

Lessons learned from 30 years of erosion research in loess catchments

- Challenging title, no ?



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This symposium looks at flooding

- Is research on soil erosion relevant ? And if so, how ?

A very quick reminder of what we understand of water erosion on (loess) soils



What do we know about soil erosion ?

- A personal evaluation of the state of affairs

Basically:

- Soil erosion = $f(\text{soil, climate, topography, land cover/use, land management})$ and interactions at different scales
 - between these factors
 - between different landscape elements

What do we know/understand about this ?

Actually, quite a bit !



We understand soil erodibility pretty well: Loess soils are among the most erodible soils on the planet

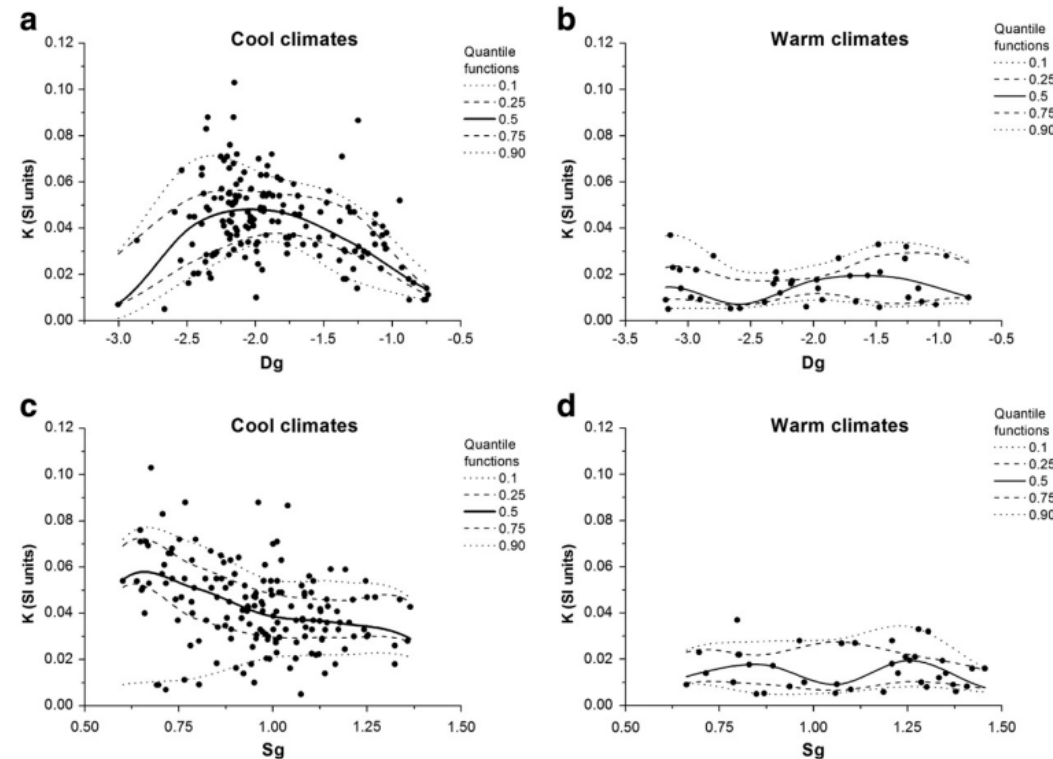
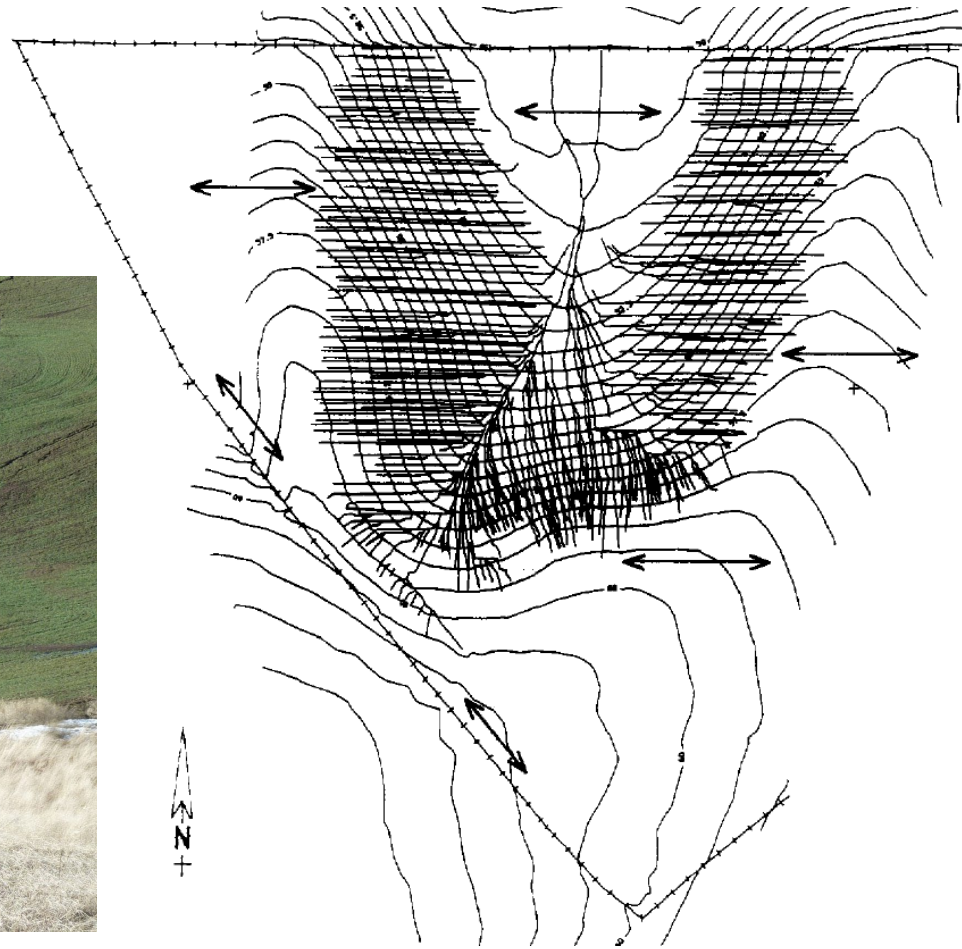


Fig. 1. Examples of quantile interpolating functions. **a, b)** Soil erodibility (K) versus the logarithm of the geometric mean particle size (D_g) for cool and warm climates and rock content <10%, **c, d)** Soil erodibility (K) versus the standard deviation of the logarithmic transformation of particle-size distribution (S_g) for cool and warm climates and rock content <10%.

Borselli et al., 2012

Topographic controls on erosion (and deposition) are also well understood



Desmet and Govers, 1997

Topographic controls on erosion (and deposition) are well understood

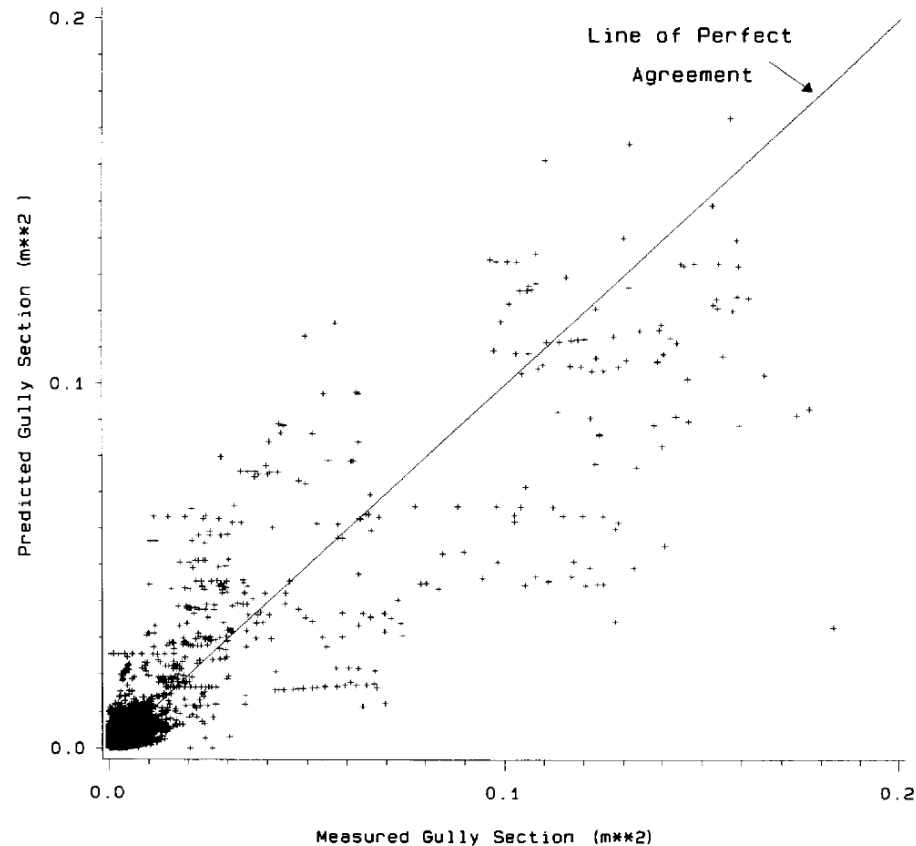


Fig. 6. Regression between predicted and measured rill and gully section.

$$G_s = 0.00090 \cdot S^{1.020} \cdot A^{0.875}$$

Desmet and Govers, 1997

We do have a tremendous number of papers on rainfall erosivity





CATENA

Volume 157, October 2017, Pages 357-362



Rainfall erosivity: An historical review

Mark A. Nearing ^a  , Shui-qing Yin ^b , Pasquale Borrelli ^c , Viktor O. Polyakov ^a 

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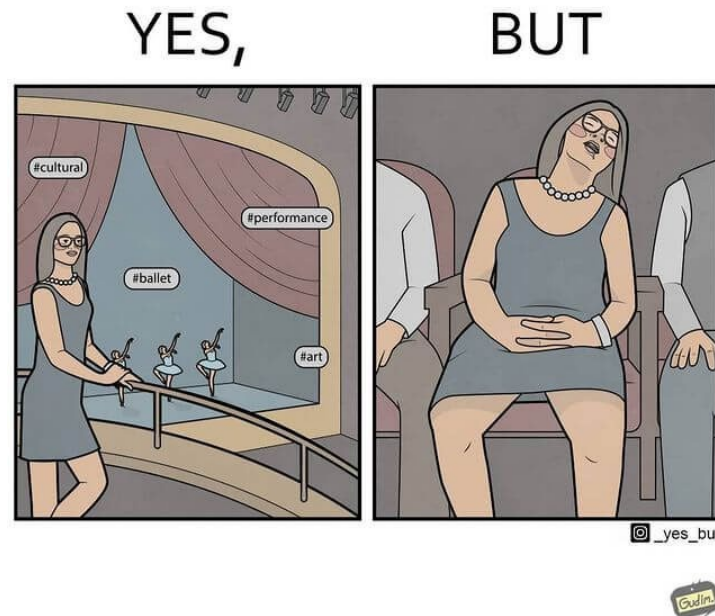
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But...

there is virtually no literature where the relationship between erosion rates and rainfall erosivity is tested, except for the original USLE publications !



We do have a reasonable understanding of the relationship between land use, land cover, agricultural techniques and erosion...

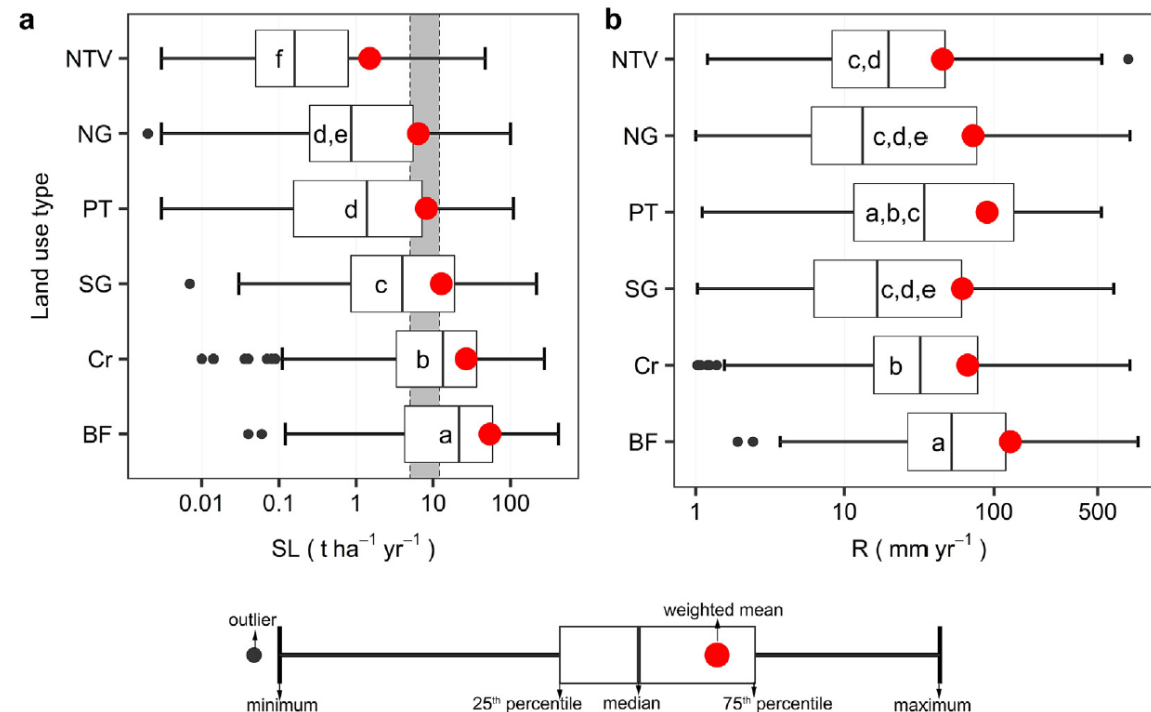
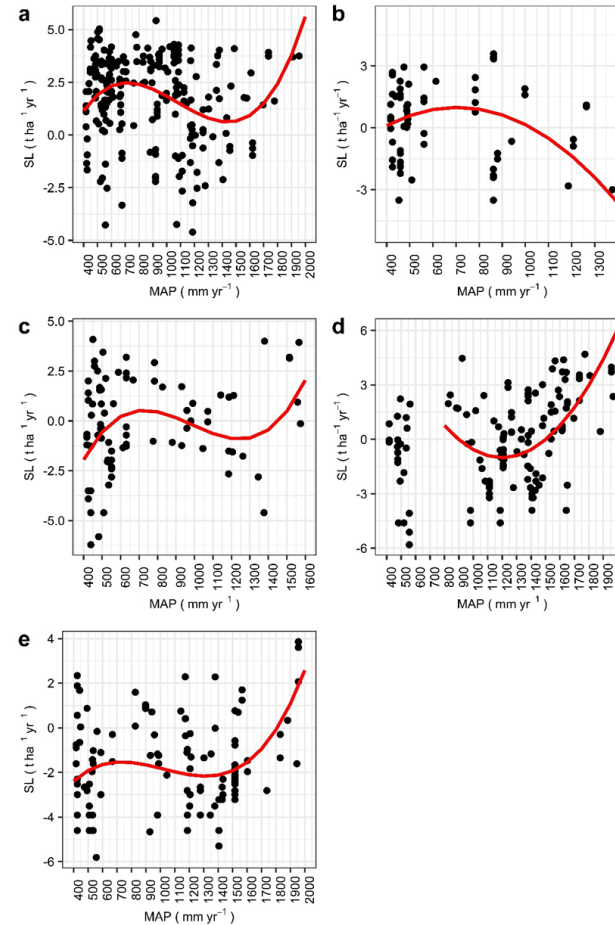


Fig. 3. Box plot of soil loss rates (SL) (a) and runoff rates (R) (b) for each land use type (BF: barren and fallow land; Cr: cropland; SG: seeded grassland; NG: natural grassland; PT: planted tree; NTV: natural tall vegetation) with indication of the weighted mean (red dot), the weighted median (central vertical bar), the 25th and 75th percentile (left and right side of box), minimum and maximum values without outliers (small vertical bars at end of whiskers) and outliers (individual black dots). The vertical grey bar in panel a represents the range of tolerable soil loss rate ranges (T value: 5-12 $t\ ha^{-1}\ yr^{-1}$) as proposed by Schertz (1983). Mean values with the same superscript are not significantly different at $p = 0.05$ (the non-parametric Kruskal-Wallis tests). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Zhao et al., 2022

But the *interaction* between climate and agricultural systems is rarely accounted for



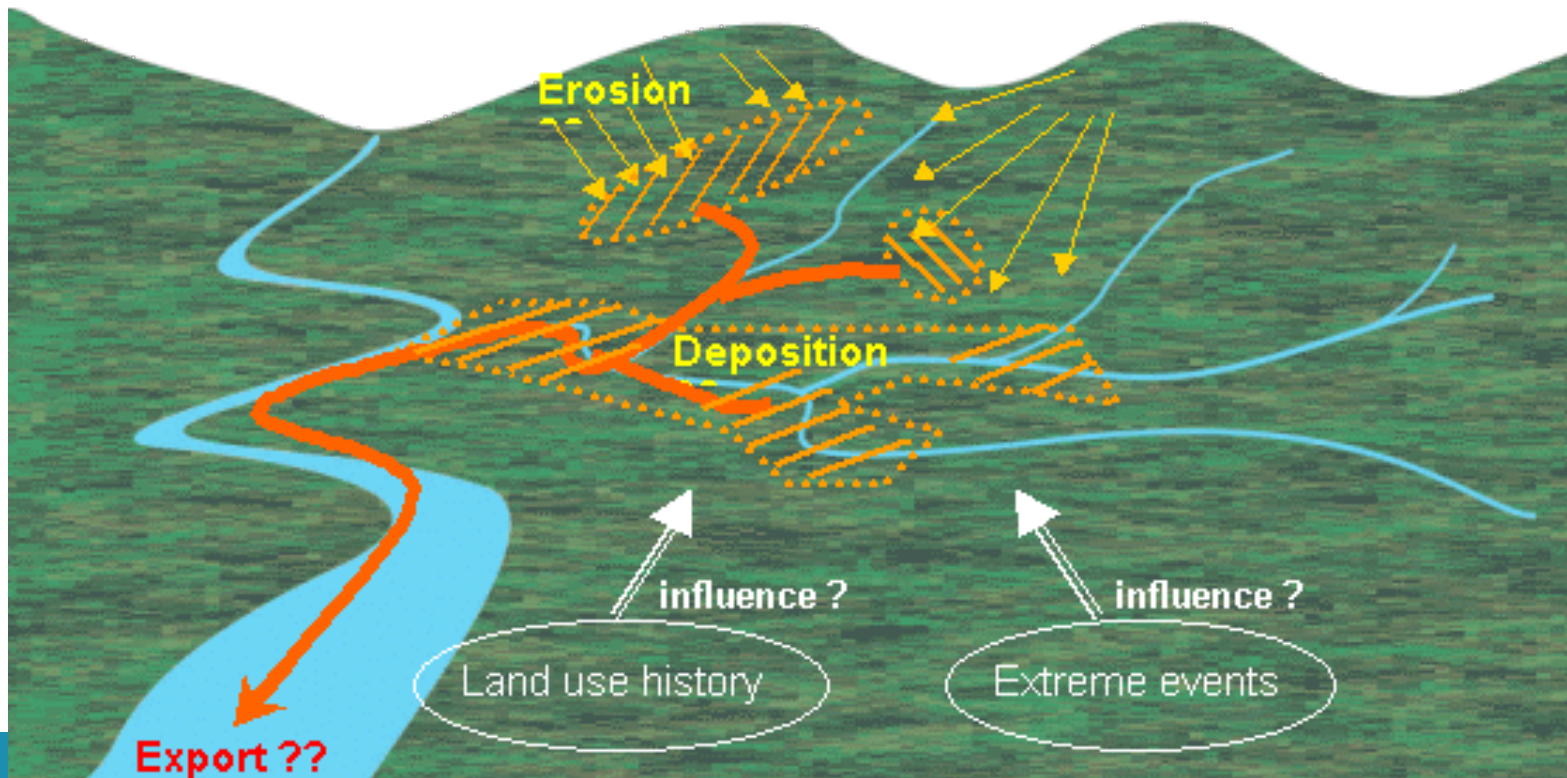
Zhao et al., 2022

We do have some understanding on how different landscape elements interact

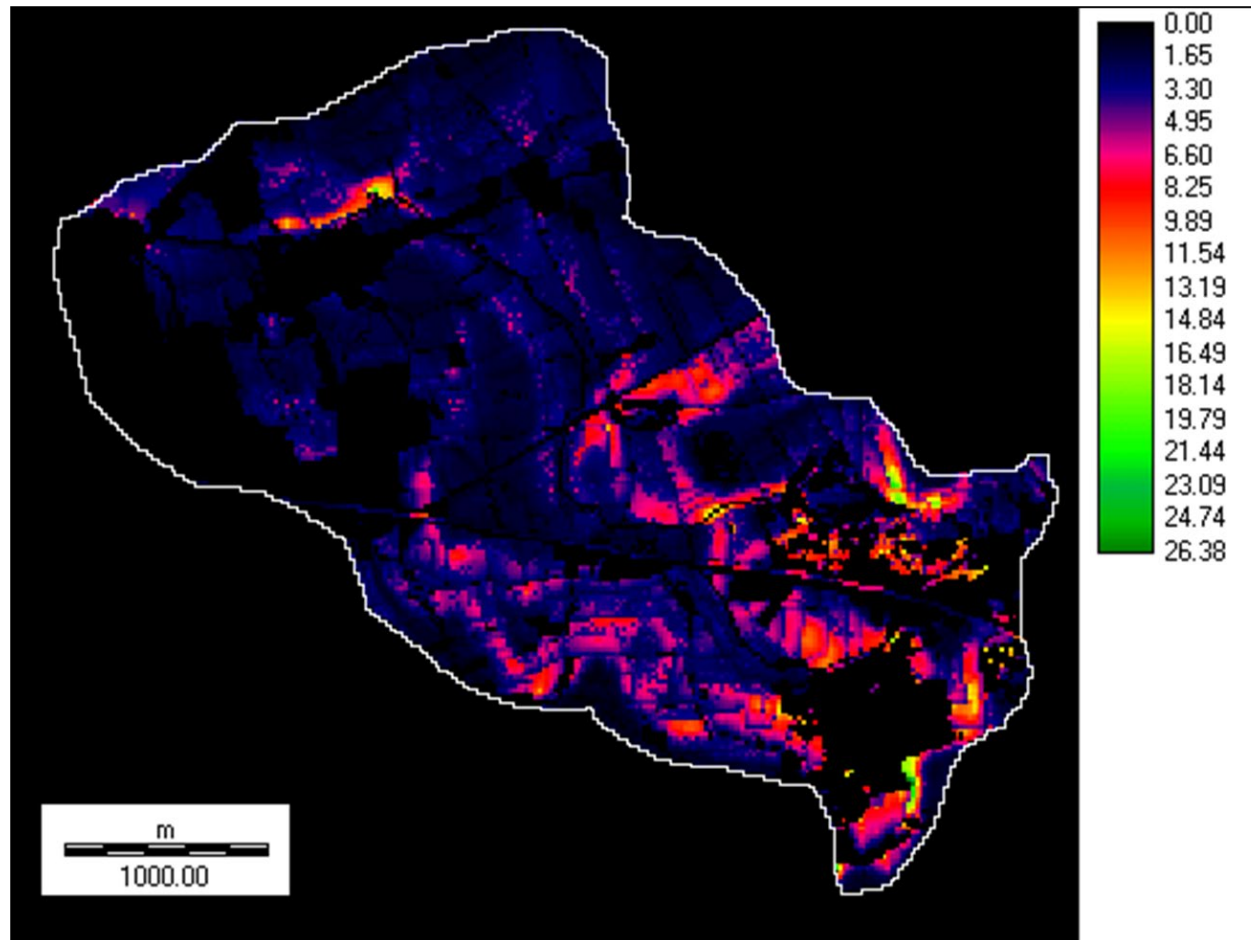


We can therefore reasonably predict *patterns* of erosion and deposition

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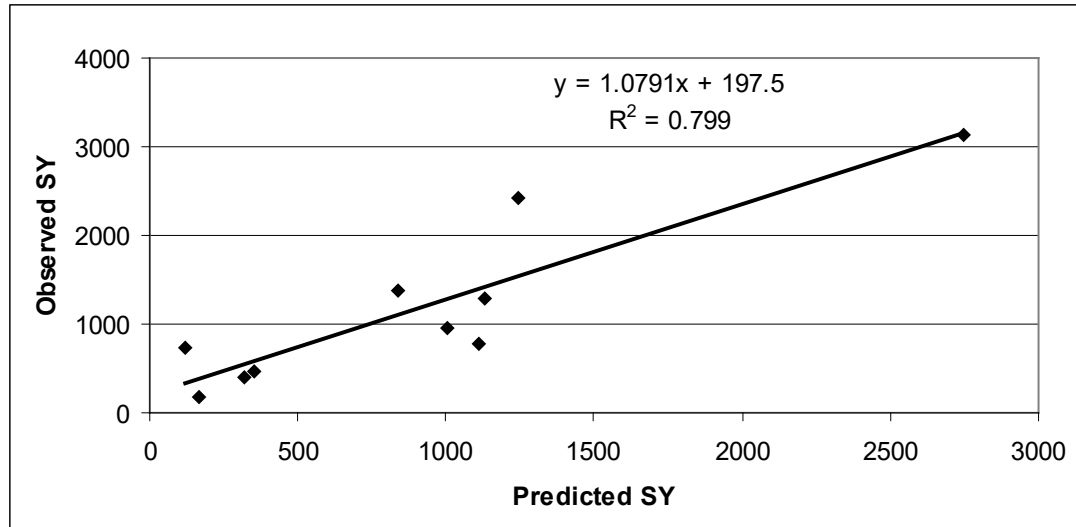


We can reasonably predict the impact of measures such as land use change on *patterns* and on *average rates*



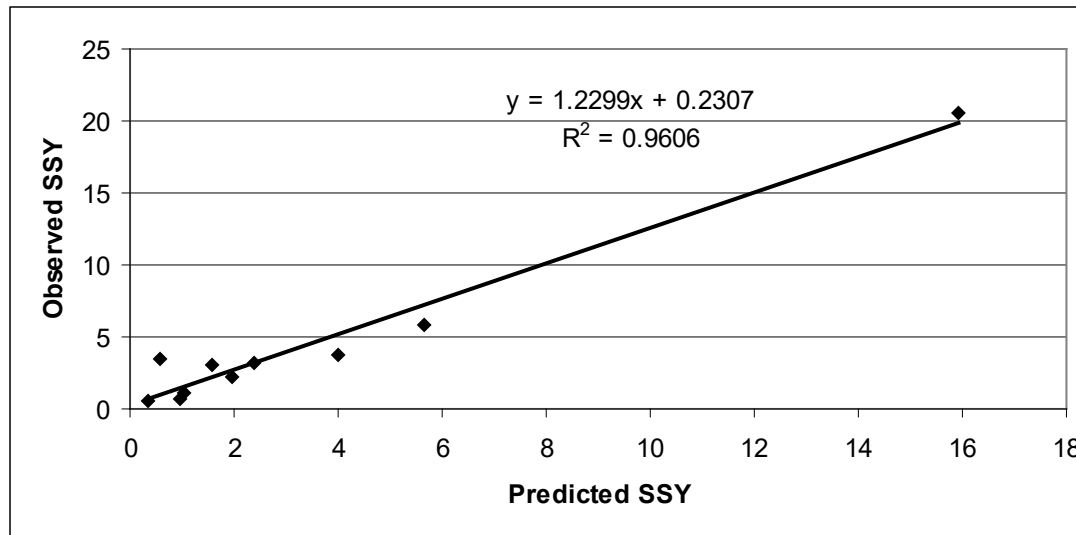
Van Rompaey et al., 1999

Model validation



Validation of Predicted Sediment Yield (ton/y)

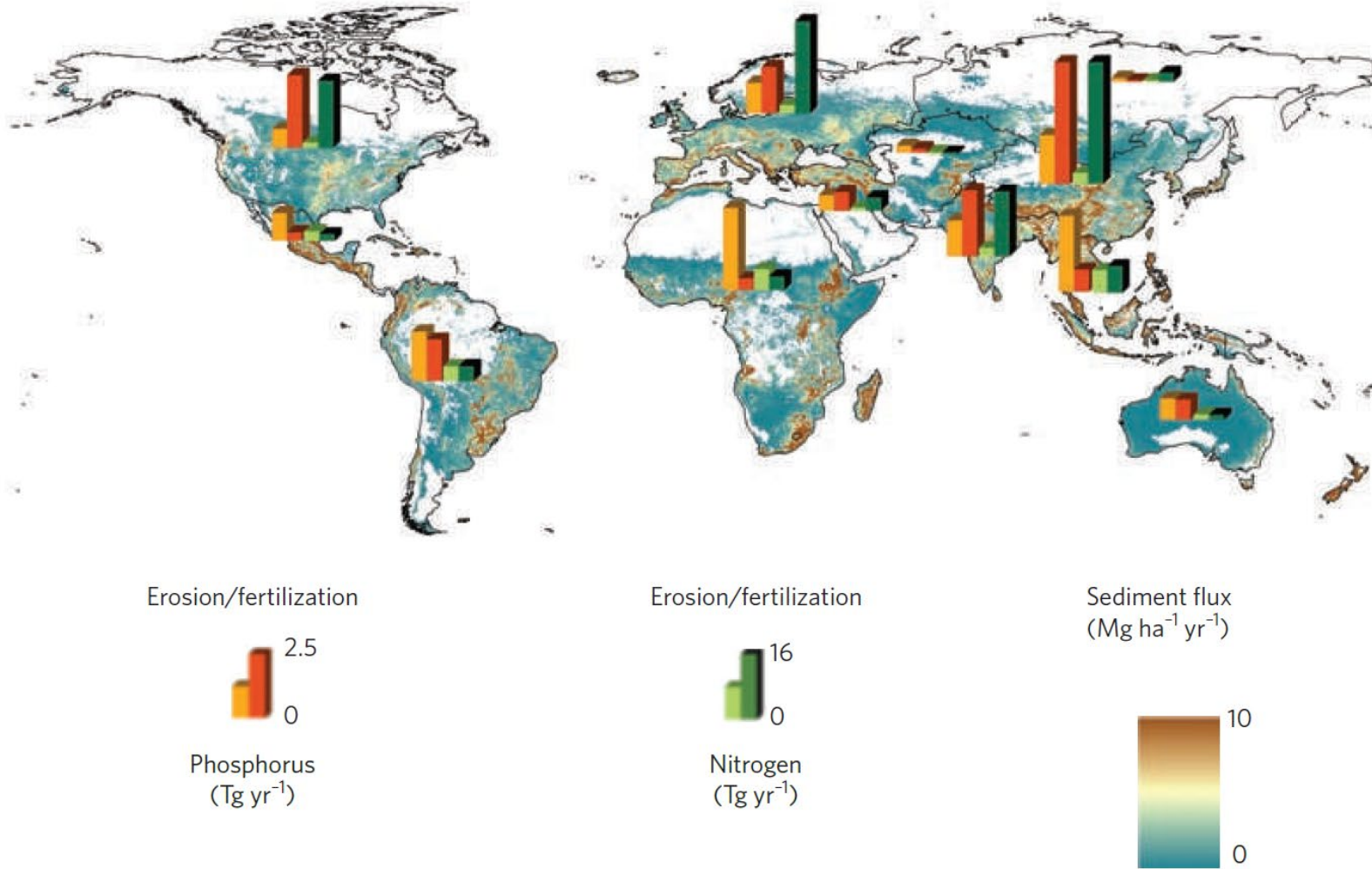
RRMSE = 36%



Validation of Predicted Area-specific Sediment Yield (ton/ha.y)

RRMSE = 36%

a

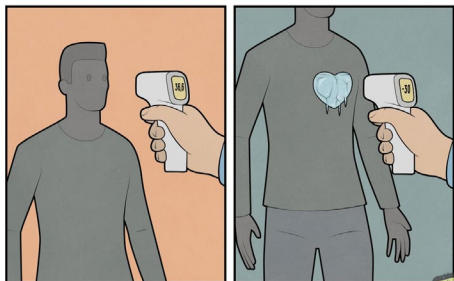


Quinton et al., 2010

But we (will continue to) struggle with getting *event-based rates* right

If this value is below -0,3 then your model is totally worthless (NSE < 0)

YES, BUT



P.V.G. Batista, et al.

Earth-Science Reviews 197 (2019) 102898

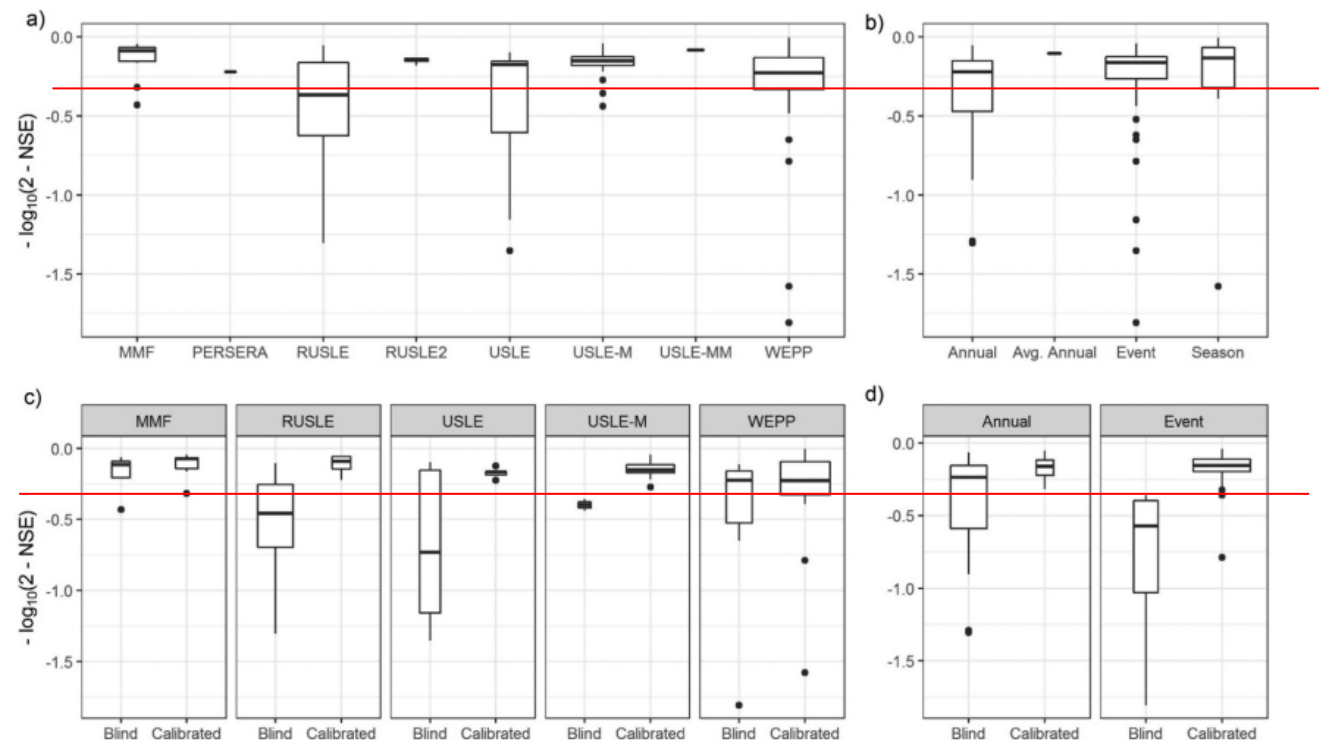


Fig. 3. NSE values reported in erosion modelling studies grouped by: (a) model; (b) temporal scale of model application; (c) model and the use or not of calibration; (d) temporal scale of model application and use or not of calibration. The width of the boxes is scaled according to the size of the datasets for each group. In figures (c) and (d) we only display models and temporal scales which were used both with and without calibration. For better visualization, NSE values have undergone log-linear transformation.

Batista et al., 2019

But is this important ?

- Driver of erosion events is unpredictable extreme weather : we are not able to predict local precipitation amounts and intensities one day ahead
- We do have a reasonable grip on how much sediment may be mobilised in such events *if we would know initial conditions and rainfall characteristics*. But we don't know those and perhaps never will.
- If we get obsessed with event-based prediction then we are barking up the wrong tree

Do we (sometimes) bark up the wrong tree ?

- “Soil erodibility”: 495 WoS papers over last 5 years
- “Soil erosion” “crop yield” : 135 papers over last 5 years

Can we stop erosion ?

and will it help to reduce flooding risk/damage ?

Soil and water conservation research has a long history

- Started in the USA, already in the 1930s: Dust Bowl, establishment of the Soil Erosion Service in 1933 (Hugh Hammond Bennett), later transformed into the Soil Conservation Service and thereafter into the NRCS (Natural Resources Conservation Service)
- Favoured research on erosion assessment and efficacy of soil conservation techniques



These modern efforts were preceded by those of far older civilisations



How effective are erosion control measures ?



We do have good data at plot level: effect of conservation tillage on erosion rates

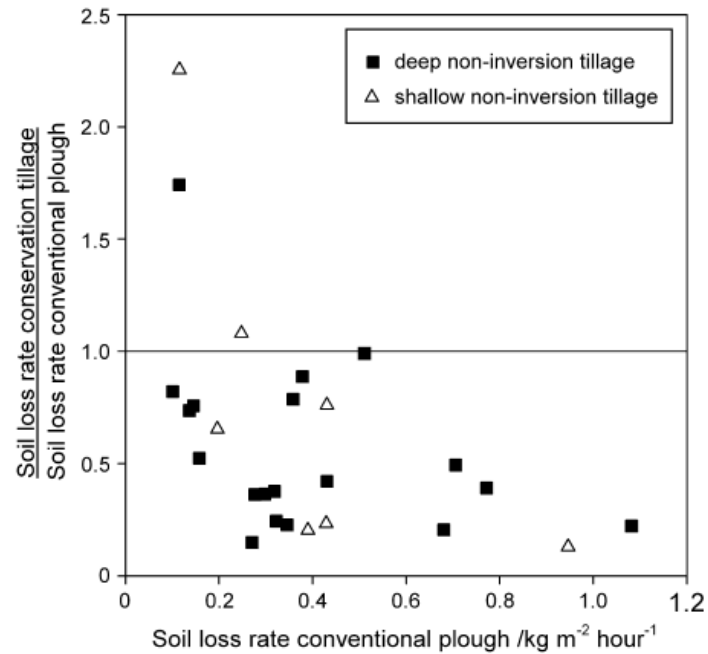


Figure 3 Interrill soil loss rate ($\text{kg m}^{-2} \text{ hour}^{-1}$) ratio for every field of the mean of the replicates on the conservation tillage part over the mean of the replicates on the conventionally tilled part versus the mean soil loss rate for the conventionally tilled part of that field. A correction was made for the mean simulated rainfall intensity and the mean plot area.

Leys et al., 2007

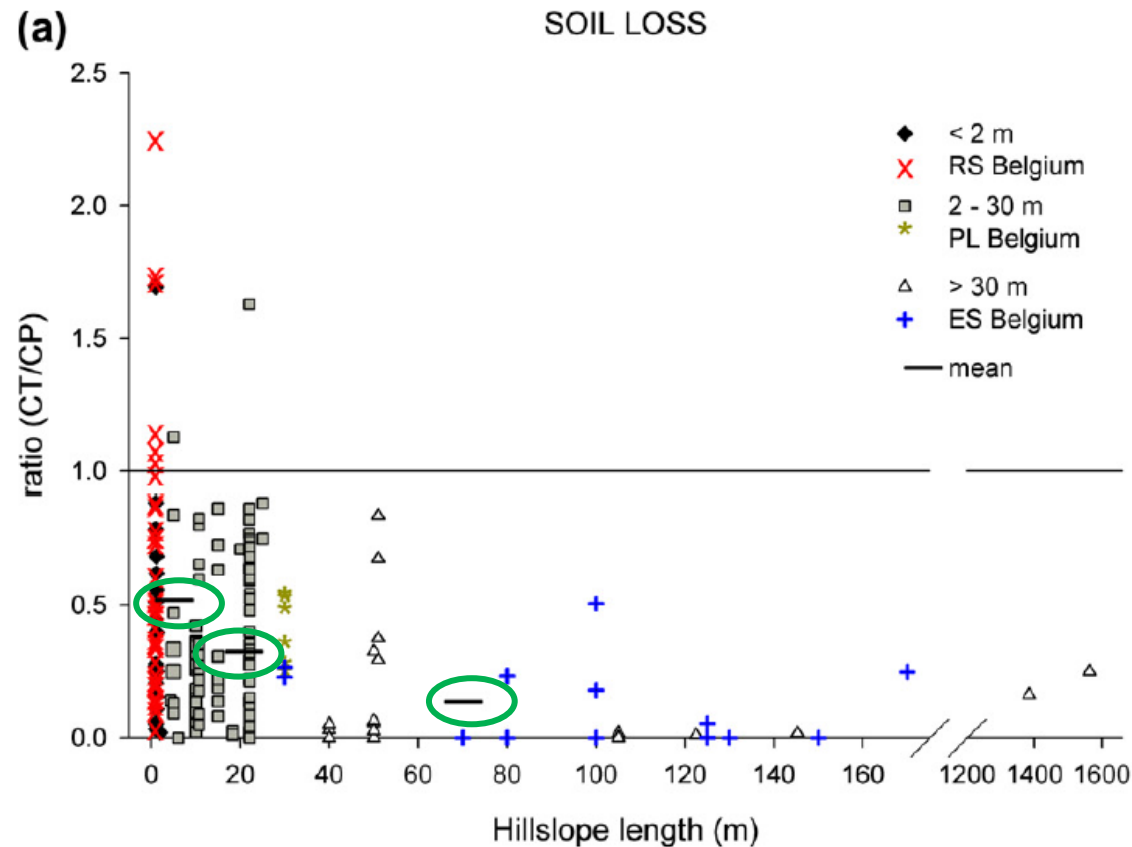


At the field scale ?



Conservation tillage is far more effective at the field scale than at the plot scale

A. Leys et al./Journal of Hydrology 390 (2010) 143–154



Overall, conservation tillage is **very** effective

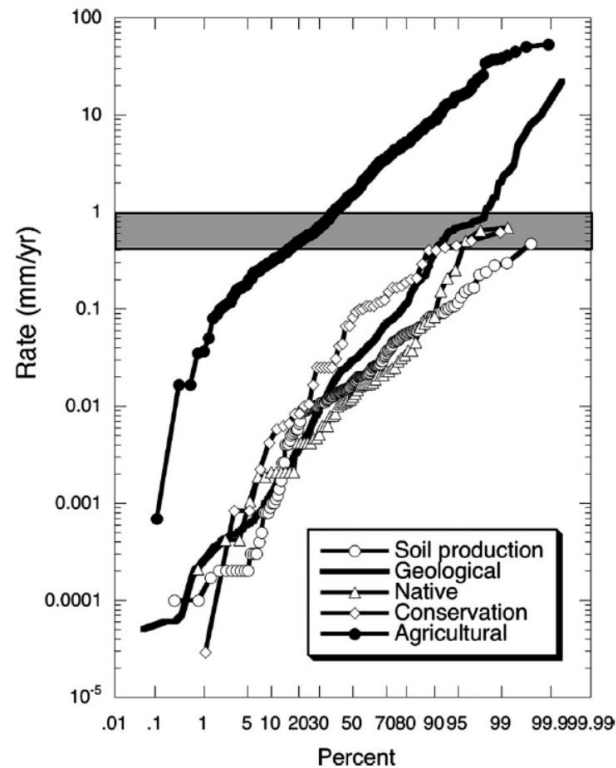


Fig. 2. Probability plots of rates of soil erosion from agricultural fields under conventional (e.g., tillage) and conservation agriculture (e.g., terracing and no-till methods), with erosion rates from areas and plots under native vegetation, rates of soil production, and geologic rates of erosion (a composite distribution of the data for cratons, soil-mantled landscapes, and alpine areas in Fig. 1). Data sources for agricultural and geologic rates are the same as for Fig. 1. Shaded area represents range of USDA. T values (0.4–1.0 mm/yr) were used to define tolerable soil loss.

If we stop erosion (which is entirely feasible), will this stop flooding ?



Erosion \neq flooding

- Runoff generation and transfer drive erosion
- However, erosion exacerbates flooding problems
 - Clogging
 - Downstream sediment deposition
 - Pollution
 -

Does conservation tillage also work for runoff ?

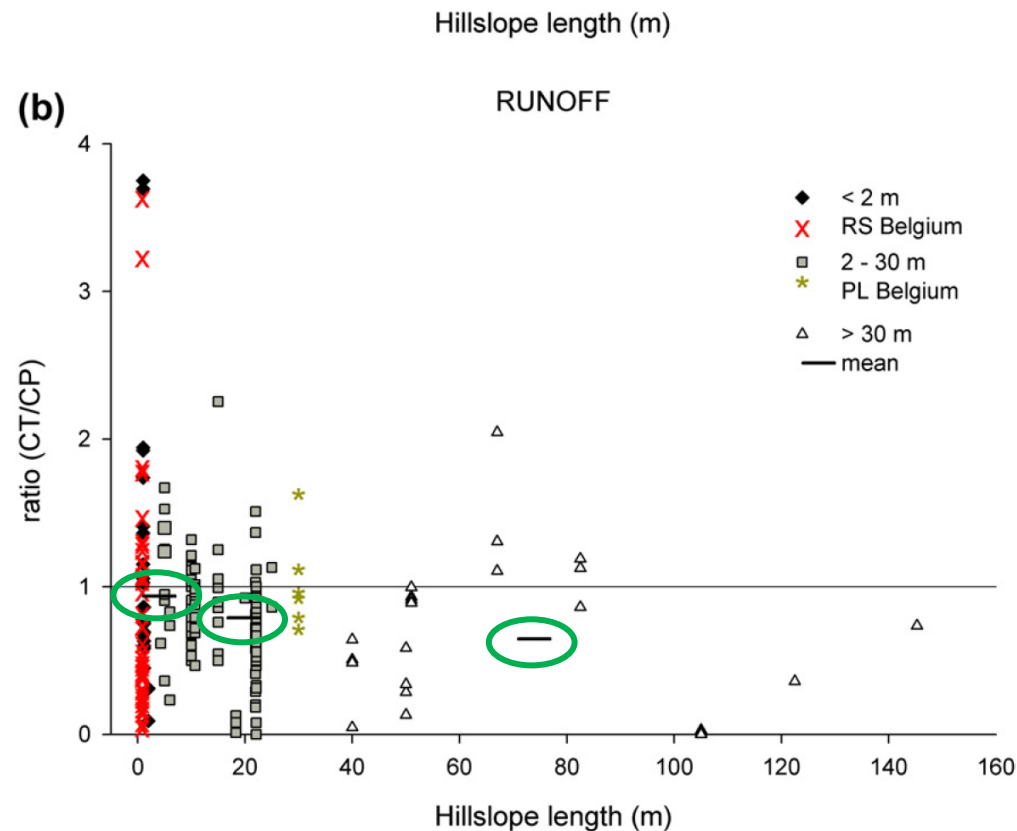


Fig. 3. Summary of soil loss (a) data and runoff data (b) from literature and from experiments in the Belgian Loess Belt. The ratio of the absolute soil loss (or runoff) measured on a conservation tillage plot/field over the absolute soil loss (or runoff) on the paired conventionally ploughed plot/field versus the plot/field length is given. (RS: rainfall simulation experiments, PL: plot studies SOWAP project, ES: erosion surveys, CP: conventional tillage, CT: non-inversion tillage; see also Table 2).

Leys et al., 2007

To some extent !

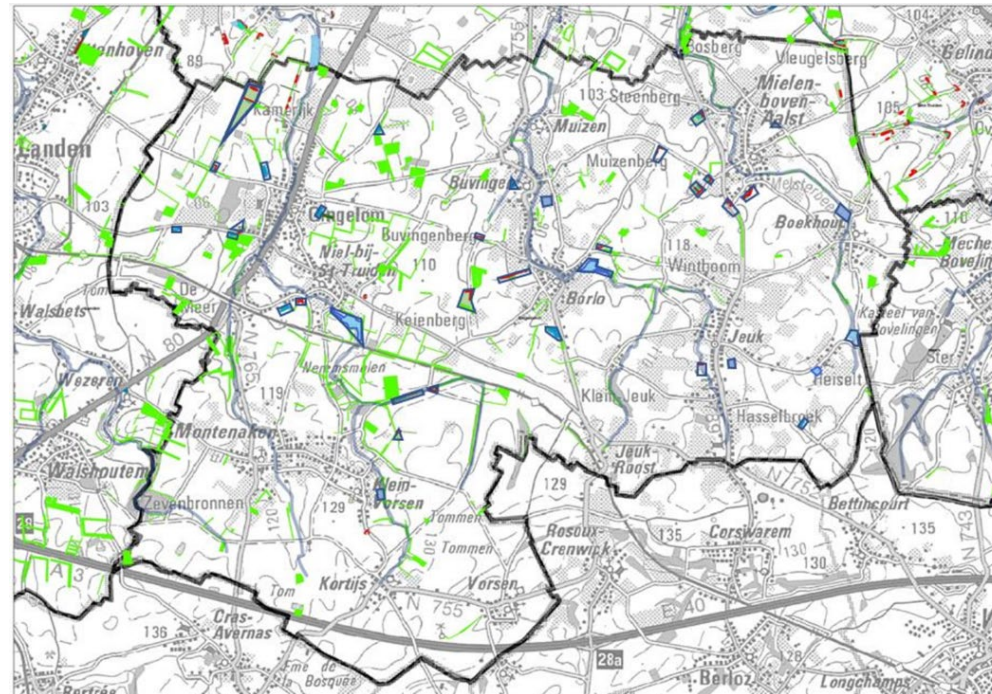
- Conservation tillage does reduce runoff production
- But to a far lesser extent than it reduces erosion: only 35% average reduction at field scale, while >90% reduction for erosion
 - Probably even less during extreme events.
 - Probably even less at river catchment scale

Why I think the latter is true ?

- 2021 event caused floods in Valkenburgh area
- But floods were even more important in Ardennes and Eifel
 - Almost no arable land
 - Permanent land cover
 - Caveat: generally thin soils

Thus, even perfect erosion control will not be sufficient for flood control

- Many communities in Belgium understood this
 - Construction of retention basins, grassed waterways etc... to delay transfer of water (and sediment) to lower lying areas: over 40 structures in Gingelom



<https://www.gingelom.be/overzicht-bufferbekkens-gingelom>

And these structure make a difference



<https://www.truineer.be/wp-content/uploads/2021/07/gingelomie.jpg>

But the regulatory framework for the application of conservation tillage/land use is still too weak in Flanders ...

- You can still choose to till along the contour lines on so-called red parcels, rather than to apply conservation tillage
- You can still plant potatoes on ridges on such parcels, even in direction of slope
- If you plant biological potatoes you are exempt from erosion control measures

6.3.2.5 Keuzepakket teelttechnische maatregelen voor **ROOD** perceel

Minstens één van de volgende maatregelen uitvoeren:

- ▶ niet kerende bodembewerking toepassen voor de inzaai van de teelt;
- ▶ directe inzaai toepassen;
- ▶ strip-till toepassen bij de inzaai van de teelt;
- ▶ zaaien volgens de hoogtelijnen bij andere dan ruggenteelten;
- ▶ bij niet-biologische aardappelen is het aanleggen van drempels sowieso verplicht. Bij biologische aardappelteelt is schoffelen en wieden toegelaten als alternatief voor drempels;
- ▶ bij andere ruggenteelten dan aardappelen is het aanleggen van drempeltjes of het toepassen van een diepe tandbewerking verplicht;
- ▶ onbeteelde zones (kopakkers) inzaaien met gras in de groeifase van de teelt.



Will that then be enough ?

- If correctly dimensioned and maintained and combined with proper land management, they will make a big difference
- There will always be the possibility of a disaster exceeding your buffering capacity

Finishing thoughts

Flooding is not a new problem: the Arenberg Castle near Leuven, 1906



Finishing thoughts

- Soil erosion is a serious problem on sloping agricultural land that exacerbates flooding risks
- We can (nearly) stop erosion
- This will reduce flooding extent and flooding damage
- But it will not be enough: specific measures, mostly to retain water, will be necessary to protect villages and cities