Modeling Water Flow and Sediment Transport in Paddy Cascades in Northwest Vietnam

UNIVERSITÄT HOHENHEIM

DFG

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Impact of Intensification on Land Use Dynamics and Environmental Services of Tropical Mountainous Watersheds

Rebecca Schaufelberger, Carsten Marohn, Georg Cadisch

Inst. of Plant Production and Agroecology in the Tropics and Subtropics, University of Hohenheim, Germany

1. Introduction

- Continuous maize cropping (without fallow) and deforestation in SE Asia increase erosion in mountainous watersheds
- LUCIA (Land Use Change Impact Assessment tool) simulates water, nutrient cycles, erosion and plant growth on landscape-scale[1]. Water flows in the model follow the steepest slopes. The influence of terraces for paddy fields on drainage pattern are not considered
- Flow velocity decreases in paddies causes settling of suspended particles eroded in the uplands influencing soil fertility
- Research area: Chieng Khoi, Son La, NW Vietnam. Subtropical climate, unimodal rainfall distribution, steep slopes

Scope

- Development of a standalone paddy module that simulates water and sediment flow and can be connected to the LUCIA model[3]. Test the module based on field measurements.

2. Model Concept

- The model runs on a daily time step, uniform paddy size (pixel)
- Water flow in the cascade follows elevation instead of local drain direction (→ no spatially routed distribution inside the paddy cascade)
- Inflow added to the water volume of the previous day before results in potential water volume. Water infiltrating in bund and in topsoil, as well as evapotranspiration (ET) and percolation are subtracted. Bund infiltration is first used to saturate the bund. The remaining water flows partly into ground water (bund percolation), partly to the neighboring field (cross flow). When the water level reaches the height of the connection to the next paddy, outflow starts. This outflow is limited by the connection capacity. The connection capacity is reached, when the connection volume between the paddies is not enough to transport the water to the next paddy. When water level reaches bund height, overflow starts. Outflow and overflow are used as inflow for the next lower paddy (Figure 1).
- $Water\ volume = water\ volume_{t-1} + rain + inflow - bund\ infiltration - topsoil\ infiltration - ET - outflow\ (-overflow)$
- Inflowing water from the uplands transports sediments into the paddies. Particles in the water remaining in the paddy are assumed to settle during 24 hours. Calculation of erosion inside paddies uses the rose equation[3].

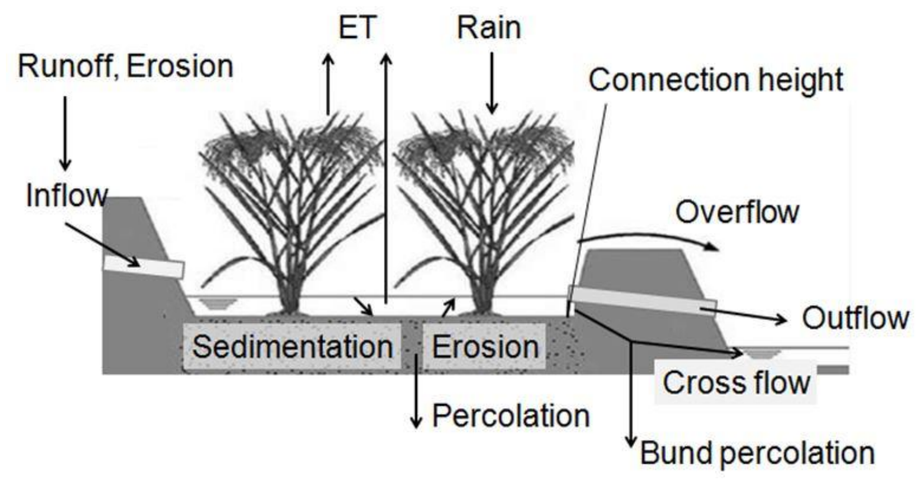

Figure 1: Simplified model concept for one paddy. Outflow and overflow form the inflow of the next lower paddy.

Figure 2: Picture of the cascade (Nov 2011, Marohn)

3. Methods

- Water base flow rates measurements with water clocks in paddy fields
- Turbidity measurements as proxy for sediment loads in paddy water flows with portable sensors (NEP160 and NEP 260, McVan Instruments)
- GIS: ArcGIS 10.0. Statistics: SAS 9.2. Modeling software: PCRaster

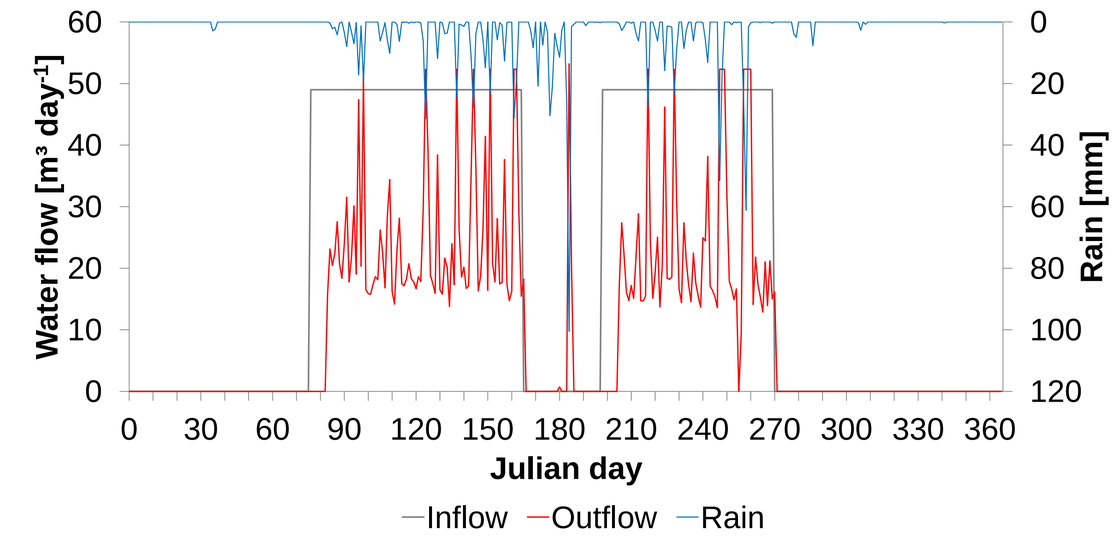

Figure 3: Rain, assumed cascade inflow and modeled outflow of the cascade during two paddy seasons.

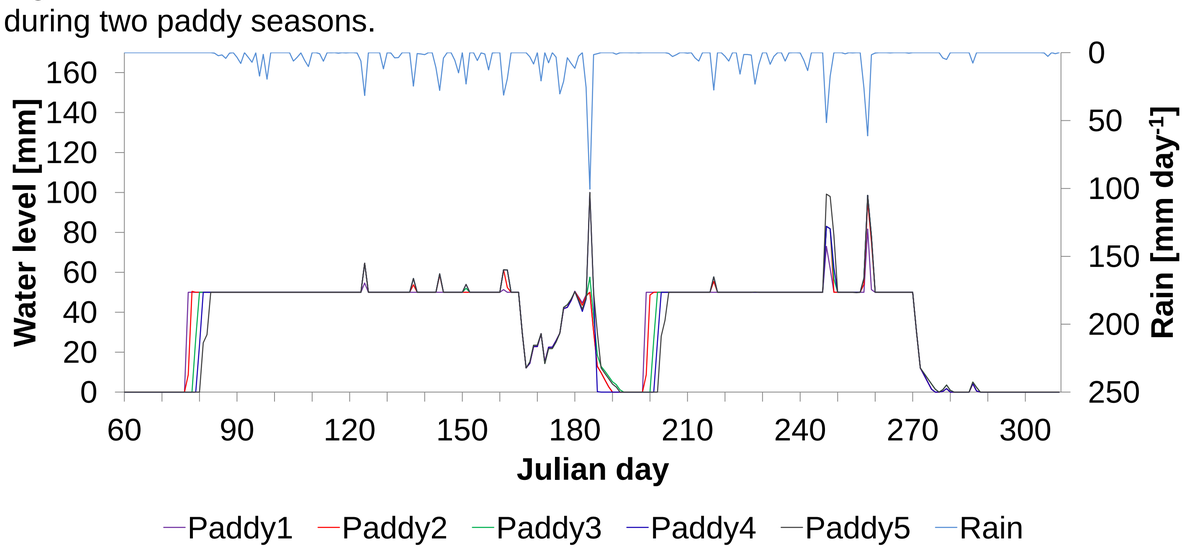

Figure 4: Rain and modeled water levels during two paddy seasons.

4. Results and discussion

Water flow

- Parameterization to an inflow of 49 m³ day⁻¹ (as measured) resulted in an outflow of around 20 m³ day⁻¹ (Figure 3) during normal base flow (measured: 24.4 m³ day⁻¹)
- Rainfall led to an increase of outflow (Figure 3); high rainfall events caused an increase of the water level due to exceeding of the connection capacity (Figure 4)

Sediment concentrations

- Measured turbidity during base flow was too low for significant differences between inflow and outflow turbidity
- Turbidity measured in the outflow during a rain event decreased along paddies and was 10% of inflowing sediment concentration
- Modeled turbidity decreased to 15% of the inflow concentration (Figure 5)

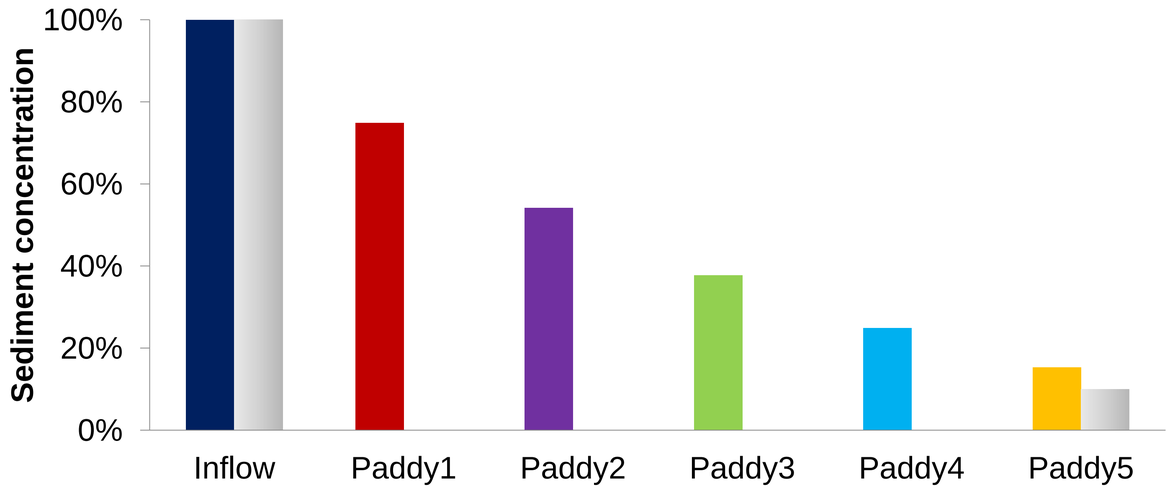

Figure 5: Measured during rain(grey; Kofler pers. comm.) and modeled (colors) sediment concentrations at day 84 (rainy) for the inflow of the cascade and the outflows of the paddies in percent of inflow concentration.

5. Conclusion and Outlook

- Modeled filling and drying of the cascade was in a realistic timeframe
- Modeled percolation, cross flow and bund percolation (data not shown) were in the range of measurements by other authors[1,2]
- To calibrate the turbidity change correctly, more measurements, especially during rain events have to be taken
- For a better validation of the model also more flow measurements during rain events and in other cascades should be carried out
- Further improvement of the sediment modeling could be done by distinguishing different texture classes
- Coupling to LUCIA is pending.

References

1. Huang, H.-C., Liu, C.-W., Chen, S.-K., Chen, J.-S. (2003). Analysis of percolation and seepage through paddy bunds. *Journal of Hydrology*, *284*(1-4): 13–25.
2. Janssen M., Lennartz B. (2009). Water losses through paddy bunds: Methods, experimental data, and simulation studies. *Journal of Hydrology*, 369(1-2):142-153.
3. Marohn, C., Cadisch, G. (2011). Documentation and manual of the LUCIA model v1.2. https://lucia.uni-hohenheim.de/.

Contact: r.schaufelberger@uni-hohenheim.de