How does the 'window' of overland flow generating rainfall react to Clausius-Clapeyron scaling?

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The Point of Departure

In many regions, climate change is likely to trigger more frequent and more intense storms.

The Clausius-Clapeyron relationship (7% increase in rainfall depth per degree of warming) is likely to describe the impact well in many cases.

Rainfall on infiltrating hillslopes will cause overland flow, if long and intense enough.

Before the background of a given IDF relationship infiltrating surfaces are associated with a window of overland flow generating rainfall durations.

The Problem

This window will be affected by climate change.

To what extent?

Method

Intensity-Duration-Frequency (IDF) relationship

$$r = \frac{s \cdot f}{(t_d + b)^p}$$

with s, b and p denoting parameters and f the Clausius-Clapeyron scaling factor (1.07 K^{-1}).

For cases of p=1 a closed-form solution can be given:

$$\Delta t_{window} = \frac{s \cdot f}{K_{sv}} \cdot \frac{\sqrt{(s \cdot f + b \cdot K_{sv} - u_0)^2 + 4 \cdot b \cdot K_{sv} \cdot [u_0 - s \cdot f - S_{av} \cdot (\theta_s - \theta_i)]}}{s \cdot f + S_{av} \cdot (\theta_s - \theta_i) - u_0}$$

with K_{sv} the vertical permeability of the soil, θ_i the initial water content, θ_s the saturated water content (both volumetric) and S_{av} the averaged suction at the wetting front.

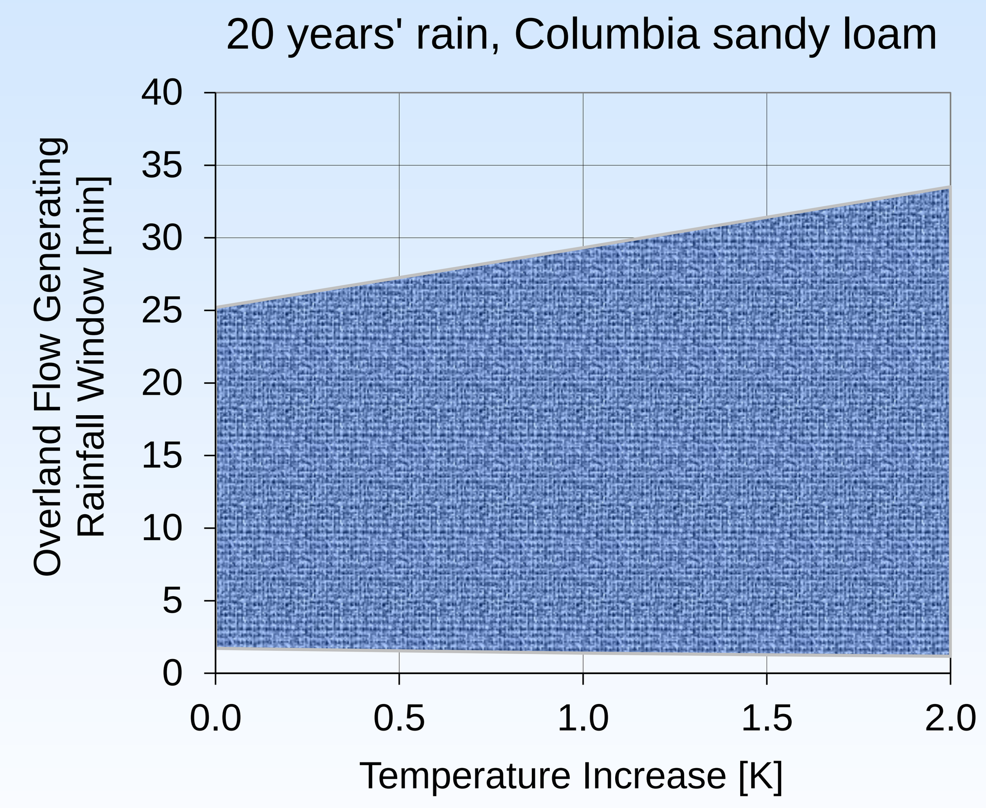
Parameters

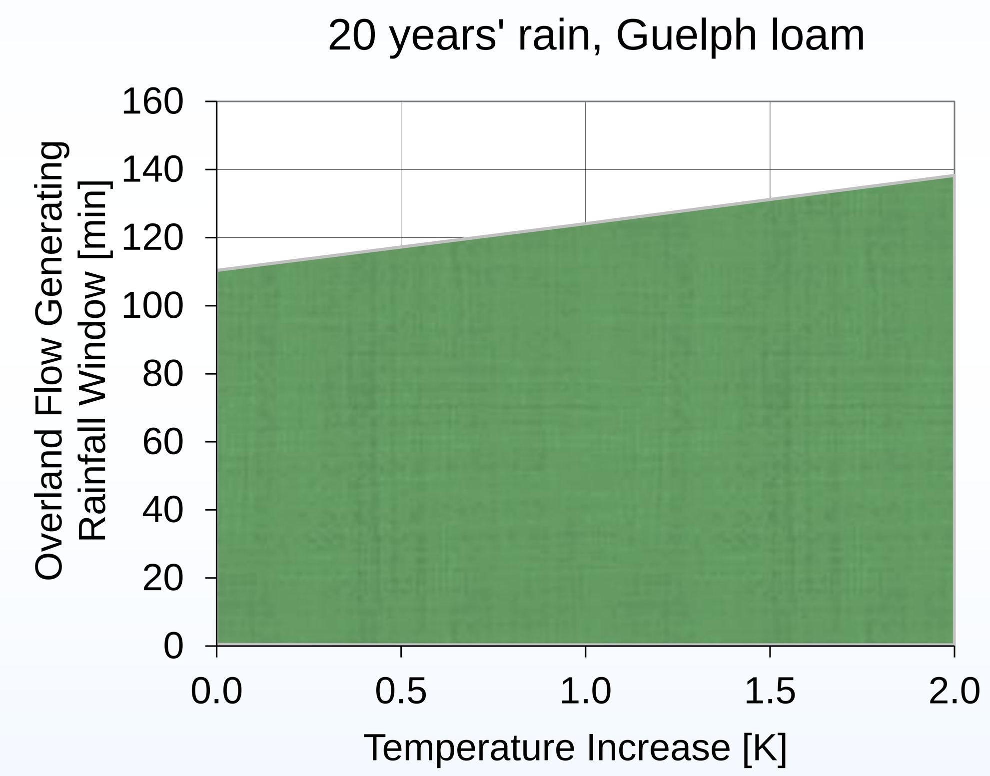
Soil	K_{sv} [m/s]	$S_{av,max}$ [mm]	θ_s [-]	θ_i [-]
Columbia sandy loam	$1.39 \cdot 10^{-5}$	238	0.516	0.300
Guelph loam	$3.67 \cdot 10^{-6}$	314	0.523	0.300
Ida silt loam	$2.92 \cdot 10^{-7}$	74	0.530	0.300

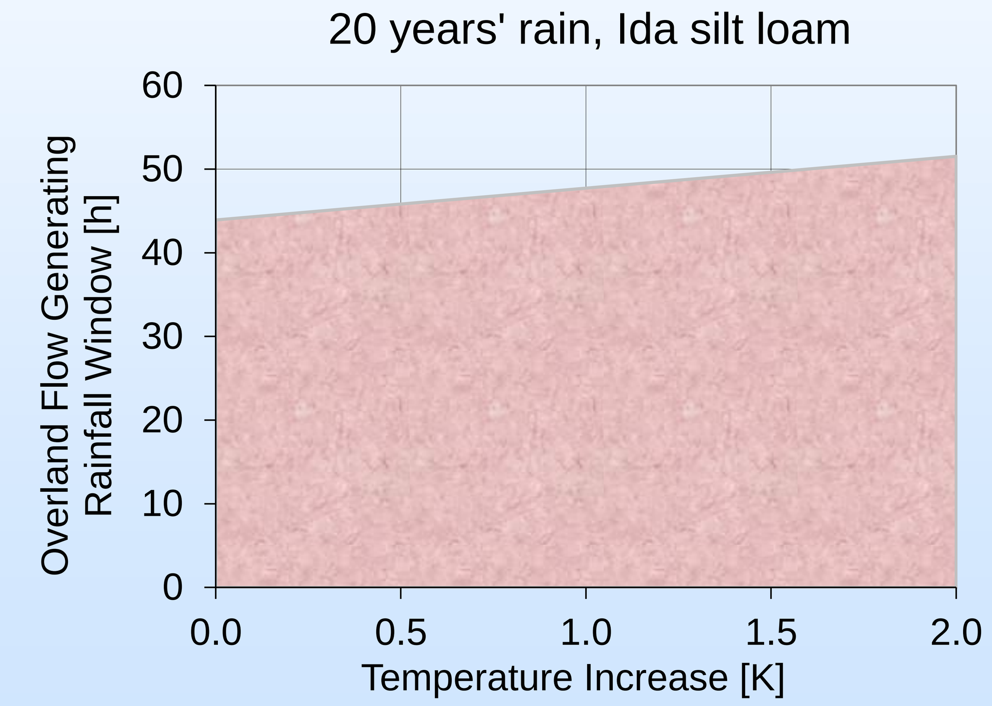
IDF:
Return period (Austrian Alps): 20 years
- b = 540 s
- s = 59.7 mm
- p = 1.0

Initial loss:
- u_0 = 0.5 mm

Results





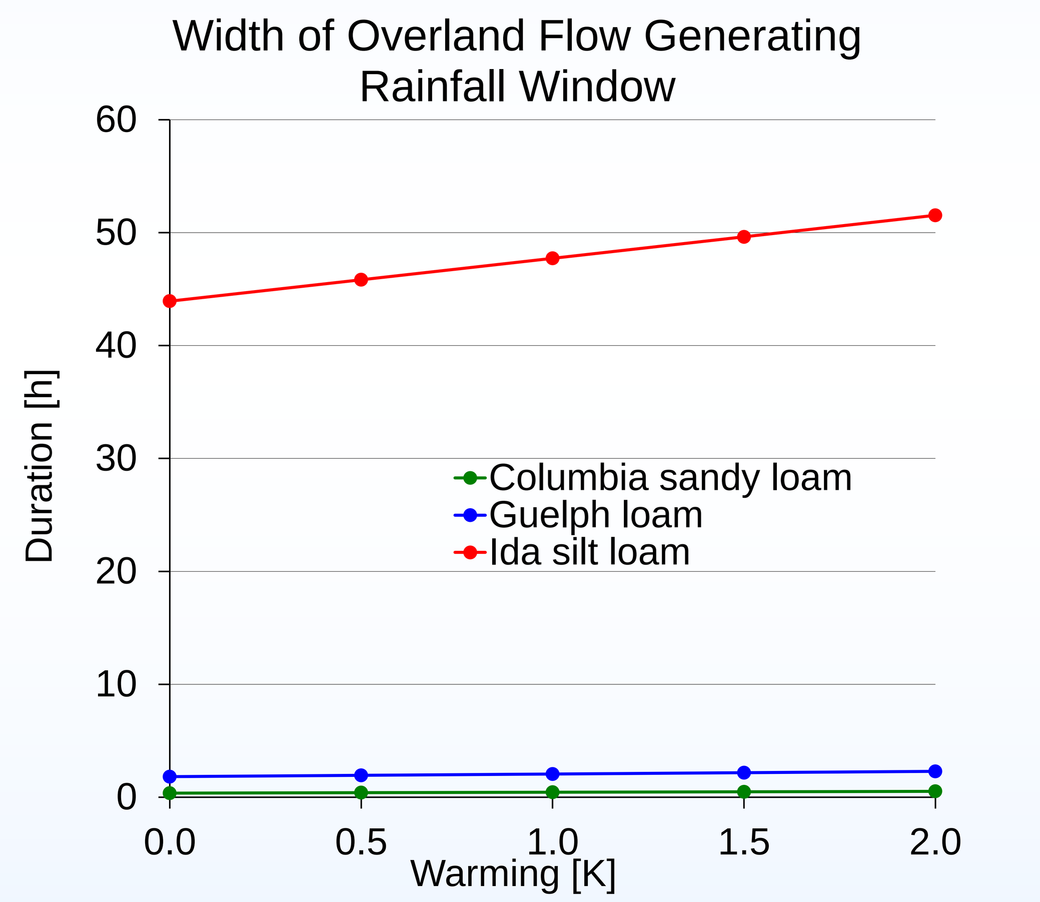


Results

For Columbia sandy loam the (short) rainfall window showed an increase of 22% (1K) and 43% (2K), resp.

In case of the 'medium' soil, Guelph loam, the increase amounted to 13% and 26%, resp.

For the finest soil, Ida silt loam, the overland flow generating window of rainfall was longest and the relative growth smallest (9% and 17%, resp.)



Conclusion

Due to climate warming more storms will qualify as triggers of overland flow, which is, thus, tending to become more pronounced and more frequent.