# Nonlinear response of soil erosion to mean annual precipitation

## evidence from erosion plot data in China

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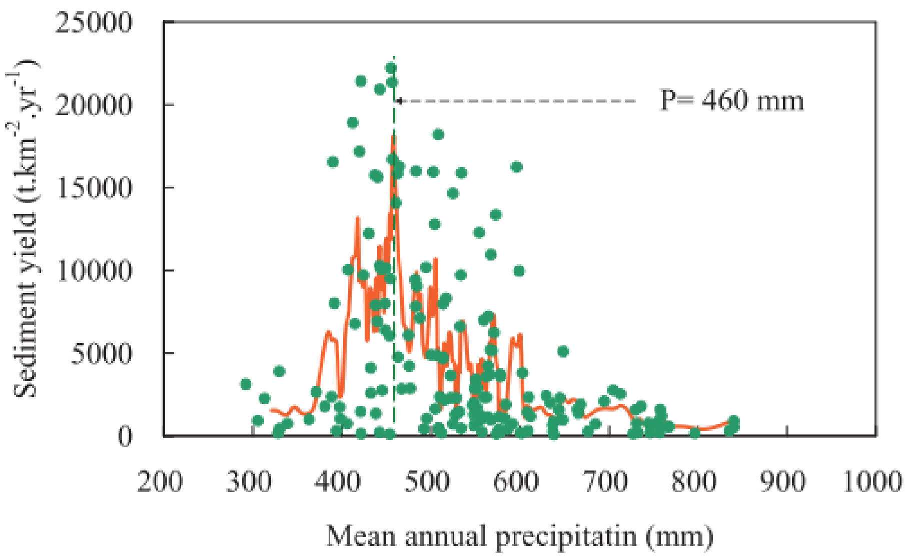
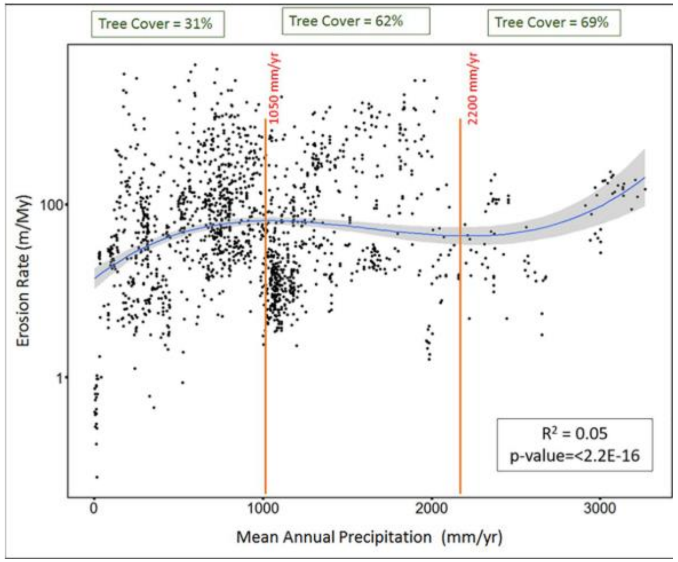
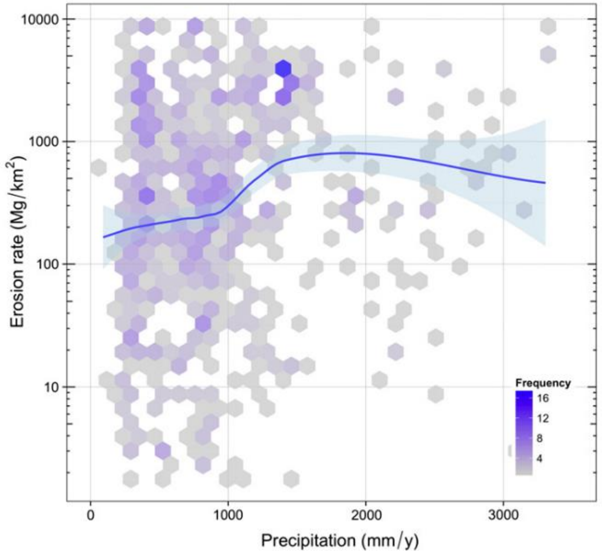
# The impact of precipitation on soil loss




Xin et al., 2011.
sediment yield/catchment




Kumar Mishra et al., 2019.
sediment yield/catchment




García-Ruiz e al., 2015.
soil loss/plot/catchment

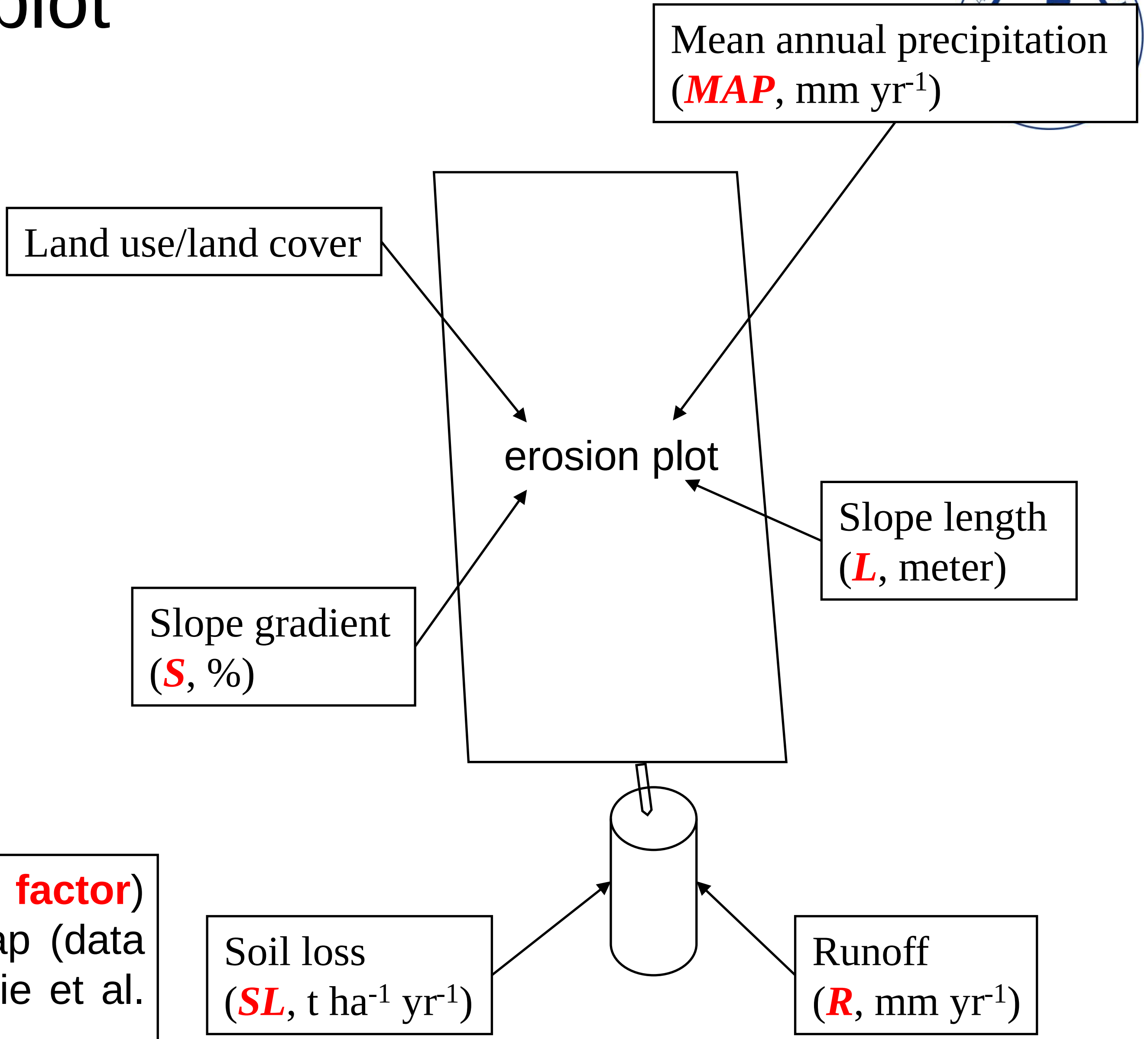
Different patterns have been observed for the relationship between soil loss/sediment yield and mean annual precipition

# Data and methods：erosion plot

*Criteria:*

- ❑ Under **natural rainfall**
- ❑Slope length should be larger **3 meter**
- ❑ At least **one year** of observations

Soil erodibility (***K* factor**) and rainfall erosivity (***R* factor**) for each site were extracted from the national map (data source: http://www.geodata.cn/ , 30m resolution, Xie et al. (2016) Liu et al., 2020)



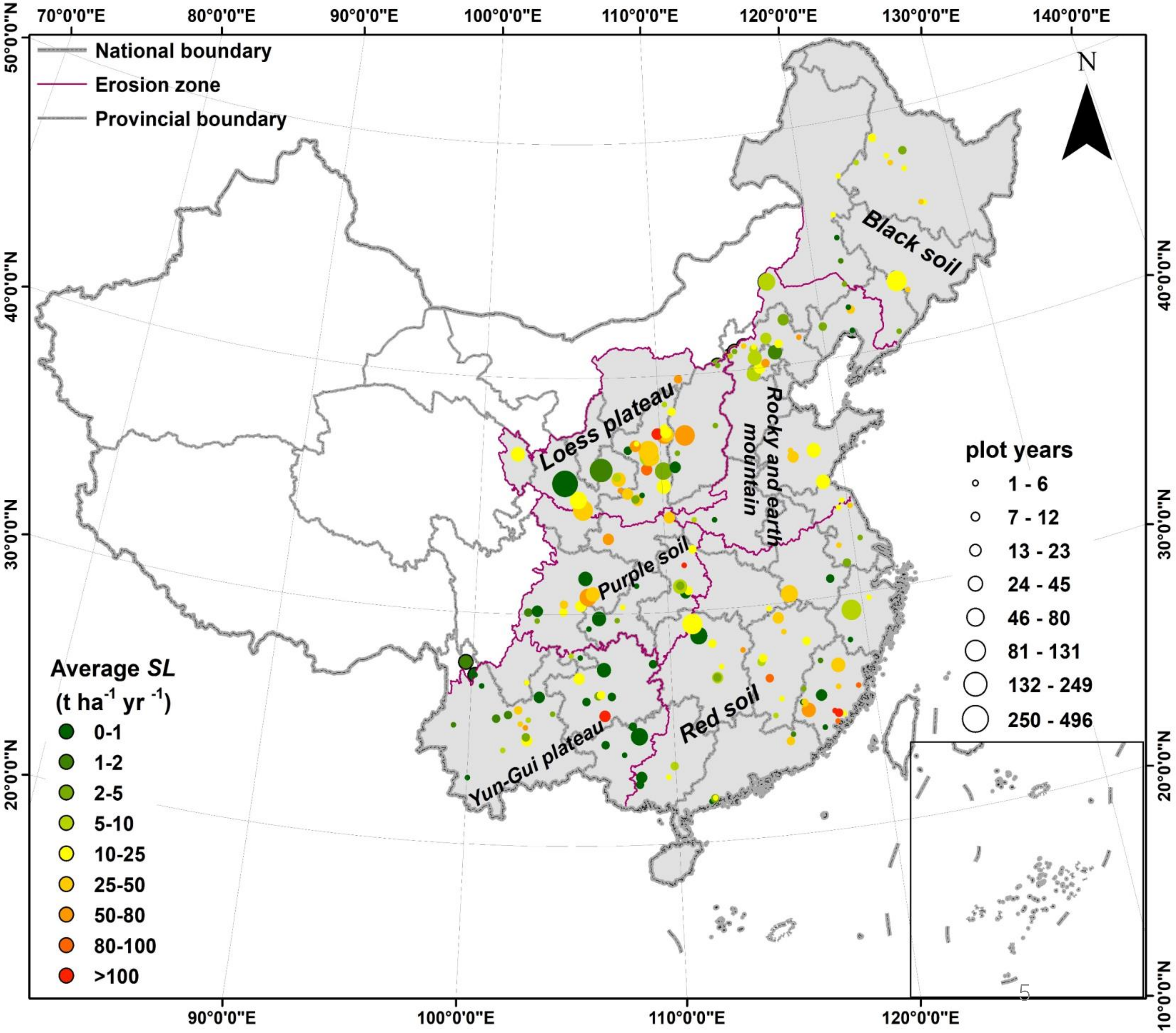
# Statistic analysis

- We calculated **mean annual soil loss rate (*SL*)** and **mean annual runoff (*R*)** for each plot.
- **(Multiple) linear regression models** and **LOESS smoothing** (local polynomial regression method) were used to analyse the overall variation of soil loss and runoff with controlling factors (slope gradient, slope length, *MAP* and *K* factor)

$$SL \sim f\,(S, L, MAP, K)$$

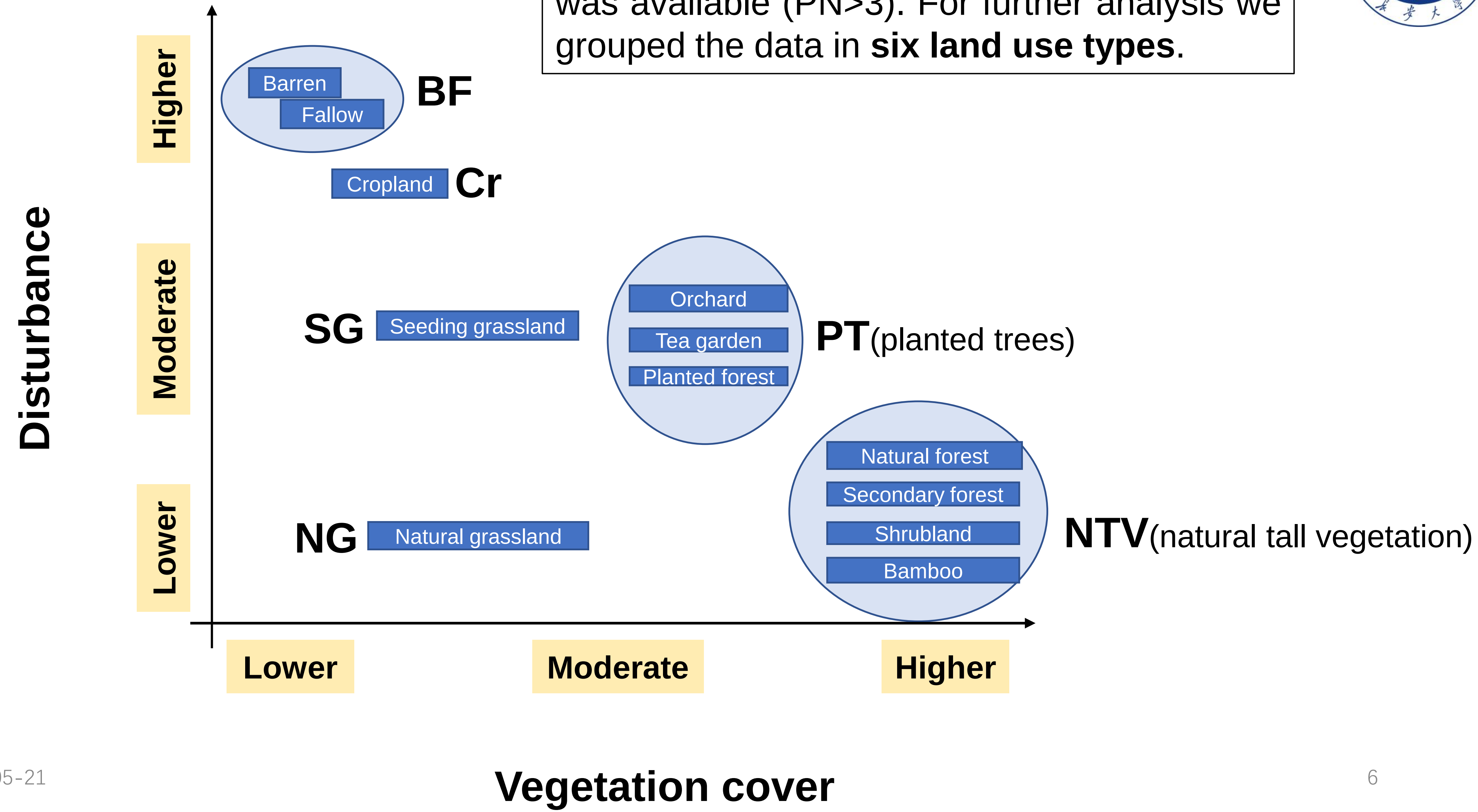
# Erosion plot database

- **1403** erosion plot
- **205** sites
- **4742** plot years
- **188** literatures.
- a broad range of precipitation (**400-2400** mm)。



# Land use

We identified **12 different land uses** for which a minimum number of observations was available (PN>3). For further analysis we grouped the data in **six land use types**.



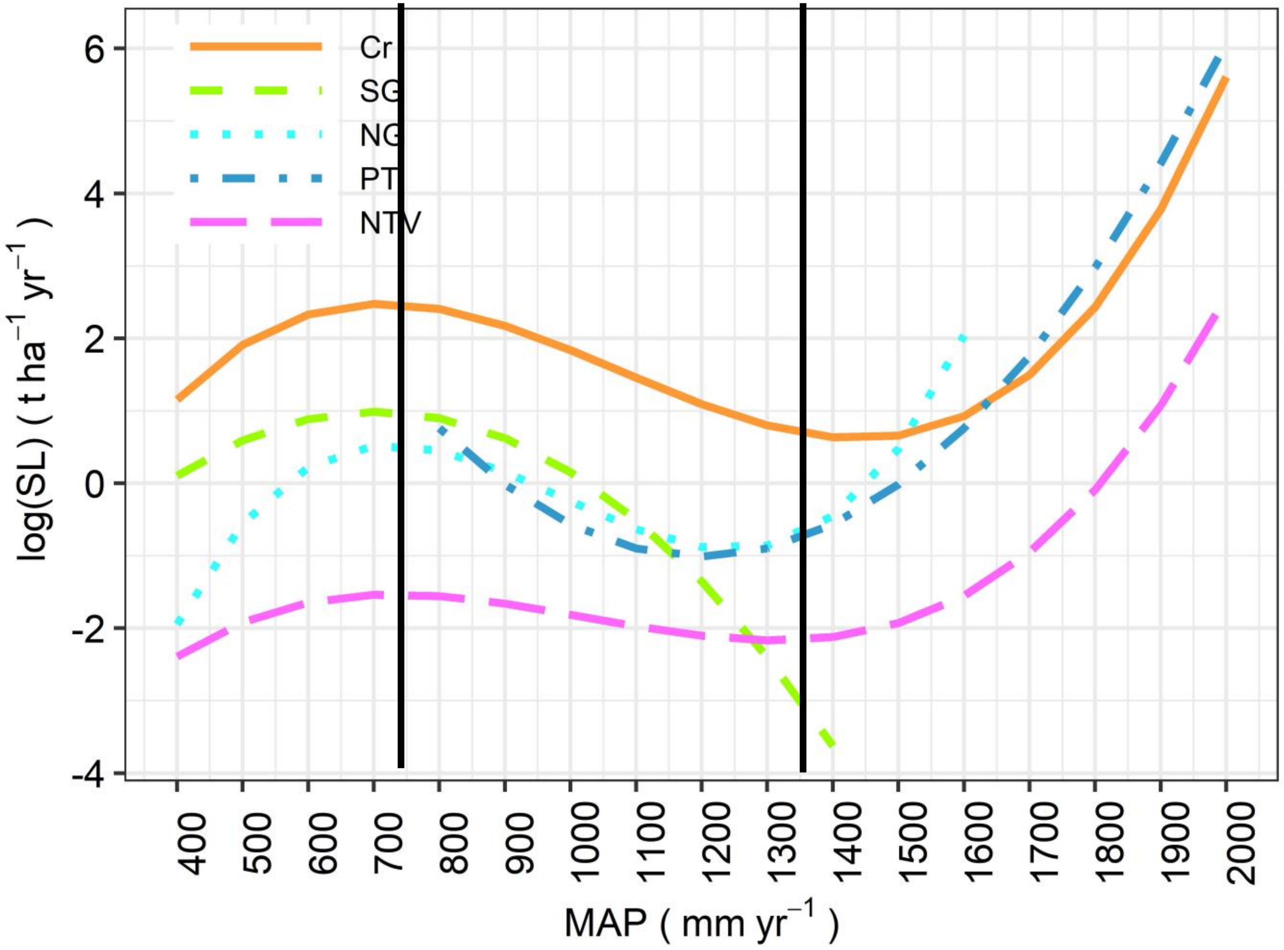
# Multiple linear regression analysis

Multiple regression analysis showed **no significant effects of slope length (*L*) or soil erodibility (*K* factor) on *SL***. **For cropland**, the slope factor and *MAP* were significantly related to soil loss. For other land use types, **only *MAP* was significantly and nonlinearly related to *SL*.**

| LU | Model | $R^2$ | p-value | n |
|---|---|---|---|---|
| Cr | $Log(SL) = -7.04 + 0.08*\boldsymbol{S} + 0.03*MAP - 3.30e^{-5}*MAP^2 + 1.04e^{-8}*MAP^3$ | 0.09 | $p<0.001$ | 222 |
| SG | $Log(SL) = -3.74 + 0.01*MAP - 9.54e^{-6}*MAP^2$ | 0.25 | $p<0.001$ | 66 |
| NG | $Log(SL) = -16.08 + 0.06*MAP - 6.17e^{-5} * MAP^2 + 2.08e^{-8}*MAP^3$ | 0.11 | $p<0.05$ | 85 |
| PT | $Log(SL) = 14.94 - 0.03*MAP + 1.11e^{-5}*MAP^2$ | 0.26 | $p<0.001$ | 120 |
| NTV | $Log(SL) = -7.09 + 1.86*MAP - 1.98e^{-5}*MAP^2 + 6.46e^{-9}*MAP^3$ | 0.12 | $p<0.001$ | 119 |

*S*: *Nearing (1999)* slope factor; *MAP*: mean annual precipitation; Cr: cropland; SG: seeded grassland; NG: nature grassland; PT: planted trees; NTV: nature tell vegetations

# Nonlinear response of soil loss to mean annual precipitation

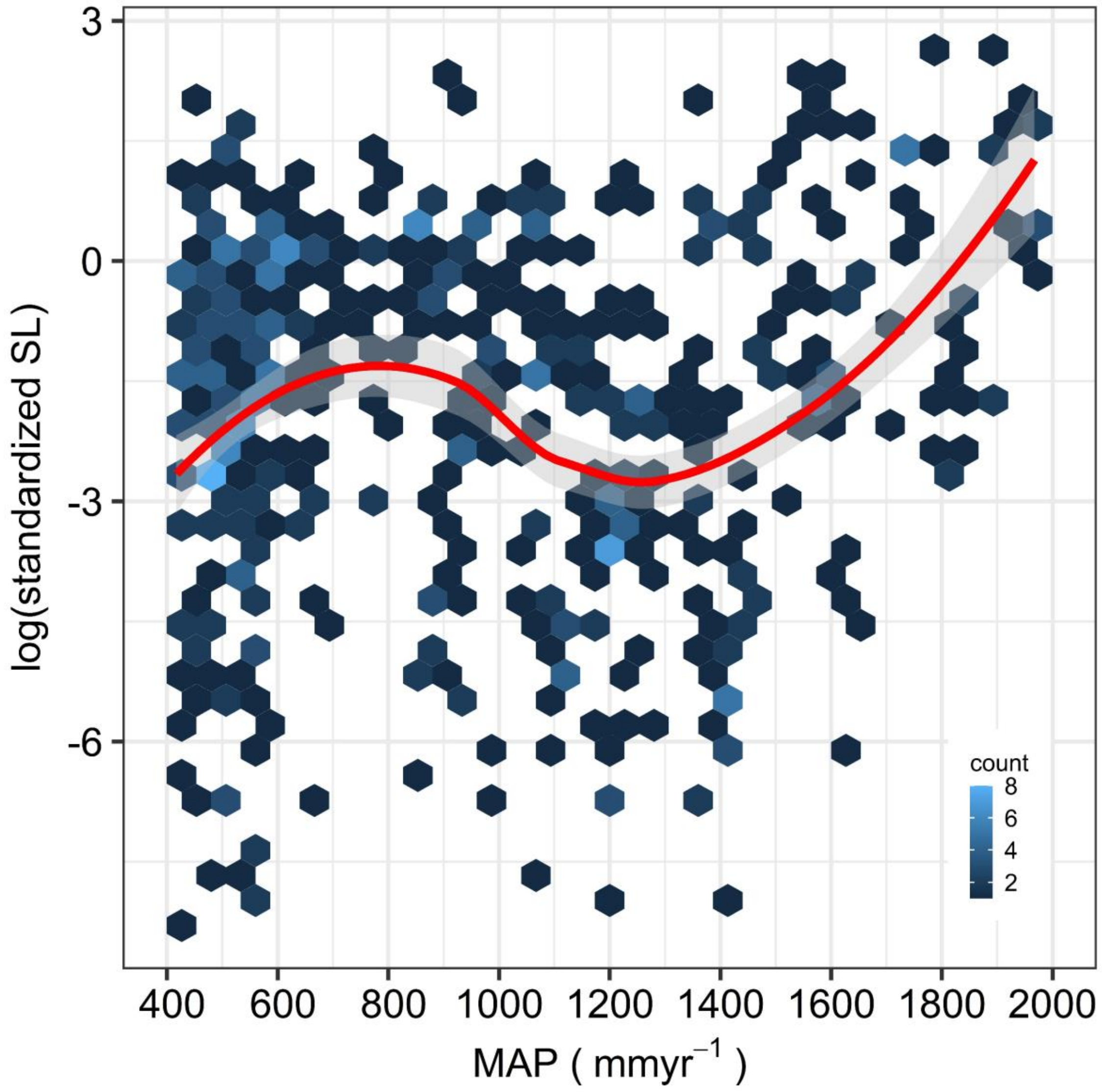



For all land use types with sufficient data a similar and nonlinear pattern between soil loss and *MAP* was observed:

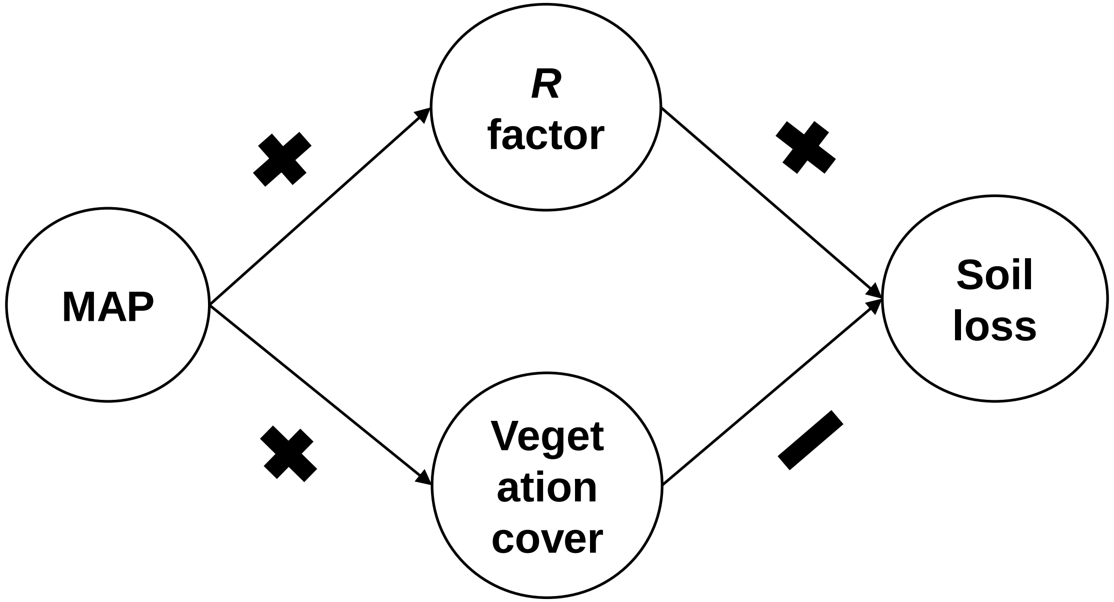
- MAP: < ca.700mm: soil loss ↑ MAP ↑
- MAP: ca. 700 -1400 mm: soil loss ↓ MAP ↑
- MAP: > ca. 1400 mm: soil loss ↑ MAP ↑

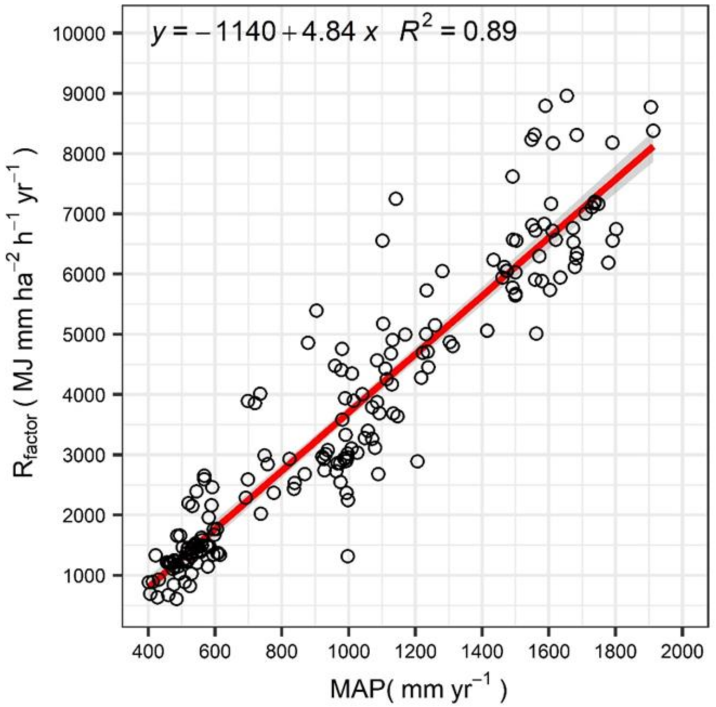
# LOESS regression analysis

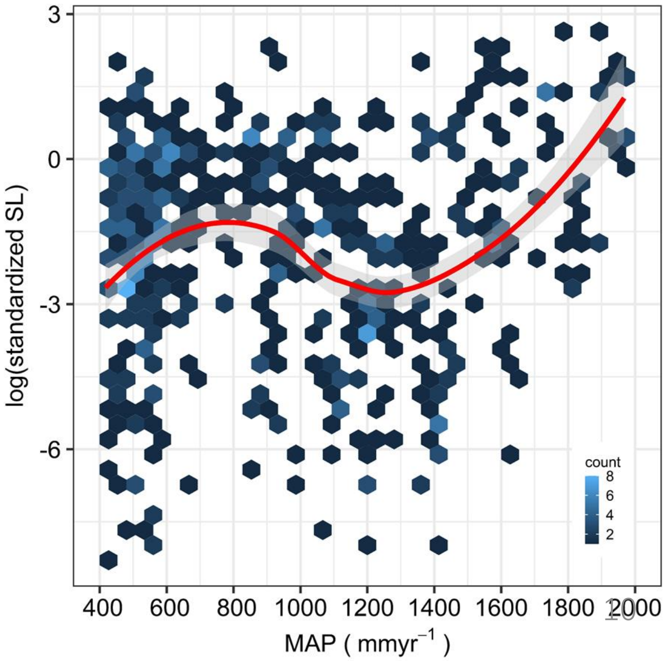
all land use combined with standardized soil loss



# The integrated impact of precipitation and vegetation on soil loss

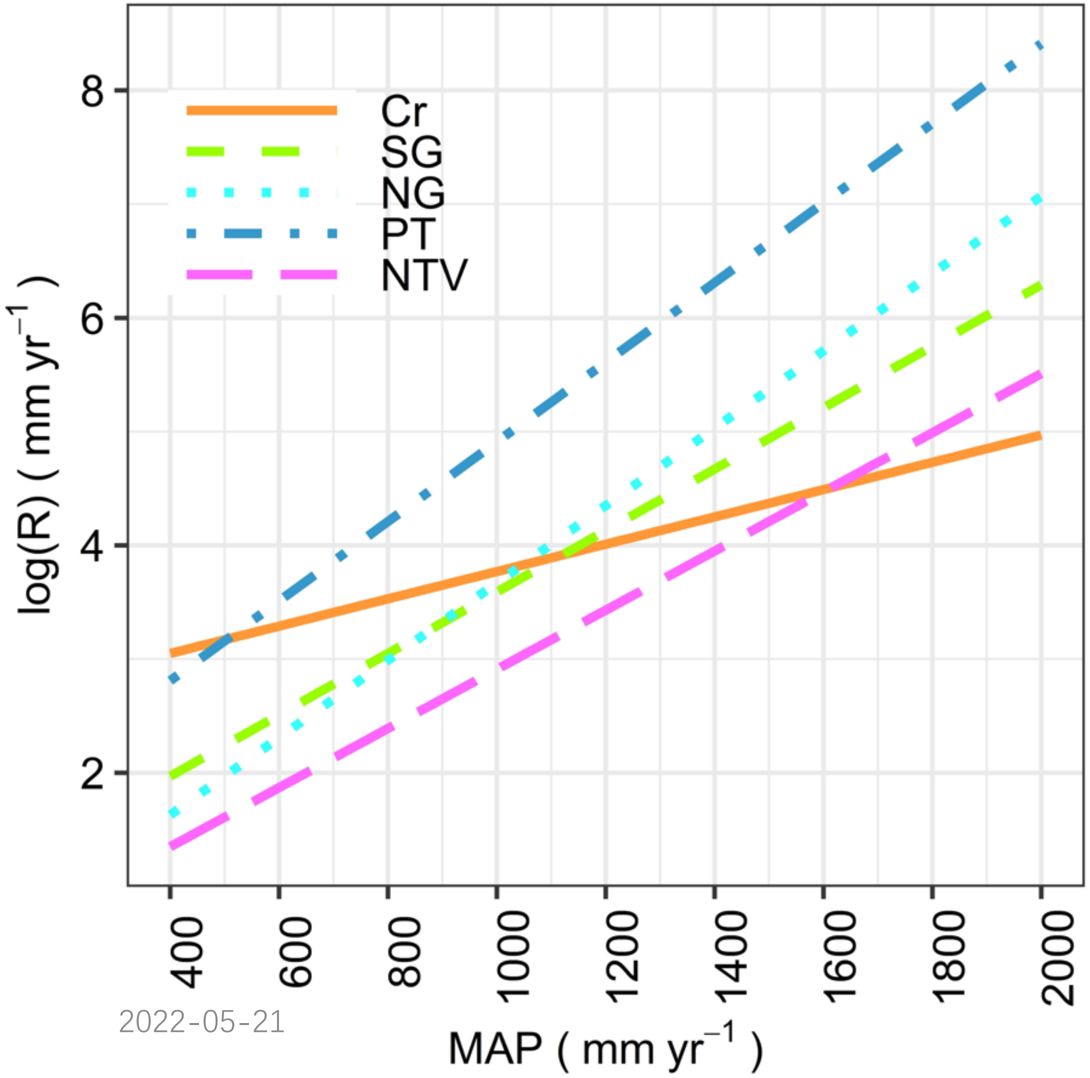


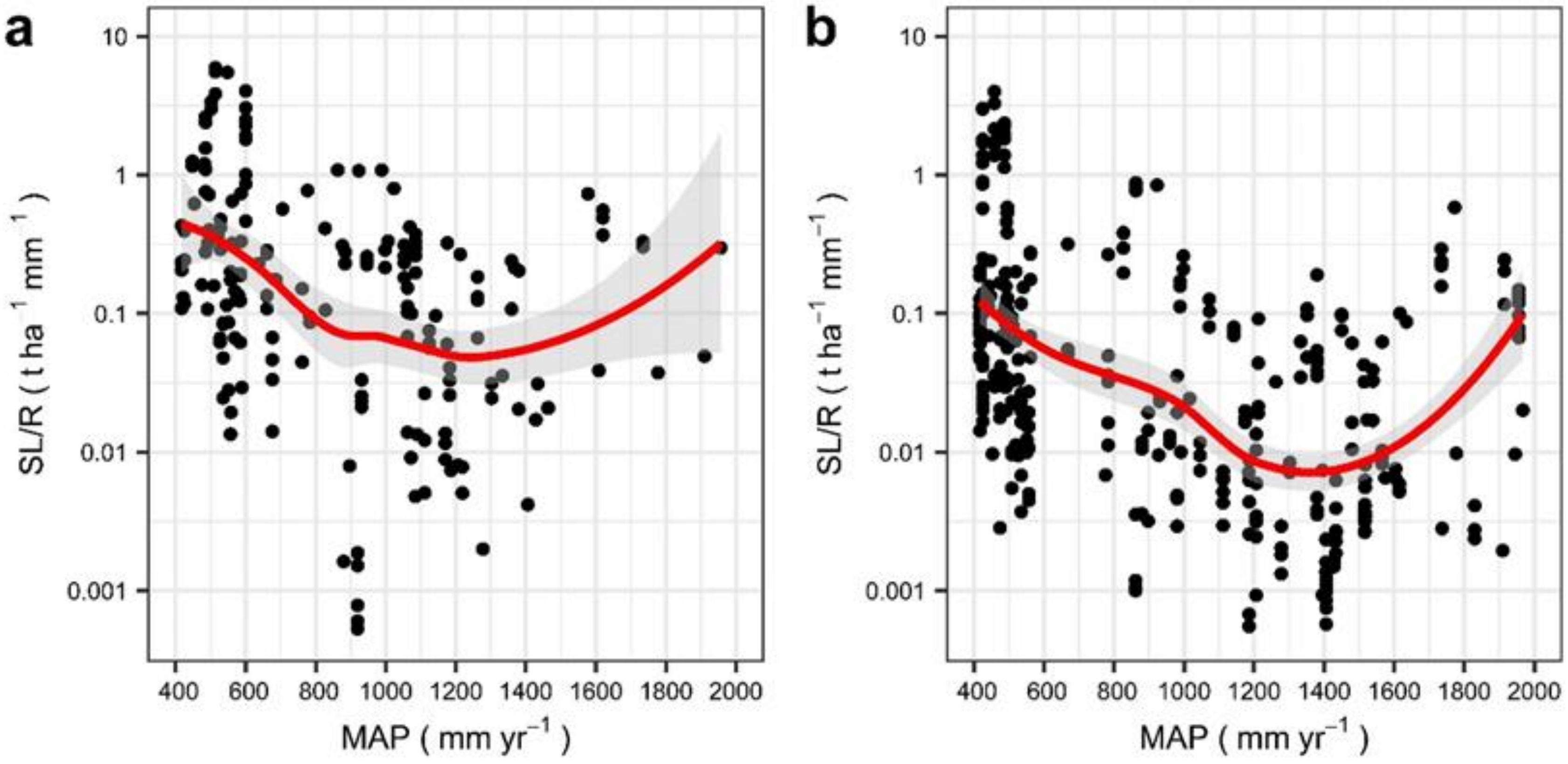

- *MAP* < 700: rainfall erosivity power > vegetation protection (insufficient cover).
- 700 < *MAP* < 1400: protection of vegetation > rainfall erosivity power.
- *MAP* > 1400: vegetation cover no longer increases.

# However, the correlation between runoff (*R*) and *MAP* is strong and linear




| Land use | Model | $R^2$ | RSE | p-value | n |
|---|---|---|---|---|---|
| Cr | Log(R) =2.57+0.0012*MAP | 0.10 | 1.99 | $p<0.001$ | 201 |
| SG | Log(R) =0.89+0.0027*MAP | 0.44 | 2.03 | $p<0.001$ | 65 |
| NG | Log(R) =0.27+0.0034*MAP | 0.50 | 1.95 | $p<0.001$ | 69 |
| PT | Log(R) =1.41-0.13L+0.0035*MAP | 0.56 | 2.15 | $p<0.001$ | 104 |
| NTV | Log(R) =0.31-0.023*L+0.0026*MAP | 0.51 | 1.75 | $p<0.001$ | 107 |

# The relationship between soil loss per unit runoff (*SL/R*) to *MAP*




The overall trend between soil loss per unit runoff for: (a) cropland; (b) non cropland (SG, NG, PT and NTV combined)

# Conclusion

- Based on erosion plot measurement in China, the influence of mean annual precipitation on soil loss follows a **non-linear** pattern for all land use type.
- The balance between the erosive force of the rainfall and runoff on the one hand and the protective effect of vegetation on the other hand is most in favour of erosion at intermediate precipitation amounts of 700-800 mm.
- In warm climates more vigorous vegetation growth reduces surface erosion at higher precipitation amounts, also on cropland, thereby reducing erosion rates until a threshold precipitation amount of ca. 1200-1400 mm is reached.

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# How soil erosion and runoff are related to land use, topography and annual precipitation: Insights from a meta-analysis of erosion plots in China

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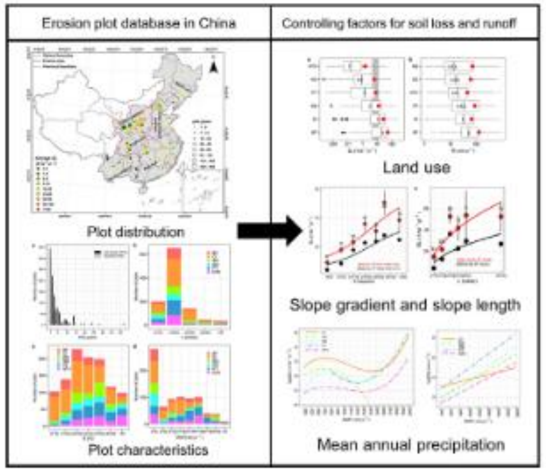
## HIGHLIGHTS

- An erosion plot database of soil loss and runoff measurements in China was compiled.
- Land use is the dominant control on soil loss with the highest rates on cropland.
- Soil loss increases with slope gradient and length on cropland.
- Runoff rates consistently increase with annual precipitation for each land use type.
- Soil losses show a local maximum at an annual precipitation of ca. 700 mm.

## GRAPHICAL ABSTRACT



# Thanks for your attention

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