Geophysical Research Abstracts
Vol. 15, EGU2013-8795, 2013
EGU General Assembly 2013

Bog discharge from different viewpoints: comparison of Ingram's theory with observations from an Estonian raised bog

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Raised bogs are typically dome shaped and have a groundwater level located close to the soil surface. Besides their typical dome shape, these peatlands are often characterized by a pronounced surface topography consisting of pools, wet depressions (hollows), stretches of Sphagnum species (lawns), drier mounds (hummocks) and higher drier areas with terrestrial vegetation (ridges). These peat bodies drain laterally by gravity to adjacent areas with lower groundwater levels. The integrity of these bogs is only ascertained when water is stored in the peat body in periods of precipitation deficit and efficiently removed in wet periods. This is realized by the fact that the bog's top layer, often called acrotelm, has a variable hydraulic conductivity. In response to precipitation its hydraulic conductivity increases, whereas, under evaporative demand the water table lowers and therefore also the hydraulic conductivity decreases.

Ingram proposed a model based on the Dupuit-Forchheimer approximation for Darcy's law that assumes vertical flow is negligible, and the slope of the water table is equal to the hydraulic gradient.

$$\frac{U}{K} = \frac{Hm^2}{L^2} \tag{1}$$

where U is net recharge (P-ET), K is horizontal hydraulic conductivity, Hm is hydraulic head above a flat bottom at the centre of the bog, L is half the width of the bog along the cross section. This model incorporates the assumption that all net rainfall reaching the water table will be discharged to the stream.

Ingram's model does not consider local heterogeneities in surface topography, like pool-ridge patterns. We hypothesize that under drier conditions it is likely that pool-ridge patterning will inhibit water from flowing along the surface gradient. Under wet conditions, however, pools can become connected and water can move through the upper highly permeable layer of ridges. In this study, we investigated the influence of ridge-pool patterning on the horizontal water flow through a raised bog and compared it with Ingram's approach.

Our study site was Mannikjarve, a raised bog located centrally in Estonia and part of the larger Endla Nature Reserve. The size of the bog is approximately 2 km^2. Mannikjarve is characterized by a surface pattern of different microtopes consisting of ridge-pool, hollow-ridge, hummock-hollow, Sphagnum lawn, and margin forest.

We created a flow-net based on the raised bogs surface elevation. This flow-net defines the direction of lateral flow in the acrotelm. Based on the flow-net we divided the bog into sub-catchments representing the area contributing to discharge at the outlets of the bog. The measured discharge was used in a double mass analysis to calculate discharge ratio's. We assume that changes in discharge ratio's can be relate to changes in contributing area as a result of variable water flow paths. Furthermore, we compared the measured discharges with calculated discharge according to Ingram's model.

Based on several reasonable estimates for input parameters, the observed discharges cannot be reproduced with the Ingram model. Furthermore, discharge ratio's between different sub-catchments within the peatland appear to be not constant over time, thus suggesting a shift in water divides that depends on atmospheric events.