

GEOG 204

LECTURE 4
Spatial Analysis

1

Spatial Analysis

- In a GIS,
 - Data are usually grouped into layers (or themes).
 - The analysis functions of a GIS use both spatial and non-spatial data
 - Analysis functions are used
 - for maintenance of the data
 - Computing new information from the data
- Spatial Analysis can be viewed as:
 - Operations that use spatial data to derive new spatial information.
 - The most distinguishing purpose of a GIS

2

2

Topology

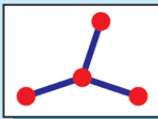
- Topology: The spatial relationships between adjacent or neighboring features.
 - Based on 3 basic elements, Adjacency, Containment and Connectivity
 - Allows analyses like as contiguity, containment, connectivity, overlap...
 - For example, it is used in routing through linear networks. Routes cannot be established through the network if the line features do not share nodes/vertices.

3

3

Topology

Line features can share endpoints



arc-node topology

Area features can overlap with other area features



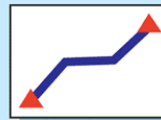
region topology

Area features can share boundaries



polygon topology

Line features can share endpoint vertices with point features



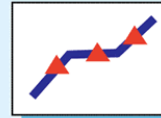
node topology

Line features can share segments with other line features



route topology

Point features can share vertices with line features



point events

Source: ESRI

4

4

Topological Relationships: Areas of Usage

Poly ID	Arcs		
	Arc ID	L-poly	R-poly
001	a	001	002
002	b	001	004
003	c	001	003
004	d	003	004
005	...		
006	...		

- Data input and representation
 - Identify and store adjacency, connectivity & containment information
 - field data collection, digitizing
 - E.g. Left/Right of polygon or line

Lo and Yeung (2006) Concepts and Techniques of Geographic Information Systems, Prentice Hall

5

Topological Relationships: Areas of Usage

Arc ID	From_node	To_node	Left_Poly	Right_Poly
...				
a			14	4
b			14	5
c			14	6
d			13	14
...				

- Spatial Search by Topological Relationships
 - Find features by adjacency, containment and connectivity

Lo and Yeung (2006) Concepts and Techniques of Geographic Information Systems, Prentice Hall

6

Topological Relationships: Areas of Usage

Arc ID	From_node	To_node	Left_Poly	Right_Poly
1	a	a	B	C
2	b	b	A	B

- Construction of Complex Spatial Relationships
 - E.g. Holes on polygons
 - Multipart polygons

Lo and Yeung (2006) Concepts and Techniques of Geographic Information Systems, Prentice Hall 7

7

Topological Relationships: Areas of Usage

Common network topological errors	Common polygon topological errors
● Floating node	Weirid polygon
Dangling arcs (not all dangling arcs are errors)	Sliver polygon
Floating arc	Missing label
Overlapping arc	Overlapping polygons

- Integrity checks and balances
 - Essentially the removal topological errors
 - E.g. No dangling arcs or overlapping polygons

Lo and Yeung (2006) Concepts and Techniques of Geographic Information Systems, Prentice Hall 8

8

Data Representation and Analysis

- Vector and Raster data models are ideally suited for solving different problems
 - Raster Model: phenomena that exhibit spatial variability
 - Temperature, topography
 - Environmental aspects at a regional or national scale
 - Habitat, biodiversity analysis

9

9

Data Representation and Analysis

- Vector and Raster data models are ideally suited for solving different problems
 - Vector Model: phenomena necessitates the need for location and individuality of spatial objects
 - Land title management, transportation management and planning, facilities management
 - Environmental aspects at a local scale (as opposed to a regional or national scale)

10

10

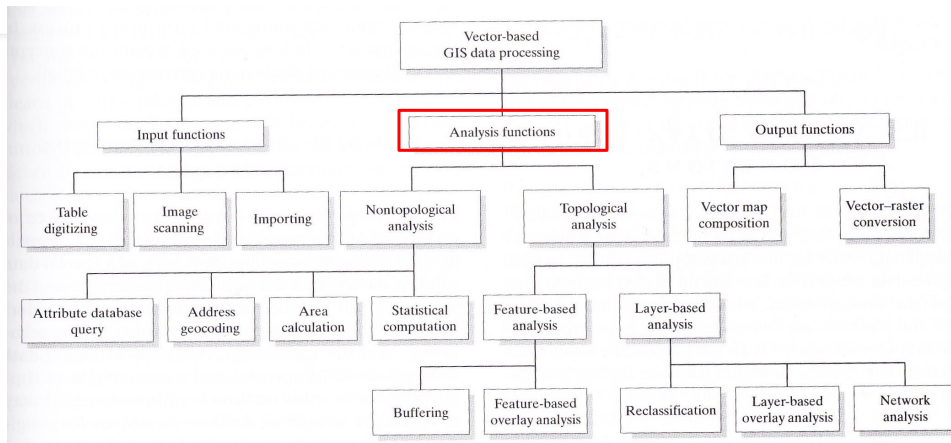
Spatial Analysis

- Analysis occurs using either:
 - **Spatial location** e.g. wetlands near a pipeline; houses within 5km
 - Distinguishes GIS from a non-spatial analysis
 - **Data attributes** e.g. wetlands with black spruce; houses in a given price range
 - Distinguishes GIS from 'non-GIS' mapping software
 - **Comparative spatial statistics**
 - e.g. the correlation of variables across space
 - e.g. wetlands clustered at local scale, uniform at regional scale
 - Statistical Spatial Data Analysis with ArcGIS, QGIS,....

11

11

Spatial Analysis



Source: C.P. Lo, A.K.W. Yeung (2007) Concepts and Techniques of Geographic Information Systems

12

12

Spatial Analysis

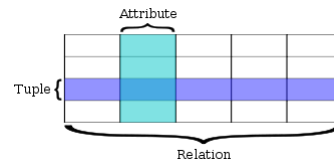
- Analysis functions
 - Non-topological functions
 - Attribute values of spatial data
 - Topological functions
 - Individual data objects
 - Feature-based
 - individual data objects
 - Layer-based
 - all objects in a layer

13

13

Nontopological Analysis

- SQL: Structured Query Language
- Goal: select only the features with (or without) particular values
- Relational table



PSME Chronologies																			
FID	Shape	Name	Code	Author	Northing	Easting	MedSer	CuDef	FIRE_YEAR	FIRE_CAUSE	SIZE_HA	MAT_1991_9	MAP_01_90	Mean_dsr	SS	Ts_count	Elevation		
9	Point ZM	Fuzzy	FUZ	Neil Thompson					1940	Person	8209.2	23	467	0	0	0	1008	NT	
10	Point ZM	Tala Lake	TL	Jodi Axelsson					1961	Person	2828.3	23	429	11	4	2	0	JA	
11	Point ZM	Bull Canyon	BC	Jodi Axelsson					2010	Person	177.2	39	325	8	7	2	174	JA	
12	Point ZM	Bull Canyon	BCA	Neil Thompson					2010	Person	177.2	39	325	0	0	0	0	935	NT
13	Point ZM	Alexis North	ALE	Neil Thompson					2010	Lightning	11638.6	30	334	0	0	0	0	959	NT
14	Point ZM	CM	CM	Jodi Axelsson					0	0	41	342	9	4	1	1050	JA		
15	Point ZM	Big Bar	BIG	Neil Thompson					0	0	31	430	0	0	0	0	1261	NT	
16	Point ZM	ML	ML	Jodi Axelsson					0	0	26	429	9	7	2	1207	JA		
17	Point ZM	Dog Creek Bluffs	DCB	Neil Thompson					0	0	46	432	0	0	0	0	1847	NT	
18	Point ZM	Epicenter South	EP	Neil Thompson					0	0	26	474	0	0	0	0	1262	NT	
19	Point ZM	Snag Lake	SS	Lori Daniels					0	0	33	490	7	5	1	1093	LD		
20	Point ZM	Judy TK	JKY	Neil Thompson					0	0	29	520	0	0	0	0	1136	NT	
21	Point ZM	Canden Lake	CAM	Neil Thompson					0	0	33	486	0	0	0	0	1087	NT	
22	Point ZM	Chimney Lake D	CD	Lori Daniels					0	0	33	563	9	3	1	992	LD		
23	Point ZM	Hayfield Bluffs	HAB	Neil Thompson					0	0	37	452	0	0	0	0	945	NT	
24	Point ZM	Chimney Lake	CHI	Neil Thompson					0	0	38	494	0	0	0	0	906	NT	
25	Point ZM	Lee's Corner	LEE	Neil Thompson					0	0	33	375	0	0	0	0	1031	NT	
26	Point ZM	Hancock North	HAN	Neil Thompson					0	0	17	459	0	0	0	0	1329	NT	
27	Point ZM	Riske Creek	RS	Neil Thompson					0	0	21	464	0	0	0	0	1259	NT	
28	Point ZM	FR	FR	Jodi Axelsson					0	0	47	417	11	9	2	1586	JA		
29	Point ZM	Enterprise Bluffs	ENT	Neil Thompson					0	0	35	473	0	0	0	0	910	NT	
30	Point ZM	Lee's Corner North	LEN	Neil Thompson					0	0	17	431	0	0	0	0	1268	NT	
31	Point ZM	Boon Lake	BO	Jodi Axelsson					0	0	26	321	0	0	0	0	1092	NT	

14

Nontopological Analysis

- Attribute Database Query Operations

- **SELECT:** Extract data items in specified rows of a table

SELECT <attribute_name> FROM <table> WHERE <condition_statement>

- **JOIN (RELATIONAL JOIN):** Merges two tables based on the values in the columns of the tables

*[a select statement] <table_1> JOIN <table_2> ON table_1.attribute= table_2.attribute
[a condition statement]*

15

15

Nontopological Analysis

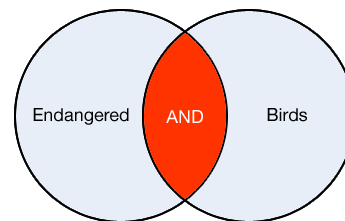
- **Boolean Logic** (after George Boole, a 19th century mathematician)

- "Create an expression reducible to a true or false condition".

- **SQL can use:**

- **Boolean Operators**

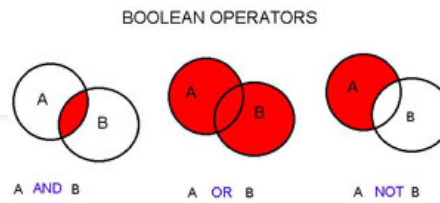
- **And** (narrows the selection)
- **Or** (expands the selection)
- **Not** (excludes/reduces results)
- **XOR** (A or B, but not both)
- **Like (Similarity)**
 - **% is wildcard**



- Relational Operators (=, >, <, >=, <=)
- Arithmetic Operators (+, -, *, /)

16

Boolean Operators (to combine conditions)



Selection by attribute

type = pine AND age > 100 ... selects all old growth pine

type = pine OR age > 100 selects all pine and any type older than 100

These may require the use of brackets to avoid ambiguity in complex queries e.g.

type = pine OR type = fir AND age > 100 selects any pine plus old growth fir

type = (pine OR type = fir) AND age > 100 selects old growth (pine and fir)

17

Nontopological Analysis

- Statistical Computation
 - Extension of attribute data query
 - Conventional statistical measures such as:
 - mean, maximum, minimum, range, standard deviation, frequency
 - Note: These are aspatial (non-spatial) statistics
 - Note: Can't do statistics on text field

18

18

Nontopological Analysis

- Spatial Calculation
 - Spatial calculation of position, area, perimeter, distance, proximity
 - Algorithms are well known
 - An intermediate step to obtain new attribute data to support specific spatial analyses
 - Be sure that data are preprocessed
 - projection, coordinate transformation, measurement unit conversion

19

19

The screenshot displays two windows from ArcGIS. On the left, the Field Calculator window is open, showing a list of fields with 'Cause_CD' selected. The expression 'Cause_CD = 1' is entered in the text box. On the right, the Statistics window is open, showing a summary of values for the 'Cause_CD' field. The statistics are as follows:

Field	Statistics
Cause_CD	Count: 33 Minimum: 0 Maximum: 1 Sum: 24 Mean: 0.727273 Standard Deviation: 0.445362 Nulls: 0

Statistics and the Field Calculator

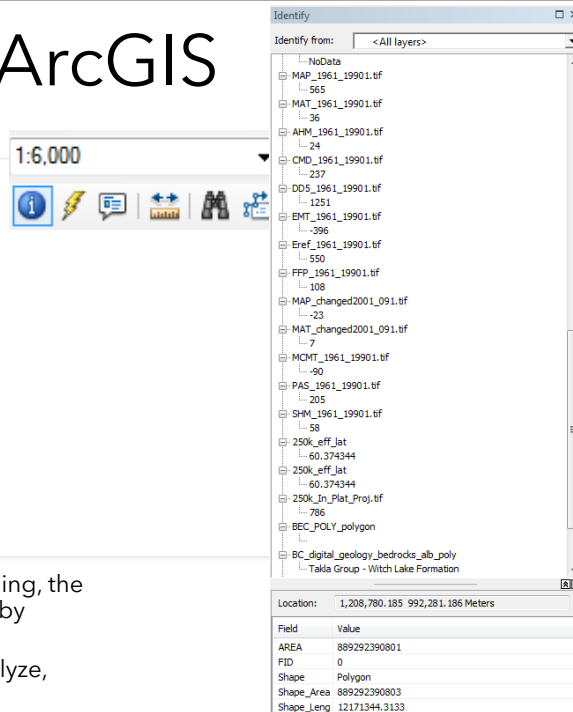
20

20

Selection in ArcGIS

- Manual selection
- By Location
- By Attributes
- Show attributes from
 - All layers
 - Selected layer
 - Visible layers
 - Top-most layer

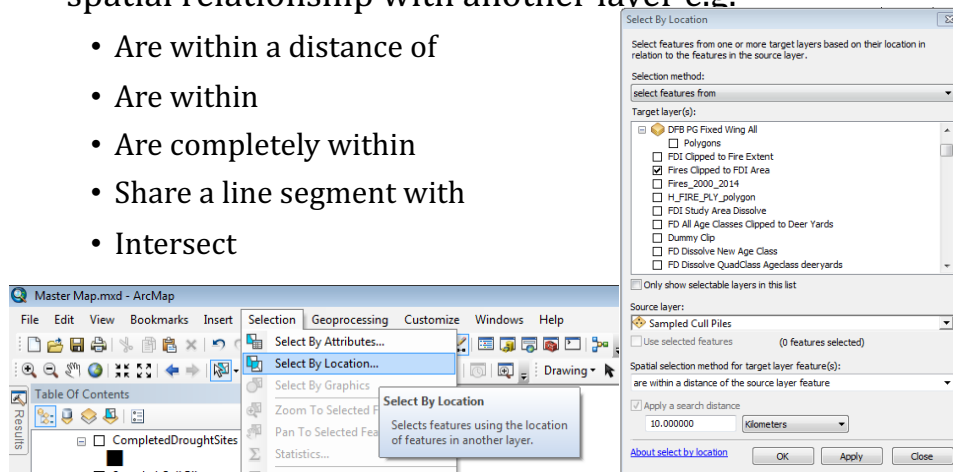
Once you have selected something, the selection will be all ArcGIS sees by default.
CAUTION when you export, analyze, compare



21

Select by Location

- Selects features from one data set based on their spatial relationship with another layer e.g.
 - Are within a distance of
 - Are within
 - Are completely within
 - Share a line segment with
 - Intersect

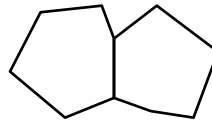


22

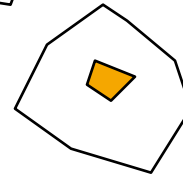
Topological Functions

- Topology: spatial relationship between entities

- Adjacency (polygons)



- Containment (e.g. points in polygons)



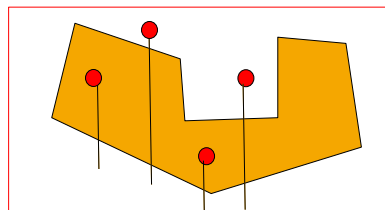
- Connectivity (lines)



23

Topological Functions

- Feature-Based Analysis: Find relationships between features of one layer and those of another
 - Common functions: Point in polygon, adjacency, connectivity, buffering
 - Point in polygon matching: whether a given point feature falls inside a polygon

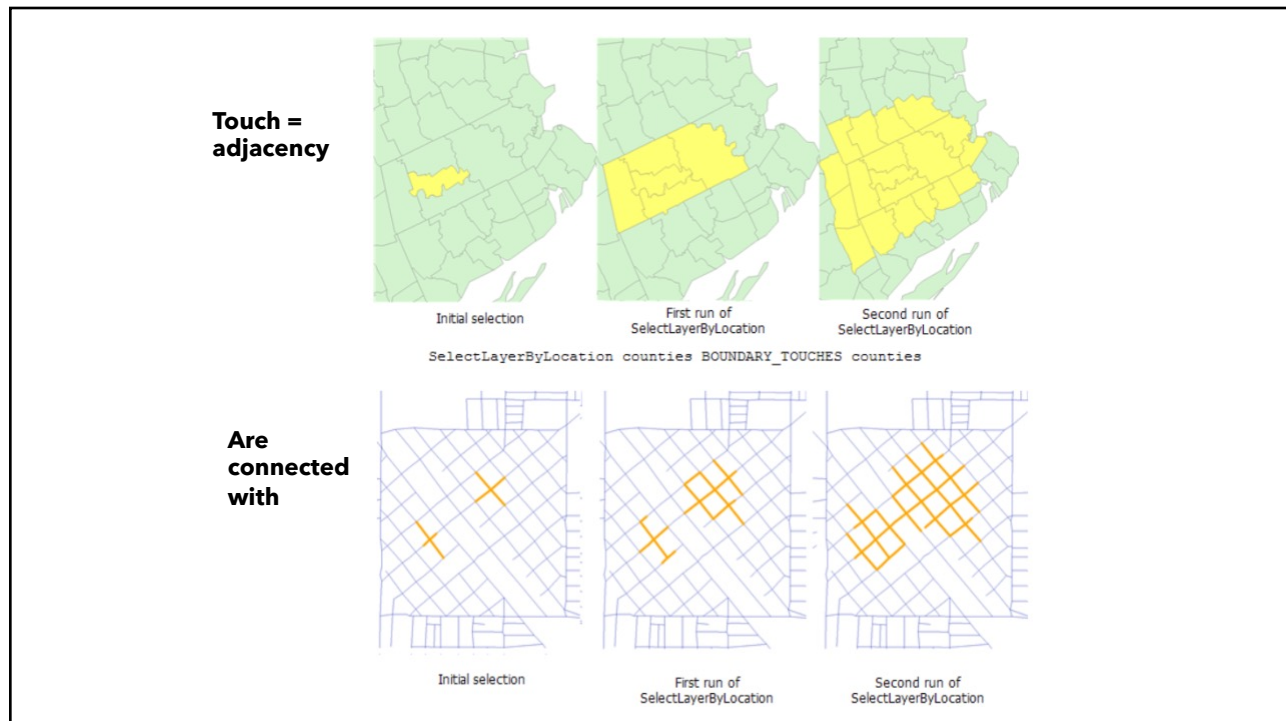


Plumb-line algorithm

Odd number of intersections: **In**
 Even number of intersections: **Out**

24

24



25

Topological Functions

- Buffering
 - A buffer is a zone covering a specified distance around a spatial feature
 - Buffer zones are polygons.
 - Buffer distance is usually user defined
 - Boundaries of overlapping buffer zones are automatically dissolved to give a single coherent buffer polygon

26

26

Useful when evaluating charactering of an area surrounding a feature.

- properties/population with walking distance of a bus stop
- delineation of restricted zones around sensitive sites

Source: C.P. Lo, A.K.W. Yeung (2007) Concepts and Techniques of Geographic Information Systems

27

Applications of BUFFER

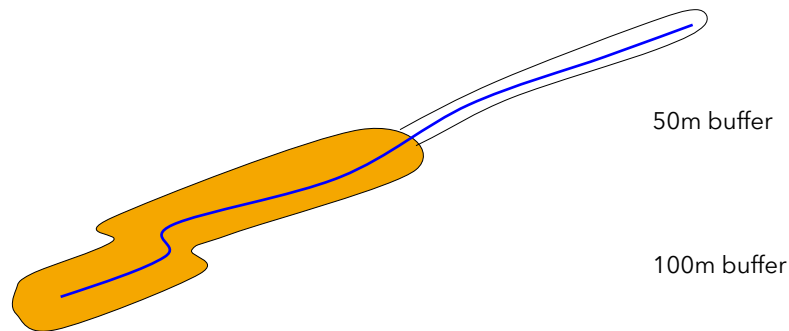
Which parcels are within 60m of the road?

For example: consideration of widening of existing roadway, to identify parcels affected by underground utility line additions, etc.

28

Topological Functions

- *Variable buffer distances* (assigned by attribute)
 - Different buffer size depending on stream attribute
 - e.g. stream protection status



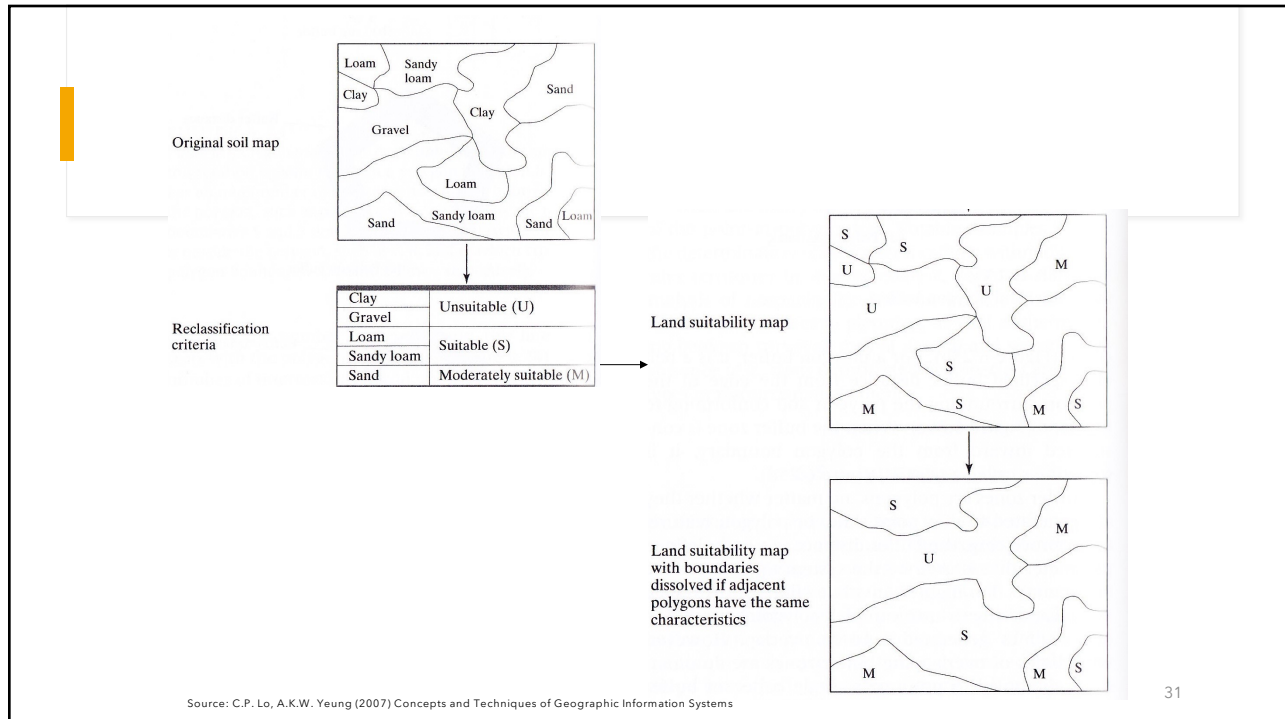
29

Topological Functions

- Reclassification
 - Database simplification process
 - reduces (modifies) the categories in attribute data
 - Two step process
 - Nontopological: select attribute e.g. a range of values and assign them a new class
 - Topological: dissolve according to new classification scheme

30

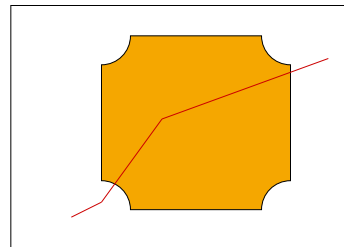
30



31

The Concept of GIS Overlay

- Overlay addresses the relationship of the overlap between spatial features.
- Overlay **combines** the spatial *and* attribute data of two input themes.



Three input feature types, overlay cover is always polygon:

- 1) point-in-polygon, \longrightarrow points are output
- 2) line-in-polygon, \longrightarrow lines are output
- 3) polygon-in-polygon \longrightarrow polygons are output

32

Line Feature Types and Map Overlay

• **Line - in - Polygon**

↑ ↑
 Input Overlay
 Theme Theme

Two new intersections

- Attach attributes of polygon to line that traverses through polygon
- Example - What types of soils does a proposed road cross?
- Line is actually broken into different line segments at polygon boundaries. Each line segment takes on attributes for the polygon it overlays.

33

Example: Spatial Matching via *Polygon-on-Polygon Overlay*

Land Use

Drainage Basins

Combined layer

The two themes (land use & drainage basins) do not have common boundaries. GIS creates combined layer permitting calculation of land use by drainage basin.

34

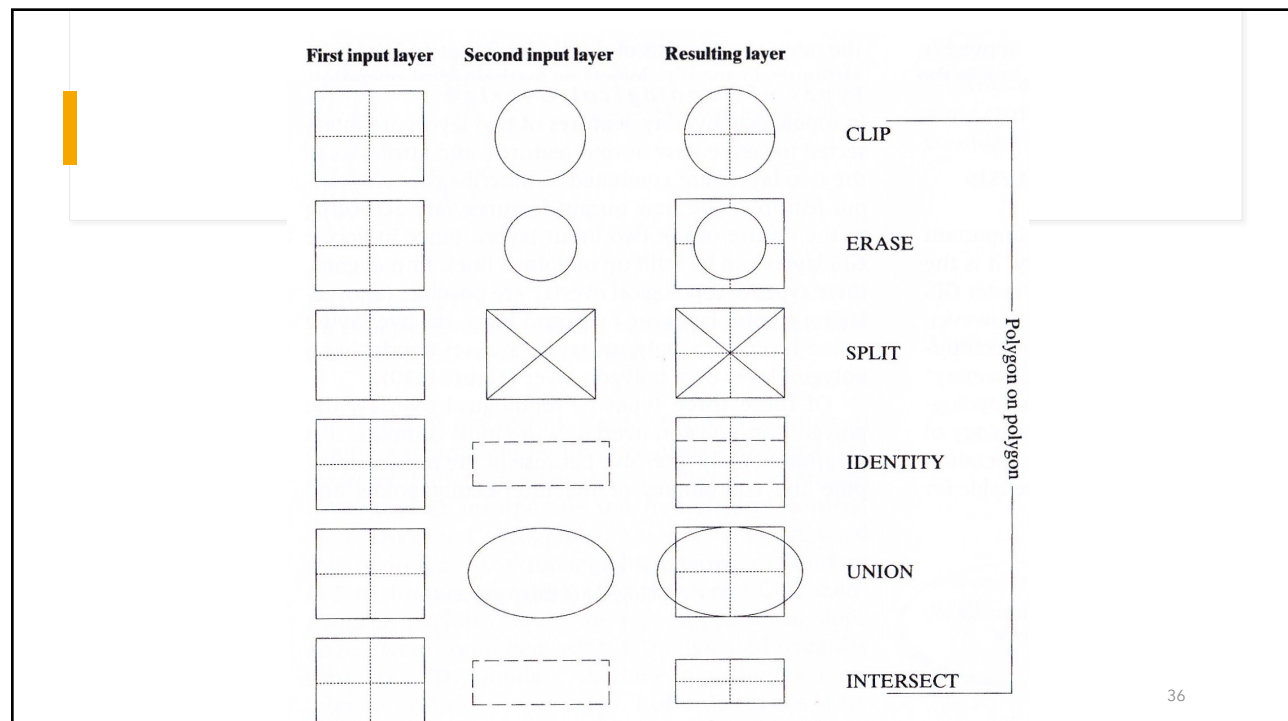
Topological Functions

• Topological Overlay Operators

- UNION: Overlays polygons and keeps all areas in both layers. Never clips data
- INTERSECT: Keeps portions of the first input layer that fall within the second input layer
- IDENTITY: Overlays polygons and keeps all input features. The input features that overlap identity features will get the attributes of the identity features.
- CLIP: Cuts out the first input layer using the second input layer as a cookie cutter
- ERASE: Erases part of the first input layer using the second input layer
- SPLIT: Divide the polygons in the first input layer into a number of smaller polygons based on the second input layer

35

35



36

36