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CAN TREE STAND WATER USE COMPENSATE FOR MAINTENANCE OF DITCH NETWORKS IN PEATLANDS? IMPLICATIONS FROM WATER BALANCE MEASUREMENTS

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SUMMARY

We estimated evapotranspiration of forest vegetation during the growing seasons of 2007-2011 based on hydrological measurements in four forested artificial peatland catchments (isolated from the surroundings by double-ditching). The catchments were dominated by Scots pine (*Pinus sylvestris* L.) with growing stand volumes between 93 and 151 m^3 ha^{-1} and were located under different climatic conditions either in southern, western, central, or northern Finland.
The estimated growing season evapotranspiration varied between 49-161% of the total precipitation sum (155-368 mm), decreased from south to north, and was highest in July or August.
The results showed that in the studied forests, a significant part of total precipitation during growing season is lost back to atmosphere by forest evapotranspiration, especially in southern and western Finland. Under these conditions, stand water use dominates the water balance, and no management of the drainage network is needed to maintain favourable drainage conditions for the tree stand growth.

KEYWORDS: peatland, drainage, *Pinus sylvestris*, evapotranspiration, runoff

INTRODUCTION

In Finland, drained peatland forests (5.7 M ha) comprise about 25% of the total forest area, and also 25% of the total annual growth of all forests. Nowadays the focus in drainage operations is on the maintenance of the existing ditch networks (DNM) and ditch cleanings and complementary ditchings are annually carried out on about 80 000 ha. DNM operations enhance the release of nutrients and suspended solids and DNM is currently regarded as the most harmful forestry operation from the viewpoint of water quality protection (Finér et al. 2010). DNM is also an additional management cost that contributes to the overall financial profitability of peatland forestry (Ahtikoski *et al.* 2008). In sites, where the DNM is expected to have only a marginal contribution to the stand growth and productivity, DNM operations should be avoided.

At present, the criterion for the timing of DNM is based mainly on the technical condition of the ditch network. Ditch network maintenance has been shown to lower the water table by 5-10 cm on average (Ahti & Päivänen 1997) and increase runoff at least temporarily (Ahti 1987). However, the technical condition of ditches does not directly indicate whether tree growth would be improved by DNM. In highly stocked stands, where the evapotranspiration (EVT) of forest stand is an important factor controlling the soil water conditions (Grelle *et al.* 1997), the hydrological responses to DNM treatments have been observed to be small or non-existent (Koivusalo *et al.* 2008)..

Earlier observations indicate that the water use potential of forest stand significantly influences the water balance of drained peatland sites (Dube *et al.* 1995, Ahti and Hökkä 2006, Jutras *et al.* 2006, Koivusalo *et al.* 2008, Sarkkola *et al.* 2010). Better understanding of EVT potential by the tree stand is a prerequisite for the development of DNM criteria guidelines for operational peatland forestry.

The aim of the study was to determine the growing season water balance components in drained peatland forests in order to estimate the role of forest stand water use in maintaining drainage conditions.. The study was carried out as water balance and water flux measurements in small artificial forested catchments located in drained peatlands in different climatic areas in Finland. We hypothesize that evapotranspiration is the dominating component of the water balance in stocked tree stands during the growing season and is one of the key-criteria when assessing the necessity to improve drainage conditions by DNM.

MATERIALS AND METHODS

We estimated evapotranspiration of forest vegetation during the growing season (June - September) based on hydrological measurements in four thick-peated drained Scots pine (*Pinus sylvestris* L.) stands in southern, western, central, and northern Finland (Table 1). The sites were of the dwarf-shrub site type (Vasander and Laine 2008) and the dominant understorey vegetation species were *Ledum palustre*, *Vaccinium uliginosum* and *V. vitis-idaea*. The condition of the drainage ditches was either poor due to extensive vegetation occupation or then the water level in the ditch network was kept high by damming so that according to the present guidelines in operational forestry, all for sites would have been in need for DNM during the monitoring period.

For water balance estimation, runoff (R) and water table level (WTL) were monitored with data loggers (TruTrack WT-HR500) for five years (2007-2011). Precipitation (P) was measured at a weather station close to the study area and the change in water storage (ΔS) in peat was estimated by utilizing the measured water table level data and the site specific water retention curves (pF) determined from the peat samples collected from each site. Forest EVT during the growing season was determined as the difference between precipitation and the sum of R and S as in the following:

$$EVT = P - R - \Delta S \quad (1)$$

Table 1. Site, stand, and climate parameters of the peatland water balance experimental sites in Southern (Tuusula), Central (Vilppula), Western (Kannus) and Northern Finland (Rovaniemi).

Experiment	Rovaniemi	Kannus	Vilppula	Tuusula
N-coordinate	66° 27.3'	63° 52.4'	62° 3.1'	60° 27.4'
E-coordinate	26° 44.1'	24° 19.1'	24° 29.0'	24° 57.2'
Area, ha	0.3	2.5	0.9	2.4
Mean temp., ^{o}C (1971-2000)	0	2.8	3.5	4.9
Mean precip, mm (1971-2000)	537	500	601	650
Mean temp. sum 1951-1985 (d.d.,>5^{o}C)	870	1100	1190	1276
Stand volume in 2007, m^3 ha^{-1}	93	110	151	140
Ditch spacing	30	40	100	30
Mean Precipitation 2007-2011(*	268	305	240	247
Mean Runoff 2007-2011(*	117	76	76	15

(* June-September

Additionally, the tree-level transpiration during the summer time (June-August) was measured with Granier type (Granier 1985) sapflow sensors installed in five to eight sapflow sample trees in two of the four catchment experiments (Vilppula and Rovaniemi) Sap flow velocity was measured at 10 min intervals and recorded by data loggers. Based on sapwood area sample trees, the measured sap flow rates were then up-scaled to quantify the tree stand transpiration for the entire catchment area. Due to failures in sap flow measurements, we utilised the sapflow data only from two summer periods in Vilppula (2010 and 2011).

RESULTS

The estimated growing season (June-September) EVT varied annually between 42-161% of the total precipitation sum (155-368 mm) and decreased from south to north (Figure 1). The overall mean EVT as % of P during the five-year study period was about 122% in the southernmost catchment, and for the northernmost catchment, 58% (Figure 2). EVT was highest in July or August. The proportion of runoff (R) as % of total P varied between 6-44%, being smallest in the southernmost site.

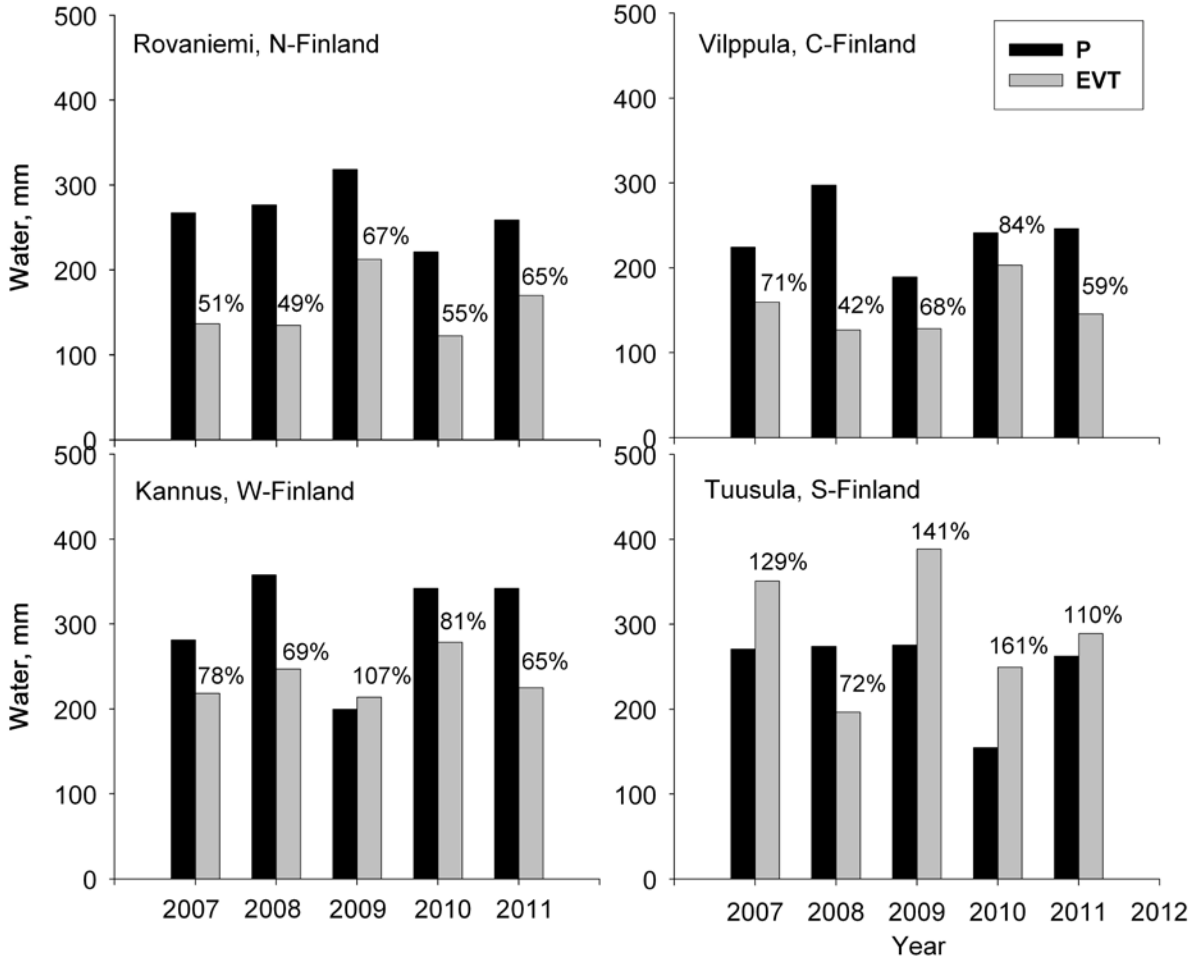

Fig. 1. Evapotranspiration (EVT) and total precipitation (P) during June-September in years 2007-2011 in the studied experimental Scots pine stands.

According to the sap flow measurements, the annual summertime transpiration of the Scots pine stand was 18-22 mm in northern Finland and 90-105 mm in central Finland. In both sites, the proportion of the tree stand transpiration was 42-50% of the total vegetation EVT. (Table 2)

Although the climatic conditions largely regulated the variation in EVT between the experiments, a significant part of the variability was related to the differences in the stand volume and its transpiration demand

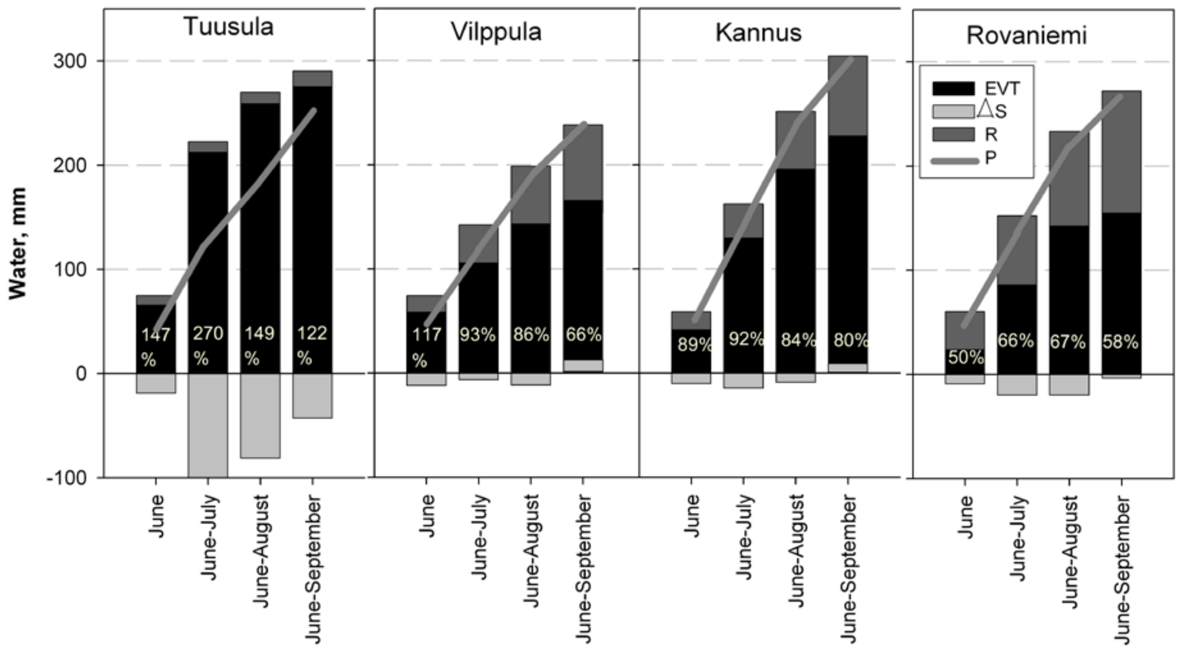

Fig. 2. The cumulative evapotranspiration (EVT), runoff (R), and total precipitation (P) in June-September (average, 2007-2011) in the studied experimental Scots pine stands, and the change of soil water storage during each period (ΔS). The percentages show the proportion of EVT from total P during each period.

Table 2. Total evapotranspiration (EVT) and forest stand transpiration (T) in summer time (June-August) in the water balance experimental sites in central (Vilppula) and northern Finland (Rovaniemi).

	Year	EVT mm	T mm	T/EVT %
Rovaniemi	2007	43.7	21.8	50
	2008	42.8	18.0	42
	2009			
	2010	41.4	19.3	47
	2011	51.1	21.4	42
Vilppula	2010	230.4	105.1	46
	2011	179.4	89.3	50

DISCUSSION

The water balance analyses showed that the total EVT was about half of the total precipitation during the growing season in north of Finland and the second largest water balance component was runoff. In southern conditions, EVT during growing season even exceeded precipitation and runoff was considerably smaller.

Both the total EVT and tree stand transpiration decreased towards cooler northern conditions, and the role of the ditch network (runoff) in controlling drainage conditions becomes more significant. However, the proportion of tree stand transpiration was about half of the total

EVT in both central and northern Finland. This is basically in line with the other studies from boreal forests, but the proportion of tree stand transpiration was lower in our peatland sites than for the forests growing on mineral soil sites (e.g. Grelle *et al.* 1997). It is possible, that in our sites, the EVT of the surface vegetation consisting of abundant and vigorous dwarf shrubs is higher than surface vegetation EVT in mineral soil sites. Depending on the leaf area and the density of the overstorey tree stands, the EVT of the surface vegetation in the boreal forests has been reported to vary between 10-60% of the total EVT (ref. Iida *et al.* 2009).

The results showed that in the studied peatland forests the water use by the tree stand dominated the growing season water balance. No drainage network management would be necessary for sustaining satisfactory drainage conditions for trees at least in the studied sites in southern and western Finland, where the stand volumes were about 100 m^3 ha^{-1} or larger and a large proportion of total precipitation was lost to atmosphere by forest evapotranspiration. In northern Finland, the site drainage conditions are largely regulated by runoff and ditch network maintenance operation may be necessary, where the drainage ditches have lost their water conduction capacity.

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