SWAT 2013
Toulouse France

Using SWAT model to evaluate the impact of community-based soil and water conservation interventions for an Ethiopian watershed

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Introduction

In Ethiopia, soil erosion by water contributes significantly to food insecurity and constitutes a serious threat to sustainability of the existing subsistence agriculture (Hurni, 1993; Sutcliffe, 1993; Sonneveld, 2002).

The extensive famine of 1973 and 1974 initiated a first governmental rethinking concerning land management and consequently large-scale soil conservation and rehabilitation programs were undertaken (Hurni, 1985).

Aim of the SWAT model

- Provide a link between local environmental characteristics and the generation of runoff and sediment loss
- Evaluate and simulate community based soil conservation interventions to support sustainable land management

Gumara-Maksegnit Watershed

Location

Lake Tana basin, north-western Amhara region, Ethiopia

Area of the watershed

54 km²

Elevation

1920 - 2860 m asl

Mean annual rainfall

~ 1150 mm (May – October)

Community based Soil Conservation Interventions

- Stone bunds
- Retention ponds

MATERIALS AND METHODS

SWAT Model

SWAT 2009

- ArcGIS 9.3
- Daily time step resolution
- SCS CN Method for surface runoff
- Soil conservation effect of stone bunds adjusted by CN-Number and P-Factor (MUSLE)

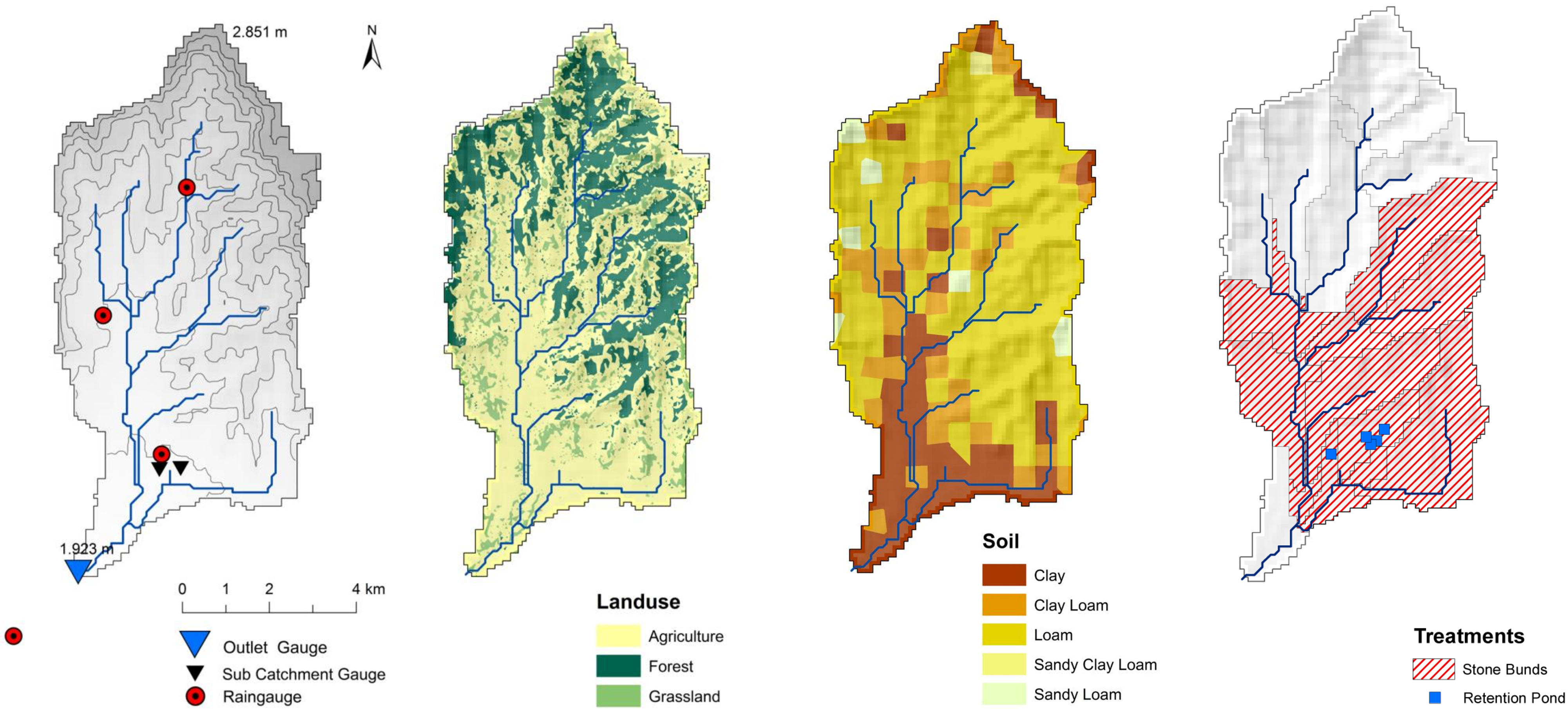
Calibration and sensitivity analyses

- Calibration based on watershed outflow (mean daily discharge)
- Calibration based on ten most affective parameters (sensitivity analyses) using SWAT-CUP (SUFI2 algorithm)

Evaluation of model performance

- NSE Nash-Sutcliffe coefficient

SWAT Input Data

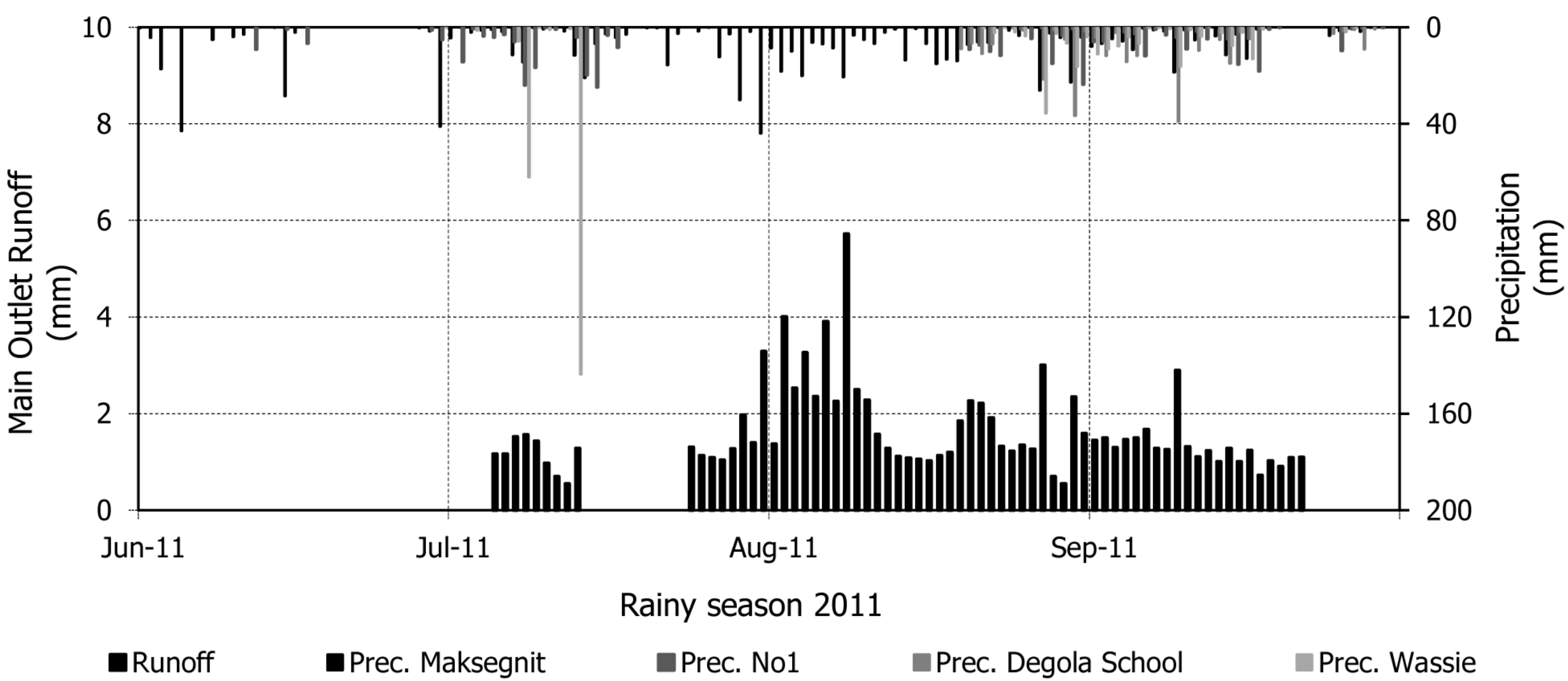


SWAT Calibration Data

Main Outlet Gauging Station

- Water level by pressure sensor
- Sediment concentration by manual bottle sampling resp. turbidity meter

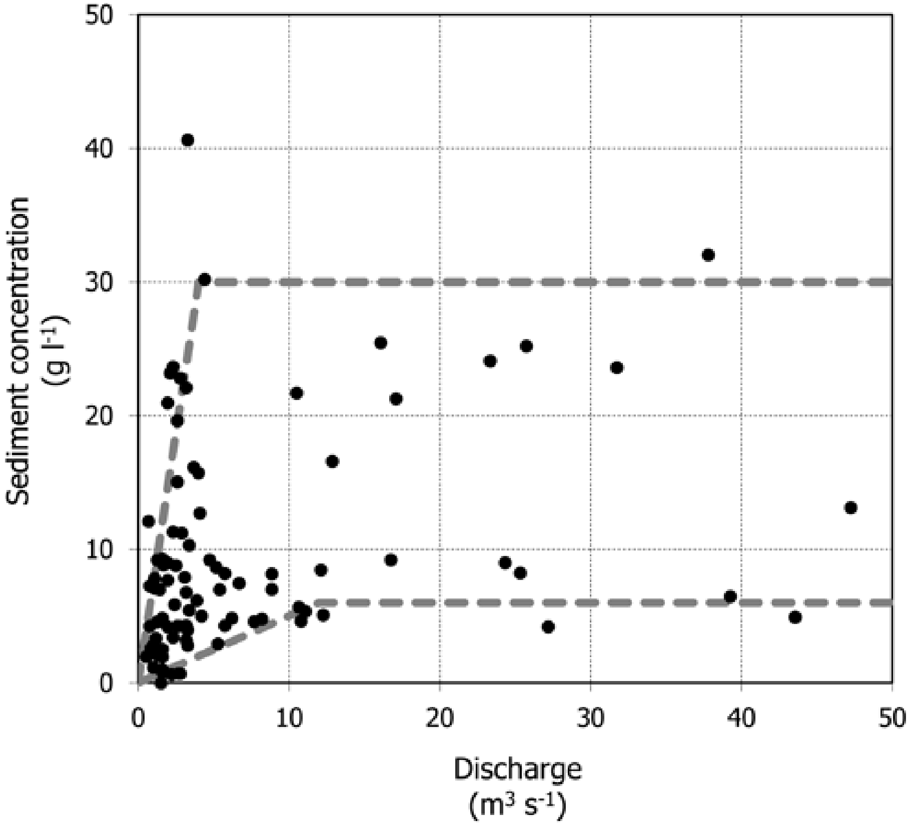
SWAT Calibration Data



SWAT Verification Data

Manual bottle sampling

- Three times (and three replications) the event
- Notation of corresponding water level/discharge



Field Monitoring (2012)

Aims

- Evaluate erosion of channels and upland regions
- Evaluate effects of soil conservation structures (stone bunds)
- Transfer soil conservation effects into SWAT usable parameters (SCS CN, MUSLE)

Field Monitoring

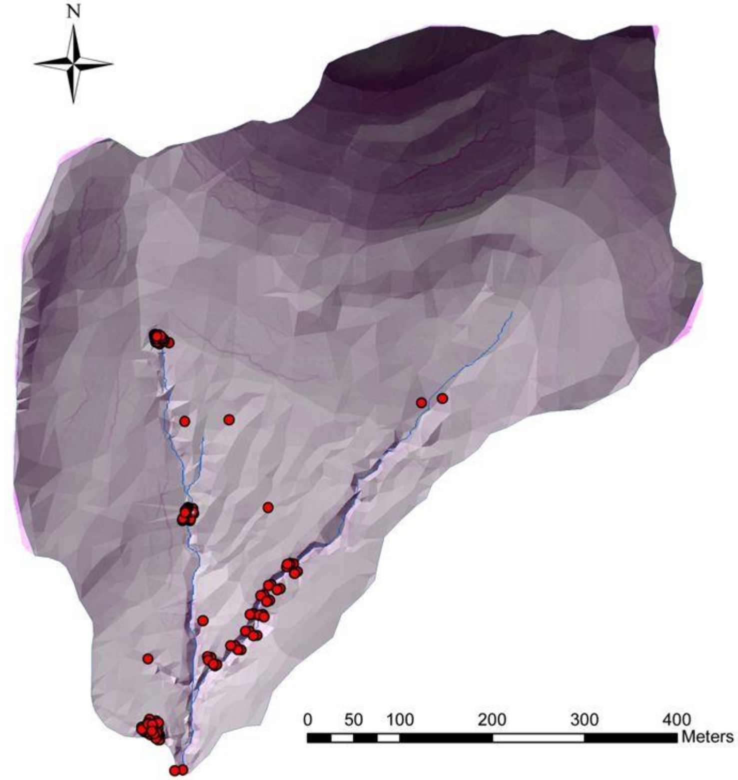
Survey of gully network

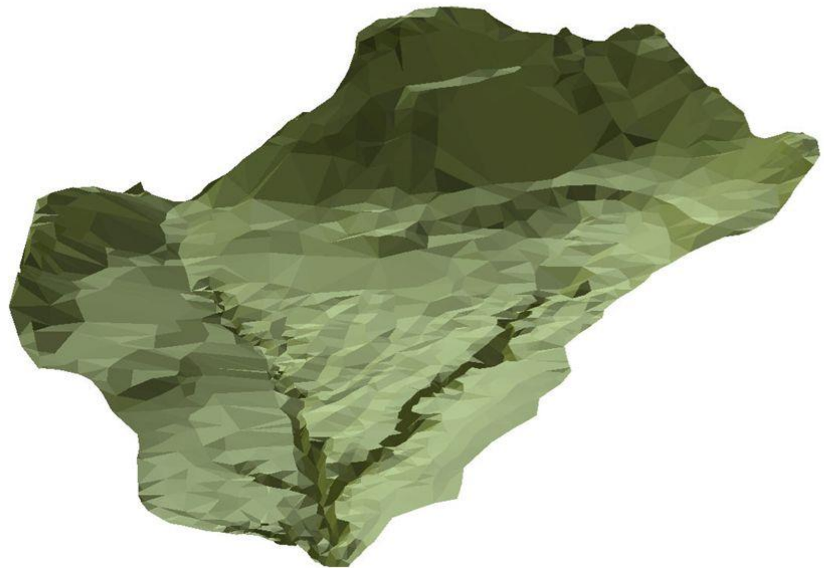
Methods

- Land survey using total station and GPS
- Manual measurement of cross sections
- Photogrammetric approach

Output (still in progress)

- Gully drainage density from 2 to 10 ha
- Cross sectional gully growth up to 1 ton per meter gully length





Field Monitoring

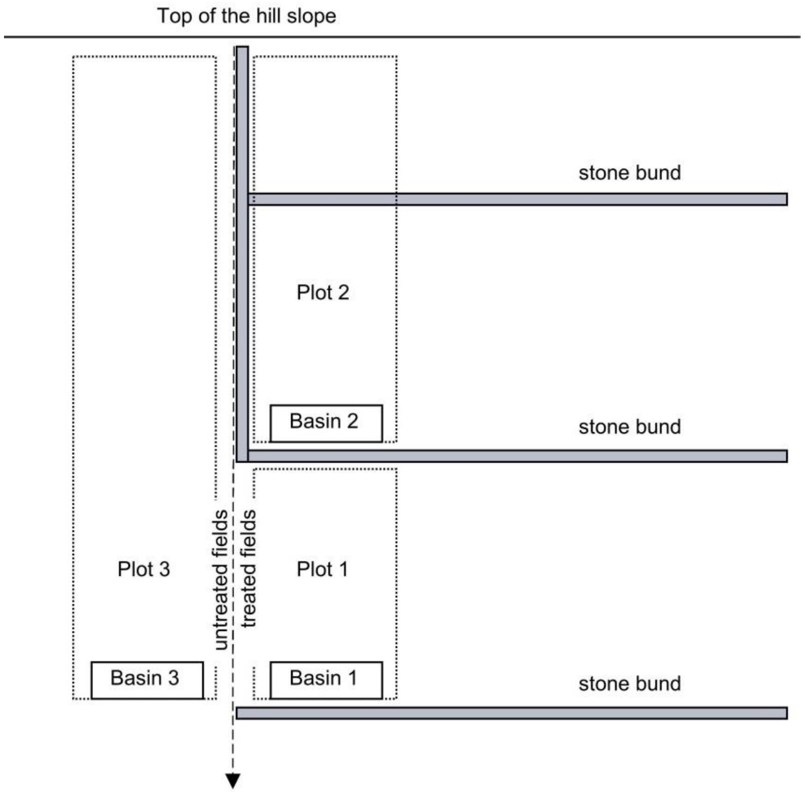
Erosion plot monitoring

Methods

- Ditches at untreated and treated hill slopes
- Weekly measurement (soil and water)

Output (still in progress)

- Highly variable soil conservation effect of stone bunds due to stone and crop cover
- Expected P-Factor ~ 0.75

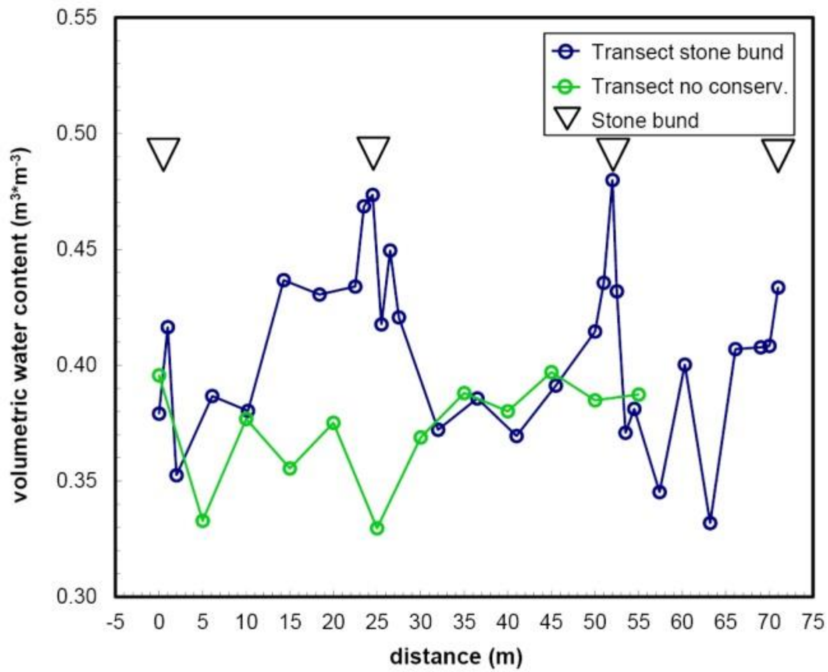


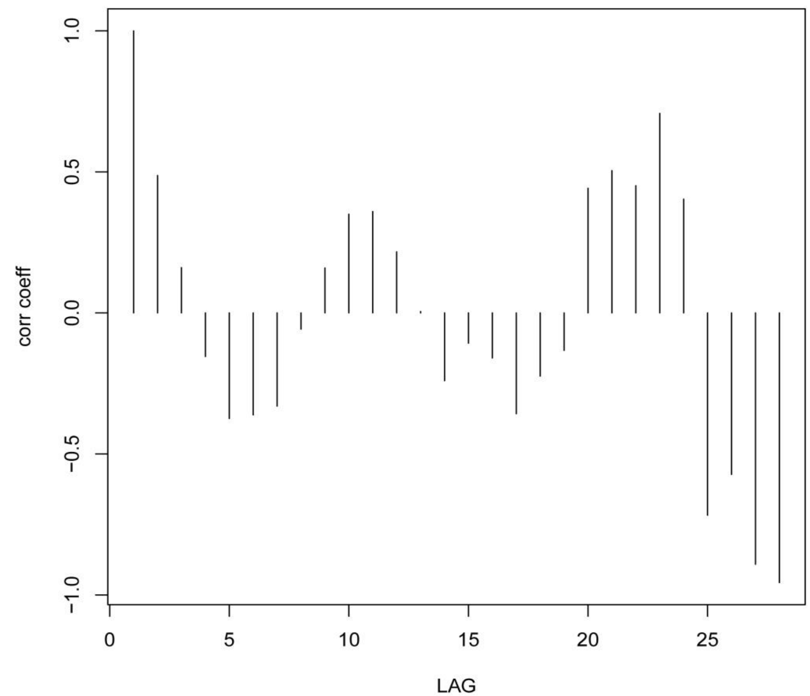
Field Monitoring

Soil physical properties

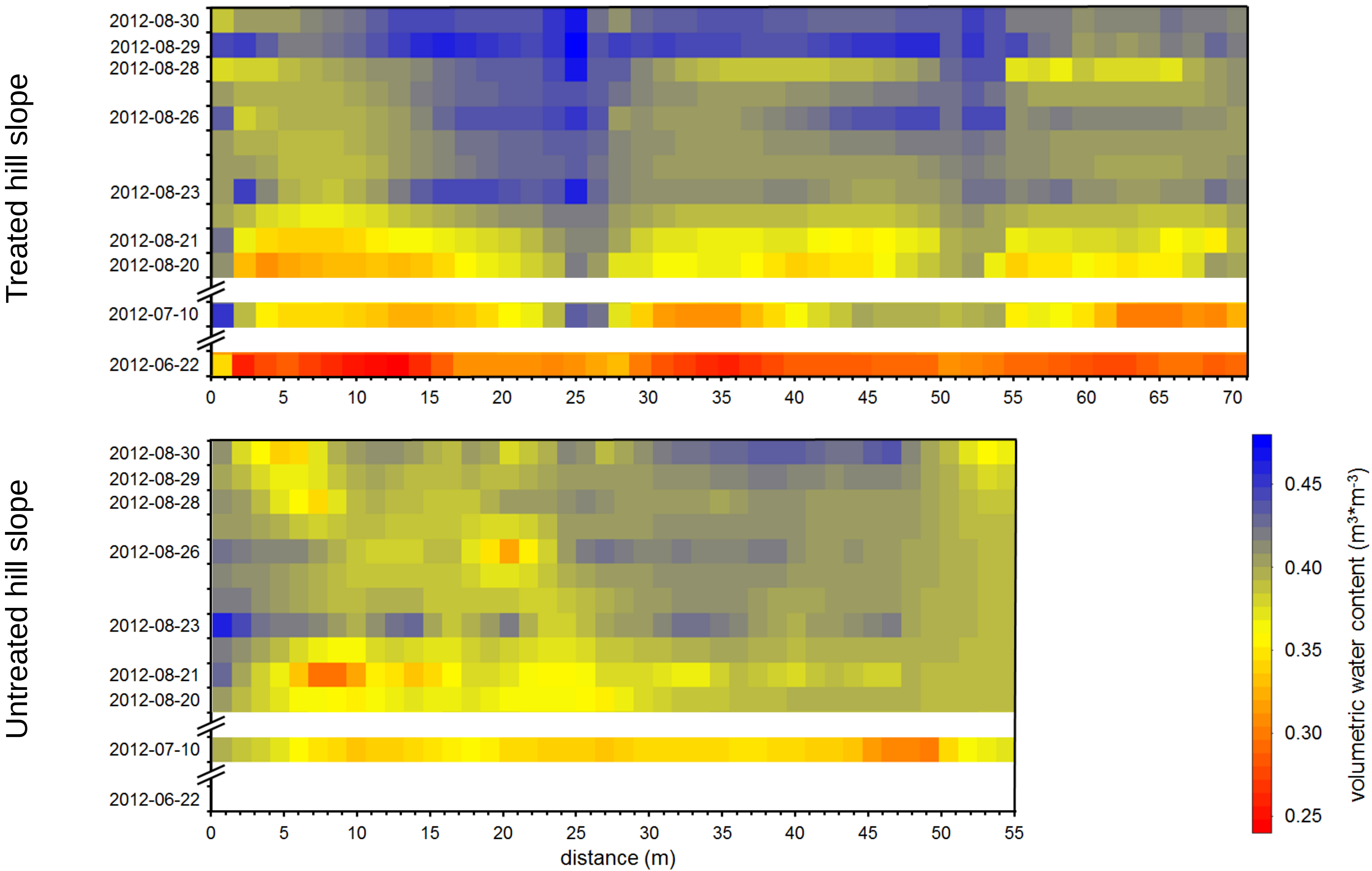
Methods
- Transects (treated and untreated)
- Measurement of soil properties (soil moisture, texture, bulk density, k-value, …)

Output (still in progress)
- Stone bunds increase infiltration
- Adjustment CN-Number in stone bund treated HRU`s (decrease of ~ three units referring to Lankriet et al. (2012))



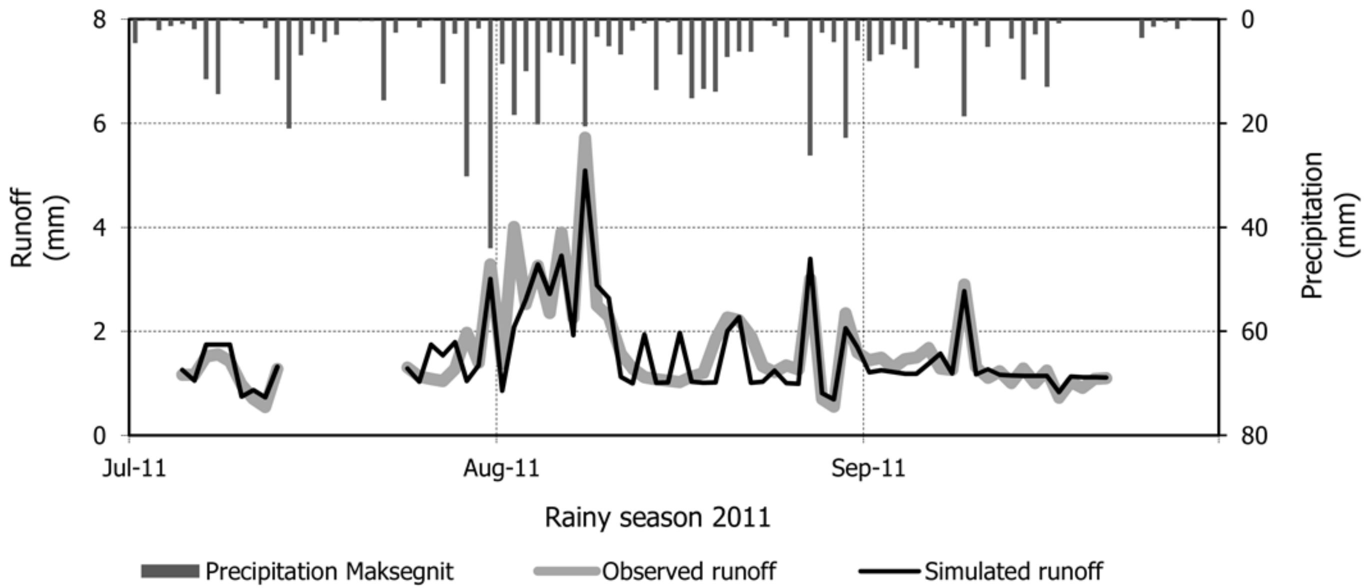


Field Monitoring

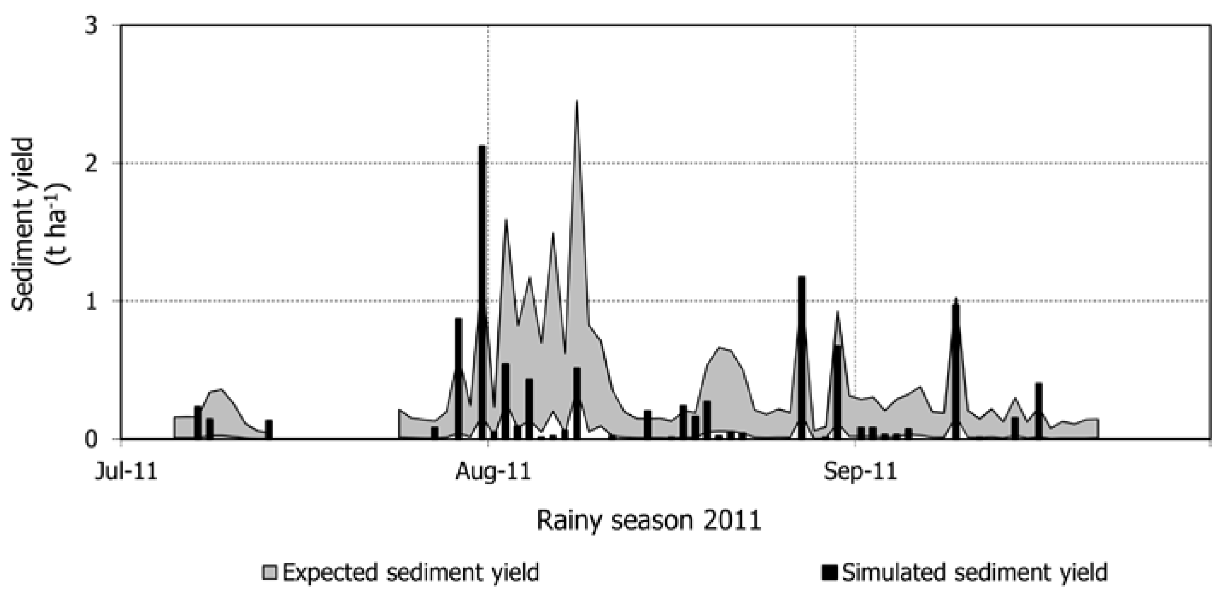


RESULTS AND DISCUSSION

SWAT Calibration and Verification



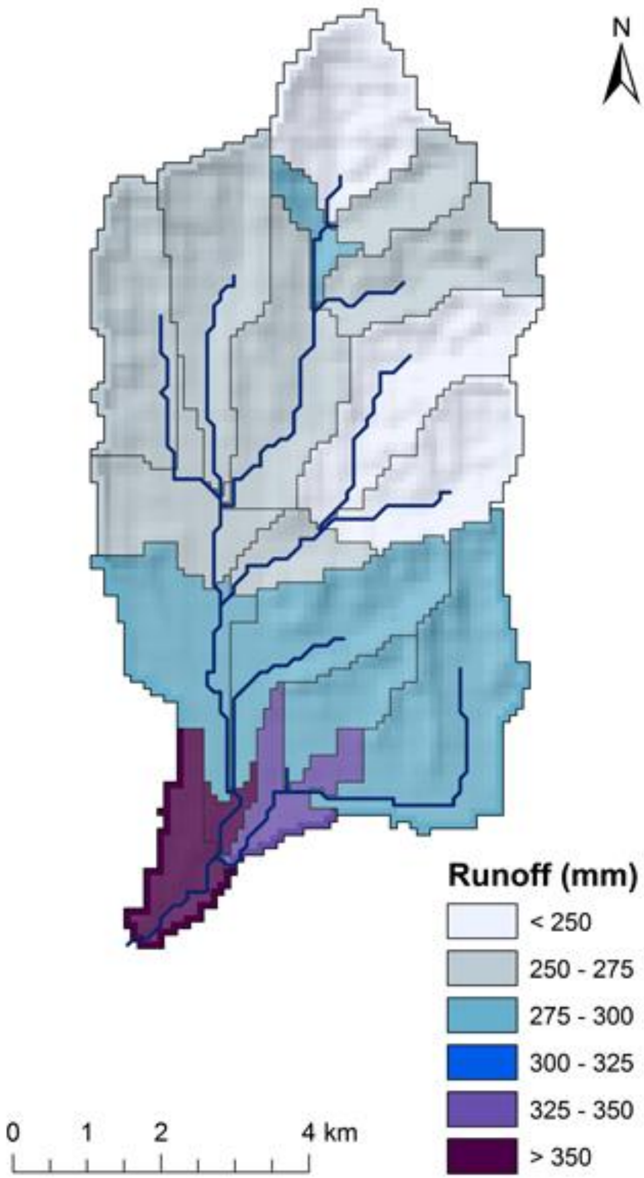
Main Outlet Runoff
NSE = 0.777

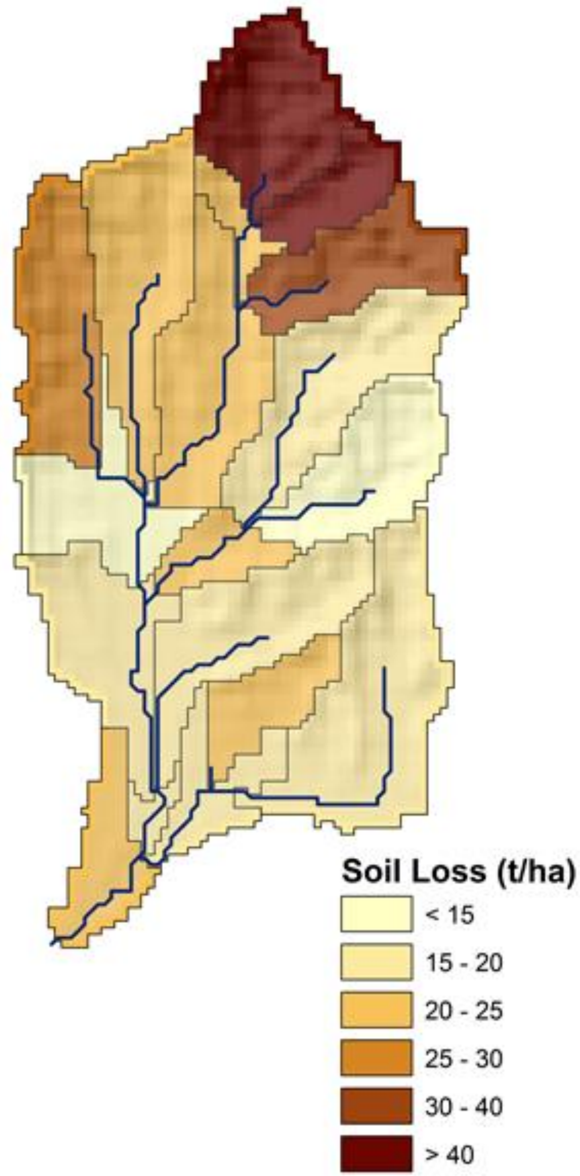


Budget of simulated sediment yield:
10.0 t ha^{-1}

Budget of expected range of sed. yield:
2.9 – 27.6 t ha^{-1}

Runoff and Soil Loss Map





Mean annual values
(1997-2011)

CONCLUSIONS

Conclusions

+ SWAT can be used to simulate daily based outflow and sediment yield of the small and steep sloped watershed in the Ethiopian highlands
+ Soil conservation effects of stone bunds and small scale retention ponds are considered by the watershed model
+ Hot spots of runoff and erosion are located
+ SWAT model might be useable as basis for simulating soil conservation scenarios (needs validation data)

– Peak flows and channel erosion might be underestimated by our model
– Quantification of upland erosion might be difficult based on lumped sediment yield data at the outlet of the watershed
– Implementation of small scale rainfall characteristics is improvable

Outlook

- Improved model calibration and validation data (Sub-Catchments, seasons 2012 and 2013, ISCO-Sampler, …) [*1,2]
- Account for gully growth (not reliably simulated by our model) [*1]
- Advanced spatial rainfall data (20 additional buckets for daily rainfall analyses) [*2]
- Advanced erosion plot monitoring for evaluation of soil and water conservation effects of stone bunds [*2]
- Effects of SC-structures on crop yield

[*1] Data already available

[*2] Field works 2013

References

Hurni, H. 1985. Erosion - Productivity - Conservation Systems in Ethiopia. *In Proc. 4th International Conference on Soil Conservation* 654-674. Maracay, Venezuela.

Hurni, H. 1993. Land degradation, famine and land resource scenarios in Ethiopia. *In: D. Pimentel (ed.) world soil erosion and conservation* 27-62. Cambridge Univ. Press, Cambridge, UK.

Sonneveld, B. 2002. Land under pressure: the impact of water erosion on food production in Ethiopia. Shaker publishing, Maastricht, Netherlands.

Sutcliffe, J. P. 1993. Economic assessment of land degradation in the Ethiopian highlands: a case study. National Conservation Strategy Secretariat, Ministry of Planning and Economic Development, Addis Ababa, Ethiopia.

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Thank you,

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