Good Reasons for Roof Planting - Green Roofs and Rainwater

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Abstract:
This presentation is expected to be an argumentative basis for a better acceptance of roof planting based on measurements made with green roofs. The experiments show that annual evaporation factors of 45% – 70% of the rainfalls can be achieved. When choosing ideal substrates an essential reduction of the peak runoff is registered. Depending on the rating of rainfalls with 100, 200 and 300 l/(s*ha) reductions of the peak runoff as much as 52%, 29% and 17% could be registered when using efficient substrates. The runoff coefficient declines with increasing watercourse. Considering a watercourse of 10,0 m single-stratum construction techniques show a 45% better runoff coefficient than multi-strata construction techniques.

INTRODUCTION
Roof planting has an important function as a part of decentral systems together with the management of rainwater. Vegetation on green roofs is capable to evaporate rainwater to a high extent and so it hasn’t to be disposed by costly processes. Even infiltration facilities can be designed as smaller units. After the rainfalls the reduction of the peak runoff from green roofs generally leads to a cost reduction concerning pipes for the surface water runoff and buildings like retarding basins (Kolb 1987). Looking at the infiltration of excess rainwater from water tanks or directly in infiltration buildings the runoff retard is also cost saving. In a system of combined roof planting, rainwater utilization and infiltration roof planting in all variations can be regarded as an ecological and long-term economical project as there are fewer intrusions upon the natural environment and it means reductions of the landscape ecosystem.

MATERIALS AND METHODS
Evaporation and runoff coefficients of intensive and extensive roof planting models were measured. All measurements have at least been performed three times. The climatic conditions at the test area in Veitshöchheim are characterized by poor rainfall with a long-term average of 635 mm (Bätz 2002) as well as a potential evaporation surplus during the vegetation period from March to October of 250 mm (Wetterwarte Würzburg, 1991). The tests aiming to find the peak runoff coefficient were performed in a vegetation hall at a temperature of 18°C-20°C after saturating watering and 24 hours drainage.

RESULTS AND DISCUSSION
Evapotranspiration of green roofs is influenced by the saturation level of the air as well as by the vegetation itself. Considering these factors the evaporation factors of roofs with intensive roof planting are basically higher than of those with rare extensive roof planting. There are lower factors in winter for both kinds of planting.

Evaporation Factors with Extensive Roof Planting
Figure 1 demonstrates that with an average monthly rainfall of 47 mm 45% or 21 mm could be evaporated during a year. Whereas in the time between May and August nearly all rainfall evaporates there is only little evaporation during the winter months November, December and January.
Evaporation with Intensive Roof Planting

Based on measurements in lysimetres with intensive roof planting with 30 cm course height and grass vegetation, an average drainage of 364 mm could be registered with annual rainfalls of 1152 mm (Figure 2). This means an evaporation rate of about 68% (Kolb, 1998). There is no need disposing water evaporated through the surface of the green roof and plants and it is only fair that there should not be any charges for rainwater (Hämmerle 1998). But if the infiltration water from green roofs should be used in rainwater reservoirs the increased evaporation on a green roof should be considered when constructing a water tank (König 2001).

Delay of Peak Runoff and Influence of Roof Angle

The peak runoff coefficient has to be considered as a measure for the likely quantity of runoff after controlled irrigation and therefore as a basis for the lay-out of infiltration. It is defined as the relation between rain runoff and amount of irrigation. There is a difference between annual $\Psi_a$, peak $\Psi_s$ and average $\Psi_m$ runoff during the period of rainfall rating.

Table 1 shows the currently valid runoff coefficients, considering that both are peak runoff coefficients (FLL 2002; DNA 1995). The runoff coefficients shown are influenced by a series of factors which cannot be taken into consideration when it comes to dealing with specification or guidelines. That is why these figures shown are to be considered only as rough guidelines and have to be proved separately. It has to be made clear that when interpreting the factors as peak runoff the enormous reduction of runoffs with green roofs has not been taken into consideration, as contrary to non-green roofs the runoff starts only a certain time after the start of the rainfall. This has been proved by investigations of Liesecke (1998), Schade (2000) and Kolb (1995).

The influence of the roof angle on the runoff coefficient has been overestimated for a long time. (FLL 1995; Henneberg and Mann 1998). Tests made by Kolb (1999) demonstrated that the runoff coefficient does not significantly change with a roof angle between 1.4° and 40° (Table2). When creating the new guidelines for roof planting (FLL 2002) these results have been taken into consideration and Table 1 shows that evaluation coefficients with a runoff coefficient of $\Psi=0.7$ for coefficients originally beginning with a roof angle of 5° have been considerably reduced (FLL 2002).

Delay of Peak Runoffs and the Influence of Substrates

The components of the substrates used for the roofs influence the runoff coefficient of course (Table 2). There are considerable differences among the substrates which make it possible to use highly effective substrates in those cases where roof planting is integrated as a part of de-central rainwater treatment (Kolb, 1999).

Influence of Length of Watercourse and Kind of Construction on Runoff Coefficient

There are only a few investigations dealing with the effects of construction and length of watercourse on runoff coefficient of green roofs (Liesecke 1995; Kolb 1995; Schade 2000). Due to lack of standardized testing methods measurements were carried out on courses between 2.50 m and 10 m long. The different construction methods have neither been considered in the normative requests of the DIN 1968/2 (DNA 1995) nor in the guidelines for roof planting 2002 (FLL, 2002). In these guidelines there is a reference to the total course height only. Figure 3 shows that watercourse and kind of construction highly influence the runoff coefficients. With increasing length of the watercourse a decrease of the runoff coefficient was registered. Considering the common hypothesis a length of watercourse of 10m seems to be acceptable as a basis for the evaluation of the reduction of peak runoffs. With a three-layer formation with a drainage consisting of numerous cavities the runoff coefficient decreases by about 25 %, with a single stratum construction the runoff coefficient even decreases by 70 % considering a 10 m watercourse compared with one of 2.50 m length.
It has been proved that the average runoff coefficients depend highly on the length of the watercourse. Both parameters correlate both for single- and two-layer constructions as well as for the values of the two testing series.

**Literature Cited**


**Tables**

<table>
<thead>
<tr>
<th>Course height</th>
<th>Roof angle &lt;= 15°</th>
<th>Roof angle &gt; 15°</th>
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<tbody>
<tr>
<td>&lt; 50 cm</td>
<td>ψ = 0.1</td>
<td>-----</td>
</tr>
<tr>
<td>&lt; 25 – 50 cm</td>
<td>ψ = 0.2</td>
<td>-----</td>
</tr>
<tr>
<td>&lt; 15 – 25 cm</td>
<td>ψ = 0.3</td>
<td>-----</td>
</tr>
<tr>
<td>&lt; 10 – 15 cm</td>
<td>ψ = 0.4</td>
<td>ψ = 0.5</td>
</tr>
<tr>
<td>&lt; 6 – 10 cm</td>
<td>ψ = 0.5</td>
<td>ψ = 0.6</td>
</tr>
<tr>
<td>&lt; 4 – 6 cm</td>
<td>ψ = 0.6</td>
<td>ψ = 0.7</td>
</tr>
<tr>
<td>&lt; 2 – 4 cm</td>
<td>ψ = 0.7</td>
<td>ψ = 0.8</td>
</tr>
<tr>
<td>Gravel roof</td>
<td>ψ = 0.8 (0.5)*</td>
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</tr>
</tbody>
</table>

Table 2. Runoff coefficients $\Psi_m$ of 6 FLL-substrates of single layer roof plantings with roof angles between 1.4° und 40°, course height 10 cm and irrigation levels of 100, 200 und 300 l/(s*ha) (from Kolb 1999).

<table>
<thead>
<tr>
<th>Roof angle</th>
<th>Substrate 1</th>
<th>Substrate 2</th>
<th>Substrate 3</th>
<th>Substrate 4</th>
<th>Substrate 5</th>
<th>Substrate 6</th>
<th>Average</th>
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<tbody>
<tr>
<td>1.4°</td>
<td>0.234</td>
<td>0.250</td>
<td>0.325</td>
<td>0.307</td>
<td>0.241</td>
<td>0.210</td>
<td>0.261</td>
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<tr>
<td>8°</td>
<td>0.200</td>
<td>0.208</td>
<td>0.154</td>
<td>0.165</td>
<td>0.235</td>
<td>0.124</td>
<td>0.181</td>
</tr>
<tr>
<td>16°</td>
<td>0.178</td>
<td>0.246</td>
<td>0.104</td>
<td>0.132</td>
<td>0.288</td>
<td>0.176</td>
<td>0.187</td>
</tr>
<tr>
<td>24°</td>
<td>0.188</td>
<td>0.258</td>
<td>0.023</td>
<td>0.107</td>
<td>0.287</td>
<td>0.180</td>
<td>0.174</td>
</tr>
<tr>
<td>32°</td>
<td>0.178</td>
<td>0.258</td>
<td>0.103</td>
<td>0.104</td>
<td>0.293</td>
<td>0.179</td>
<td>0.186</td>
</tr>
<tr>
<td>40°</td>
<td>0.172</td>
<td>0.259</td>
<td>0.085</td>
<td>0.108</td>
<td>0.296</td>
<td>0.241</td>
<td>0.194</td>
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<tr>
<td>Average</td>
<td>0.192</td>
<td>0.246</td>
<td>0.133</td>
<td>0.154</td>
<td>0.274</td>
<td>0.185</td>
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<th>Substrate 4</th>
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<tbody>
<tr>
<td>1.4°</td>
<td>0.442</td>
<td>0.478</td>
<td>0.491</td>
<td>0.480</td>
<td>0.426</td>
<td>0.458</td>
<td>0.462</td>
</tr>
<tr>
<td>8°</td>
<td>0.417</td>
<td>0.468</td>
<td>0.419</td>
<td>0.407</td>
<td>0.488</td>
<td>0.409</td>
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<tr>
<td>16°</td>
<td>0.459</td>
<td>0.467</td>
<td>0.339</td>
<td>0.340</td>
<td>0.501</td>
<td>0.400</td>
<td>0.418</td>
</tr>
<tr>
<td>24°</td>
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<td>0.482</td>
<td>0.271</td>
<td>0.378</td>
<td>0.535</td>
<td>0.437</td>
<td>0.424</td>
</tr>
<tr>
<td>32°</td>
<td>0.590</td>
<td>0.540</td>
<td>0.341</td>
<td>0.412</td>
<td>0.576</td>
<td>0.454</td>
<td>0.485</td>
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<tr>
<td>40°</td>
<td>0.432</td>
<td>0.476</td>
<td>0.296</td>
<td>0.370</td>
<td>0.514</td>
<td>0.429</td>
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<tr>
<td>Average</td>
<td>0.463</td>
<td>0.485</td>
<td>0.359</td>
<td>0.398</td>
<td>0.507</td>
<td>0.431</td>
<td>0.441</td>
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<tbody>
<tr>
<td>1.4°</td>
<td>0.553</td>
<td>0.550</td>
<td>0.576</td>
<td>0.453</td>
<td>0.537</td>
<td>0.414</td>
<td>0.514</td>
</tr>
<tr>
<td>8°</td>
<td>0.532</td>
<td>0.577</td>
<td>0.519</td>
<td>0.536</td>
<td>0.589</td>
<td>0.546</td>
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<td>16°</td>
<td>0.560</td>
<td>0.594</td>
<td>0.489</td>
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<td>0.623</td>
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<tr>
<td>32°</td>
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<td>0.467</td>
<td>0.467</td>
<td>0.618</td>
<td>0.583</td>
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<tr>
<td>40°</td>
<td>0.656</td>
<td>0.604</td>
<td>0.464</td>
<td>0.495</td>
<td>0.642</td>
<td>0.534</td>
<td>0.566</td>
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<tr>
<td>Average</td>
<td>0.570</td>
<td>0.588</td>
<td>0.501</td>
<td>0.502</td>
<td>0.605</td>
<td>0.529</td>
<td>0.549</td>
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</tbody>
</table>
Figures

Fig. 1. Evapotranspiration coefficient for 11 roof models with low maintenance in the course of a year at the location Veitshöchheim (course height: 5-14cm)

Fig. 2. Evapotranspiration coefficient of 8 lysimetres with high maintenance with a 30 cm construction course during a period of 5 years with a rainfall of 5762 mm
Fig. 3. Relation between runoff coefficient and length of water course at different construction systems of green roofs (amount of irrigation 300 l/(s x ha), course height 10 cm)