

Zonal Analysis:

A GIS lecture tutorial

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2011

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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

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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

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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.

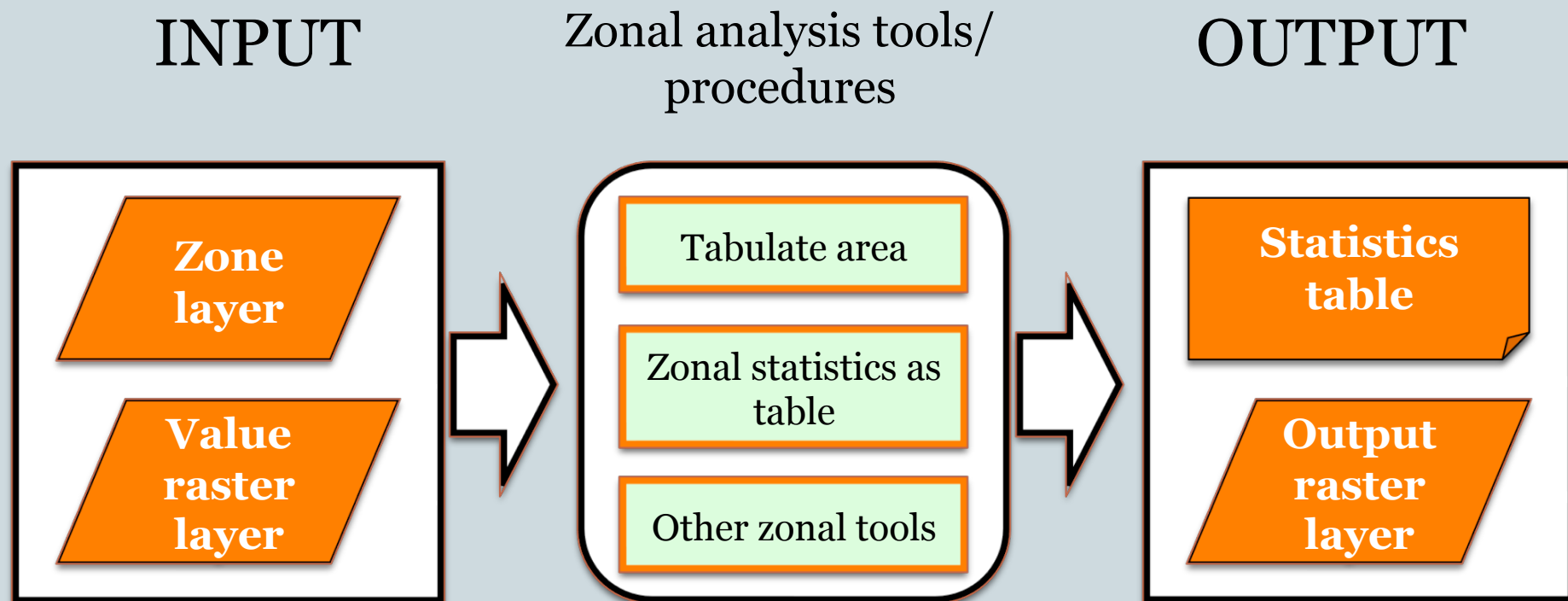
An input value raster

- 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

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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.

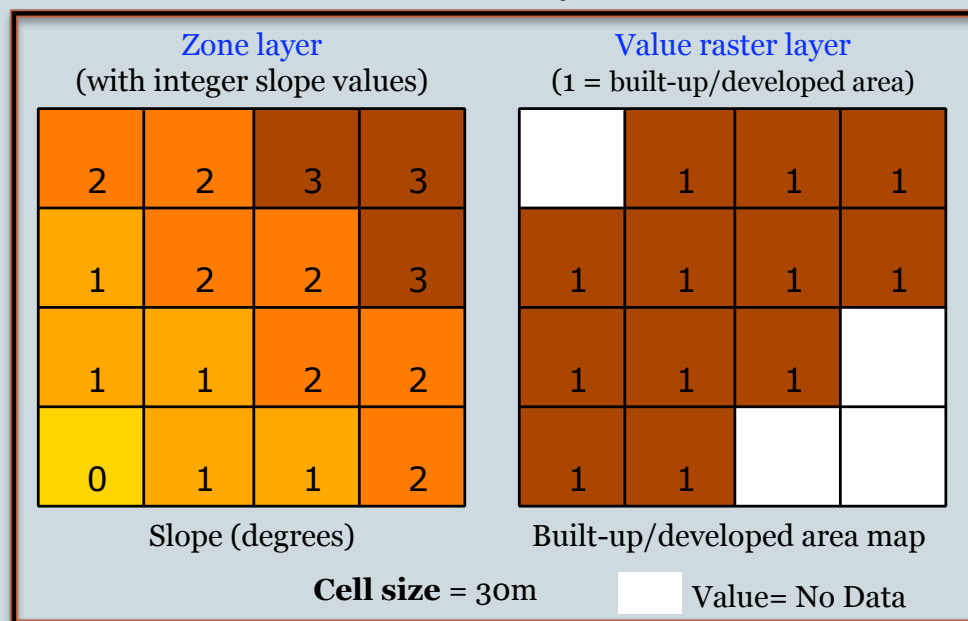
4. Zonal tool – Tabulate area

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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 (m²) 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

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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

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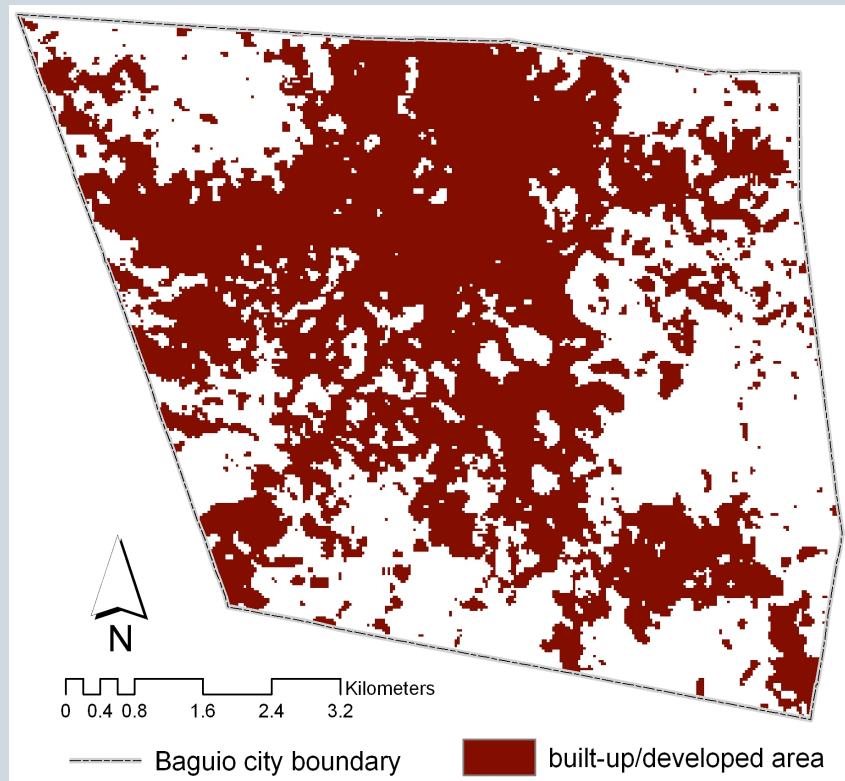
Example – List of data inputs

- 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

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Example – Input maps



Attributes of built-up/developed area

Rowid	VALUE *	COUNT
0	1	33168

Record: 1 Show: All

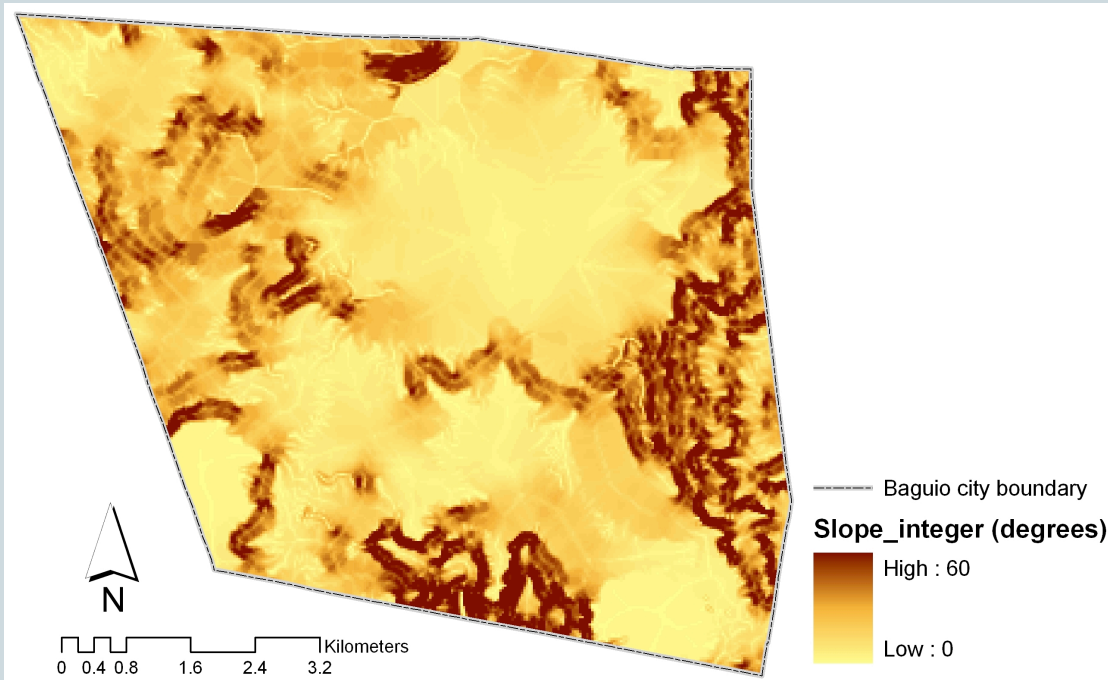
Note:

- 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

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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

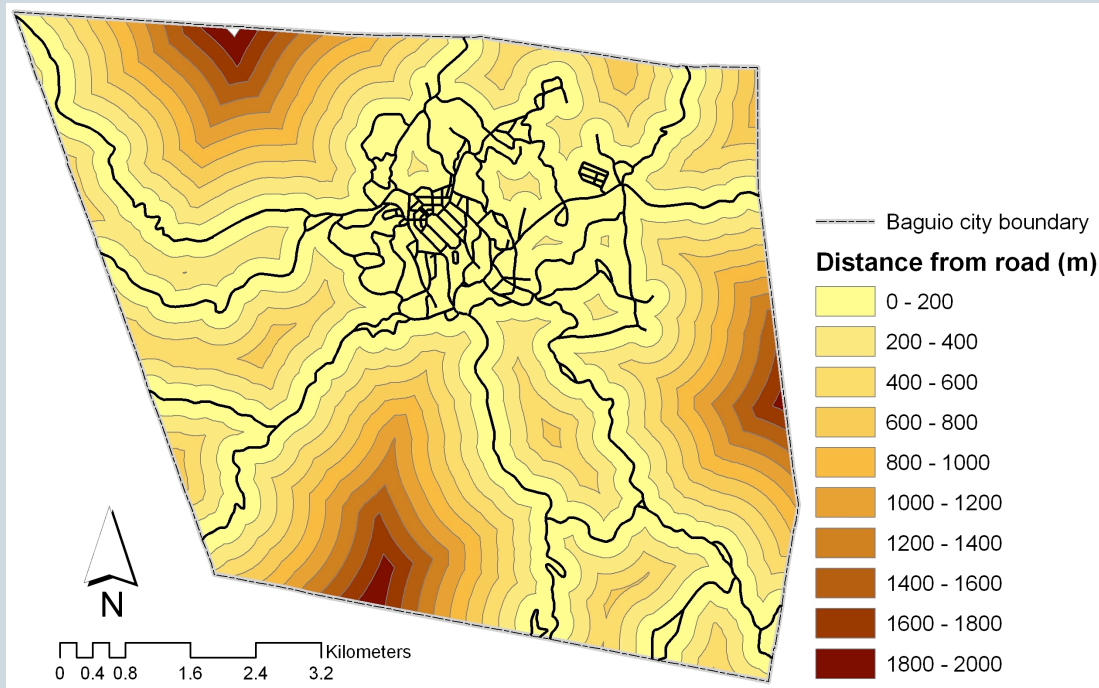
Note:

- 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

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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

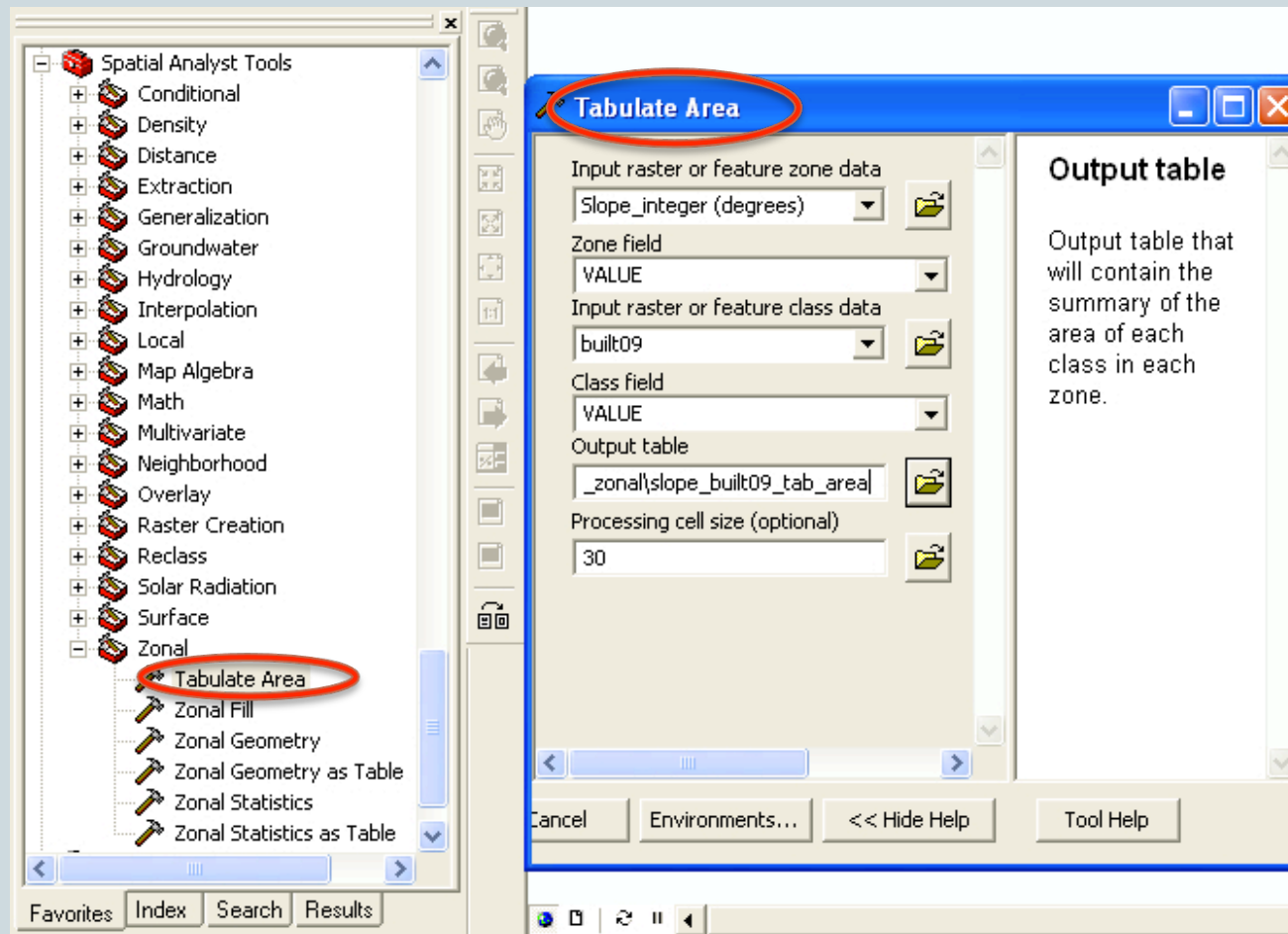
Note:

- 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

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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".

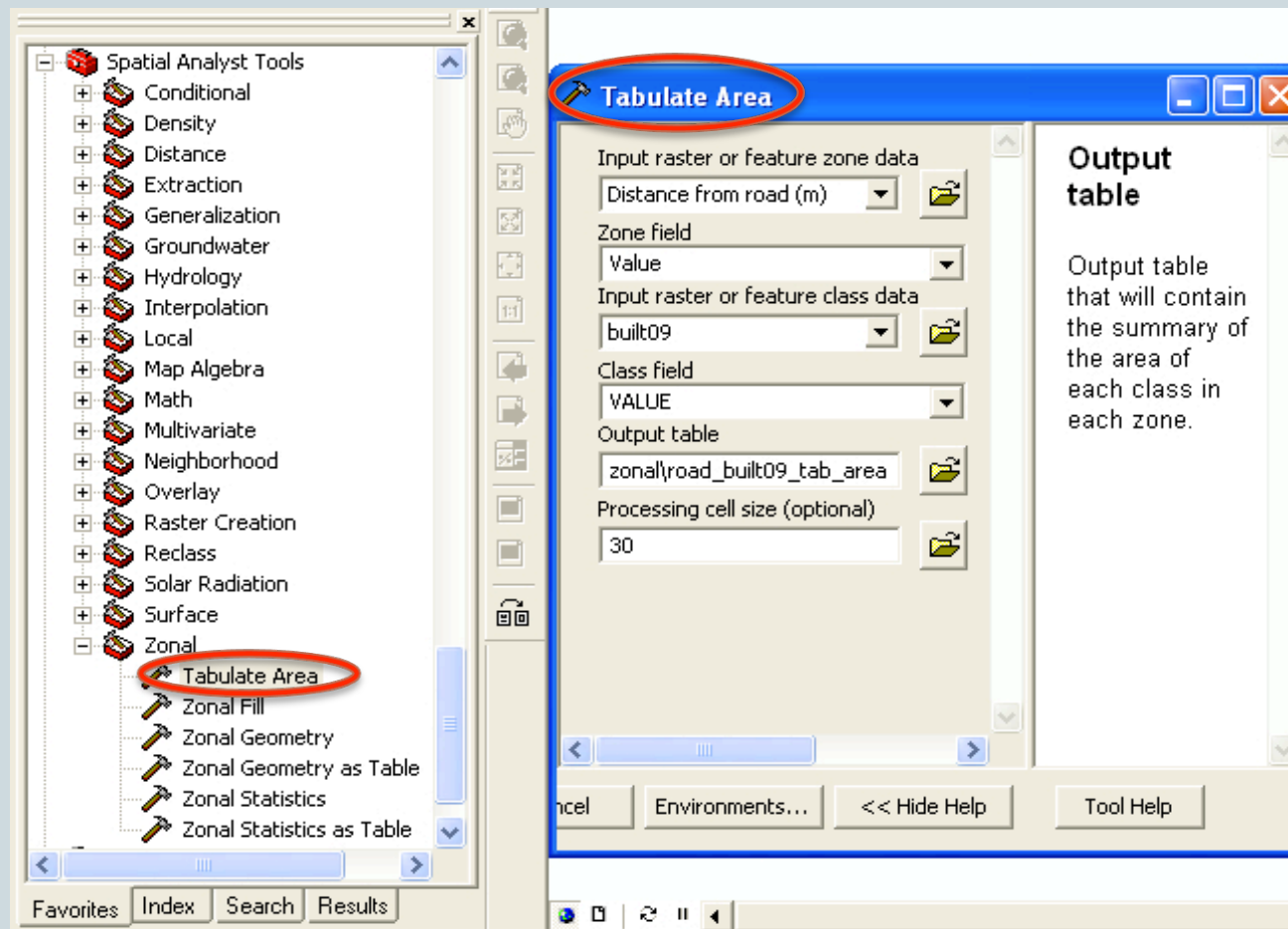
Value raster layer

- Built-up/developed area map
- Class field = VALUE

4. Zonal tool – Tabulate area

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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

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Output – Built-up/developed area and Slope

The screenshot shows the ArcGIS interface with the 'Attributes of slope_built09...' table open. The table contains 33 rows of data. The 'Export Data' dialog is open, showing the export path 'E:\Presentations\TA_zonal\Export_Output_slope_vs_built09.dbf'. The 'Saving Data' dialog is also open, showing the file name 'Export_Output_slope_vs_built09.dbf' and the save type 'dBASE Table'.

Rowid	VALUE	VALUE_1
1	0	308700
2	1	1683900
3	2	4130100
4	3	3898800
5	4	2570400
6	5	1954800
7	6	1377900
8	7	1349100
9	8	1584900
10	9	1465200
11	10	1348200
12	11	1221300
13	12	820800
14	13	812700
15	14	644400
16	15	639000
17	16	524700
18	17	504000
19	18	437400
20	19	302400
21	20	350100
22	21	237600
23	22	250200
24	23	173700
25	24	162900
26	25	165600
27	26	139500
28	27	168300
29	28	88200
30	29	81000
31	30	59400
32	31	54900
33	32	87300

- 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 (m²) of built-up/developed areas.

4. Zonal tool – Tabulate area

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

The screenshot shows the ArcGIS Desktop interface. The main window displays a map with a legend for 'Distance from road (m)' and 'Slope_integer_(degrees)'. The 'Attributes of road_built09...' table is visible, showing columns for Rowid, VALUE, and VALUE_1. The 'Export Data' dialog is open, showing the export path and options. The 'Saving Data' dialog is also open, showing the file name and save type.

Rowid	VALUE	VALUE_1
1	200	16260300
2	400	6379200
3	600	3501000
4	800	1536300
5	1000	1044900
6	1200	597600
7	1400	253800
8	1600	118800
9	1800	113400
10	2000	33300

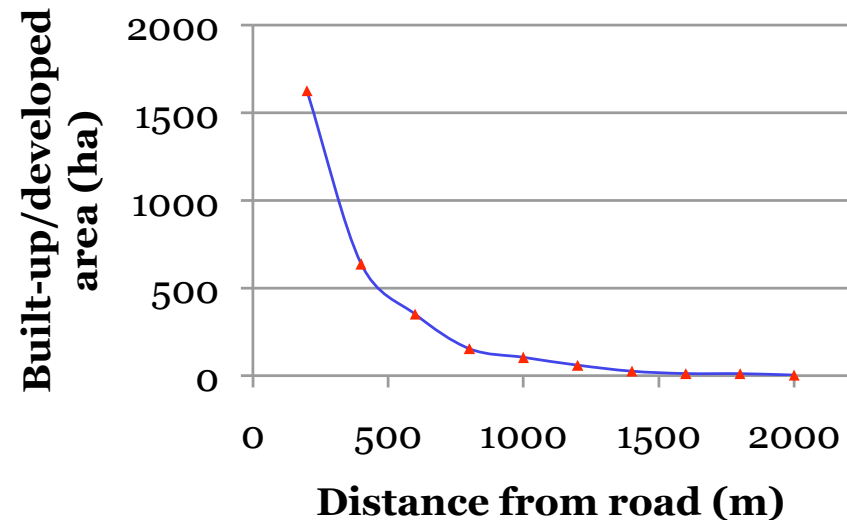
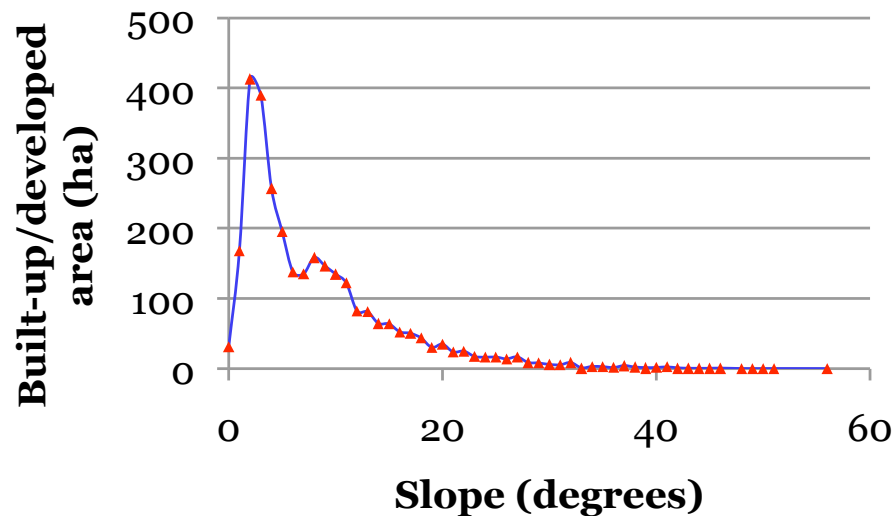
- The result (table) can be accessed from the “Source” window and can be exported and saved as dbf, text file, etc.

- The “VALUE” column contains the distance from road integer values, while the “VALUE_1” column contains the corresponding area (m²) of built-up/developed areas.

4. Zonal tool – Tabulate area

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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.

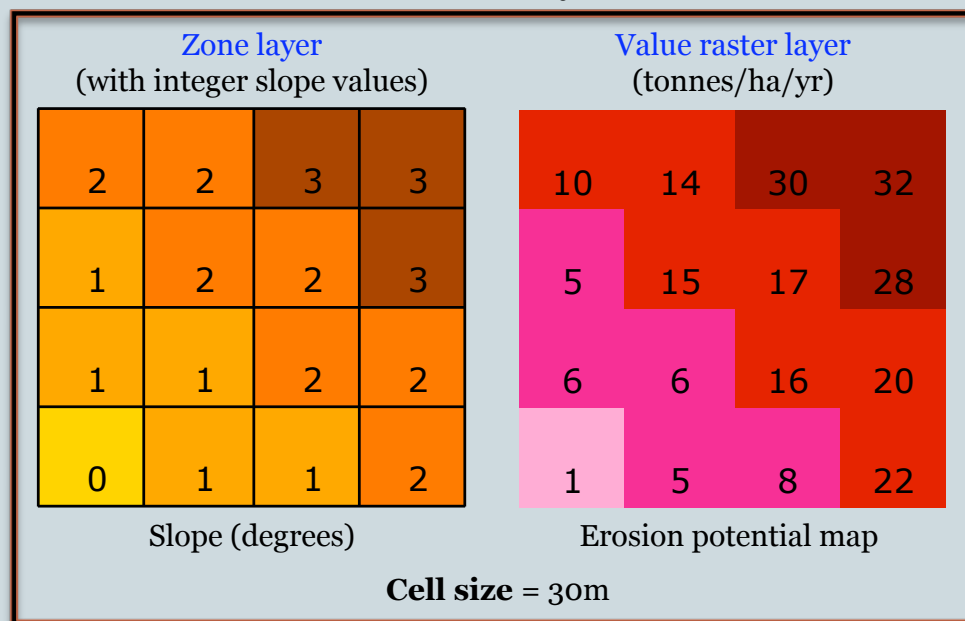
5. Zonal tool – Zonal statistics as table

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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

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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

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Example – List of data inputs

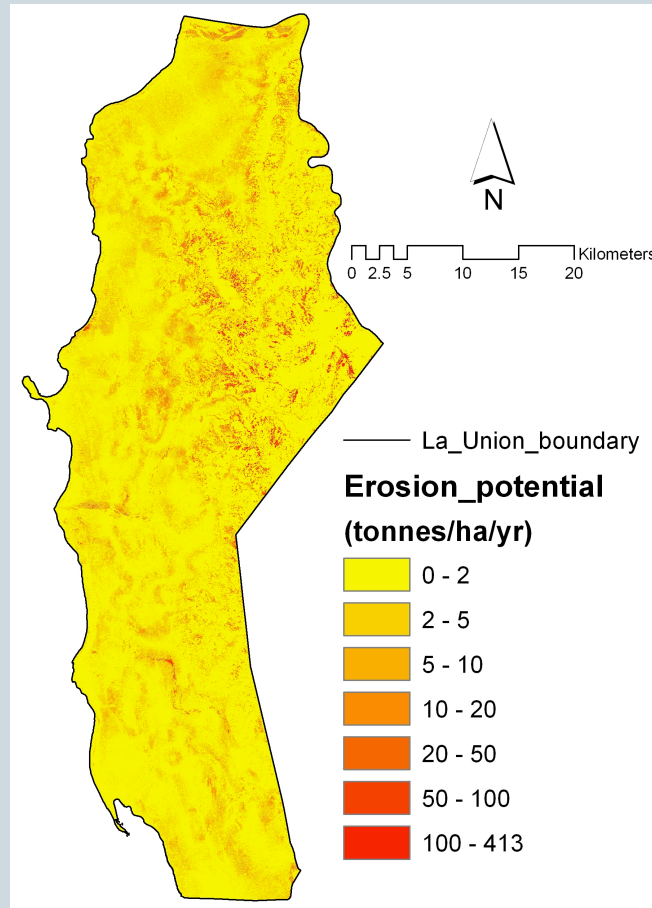
- erosion potential map (**value raster layer**)
 - this erosion potential map was empirically developed following the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997). (Source: [Estoque et al., 2006](#))
- slope map (**raster zone layer**)
 - the slope values, expressed as integers, 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

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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:

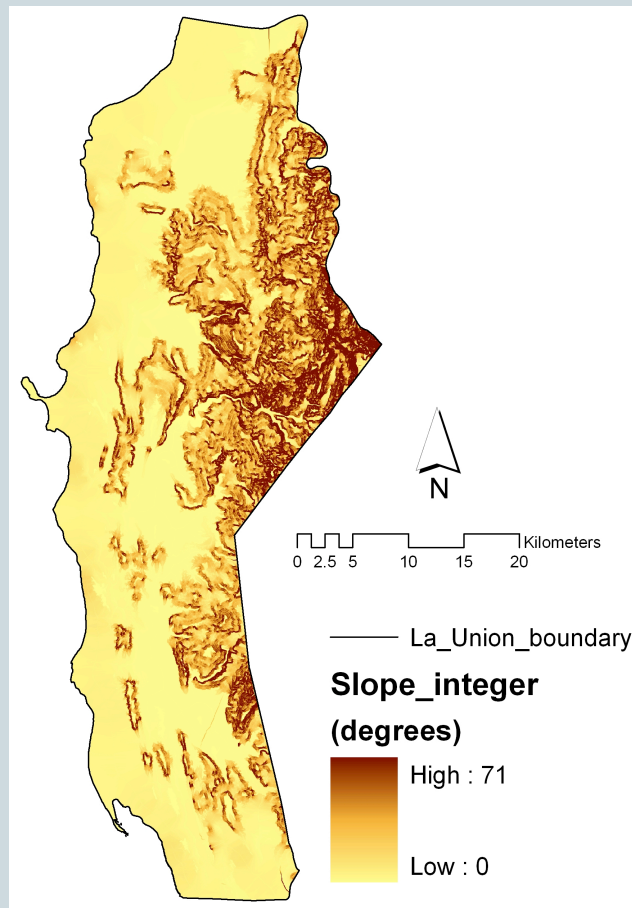
- The column “VALUE” contains the erosion potential rates, while the column “COUNT” contains the number of pixels that correspond to each erosion potential rate.
- The pixel or cell size is 30m.

5. Zonal tool – Zonal statistics as table

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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:

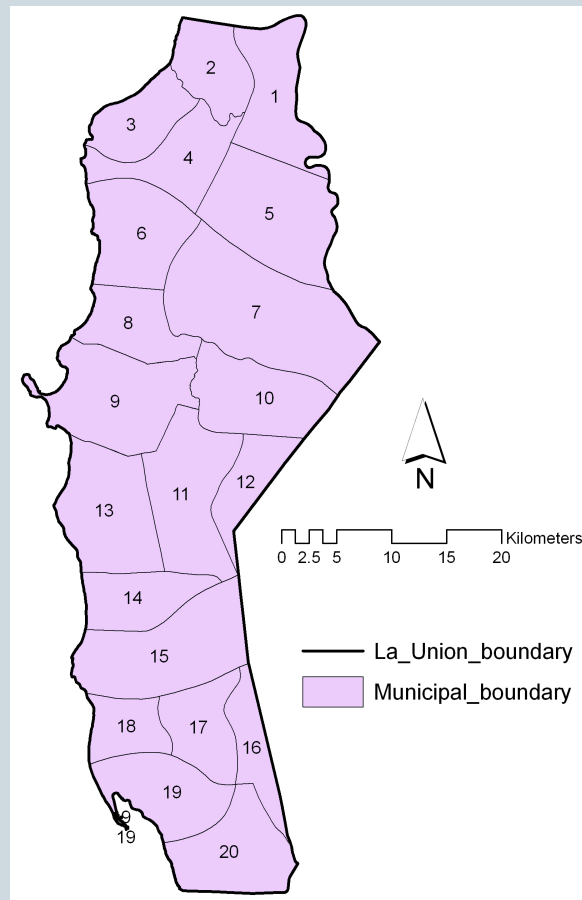
- The “VALUE” column contains the integer slope values, while the “COUNT” column contains the number of pixels that correspond to each integer slope value.
- The pixel or cell size is 30m.

5. Zonal tool – Zonal statistics as table

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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

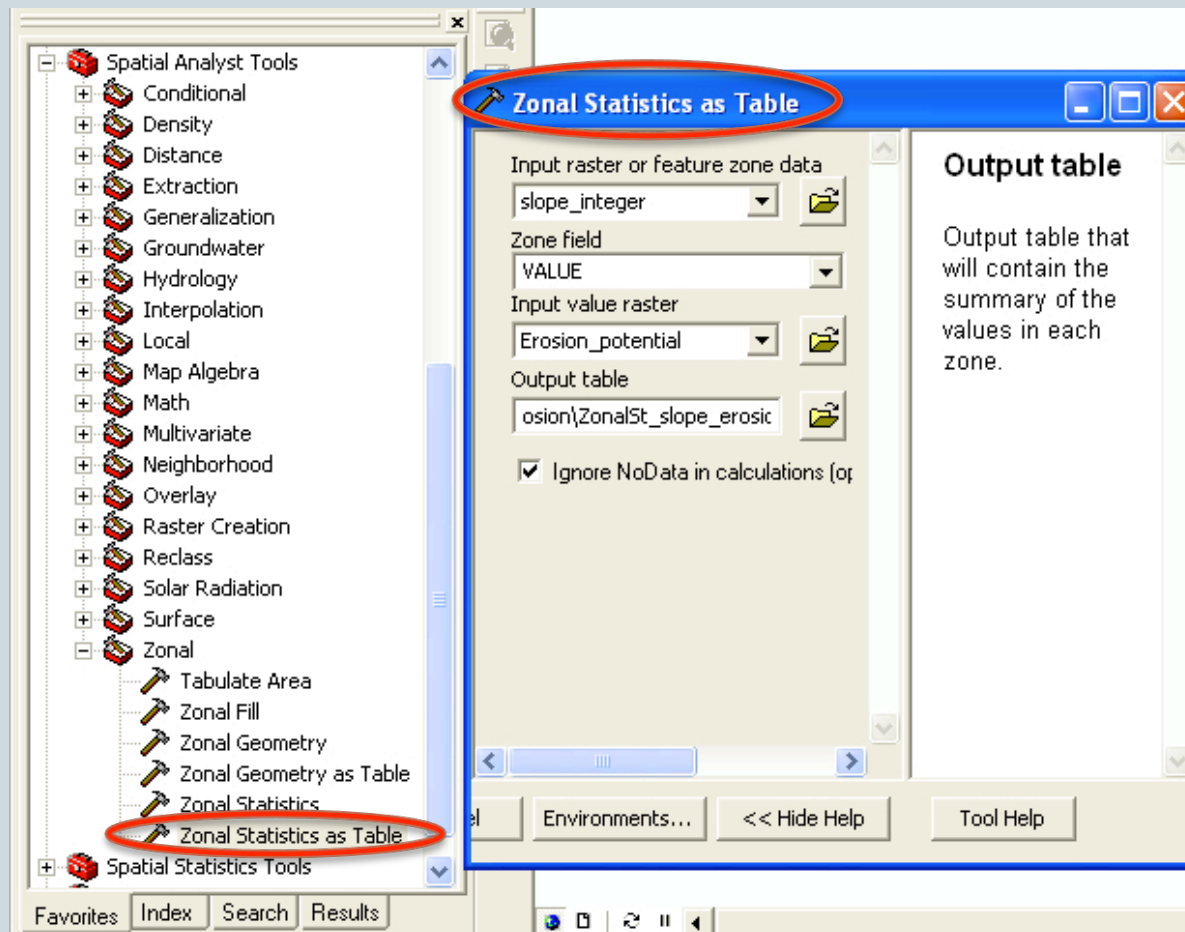
Note:

- 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

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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".

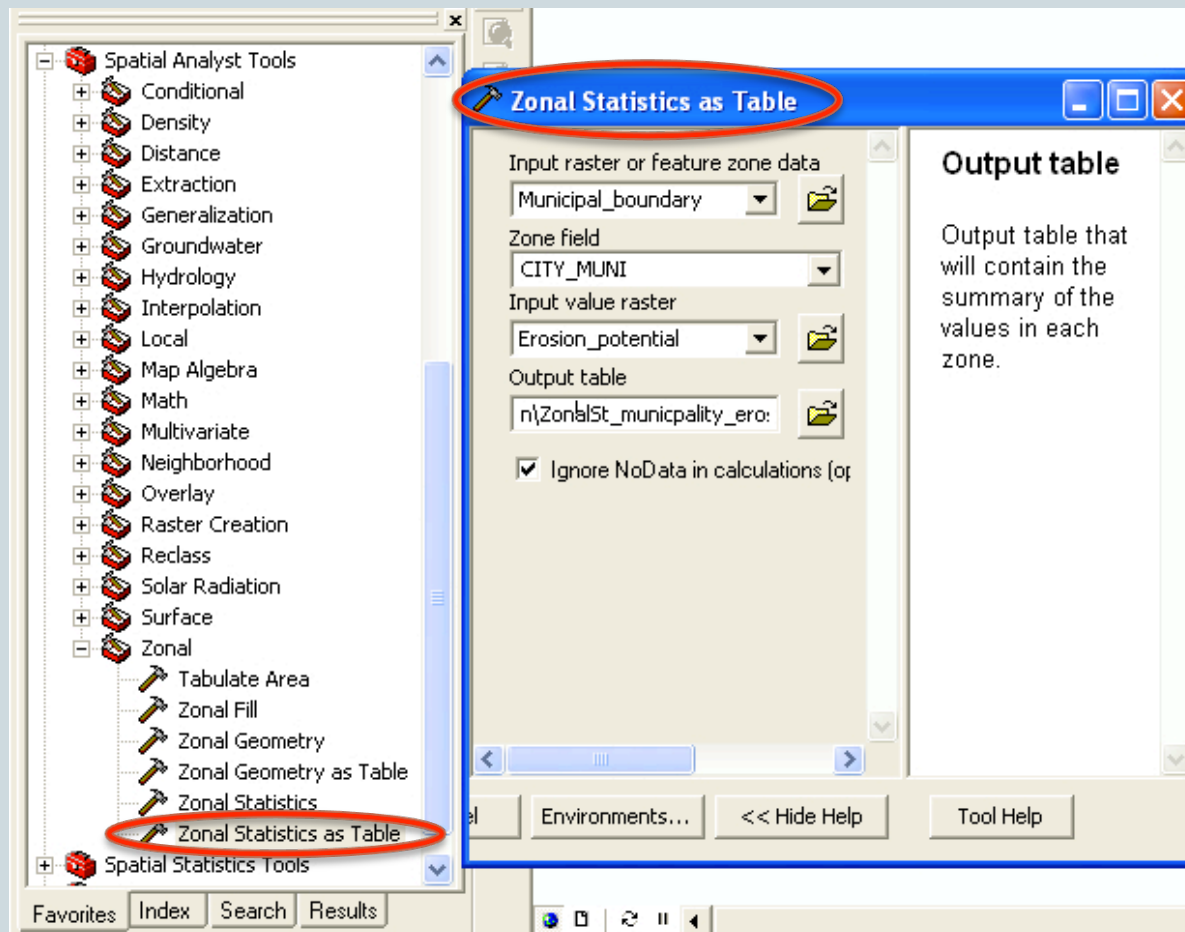
Value raster layer

- Erosion potential map

5. Zonal tool – Zonal statistics as table

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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

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Output – Erosion potential and Slope

The screenshot displays the ArcGIS Desktop interface. The main window shows the 'Attributes of zonalst_slope_vs_erosion' table with the following columns: Rowid, VALUE, COUNT, AREA, MIN, MAX, RANGE, MEAN, and STD. The table contains 32 rows of data. The 'Layers' panel on the left shows the 'Erosion_potential (tonnes/ha/yr)' layer selected, with a legend indicating values from 0 to 413. The 'Export Data' dialog is open, showing 'All records' selected for export. The 'Output table' is set to 'E:\Presentations\TA_zonal\erosion\Export_Output_slope_vs_erosion'. The 'Saving Data' dialog is also open, showing the file name 'Export_Output_slope_vs_erosion.txt' and the 'Text File' format selected.

Rowid	VALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD
1	0	467357	420621310	0	240	240	2.193893	5.7728
2	1	313269	281942110	0	230	230	1.770453	5.1914
3	2	97545	87790496	0	242	242	2.50264	9.7839
4	3	46456	41810400	0	280	280	3.637743	14.7630
5	4	35155	31639500	0	298	298	4.699758	18.0079
6	5	30654	27588600	0	293	293	5.264468	20.3494
7	6	29104	26193600	0	347	347	5.4453	21.4679
8	7	29703	26732700	0	413	413	6.050298	23.1119
9	8	31142	28027800	0	315	315	5.919466	22.9104
10	9	31867	28680300	0	326	326	5.953839	23.4507
11	10	32235	29011500	0	342	342	6.035862	23.2045
12	11	31767	28590300	0	327	327	6.575346	22.2045
13	12	32825	29542500	0	298	298	6.466108	22.2045
14	13	32586	29327400	0	304	304	6.554993	22.2045
15	14	29600	26640000	0	348	348	6.587466	22.2045
16	15	27779	25001100	0	381	381	6.68415	22.2045
17	16	28387	25548300	0	382	382	6.440483	22.2045
18	17	22939	20645100	0	362	362	6.12276	22.2045
19	18	24554	22098600	0	350	350	5.802639	22.2045
20	19	22192	19972800	0	341	341	5.955029	22.2045
21	20	16090	14481000	0	344	344	5.292915	22.2045
22	21	19216	17294400	0	331	331	5.884211	22.2045
23	22	15560	14004000	0	340	340	5.901671	22.2045
24	23	17742	15967800	0	359	359	5.45288	22.2045
25	24	10996	9896400	0	346	346	5.658967	22.2045
26	25	9720	8748000	0	296	296	4.821708	22.2045
27	26	11262	10135800	0	338	338	5.211153	22.2045
28	27	8193	7373700	0	297	297	5.30343	22.2045
29	28	13479	12131100	0	303	303	5.490022	22.2045
30	29	7815	7033500	0	283	283	5.515291	22.2045
31	30	7075	6367500	0	283	283	6.439011	22.2045
32	31	3774	3396600	0	299	299	5.711447	22.2045

• 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 m².

5. Zonal tool – Zonal statistics as table

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Output – Erosion potential and Municipality

The screenshot displays the ArcGIS Desktop interface. The main window shows the 'Attributes of zonalst_municipality_vs_erosion' table with 20 rows of data. The 'Layers' panel on the left shows the 'Erosion_potential' layer selected. The 'Export Data' dialog box is open, showing the 'Export' tab with 'All records' selected. The 'Output table' is set to 'ntations\TA_zonal\erosion\Export_Output_municipality_vs_erosion.txt'. The 'Saving Data' dialog box is also open, showing the 'Look in' folder 'erosion' and the 'Name' 'Export_Output_municipality_vs_erosion.txt'. The 'Save as type' is set to 'Text File'.

Rowid	CITY_MUNI	ZONE-CODE	COUIT	AREA	MIN	MAX	RANGE	MEAN	STD
1	SUDIPEN	1	77614	69852600	0	276	276	3.535097	12.133
2	BANGAR	2	54005	48604500	0	93	93	2.799648	5.418
3	LUNA	3	52773	47495700	0	77	77	1.750422	2.400
4	BALAOAN	4	65344	58809600	0	227	227	2.284158	6.293
5	SANTOL	5	116835	105151500	0	252	252	5.21628	19.383
6	BACNOTAN	6	83057	74751296	0	209	209	2.171737	6.464
7	SAN GABRIEL	7	176394	158754590	0	382	382	9.623263	33.185
8	SAN JUAN	8	56508	50857200	0	155	155	2.281394	5.525
9	SAN FERNANDO	9	110549	99494096	0	167	167	2.026396	5.437
10	BAGULIN	10	84470	76023000	0	413	413	8.841707	31.802
11	NAGUILIAN	11	101832	91648800	0	273	273	2.523784	11.161
12	BURGOS	12	42368	38131200	0	346	346	8.836197	31.161
13	BAUJANG	13	97546	87791400	0	153	153	1.893548	6.464
14	CABA	14	54732	49258800	0	143	143	1.639096	5.418
15	ARINGAY	15	118039	106235100	0	239	239	2.261829	9.161
16	PUGO	16	39736	35762400	0	160	160	1.355924	5.418
17	TUBAO	17	55144	49629600	0	141	141	1.836592	6.464
18	AGOO	18	39288	35359200	0	95	95	1.277286	4.000
19	SANTO TOMAS	19	72908	65617200	0	137	137	1.228109	5.418
20	ROSARIO	20	81320	73188000	0	99	99	1.587654	6.464

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

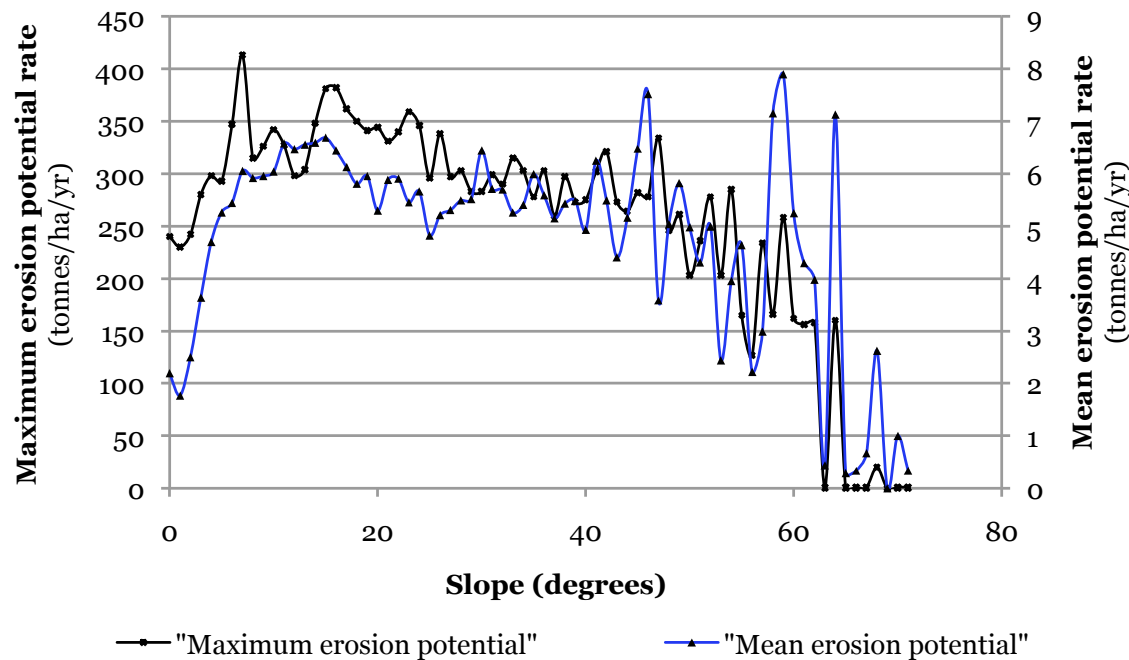
• The “MAX” and “MEAN” columns contain the maximum & mean erosion potential rates, respectively, for each integer slope value.

• The unit of the “AREA” in the attribute table is m².

5. Zonal tool – Zonal statistics as table

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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

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- 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.

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