Design principles for successful nature based solutions for healthy, climate resilient cities

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Requirements for successful design of NBS

Aims and ambitions

- Healthy Urban Living
- Climate adaptation

Required for design

- Insight in effectiveness of measures
- Design principles
- Interactive design support tools
- Insight in local critical parameters
Insight in effectiveness of green measures & design principles

Mechanisms Effectiveness

- Interceptior
- Infiltration
- (root uptake and transpiration)
Interactive design support tools

Adaptation Support Tool

1. Draw measure (e.g. green roof)

2. Effect calculated for water storage and temperature
**Critical parameters: Water dependence**

**Stepwise assessment framework**

1) **Inventory of relevant ecosystem services of GI**

Table.

2) **Assessment of the dependence on water quality and quantity for ecosystem service delivery**

Table & literature

3) **Assessing water availability**

Water balance model

<table>
<thead>
<tr>
<th>Ecosystem services</th>
<th>Effectiveness limited by</th>
<th>Quantity</th>
<th>Quality</th>
<th>Timing</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature regulation (cooling) through:</td>
<td>- no</td>
<td>- yes</td>
<td>- no</td>
<td>Water needed for evapotranspiration in summer, in particular during hot &amp; dry spells</td>
<td></td>
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<tr>
<td>- shadow</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- evapotranspiration</td>
<td></td>
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<tr>
<td>- heat exchange</td>
<td></td>
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<tr>
<td>Storm water runoff mitigation through:</td>
<td>- no</td>
<td>- yes</td>
<td>- no</td>
<td>Slowdown of discharge desirable during heavy rain (intensity and duration) to prevent sewer overflow and flooding</td>
<td></td>
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<tr>
<td>- interception</td>
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<tr>
<td>- infiltration</td>
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<tr>
<td>- surface storage in green spaces with low surface level</td>
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<tr>
<td>Air quality regulation through</td>
<td>- no</td>
<td>- yes</td>
<td>- no</td>
<td>Services by deciduous vegetation altered by season (presence of leaves)</td>
<td></td>
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<tr>
<td>- influence on air circulation</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>- filtering air pollutants</td>
<td></td>
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<tr>
<td>Noise reduction through</td>
<td>- no</td>
<td>- yes</td>
<td>- no</td>
<td>Services by deciduous vegetation only delivered during spring and summer</td>
<td></td>
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<tr>
<td>- noise reduction</td>
<td></td>
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<tr>
<td>- reduced perception when noise source visually camouflaged</td>
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</tbody>
</table>

*Shadow function only affected when tree loses leaves due to severe drought or raising groundwater*. Drought limits evapotranspiration; especially grass susceptible to drought.

*Interception only affected when tree loses leaves due to severe drought or raising groundwater*. In dry situation (summer): hydrophobic soil hampers infiltration Under very wet conditions (high groundwater table): limited or no storage capacity Quality of the storm water could make direct infiltration undesirable although treatment by soil filtration is generally sufficient.

*Influence on air circulation (either positive or negative) and particulate matter capture altered when tree loses leaves due to severe drought or raising groundwater*. Drought or very wet conditions may reduce the vegetation’s effectiveness for absorption of gasses through the stomata of vegetation (they close).

*Noise reduction only affected when tree loses leaves due to severe drought or raising groundwater*. 
Case study Utrecht Fair and Central train station area

Most critical:

- Impact of drought on temperature regulation (cooling) via evapotranspiration
- Impact of very wet conditions, when ponding occurs, on recreation potential of green spaces.
- High groundwater tables limit the role of green spaces in stormwater runoff mitigation due to the reduced capacity of the soil to drain and store water.
Exploring drought in Utrecht

Impact of drought on cooling

![Graph showing potential and actual transpiration over months]

Potential transpiration
Actual transpiration

Month:
Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec

Transpiration (mm/month):
0, 20, 40, 60, 80, 100, 120

Deltare
Publications and tools:
www.adaptivecircularcities.com/downloads
Exploring drought in Utrecht

Visual observations water stress  Water balance of the city  Calculated water stress

Impact of drought on cooling  Effectiveness measures to reduce water stress

- Potential transpiration
- Actual transpiration

- Disconnection roofs
- Water retention (roof)
- Green roofs intensive
- Green roofs extensive
- More pavement
- All pavement permeable
- Semi-permeable pavement to permeable
- More permeable pavement to permeable
- More vegetation (from 33% to 40%)

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