Building Models

- Thinking spatially is **not intuitive**
  - First step: **recognizing the spatial components** of a problem
    - Often best to **envision the desired outcome** first
      - The **spatial information product (SIP)** (Marble 1994)
      - Problem dissection
  - All problems are **unique**
  - All problems have **some basic similarities** as well

Problem Guidelines

- A cartographic SIP is **composed** of simpler, more elemental, intermediate SIPs
- Intermediate SIPs **are often models themselves** that eventually break down to **elements**
- The elements can be **GRIDs** (whole thematic maps), **GRID subsets** (e.g. particular extents), **numerical values**, or **variables**
- Elements are **connected** (functionally) by **operators**
- Some elements will be **used more than once**
- **GIS models** are models; they **require** verification, validation, decision justification, and refinement

Preparing Our Geographic Filter

- **Identification** of pattern
  - Finding and tagging
    - e.g. identifying streams in a DEM
    - **Assumes you know** there is something there to identify

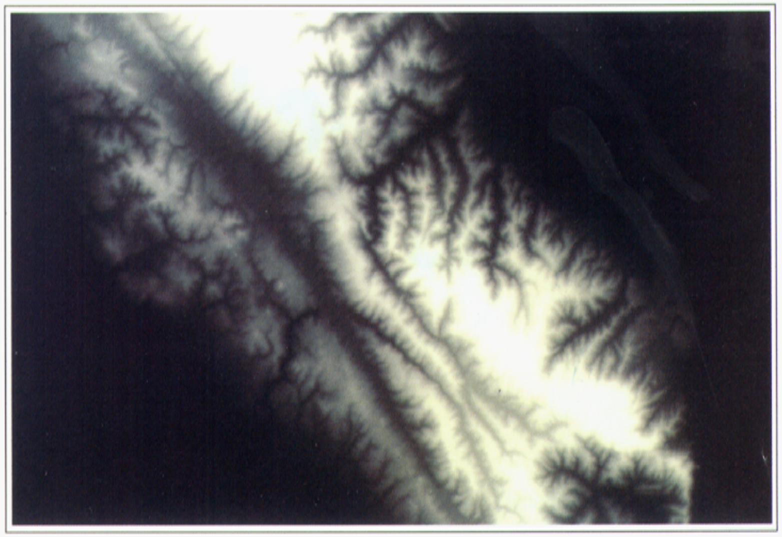


Figure 28. Digital elevation model of San Mateo County, CA.

- **Recognition** of pattern
  - More to the point here
  - First step in **explaining and exploiting** them for model building
    - » Much like the **first step in the scientific method** (observation)

Spatial Patterns

- **First step** in a project development
- **Recognize** patterns
  - **Visible patterns** in the landscape
    - Visible through **overlays**
  - **Functional patterns** (not immediate visible)
    - Pattern is functionally **observable through time**
    - Pattern **can be extracted** through complex methods
- **Places to find pattern**: From direct observation, remote sensing images, and maps

Visible Patterns - Random

Result of seed or propagule dissemination

Visible Patterns - Clustered

Clustered Patterns

Visible Patterns - Uniform

Human intervention

Visible Patterns – Alluvial Fan

Geomorphologists see a **particular land form** distribution:

Alluvial fan resulted from **sedimentation**

Visible Patterns - Aeolian

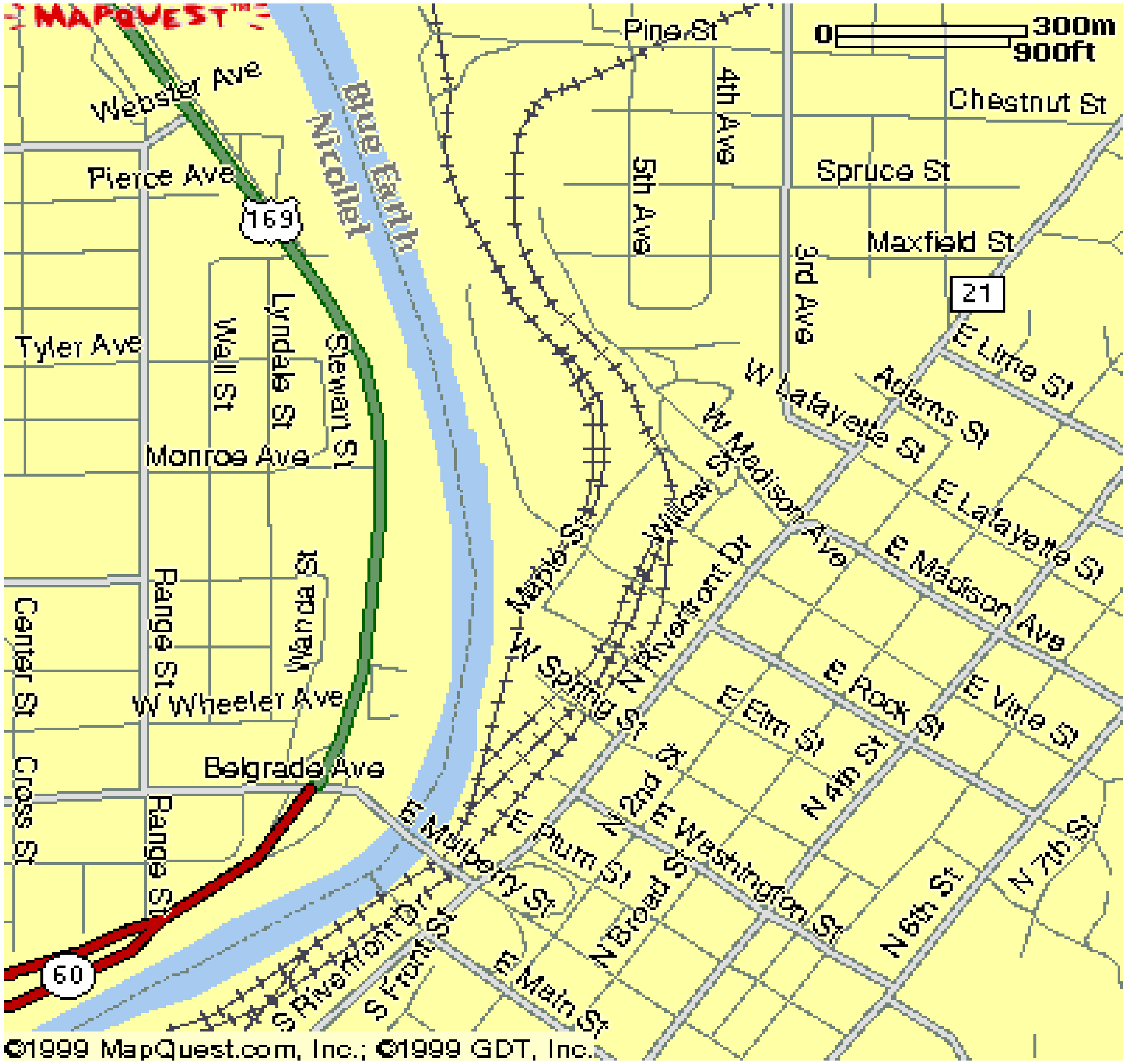
Aeolian Patterns

Visible Patterns – Urban

A **typical** urban pattern is a function of **several factors**:

- Topography
- Hydrology
- Historical land divisions

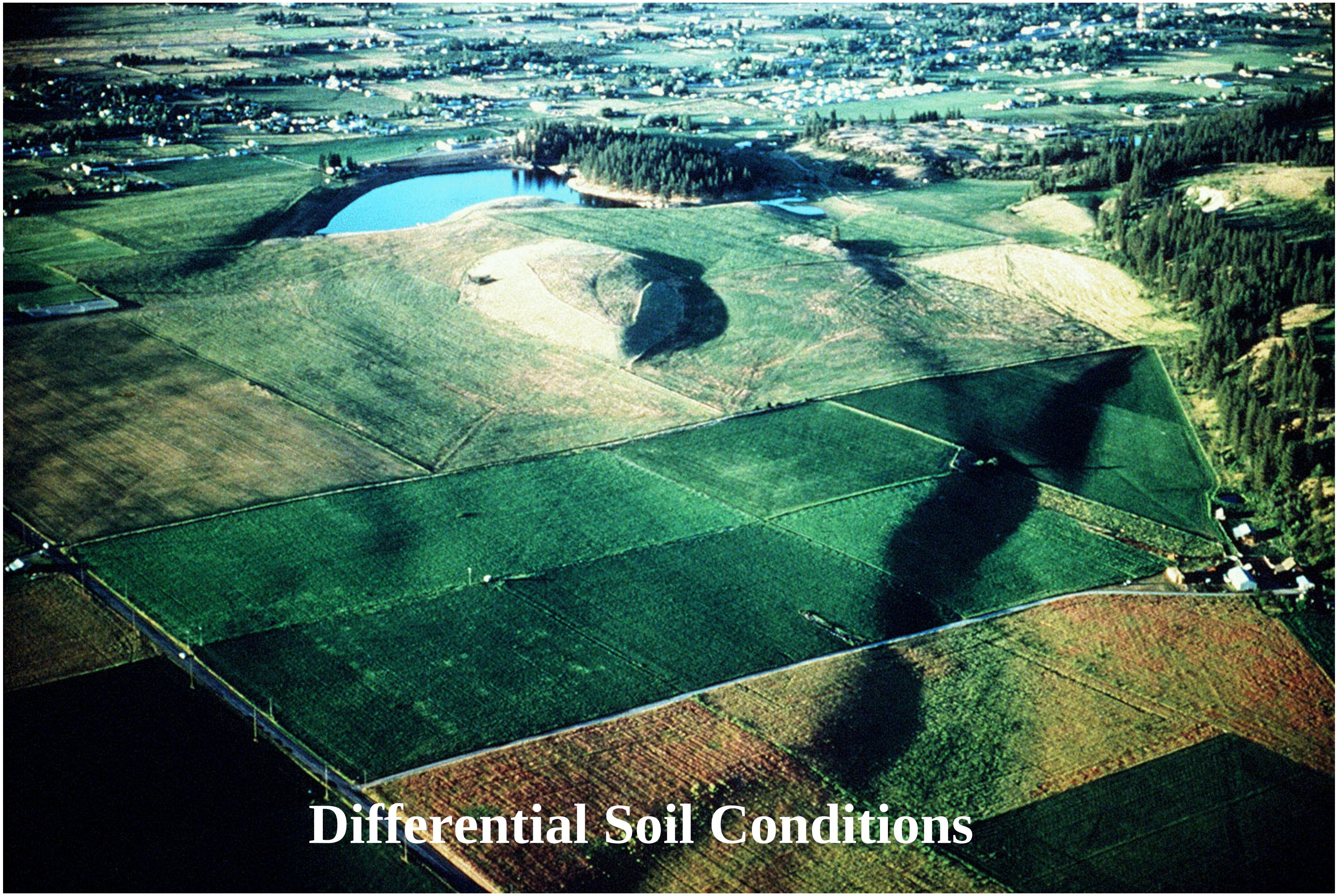
The pattern is **managed** to control growth, improve access, maximize quality of life



Visible Patterns – Patch/Matrix

Patch / Matrix

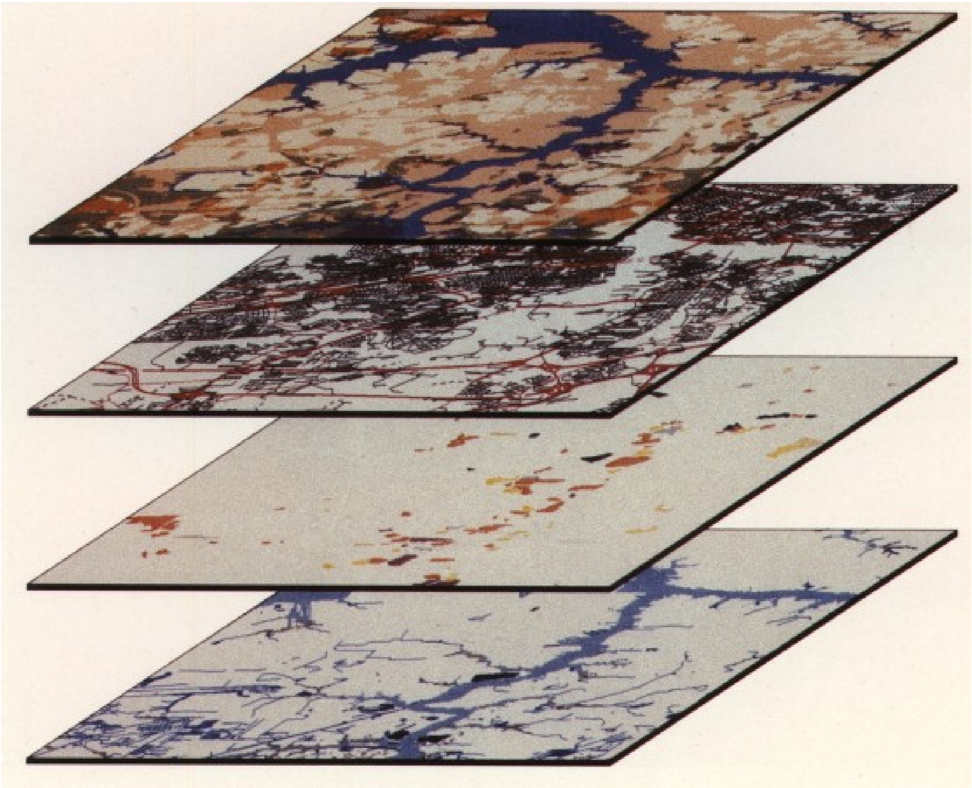
Visible Patterns - ?



Functional Patterns

Pattern Correspondence:

Notice how **portions** of the individual spatial patterns **repeat** from thematic map to thematic map



This may indicate a **functional linkage** as well

Functional Patterns - Study

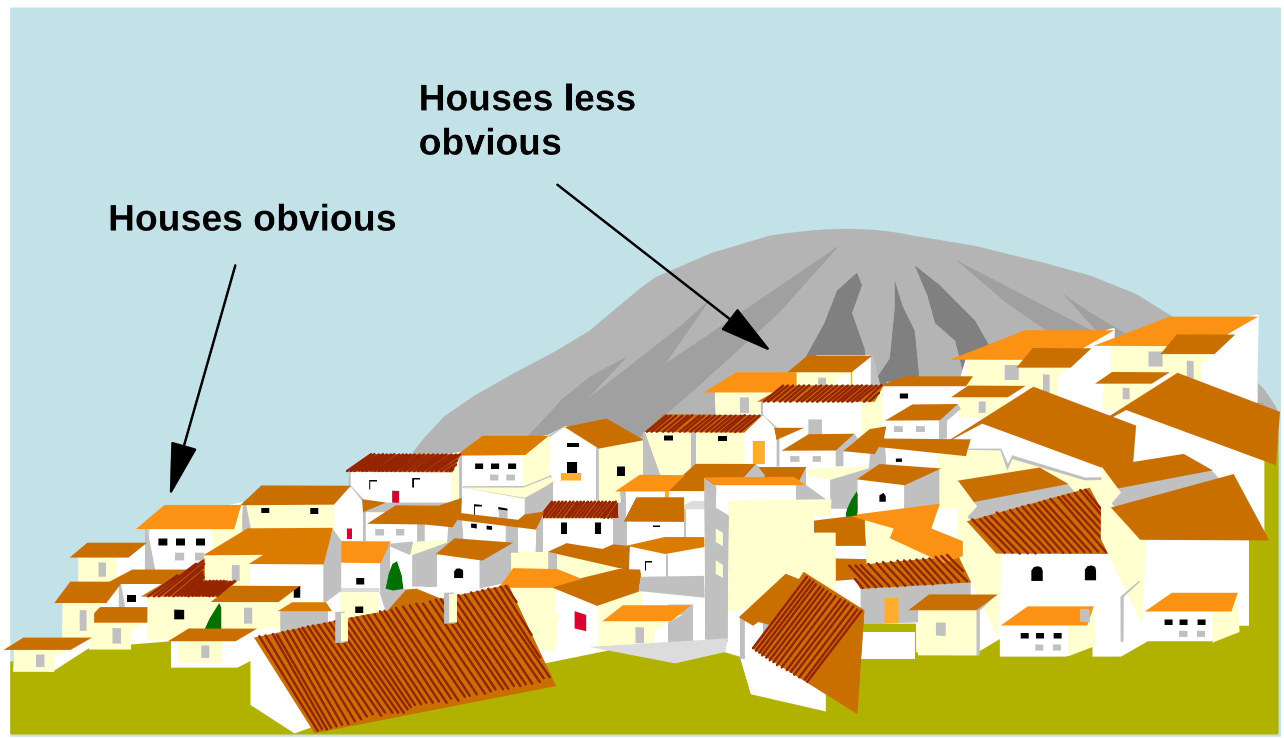
- What are the **causal** mechanisms?
- What is the **influence** of pattern?
- How do we **quantify patterns** (size, type, number, distance, density, perimeter to area ratio, lengths, and orientations)
- Do we **think of the landscape** in terms of **patches, corridors, a surrounding matrix**?
- How will we form a **mathematical description** ?

Functional Patterns

- May be **visible** through **aerial correspondence** – or they may not
- May be **latent**
  - May require some **threshold**
  - May be **too slow or too fast** to observe
    - May require **special tools, multiple themes** (e.g. time frames) to be observable:
      - » Plant succession
      - » Land use change
      - » Crime clustering
      - » Differential (time critical) traffic patterns

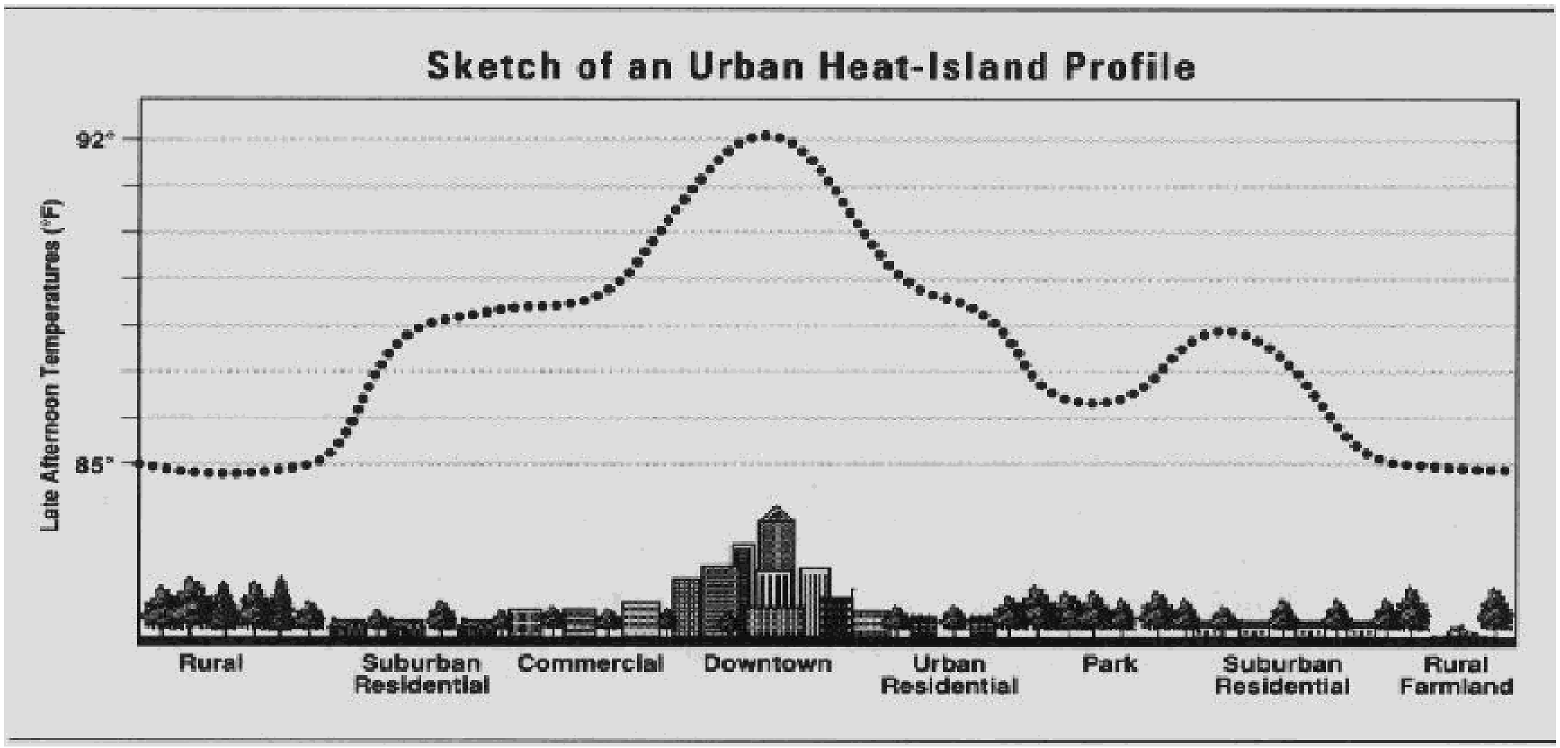
Functional Patterns

- Sometimes require a **different perspective**
  - e.g. Peter Fisher's work on **viewsheds**



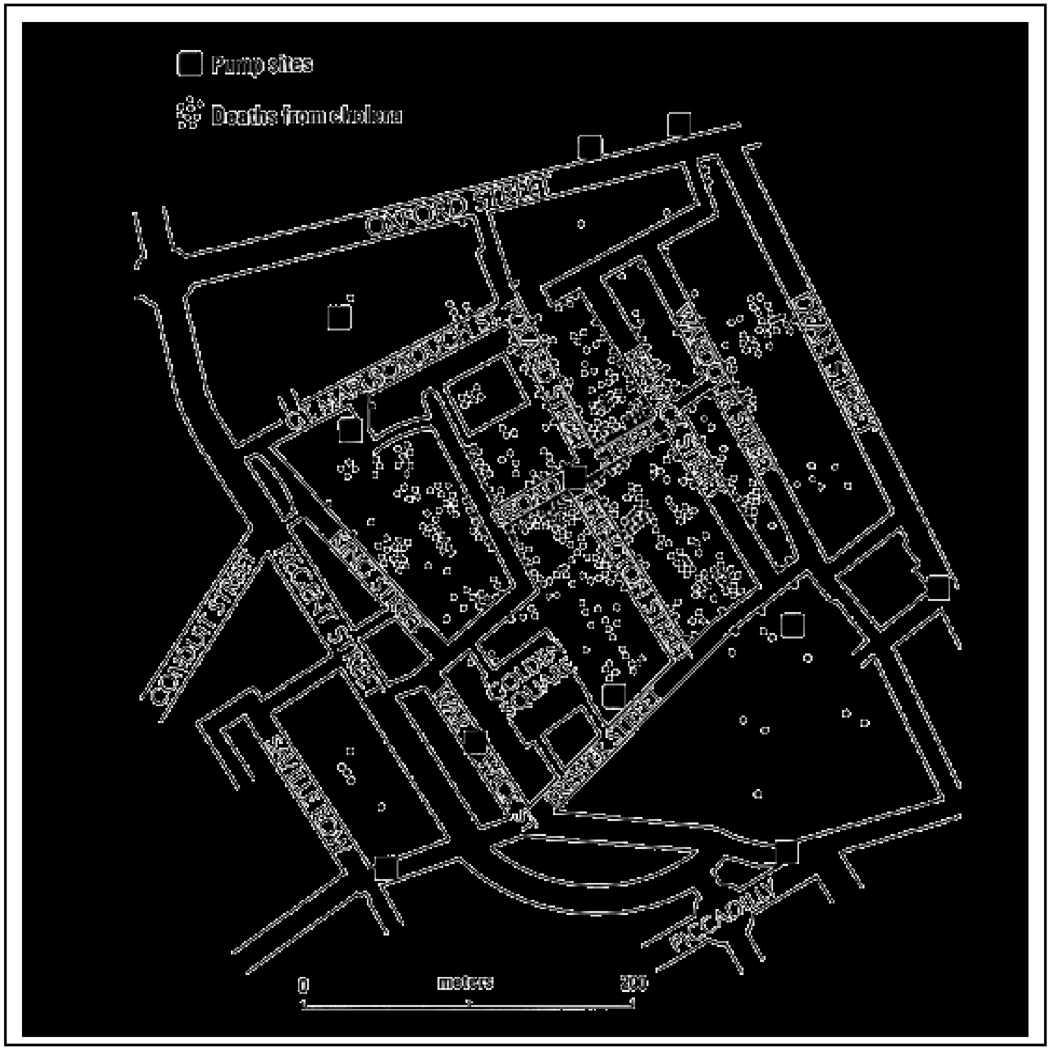
Functional Patterns

- Sometimes the patterns are **not visual**, but are '**observable**'
  - e.g. temperature – **urban heat island**



Functional Patterns

- May employ **graphic techniques**
  - e.g. scatterplots, regression curves, etc.
- May not be visible **until mapped**
  - e.g. Cholera map, with respect to pump sites



Tools for Identifying Pattern

- The landscape itself
- Literature survey
- Knowledge engineering
- Maps
- Aerial photography
- Satellite imagery
- Statistical techniques

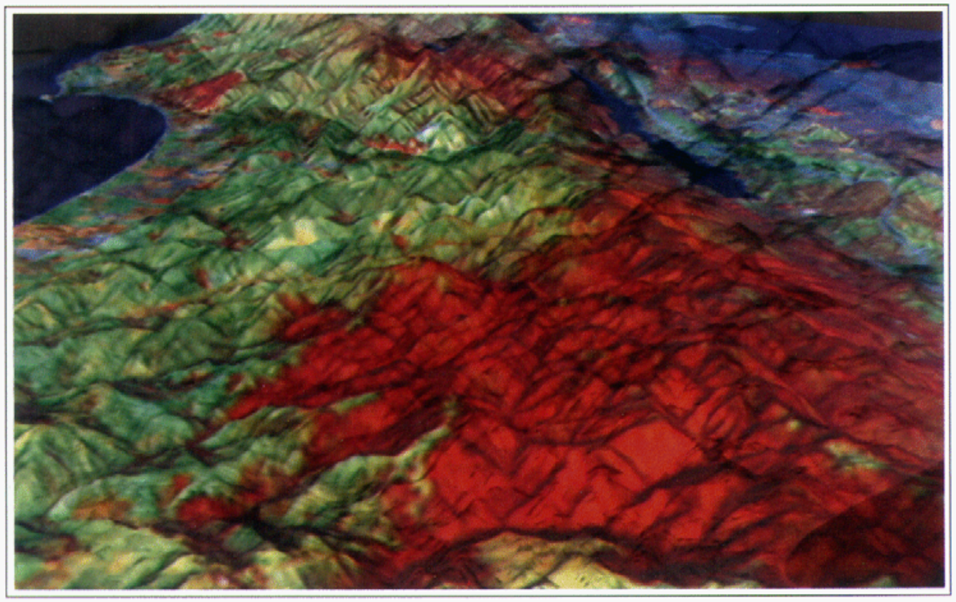


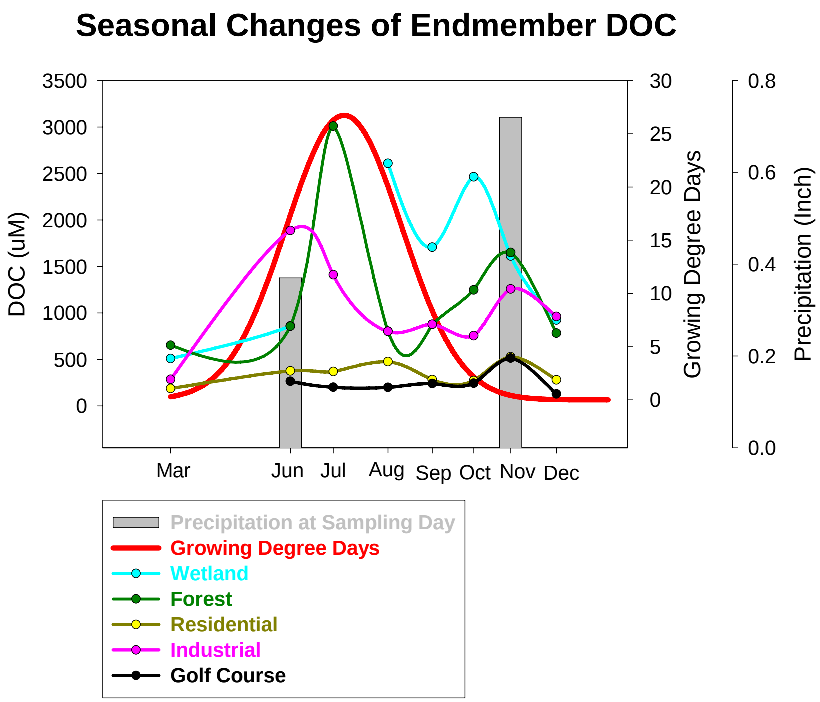
Figure 30. Perspective view of San Mateo County, CA.

Recognizing Spatial Interactions

Spatial Dimension	Object	Character	Measure	Cause	Effect
Surface	Slump Block	Volume	Morphometry	Gravity / fluid input / pressure	Slope instability
Surface	Topographic Ridge	Slope/Aspect	Angular degress / azimuth	Uplift	North versus South vegetation
Area	Forest Patch	Size	Perimeter or Permimeter / area	Forest Clearing	Interaction with matrix
Area	Linear Forest Patch	Orientation	Long axis azimuth	River corridor	Migratory Bird roosting
Line	Hedgerow	Extent	Length	Human	Animal movement
Line	Road Network	Connectivity	Alpha Index	Human	Traffic flow
Point	Gopher Holes	Density	#/Unit Area	Colonization	Competition
Point	Fruit Trees	Arrangement	Nearest Neighbor	Planting	Crop efficiency

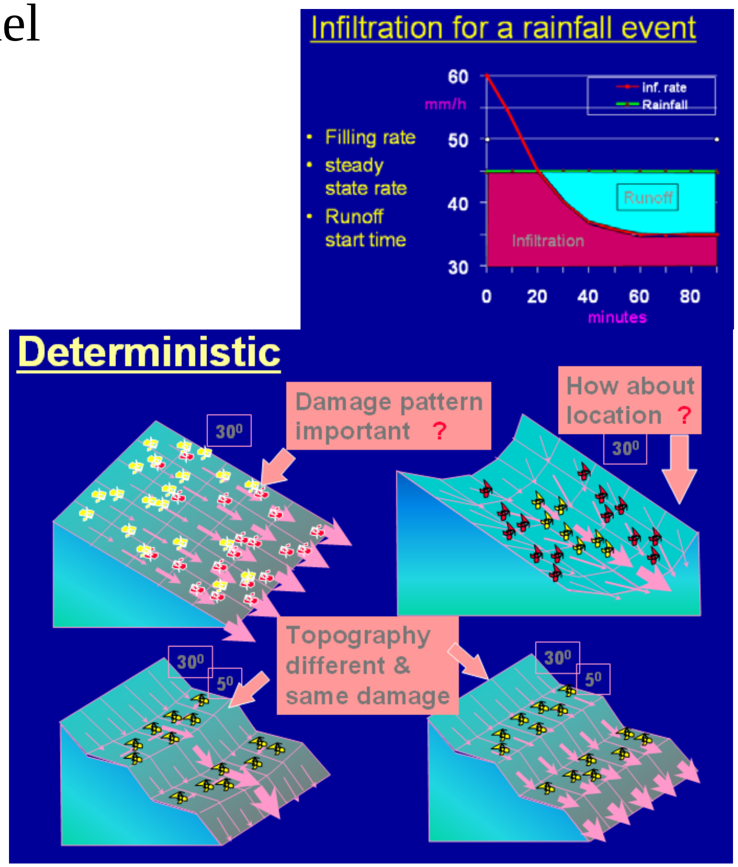
Types of GIS Models

- Models based on **purpose**:
  - **Descriptive** – passive (what is/has been)
    - Functions do not focus on prediction, but focus more on the **intrinsic structure, relations, interconnectedness**
  - **Prescriptive** – active (what will be)
    - Algorithmic for a **best solution**, less concern for correctness of intermediate structure



Types of GIS Models

- Models based on **methodology**:
  - **Stochastic**
    - Based on **probability theory**
      - e.g. timber harvest breakage model
  - **Deterministic**
    - Based on **functional linkages**
      - e.g. hydrologic flow modeling
      - Soil loss modeling based on the universal soil loss equation



Types of GIS Models

- Models based on **logic**:
  - **Inductive logic**
    - Use **specific instances** to **build a general model**
      - Requires **substantial empirical data**
      - May employ (spatial) **data mining**
  - **Deductive logic**
    - Move from **general to specific**
      - More often **algorithmic**

Chapter 5: Modeling Essentials

- **Thinking Spatially**
  - spatial **components** of a problem
  - spatial information product (**SIP**)
    - SIP **elements**: Thematic maps, subsets, numerical values, or variables
    - Elements are **connected** (functionally) **by operators**
  - **Recognize patterns**:
    - Visible:
    - Overlay and functional patterns
  - Pattern studies: Causality & influence, **quantify**
  - Functional patterns: sometimes **not visible** immediately
- **Models Based on …**
  - **Purpose**: Descriptive and prescriptive
  - **Methodology**: Stochastic and Deterministic
  - **Logic**: Inductive logic and Deductive logic

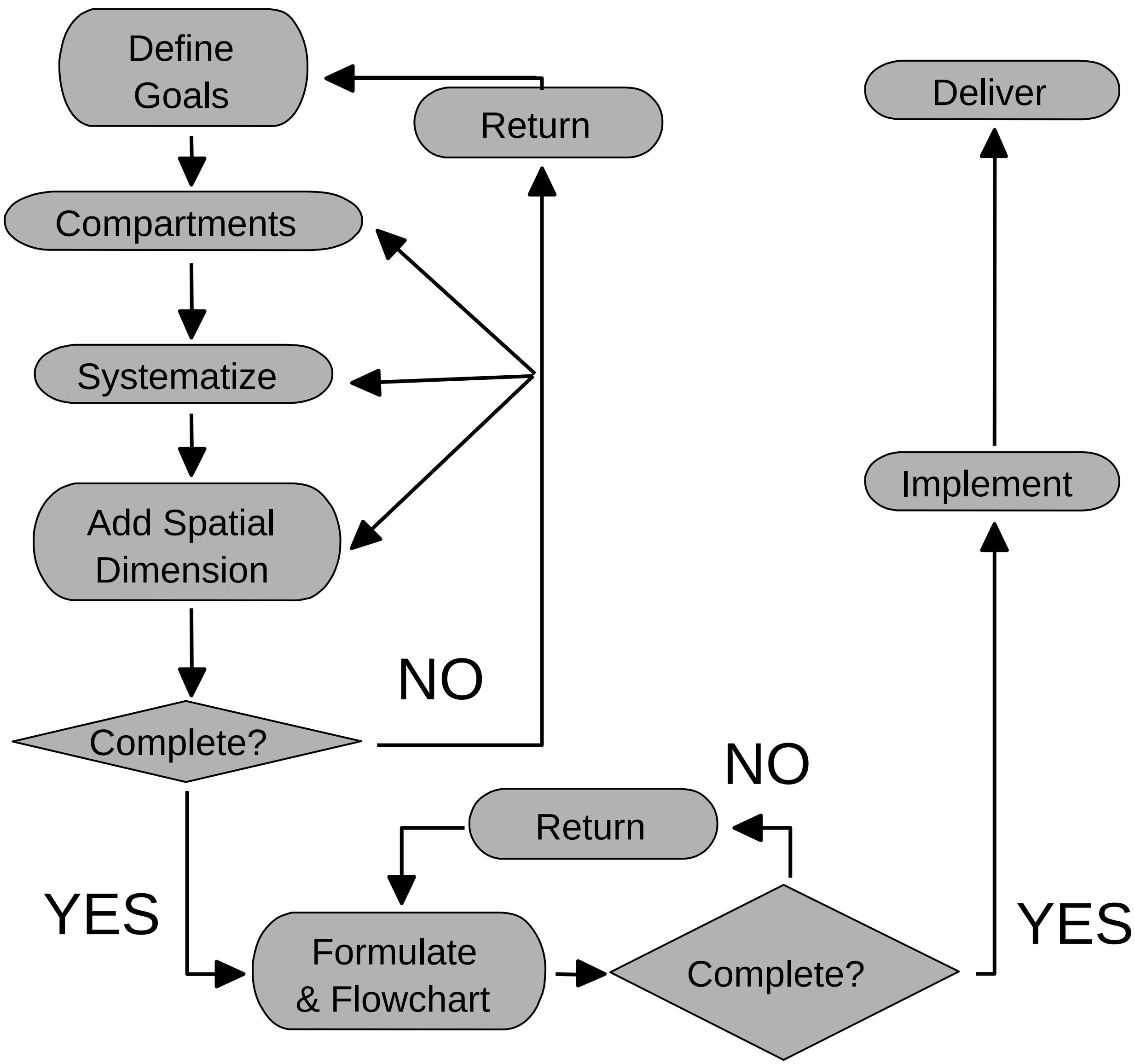
Conceptualizing the Model

- Defining your **goals**:
  - Best to **start with your intended product** rather than with the database.
  - Why? Existing **non-model specific database** may…
    - Lack necessary integrity, accuracy, scale, classification system, etc. etc. **to be compatible with the model**

Why Your Model Should NOT Be Data-driven

1. Datasets may contain **irrelevant themes**
2. Datasets may be **incomplete** for model
3. Datasets may **bias** (or even dictate) **methodological and conceptual approaches**
4. Area coverage and sampling may be **inadequate for modeling tasks**

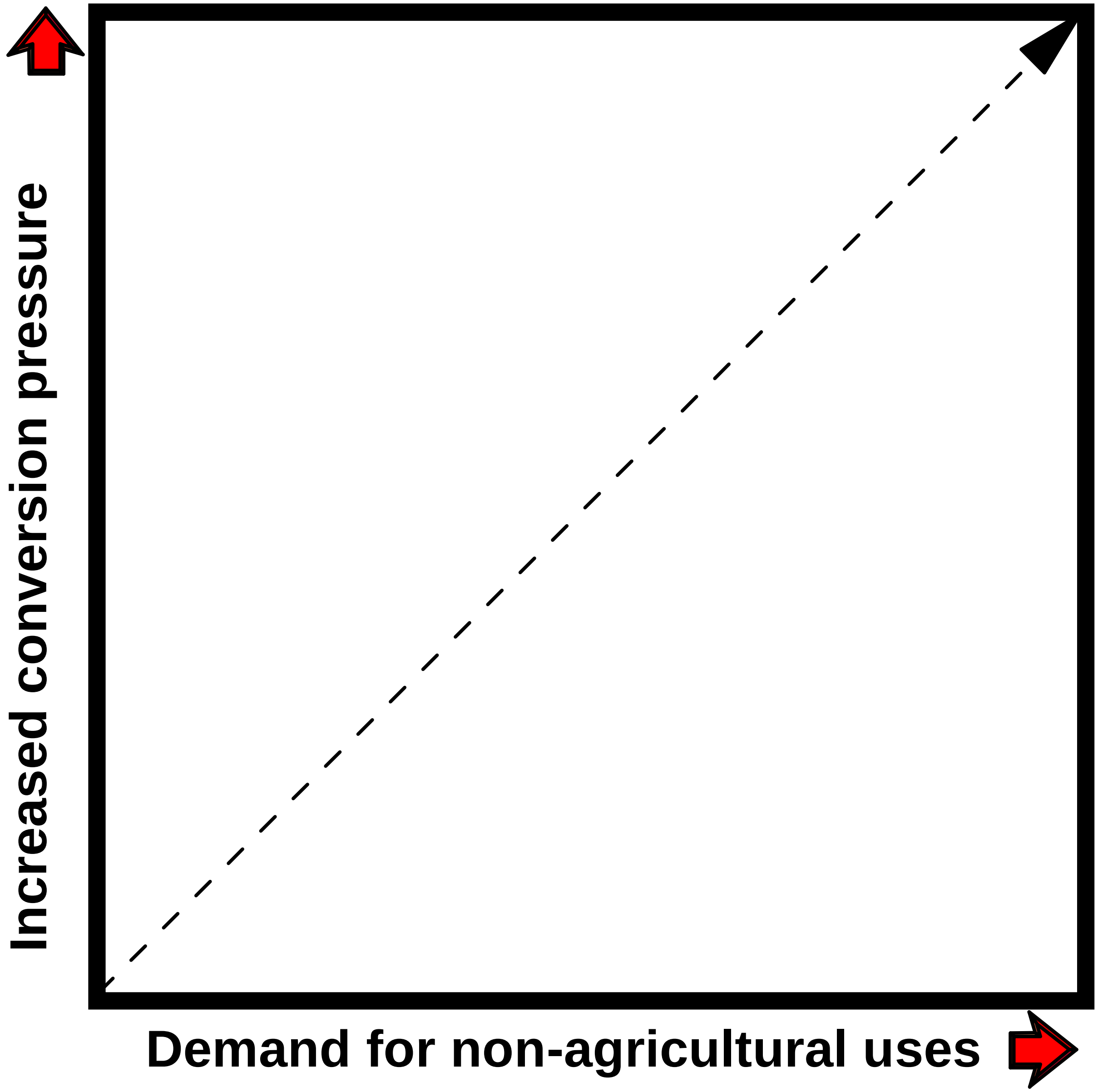
The General Modeling Process

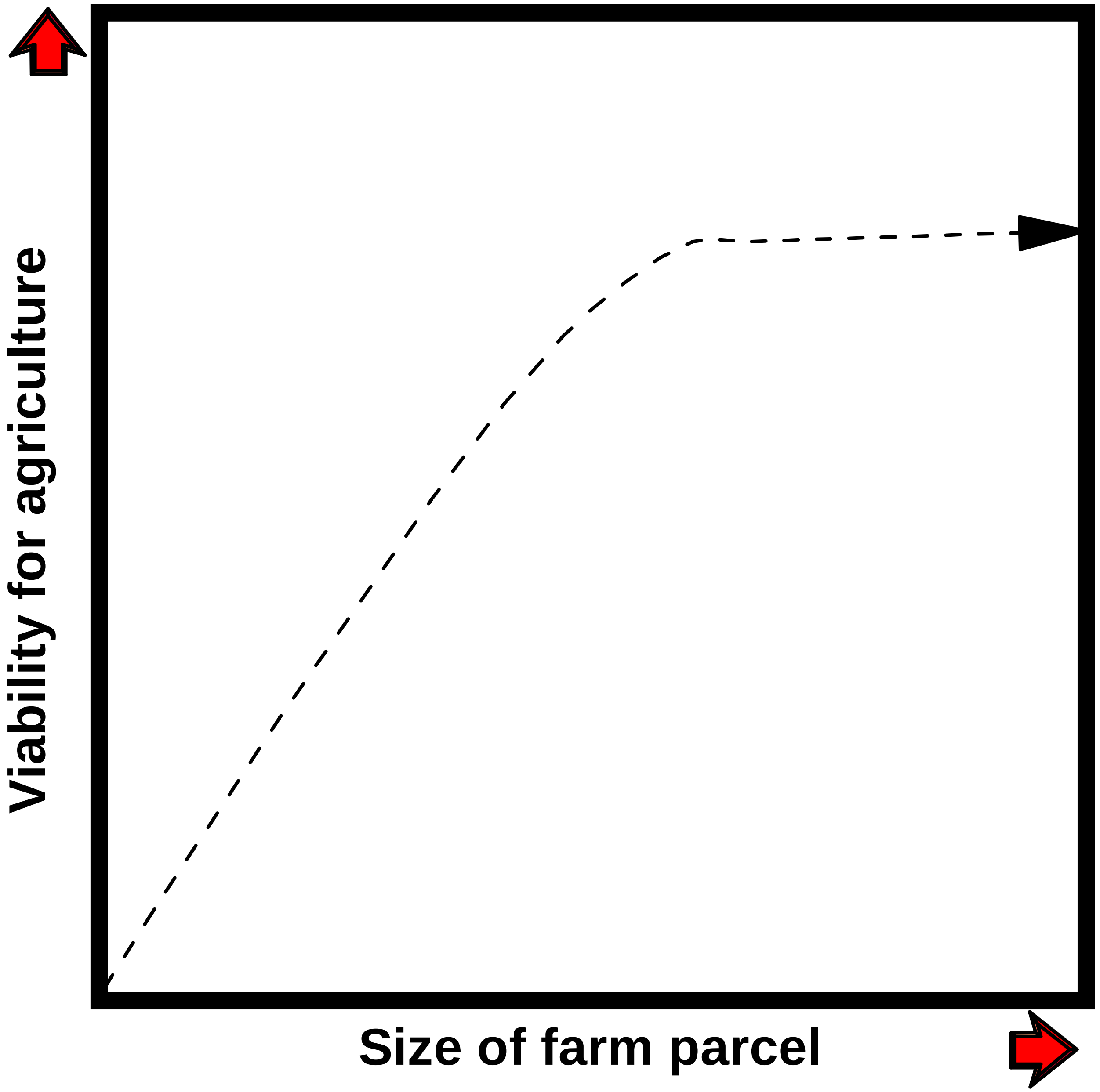


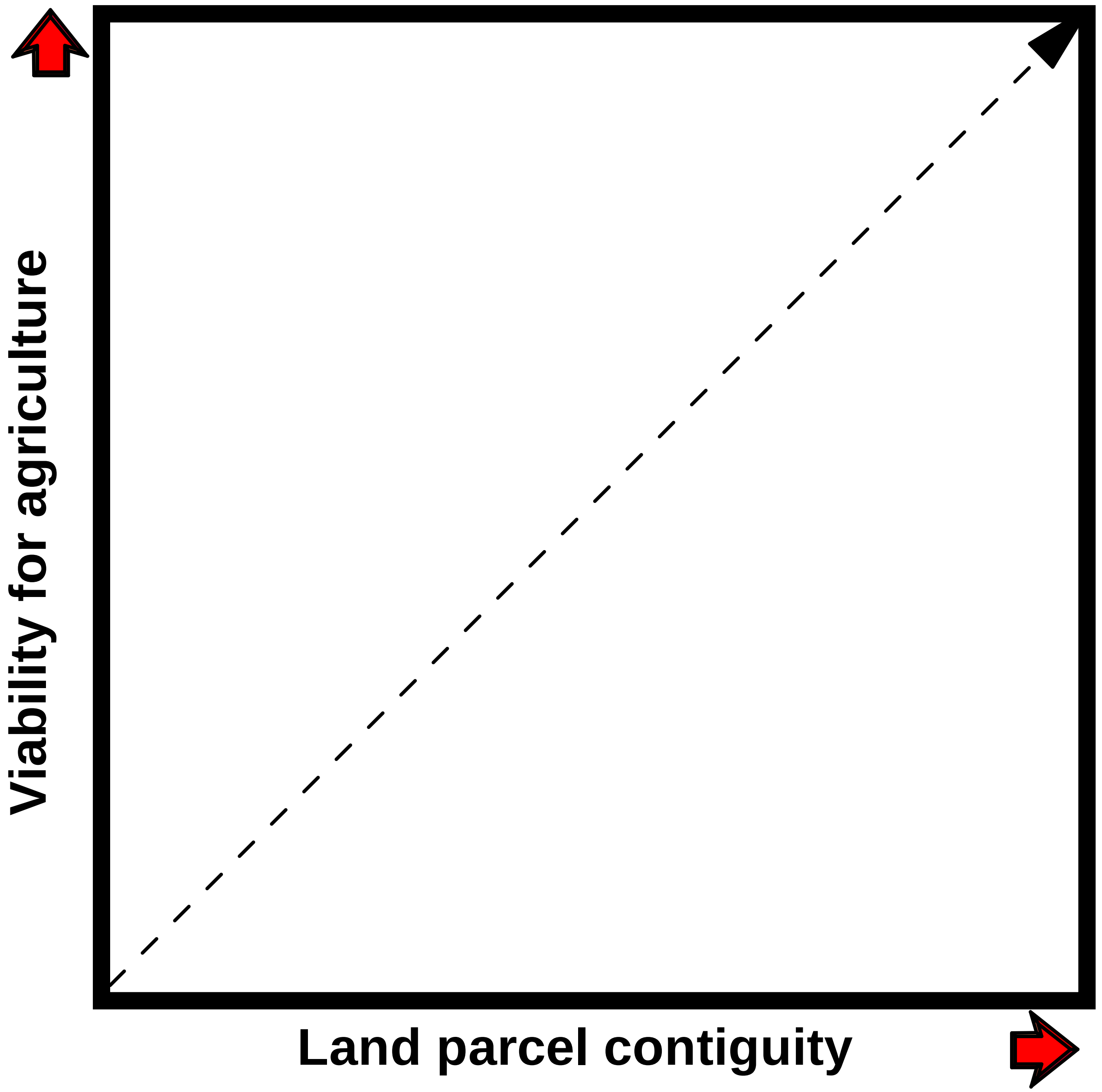
An Example using LESA

- **Land Evaluation and Site Assessment** Model
  - Designed to evaluate land-use at the **county level**
    - Focus is the proper **allocation** of agr. land for non-agr.
  - The goal is to **preserve good farmland**
  - Review some **relationships** (following slides)
    - Infrastructure, socioeconomic factors, and zoning regulation
  - Now prescribe, rate **every land site**

Demand for non-agr. uses is **not an explicitly spatial factor** (surrogates)

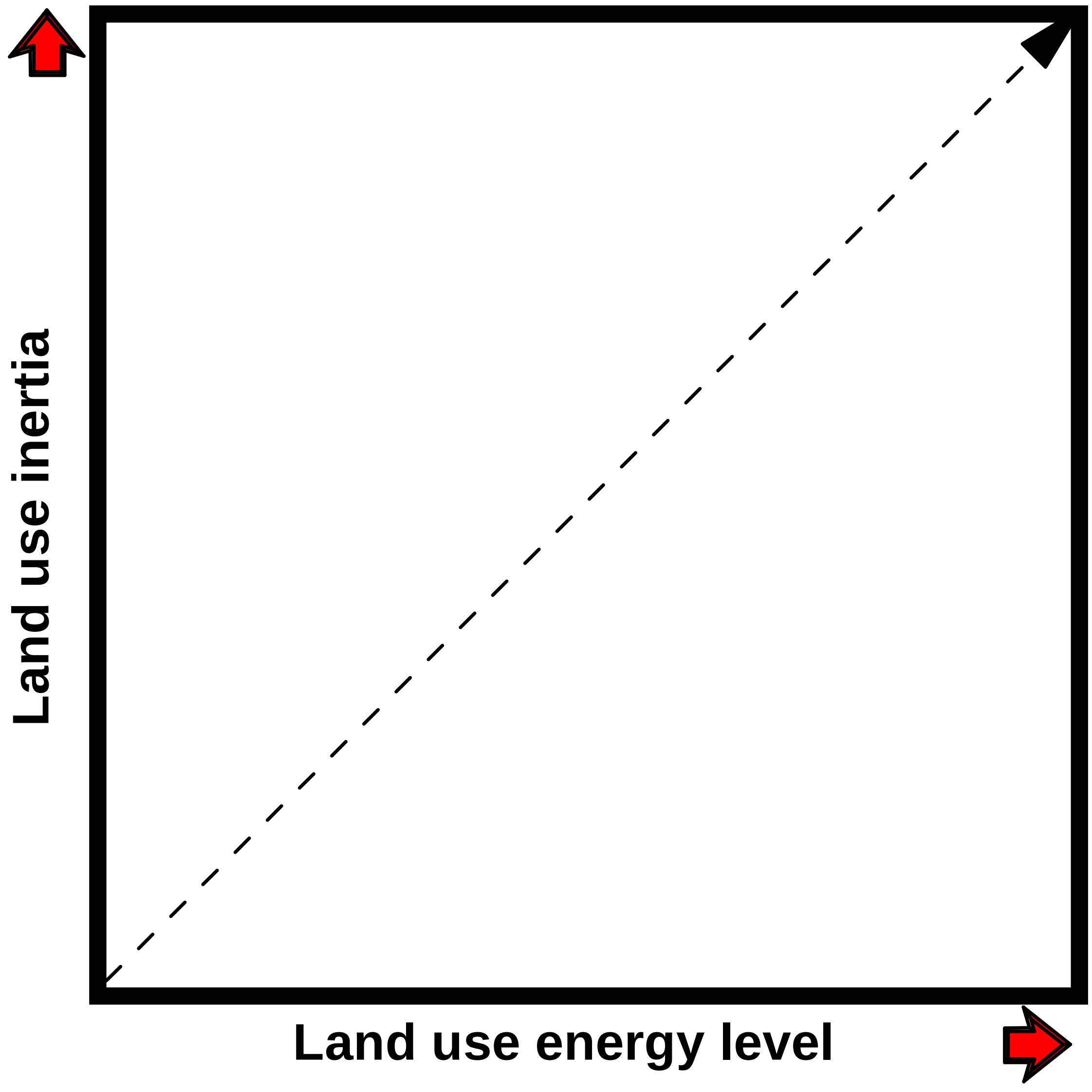


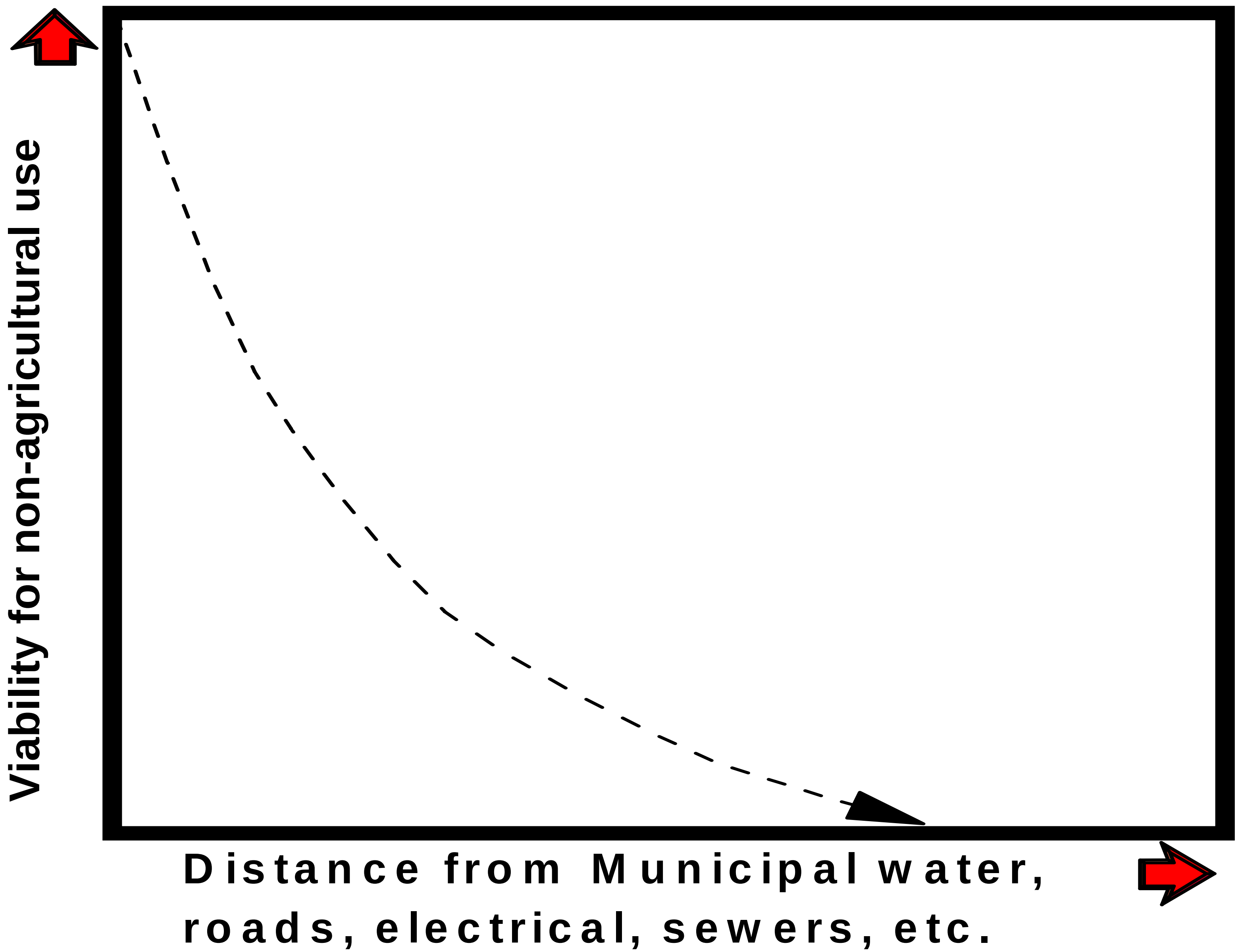

Viability for agriculture
Size of farm parcel


Viability for agriculture
Land parcel contiguity

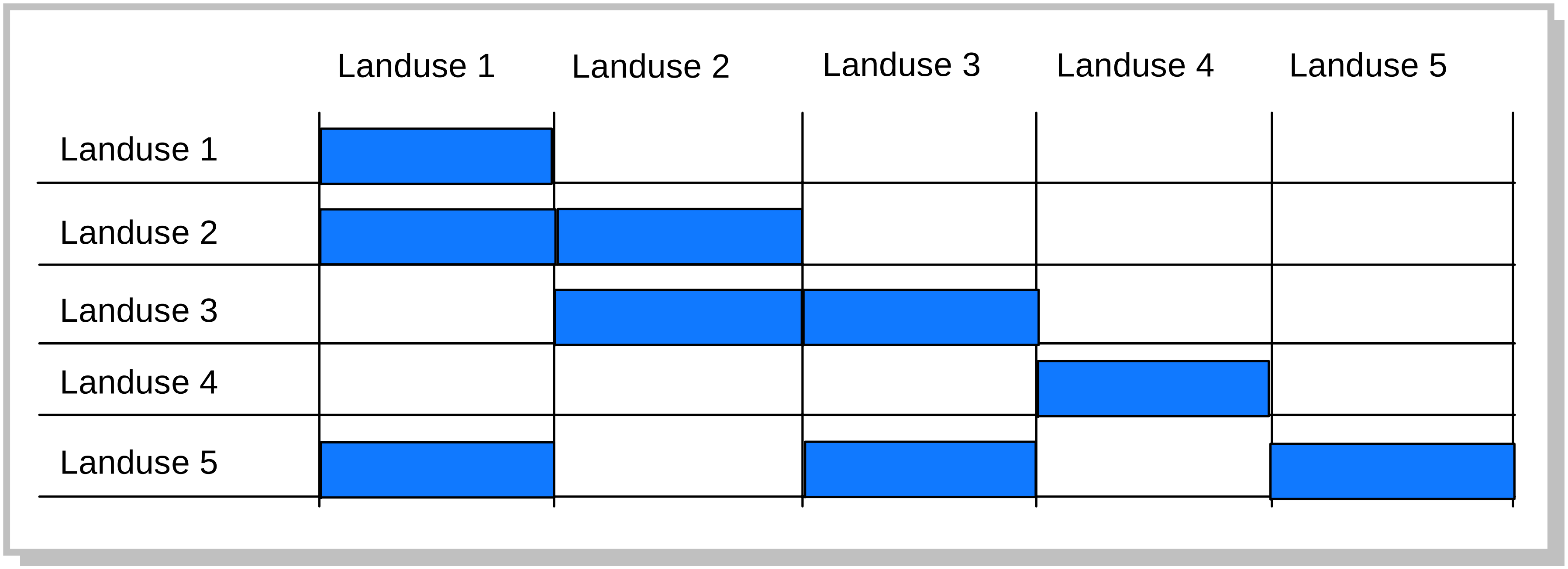
Land use inertia (to stay the same) vs. **energy level** by land use type

High energy land uses usually **require substantial inputs** of money, material, and construction



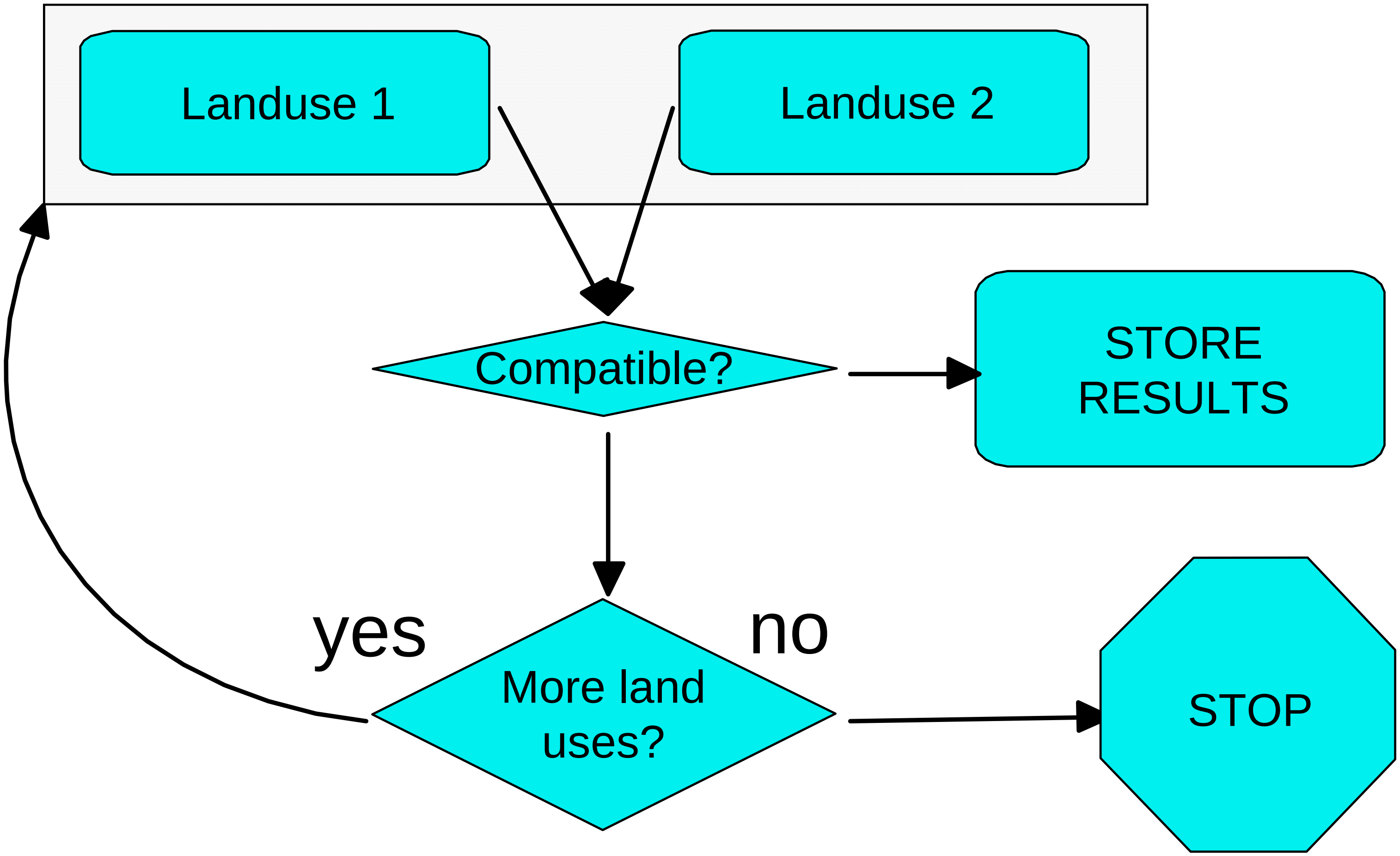

Viability for non-agricultural use
Distance from Municipal water, roads, electrical, sewers, etc.

Land Use Compatibility Matrix



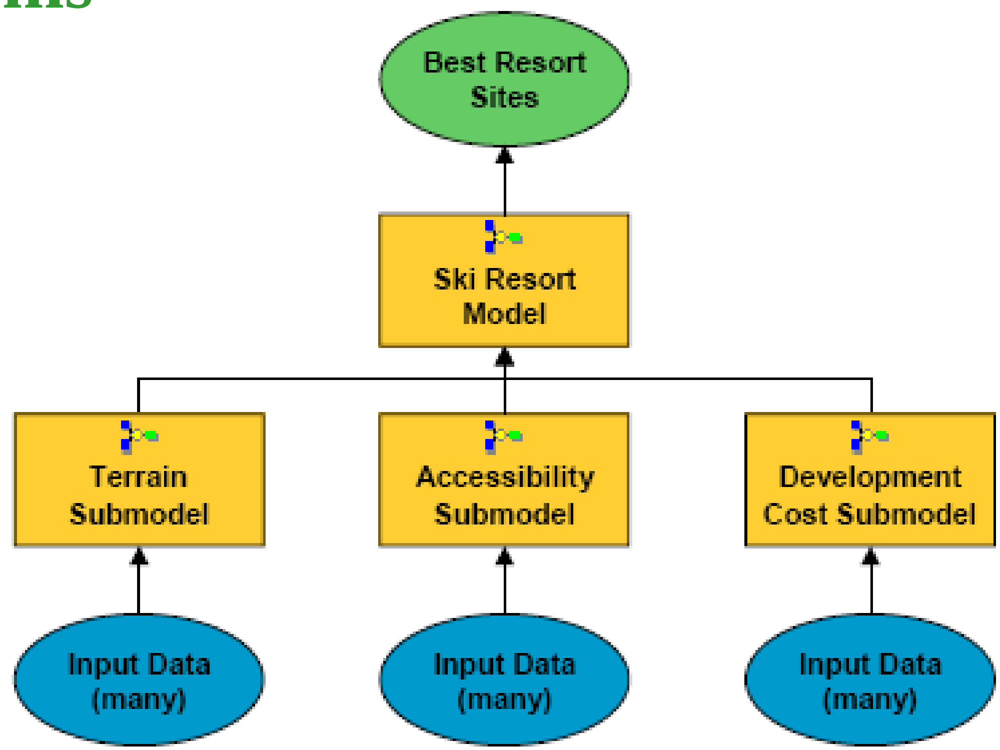
One method of reviewing the compatibility of land uses, or any other factors you might be modeling, is to create a **simple matrix**. In this case, the **shaded compartments** show land uses in columns that are **compatible** with others in the corresponding rows.

Compatibility Flowchart



Break Big Models into Sub-models

- This is a good **general strategy** to help deal with **complexity**
  - It helps **clarify relationships** and **simplifies problems**



Hierarchical Compartmentalization

LESA Model Components (Compartments)

1. Land use / agriculture (local and adjacent)
2. Agricultural economic viability (investment, size)
3. Land use regulations (% zoned agr., adjacent to zone)
4. Alternative locations (availability, productivity)
5. Compatibility of proposed use (surrounding hydrology, for example)
6. Compatibility with master plans
7. Infrastructure (city, transportation, utilities)

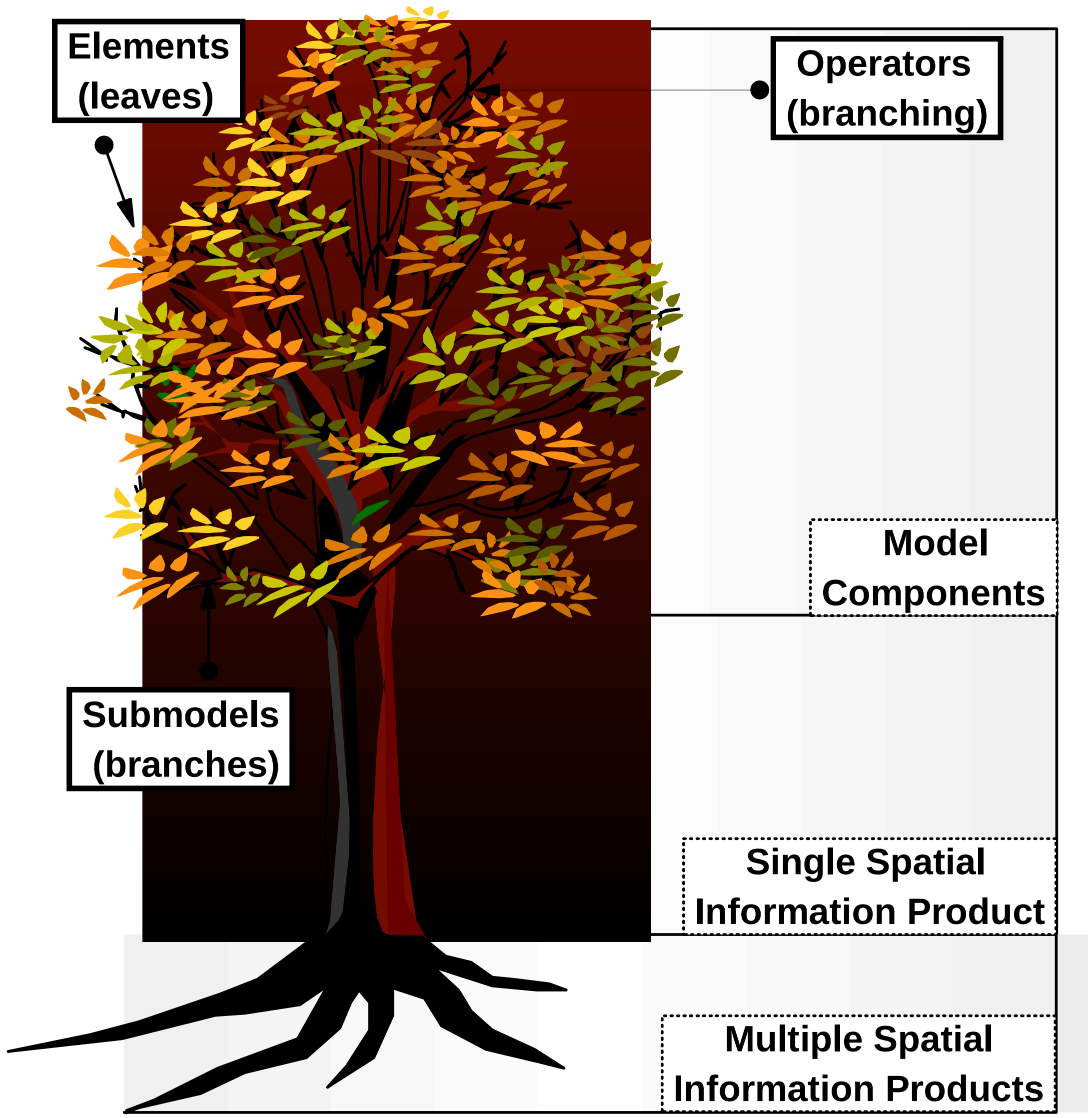
Adding the Spatial Dimension

- **Land use / agriculture**
  - Existence of **agricultural land** in and around the proposed land conversion sites
    - **Three components** (that are basically spatial in nature):
      - Land on site
      - Land adjacent to site
      - Land within a specified distance of site
  - **Size of farm** (which is fundamentally spatial)
    - Restricts use
  - **Agrivestment** (aspatial)
    - Do we abandon this factor?
    - Or do we find spatial surrogates?

Finding Spatial Surrogates

- **Agrivestment**
  - Obtain **financial records** (machinery, roads, buildings, improvements…)
    - Divide investments **by farm size** (a ratio)
    - Or we could **incorporate a $/ft^2** for individual items
  - Alternatively, we could use agrivestment as a **non-spatial multiplier or operator**
    - e.g. average annual investment **for each farm**

Dana Tomlin's Hierarchical Model

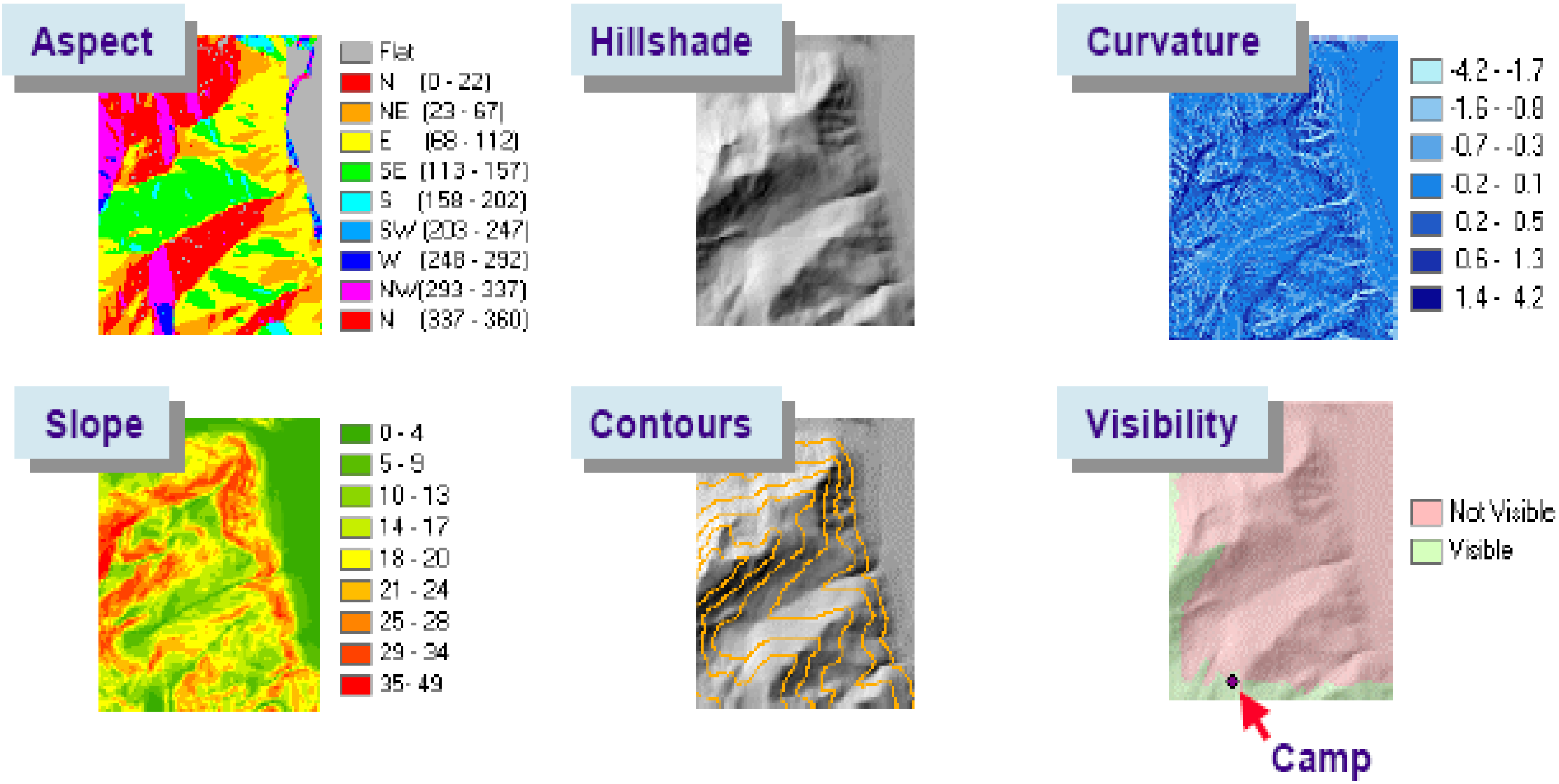


Exercises 5 & 7

- EXERCISE 5: RASTER PROCESSING TOOLS
- EXERCISE 7: ANALYZE TOPOGRAPHY

Using surfaces in ArcGIS Spatial Analyst

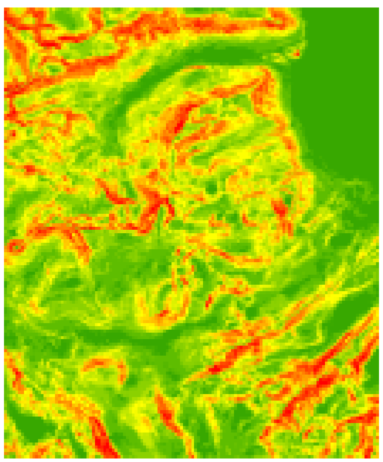
- ArcGIS Spatial Analyst provides tools to derive:



- Also hydrologic analysis [redacted]

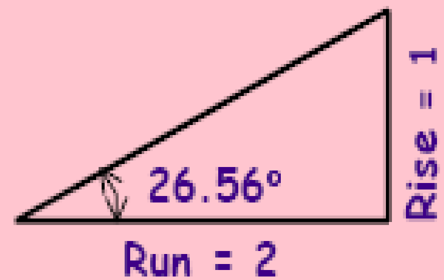
Derive slope

- Maximum rate of change of **Z** through the cell
  - Uses neighboring cell Z values
  - Returns degrees or percent



Degree of slope = θ

$$\frac{Rise}{Run} = \tan\theta$$



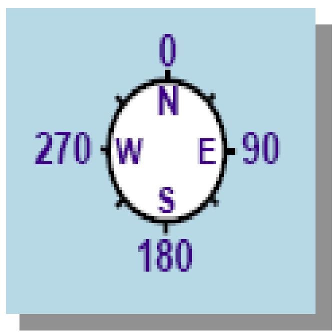
$$\text{Percent rise} = \frac{Rise}{Run} * 100$$

$$50\% = \frac{1}{2} * 100$$

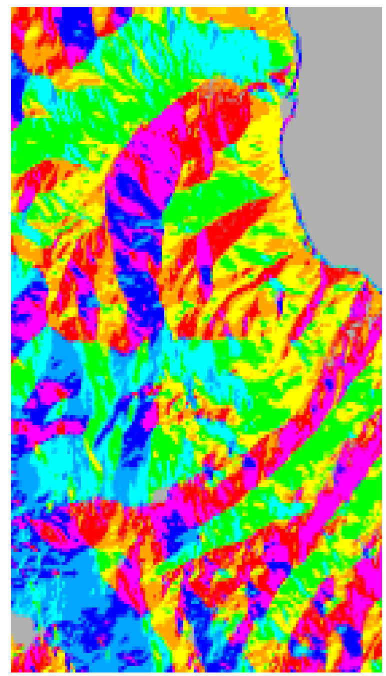
```
SLOPE(<grid>, <z_factor>, {DEGREE | PERCENTRISE})
```

Derive aspect

- Direction of the maximum rate of change in Z
  - Orientation of cell relative to north
  - Returns compass direction 0 to 360
  - Flat areas are given a value of -1

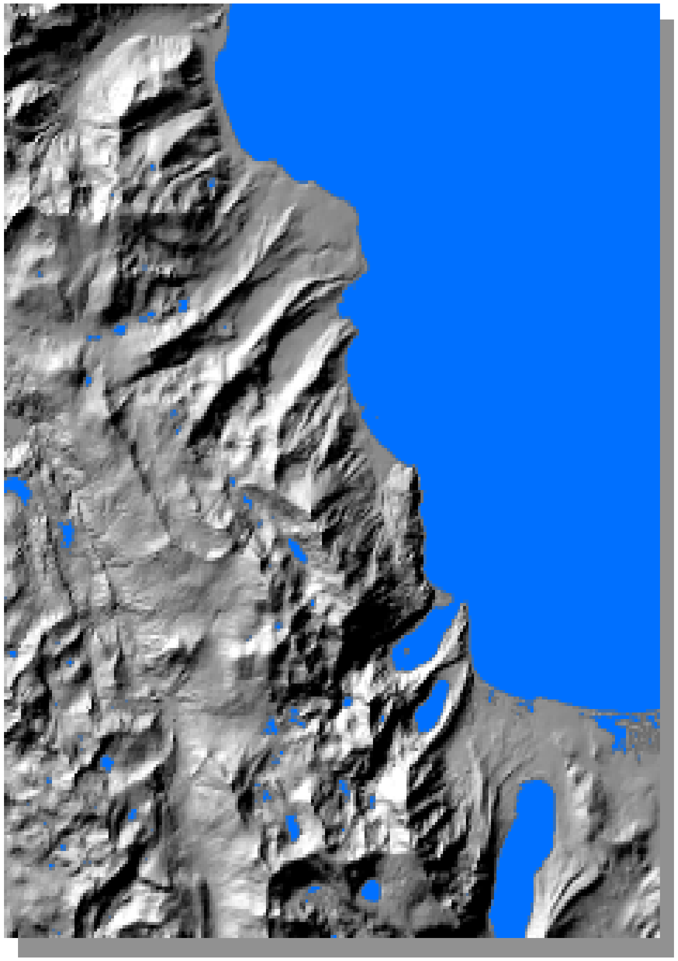



```
ASPECT(<grid>)
```



Hillshade

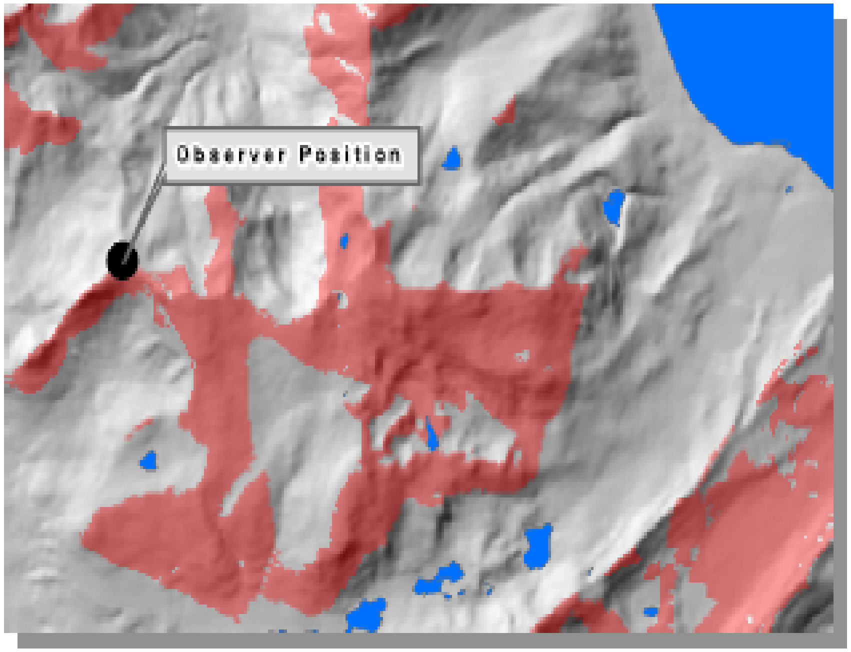
- Illuminates a surface
  - Sets sun position
  - Returns gray scale 0-255
- Cartographic and analytic uses



```
HILLSHADE(<grid>,{azimuth},{altitude},{ALL | SHADE | SHADOW},{z_factor})
```

Visibility analysis

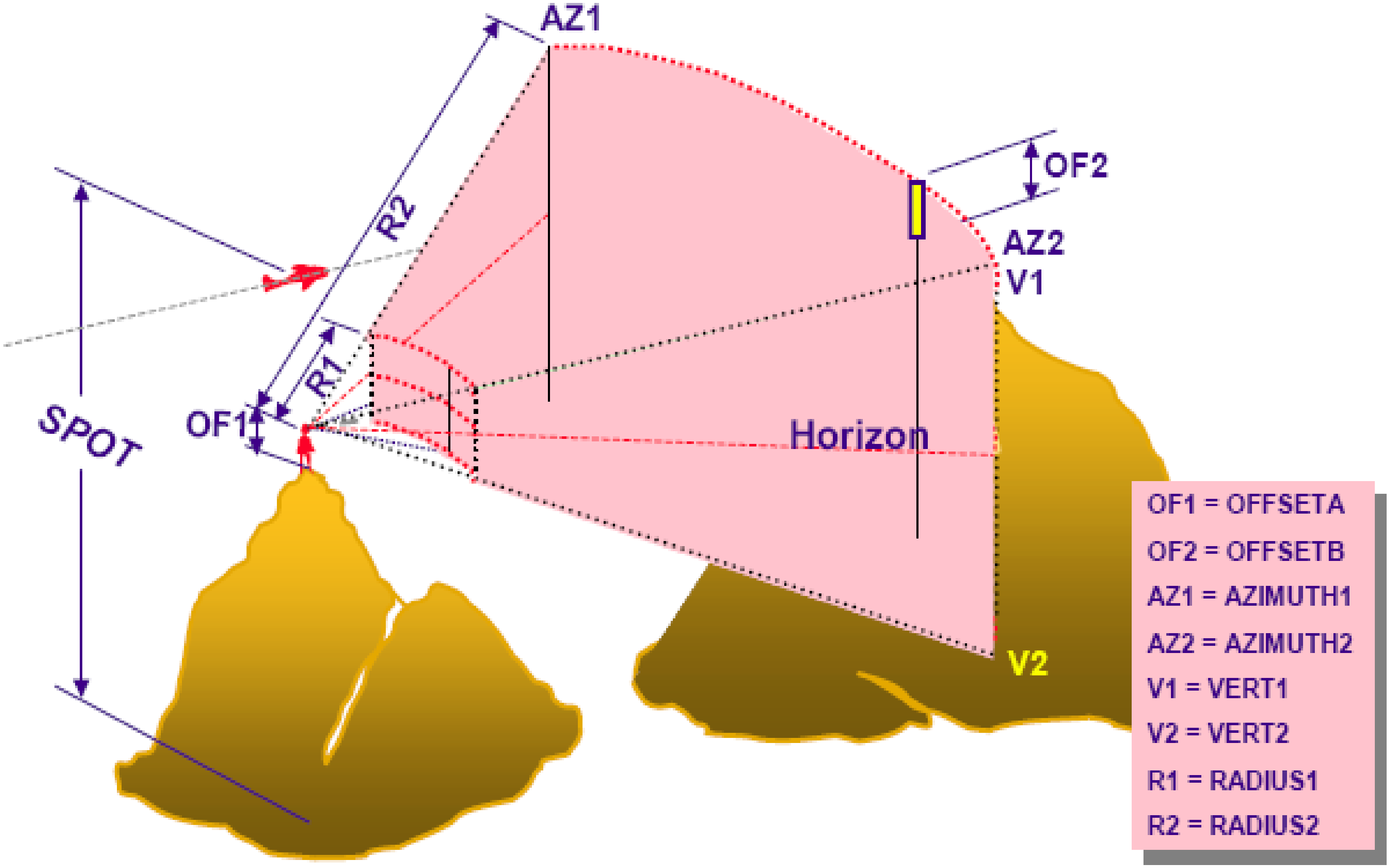
- Visibility of cells from observation points or lines



- Output attributes identify observer count or ID

Controlling visibility in a viewshed

- Set parameters as observer point attributes



Next Topic(s):

Building Spatial Models II

Raster Analysis and Functions II