Green Roofs Technologies - Targeting Retention

Contents of the presentation
(1) Introduction
(2) Decentralized Stormwater Management – Role of Green Roofs
(3) Optimize Green Roofs for more retention
(4) Green Roofs in Urban Stormwater M. - Research at HCU
Research – Prof. Dickhaut and Team

- Contribution „Water Sensitive Urban Design“ in EU-Project SWITCH - Water Management for Tomorrows Cities; since 11-2009

- Contribution „Water Framework Directive“ in EU-Project „SAWA - Strategic Alliance for integrated Water management Actions“; since 2008-2013

- Contribution „Decentralized Stormwatermanagement Management“ in Project KLIMZUG-NORD, BMBF-Förderung: „Adaption to Climate Change in the Metropolitan Region Hamburg“; 2009-2014

- Contribution „Urban and landscape planning“ in Project RISA (Rainwater Infrastructure Adaption Hamburg), since 2010,


- **Greenroofs - impact in stormwatermanagement (2010); BMUB since 2015**

- Climate Adaption of urban trees; BMUB; since 2015

- Climate Adaption in dense urban areas – ex. Hamburg; BUE-Hamburg, since 2915
Research Green roofs - current + former projects

Green roofs
„guide about green roof promotion“
• HCU and DDV e.V. until end of 2010, Funding DBU

“Hamburg Green Roof Strategy”
1. function of green roofs in the water management
2. Evaluation of instruments
• Funding BMUB, since 2015

Staff: Elke Kruse, Michael Richter
International green roof research – literature review

Studies/experimental set-up per country

![Graph showing experimental set-up per country]
research at HCU-greenroof

Targets of research:
Survey of precipitation and discharge over a long time
- Ca. 2,200 m² Greenroof (extensiv)
  - 470 m² “roof for measurements”,
- Continues measurement (5-min.), Focus to
  - Heavy rainwater events
  - Discharge after several rainfalls
  - Comparation with type “Retention”

others
- Microclimate, combination fotovoltaik

Cooperation
- DDV e.V. / ZINCO
- Umweltgerätetechnik UGT (measurement-devices)
MESSUNGEN AN DER HCU

Gesamtfläche Gründach: 2232 m²
Messfläche Dachabfluss (schattiert): 598 m²; davon 130 m² Dachriegel ohne Begrünung

Abfluss über 3 Dachabläufe

Standort Niederschlags-Sensor

Regensensor
Measurements

green roof area: 2232 m²
runoff measurement area: 468 m²
ca. 80 m² technical infrastructure (Dachaufbauten)
Measurements

HCU-Rooftop

Measurements of precipitation

Measurements of discharge

Measuring weir

Tipping bucket
Tipping bucket
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Decentralized Stormwater Management – Role of Green Roofs

Paradigm change in water management

- Separate system (= separate storm- and wastewater) as minimum standard
- Less centralized drainage of stormwater, no huge sewers
- Decentralized drainage orientated on natural water cycle
- Very differentated drainage systems
- A lot of different types of measures
- **Green roofs** are one of these types
Decentralized Stormwater Management – Role of Green Roofs

Possible role of green roofs in water management planning

retention - evaporation - slowed discharge

Quelle: DDV: Das 1x1 der Dachbegrünung, 2007
Quelle: Stifter, R.; 1988
Technologies DSWM: green roofs

- Water Retention
- Microclimate / air quality
- Sound Insulation
- Thermal Insulation
- Why? Private and Public Goods
- Life Expectancy
- Additional Space
- Habitat for Flora and Fauna

Base of the slide: DDV e.V., Wolfgang Ansel, 2009; translated and added by W. Dickhaut, 2010

Prof. Dr.-Ing. W. Dickhaut
Conference Barcelona 17.3.16
# Technologies DSWM: green roofs

## Types of greening according to FLL-Richtlinie 2002 (Germany)

<table>
<thead>
<tr>
<th>Extensive Roof Greening</th>
<th>Simple Intensive Roof Greening</th>
<th>Intensive Roof Greening</th>
</tr>
</thead>
<tbody>
<tr>
<td>low maintenance</td>
<td>mean maintenance</td>
<td>high maintenance</td>
</tr>
<tr>
<td>without extra-irrigation</td>
<td>periodical irrigation</td>
<td>regular irrigation</td>
</tr>
<tr>
<td>Moss-Sedum- to Gras-herb-greening</td>
<td>Gras-herb- to wood-greening</td>
<td>gras or bush to trees</td>
</tr>
<tr>
<td>thickness: layer 6 - 20 cm</td>
<td>thickness: layer 12 - 25 cm</td>
<td>thickness: layer 15- &gt;100 cm</td>
</tr>
<tr>
<td>weight 50 - 150 kg/m²</td>
<td>weight 150 - 200 kg/m²</td>
<td>weight 200 - &gt; 500 kg/m²</td>
</tr>
</tbody>
</table>

- **Low maintenance greening instead of gravel layer**
- **designed greening for more requirements**
- **Well-kept gardens for used flat-roofs**

Technologies DSWM: green roofs

Low care

Easy care

intensiv

maintenance

“well kept garden / park”

„english grass“

„used grass“

„Moss-Sedum-greening“

„Wild meadows“

Light-weight

weight

heavy

base of the slide: DDV e.V., Wolfgang Ansel, 2009; translated and added by W. Dickhaut, 2010

Prof. Dr.-Ing. W. Dickhaut
Conference Barcelona 17.3.16
Privater Wohnungsbau - Extensivbegrünung

Carport
Adickestr. 6, Hamburg
Privater Wohnungsbau - Intensivbegrünung

Wohnanlage über REWE
Amandastraße 1-7
Hamburg
Öffentliche Gebäude - Extensiv- / Intensivbegrünung

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Behörde für Stadtentwicklung und Umwelt (BSU)
Neuenfelder Str. 19, Hamburg

Prof. Dr.-Ing. W. Dickhaut
Conference Barcelona 17.3.16
Firmengebäude - Extensivbegrünung

Möbelhaus Höffner
Hamburg-Barnsbüttel
Öffentliche Gebäude - Extensivbegrünung

Kindertagesstätte Himmelblau
Steinreye 23, Hamburg
Firmengebäude - Intensivbegrünung

Generali-Versicherungen
Besenbinderhof 43, Hamburg
Decentralized Stormwater Management – Role of Green Roofs

Possible role of green roofs in water management planning

The experts in the watermanagement-administration are very sceptical in the impact of green-roof to reduce the discharge (at least in Germany)

Quelle: DDV: Das 1x1 der Dachbegrünung, 2007
Quelle: Stifter, R.; 1988
Decentralized Stormwater Management – Role of Green Roofs

Important Questions for the integration of green roofs in the Water Management Planning …..

- How big is the impact of reduction of the discharge from green-roofs in comparison to black-roofs (e.g. tile, gravel)?
- Do we always have an impact of green-roofs to decrease the run-off?
  - … in case of mean yearly precipitation
  - … in case of relevant design-parameter for storm-runoff
    - Short periods (5 to 15 minutes), high intensity
    - Return-periods / rainfall frequency (1 – 10 years)
  - … after a period of rainy days with saturated soil of the green-roofs
- Are we able to guarantee the proper planning, implementation, maintenance and function of green roofs to insure the permanent impact?
Decentralized Stormwater Management – Role of Green Roofs

Important Questions for the integration of green roofs in the Water Management Planning

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Decentralized Stormwater Management – Role of Green Roofs

- Evaporation and retention of rainwater
- Discharge after saturation capacity of the soil is reached
- Capacity of storage: ~ 30 mm (extensive g.r.) to 60 mm or more (intensive g.r.)
- Evaporation: HH ca. 525 mm / J. *
  ~ 0.5 - 3.5 mm/day (Winter – Summer)
- Emptying time (Extensive green-roof)
  ~ 10-15 days (Summer)
  ~ 60 days (Winter)
- Retention and evaporation of 50 – 90% of the yearly precipitation **
- Retention of > 90% von $N_{total}$ und $PO_4$ ***

sources:
* Hydrologischer Atlas Deutschlands, tat
** Deutscher Dachgärnterverband
*** Schmidt & Teschner, TU Berlin
Decentralized Stormwater Management – Role of Green Roofs

Coeficients of discharge ... depend on
- thickness of soil-layer and slope of roof
- Type of greening / plants
- local rainfall-intensity and temperature

... are different
- Peak precipitation and mean yearly precipitation
- Different regions

Coeficients of discharge according to DWA – Arbeitsblätter M 153 (Germany)

<table>
<thead>
<tr>
<th>Flächentyp</th>
<th>Art der Befestigung</th>
<th>$\psi_m$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schrägdach</td>
<td>Metall, Glas, Schiefer, Faserzement</td>
<td>0.9 – 1,0</td>
</tr>
<tr>
<td></td>
<td>Ziegel, Dachpappe</td>
<td>0.8 – 1,0</td>
</tr>
<tr>
<td>Flachdach</td>
<td>Metall, Glas, Faserzement</td>
<td>0.9 – 1,8</td>
</tr>
<tr>
<td>(Neigung bis 3° oder ca. 5%)</td>
<td>Dachpappe</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kies</td>
<td>0.9</td>
</tr>
<tr>
<td>Gründach</td>
<td>humusiert &lt; 10 cm Aufbau</td>
<td>0.5</td>
</tr>
<tr>
<td>(Neigung bis 15° oder ca. 25%)</td>
<td>humusiert ≥ 10 cm Aufbau</td>
<td>0.3</td>
</tr>
<tr>
<td>Straßen, Wege und Plätze (flach)</td>
<td>Asphalt, fugenloser Beton</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pflaster mit dichten Fugen</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>fester Kiesbelag</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>Pflaster mit offenen Fugen</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>lockerer Kiesbelag, Schotterrasen</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>Verbundsteine mit Fugen, Sickersteine</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Rasen, Gittersteine</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Other regulation: Coeficients of drainage according to DIN und „FLL-RiLi Gründächer“ (Germany)

DWA, M 153, 2002
Decentralized Stormwater Management – Role of Green Roofs

Important Questions for the integration of green roofs in the Water Management Planning …..

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Decentralized Stormwater Management – Role of Green Roofs

Mean precipitation per year in Karlsruhe: **720 mm**

Mean discharge of a green roof (extensiv), soil layer ca. 70 mm: **310 mm**

Mean retention of water: **ca. 57 %**

measurements from LWG-Veitshöchheim

base of the slide: DDV e.V., Wolfgang Ansel, 2009; translated and added by W. Dickhaut, 2010
Green roof measurements HCU

Daily precipitation/runoff HCU greenroof Mar 2015 - Feb 2016

Long term impact - 11-month

Total precipitation: 840 mm in 11 months
Total runoff: 385 mm = 45%
Decentralized Stormwater Management – Role of Green Roofs

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Decentralized Stormwater Management – Role of Green Roofs

Duration in minutes

0 15 30 45 60 75 90 105 120 135 150 165 180

Rainfall intensity in mm

- Peak discharge:
  - 80% ($\Psi = 0.8$)
  - 25% ($\Psi = 0.25$)
  - 50%

- Discharge after 1 h:
  - > 95%

Measurement: Dr. Walter Kolb, LWG-Veitshöchheim

Base of the slide: DDV e.V., Wolfgang Ansel, 2009; translated and added by W. Dickhaut, 2010

Example: In Hamburg, 20 mm rainfall in 15 min. occurs once in 20 years.
Statistics

Interdependencies/Correlations

**Chicago**
6968 m² extensive green roof, 76 mm substrate, rainstorm: 92 mm in 24 h (return period = 277 for HH), retention: 58%

**Berlin**
215 m² extensive green roof, 60 mm substrate, rainstorm: 11 mm in 206 min (return period <0.1 for HH), retention: 93%

**Toronto**
241 m² intensive green roof, 140 mm substrate, rainstorm: 24 mm in 109 min (return period = 7 for HH), retention: 80%
Decentralized Stormwater Management – Role of Green Roofs

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Water retention in Greenroofs

testroofs 15 m² / different Types of Greenroof / Stormwater 15 minutes, 100 yearly

Diagramm 1: Prozentualer Abfluss der Regenspende von verschiedenen Gründachaufbauten (hellblau hinterlegt ist der Bemessungsregen $r_{15}=300\ l/(s\cdot ha)$)

Measurements

HCU green roof

**Precipitation:** 65.3 mm in 72 h (return period for HH: 4)
**Peak discharge coefficient:** 0.25
**Runoff:** 29.4 mm = 45%
Measurements

**HCU green roof**

**Precipitation**: 17 mm in 60 min (return period for HH: 1,7)
**Peak discharge coefficient**: 0.5
**Runoff**: 8 mm = 47%

---

Short term impact – 1-hour
Measurements

HCU green roof

precipitation: 15.4 mm in 31 min (return period for Hamburg: 2a)
runoff: 8 mm = 52%, peak discharge coefficient: 0.23

Short term impact – 0.5-hour
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Opportunities to optimize the retention of green roofs

Ansätze

• Development of special greenroofs “retention”, which will be optimized for more retention and evapotranspiration

Results of an interview series with experts in the research project KLIMZUG_Nord; 2012

Discharge:
20-50%

Quelle: DDV: Das 1x1 der Dachbegrünung, 2007
Opportunities to optimize the retention of green roofs

**Ansätze**

- Development of special green roofs, which will be optimized for more retention and evapotranspiration.

Results of an interview series with experts in the research project KLIMZUG_Nord, 2012

Different companies have already developed different retention types of green roofs

<table>
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<tr>
<th>Discharge:</th>
<th>20-50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge:</td>
<td>0-10%</td>
</tr>
</tbody>
</table>

Quelle: DDV: Das 1x1 der Dachbegrünung, 2007
Opportunities to optimize the retention of green roofs

**Approaches**

**Optimizing substrat**
- Usage of material with higher absorption for water (e.g. Lava)
- Higher percentage of fine material or silt to increase the shortterm absorption

**Meet a minimum thickness of the material layer**
- Thickness min. ca. 12 cm
- Minimum requirements in the practice
- Differentiation of stormwater fees related to the thickness of the layer
Opportunities to optimize the retention of green roofs

Approaches

Change build-up of greenroofs

- **Multilayer build-up as standard**
- Technical elements for more retention in the drainagelayer
- Usage of active emptying elements in the drainagelayer
- Optimizing of evapotranspiration with the usage of special plants
Opportunities to optimize the retention of green roofs

**Approaches**

**Other**

- Improvement of **Software-Programme**, to simulate the combination of green roofs and other measurements in a better way
- Measurements of the impact of large scale green roofs to get more data of the realistic impact
  - especially heavy stormwater events
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Greenroofs for more retention– Measurement on new residential buildings SAGA_Hamburg

- Cooperation: HCU, SAGA_HH, BSU (RISA), Hamburg Wasser, ZINCO, Optigrün
- Target: to build special retention greenroofs (requirements: precipitation $r_{15}(100)$, no discharge for defined duration, defined throttle-discharge, defined time for emptying)
Optigrün retention roof „Wasser Retentions Box“ 75 mm

Optigrün retention roof „Mäander 60“

Runoff measurement
Jeweils mit Drossel

1 Vegetation
1a Einfache Extensivbegrünung, realisiert als Sedumsprenge
1b Artenreiche Extensivbegrünung, realisiert mit Flachbalkenpflanzen (12 Stück/m²)
2 Vegetationsgrundschicht
2a 6 cm Systemerde Sedumteppich
2b 9 cm Systemerde Steinrosenfutter
3 Bewässerungsschutzmatte BSM 64
4 Spacerelement
4a Spacerelement, Höhe 100 mm (Einstauvolumen 80 Liter/m²)
4b Spacerelemente, Höhe 40 mm (Einstauvolumen 30 Liter/m²)
5 Filtervlies PV
6 Wurzelfeste Dachabdichtung
7 Dachaufbau (schematisch)
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Thanks for your attention!
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