Hydrological Responses to Anthropogenic Disturbance in Peatlands: a Numerical Approach

Meseret Walle Menberu[1], Anna-Kaisa Ronkanen[1], Hannu Marttila[1], Ali Torabi Haghighi[1], Bjørn Kløve[1]

[1]Water, Energy and Environmental Engineering Research Unit , University of Oulu, Finland

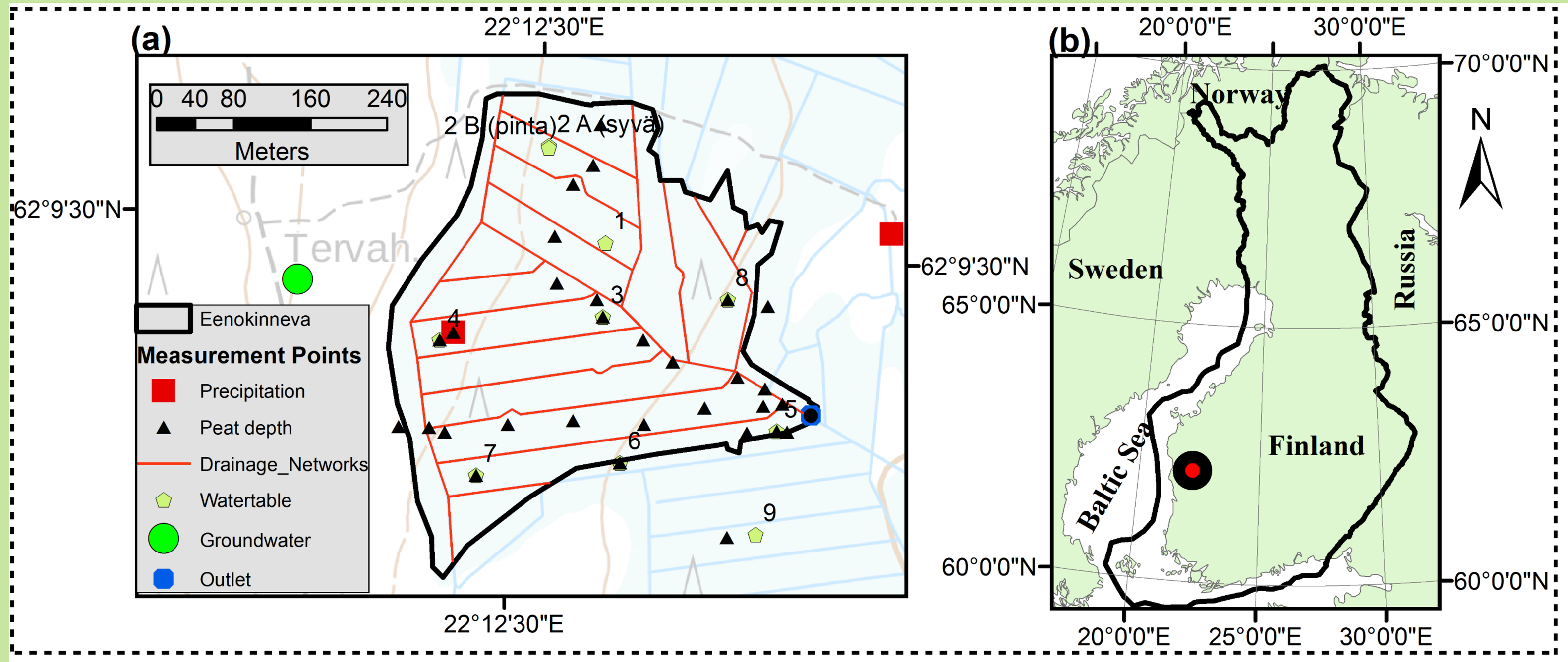
1. BACKGROUND

Globally, peatlands are used for a variety of purposes. Peatlands in undisturbed conditions provide substantial ecosystem services by regulating the hydrological functions, ecological and biogeochemical processes; hence are essential habitats for unique biodiversity. However, about 14-20% of the total peatland area (56-80 million ha) has been disturbed for a variety of human use which modified the structure and function of peatlands. For this study, the hydrology of previously drained, now restored peatland catchment has been monitored and studied using numerical and empirical techniques.

2. OBJECTIVES

- To study the effect of drainage and subsequent peatland restoration on:
  - Runoff dynamics
  - Catchment-scale water storage capacities and dynamics
  - Spatial water tale depth variations

3. Study site



(a) The Eenokinneva peatland catchment study boundary, drainage networks and hydrological monitoring set up, (b) location of the study site in Finland

4. METHODS

The study was carried out at the Eenokinneva peatland catchment (about 11.4 ha) located in Western Finland. High temporal resolution (1-hour interval) WT depth data in the peat layer at 10 locations (see Figure a, above) were collected by installing a standpipe well of length 1-2 m and diameter 32 mm perforated from tip to center of the pipe. Continuous runoff at the catchment outlet was measured using a 90° V-notch. High temporal resolution rainfall (1-hour interval) data was collected using automated tipping bucket rain gauges at two locations.

Runoff monitoring V-notch weir at the study site

4.1 Numerical methods

The HydroGeoSphere, a three dimensional fully integrated surface-subsurface hydrological modelling code (Aquanty, 2015) was used to solve the hydrology of the Eenokinneva peatland catchment under drained and restored conditions.

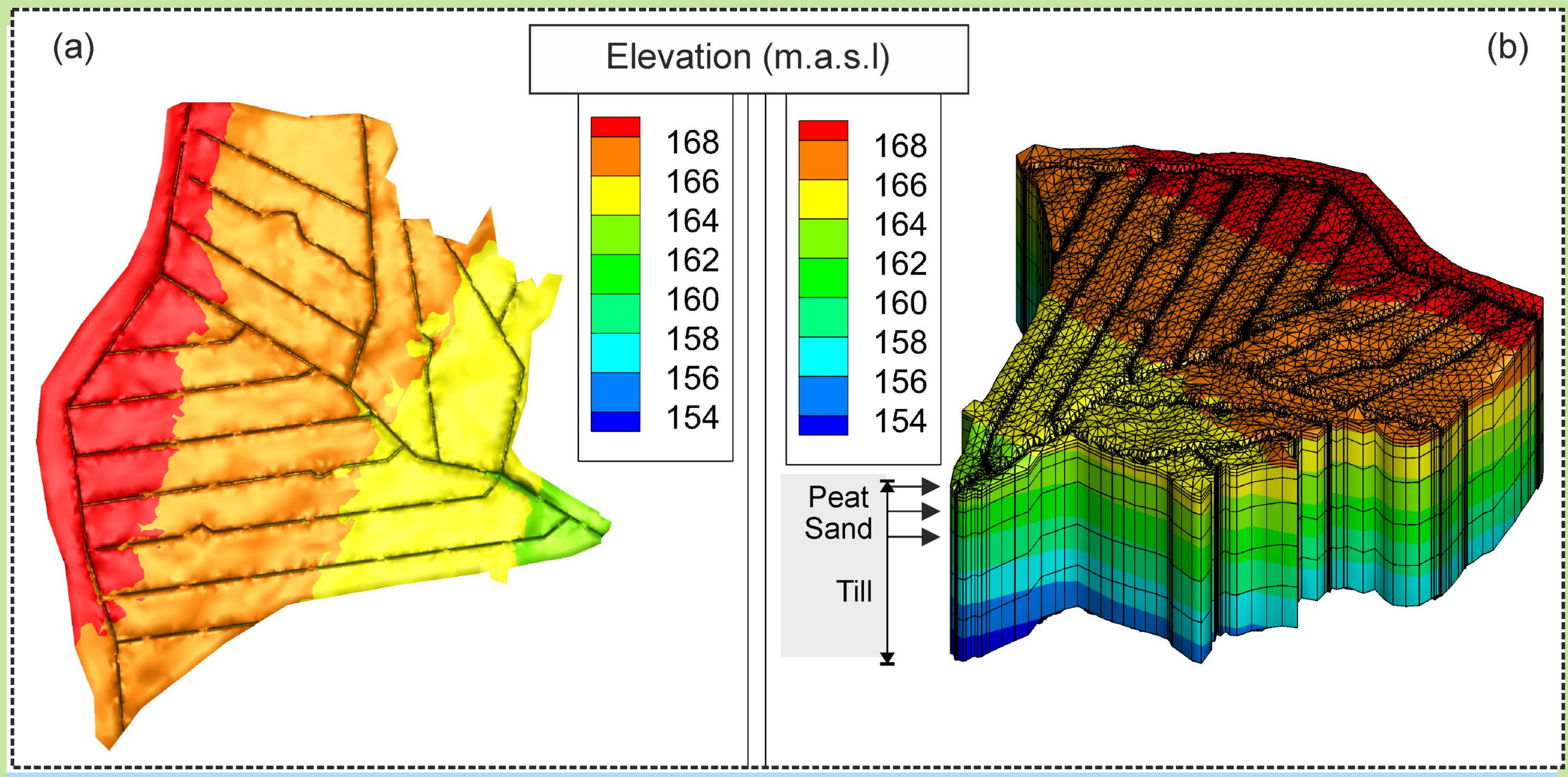
Surface domain:

- 2-D triangular mesh generated using a 2x2 m grid size DEM, and refined along the drains and, peat soil and mineral soil transition, and along higher surface slopes.

Subsurface domain:

- The 2-D mesh replicated in the third dimension from ground-surface to the bedrock (Bedrock depth estimated from Geological data ~ 10.2m and verified by the GPR data obtained in the field)
- Peat depth (field data) – average depth of 1.1 m used
- A detailed channel geometry (V-shaped drainage channels) defined (depth about 1m and width 1.5m)
- To mimic the site condition after restoration, several dams (width of dam 5 to 10 m and distance between dams about 40 m) across the drainage networks were created by modifying the elevation of the longitudinal profile of each drainage channel using Tecplot software

- The model domain (see Figure below) contained seven vertical finite element layers (146744 nodes, 255206 elements), in which each finite element has triangular prismatic-shape with 6-nodes
- The HydroGeoSphere uses the 2-D depth-averaged diffusion-wave approximation of the Saint Venant equation to solve the surface flow and Richard's equation to solve the saturated/unsaturated subsurface flow
- In the bottom of the model domain (bedrock surface), a no flow boundary condition was assigned, specified head boundary condition around the perimeter of the porous media domain and critical depth boundary condition around the perimeter of the surface domain was assigned
- Firstly, the model was run into a steady state using effective annual rainfall amount of 315 mm to get an initial condition for spin-up (transient spin-up runoff) model and then run the spin-up model to get representative initial conditions for the actual model run



(a) Overland flow domain showing drainage netwoks, (b) Finite element mesh configuration of the study site

5. PRELIMINARY RESULTS

- **Empirical techniques:**

The difference of the mean amplitude of water table fluctuation (AWTF) before and after restoration at each measuring location was not significantly different, except for well_9, which is located outside of catchment area. Except at well_2B, well_5 and well_6, the mean AWTF after restoration for the rest of WT measuring locations was slightly higher than before restoration. However, analysis of the aggregated water table of all measuring locations revealed that the mean AWTF before restoration was slightly higher (but not significant) than the after restoration.

- **Numerical techniques:**

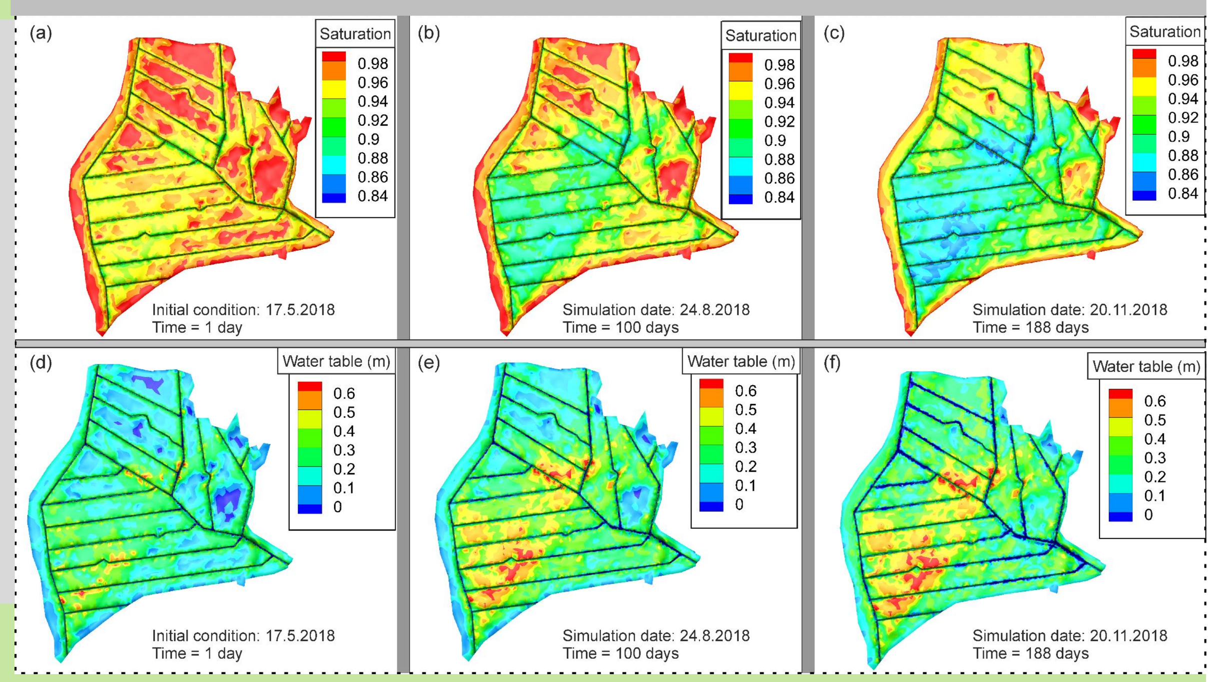
The three-dimensional distributed hydrologic model (HydroGeoSphere) generated significantly higher runoff amount under drained conditions than simulated under restored conditions in all of the three different summer rainfall situations. This was clearly shown by the significantly large effect size index calculated for each year (Cohen's d = 0.95 for 2016; Cohen's d = 2.43 for 2017, Cohen's d = 2.51 for 2018). The effect is small, medium, and large when Cohen's d is between 0 and 0.20, 0.20 and 0.50, and greater than 0.50, respectively. Furthermore, restoration moved the water table closer to the ground surface significantly (Cohen's d = 1.04 for 2016; Cohen's d = 2.73 for 2017, Cohen's d = 2.14 for 2018) than the water table level simulated under drained conditions.

➢ **Spatiotemporal variability in water table depth and degree of saturation**

The spatiotemporal variability in water table depth and degree of saturation showed clear hydrological differences between drained and restored conditions (see Figure below)

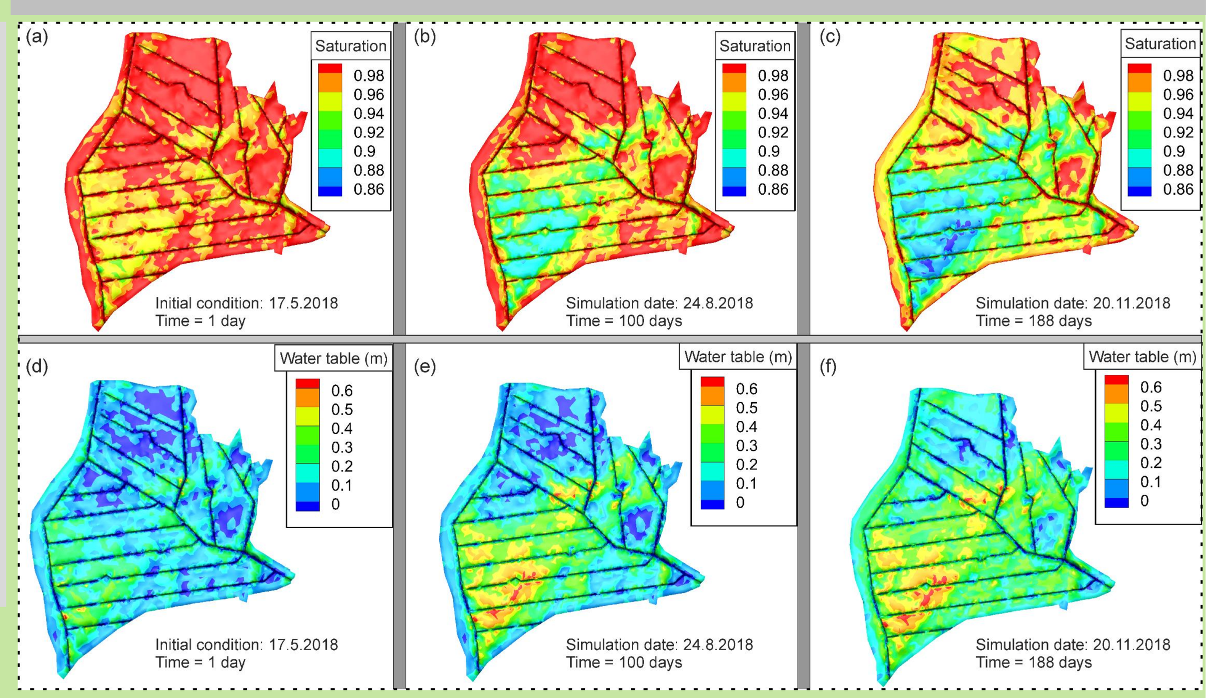
Model simulated under drained model conditions

Degree of saturation (top row) and water table depth (bottom row) showing model outputs for drained condition in 2018: (a, d) for the first day of simulation (day 1), (b, e) 100 days after start of simulation, and (c, f) 188 days after start of simulation



Model simulated under restored model conditions

Degree of saturation (top row) and water table depth (bottom row) showing model outputs for restored condition in 2018: (a, d) for the first day of simulation (day 1), (b, e) 100 days after start of simulation, and (c, f) 188 days after start of simulation



WATER, ENERGY AND ENVIRONMENTAL ENGINEERING RESEARCH UNIT

UNIVERSITY OF OULU

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