Parameterization of the process-based soil erosion model LISEM and validation by means of experimental measurements and field mapping

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Introduction

- The process-based soil erosion model LISEM is parametrized for a small catchment in the Central Spanish Pyrenees using detailed soil and vegetation data with a high spatial resolution as well as climate data.
- The aim of the study is to examine the influence of different spatial parameterizations on the model results.
- For the spatial parameterization of the vegetation dependent parameters two different vegetation maps are used for comparison of the results.
- The spatial and temporal pattern of overland-flow generation processes are assessed by means of small plot-scale rainfall experiments in the field, the gained data is used for model validation.
- For validation of the simulated results, first of all gauge data on runoff and suspended sediment load are used.
- Furthermore, the spatial pattern of simulated soil erosion processes can be analysed and compared to field mappings.

Study Area

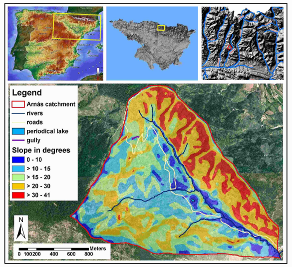

Fig. 1: Map of the study area Arnas

- Flysch-Zone of the Central Spanish Pyrenees
- 900-1340 m a.s.l.
- catchment area: 284 ha
- annual precipitation: approx.1000 mm
- mean annual temperature: 10°C
- negative water balance in summer
- agricultural use abandoned since 60 years
- soils on the steep slopes severely degraded by soil erosion
- nowadays: used extesively as pasture for cattle, sheep and goats
- vegetation: shrub formations (matorral) Genista scorpius, Buxus sempervirens, and in the highest areas also Echinospartum horridum

Methods

1) Small portable rainfall simulator:

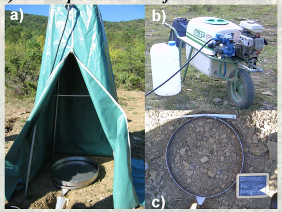

Fig. 2: Main parts of the rainfall simulator.

a) Aluminium linkage for the adjustment of the nozzle 2m above ground
b) motor driven pump with 100 l water tank
c) test plot bounded by a steel ring with 60cm diameter, plot area: 0.283m²

- simulated rainfall intensity: 40 mm h^{-1}
- duration: 30 minutes
- runoff with suspended sediments gathered
- recorded plot characteristics: surface cover with vegetation or stones, surface roughness, antecedent soil moisture

2) Mapping Methods

Field mapping

- soil mapping
- mapping of geomorphodynamics (e.g. intensity of rill erosion)
- geomorphological mapping (DVWK, 1996)

GIS mapping

- supervised classification of an aerial photograph using GRASS GIS
- digitalization of the field mappings in ArcGIS 9.1

Methods

2) Process-based soil erosion model LISEM (Roo et al., 1996; Jetten, 2002)

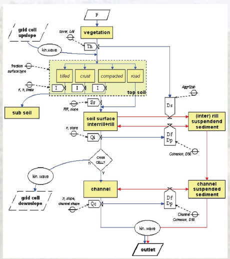

Fig. 3: Flow Chart LISEM (Jetten, 2002; p. 6)

- the process-based **LI**mburg **S**oil **E**rosion **M**odel (LISEM) includes the processes rainfall, interception, infiltration, vertical movement of water in the soil, overland flow, splash and flow detatchment and transport capacity
- the model is completely integrated into a raster-GIS (PC-Raster)
- most important calibration parameters:
  - ksat (saturated hydraulic conductivity)
  - Manning n (surface resistance to flow)
  - rr (random roughness => micro relief)
  - thetai (initial volumetric soil moisture content)
  - thetas (saturated volumetric soil moisture content)

Results

Spatial parameterization for the soil dependent parameters

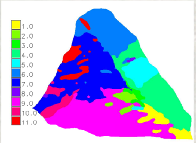

Fig. 4: Classes of the soil map

Tab. 1: Table with the parameter values attributed to the classes of the soil map

Soil_ID	KSAT1	THETAS	PWP	Soildepth	PSI	D50	Soil_Type
0	1	2	3	4	5	6	
1	7	0.5976	0.2492	600	27	32.5	Stagnic Regosol
2	8	0.5154	0.1435	1000	27	32.5	Gleyic Calcisol
3	15	0.5976	0.2492	1300	27	32.5	Stagnic Luvisol
4	10	0.5180	0.1740	600	27	32.5	Haplic Regosol
5	8	0.5963	0.1720	650	27	32.5	Leptic Regosol
6	15	0.5607	0.2001	600	27	32.5	Orthicalcic Regosol
7	38	0.5564	0.2039	900	27	32.5	Luvic/Orthicalcic Regosol
8	10	0.5286	0.2483	600	27	32.5	Mollic Regosol
9	42	0.6045	0.2548	800	27	32.5	Calcic Cambisol
10	47	0.6178	0.2105	900	27	32.5	Calcaric Cambisol
11	14	0.5766	0.1809	900	27	32.5	Luvic Calcisol

Spatial parameterization for the vegetation dependent parameters

1st spatial parameterization: landcover map

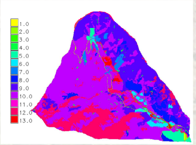

Fig. 5: Classes of the landcover map

Tab. 2: Table with the parameter values attributed to the classes of the landcover map (1st spatial parameterization)

SCS_COVER	LU ID	N Manning	LAI	crop height	Veg. cover	random rough.	rock frag. cov.	aggregate stab.	COHADD	cohesion
	0	1	2	3	4	5	6	7	8	9
Lots	1	0,030	0,0	0,00	0,0	3,98	0,0	100	1	100
Farmstead	2	0,030	0,0	0,00	0,0	3,98	0,2	15	1	20
Aluvial deposit	3	0,030	0,0	0,00	0,0	3,98	0,2	15	1	20
Bare soil	4	0,030	0,0	0,00	0,0	3,98	0,6	15	1	20
Meadow	5	0,035	1,0	0,10	0,8	4,22	0,4	50	4	25
Pasture Fair	6	0,035	1,0	0,10	0,8	4,22	0,6	50	4	25
Pasture Good	7	0,035	1,0	0,15	0,9	4,22	0,6	55	5	25
Brush Poor	8	0,040	1,5	0,40	0,6	4,43	0,8	50	2	30
Brush Fair	9	0,050	2,0	0,50	0,8	4,81	0,8	55	3	30
Brush Good	10	0,075	2,5	0,60	0,9	5,60	0,6	60	3	30
Wood Fair	11	0,110	3,0	2,00	0,8	6,45	0,8	70	6	40
Wood Good	12	0,150	4,0	5,00	0,9	7,24	0,6	80	6	40
Wood-grass Good	13	0,150	4,0	3,00	0,9	7,24	0,6	80	6	40

2nd spatial parameterization: classified aerial photograph map

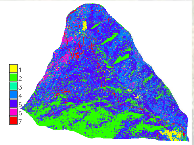

Fig. 6: Classes of the aerial photograph map

Tab. 3: Table with the parameter values attributed to the classes of the classified aerial photograph map (2nd spatial parameterization)

class arn2008	LU ID	N Manning	LAI	crop height	Veg. cover	random rough.	rock frag. cov.	aggregate stab.	COHADD	cohesion
	0	1	2	3	4	5	6	7	8	9
pasture	1	0.07	1	0.1	0.8	4.22	0.6	40	4	25
forest	2	0.3	4	4	0.9	7.24	0.6	70	6	40
buildings	3	0.06	0.0001	0.0001	0.0001	3.98	0.01	100	100	100
shrub fair	4	0.1	2	0.5	0.7	4.81	0.8	50	2.5	30
shrub dense	5	0.15	2.5	0.6	0.9	5.60	0.6	55	3	30
cussion shrub	6	0.18	2.5	0.3	0.9	5.99	0.6	55	3	30
bare soil	7	0.06	0.0001	0.0001	0.0001	3.98	0.3	15	0	20

Results

Tab. 4: Table with the parameter values 1st spatial parameterization

run	ksat	n	thetas	thetai	Peak discharge [l s^{-1}]	Total discharge [m³]	Total soil loss [t]
3	0.75	1	1	1	1804	2770	189.9
4	0.75	1	0.8	1.2	4867	6082	487.6
5	0.75	2	0.8	1.2	2496	5455	400.1
6	0.75	1.5	0.8	1.2	3346	5735	444.6
7	0.6	2	0.8	1.2	3745	7429	588.0
8	0.6	1.8	0.8	1.2	4135	7539	606.2

Tab. 5: Table with the parameter values 2nd spatial parameterization

run	ksat	n	thetas	thetai	Peak discharge [l s^{-1}]	Total discharge [m³]	Total soil loss [t]
7	0.75	2	1	1	519	1684	49.6
8	0.5	2	1	1	1764	4248	228.9
9	0.5	1	1	1	3607	4924	330.3
10	0.75	1	0.8	1	2997	4261	266.2
11	0.75	1	0.8	1.2	3932	5308	361.3
12	0.75	2	0.8	1.2	1921	4627	257.8
13	0.6	2	0.8	1.2	3048	6568	436.5
14	0.5	2	0.8	1.2	4085	8293	604.5
15	0.55	2	0.8	1.2	3528	7366	513.1

Tab. 6: Table with the measured characteristics of the modelled rainfall runoff event

Rainfall runoff event September 7th 2003	Peak discharge [l s^{-1}]	Total discharge [m³]	Total soil loss [t]
	4169	7863	27.2

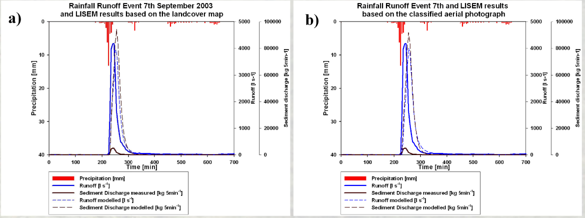

Fig. 7: runoff and sediment discharge for two modell runs
a) 1st spatial parameterization
b) 2nd spatial parameterization

Results Summary

- with the presented parameter sets it was either possible to gain a good result for the runoff or for soil erosion.
- the runs with good representation of runoff over-estimated the sediment discharge by the factor of 20
- the runs with a good representation of sediment discharge under-estimated the runoff by the factor 8
- The two different spatial parameterizations show similar results concerning spatial pattern of soil erosion.
- The high erosion rates on the steep south-faced slopes matches well to the erosion mapping.

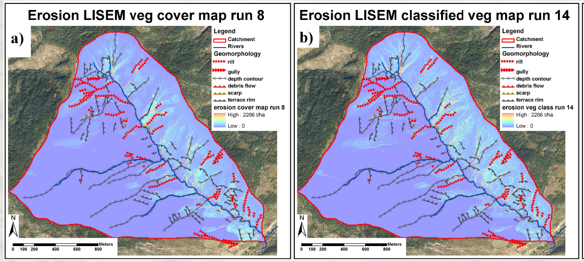

Fig. 8: LISEM Erosion maps
a) 1st spatial parameterization
b) 2nd spatial parameterization

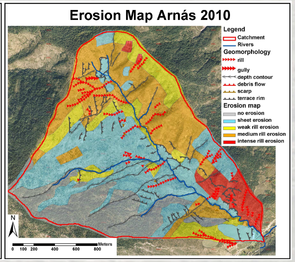

Fig. 9: Field mapping of soil erosion prosesses and intensity

Conclusions

- The modelled hydrological response of the catchment (Peak discharge, total discharge, time of the runoff peak, form of the hydrograph) match very well to the measured rainfall runoff event.
- The modelled spatial pattern of soil erosion seems plausible and matches to mappings, at least for the steep slope.
- The modelled erosion values are all far to high with the present parameterization.
- In order to improve the results concerning erosion, new parameterizations based on the rainfall experiments will be carried out for the parameters cohesion and aggregate stability.

Literature

Jetten, V. (2002), LISEM User manual, version 2.x., Utrecht University, The Netherlands.

Roo, A. P. J. D., C. G. Wesseling, and C. J. Ritsema (1996), LISEM: A single-event physically-based hydrological and soil erosion model for drainage basins. I: Theory, input and output, Hydrological Processes, 10(8), 1107-1117, doi:10.1002/(SICI)1099-1085(199608)10:8<1107::AID-HYP415>3.0.CO;2-4.

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