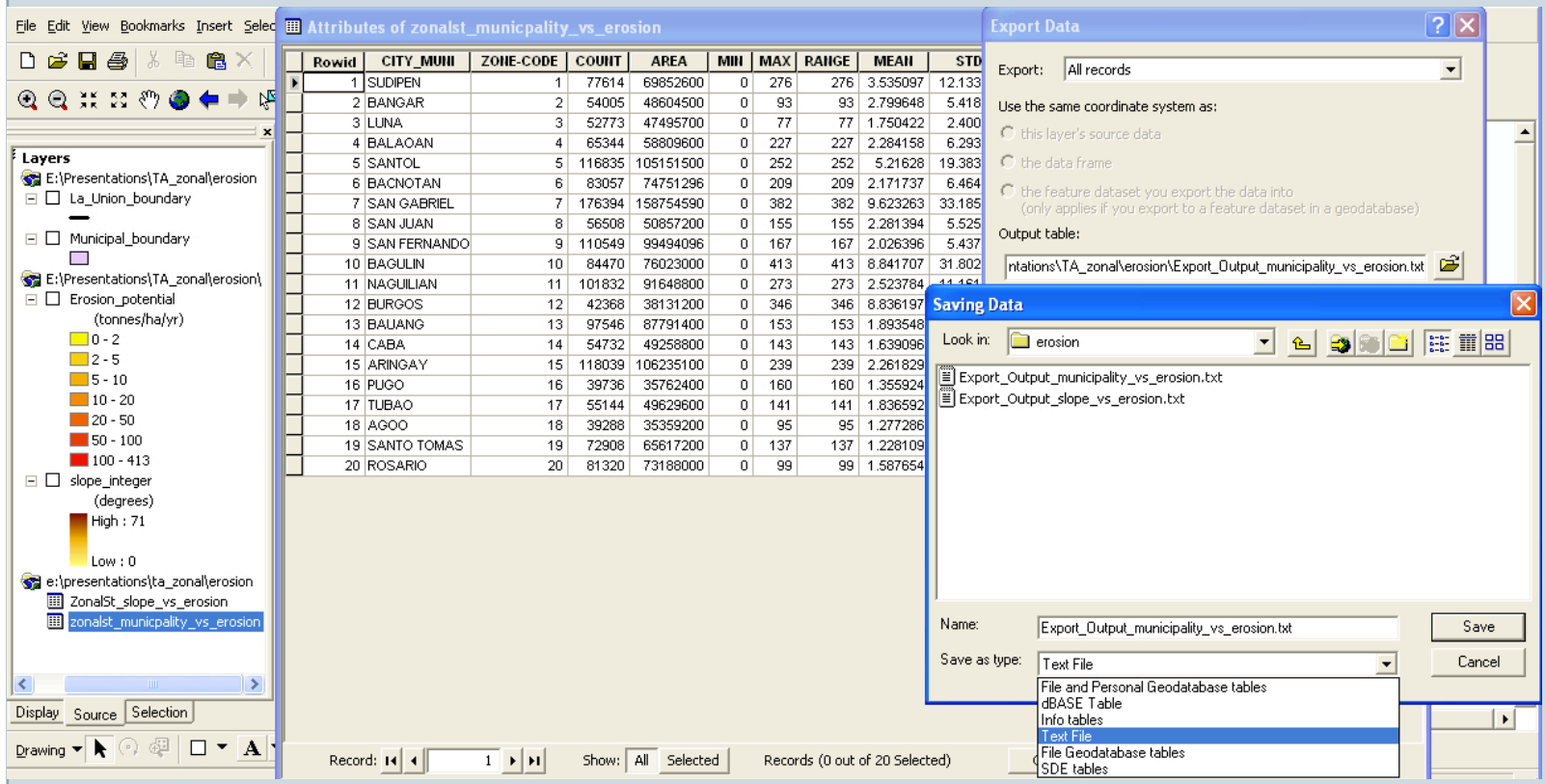
- The result (table) can be accessed from the "Source" window and can be exported and saved as dbf, text file, etc.

- The "MAX" and "MEAN" columns contain the maximum & mean erosion potential rates, respectively, for each integer slope value.

- The unit of the "AREA" in the attribute table is m^2.

5. Zonal tool – Zonal statistics as table

Output – Erosion potential and Municipality



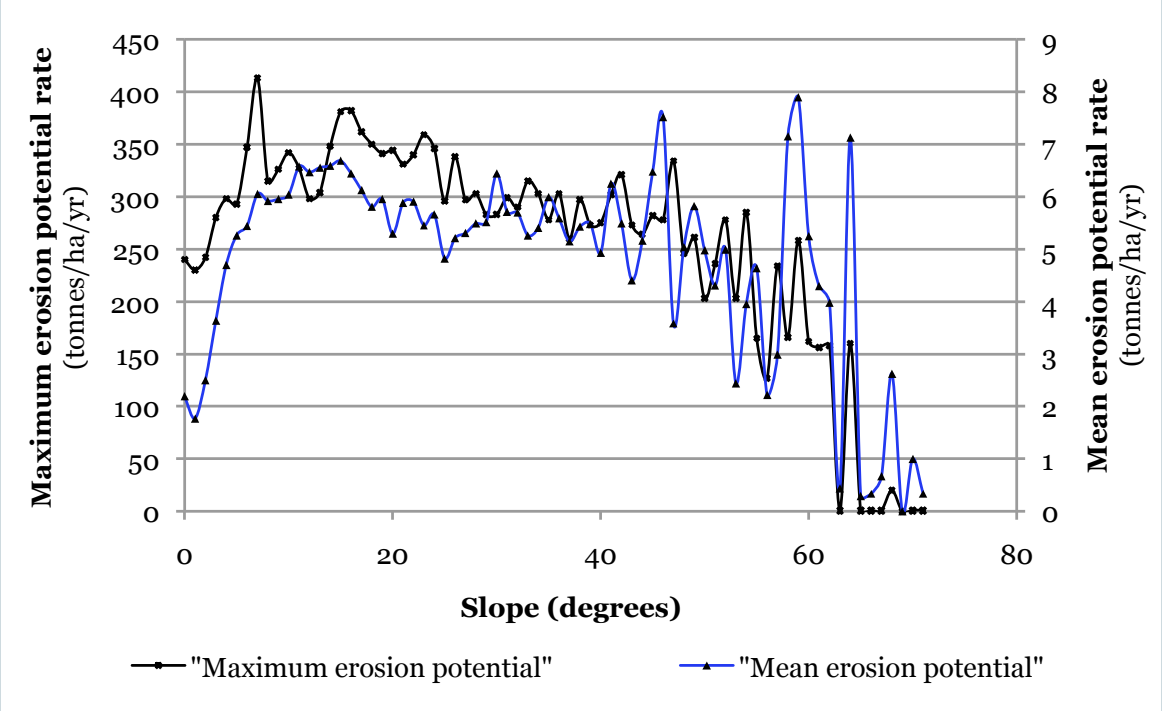
- The unit of the "AREA" in the attribute table is m².

- The result (table) can be accessed from the "Source" window and can be exported and saved as dbf, text file, etc.

- The "MAX" and "MEAN" columns contain the maximum & mean erosion potential rates, respectively, for each integer slope value.

5. Zonal tool – Zonal statistics as table

Analysis



MUNICIPALITY	CODE	EROSION POTENTIAL RATES Maximum	Mean
SUDIPEN	1	276	3.54
BANGAR	2	93	2.80
LUNA	3	77	1.75
BALAOAN	4	227	2.28
SANTOL	5	252	5.22
BACNOTAN	6	209	2.17
SAN GABRIEL	7	382	9.62
SAN JUAN	8	155	2.28
SAN FERNANDO	9	167	2.03
BAGULIN	10	413	8.84
NAGUILIAN	11	273	2.52
BURGOS	12	346	8.84
BAUANG	13	153	1.89
CABA	14	143	1.64
ARINGAY	15	239	2.26
PUGO	16	160	1.36
TUBAO	17	141	1.84
AGOO	18	95	1.28
SANTO TOMAS	19	137	1.23
ROSARIO	20	99	1.59

- The results of the zonal analysis show that erosion potential rate increases rapidly then decreases gradually as the slope gets steeper. However, there are also isolated cases in steep slopes where erosion potential rates are relatively higher.
- Three (3) of the 20 municipalities (including 1 city) have relatively higher maximum and mean erosion potential rates. These municipalities can be considered “hot spots” for erosion.

6. Remarks

- In this lecture tutorial, the basic concepts of zonal analysis were explained and two zonal tools, namely “tabulate area” and “zonal statistics as table” were explored.
- Step-by-step procedures on how to use these tools were illustrated using actual research studies on urban development pattern analysis and erosion potential estimation conducted in Baguio city and the province of La Union in the Philippines.
- Zonal analysis is just one of the many analysis tools that are available in ArcGIS, thus it can be used as a complementary method. Nevertheless, zonal analysis can provide initial results that can be used as inputs in a more rigorous analysis.

References & Suggested Readings

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- ESRI. Tabulate area (2). http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=tabulate_area (Retrieved November 16, 2011).
- ESRI. Zonal statistics as table (1). http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/Zonal_Statistics_as_Table/009z000000w8000000/ (Retrieved November 16, 2011).
- ESRI. Zonal statistics as table (2). http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=Zonal_Statistics_as_Table (Retrieved November 16, 2011).
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- Estoque, R.C., Smith, P.D., and Packwood, A. 2006. Establishing spatial information of soil erosion in La Union, Philippines, using GIS and the RUSLE. In: Proceedings of the Conference on Watershed Management in the Philippines, May 26-28, 2006, DMMMSU, Bacnotan, La Union, Philippines. DMMMSU Publishing. Pp. 172-190.
- Renard, K.G., Foster, G.R., Weesies, G.A., McCool, D.K., and Yoder, D.C. (coordinators). 1997. *Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)*. USDA Agr. Handb. No. 703.