Applied GIS (GEOG 489)

Week 4: Suitability Modeling (Case studies)
Slides of this class: https://git.io/vDG0Q

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Recall: Basic steps of suitability modeling

1. Defining criteria
2. Mapping criteria
3. Standardize criteria
4. Assigning weights
5. Combining into final suitability map

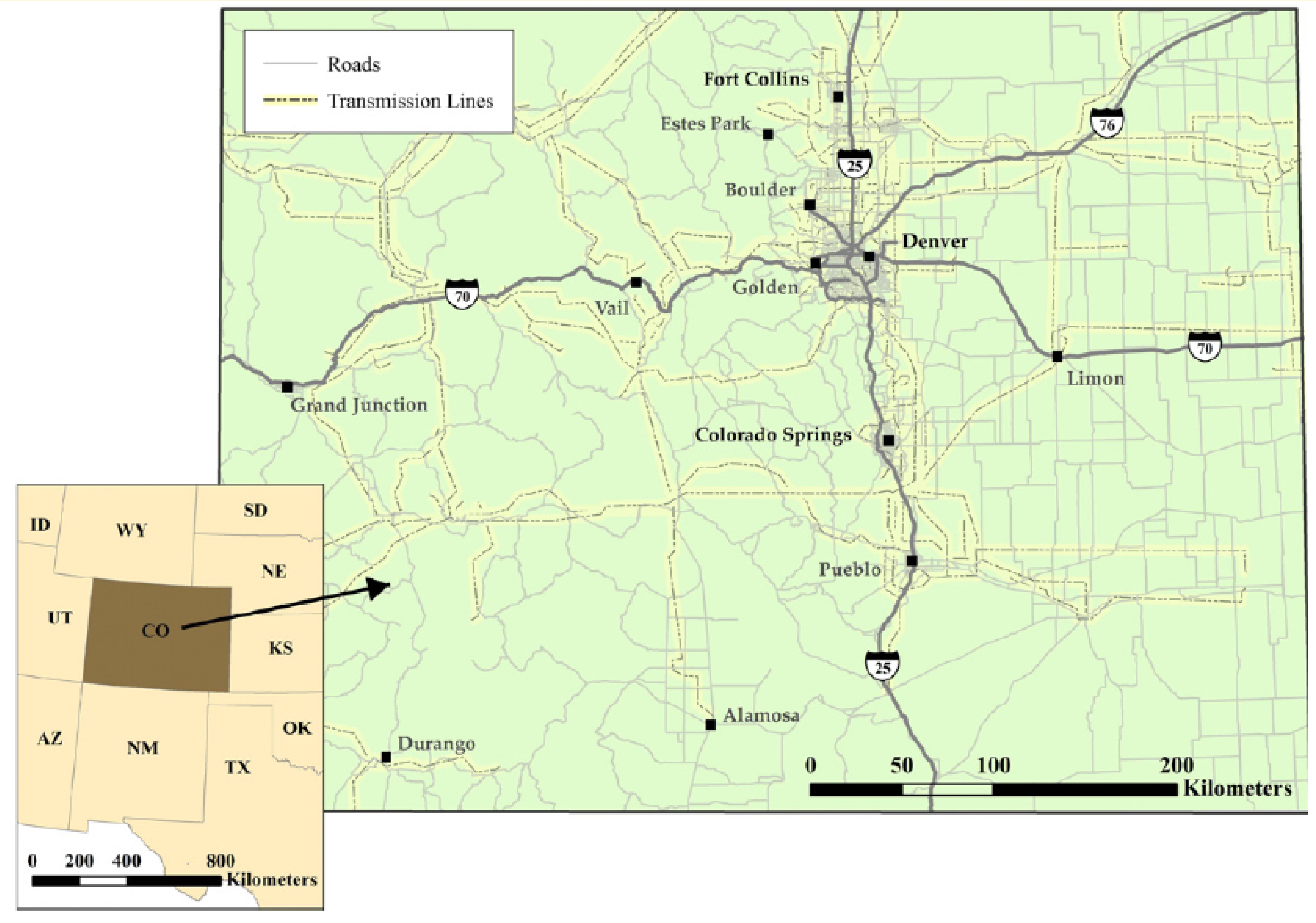
Example 1: Wind and solar farm

Janke, J. R. (2010). **Multicriteria GIS modeling of wind and solar farms in Colorado**. *Renewable Energy*, 35(10), 2228-2234.pdf

Objective

The objectives of this project are twofold: 1) explore which landcover classes have high wind or solar potential in Colorado based on existing National Renewable Energy Laboratory (NREL) data sets; and 2) identify areas are suitable for wind or solar farm development using multicriteria GIS modelling techniques.

Study Area (Colorado)



Defining Criteria

Variable	Ideal Conditions	Type of criteria
Wind Potential	NREL Class 7 (superb)	Discrete
Solar Potential	Maximize W/m^2/day	
Distance to Transmission Lines	Closer to Transmission Lines	
Distance to Cities	Far Away from Cities	Continuous
Population Density	Low Population Density per Block Group	
Distance to Roads	Close to Roads	
Landcover	Short Vegetation, Subdued, Stable Topography	Discrete
Federal Lands	Not in Federal Lands	Binary

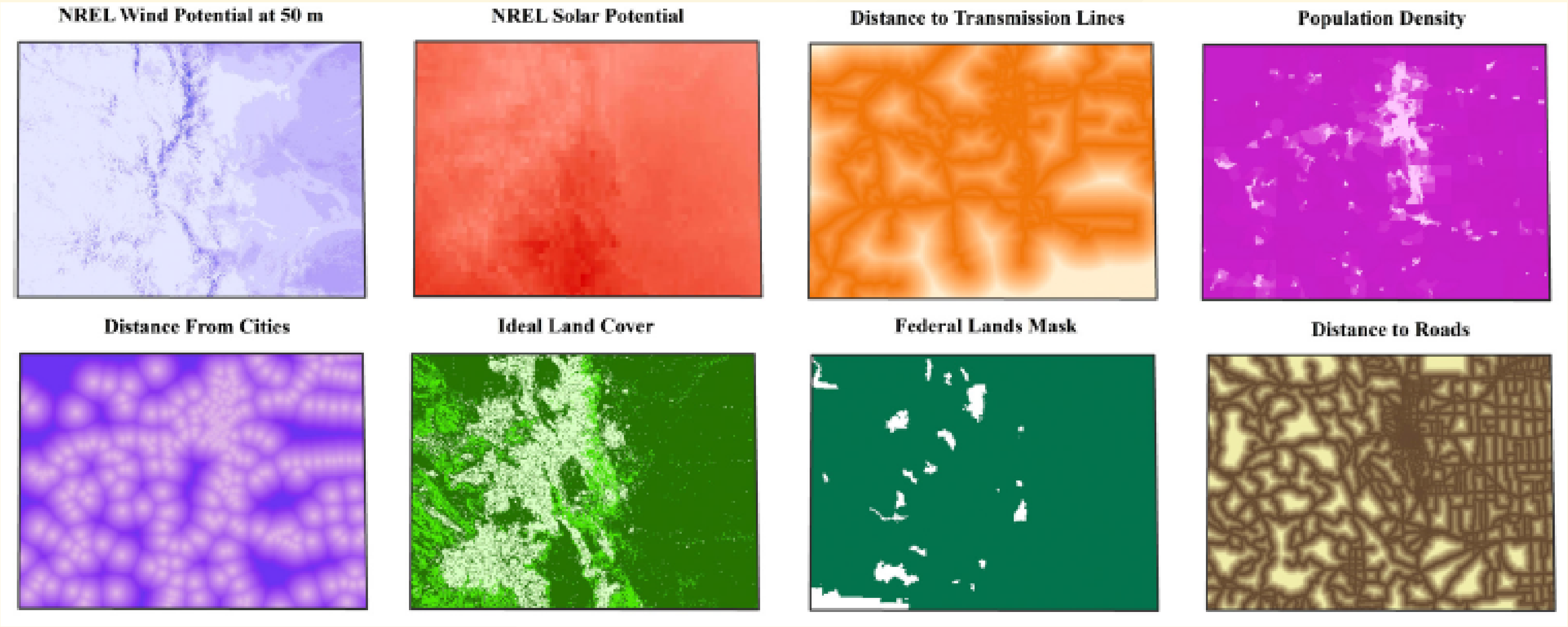
Identifying Data and Mapping Criteria

Variable	Type	Final Data	Type
Wind Potential	Grid	Categorical	Grid
Solar Potential	Grid	Continuous	Grid
Distance to Transmission Lines	Line	Continuous	Grid
Distance to Cities	Point	Continuous	Grid
Population Density	Polygon	Categorical	Grid
Distance to Roads	Line	Continuous	Grid
Landcover	Polygon	Categorical	Grid
Federal Lands	Polygon	Categorical	Grid

Authors' comment on raster and vector

Multicriteria analysis in a vector data model (discrete point, line, and polygon representations) often involves Boolean operators such as AND or OR [16]. An AND operator (intersection) can result in rigid solutions – a variable meets the criterion or it does not. An OR operator (union) is very liberal – results will be included even if a single variable meets the criterion. Multicriteria analysis in a raster data model (continuous grid-based representations) allows more trade-off among variables – a low score on criterion can be offset by a high score on another [16]. GIS data model selection can lead to different optimal solutions [16]. For the aforementioned reasons, most researchers prefer using a combination of data models to control the degree of substitutability among criteria.

Mapping Criteria



Standardize Criteria and Assign Weights

Variable	Possible Values	Weight
Wind Potential	[0.14, 0.29, 0.43, 0.57, 0.71, 0.86, 1.00]	3
Solar Potential	[0–1]	3
Distance to Transmission Lines	[0–1]	2
Distance to Cities	[0–1]	1
Population Density	Discrete Values Ranging from [0–1]	1
Distance to Roads	[0–1]	1
Landcover	[0.33, 0.67, 1.00]	1
Federal Lands	[0, 1]	1
	Standardized value	Weight

Final suitability score of wind farm

Final suitability score of solar farm

Example 2: Find suitable locations for wetland mitigation sites

Van Lonkhuyzen, R. A., LaGory, K. E., & Kuiper, J. A. (2004). **Modeling the suitability of potential wetland mitigation sites with a geographic information system**. *Environmental Management*, 33(3), 368-375.pdf

Study site: DuPage County, Illinois, USA

Criteria and weights

Table 1. Suitability scores and weights applied to variables in the GIS model

Variable	Weight	State	Suitability
Hydrology	3	Surface water (stream, pond)	1.00
		100-year floodplain	1.00
		Local topographic depressions	0.50
		Upland	0.10
Soil	3	Hydric soils (including water)	1.00
		Nonhydric soils	0.25
Historic condition	3	Historic wetland	1.00
		Historic depression	0.75
		All others	0.50
Adjacent vegetation	2	Forest	1.00
		Pine plantation	0.25
		Old field	0.75
		Wetland/open water	0.75
		Mowed lawn	0.25
		Disturbed	0.10
		Existing buildings, roads, etc.	0.10
Vegetation cover	1	Deciduous forest	0.00
		Pine plantation	0.00
		Old field (woody dominants)	0.50
		Old field (herbaceous dominants)	1.00
		Wetland/open water	0.00
		Mowed lawn	0.25
		Disturbed	0.10
		Existing buildings, roads, etc.	0.00
Land use	1	Open space	1.00
		Dedicated for development	0.25
		Existing buildings, roads, etc.	0.00
		Contaminated	0.00

Mapping Criteria

Equation used to combine criteria

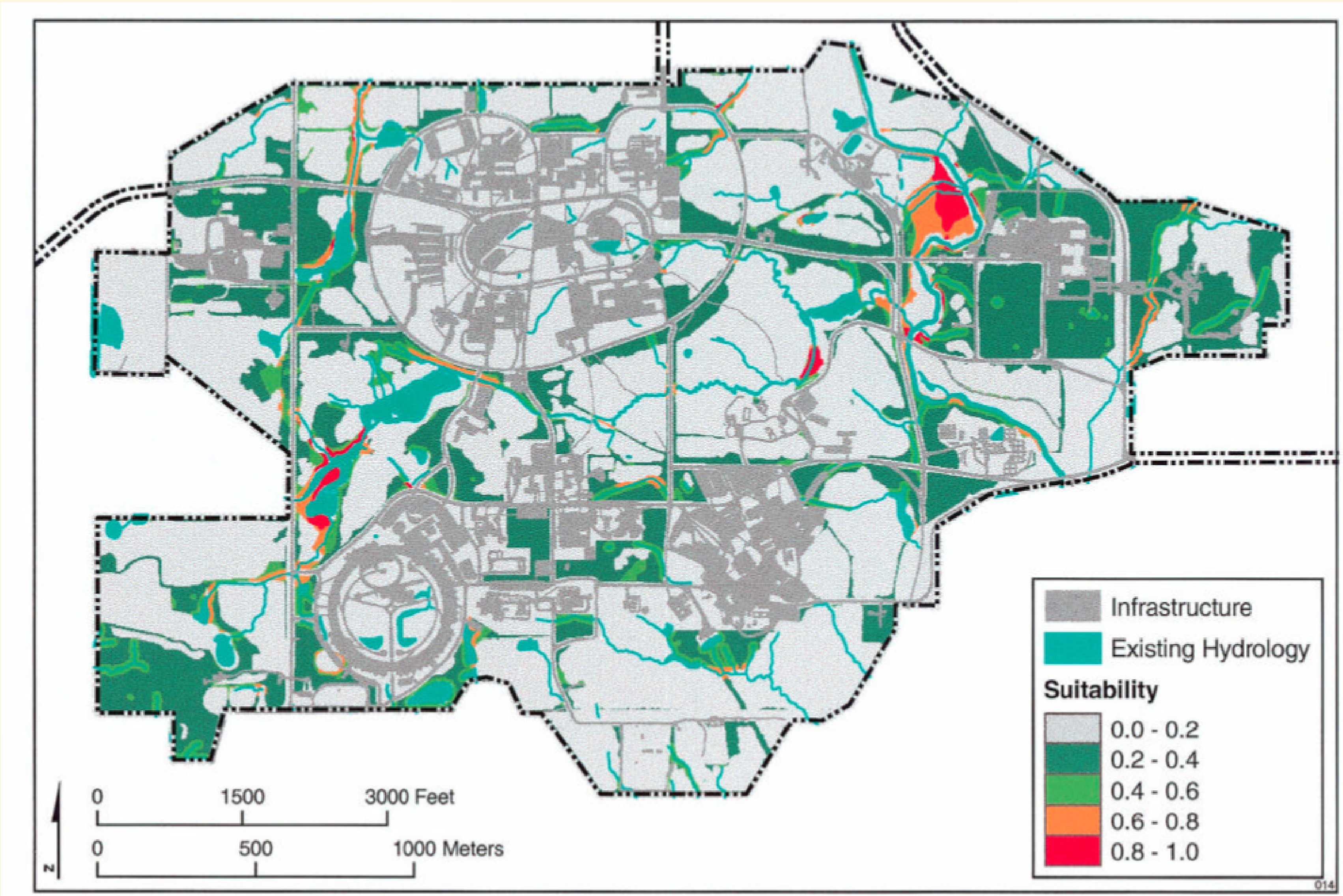
$$\text{Suitability} = \left(\prod_{i=1}^{n} \mathrm{SI}_i^{W_i} \right)^{1/\Sigma_i^n = 1^{w_i}}$$

where SI_i is the suitability index score for variable i and w_i is the weight given to variable i.

For our model,

$$\text{Suitability} = \mathrm{SI}_{\text{hydrology}}{}^{3}\mathrm{SI}_{\text{soils}}{}^{3}\mathrm{SI}_{\text{historic}}{}^{3}\mathrm{SI}_{\text{adjacent vegetation}}{}^{2}$$
$$\mathrm{SI}_{\text{vegetation cover}}\mathrm{SI}_{\text{land use}}{}^{1/13}$$

Final output



Question:

What is the major issue of the above analyses?

The linear weighted combination is too arbitary

- Subjective suitability score for each criterion
- Subjective weghts
- Subjective equation to combine criteria
- No empirical analysis
- No validation

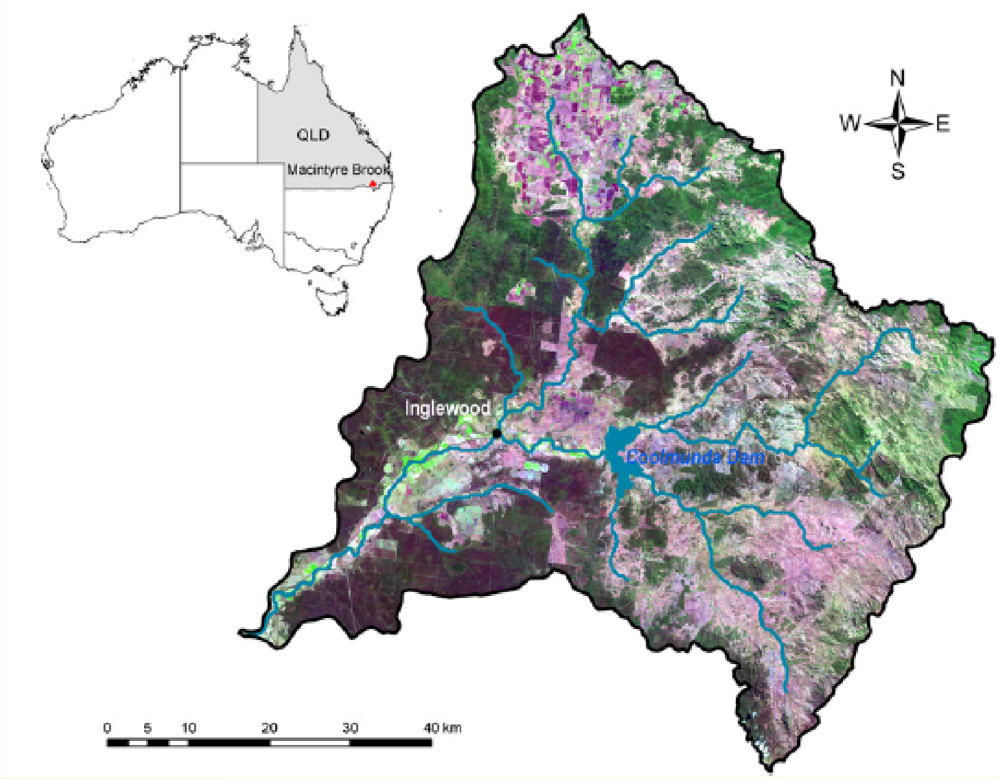
Example 3: Sensitivity Analysis

Test how the suitability map differs with different weights

Chen, Y., Yu, J., & Khan, S. (2010). **Spatial sensitivity analysis of multi-criteria weights in GIS-based land suitability evaluation**. *Environmental Modelling & Software*, 25(12), 1582-1591.[pdf]

Model to be tested

Suitability for irritated cropping landuse in Queensland, Australia

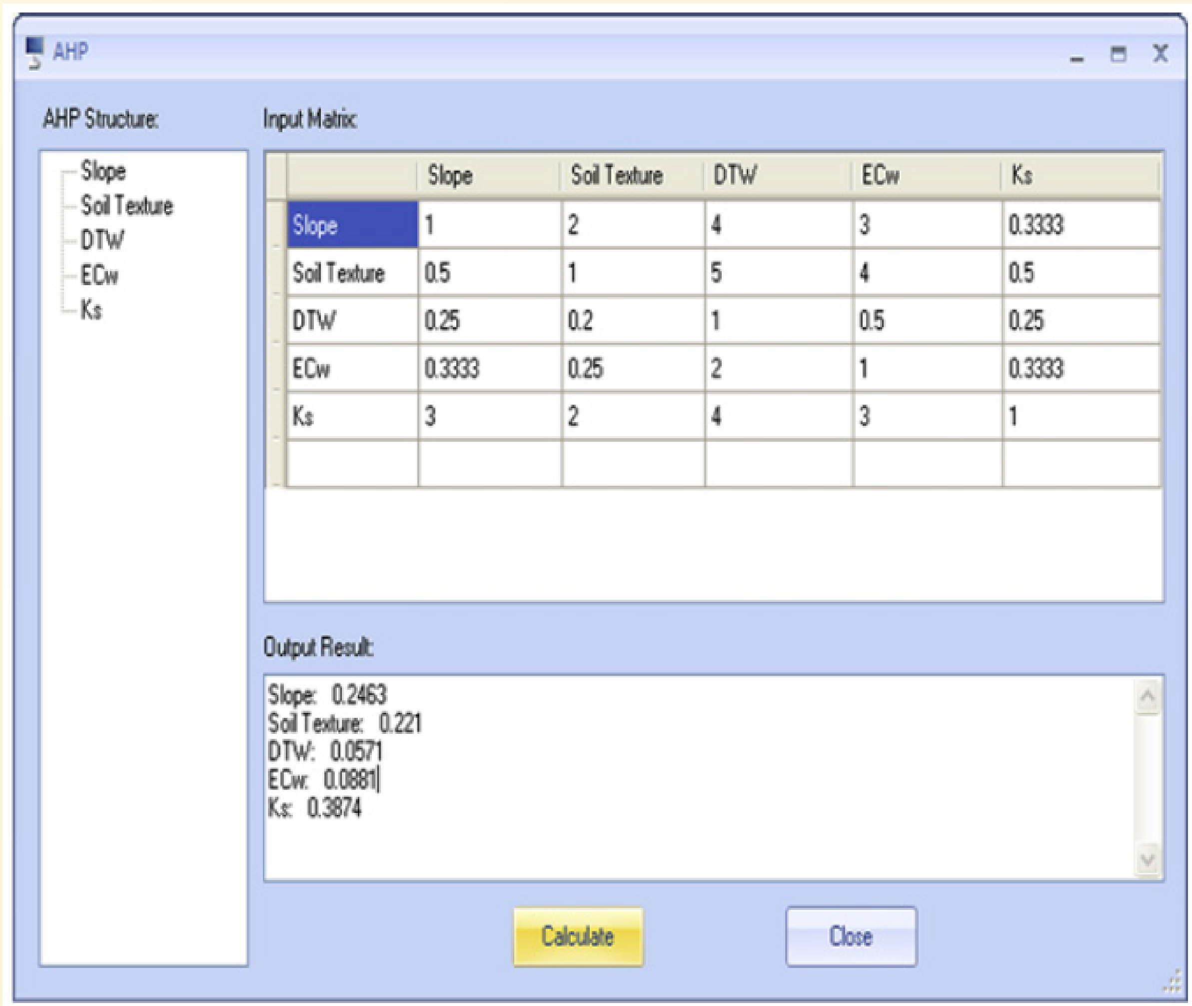


Criteria

- Rank suitability of each criteria

	Highly suitable	Moderately suitable	Marginally suitable	Unsuitable
Ks (m/d)	0.3–1	0.05–0.3 or 1–2	2–2.5	<0.05 or >2.5
S (%)	0–2	2–4	4–8	>8
ST	Fine to medium	Heavy clay	Coarse or poorly drained	Very coarse or shallow depth
DTW (m)	>4	3–4	2–3	<2
ECw (dS/m)	0–0.5	0.5–2	2–5	>5 (if depth <4m)

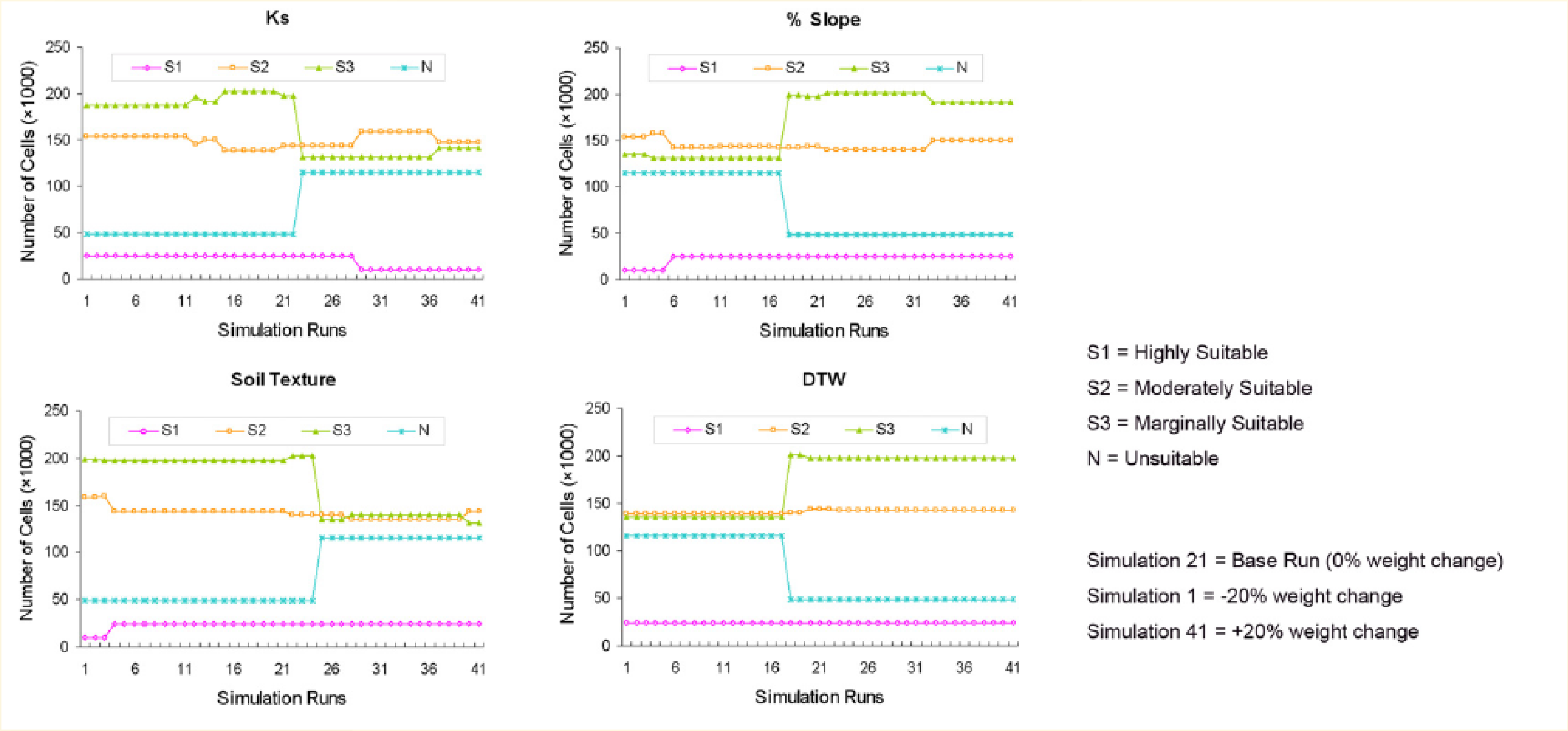
- Define benchmark wegiths using Analytical Hierarchy Process



	Slope	Soil Texture	DTW	ECw	Ks
Slope	1	2	4	3	0.3333
Soil Texture	0.5	1	5	4	0.5
DTW	0.25	0.2	1	0.5	0.25
ECw	0.3333	0.25	2	1	0.3333
Ks	3	2	4	3	1

Simulation by changing the weight of KS

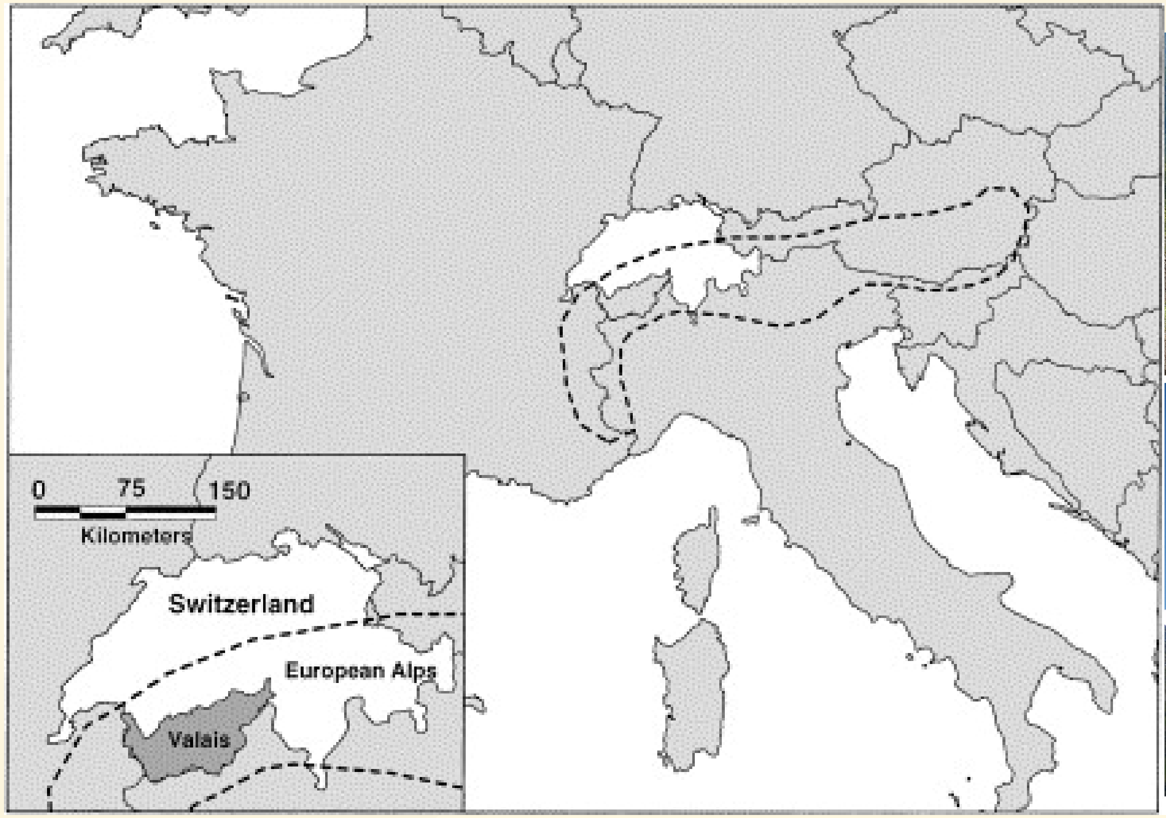
- Some tipping point can be found - suitability map changes significantly with only a small change of the weight



Example 4: Predict Wolf Habitat Suitability

Glenz, C., Massolo, A., Kuonen, D., & Schlaepfer, R. (2001). **A wolf habitat suitability prediction study in Valais (Switzerland)**. *Landscape and Urban Planning*, 55(1), 55-65.pdf

Study Area



Canton of Vailas, Switzerland

Criteria and data source

Table 2.
Data sources of the habitat variables

Habitat variable	Origin and resolution of data
Urban areas (%)	Land–use map (1992–1997), SFSO's GEOSTAT (hectometric raster)
Inhabitant density (Ind./km^2)	National census of the population 1990, SFSO's GEOSTAT (aggregation ha)
Arable lands (%)	Land – use map (1992/97), SFSO's GEOSTAT (hectometric raster)
Minimum of altitude (m a.s.l)	Topographical data, SFSO's GEOSTAT (hectometric raster)
Northwest exposure (%)	Topographical data, SFSO's GEOSTAT (hectometric raster)
Wild ungulate diversity index (WUDI)	Wild ungulate distribution map (Hausser, 1995), 1 km grid, Cantonal census of wild ungulates (1998), Fish and Hunting service (Valais)

Criteria Mapping

Data for the calculation of the wild ungulate diversity index were in **numerical and cartographical form** and have been processed for further analysis in GIS. **The habitat variables were calculated on a 4 km^2 grid**, in order to consider pronounced variations of the geo-morphological conditions in the study region, as well as its environmental and demographic peculiarities.

Building Equation

- An empirical study using logistic regression model
- Building relation (equation) between wolf presence and environmental variables

$$\mathrm{logit}(p) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n, \quad n = 10 \quad \text{and} \quad \mathrm{logit}(p) = \log\left(\frac{p}{1-p}\right)$$

resulting in

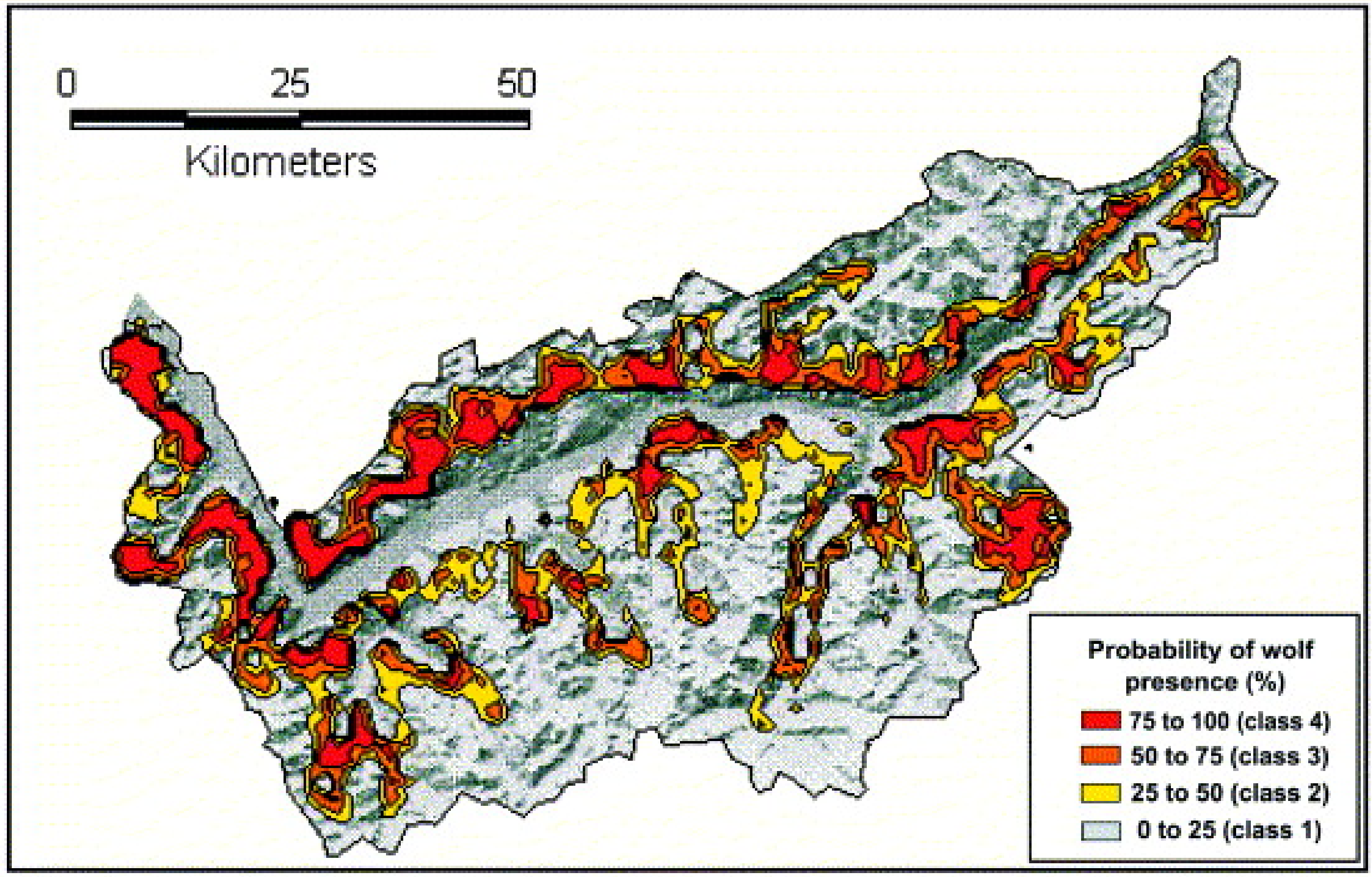
$$p = \frac{1}{1 + \exp(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n)}$$

Building Equation

Table 3.
Habitat variables with the regression coefficients

Habitat variable	Estimates β_i	Standard error	Wald statistic	*P*-value	*R*
Urban areas (%)	−0.6453	0.3340	3.7329	0.04	−0.0968
Inhabitant density (ind./km^2)	−0.0798	0.0255	9.8132	0.00	−0.2054
Arable lands (%)	−0.0986	0.0321	9.4505	0.00	−0.2006
Minimum of altitude (m a.s.l)	−0.0033	0.0014	5.6495	0.01	−0.1404
Northwest exposure (%)	−0.0289	0.0151	3.6469	0.04	−0.0943
Wild ungulate diversity index	3.4865	0.9643	13.0722	0.00	0.2446
Constant (β_0)	3.9664	1.2527	10.0248	0.00	–

Estimating Wolf Presence Probability



With empirical analysis, the equation and weights are not subjective.

Question: Any other issues with this approach?

Logistic regression still assumes a linear relation between suitability and criteria, which is not usually true in the real-world.

Some thinkings

- What are the difference of using vector/raster in suitability modeling, and what are the pros and cons.
- What are the major issues in suitability modeling? What are the solutions?

Continue Lab Exercise 2:

Download the assignment from **https://git.io/vDeAZ**

Submission due Feb. 17