Estimation of critical source areas and spatial distributed SDR for quantifying sediment discharge of surface waters in mesoscale

Stefan Halbfaß
How to close the gap between source and sink using empirical models?
SDR – Models based on different Parameters

e.g. Soil erosion, Soil texture, Watershed area, Slope, Land use, Grain size

An example based on watershed area

\[ SDR = \alpha \cdot A^\beta \]

- Vanoni: \[ SDR = 0.42 A^{-0.125}, A \text{ in square miles} \]
- USDA SCS: \[ SDR = 0.51 A^{-0.11}, A \text{ in square miles} \]
- Renfro: \[ \log(SDR) = 1.7935 - 0.14191 \log(A), A \text{ in km}^2 \]
- Neufang et al.: \[ SDR = 0.385 A^{-0.2}, A \text{ in km}^2 \]
Problems & Questions

<table>
<thead>
<tr>
<th>Example</th>
<th>Small scale</th>
<th>Mesoscale</th>
<th>Large scale</th>
</tr>
</thead>
</table>
| Physically Based Erosion 3D | | | empirical $SDR = \alpha \cdot A^B$

Parameter Requirement

- Model Complexity: yes, no
- Accuracy: local, global

SDR Localization: yes, no

Derivation CSA: local, global

Complexity

- Small scale
- Mesoscale
- Large scale
Goal of model development

Results
- Spatially distributed SDR
- Delineation of Critical Source Areas

Method
- Mesoscale approach
- General available or derivable Parameters
- Consideration of important factors controlling sediment transfer from source to sink
- Basic GIS-operations only (no cell to cell calculations)

Fundamental research has been done by Voges (1999) and Veith (2002)


SE = SDR x A

Estimation formula
Estimation of critical source areas and spatially distributed SDR for quantifying sediment discharge of surface waters in mesoscale.
Estimation of critical source areas and spatially distributed SDR for quantifying sediment discharge of surface waters in mesoscale
Estimation of critical source areas and spatial distributed SDR for quantifying sediment discharge of surface waters in mesoscale

Model Description

Examples

Discussion

SDR and CSA

Hydrological Connectivity

Sediment delivery ratio (SDR)

Estimation formula

SE = SDR x A

Likelihood of connectivity

Distance to waters

Sediment input in waters

Sediment hotspot areas

Soil erosion

Surface runoff

Flowpath length

Land use coefficient

Slope

Elevation model

Barriers like Roads, railways etc.

Arable Area of Federal State of Saxony [%]

70
60
50
40
30
20
10
0

hydrological connected
disconnected
Estimation of critical source areas and spatial distributed SDR for quantifying sediment discharge of surface waters in mesoscale.

**Model Description**
- Examples
- Discussion

**Hydrological Connectivity**
- Distance to waters
- Soil erosion
- Surface runoff
- GIS-preprocessing
- Elevation model
- Barriers like roads, railways etc.
- Sediment delivery ratio (SDR)
- Land use coefficient
- Slope
- Flowpath length
- Likelihood of connectivity
- Sediment input in waters
- Sediment hotspot areas

**Estimation formula**

\[ SE = SDR \times A \]

**SDR Distribution**

Histogram of SDR for Saxony (500m cell size, arable area only)
Estimation of critical source areas and spatial distributed SDR for quantifying sediment discharge of surface waters in mesoscale

**Model Description**

- **Hydrological Connectivity**
- **SDR Distribution**
- **Correlation function**

**Formula**

\[ SE = SDR \times A \]

**Areas with a hydraulic connection**

**Hydrological Connectivity**

**SDR Distribution**

**Correlation function**

\[ y = 10.782x^{0.3029} \]

**Likelihood of connectivity**

- **Distance to waters**
- **Surface runoff**
- **Flowpath length**
- **Land use coefficient**
- **Slope**

**Sediment delivery ratio (SDR)**

- **Soil erosion**
- **Surface runoff**
- **GIS-preprocessing**
- **Elevation model**
- **Barriers like Roads, railways etc.**

**Sediment input in waters**

**Sediment hotspot areas**

**CSA**

- 5 – 10 % of Arable areas

**www.galf-dresden.de**
**www.stoffbilanz.de**
Reservoir Saidenbach / Ore Mountains / Saxony

Watershed area ~ 61 km²
Terrain height ~ 437 – 708 m
Mean Temp. ~ 6.8 °C
Mean Precipitation ~ 957 mm/a

Estimation of critical source areas and spatial distributed SDR for quantifying sediment discharge of surface waters in mesoscale
Conservation tillage

Conservation Tillage ~ 70 %

Estimation of critical source areas and spatial distributed SDR for quantifying sediment discharge of surface waters in mesoscale.
Hydrological Connectivity

dependent on river network and accuracy of digital height model
Likelihood of Connectivity for Sediment Transport

Highest connectivity closed to rivers

Estimation of critical source areas and spatial distributed SDR for quantifying sediment discharge of surface waters in mesoscale
Sediment Delivery Ratio

High SDR values near by streams

Estimation of critical source areas and spatial distributed SDR for quantifying sediment discharge of surface waters in mesoscale
Sediment Discharge to Surface Waters due to Soil Erosion by Water

Total sediment input: 500 t/y → corresponds 6% of soil erosion

Estimation of critical source areas and spatial distributed SDR for quantifying sediment discharge of surface waters in mesoscale
Critical Source Areas for Sediment Input

12% of arable areas are calculated as CSA. About 70% of sediment discharge is generated from CSA.

<table>
<thead>
<tr>
<th>Arable Areas</th>
<th>Soil Erosion [t/ha/a]</th>
<th>Sediment Input [t/ha/y]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3.0</td>
<td>0.17</td>
</tr>
<tr>
<td>CSA</td>
<td>6.5</td>
<td>1.1</td>
</tr>
</tbody>
</table>
Restrictions / Questions

- Method for Quantifying Soil Erosion → Which erosion types are considered? (sheet erosion, rill e., gully e.)
- Sediment Sources? → agriculture, river bed, urban areas
- Spatial resolution of model grid?
- Type of digital river network? → spatial accuracy, generalization, completeness