Rainfall Erosivity in Austria

Andreas KLIK, and Franz KONECNY

University of Natural Resources and Life Sciences Vienna
Institute of Hydraulics and Rural Water Management
Institute of Mathematics

International Symposium on Erosion and Landscape Evolution (ISELE)
Anchorage, Alaska
September 18-21, 2011
Rainfall Kinetic Energy

\[ KE = \frac{m \cdot v^2}{2} \]

Drop \( \varnothing = 0.2 – 6 \) mm
\( v = 0.5 – 13 \) m.s\(^{-1} \)

Dependence of kinetic energy of rain on drop size
（Payne, unpubl.）

Erosion and conservation

Distrometers
Joss and Waldvogl
2D-video
Parsivel

Introduction
Rainfall Erosivity in Austria
Andreas Klik
Rainfall in Austria

Average annual precipitation ranging from 450 mm in the East to 1700 mm in the Alps

Water Balance in Austria (Kresser, 1994)

- Precipitation: ~1170 mm
- Evapotranspiration: ~516 mm
- Evaporation: ~116 mm
- Transpiration: ~400 mm

- 
  - Industry: ~20 mm
  - Households: ~8 mm
  - Irrigation: ~2 mm
  - Zoמר: ~340 mm
  - Ao: ~854 mm
  - Au: ~140 mm
Objectives of the study

1) to calculate a rainfall erosivity factor for north-eastern Austria
2) to analyze whether there exists a temporal evolution in annual rainfall erosivity.

RUSLE Rainfall-Runoff Factor (R) widely used parameter estimating erosional impact
R includes
• kinetic energy KE representing the direct impact of the falling raindrops on the soil
• maximum 30-min intensity $I_{30}$ of each rainfall representing the erosional force of surface runoff

Actual Situation in Austria

Areal soil loss by water is estimated using USLE
(\textit{Hydrologic Atlas of Austria})
R factor based on data series 1961 – 1990 using following relationship (\textit{Strauss et al., 1995}):

\[ R = 4.3 + 0.078 \cdot \text{annual } P \]
Two federal states in the north and east of Austria: Upper Austria (UA) and Lower Austria (LA)

Area covered: 31,200 km² which is about 36% of Austria’s surface

51 rain gauges with data series from 9 to 53 years (with missing years): average length 24.5 years

Rainfall measurements from May to October available for all stations (5-15 min intervals)

In this region 95% of all erosive rainstorms occur during this period (Rogler and Schwertmann, 1981)
R-Factor Calculation

1249 station years with overall 23,095 rainstorms were analyzed using

**Rainfall Intensity Summarization Tool (RIST)**
developed by Dabney et al. ([http://www.ars.usda.gov/Research/docs.htm?docid=3251](http://www.ars.usda.gov/Research/docs.htm?docid=3251))

\[
R = \frac{1}{n} \sum_{j=1}^{n} \left[ \sum_{k=1}^{m} (E)_k (I_{30})_k \right]_j
\]

R-factor calculation adapted to European conditions due to different rainfall regime and more moist soils; Storms exceeding 10 mm or \( I_{30} > 10 \text{ mm.h}^{-1} \) are considered as erosive ([Rogler and Schwertmann, 1981](#))

From breakpoint data kinetic energy for each rainfall event was calculated based on the equation by [Brown and Foster (1987)](#)

\[ e_i = 0.29 \left( 1 - 0.72 \exp^{-0.05 I} \right) \]

where \( e_i \) is the rainfall energy per unit depth of rain for each time increment (MJ.mm\(^{-1}\).ha\(^{-1}\)) and \( I \) is the average intensity during this period (mm.h\(^{-1}\)).
Statistical Analyses

Time Series Analysis

The **Mann-Kendall Test** (Mann, 1945; Kendall, 1975) is suitable for data series where the trend may be assumed to be monotonic and thus no seasonal or other cycle is present in the data.

< 10 data points: S Test

\[
S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sign}(x_j - x_i)
\]

- \( 1 \) if \( x_j - x_i > 0 \)
- \( 0 \) if \( x_j - x_i = 0 \)
- \( -1 \) if \( x_j - x_i < 0 \).

\[\text{sign}(x_i - x_j) = \begin{cases} 
1 & \text{if } x_j - x_i > 0 \\
0 & \text{if } x_j - x_i = 0 \\
-1 & \text{if } x_j - x_i < 0.
\end{cases}\]

\[\sigma_s = \sqrt{\frac{n(n-1)(2n-5)}{18}}\]

\[Z = \frac{S - 1}{\sigma_s}\] if \( S > 0 \)

\[Z = 0\] if \( S = 0 \)

\[Z = \frac{S + 1}{\sigma_s}\] if \( S < 0 \).

≥ 10 data points: normal approximation test
### R Factor Results: Rainfall Erosivity in Austria

**Andreas Klik**

#### Linear Equations

- **Lower Austria (LA):**
  
  \[ y = 1.8448x - 65.378 \]
  
  \[ R^2 = 0.7653 \]
  
  \[ n = 31 \]

- **Upper Austria (UA):**
  
  \[ y = 1.8834x - 246.64 \]
  
  \[ R^2 = 0.8489 \]
  
  \[ n = 20 \]

#### Statistical Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Lower Austria</th>
<th>Upper Austria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>average</td>
<td>range</td>
</tr>
<tr>
<td>altitude (masl)</td>
<td>447</td>
<td>146 - 917</td>
</tr>
<tr>
<td>annual precipitation (mm.a(^{-1}))</td>
<td>514</td>
<td>295 - 905</td>
</tr>
<tr>
<td>number of storms (a(^{-1}))</td>
<td>15.9</td>
<td>8.9 - 27.5</td>
</tr>
<tr>
<td>R factor (MJ.mm.ha(^{-1}).h(^{-1}))</td>
<td>884</td>
<td>273 - 1599</td>
</tr>
<tr>
<td>R single storm (MJ.mm.ha(^{-1}).h(^{-1}))</td>
<td>52.4</td>
<td>27.2 - 73.9</td>
</tr>
<tr>
<td>I30 (mm.h(^{-1}))</td>
<td>10.9</td>
<td>8.1 - 13.8</td>
</tr>
<tr>
<td>MJJ (%)</td>
<td>63</td>
<td>47 - 79</td>
</tr>
<tr>
<td>ASO (%)</td>
<td>37</td>
<td>21 - 44</td>
</tr>
</tbody>
</table>

- **Higher variability of data in Lower Austria than in Upper Austria**
- **Higher erosivity of storms in Lower Austria**
- **Similar seasonal distribution of erosivity**
Spatial distribution of R factor in Lower and Upper Austria

Stations with increasing trend in rainfall erosivity

Mainly stations which showed the lowest R factors
Rainfall Erosivity in Austria

Andreas Klik

![Graphs showing rainfall erosivity, number of storms, single storm erosivity, and rainfall intensity over years.](image)

- **R-Factor** (EI (MJ.mm.ha⁻¹.h⁻¹) V-X)
  - **UA** and **LA**

- **No. storms**
  - **UA** and **LA**

- **Single storm erosivity**
  - **UA** and **LA**

- **Rainfall intensity**
  - **UA** and **LA**
Results

- high number of stations in LA show significant increasing trend for most investigated parameters (stations with lowest R factors)
- nearly no significant trend can be detected for UA stations
- highest significance for I₃₀
- significant increase in the last decade
Summary and Conclusions

- Acceptable relationships between average rainfall and R-factor could be derived.
- Data in Lower Austria show higher variability leading to lower correlation coefficient.
- Regional differences can be observed (flat land vs. alpine regions).
  - One relationship describing R factor distribution for Austria not suitable.
- Time series analyses showed significant increasing trend for rainfall, erosivity, rainfall intensity and number of storms for most of stations in Lower Austria but only for a few in Upper Austria.
- Most of data series (with length between 9 and 53 years) too short for long-term predictions.
- Appearance of these positive trends at 90% of the investigated sites with data series > 25 years indicate possible future R-factor increases and increasing erosion risk.
- Changes may have implications on future runoff, infiltration and erosion processes in this area.