Vegetation Dynamics

Vegetation dynamics plays a vital role for the redistribution processes of water and soil resources. However, many current modelling approaches for water, sediment and nutrient transport neglect the reproduction of vegetation dynamics. This poster reviews the importance of vegetation dynamics at different spatial and temporal scales and investigates its implementation in current hydrological and erosion models. For this purpose, two case studies are presented that signify the importance of the representation of vegetation dynamics in hydrological and erosion models. Finally, the poster discusses and develops future research objectives and ideas of how to include ecohydrological processes at the micro- and meso-scale in process-based, spatially distributed modelling frameworks to increase the predictive ability of models in water research.

Significance

Vegetation dynamics and associated parameters such as type, mortality and growth, cover, LAI, root depth, canopy height, albedo etc. interact with hydrological and soil erosion models in manifold ways and at different scales:

- **Plot-scale to hillslope models:**
  - **SCALE:** Plant-plant and patch dynamics
  - **PROCESS:** Spatial layout of individual plants influences routing of overland flow, accumulation and usage of soil resources, nr-vegetation cycling and mortality of individual plants

- **Catchment-scale models:**
  - **SCALE:** Assemble of multiple patches and mosaics defined by distinct vegetation types with topographic features
  - **PROCESS:** Seasonal changes of natural or agricultural vegetation and land-use management become dominant for the generation of river runoff and flood events, groundwater interaction and micro-climate

- **Regional to global scale models:**
  - **SCALE:** Large-scale landscapes derived within a genetic bioclimatic zone
  - **PROCESS:** Impact of regional and global climate change and large-scale land-use changes due to national or international policies

The missing link

Major deficiencies are apparent, as shown by the two case studies, if the feedback mechanisms between vegetation dynamics and transport processes of water and soil resources are not accounted for in a modelling framework. For the linking of vegetation dynamics to hydrological and soil-erosion process modelling, often called ecohydrological modelling, two major working areas can be identified (Boud 2003):

- Intra-inter-event interactions: Hydrologists focus on phenomena that occur during events, whereas the ecologists tend to focus on inter-event conditions and longer-term averages.

- Dimensionality approaches: Ecohydrologists tend to develop vertical conceptual models of exchanges of matter and energy between the atmosphere, biosphere and atmosphere, whereas hydrologists tend to develop 0-D conceptual models, but often restricted to the geosphere.

An improved model representation of ecohydrological processes is expected to advance in three core areas of environmental research:

1) Man-induced changes of natural vegetation
2) Extreme land-use changes (e.g. the increased production of bio-energy)
3) Control and prevention of soil erosion

References

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The importance of vegetation dynamics: The missing link in hydrological and soil resource modelling

Case study 1: Macro-scale modelling

**Background**

Desertification in the south-western part of the United States has led to a significant vegetation change from productive grassland to desert scrubland within the last 150 years, mainly due to excessive overgrazing. Overland flow generated by high-intensity rainstorms has been suggested as having an important role in the degradation processes through the redistribution of water and soil resources.

**Connectivity approach**

Spatially distributed, process-based models for water, sediment and nutrient fluxes were parameterised by using a connectivity approach that intrinsically represented the pattern formation of spatial input parameters such as friction factor, infiltration and nutrient content in the soil related to the patchiness of vegetation in the form of individual shrub mosaics.

**Fluxes across boundaries**

Fluxes of transport agents and nutrient were calculated across vegetation boundaries of grasslands and shrublands of a typical desert environment in the Jornada Basin, New Mexico (Figure 3). Modeling results for water and nutrient fluxes are depicted in Figure 4.

Result 1: Fluxes from shrubland into grassland lead to a gain of water resources, but a loss of nutrient resources in the grassland areas close to the boundary.

Result 2: Fluxes from grassland into shrubland do not lead to a gain of water resources, but to an increase of nutrient resources for shrubland areas close to the boundary.

**Novel hypothesis**

It is hypothesised that a vegetation boundary is stable when two conditions prevail that balance the lower resistance of grassland towards the existing environmental setting with the higher resistance of shrubland. First, the soil depletion of nutrients by the action of overland flow in the grassland zone close to the boundary is in balance with the replenishment rates of grassland by nutrient cycling. Second, the grassland gains enough water resources from the upland shrublands. On the contrary, a vegetation boundary potentially becomes unstable when the grassland acquires a competitive disadvantage towards shrubland regarding water benefit and nutrient depletion due to the combined effects of overland flow dynamics and some external stresses.

To test this stability hypothesis, the implementation of vegetation dynamics in the current modelling framework requires substantial development to include inter-storm dynamics of nutrient cycling and dynamic adjustment of hydrological and soil parameters as a function of shrub propagation.

Case study 2: Meso-scale modelling

**Background**

The sedimentation of reservoirs as a results of soil erosion in the upland catchments of drylands such as Spain or Brazil threatens the water availability for drinking-water supply, irrigation and power generation. The SESAM (Sediment Export from Semi-Arid Model) is a process-based, multi-scale, hierarchical approach for landscape discretisation on spatial scales ranging from the soil profile scale, soil-vegetation components and terrain components up to the scale of landscape units and river basins.

**Vegetation dynamics in model**

In the WASA models vegetation dynamics interact with the calculation of evapotranspiration and soil moisture following a seasonal interpolation of vegetation parameters as a function of beginning and end of the rainy and dry seasons (interception coefficient, height, depth, albedo, soil moisture potential and stomatal resistance).

**Sensitivity**

A sensitivity analysis of the incorporated vegetation dynamics by Güntner (2002, Figure 6) showed that large deviations occur for the parameters canopy height, root depth, stomata resistance and albedo. An increase of root depth by a factor of 2 e.g. leads to a runoff reduction of up to 30 %, whereas a decrease of the stomata resistance results in an increase of up to 30 %. Low sensitivity to runoff simulations were found for all other parameters.

**Scenario 1: Badlands**

Badlands in the Pre-Pyrenees of Spain are hilltops of unconsolidated sediments with no or little vegetation cover that are characterized by extremely high soil erosion rates thus causing severe sedimentation in downslope reservoirs. The impact and efficiency of vegetation buffer zones for strategic locations at select-ed hillslope transition zones will be studied with an extended WASA model.

**Scenario 2: Restorestation**

Since 1940 intensive reforestation has occurred to control the hydrologic and geomorphic processes of slope erosion over large areas of the Pre-Pyrenees. The effects of this extensive land-use change on the hydrological cycle and sediment transfer is being studied.

**Scenario 3: Intensive land-use**

The semi-arid NE of Brazil is characterised by a severe shortage of water and food availability. Degraded areas, where high agricultural practices are not carried out in a sustainable manner, leading to severe soil degradation and the desertification of land.