International Conference on
Land and Water Degradation
October 7-10, 2009, Magdeburg, Germany

Evaluation of a dynamic multi-class sediment transport model in catchments under soil-conservation agriculture

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Introduction – why developing a new erosion model ?

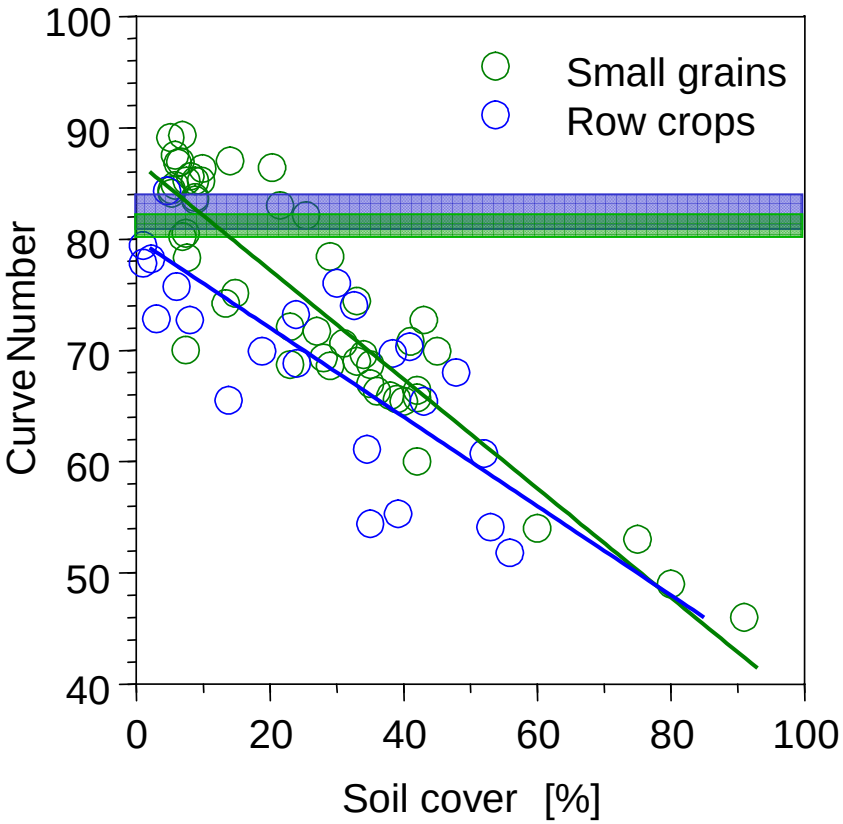
Needs an erosion model should fulfill:

- We need a good spatial representation of where erosion is actually occurring at different scales
- We need prediction of sediment delivery and sediment quality
- We need models accounting for effects of erosion control measures (changes in tillage techniques, in field layout, implementation of grass strips etc.)
- We need models that do not become very complicated and parameter intensive

Basic principle of the model presented here:

- The model allows to address the needs above at an event scale
- The model is basically relatively simple, partly using standard technology
- The model focuses on sediment quality

Soil cover - to calculate rain excess



$CN_{SG} = 87 - 0.49 \bullet \text{Soil cover [\%]}$
$R^2 = 0.83, n = 53$

$CN_{RC} = 80 - 0.40 \bullet \text{Soil cover [\%]}$
$R^2 = 0.60, n = 23$

Rainfall experiments area of Scheyern, Germany.
Plot size: 7-187 m², 1-h rain (60-74 mm),
SCS-CN hydrologic soil group C.

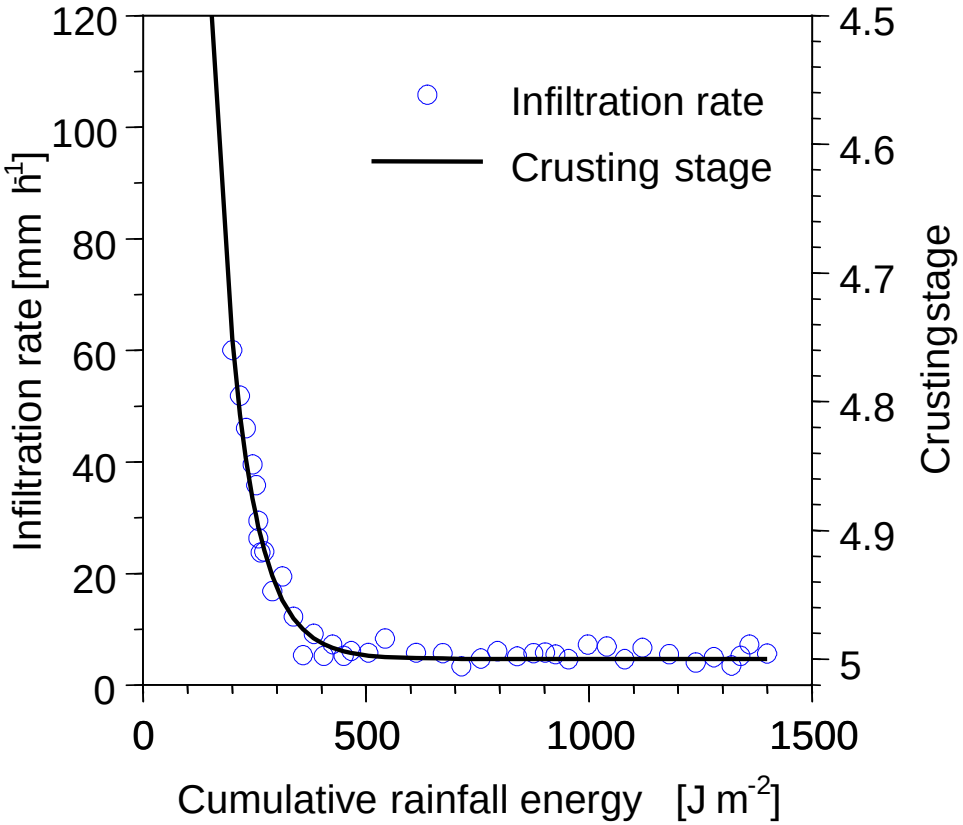
(Auerswald & Haider 1996; Auerswald, Schröder & Fiener, 2001)

Crusting Stages - to calculate rain excess

$$CN_{II} = CN_{RC/SG} + (CR / 5) \square (CN_{RC/SG} - CN_{Max\ RC/SG})$$

CN_{II} = Curve Number for AMC II

CR = Crusting Stage (CR = 0 no crust, CR = 5 totally crusted)



Rainfall experiment Scheyern, Germany.
Plot size: 8 m², 1-h rain (60-63 mm).
(Schröder & Auerswald, 2001)

Modeling runoff concentration

- Kinematic wave approach

- Taking tillage direction into account to determine runoff direction:

  $\text{Logit}(p) = -5.92 + 0.133\,S + 0.12\,\lambda - 0.417\,R_0$ (Takken et al., 2001)

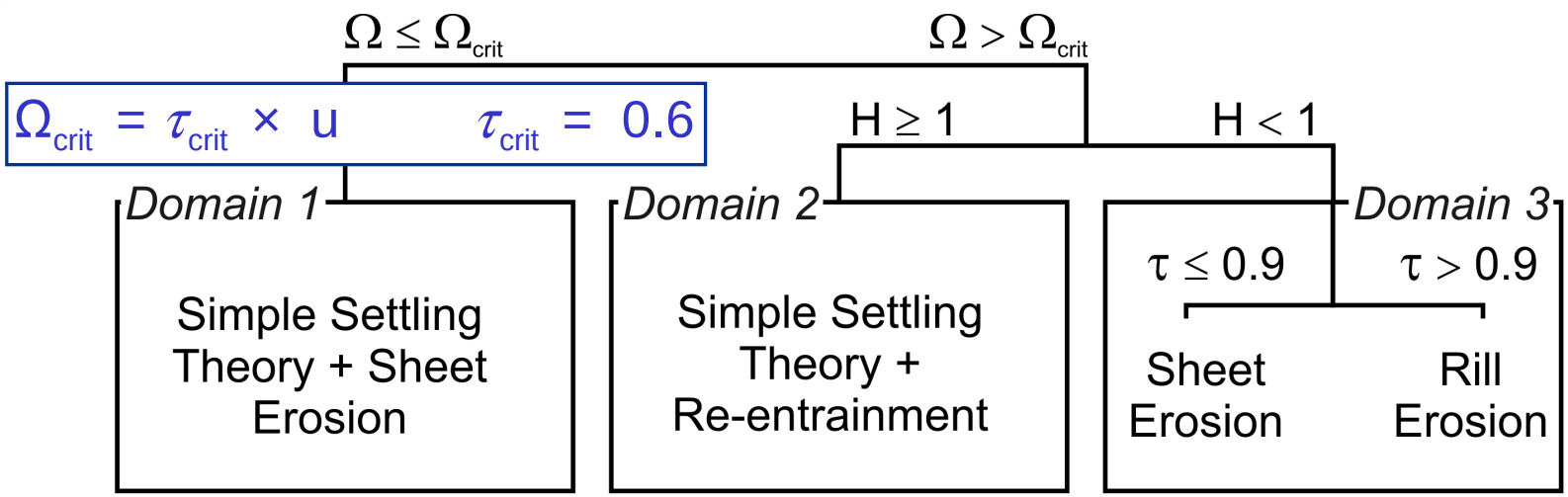
  p = probability that runoff follows topography;
  S = slope [%];
  λ = angle between tillage orientation and slope direction (°);
  R_0 = orientated roughness (cm).

- Separate calculation of runoff in interrill areas and rills

- Allow for re-infiltration and afterflow-infiltration

Modeling erosion and deposition

according to effective runoff

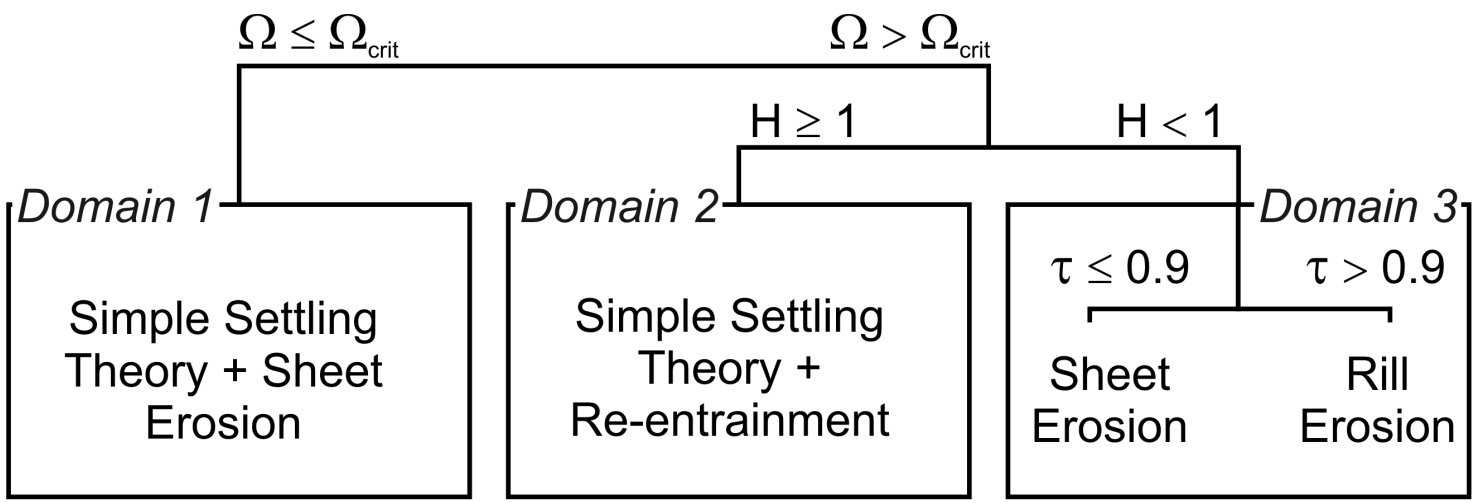


Domain 1 *(Everaert 1991)*:

- Erosion depends on Ω and median grain size D_{50}.
- Grain size dependent deposition in 10 texture classes.

Modeling erosion and deposition

according to effective runoff

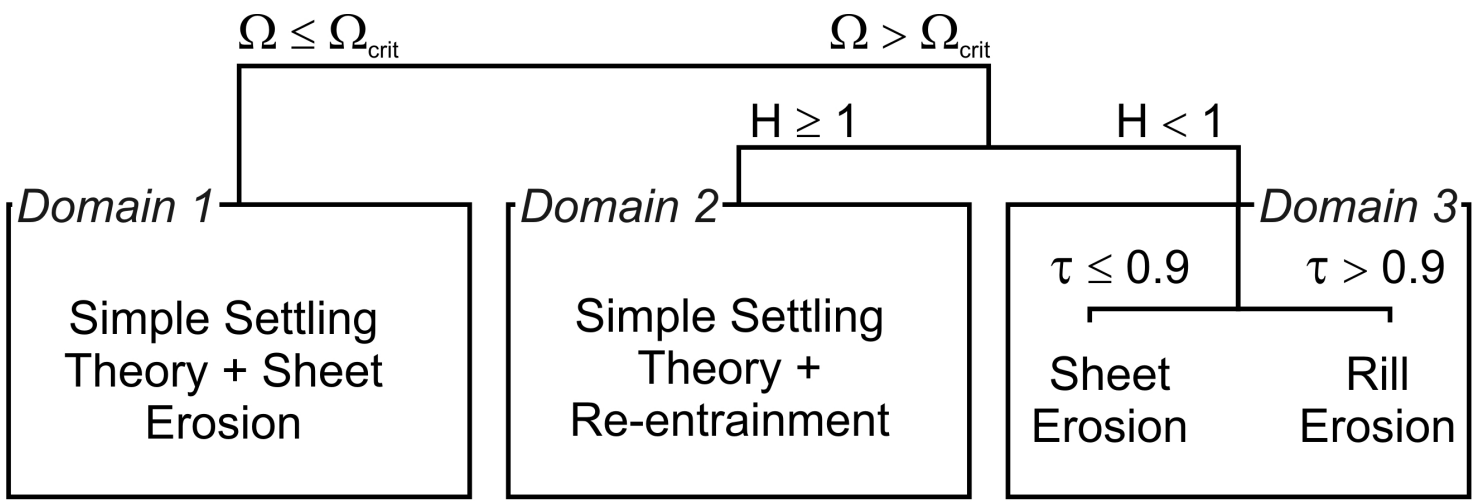


Domain 2 *(Hairsine & Rose 1992, Van Oost et al. 2004)*:

- Net-deposition with simultaneous re-entrainment of deposits.
- Modeling is size-selective.

Modeling erosion and deposition

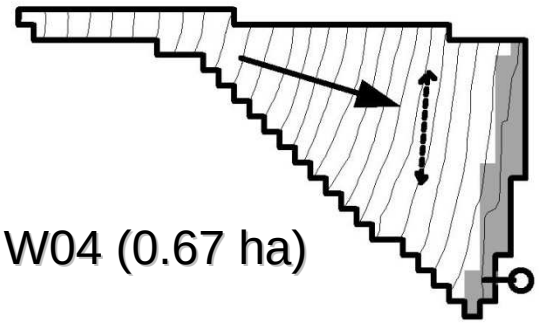
according to effective runoff

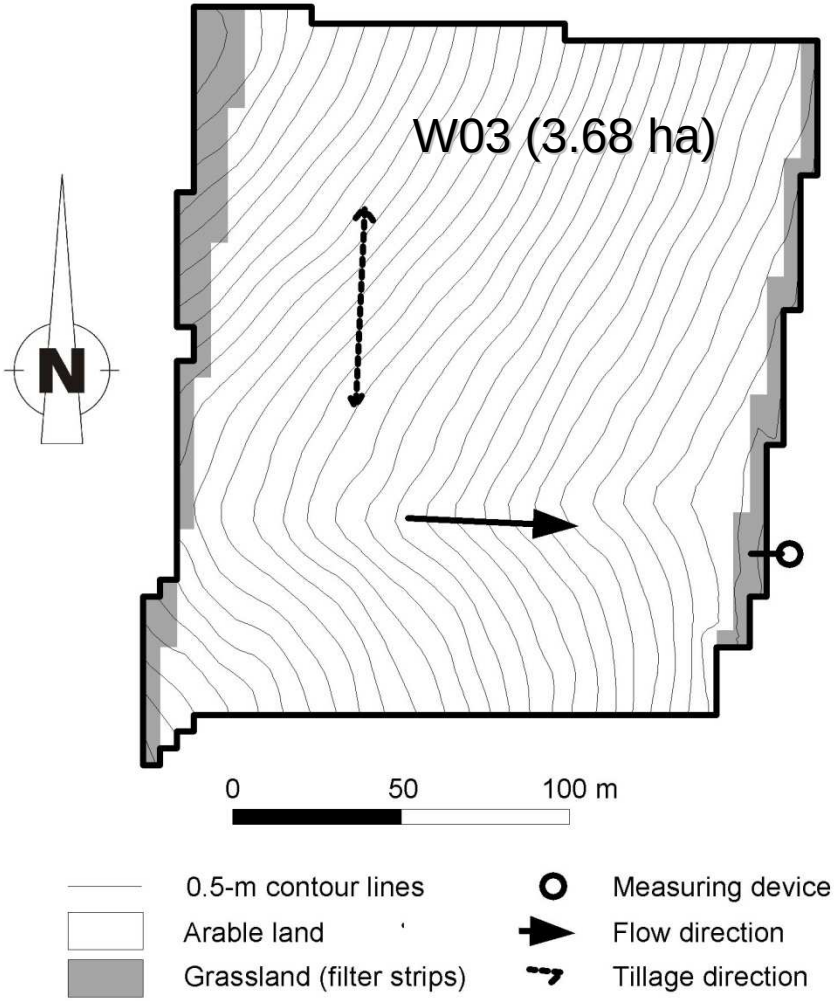


Domain 3 (*Hairsine & Rose 1992, Gimenez & Govers, 2002*):

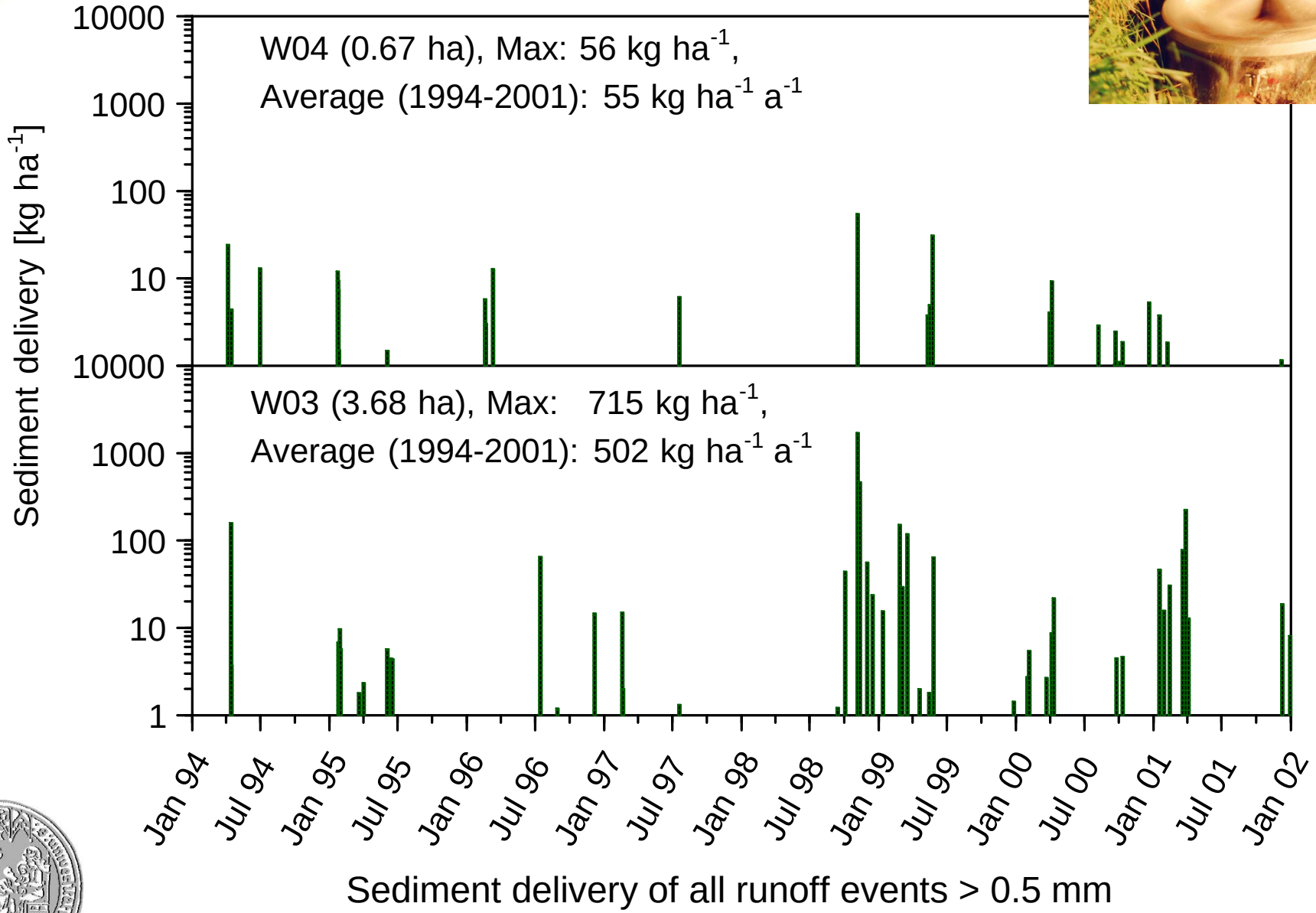
- Net-erosion in rills depending on slope, runoff rates and rill erodibility factor - process is not size-selective.
- Deposition is size-selective.

Test site in Scheyern, Germany (FAM 1994 – 2001)



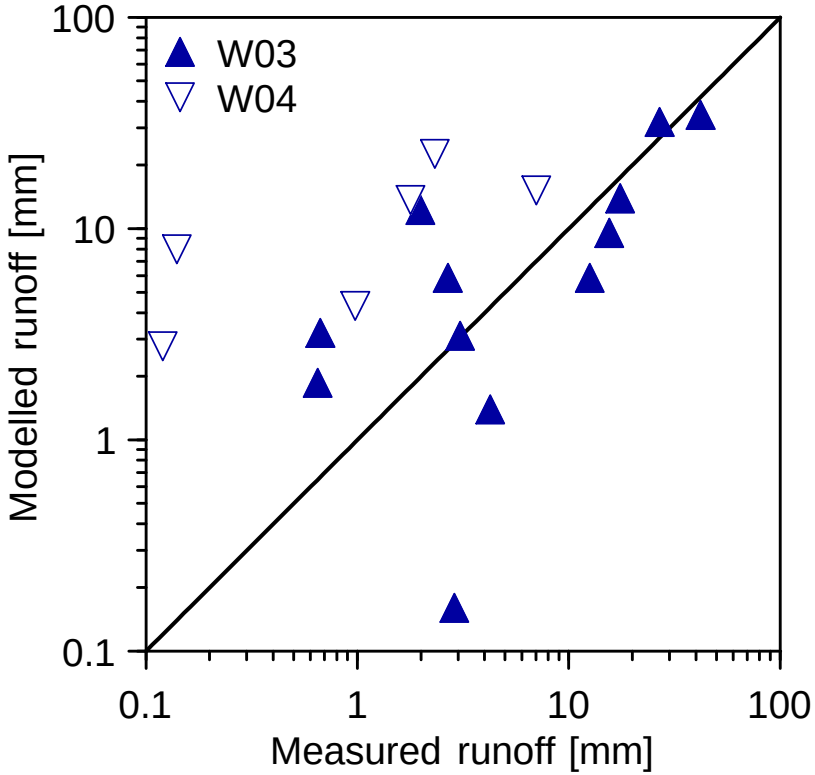


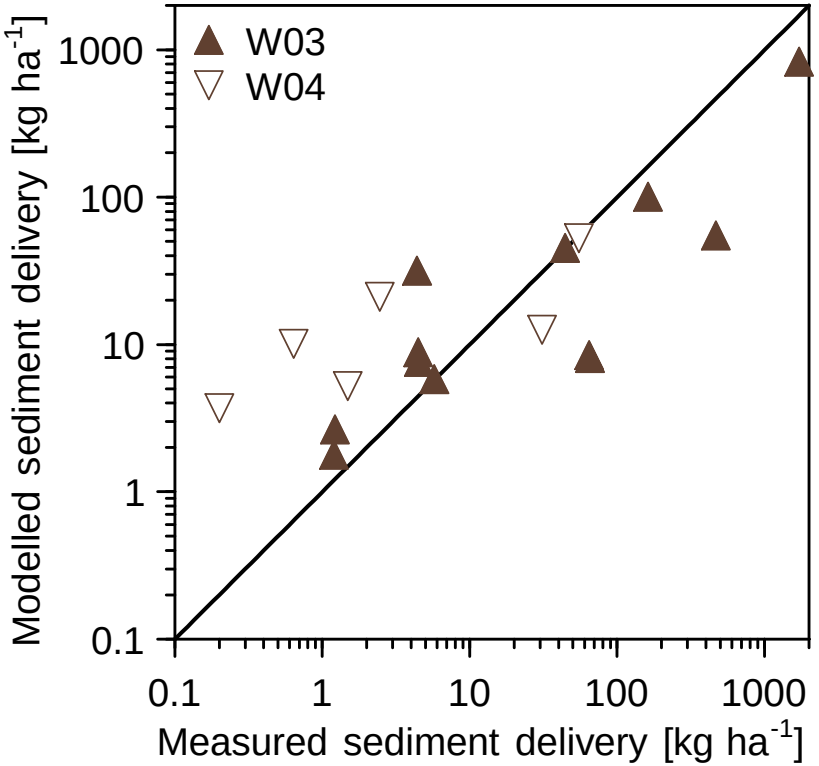
Sediment delivery (1994 – 2001)



Sediment delivery of all runoff events > 0.5 mm

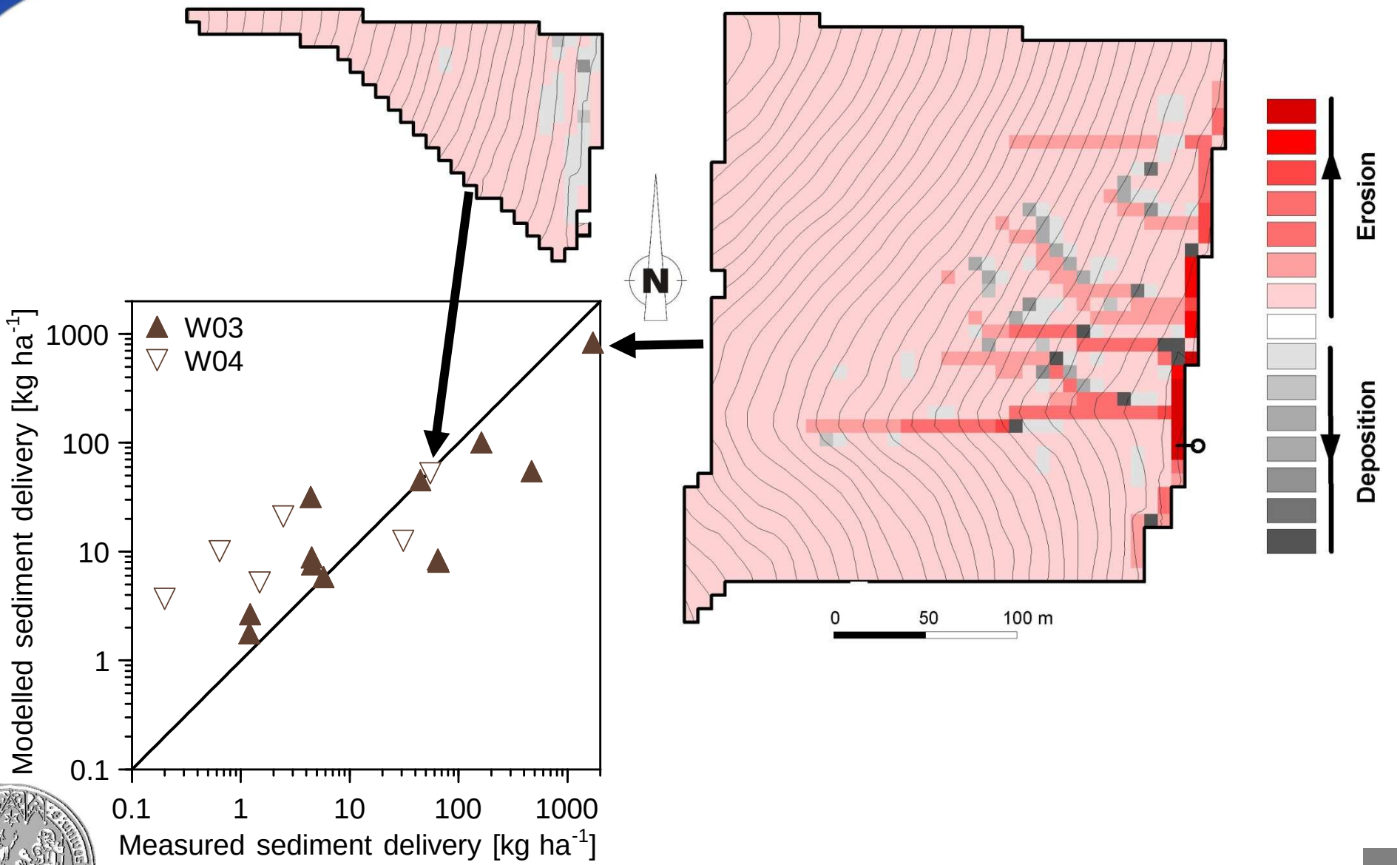
Model vs. measurements – runoff & sediment delivery



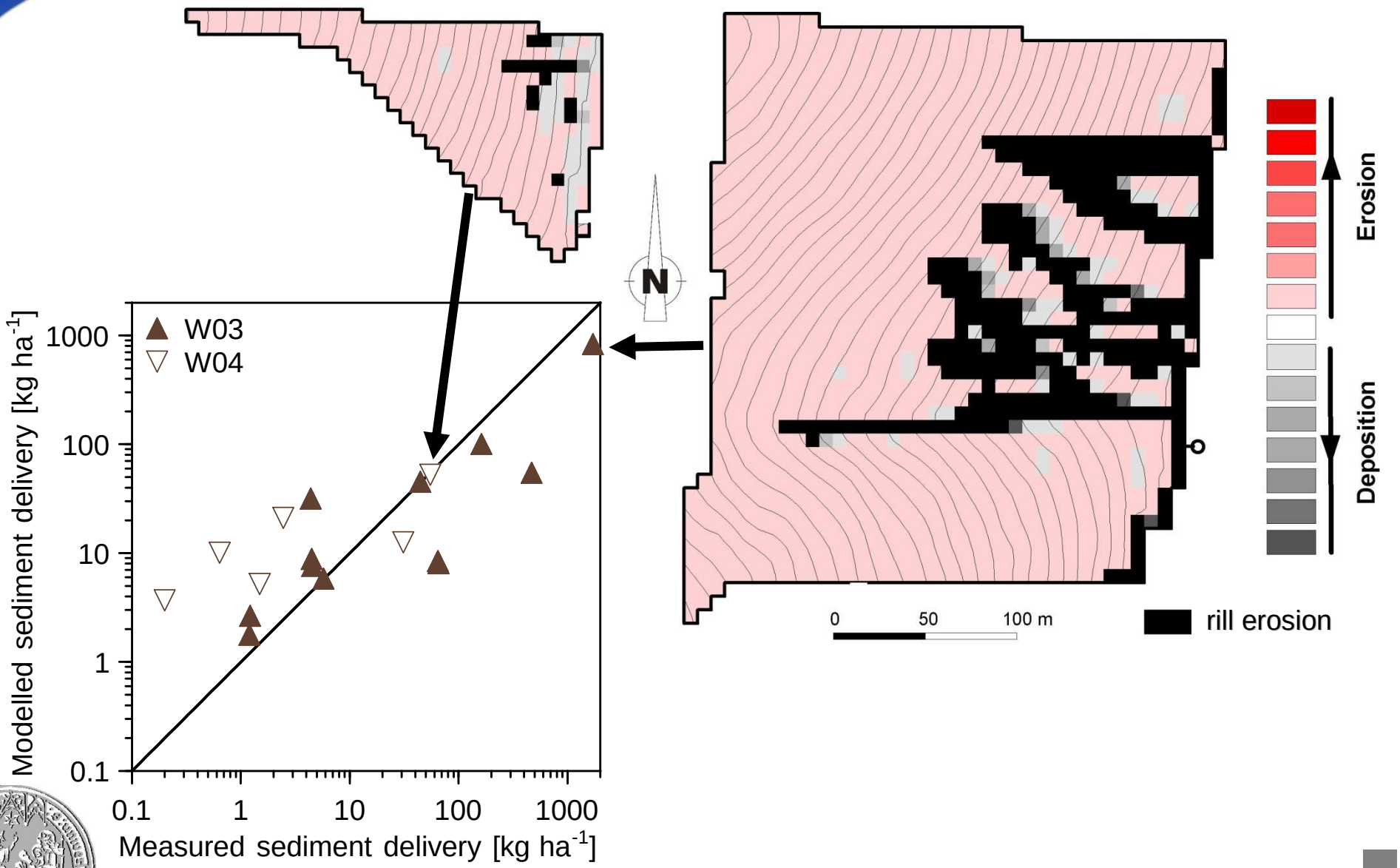


Measured runoff events > 0.5 mm, in W03 between April and November (1994-2001)

Spatially distributed erosion and deposition modeling

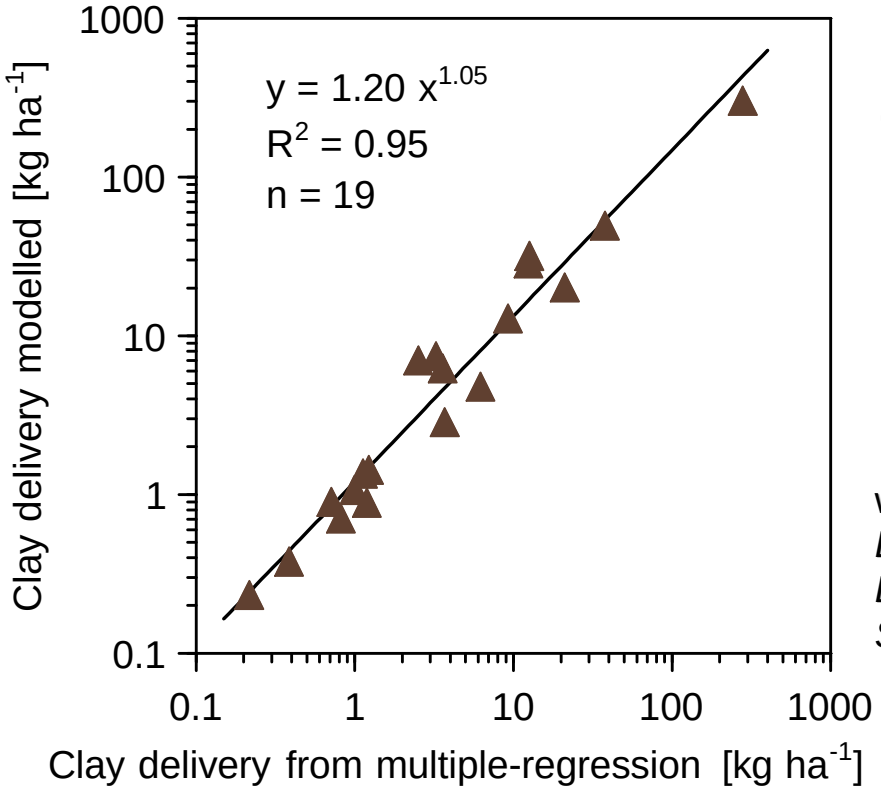


Spatially distributed erosion and deposition modeling



Modeling clay enrichment

Modeled clay enrichment vs. multiple-regression approach



Multiple-regression approach for clay and organic matter enrichment

(Auerswald & Weigand 1999)

$$\log(ER) = -0.27 + 0.45\ \log(D_{50}) - 0.05\ \log(SD)$$

$$(R^2 = 0.51,\ n = 195)$$

where
ER is the enrichment of clay and organic matter (-),
D_{50} is the median grain size (µm) of a watershed,
SD is the sediment delivery (t ha^{-1}).

Conclusions

- From the 8-year monitoring it is obvious that the optimized soil conservation minimized soil loss from the two agricultural watersheds.
- As erosion events are more rare compared to conventional agriculture, even longer data sets are required to rigidly test models.
- In general the model showed promising results in predicting size-selective sediment transport with a high spatial and temporal resolution.
- These results could be obtained using a reduced model complexity and parameter space.
- The model allows to take several soil conserving techniques into account; it can therefore be used for conservation planning.
- Due to multi-class sediment transport modeling, the model has a high potential to simulate transport of sediment bound substances.