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
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

\[ \text{CN}_{II} = \text{CN}_{RC/SG} + \left( \frac{\text{CR}}{5} \right) \times (\text{CN}_{RC/SG} - \text{CN}_{Max \, RC/SG}) \]

\( \text{CN}_{II} \) = 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:**
  \[ \text{Logit}(p) = -5.92 + 0.133 S + 0.12 \lambda - 0.417 R_0 \]  
  \( p \) = probability that runoff follows topography;  
  \( S \) = slope [%];  
  \( \lambda \) = 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

\[
\Omega_{\text{crit}} = \tau_{\text{crit}} \times u \quad \tau_{\text{crit}} = 0.6
\]

**Domain 1** (Everaert 1991):

- Erosion depends on \( \Omega \) and median grain size \( D_{50} \).
- Grain size dependent deposition in 10 texture classes.
Modeling erosion and deposition according to effective runoff

\[ \Omega \leq \Omega_{\text{crit}} \quad \Omega > \Omega_{\text{crit}} \]

\( \text{Domain 1} \)
- Simple Settling Theory + Sheet Erosion

\( \text{Domain 2} \)
- Simple Settling Theory + Re-entrainment

\( \text{Domain 3} \)
- \( \tau \leq 0.9 \)
  - Sheet Erosion
- \( \tau > 0.9 \)
  - Rill Erosion

**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)

W04 (0.67 ha)
W03 (3.68 ha)
Sediment delivery (1994 – 2001)

W04 (0.67 ha), Max: 56 kg ha\(^{-1}\),
Average (1994-2001): 55 kg ha\(^{-1}\) a\(^{-1}\)

W03 (3.68 ha), Max: 715 kg ha\(^{-1}\),
Average (1994-2001): 502 kg ha\(^{-1}\) a\(^{-1}\)

Sediment delivery of all runoff events > 0.5 mm
Measured runoff events > 0.5 mm, in W03 between April and November (1994-2001)
Spatially distributed erosion and deposition modeling

![Graph showing measured and modeled sediment delivery]

Measured sediment delivery [kg ha\(^{-1}\)]

Modelled sediment delivery [kg ha\(^{-1}\)]

- **W03**
- **W04**
Spatially distributed erosion and deposition modeling

![Diagram showing measured and modeled sediment delivery]

- Measured sediment delivery [kg ha\(^{-1}\)]
- Modeled sediment delivery [kg ha\(^{-1}\)]

Points represent:
- W03
- W04

Erosion and deposition mapped on the right:
- Rill erosion indicated in black

Graphical representation of measured vs. modeled sediment delivery.
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 (\text{\textperiodcentered})
- \( D_{50} \) is the median grain size (\text{\textmu}m) 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.