Rainfall Erosivity in Austria

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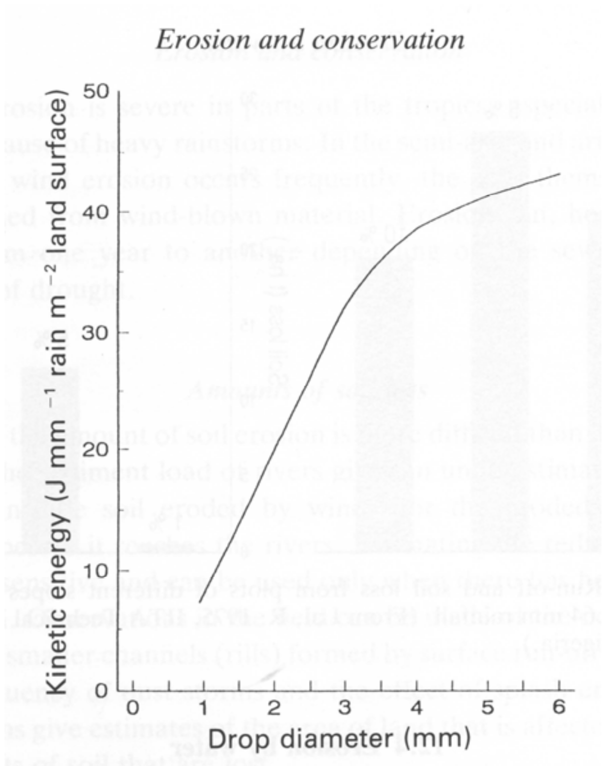
Rainfall Kinetic Energy

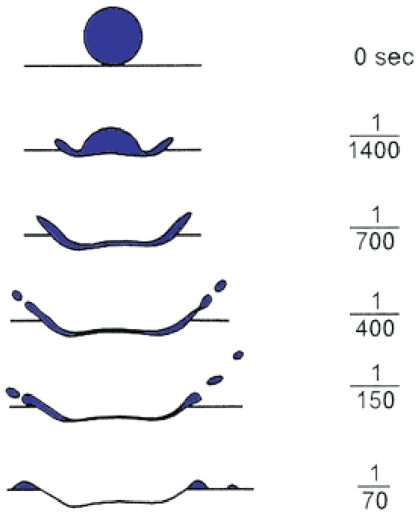
$$KE = \frac{m \cdot v^2}{2}$$

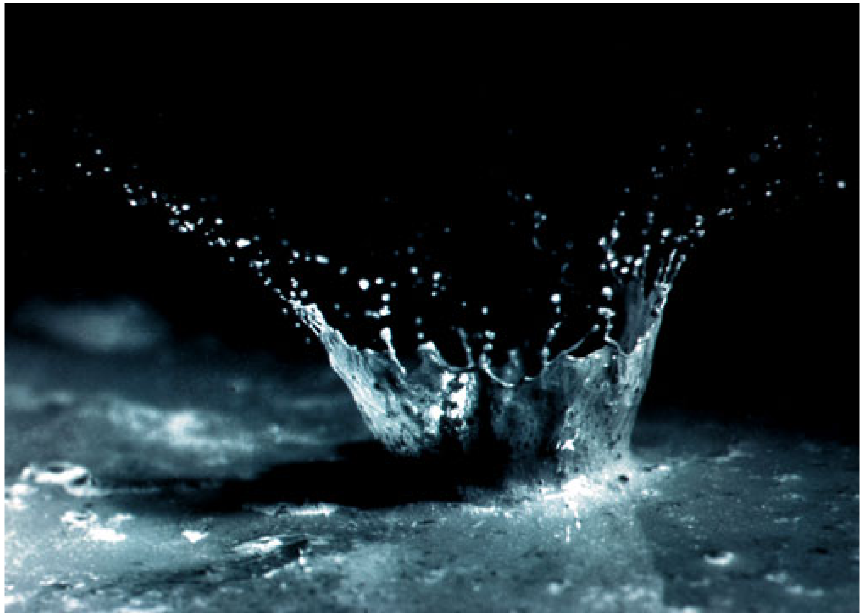
Drop ∅ = 0.2 – 6 mm

v = 0.5 – 13 m.s^{-1}



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





Distrometers

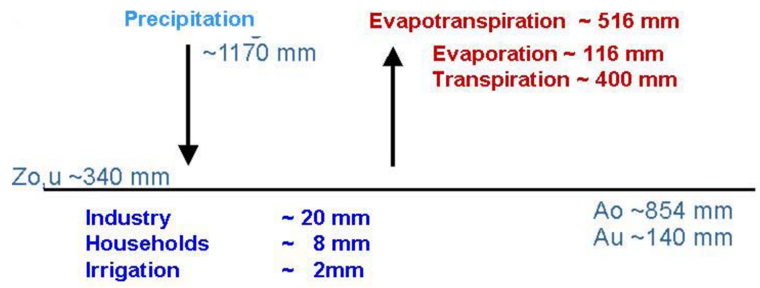
Joss and Waldvogl

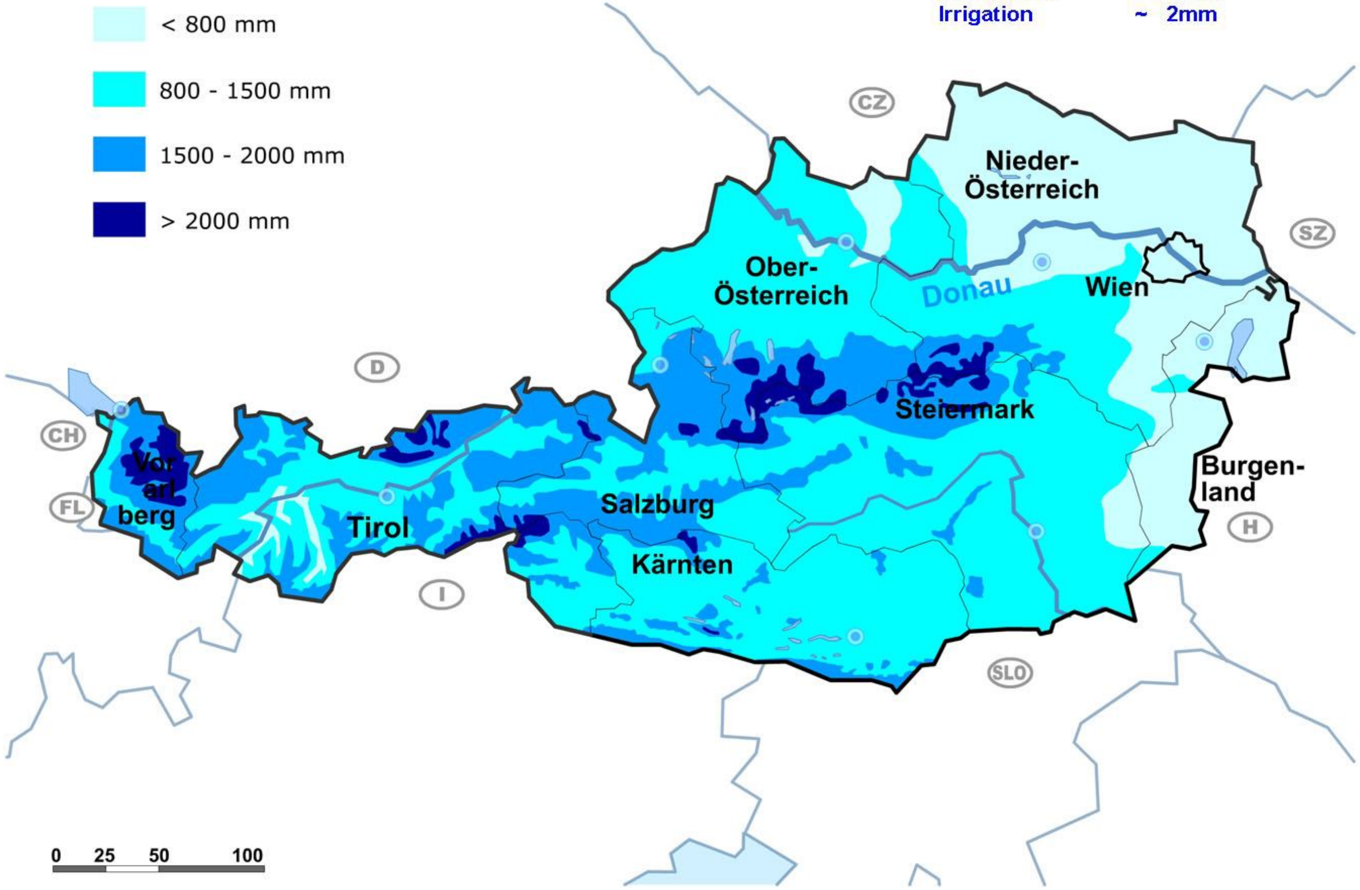
2D-video

Parsivel

Rainfall in Austria

Water Balance in Austria (*Kresser, 1994*)





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

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

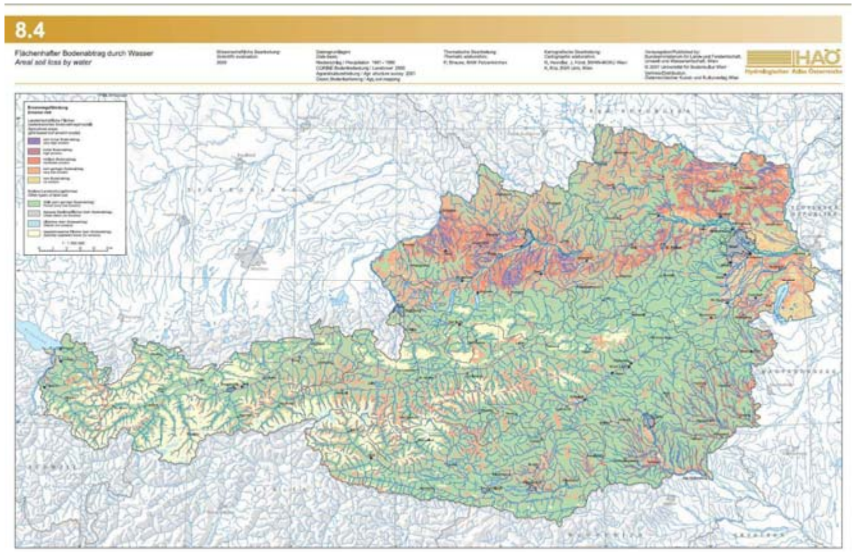
- **kinetic energy** KE representing the direct impact of the falling raindrops on the soil
- **maximum 30-min intensity** I_{30} of each rainfall representing the erosional force of surface runoff

Actual Situation in Austria

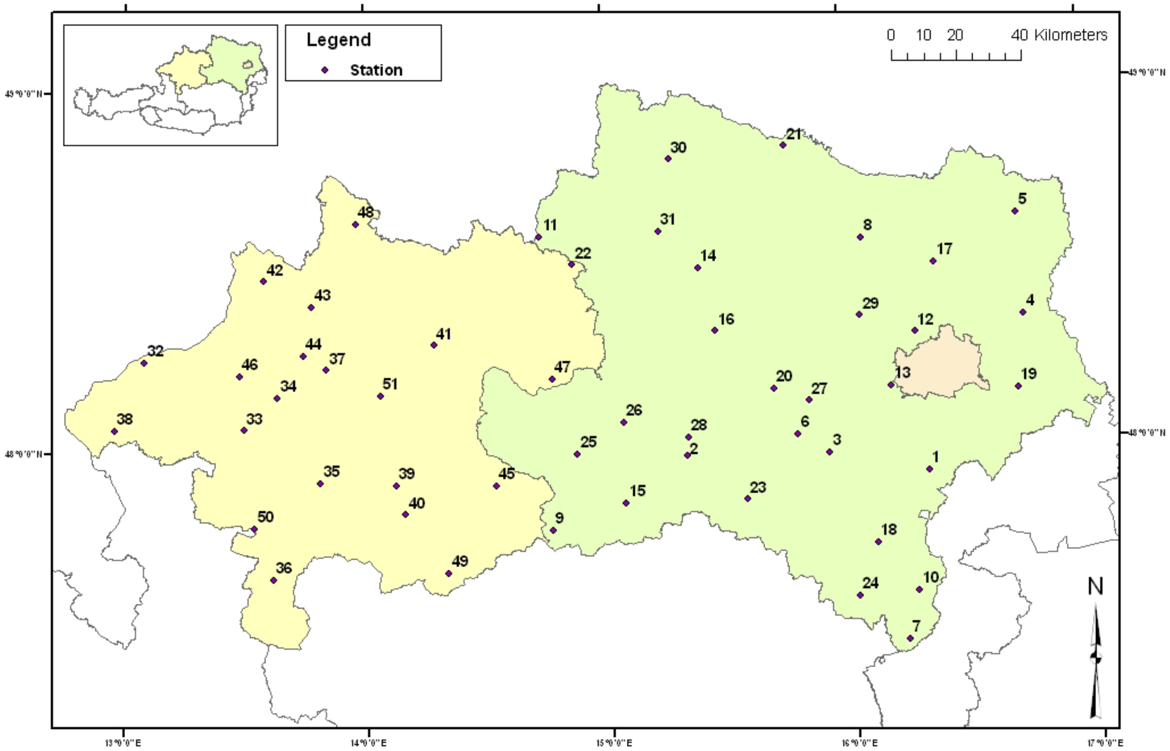
Areal soil loss by water is estimated using USLE (*Hydrologic Atlas of Austria*)

R factor based on data series 1961 – 1990 using following relationship (*Strauss et al., 1995*):

$$R = 4.3 + 0.078 \cdot annual\ P$$



Study Area



- 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 oocur 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*)

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

R-factor calculation adapted to European conditions due to different rainfall regime and more moist soils;

Storms exceeding 10 mm or I_{30} > 10 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

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign\left(x_j - x_i\right)$$

$$sign\left(x_i - x_j\right) = \begin{cases} 1 & if \quad x_j - x_i > 0 \\ 0 & if \quad x_j - x_i = 0 \\ -1 & if \quad x_j - x_i < 0. \end{cases}$$

≥ 10 data points: normal approximation test

$$\sigma_S = \sqrt{(n/18)(n-1)(2n-5)}$$

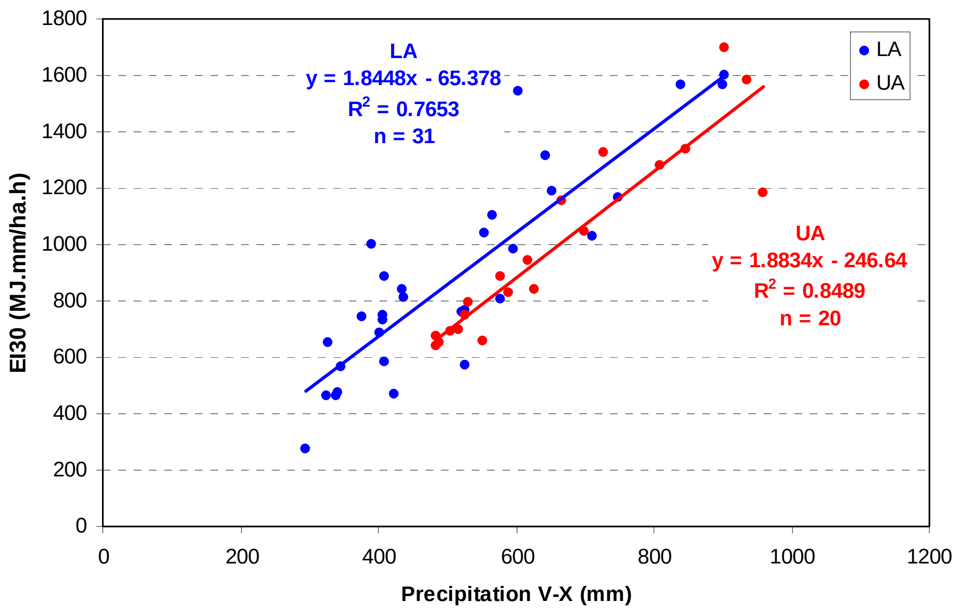
If Z > than $Z_{1-\alpha/2}$ zero hypthesis is rejected

Z positive: upward monotone trend

Z negative: downward monotone trend

$$Z = \begin{cases} \frac{S-1}{\sigma_S} & if \quad S > 0 \\ 0 & if \quad S = 0 \\ \frac{S+1}{\sigma_S} & if \quad S < 0. \end{cases}$$

R Factor



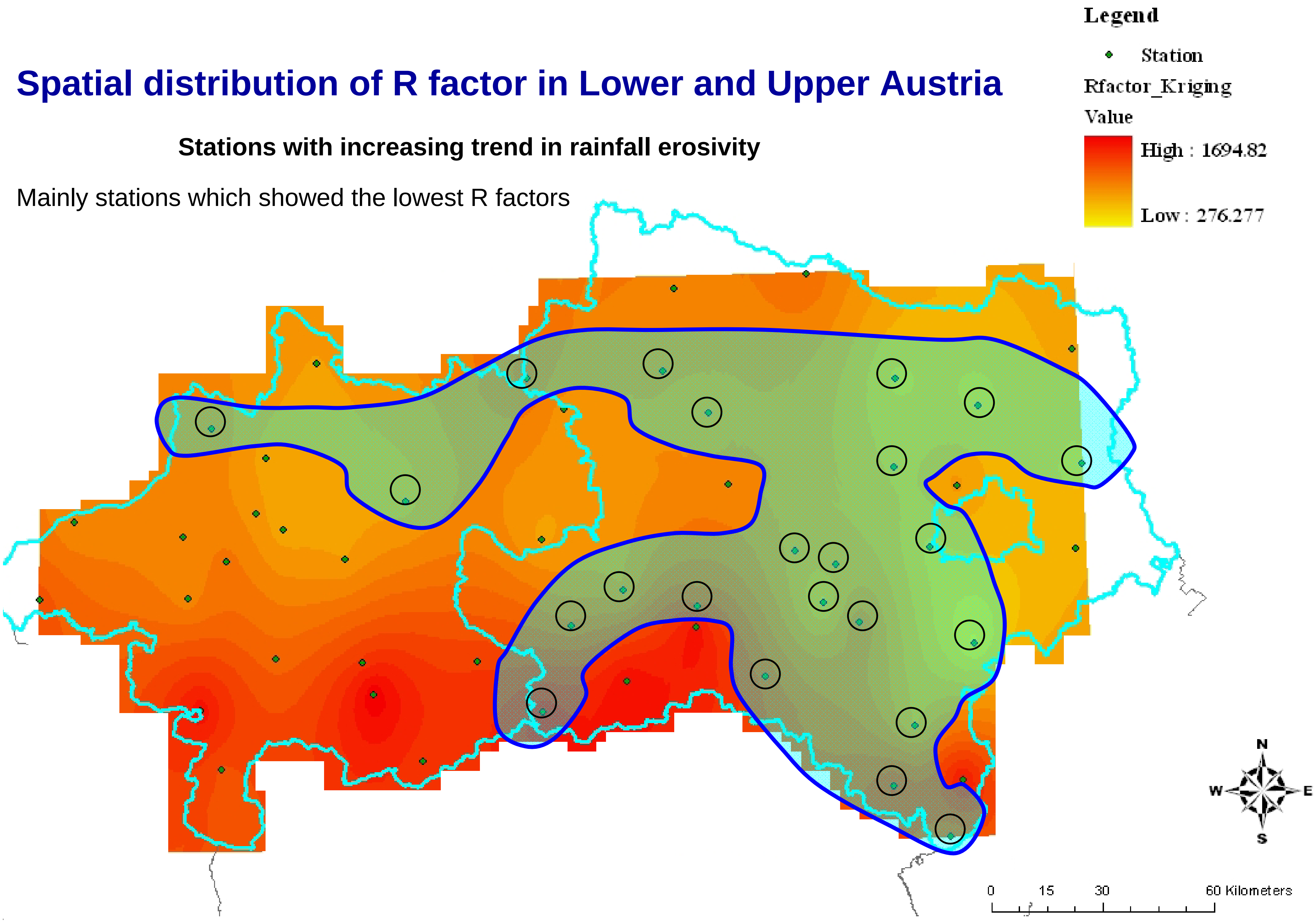
Parameter	Lower Austria		Upper Austria	
	average	range	average	range
altitude (masl)	447	*146 - 917*	440	*235 - 630*
annual precipitation ($mm.a^{-1}$)	514	*295 - 905*	642	*483 - 945*
number of storms (a^{-1})	15.9	*8.9 - 27.5*	21.7	*15.9 - 29.5*
R factor ($MJ.mm.ha^{-1}.h^{-1}$)	884	*273 - 1599*	982	*637 - 1697*
R single storm ($MJ.mm.ha^{-1}.h^{-1}$)	52.4	*27.2 - 73.9*	44.9	*34.6 - 58.8*
I_{30} ($mm.h^{-1}$)	10.9	*8.1 - 13.8*	10.7	*9.2 - 11.0*
MJJ (%)	63	*47 - 79*	63	*57 - 71*
ASO (%)	37	*21 - 44*	37	*31 - 42*

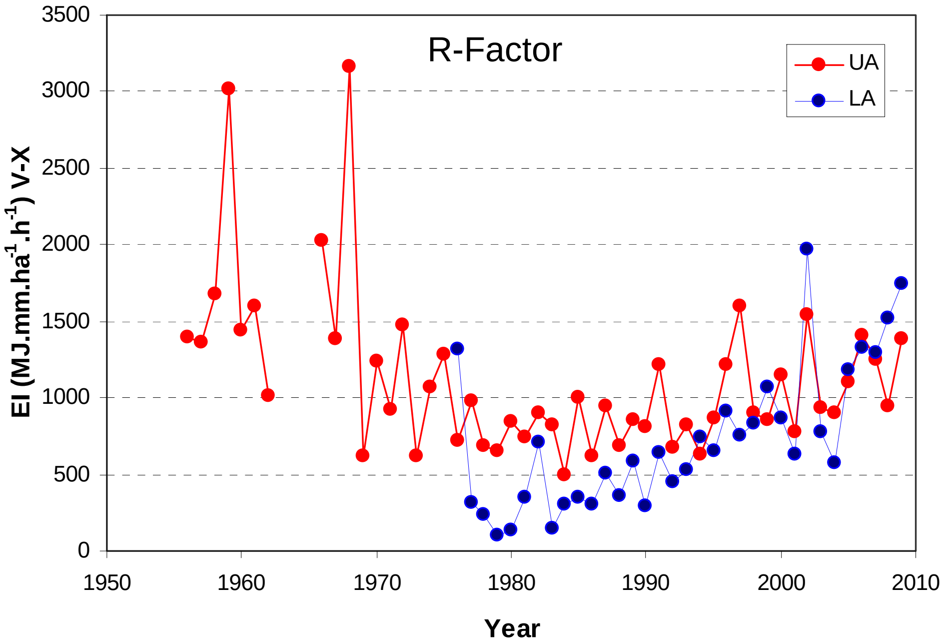
- ✓ Higher variability of data in Lower Austria than in Upper Austria
- ✓ Higher erosivity of storms in Lower Austria
- ✓ Similar seasonal distribution of erosivity

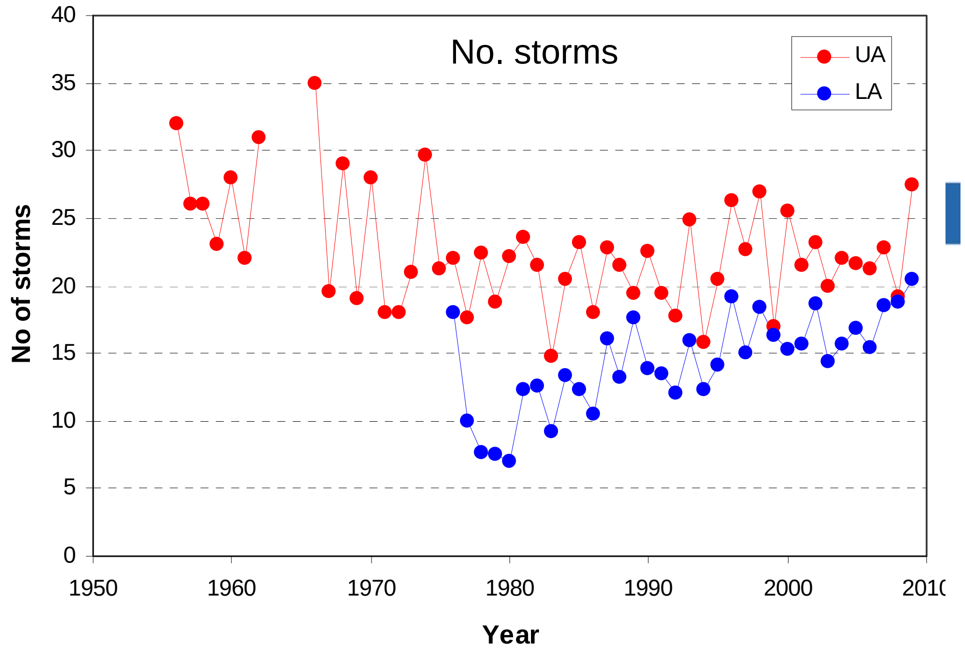
Spatial distribution of R factor in Lower and Upper Austria

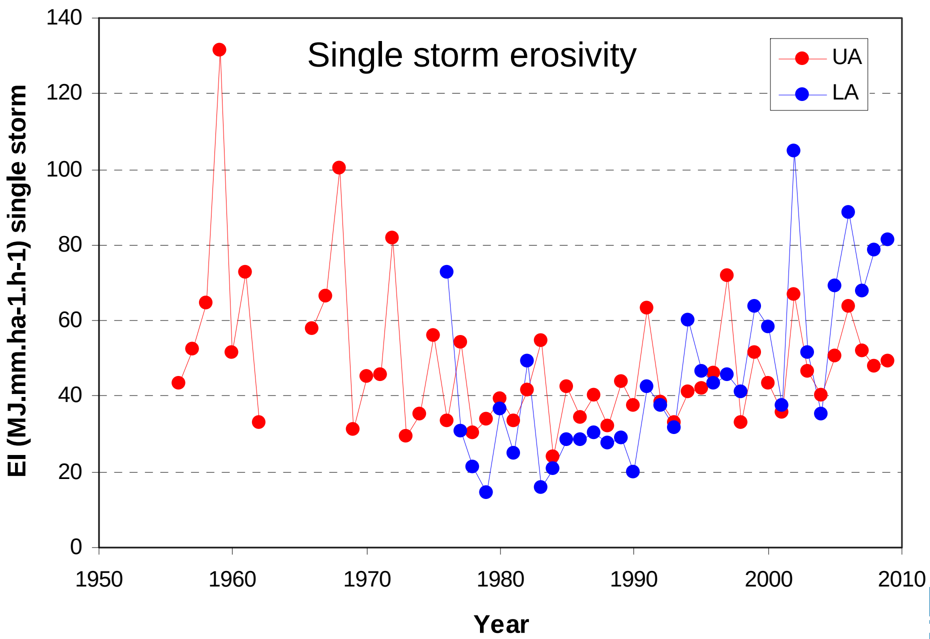
Stations with increasing trend in rainfall erosivity

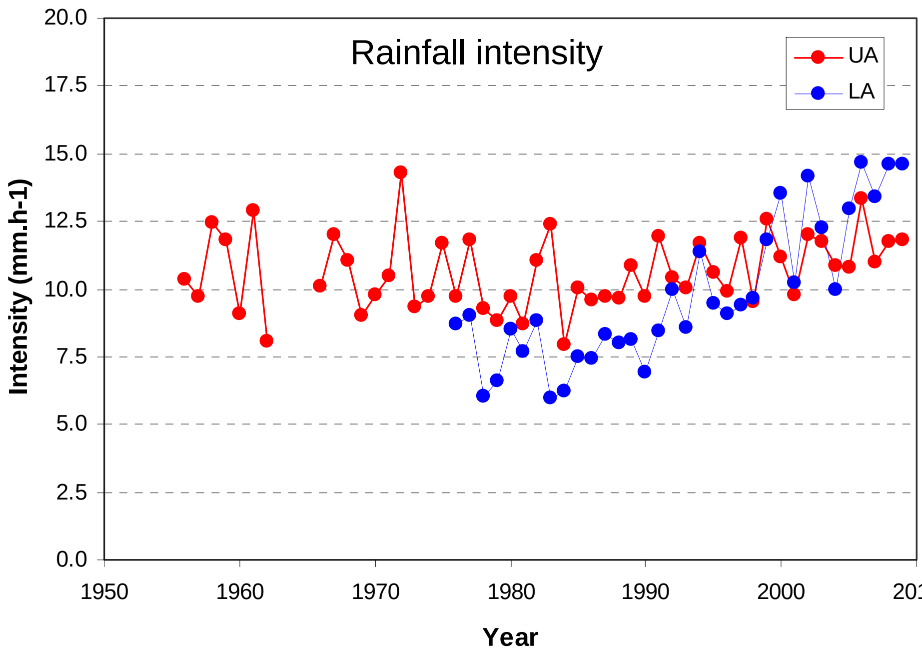
Mainly stations which showed the lowest R factors



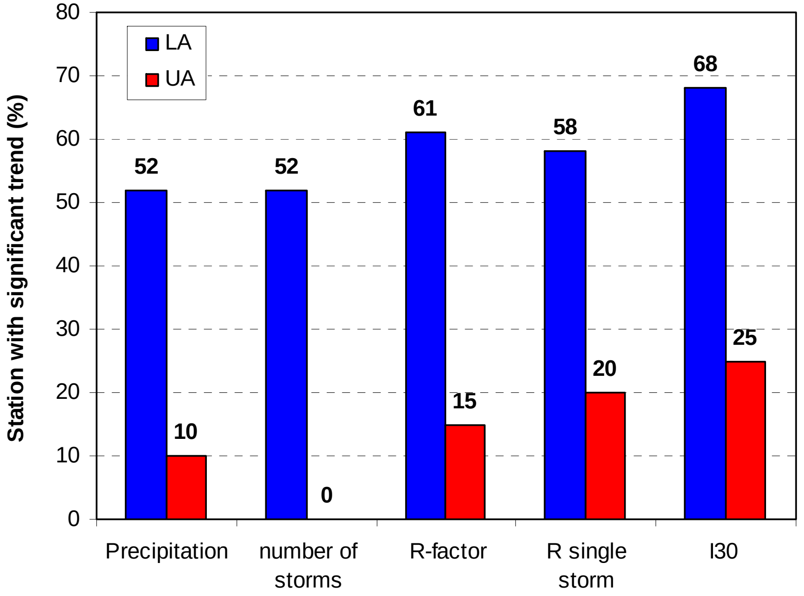

R-Factor
UA
LA
EI (MJ.mm.ha-1.h-1) V-X
3500
3000
2500
2000
1500
1000
500
0
1950
1960
1970
1980
1990
2000
2010
Year


No. storms
UA
LA
No of storms
40
35
30
25
20
15
10
5
0
1950
1960
1970
1980
1990
2000
Year


Single storm erosivity
UA
LA
EI (MJ.mm.ha-1.h-1) single storm
140
120
100
80
60
40
20
0
1950
1960
1970
1980
1990
2000
2010
Year

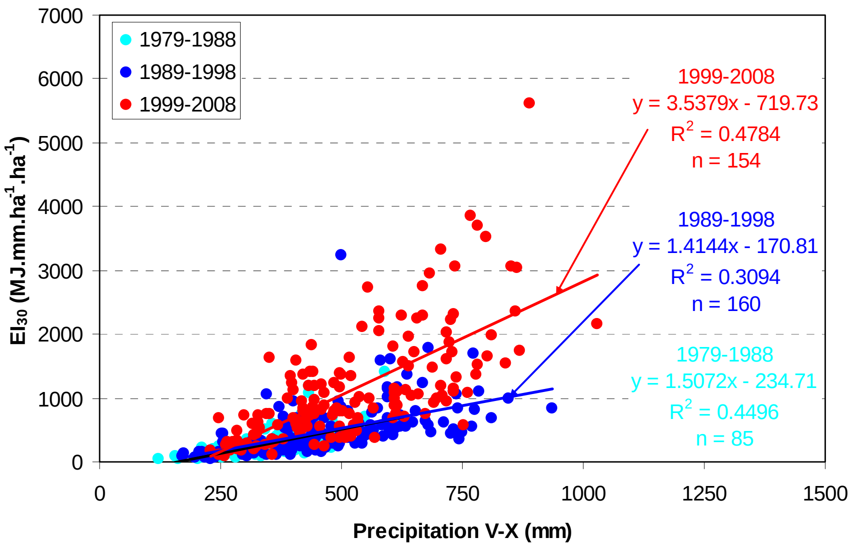

Rainfall intensity
UA
LA
Intensity (mm.h-1)
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
1950
1960
1970
1980
1990
2000
2010
Year

Results

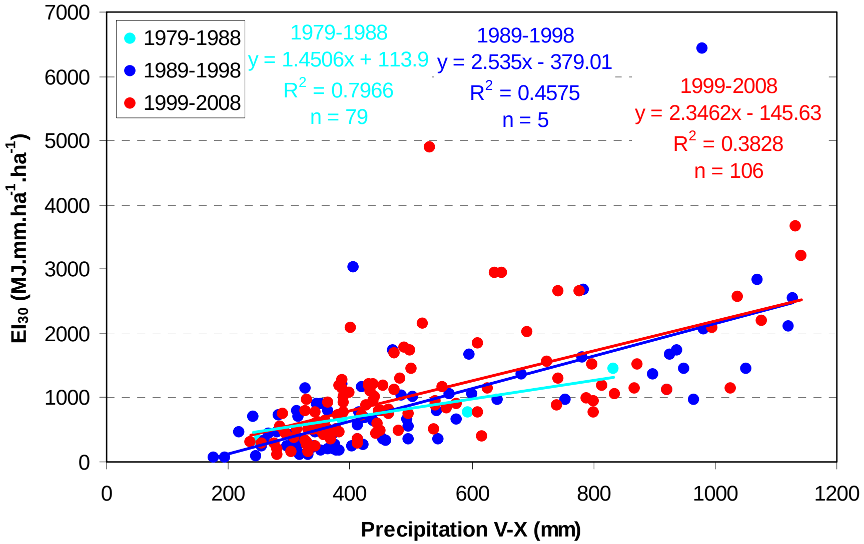


- high number of stations in LA show significant increasing trend for most investigated parameters (stations with lowest R factors)
- nearly no significant trend can be detected for UA stations
- highest significance for I_{30}
- significant increase in the last decade

Stations with significant trend



Stations with no significant trend



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 predicitions
- ✓ 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