Influence of soil characteristics and earthworm activity on the hydrological response of Alpine pasture sites to precipitation events

Gertraud Meißl [a], Clemens Geitner [a,c], Romed Ruggenthaler [a], Alexandra Mätzler [b], Markus Tusch [a] and Erwin Meyer [b]

a Institute of Geography, University of Innsbruck, Austria; Gertraud.Meissl@uibk.ac.at; b Institute of Ecology, University of Innsbruck, Austria c Mountain Research: Man and Environment, Austrian Academy of Sciences, Innsbruck, Austria

1 BACKGROUND AND OBJECTIVE

The response of small catchments (< 10 km²) to intense precipitation is strongly controlled by the spatial properties (geology, soil, vegetation, land use) of the contributing subareas. Especially soil characteristics – which are among others influenced by the abundance and biomass of earthworms – can play a crucial role for the runoff response of sites. The objective of this study is to elucidate the influence of soil characteristics and biological activity on the hydrological response to precipitation events in Alpine pastures. The study was carried out in a typical small Alpine catchment of medium altitude (Brixenbachtal in the Kitzbüheler Alps, Tyrol, Austria, 9 km², 800-2000 m a.s.l.) in the greywacke zone which is dominated by shale, porphyroids, and partly also by dolomites. Main types of land use are forest and seasonal pasture management.

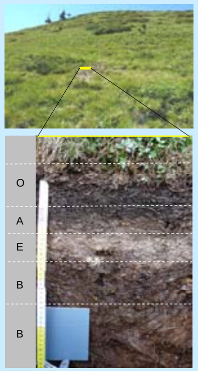
2 METHODS

Soil characteristics were surveyed by pedological field work at 31 soil profile pits and auger drillings on approximately 70 sites. Additionally standard pedological properties (bulk density, skeleton content, sand content, organic matter content, carbonate content, pH value, C/N ratio) were analysed in the laboratory.
Earthworm populations were determined by collecting soil samples and Kempson extraction, Thielemann's electrical octet method and hand sorting.
Hydrological reaction of the sites to precipitation events, i.e. the dominant runoff process (DRP), was determined by using the decision schemes of Scherrer & Naef (2003) and Scherrer (2006) under consideration of vegetation mapping, soil moisture measurements, double ring infiltrometer measurements, and sprinkling experiments with a small rainfall simulator.

3 CHARACTERISTICS OF TWO REPRESENTATIVE INVESTIGATED SITES

SITE 9: PODSOL on siliceous talus material/partially moraine, oligotrophic pasture with mat grass (nardus stricta) and dwarf shrubs

1680 m a.s.l., slope 22°, aspect SSE



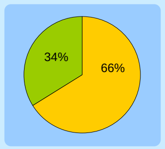
Soil characteristics of the upper horizons   Organic layer: 6-8 cm

horizon	depth (cm)	skeleton content (%)	sand content (%)	organic matter content (%)	carbonate content (%)	pH value	C/N ratio
A	0-4	5	32	31	0	3,4	14
E	4-12	15	40	6	0	3,3	-

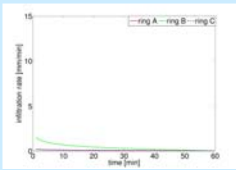
Earthworm population

biomass 9 g/m² - abundance 125 ind./m²

Life-forms (biomass in %)



Hydrological characteristics



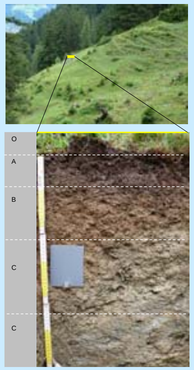
measured with double ring infiltrometers (17-08-2009); soil moisture content at the beginning of the infiltration in 10 cm soil depth: 48 vol.%

Fast subsurface flow (SSF1) in the duff layer after intense precipitation (thunderstorm) on 02-07-2008. Hortonian Overland flow (HOF) was observed near to the site at the same time.

Dominant runoff process: HOF/SSF1

SITE 10: CAMBISOL on siliceous shale, oligotrophic pasture with mat grass (nardus stricta)

1280 m a.s.l., slope 30°, aspect WNW



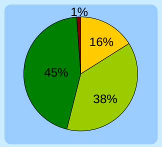
Soil characteristics of the upper horizons   Organic layer: 0-2 cm

horizon	depth (cm)	skeleton content (%)	sand content (%)	organic matter content (%)	carbonate content (%)	pH value	C/N ratio
A	0-10	45	52	11,0	0	5,3	11,0
B	10-25	45	59	4,1	0	4,7	9,4

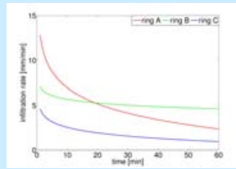
Earthworm population

biomass 20,6 g/m² - abundance 163 ind./m²

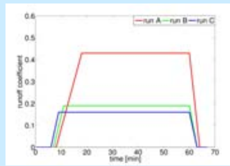
Life-forms (biomass in %)



Hydrological characteristics



measured with double ring infiltrometers (13-08-2009); Soil moisture content at the beginning of the infiltration in 10 cm soil depth: 31 vol.%



measured with a 1 m²-rainfall simulator (26-07-2010); Soil moisture content at the beginning of the irrigation in 10 cm soil depth: 31 vol.%

Dominant runoff process: SSF2

4 RESULTS

Biological activity
Sites with the dominant runoff process Hortonian Overland Flow (HOF) according to the decision scheme of Scherrer (2006) show high proportions of epigeic earthworms which live in the organic layer and thus hardly influence the mineral soil. At site 2 hemiedaphic earthworms dominate which switch between epi- and endogeic dwellings depending on soil conditions.
At sites with Deep Percolation (DP) as the dominant runoff process the endogeic or anecic life forms are generally predominant. The endogeic and anecic life-forms have a positive effect on soil stabilization, ventilation and water retention capacity. Site 6 with high proportion of epigeics reflects a special situation: high skeleton content in the soil column and an extraordinary low bulk density (air holes beside the stones).

Tab. 1: Abundance [ind. m^{-2}] and biomass [g m^{-2}] of earthworms. DRP = dominant runoff process, HOF = Hortonian overland flow, SSF1 = fast subsurface flow, SSF2 =delayed subsurface flow, DP = deep percolation

		abundance	biomass	proportion of abundance/biomass [%]										
site	soil type	ind. m^{-2}	g m^{-2}	epigeic		hemiedaphic		endogeic		anecic		indetermined		DRP
2	dystric cambisol	139	9,65	14	6	69	80	17	14	0	0	0	0	HOF
5	dystric cambisol	213	4,10	93	91	5	8	0	0	0	0	2	1	HOF
7	gleysol	23	1,14	80	86	0	0	0	0	0	0	20	14	HOF
13	gleyic dystric cambisol	53	2,08	76	42	14	56	0	0	0	0	9	2	HOF
15	gleyic dystric cambisol	63	2,54	88	80	0	0	4	19	0	0	7	1	HOF
12	gleyic dystric cambisol	218	11,04	51	36	10	29	33	31	0	0	7	4	HOF
9	podsol	132	9,51	84	66	16	34	0	0	0	0	0	0	HOF/SSF1
10	gleyic cambisol	147	9,10	55	47	22	33	18	15	0	0	5	5	SSF2
1	cambisol	240	20,15	19	10	51	64	23	21	0	0	8	5	DP
6	cambisol	43	2,66	65	73	23	15	0	6	0	0	12	6	DP
11	rendzina	100	10,65	31	15	27	53	37	31	0	0	5	0	DP
24	rendzina	134	25,97	17	2	38	65	44	33	0	0	0	0	DP

Soil characteristics
Sites with the dominant runoff process HOF tend to be more compacted (e.g. by cattle trail) than other sites. According to the soil types it can be stated that podsolic cambisols and podsols tend to have a faster hydrological reaction than cambisols and rendzinas.
No interdependency could be found between grain size and dominant runoff process. However, at most of the investigated sites vegetation cover plays a decisive role for its hydrological reaction.

5 CONCLUSION

Interdependencies between soil characteristics and activity of earthworms respectively and the hydrological reaction on the sites are obviously existent but only weak. High surface flow rates result from a combination of different interacting factors such as the soil characteristics and soil formation processes (e.g. gleysation, podsolisation), vegetation type and dead organic matter imbricatively arranged, a dense root felt on some pastures as well as low earthworm abundance and biomass consisting of epigeic life-forms.

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