Geographic Information Systems

ESM 263 - Winter 2023

GIS Models

What is a Model?

An analysis pattern: step-by-step implementable strategy

Developing a GIS Model

1. identify goals
   - Phenomena
   - Scales
   - Parameters vs. Variables

2. identify elements
   - Data
   - Operations

3. Implement
   - Layers
   - Functions/tools

GIS Models for Decision Support

- Analytical
  - Reducible to computational workflow

- Repeatable
  - Same conditions + Same assumptions = same answer

- Transparent
  - “it is better for stakeholders to argue in principal about the merits of different factors and how their impacts should be measured, than to argue in practice about alternative decisions.” Longley et al, Geographic Information Systems and Science, 2nd ed.

Multi-Criteria Models

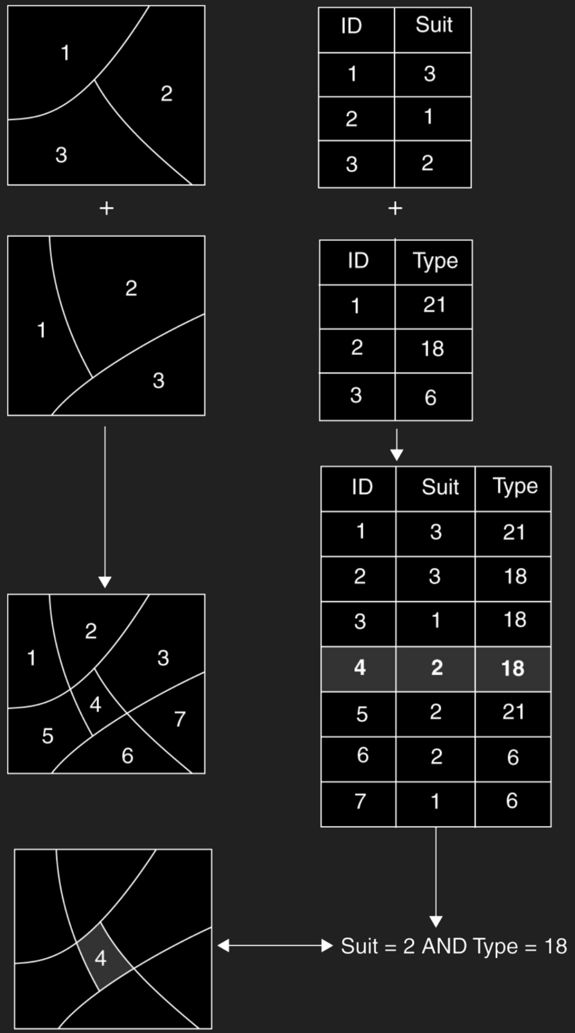
- output = f(multiple inputs)
  - spatial overlay
    - composite feature layer
    - multiple rasters
  - attribute combination

- binary models
  - logical expression → feature/cell yes/no
    - common application: siting analysis

- index models
  - combination formula → feature/cell index (rank) value
    - common application: suitability analysis

Vector-Based Binary Model

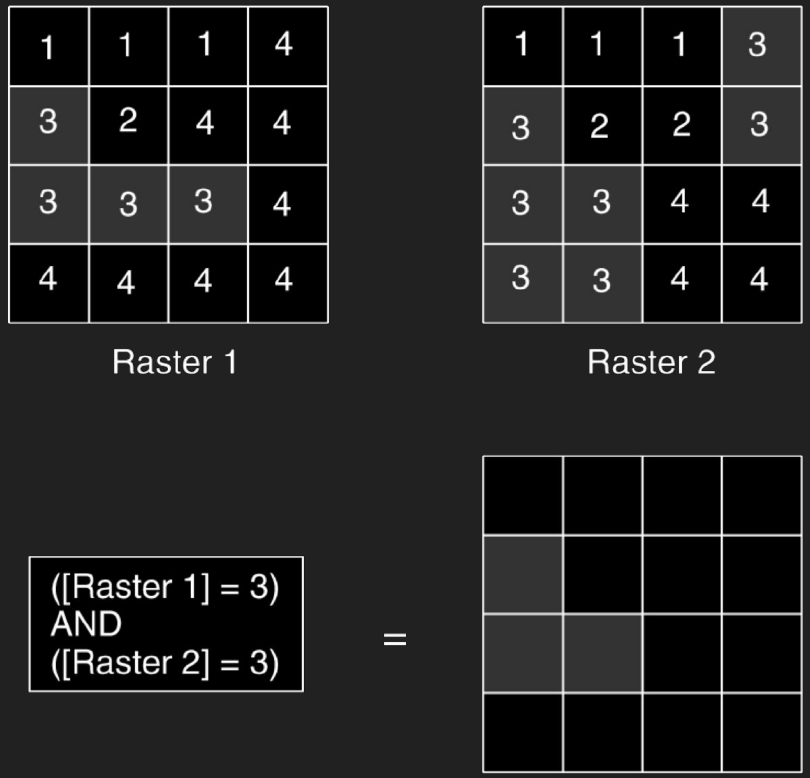
- Combine layers
  - UNION
- Query
  - all relevant attributes pass logical test



Raster-Based Binary Model

Query

- all relevant attributes pass logical test
- no need to combine: cells already line up



Multi-Criteria Analysis (aka Index Modeling)

1. Identify criteria: What will decision be based on?
    - Geographic datasets
2. Standardize factors
    - Interval or ratio scales
3. Establish relative importance: How much does each factor matter?
    - Numeric weights
4. Combine constraints and weighted factors
    - Decision score

MCA Step 1. Identify Criteria

- What measurable geographic phenomena affect the decision?
  - NB: Different objectives →different criteria

- Constraints
  - combine: Boolean logic → result: yes/no

- Factors
  - combine: weighted sum → result: numeric score

- **Result**: GIS layers

MCA Step 2. Standardize Factors

- All factors must be
  - Same interval (or ratio) scale
    - must be possible to add them together
  - Same ordering
    - ↑ value →↑ score (e.g. "more suitable")

- Example: linearized score

  $$score = ((raw - raw_{min}) \div (raw_{max} - raw_{min})) \times (std_{max} - std_{min}) + std_{min}$$

- **Result**: Reclassified GIS layers

MCA Step 3. Assign Weights

- Simple case
  - few factors
  - stakeholder consensus
  - overall weighting "obvious" (yeah right ...)
- Manually assign weights that sum to 1

- Not-so-simple case
  - many factors
  - stakeholder conflict
  - overall weighting not obvious
- Use analytical framework (e.g., AHP)

MCA Step 4. Combine

- $score = \sum(weight_i \times factor_i) \times \prod(constraint_j)$
- Easily implemented with map algebra

- **Result**: “score” layer

MCA Weights: Saaty's Analytic Hierarchy Process (AHP)

1/9	1/7	1/5	1/3	1	3	5	7	9
extremely	very	strongly	moderately	equally	moderately	strongly	very	extremely

less important ⟶ more important

(a)

	Proximity to roads	Proximity to labour force	Slope gradient	Distance from wildlife reserves
Proximity to roads	1			
Proximity to labour force	1/3	1		
Slope gradient	1	4	1	
Distance from wildlife reserves	1/3	2	1/2	1

(b)

Factor	Derived weight
Proximity to roads	0.3770
Proximity to labour force	0.0979
Slope gradient	0.3605
Distance from wildlife reserves	0.1647

(c)

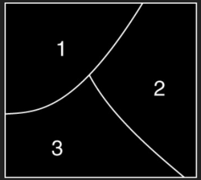
Fig 4. Saaty's pairwise comparison procedure for the derivation of factor weights. Using a 9-point rating scale (a) each factor is compared to each other factor for its relative importance in developing the final solution (b). The principal eigenvector of this matrix is then calculated to derive the best-fit set of weights (c).

MCA Weights: AHP Calculation Shortcut

1. Fill in missing reciprocal scores
2. Normalize score columns
3. Sum normalized score rows → weight vector
4. (optional) Normalize weight vector

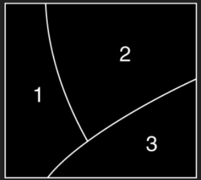
Vector-Based Index Model

1. Standardize relevant attributes
2. Combine layers
   UNION
3. Weighted sum of standardized attributes

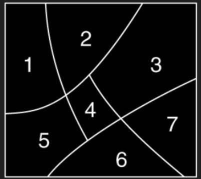


ID	Suit	S_V
1	3	1.0
2	1	0.2
3	2	0.5

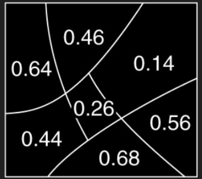
+



ID	Type	T_V
1	21	0.4
2	18	0.1
3	6	0.8



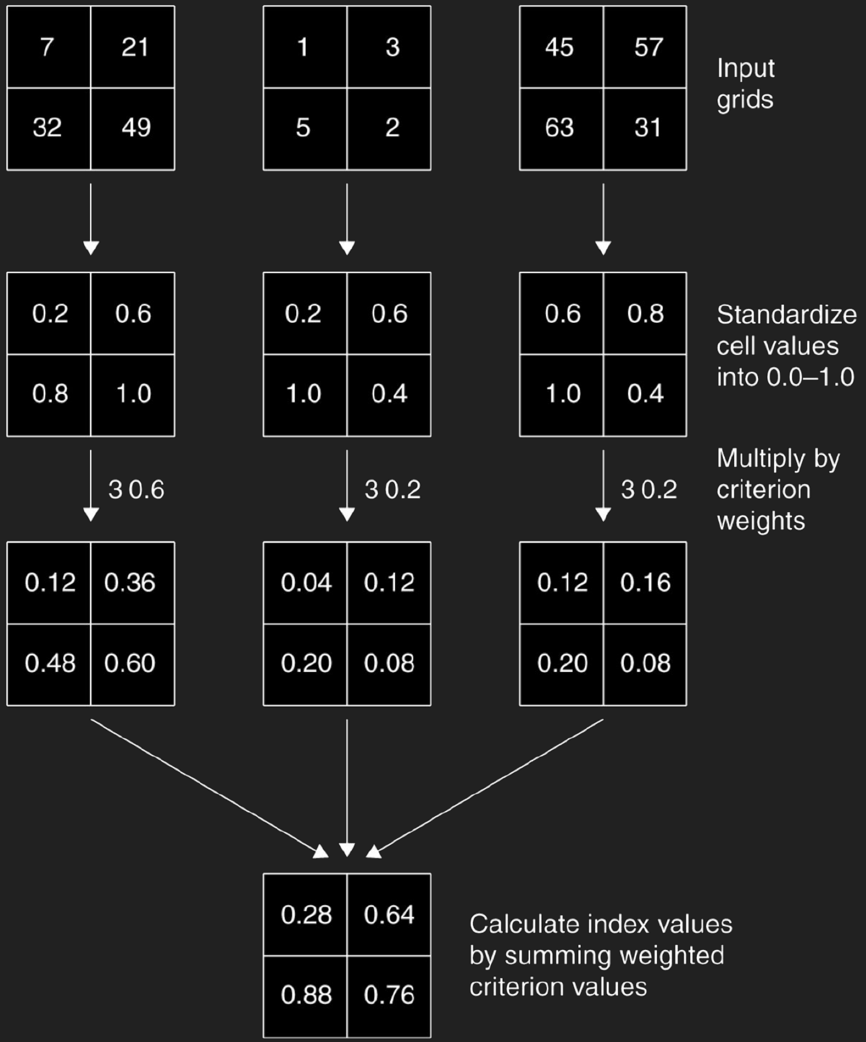
ID	S_V	T_V
1	1.0	0.4
2	1.0	0.1
3	0.2	0.1
4	0.5	0.1
5	0.5	0.4
6	0.5	0.8
7	0.2	0.8



(S_V * 0.4) + (T_V * 0.6)

Raster-Based Index Model

1. Standardize cell values
2. Multiply by criterion weights
3. Sum weighted criteria



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- Geographic Information Systems and Science, 2nd ed.
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- Geographical Information Systems: Principles, Techniques, Management and Applications, 2nd ed.
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