Land cover and spatial heterogeneity
Place-based assessments of ecosystem services

Ulrich Walz & Ralf-Uwe Syrbe
Outline

1. Hypotheses

2. Spatial relations – service providing and benefiting areas

3. Spatial units – landscape classification

4. Structure metrics for service evaluation

5. Methodical issues

6. Conclusions
1. Hypotheses

- A place-based assessment approach for evaluating of ecosystem services is necessary
- Area’s heterogeneity is a key to discover the process pattern in a landscape
- The quantification of structure metrics should be included into the methodical framework of landscape services
- Several methods already exist using structure metrics for landscape assessment
- Precondition is a place-based spatial database
2. Spatial relations – service providing and benefiting areas

- **ESP / SPU** – approach: taxonomic aspect: ecosystem service providers and units
  - species, functional groups, populations, individuals

- **Geographic aspect**: habitat of service providing units, residence of service beneficiary and the space between
  - Service providing area (SPA)
  - Service connecting area (SCA)
  - Service benefiting area (SBA)
Spatial relationships

1. ‘in situ’: SPA and SBA are identical, the service is provided and the benefits are realized in the same area, i.e. landscape scenery

2. ‘omni directional’: SBA extends SPA without any directional bias, i.e. pollination in agriculture

(According to Fisher et al. 2009)
Spatial relationships

3. ‘directional’ - slope depending: SBA lies downslope (downstream) to SPA, the service is realized by gravitational processes, i.e. cold air, water, avalanche, landslide

4. ‘directional’ – without strong slope dependence: SBA lies ‘behind’ the SPA relating to higher-ranking directional effects, i.e. drinking water provisioning

(According to Fisher et al. 2009)
3. Spatial units

The following spatial units are suitable as basis for ecosystem services assessment if the services are:

1. generated by a specific ecosystem resp. population:
   - habitat of that population

2. based on selected resources or abiotic processes:
   - natural unit with the given resource
   - effect area of that process

3. depending on certain site characteristics:
   - land unit with similar spatial relations
   - land use practices and composition

4. rooted in history and culture:
   - cultural heritage landscape (elements)
Example ‘in situ’ relation: Appreciated scenery

**Diversity** Calculation the amount and variety of landscape elements

**Peculiarity** Expert knowledge about the uniqueness and historic continuity of structure and outstanding elements

**Beauty** Appreciation of an „ordinary average observer“ (no expert!)
Example ‘in situ’ relation: Appreciated scenery

- Areas with similar use or characteristic land use mosaic
- Division of main surface types (valley, slope, plateau)
Example ‘omni directional’ relation:
Biotope network

Source: Hoffmann et al. 2002
Example ‘directional’ - slope depending relations: Flood regulating service in Saxony Weisseritz Catchment
Example Flood regulating service in Saxony

Legend

Flood regulating service
- Benefiting areas
- Connecting areas
- Providing+benefiting
- Providing areas
- Watershed
Example ‘directional’ relation – without strong slope dependence:
Drinking water provisioning
Baden-Württemberg

Source: http://www.lw-online.de/
## 4. Structural metrics for assessment

<table>
<thead>
<tr>
<th>Service</th>
<th>Process</th>
<th>Structure metric</th>
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<tbody>
<tr>
<td>Groundwater recharge</td>
<td>above and underground water movement</td>
<td>roughness, surface orientation, other relief types</td>
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<tr>
<td>Fodder and fertilizer</td>
<td>livestock drive</td>
<td>pastoral paths</td>
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<tr>
<td>Protection against snowdrift, storm</td>
<td>wind retarding</td>
<td>roughness, edge contrast</td>
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<tr>
<td>Erosion prevention</td>
<td>wind /water retarding and water infiltration</td>
<td>edge density and contrast, mesh size, slope length</td>
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<tr>
<td>Flood prevention</td>
<td>runoff, retarding, retention, infiltration</td>
<td>roughness, stream characteristics</td>
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<tr>
<td>Climate regulation (cold / fresh air)</td>
<td>gravitational air movement, air purification / renewal</td>
<td>slope length, edge contrast, roughness, leaf area index</td>
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<tr>
<td>Avalanche prevention</td>
<td>retarding of snow</td>
<td>slope length, edge contrast, roughness</td>
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<td>Pollination, pest control</td>
<td>animal movement</td>
<td>biotope density</td>
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<td>Stream water purification</td>
<td>microbial activity, chem. oxidation</td>
<td>stream characteristics</td>
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<tr>
<td>Housing quality</td>
<td>visual composition</td>
<td>proximity to wood, water, nature</td>
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<tr>
<td>Appreciated scenery</td>
<td>visual composition, observer psychology</td>
<td>diversity, edge density, proximity to sights and nature</td>
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<tr>
<td>Recreation activities</td>
<td>visitor movement</td>
<td>path network, landscape’s accessibility</td>
</tr>
</tbody>
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Landscape metrics I: composition

- **Point density**: number of landscape elements per area
  - different element types, e.g. big plants (scenery), small wet holes, deadwood (both habitate quality)

- **Length density**: length per area
  - road / path network, flowing waters, hedges, stone walls, tree lines
  - special case: edge density, e.g. edge of wood / waterside (scenery)

- **Proportion of preferable landscape elements**
  - historic vs. industrialized landscape, regional typical vs. common elements (scenery: peculiarity)
  - free space vs. built area within towns (bioclimatic regulation)
  - degree of sealed surface and built area (regulation demand: SBA)

- **Leaf area index**: total leaf area per ground area
  - vitality, energy and gas exchange of vegetation stocks
Landscape metrics II: configuration

- Diversity: variability of phenomena
  - basis for scenery assessment
- Proximity: to wood, water, nature protected areas
  - determine the housing quality by hedonic models
- Contrast: different height or potential differences of adjacent land elements – completing the edge density
  - indicators for wind erosion prevention
  - substitute for diversity measures (regarding scenery)
- Core area and fragmentation: network analyses of roads and paths
  - accessibility and habitat suitability of landscape
- Shape metrics: i.e. effective hectare width (ratio between length and width of acre fields)
  - cultivation by least effort regarding energy and driveway
Landscape metrics III: 3-D

- Roughness of surface and vegetation
  - retards material fluxes creating a turbulence boundary layer

- Surface orientation
  - solar radiation: measure for energy balance
  - to the direction of mass movements: measure mass turnover

http://www.ioer.de
Ulrich Walz, Ralf-Uwe Syrbe, 08.06.2010
Landscape metrics III: 3-D

- Effective slope length: acceleration of gravitational induced movements
  - positive: fresh air supply to cities
  - negative: soil erosion, long and steep slopes should be subdivided
  - degree of sealed surface and built area (regulation demand: SBA)

- Number of vegetation layers
  - Biomass, habitat function

- Average number of storeys in built area
  - need for bioclimatic regulation: SBA
5. Methodical issues
Steps of a framework

1. Determination of the spatial and temporal structure of the landscape according to the demanded services
   a. Differentiating and delineating SPA/SBA, remote areas: SCA
   b. Data inquiry: ecosystems, resources, structures, trends, time performance

2. Determination of potential services
   − area, mass and energy balances and risk estimations
   − act as proxy indicators for the later monetary evaluation

3. Determination of actual services based on land use
   − Including a monetary evaluation if needed
Assessment methods

**Large scale**

- **Total area approach**
  
  Assessment of heterogeneous units in total based on regionalised data / methods

  → Thematic delimited spatial units

- **Subarea approach**
  
  Disaggregating into essentially different subareas with subsequently aggregating of results

  - Subareas decidedly located
  - Subtypes (poss. relatively located)

  → Intersections → Characteristic traits

**Small scale**

- **Single patch approach**
  
  Isolated consideration of smalls roughly homogenous spatial elements with aggregation of the results

  → Grids, hexagons, points → Smalles common geometrie
Gradient based analysis

- Use of moving window analysis methods

Source: Lutze & Schultz 2002
6. Conclusions

- Area’s heterogeneity can be addressed by landscape metrics
- Special landscape metrics are useful for different area types (SPA – SCA – SBA)
- Spatial units are useful basis for evaluation of ecosystem services
- Selection and delineation of spatial units depends on processes
Thank you for your attention!

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