Field Data-Based Implementation of Land Management and Terraces on the Catchment Scale for SWAT in the Three Gorges Region, China

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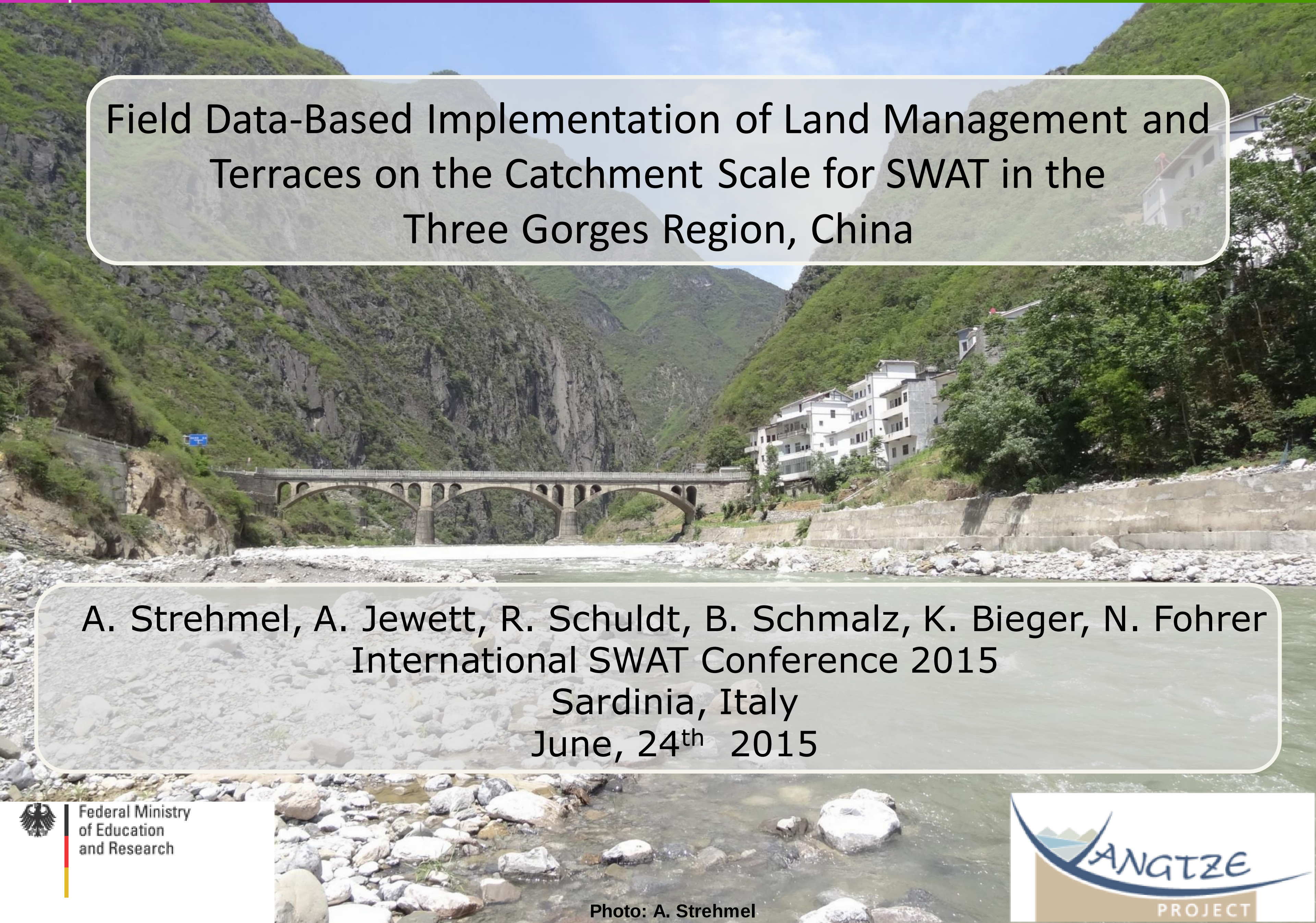


Photo: A. Strehmel

Federal Ministry of Education and Research
YANGTZE PROJECT

YANGTZE-GEO
2009 - 2015

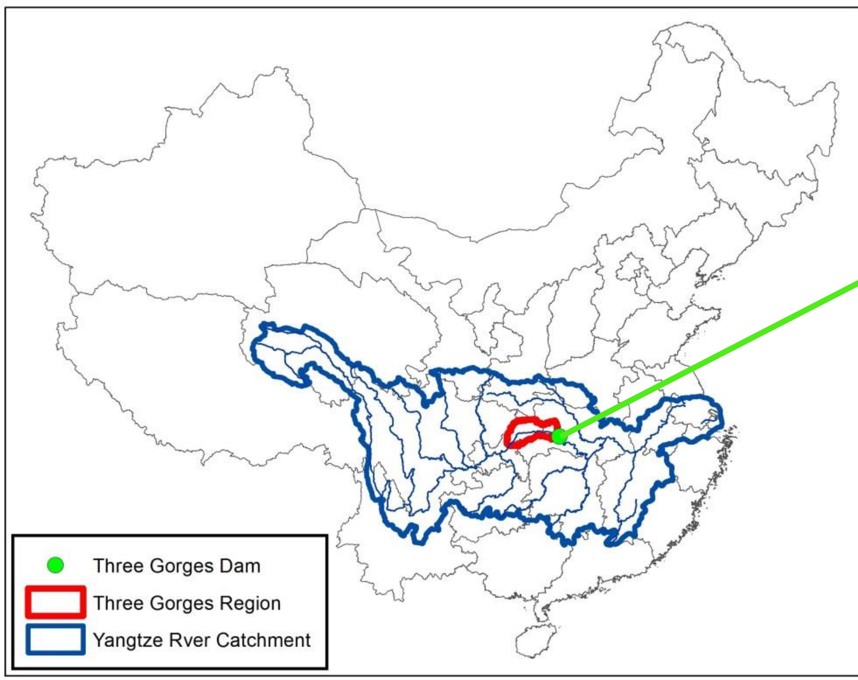
Land use change, erosion, mass movements and diffuse matter inputs in the Three Gorges Region

Erosion Tübingen	Landslides Erlangen	Landslide Monitoring DMT Essen	Diffuse Matter Inputs Kiel	Remote Sensing Trier
Assessment and analysis of soil erosion	Assessment and analysis of landslides	Assessment of mass movements using geo-monitoring techniques	Analysis of sediment and phosphorus inputs using SWAT and HEC-RAS	Classification of land use and land use change assessment

Aim:
Analysis of land use change, risk assessment of mass movements, soil erosion and diffuse inputs to rivers

Background – The Three Gorges Region in China

- Area upstream of the Three Gorges Dam at the Yangtze River in central China
- Strong land use change caused by the reservoir



Photos:
A. Strehmel

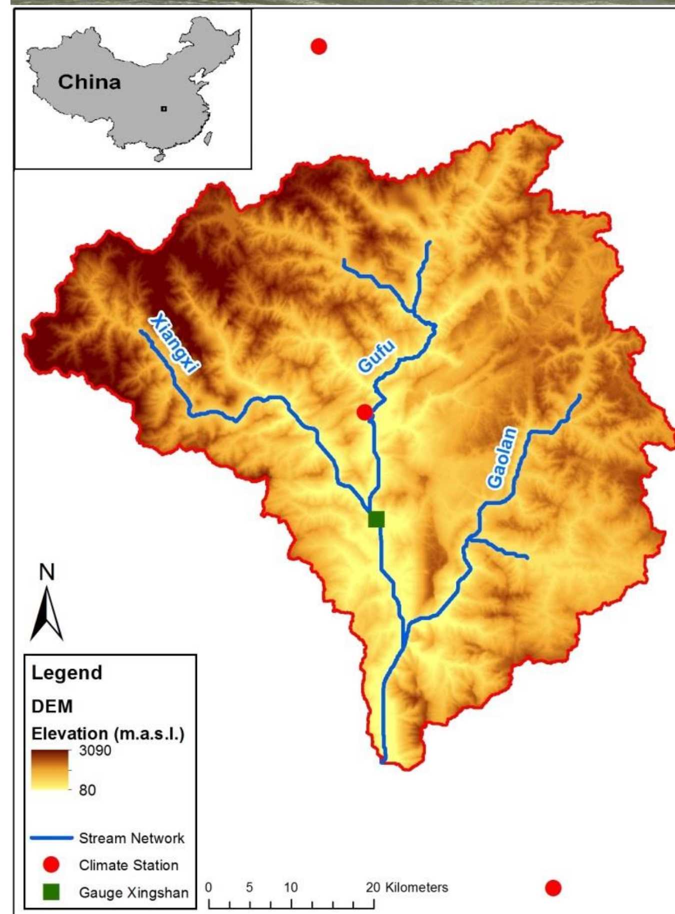
Background – The Three Gorges Region in China

- Area upstream of the Three Gorges Dam at the Yangtze River in central China
- Significant land use change
- Small scale agricultural
- High diversity in land use
- Farming on very steep slopes
  → Terraces as soil conservation measures
- Terraces often lack maintenance

Photo: S. Schönbrodt-Stitt

Background – The Three Gorges Region in China

- high inputs of sediment and nutrients through non-point source pollution → risk of eutrophication
- A SWAT modelling approach in the Xiangxi catchment in the Western TGR as a blue print for the development of management strategies (K. Bieger, 2009-2011)
- **This approach has to consider the characteristics of land management as well as the abundance and con-ditions of measures for soil and water conservation**



Motivation

- **Spatially-distributed data** on **land management practices** as well as the **measures for soil and water conservation** are crucial model input data
- Usually, these data are derived from statistical or cadastrial information for meso- and large-scale catchments
- Many world regions, however, are lacking these structural datasets on the agricultural environment

Goal

Development and evaluation of a method for the inclusion of spatially-distributed data of land management and terrace quality in a data scarce region

Challenges:

- No management data, no crop rotation data
- Accessibility of the region
- Full spatial coverage

Methods:

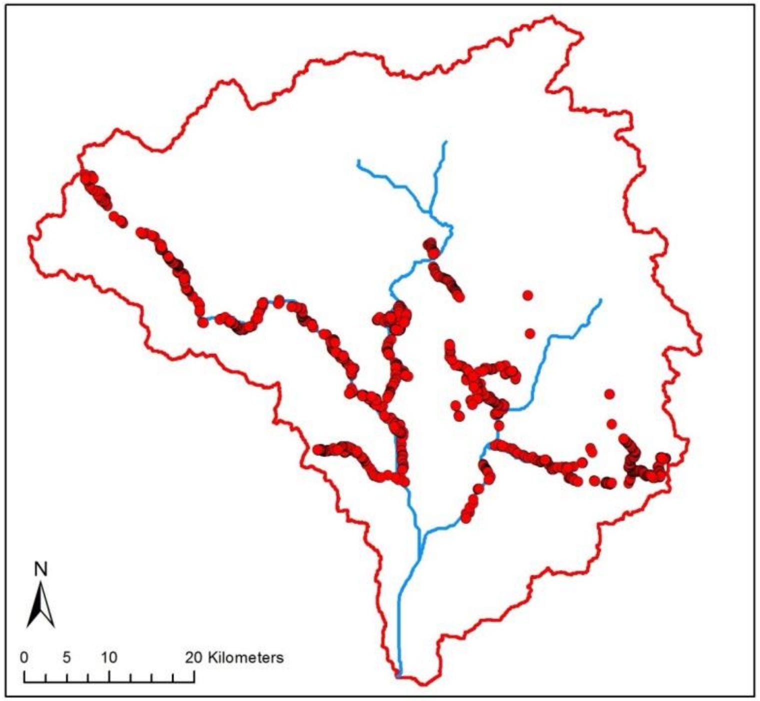
– Field data aquisition
– Spatial extrapolation
– Evaluation of the effects of the additional data on the SWAT modelling approach

Field Campaign

Field campaigns in autumn 2012 and 2013, as well as in spring 2013:

- Geo-referenced photos using a GPS-equipped camera:
  - mostly from the car along the main rivers and valleys
  - also on some high plateaus
  - in total 2,500 geo-referenced photos

Photo: G. Buzzo

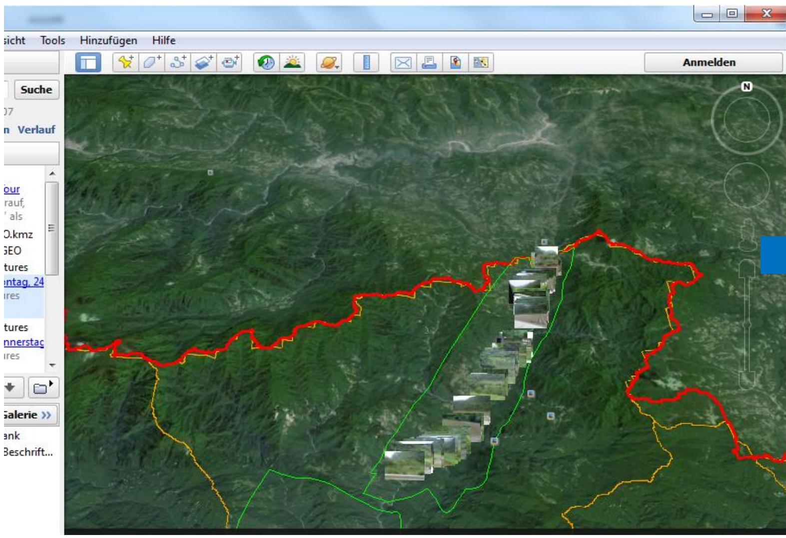


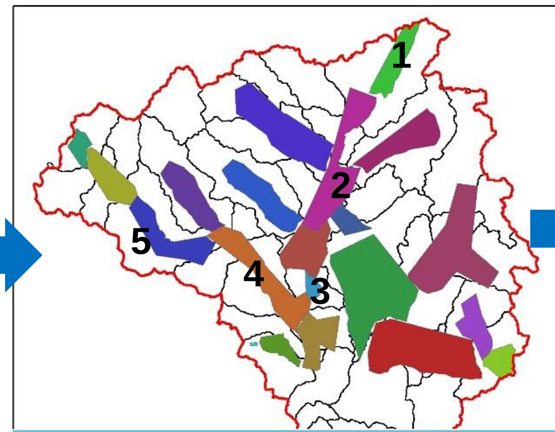
Field Campaign

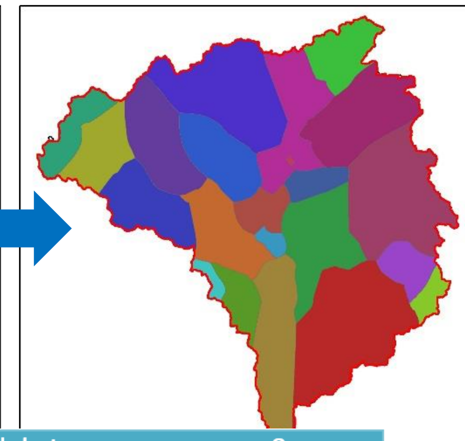
- Farmer interviews:
  - in total 15 semi-standardized interviews with farmers
  - in different agricultural zones of the catchment
  - Questions on: - planting and harvesting times
    - Crop rotations
    - Yield
    - Fertilizer use: when? what? how much?

1. Implementation of Agricultural Management

- Analysis of the geo-referenced photos from the field campaigns
- Derivation of sub-areas with uniform cultivation patterns



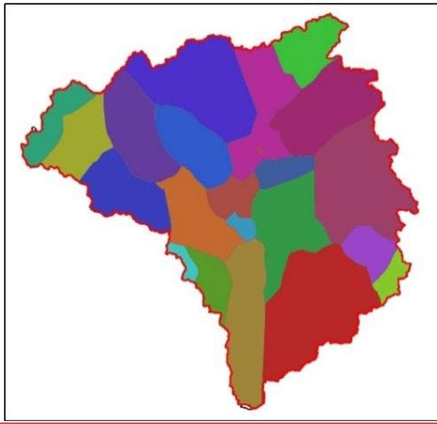




Subarea	Date of observations	Cultivated plants	Oranges
1	17.05.2013	80% rape-corn; 10% walnut; 5% potato; 5% others (wheat, pumpkin, tomato, beans)	Some oranges
2	17.05.2013	55% rape-corn; 20% rice; 15% potato; 5% wheat; 5% other (sweet potato)	no
3	18.05.2013	55% rape-corn; 20% potato; 25% others (tomato, cabbage, sweet potato)	few oranges
4	18.05./20.05.2013	85% rape-corn; 5% potato; 10% others (sweet potato, cabbage, tomato)	60% oranges
5	20.05/23.05.2013	50% tea; 22 % rape-corn; 20% potato; 5% tobacco; 3% others (sweet potato, tomato, cabbage	no

Extrapolation of the sub-areas onto the whole basin

Implementation of Agricultural Management



Areas of uniform management as derived from field data:

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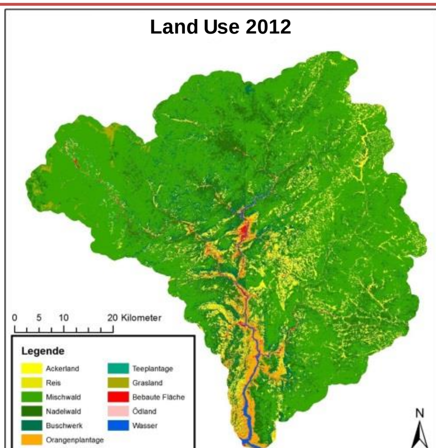
intersect with land use map considering subarea crop percentages per subbasin

Result: Land use map with one class per crop/crop rotation



Implementation of management in SWAT based on data from the farmer interviews

Rape-corn rotation:

Corn:

Planting: *15th March*

Fertilizer appl.: *16th March*; FERT_ID: *15-15-15*; FRT_KG: *35*

1st June; FERT_ID: *Elemental Nitrogen*; FRT_KG: *70*

1st July; FERT_ID: *Elemental Nitrogen*; FRT_KG: *70*

Harvest and kill: *1st September*

Rape:

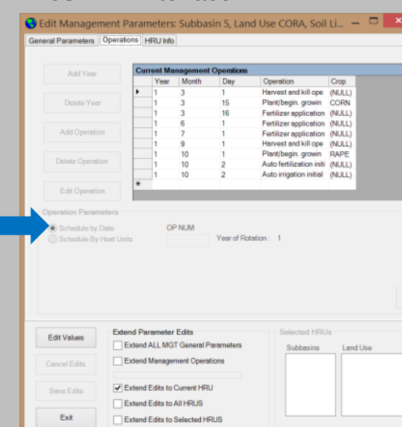
Planting: *1st October*

Auto irrigation: *2nd October*; WSTRS_ID: *Plant Water Demand*; AUTO_WSTRS: *0.9*; IRR_SCA: *3*; IRR_NOA: *Number of Subbasin*

Auto fertilization: *2nd October*; AFERT_ID: *15-15-15*; AUTO_NSTRS: *0.9*

Harvest and kill: *1st March*

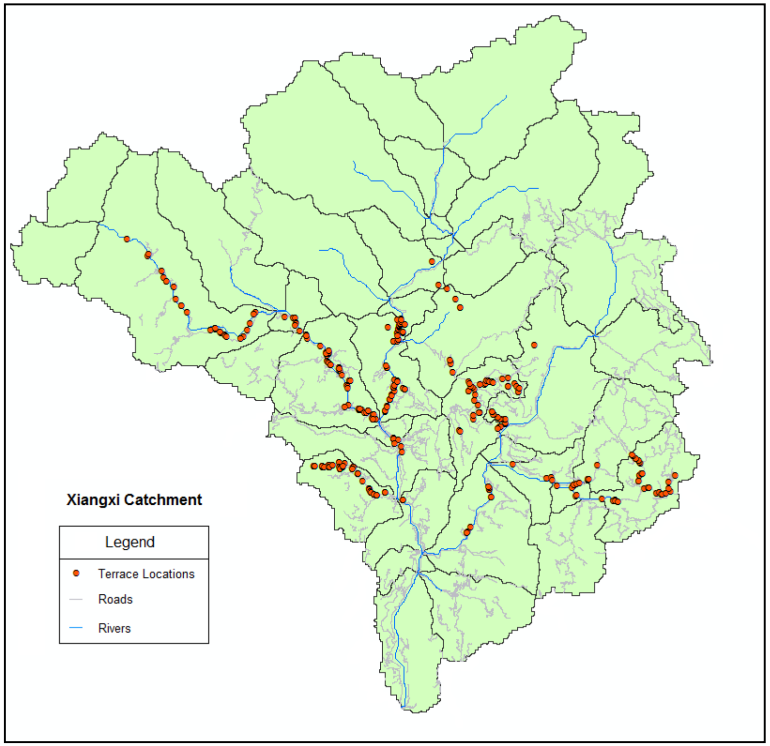
ArcSWAT-Interface



2. Implementation of Terraces

<u>Terrace mapping:</u>

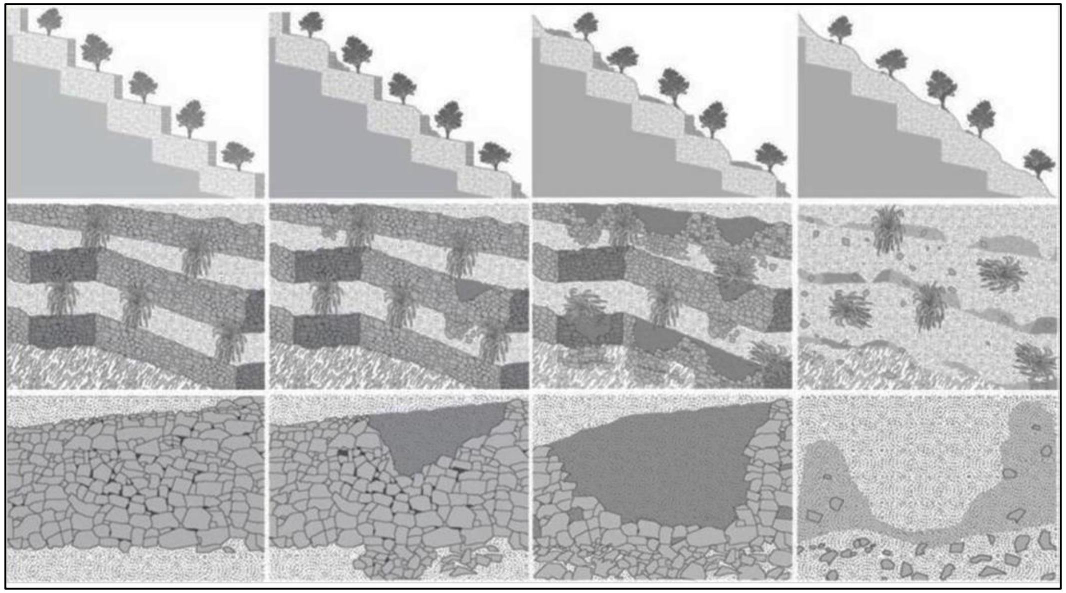
420 terraces for analysis



<u>Classification of terraces by condition:</u>

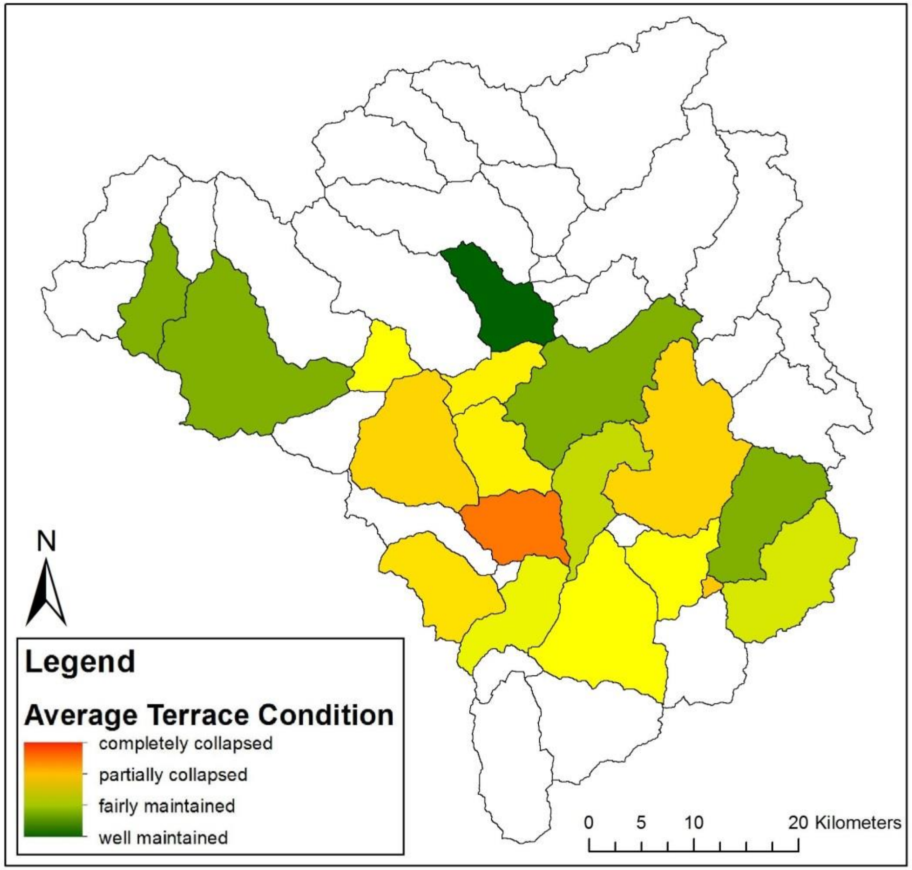
Better terrace conditions exhibit a stronger protection against soil erosion

1 Well maintained	**2** Fairly maintained	**3** partially collapsed	**4** completely collapsed



Approach: Determination of the average terrace condition per subbasin

Implementation of Terraces

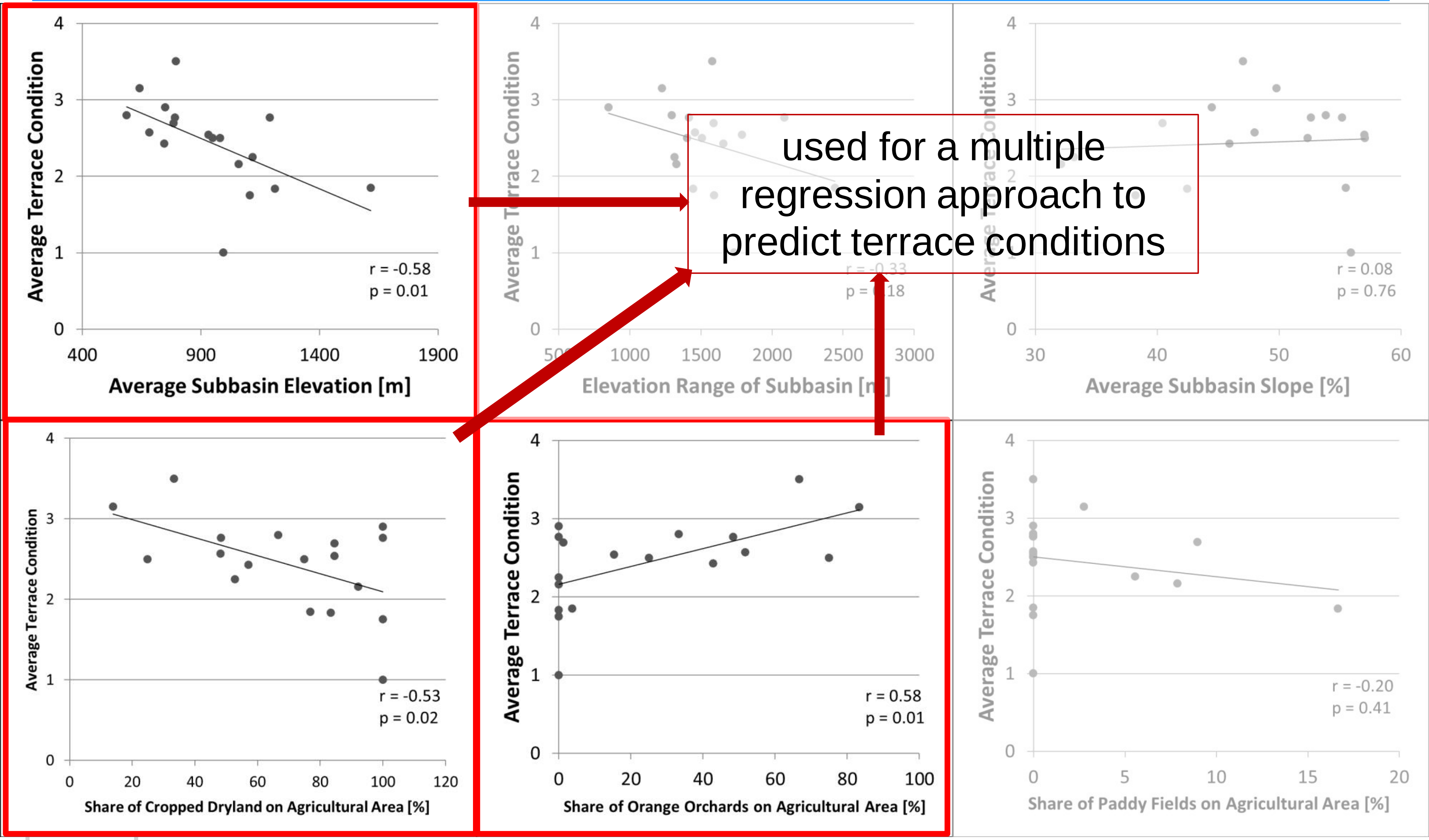


How to extrapolate the information onto the whole catchment?

Idea:
Prediction of the average terrace condition in a subbasin by means of explanatory variables related to:

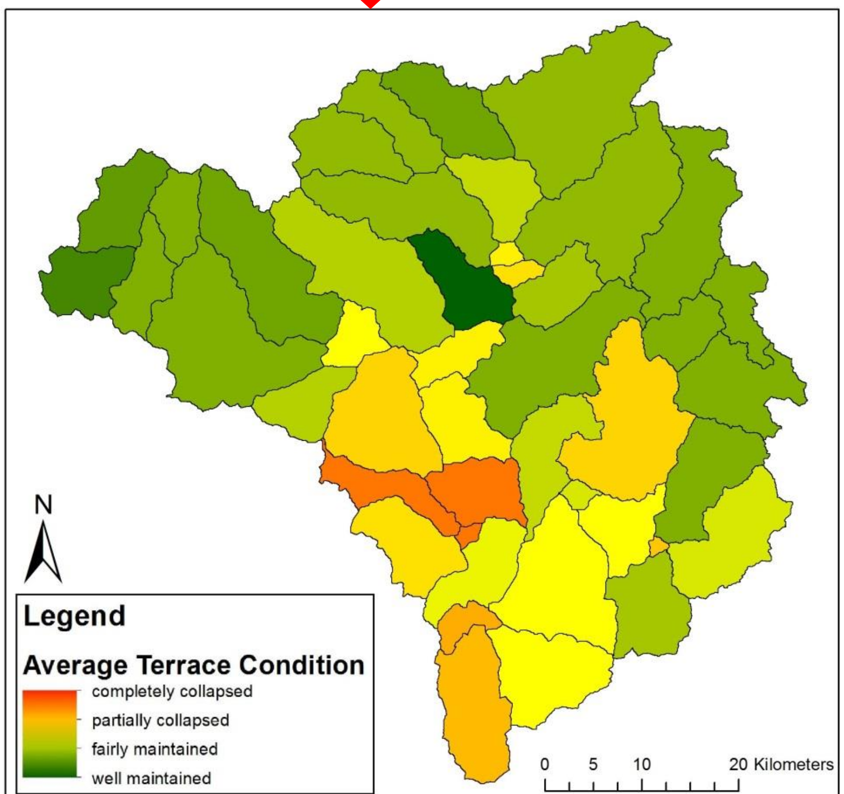
- Topography
- Land Use

Implementation of Terraces



Implementation of Terraces

$$TerraceCondition_{sub} = f\,(Elevation; Share\ of\ Cropped\ Dryland; Share\ of\ Orange\ Orchards)$$

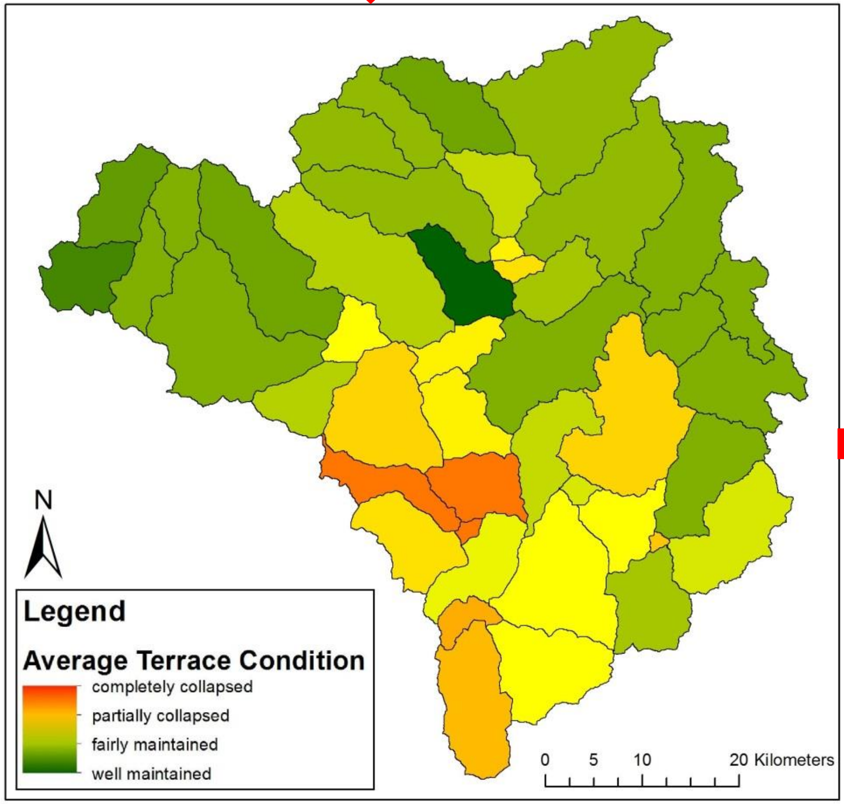


Validation:

Subbasin	Predicted Terrace Condition	Difference to Measured Condition
11	2.17	-1.17
18	2.79	-0.29
20	1.72	0.12
22	3.15	0.00
23	2.06	-0.31
24	2.75	0.02
27	2.86	-0.29
28	2.15	0.01
29	1.99	0.78
30	2.80	0.00
32	2.37	0.13
34	2.05	-0.22
35	2.87	0.63
36	2.39	0.51
38	2.45	0.25
39	2.30	-0.05
41	2.73	-0.30
42	2.34	0.19
	Mean absolute error:	**0.29**
	RMSE:	**0.42**

Implementation of Terraces

$$TerraceCondition_{sub} = f\ (Elevation; Share\ of\ Cropped\ Dryland; Share\ of\ Orange\ Orchards)$$



Translation of terrace conditions into SWAT parameters (after Arabi et al., 2006):

Terrace Condition	CN2 (add)	P_USLE (absolute)	Slope Length (relative)	Slope Length (steep)* (relative)
well maintained	-6	0.2	-40%	-20%
fairly maintained	-5	0.4	-30%	-15%
partially collapsed	-4	0.6	-20%	-10%
completely collapsed	-2	0.8	-10%	-5%
not terraced**	0	1.0	-0%	-0%

* steeper 50%
** only agricultural land steeper than 20% slope is terraced

Streamflow Calibration & Validation

Setup of four SWAT models:

Calibration towards setup with land management and terraces

Calibration/Validation Streamflow (daily)	base model	model with land management	model with terraces	model with management & terraces
NSE	0.69/0.70	0.69/0.70	0.69/0.70	0.69/0.70
KGE	0.81/0.75	0.81/0.75	0.81/0.75	0.81/0.75
PBIAS	-0.01/-1.25	0.07/-1.16	-0.43/-1.59	-0.36/-1.48

Sediment Calibration & Validation

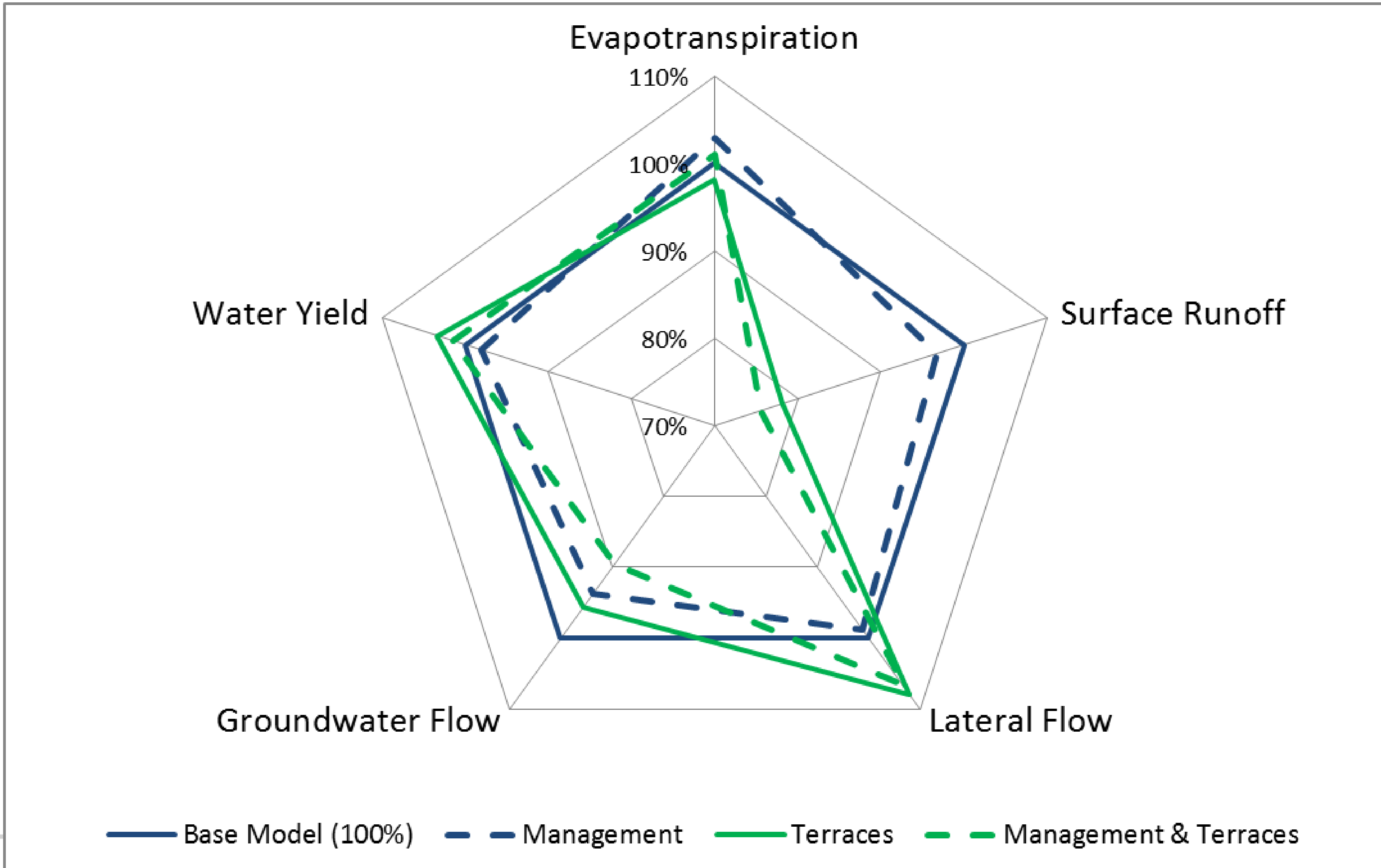
Calibration towards setup with land management and terraces →

Calibration/Validation Sediment (monthly)	base model	model with land management	model with terraces	model with management & terraces
NSE	0.53/-0.60	0.58/-0.32	0.82/0.45	0.81/0.51
KGE	-0.13/-0.44	-0.07/-0.31	0.78/0.55	0.77/0.59
PBIAS	-59.55/-129.14	-57.41/-118.88	5.33/-26.87	5.54/-22.25

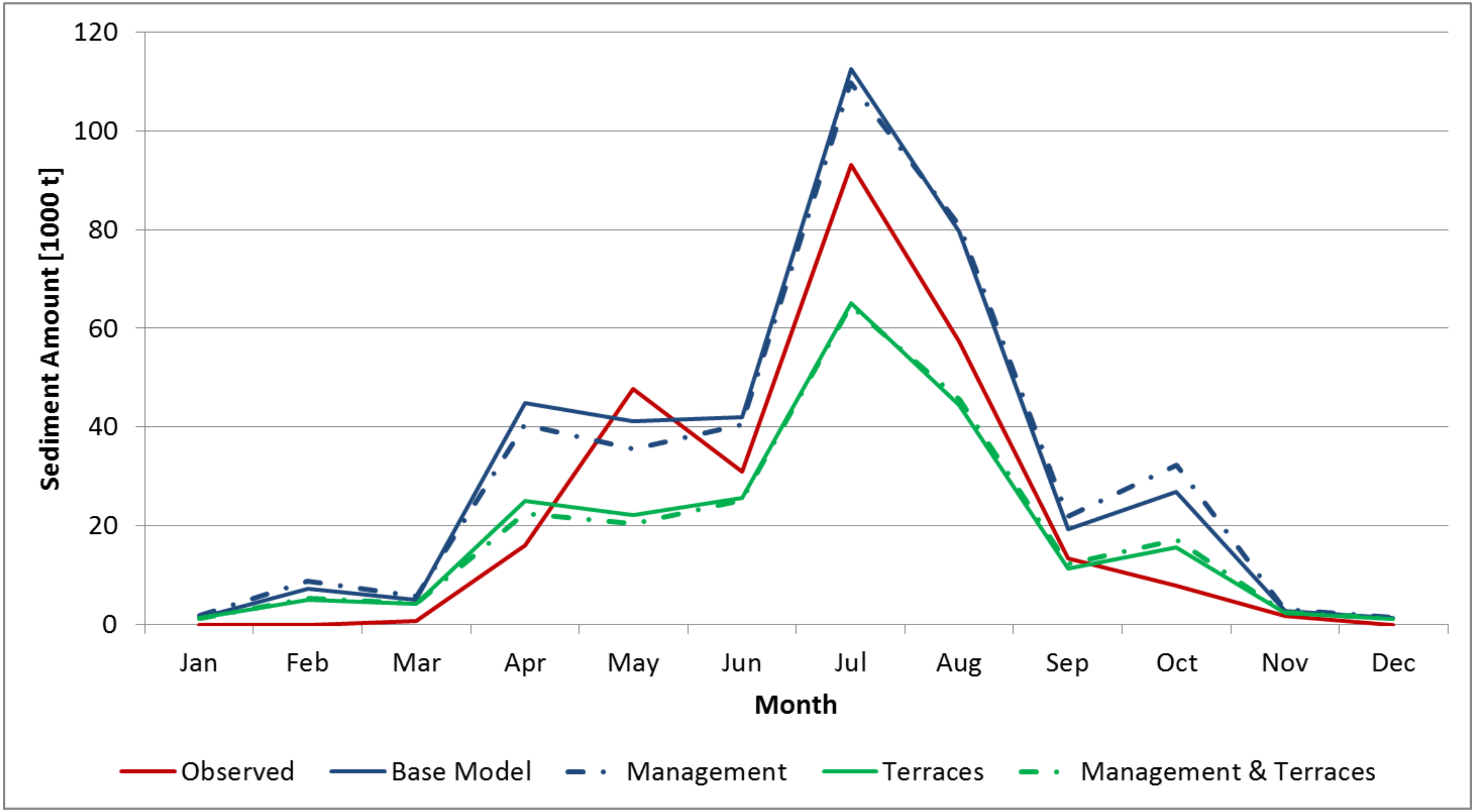
But:
There are different calibration parameter sets showing only slightly lower model efficiencies than the terrace models

→ Equifinality problem
→ Process representation?

Water Balance on Agricultural Areas



Long-Term Average Annual Sediment Graph



Conclusions

- An approach for the generation of spatially explicit datasets on land management and terrace conditions in data scarce regions was developed
- The inclusion of land management and terraces shows almost no effect on total streamflow on the watershed level
- The inclusion of terrace information was able to improve the sediment prediction strongly
- Terraces cause a reduction of surface runoff on agricultural plots, which is compensated by higher lateral flow

Photo: A. Strehmel

Thank you for your attention!

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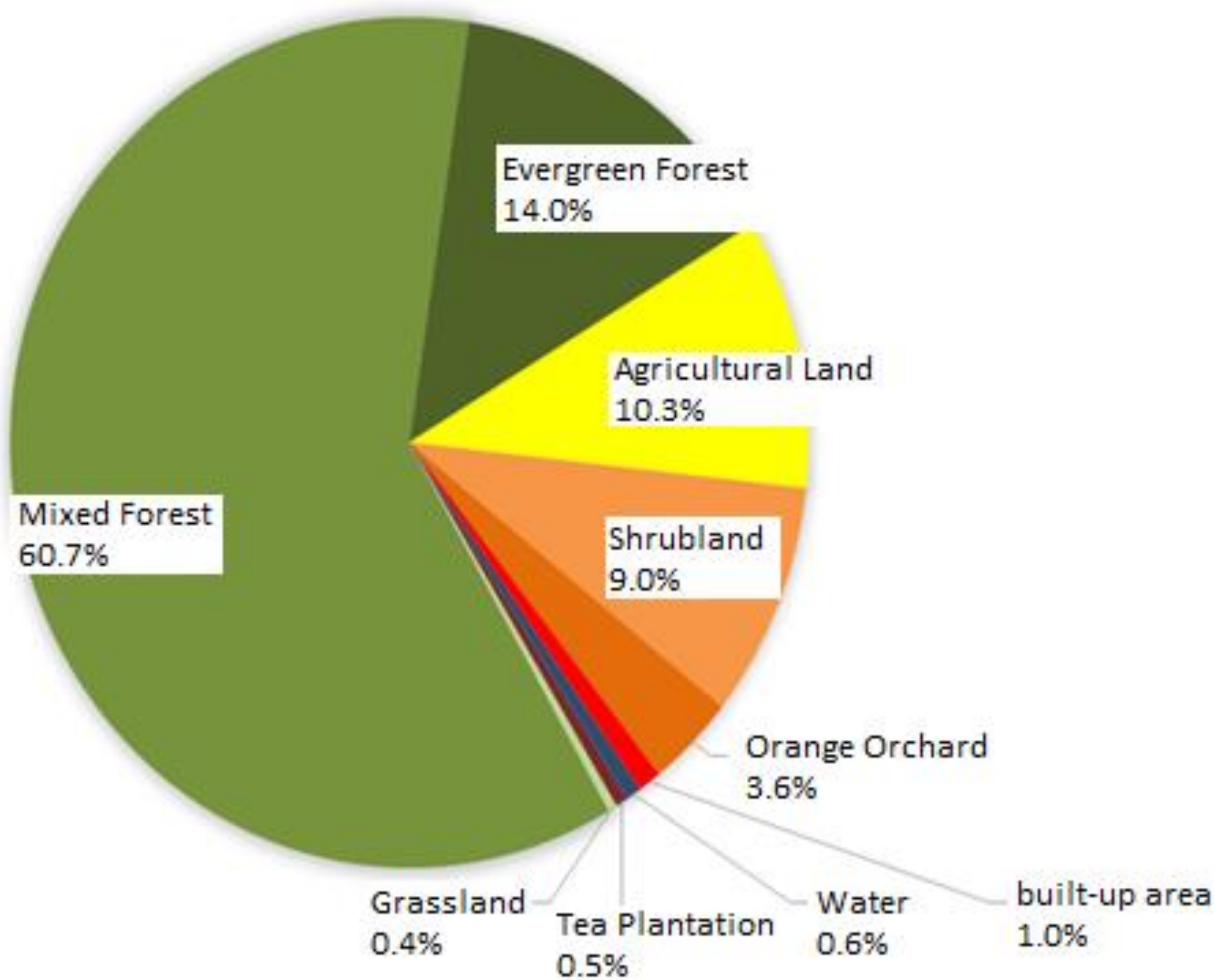
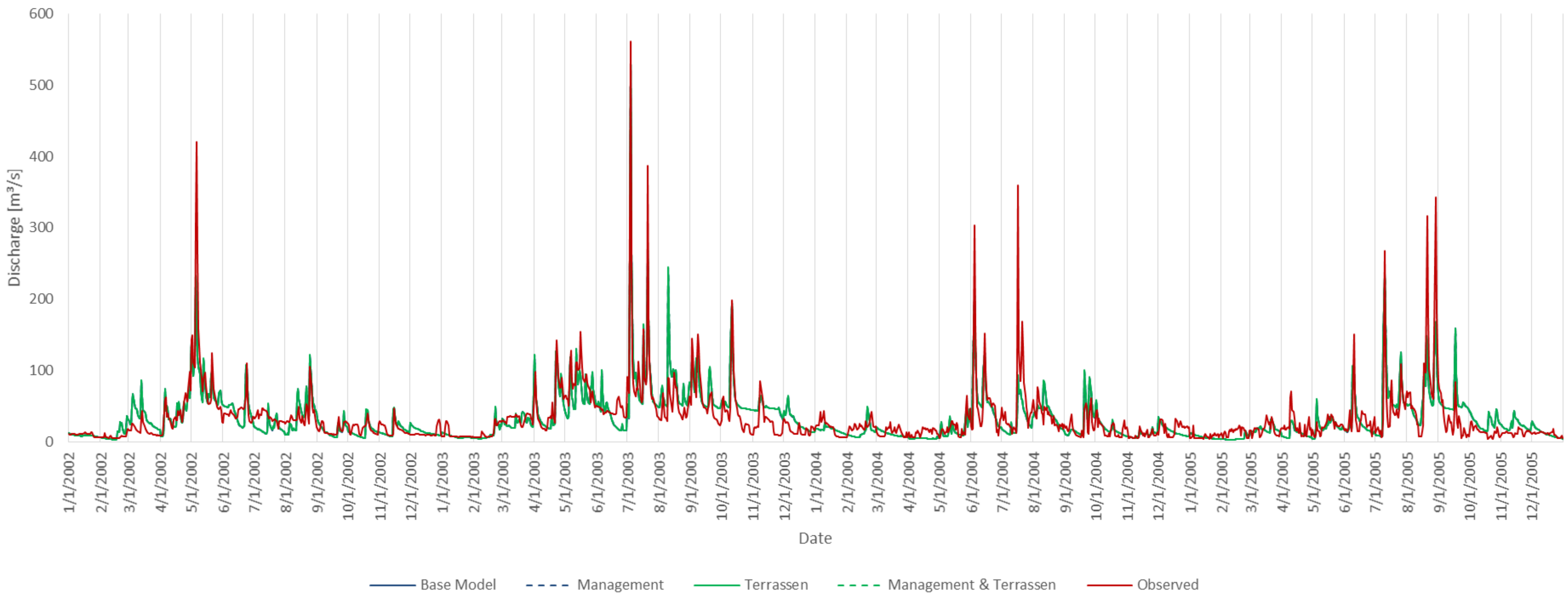
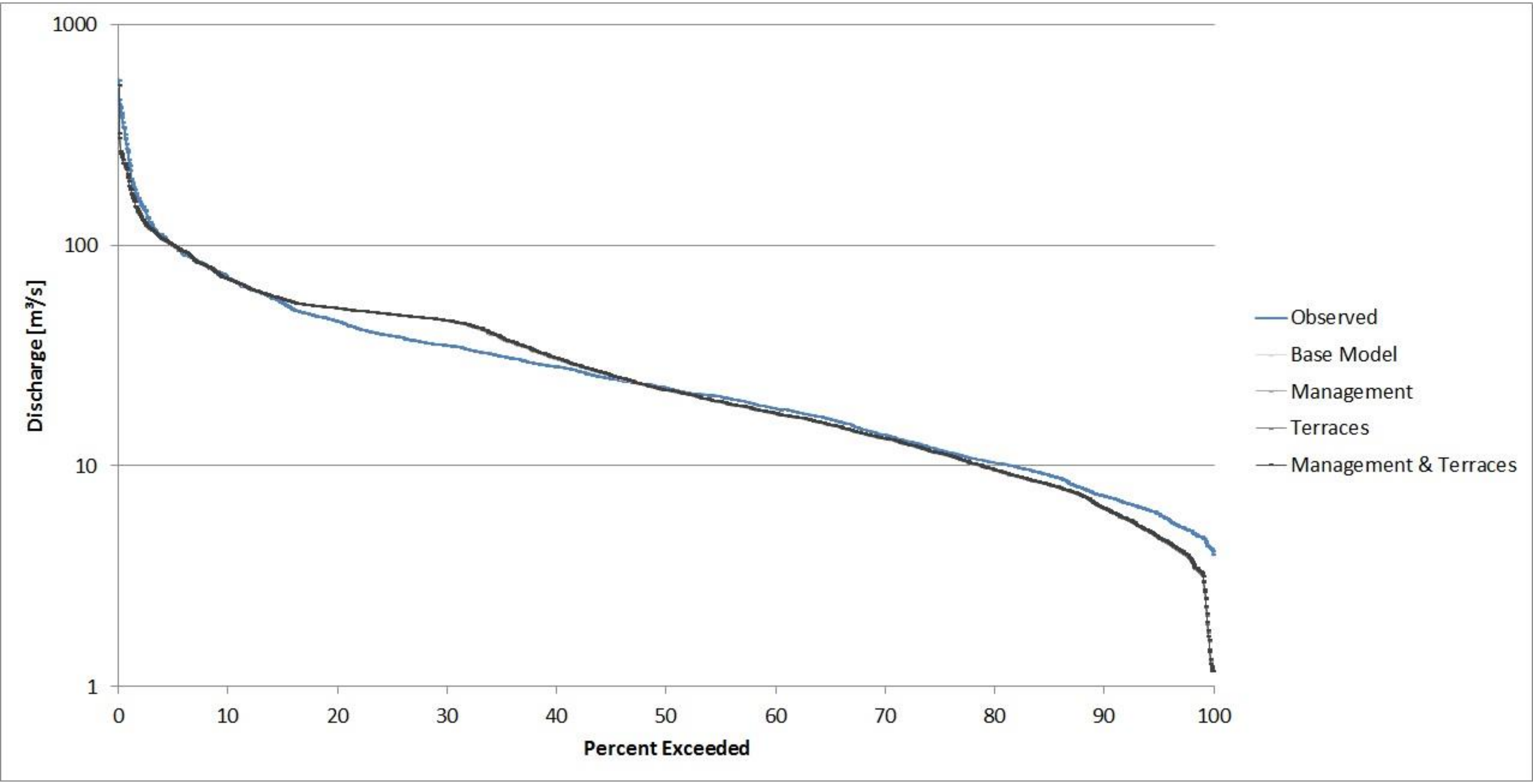
Land Use Distribution in the Xiangxi Catchment



Hydrograph (Calibration Period)



Flow Duration Curve (Calibration Phase)



Parameters for SWAT Calibration

Streamflow Parameters	File	Type of value change	Fitted value	
ESCO	.bsn	Replace value	0.61	Evapotranspiration
CN2	.mgt	Percent change	-14.5%	Surface Runoff
SURLAG	.bsn	Replace value	0.11	
SLSUBBSN	.hru	Percent change	-40.7%	Lateral Flow
SOL_K(1)	.sol	Percent change	-13.8%	
SOL_AWC(1)	.sol	Percent change	-8.0%	Soil Water
SOL_Z(1)	.sol	Percent change	+27.9%	
ALPHA_BF	.gw	Replace value	0.08	
GW_DELAY	.gw	Replace value	29.7	
GW_REVAP	.gw	Replace value	0.20	Groundwater
GWQMN	.gw	Replace value	1291.25	
ALPHA_BNK	.rte	Replace value	0.18	
CH_K2	.rte	Replace value	29.00	Channel
CH_N2	.rte	Replace value	0.07	

Sediment Parameters	File	Type of value change	Fitted value	
USLE_P	.mgt	Percent change	-13.4%	Landscape
USLE_K(1)	.sol	Percent change	+19.5%	
LAT_SED	.hru	Replace value	154.5	Lateral Flow
SPCON	.bsn	Replace value	0.0016	Channel
SPEXP	.bsn	Replace value	1.05	

Open Questions / Problems

- How can the spatial extrapolation approach be validated?
- Is the approach easily transferable to other regions?
- How can a more sophisticated approach for terrace representation (e.g. Shao et al, 2013) yield even higher model efficiencies?
- Equifinality problem: How to validate the accuracy of the process representation in SWAT?