Comparison of multi-criteria decision making methods for selection of afforestation sites

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Problem statement

• Where to plant **pine** in order to achieve **optimal land performance** after 30 years?

• Optimization in terms of conflicting criteria (land performance attributes):
  1. Water runoff at surface
  2. Sediment production
  3. Soil Organic Carbon (SOC)
  4. Biomass Organic Carbon (BOC)
  5. Economic income

• Land performance attributes
  o Cumulated over 30 years
  o On-site
Study region

Tabacay river basin (southern Andes of Ecuador)
Problem statement

- Decision alternatives:
  Areas with homogeneous performance → land performance units
- Where ? ↔ In which land units ?
- Expected output:
  Ranking of land units, from most (rank 1) to least (rank 20) suitable
Multi-Criteria Decision Making Methods (MCDM)

1. ELECTRE III
2. PROMETHEE II
3. Analytic Hierarchy Process (AHP)
4. Compromise Programming (CP)
5. Stochastic Multi-criteria Acceptability Analysis (SMAA-2)
6. Iterative Ideal Point Thresholding (IIPT)
ELECTRE III (Roy, 1971)

- Suitability of alternatives is determined by outranking relationships
- Outranking is determined by:
  - Concordance: For a certain number of attributes, one alternative is preferred to another
  - Discordance: There is no attribute for which one alternative is considered much more suitable than another
- Alternative $i$ fulfills thresholds for concordance and discordance with respect to alternative $j \rightarrow i$ outranks $j$
- Parameters:
  - Preference threshold
  - Indifference threshold
  - Veto threshold
  - $s(\lambda)$
  - One weight for each criterion (relative importance)
PROMETHEE II (Brans and Vincke, 1985)

\[ \text{pref}_{ij} = f(\text{diff}_{ij}) \]

Parameters:
- Preference function \( f \)
  - Usual-criterion
  - Quasi-criterion
  - Linear
  - Gaussian
  - Etc
- Depending on the function additional parameters may be necessary
- One weight for each criterion
Analytic Hierarchy Process (AHP) (Saaty, 1977)

• Two-level hierarchy:
  o First level: Criteria
  o Second level: Alternatives

• Pairwise comparison
  o Express preference with a number from a scale
    • 1: equally important
    • 9: extremely more important
  o Preference values are processed to obtain a score for each alternative

• Parameters:
  o Preference: number between 1 and 9
  o One weight for each criterion
Compromise Programming (CP) (Yu, 1973)

• Ideal Point:
  o Hypothetical alternative
  o Optimal value for each attribute

• Alternatives are ranked according to distance to ideal point

• Parameters:
  o Distance function
  o One weight for each criterion
Stochastic Multi-criteria Acceptability Analysis (SMAA-2) (Lahdelma et al., 1998)

- No user-defined parameters
- Can deal with uncertainty on the data
- Output:
  - Probability that a ranking position is assigned to an alternative
  - For every combination of alternative-ranking
- No user-defined parameters are required
Iterative Ideal Point Thresholding Method (IIPT) (Gilliams et al., 2005)

1. Determine ideal point
2. Determine thresholds with respect to ideal point
3. If alternative fulfills thresholds
   • Ranking position according to iteration step is assigned
4. Thresholds are “relaxed”
5. Repeat 3 and 4 until every alternative has been ranked or until the maximum number of iterations has been reached

Parameters:
• Maximum number of iterations
• One weight for each criterion
Results

Legend

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ELECTRE III

PROMETHEE II

AHP

CP

SMAA-2

IIPT
## Results

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<th>CP</th>
<th>SMAA-2</th>
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Conclusions

• Consistency in resulting rankings despite differences in nature of methods:
  o MCDM: not decisive factor
  o User has freedom to choose MCDM:
    • Ease of use
    • Reduced complexity
    • E.g. SMAA-2 may be preferred since it does not require the user to set parameters

• Parameters used for each method have impact on the output
  o Fine tuning
  o Sensitivity analysis
Options for further work

- Off-site in addition to on-site criteria, e.g. sediment at the outlet of a river basin
- Budget restrictions
- Distribution of a number of tree species over a region: How?
- Temporal dimension, afforestation effects occur gradually: When? and For How Long?