Hydrological dynamics can be described in terms of water sources, flowpaths, solute transport and water ages. Reliable predictions of water quantity and quality at unsampled sites or under changing environmental conditions need a profound understanding of the underlying processes controls.

Vegetation is known to be a principal, but in both space and time highly variable driver of these dynamics. Not only the hydrological response, but also the time-variant water ages are expected to differ among contrasting vegetation covers. In order to identify effects of vegetation on hydrological dynamics, other controlling variables must be eliminated.

We thus studied this in a hillslope hydrometric observation network, that was intended for the intercomparison approach. Our aim is to map hillslope dynamics of shallow water tables, subsurface flow and solute transport in the field and replicate the experimental observations with the hillslope model HIBM.

Introduction

Hydrological response under different vegetation covers

Study site and instrumentation

Large-scale monitoring and intercomparison network

Objective: Assessing the influence of vegetation cover on shallow water tables and subsurface flow dynamics and associated spatiotemporal variability

Three adjacent hillslopes:

- Shallow groundwater wells
- Topography (slope, aspect)
- Vegetation type

Different vegetation cover:

- Grassland with green (150 m²)
- Grassland with white (150 m²)
- Coniferous forest (150 m²)

Previous studies at the site revealed:

- High variability of water tables and subsurface flow response within the severally homogeneous hillslopes.
- Patterns of water table development/erosion differ between adjacent wells, transects and seasons.

Hillslope instrumentation

- 50 shallow groundwater wells
- Topography (slope, aspect)
- Vegetation type

Results

- Measured throughflow volumes and flow-rates vary over orders of magnitude throughout the year.
- Water table heights and throughflow are strongly influenced by rainfall events.
- E C data of both throughflow and near-surface groundwater show marked responses to rainfall events.

The double box plot shows increased chloride export by the stream during the rainy season, despite no corresponding increases in throughflow EC.

Conclusions

- Chloride recovery in throughflow was practically not noticeable.
- Hillslope transmissivity connectivities provide a deep (>10 m²) and shallow (<2 m²) flowpaths.
- Shallow subsurface flow is probably not restricted solely to the basal layer and shallow soil horizons may significantly contribute to the observed throughflow dynamics.
- Model results show moderate to good agreement for throughflow data. However, groundwater level dynamics are not sufficiently reproduced.
- Simulated water ages of storages and fluxes are highly variable in time.

Current process knowledge about the study site is not yet sufficient to isolate and assess the influence of contrasting vegetation covers. For more reliable results several hillslopes of each vegetation type must be monitored.

Model experiment

Hilf IVI model

- Easily digitized
- Fully physically based
- Wind/hydrogen and thermal convection
- Solar/precipitation

- Variable hillslope fluxes (variability ranges from season to season)
- Experimental hydraulic conductivity with soil depth
- Variable heads of depth to base layer (holding water)

Results (100 best parameter estimations)

Outlook: Time-variant residence and transit time estimations

The stochastic transport model of HIBM was modified to allow for spatially and temporally variable transport parameters (akin to the 2D-3D model). Such modifications allow for the estimation of residence times and transit times and the spatial variability of storage and flow paths, a fundamental output of hillslope hydrological processes. This will allow for the investigation of the influence of vegetation cover on hillslope hydrological processes.

Although the simulated hillslope models may not represent vegetation effects, the findings on hillslope water ages and transit times have the potential to be useful for further analysis. By this virtual experiment we expect further insight into the key controls of water age dynamics at the hillslope scale.