# Applied GIS (GEOG 489)

**Week 4: Suitability Analysis (Case studies)**
Slides of this class:

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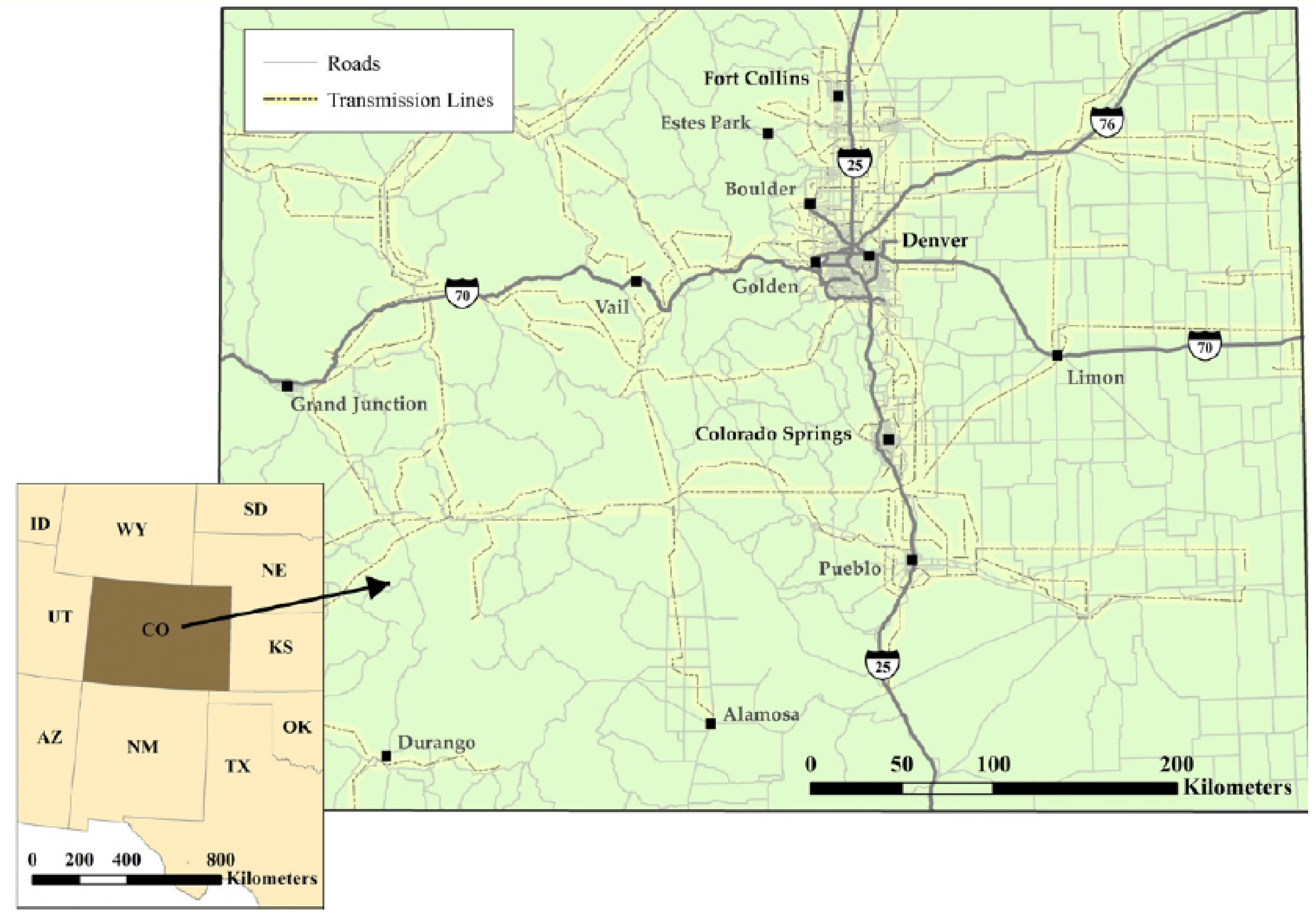
# Example 1: Wind and solar farm

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



Roads
Transmission Lines
Fort Collins
Estes Park
Boulder
Denver
Golden
Vail
Grand Junction
Limon
Colorado Springs
Pueblo
Alamosa
Durango
70
76
25
0 50 100 200
Kilometers
ID
WY
SD
NE
UT
CO
KS
AZ
NM
TX
OK
0 200 400 800
Kilometers

# Finding 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 |

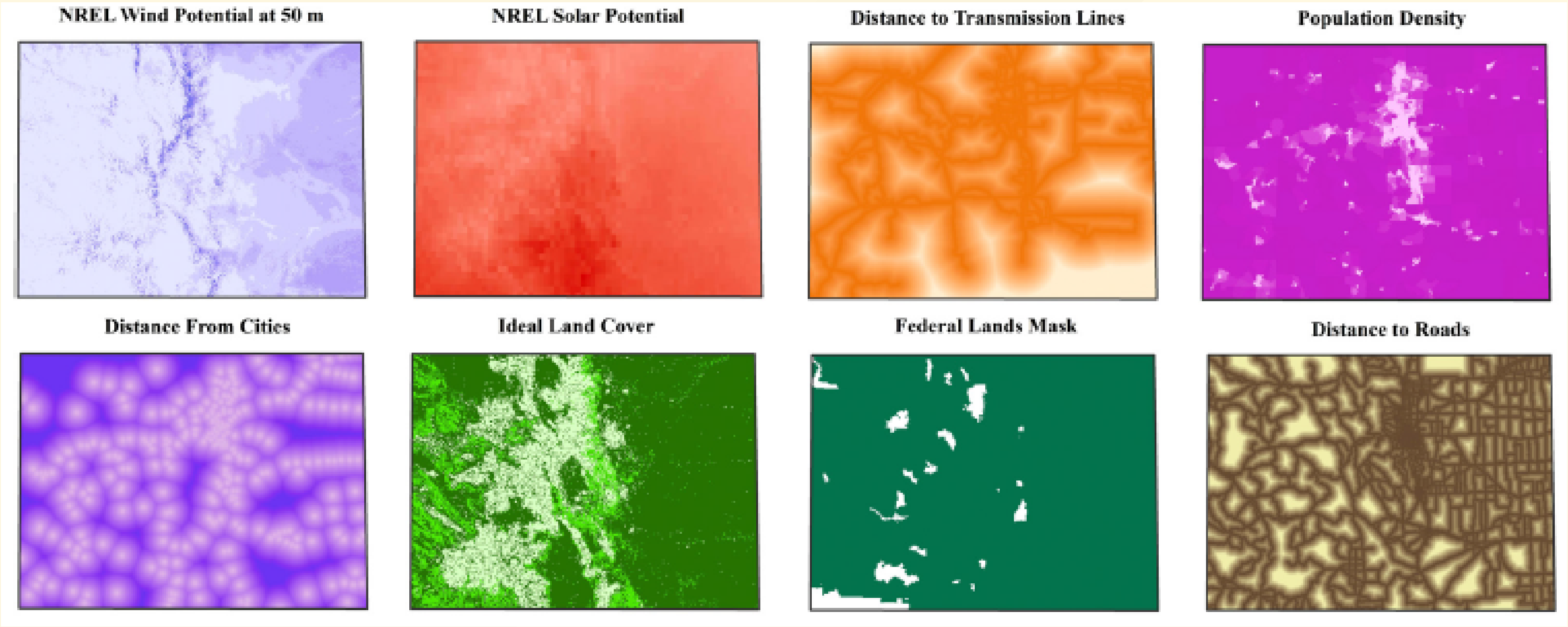
# Identifying Data and Mapping Criteria

| 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.

# Mapped 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.

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

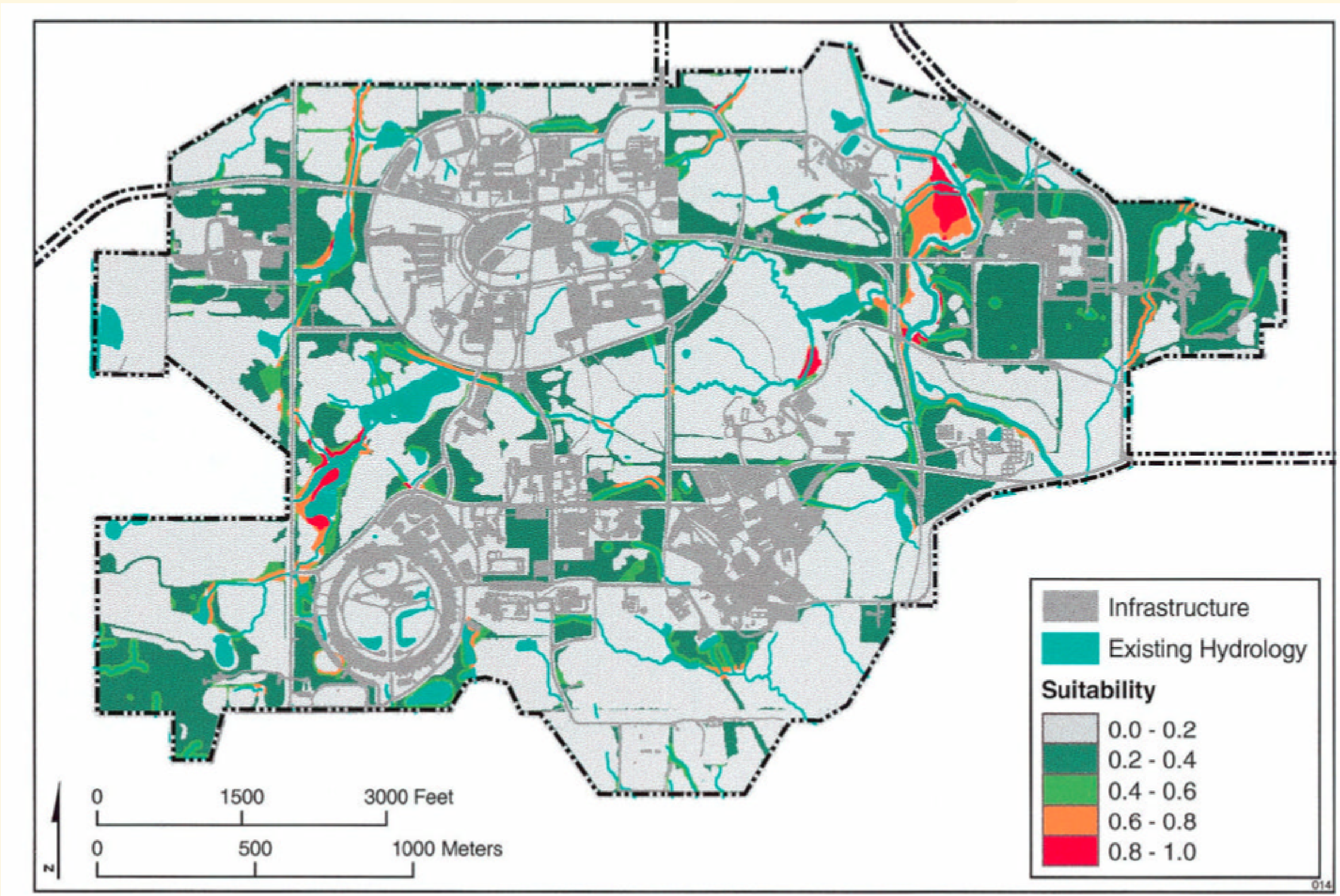
$$\text{Suitability} = \left( \prod_{i=1}^{n} \mathrm{SI}_i^{W_i} \right)^{1/\Sigma_i^n = 1^{w_i}}$$

where $\mathrm{SI}_i$ 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?

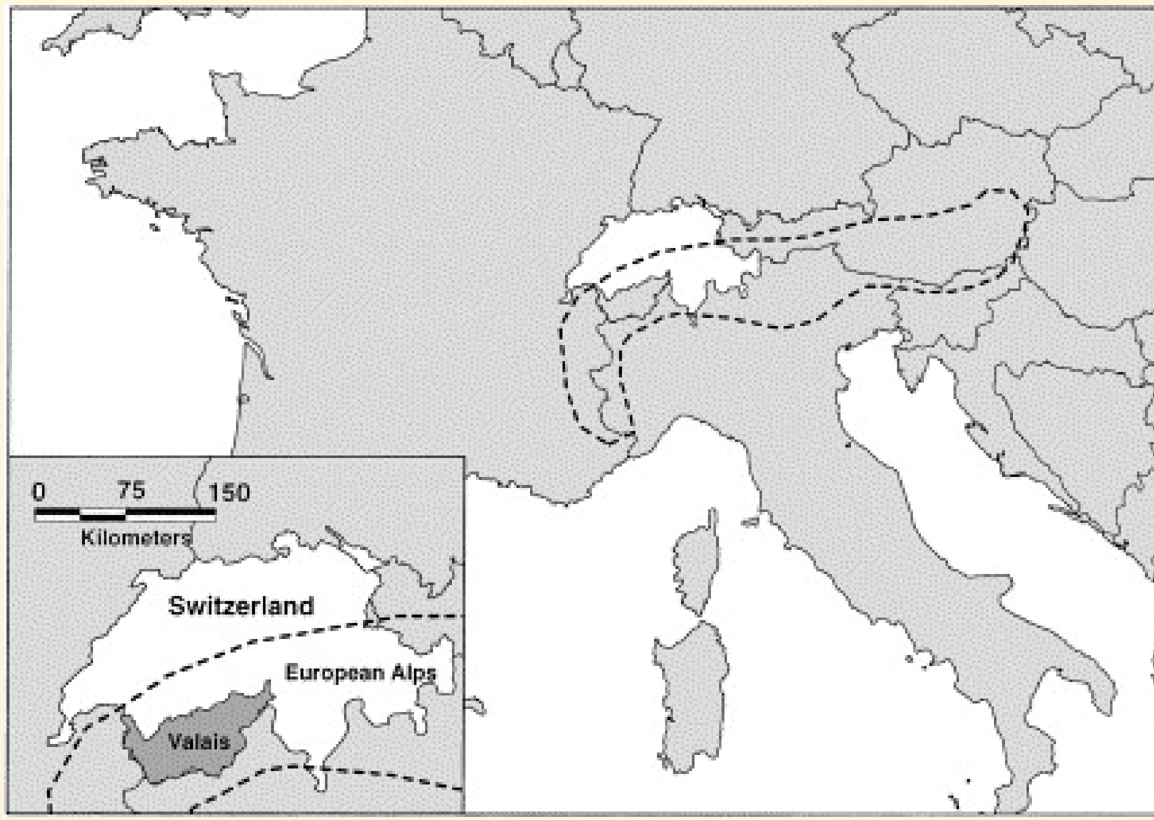
# The linear weighted combination is too arbitary

- Arbitary equation
- Arbitary/subjective weights
- No empirical analysis
- No validation

# Example 3: 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.

# Study Area




Canton of Vailas, Switzerland

# List 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 km2 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
- Building relation (equation) between wolf presence and environmental variables

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

resulting in

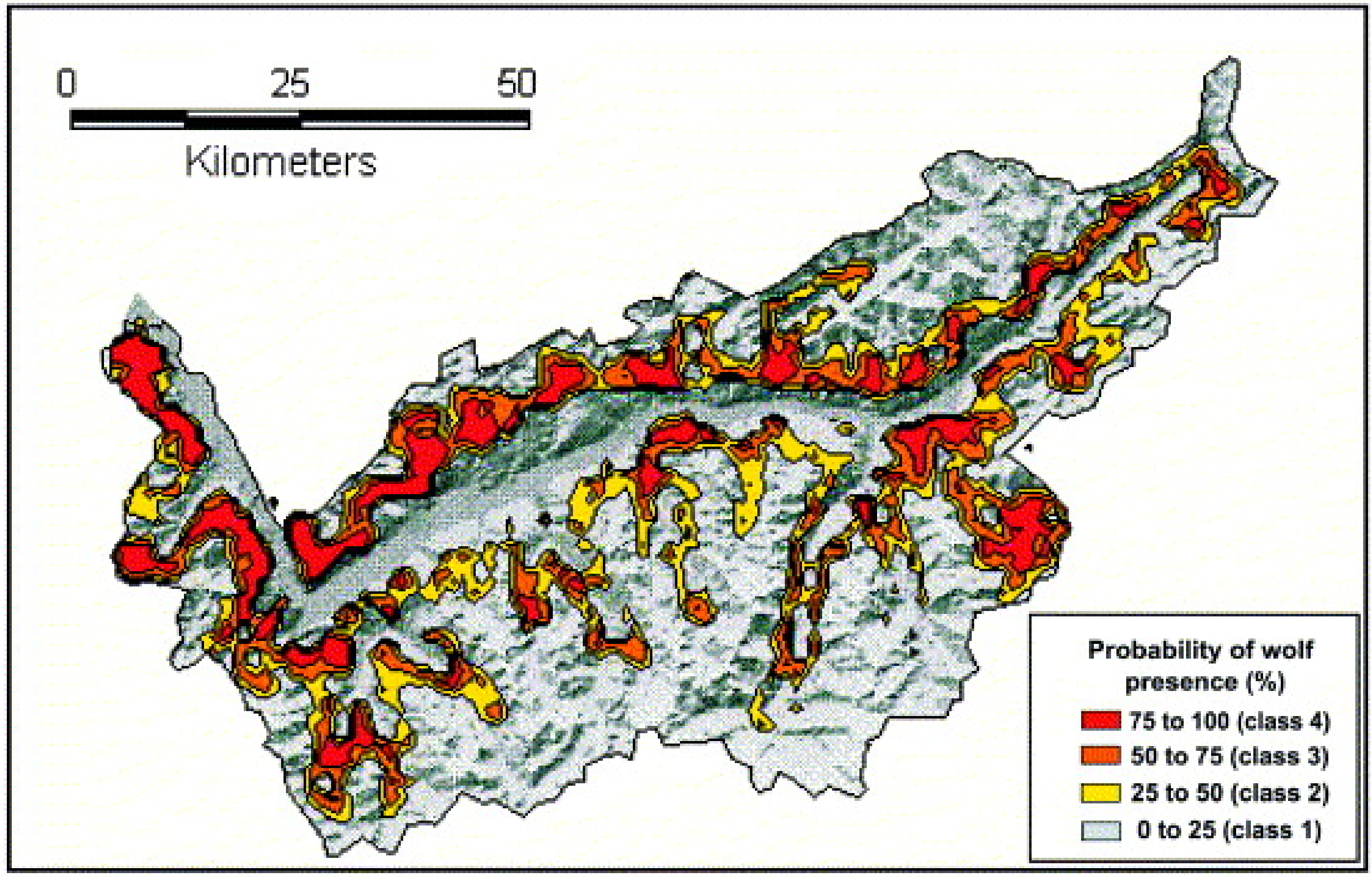
$$p = \frac{1}{1 + \exp(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n)}$$

# Building Equation

Table 3.
Habitat variables with the regression coefficients

| Habitat variable | Estimates $\beta_i$ | 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 ($\beta_0$) | 3.9664 | 1.2527 | 10.0248 | 0.00 | – |

# Combining Criteria using Logisitic Regression Model



**With empirical analysis, the equation and weights are not arbitary.**

**Question: Any other issues with this approach?**

**Logistic regression still assume a linear relation between suitability and criteria, which is not usually true.**

# After class thinkings

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

# Lab Exercise 2:

Please download the assignment from
**https://git.io/vDeAZ**

You will do the exercises in this lab and next week's lab (no more assignment next week).

Submission due Feb. 17