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Water table rise after harvesting in a treed fen previously drained for forestry

Sylvain Jutras & André P. Plamondon

Sylvain Jutras, Forest Biology Research Centre, Université Laval, Sainte-Foy, QC G1K 7P4, Canada (e-mail: sylvain.jutras.1@ulaval.ca)
André P. Plamondon, Forest Biology Research Centre, Université Laval, Sainte-Foy, QC G1K 7P4, Canada (e-mail: andre.plamondon@sbf.ulaval.ca)

Water table measurements were obtained in a treed fen that was drained in 1987 and harvested for timber in 1997. The water table level was quantified at five different distances from the ditch for three ditch spacing. Water table levels were compared between pre-drainage, post-drainage and post-removal of the canopy. The phenomenon of watering-up after clear-cutting did not occur where a drawdown of at least 10 cm was caused by the drainage. This lowering was observed across the 20 m ditch spacing and within the first 6 m from the ditch, in the 40 and the 60 m spacing. The water table fluctuations were also reduced after harvesting.

Keywords: forested peatland, forest drainage, water table level, black spruce.

Introduction

Water table rise, also called watering-up, has been observed on undrained forested peatlands in Canada after timber harvesting (Dubé et al. 1995, Roy et al. 1997, Roy et al. 2000b). Observations of watering-up have also been made after harvesting in forested peatlands previously drained in Finland (Heikurainen & Päivänen 1970, Päivänen 1980). Drainage on recently harvested sites is known to reduce watering-up (Prévost et al. 2001), to avoid further paludification, to improve rooting zone conditions (Roy et al. 2000a), and to improve seedling growth (Jutras et al. 2002). Vompersky & Sirin (1997) and Braekke (1983) found that the water table level in a drained peatland was largely dependent on the distance from the ditch and drainage intensity. However, these two factors have not been studied when drainage occurred several years before harvesting.

The objective of this study was to quantify the effect of harvesting on the water table level at five different distances from a ditch (3, 6, 10, 20 and 30m) for three different ditch spacing (20, 40 and 60 m width) in an old stagnant black spruce stand drained 10 years before clearcutting.

Material and methods

The study was carried out on property owned by Stadacona Paper Inc, located 50 km southwest of Quebec City, Quebec Canada, (46°27'N, 71°23'W). Based on data collected at the St-Flavien meteorological station located 10 km from the study site (46°29'N, 71°34'W), the thirty-year mean annual precipitation is 1125 mm (Environment Canada 2004). For this same period, the mean annual temperature is 3.9°C and the mean annual degree-days above 5°C is 1674. Potential evapotranspiration is 550 mm based on Thornthwaite's method (Wilson 1971)

This project evaluated two sites. They were located 270 m apart in a stand dominated by black spruce (*Picea mariana* (Mill.) B.S.P.). Other tree species that were present were larch (*Larix laricina* (Du Roi) K. Koch), balsam fir (*Abies balsamea* (Mill.)) and red maple (*Acer rubrum* L.). *Nemopanthus mucronatus* (L.) Trel., *Kalmia angustifolia* L. and *Ledum groenlandicum* Retz. dominated the shrub layer. On both sites the degree of humification of the *Sphagnum* peat layer increased with depth, ranging from a Von Post 7 at 10 cm to a Von Post 10 at 60 cm. On the drained site, this humified peat lay over a 20 cm layer of slightly less decomposed *Carex spp*. The underlying fine textured mineral soil of both sites was originating from the post-glacial Champlain Sea. Table 1 presents stand and peat characteristics of both sites.

The control site was left undrained and non-harvested during the study. The treated site was drained in April 1987 by digging five parallel parabolically-shaped ditches, 1 m deep, at 20, 40 and 60 m spacing, respectively (Fig. 1). The water was discharged through a roadside ditch. The drained site was harvested ten years later (January 1997) on frozen ground thereby protecting the regeneration and the soil. The trees were felled with chain saw and transported with a grapple skidder. The estimated harvested merchantable volume was approximately 60 m³ ha⁻¹.

Table 1: Mean peat and stand characteristics of the study areas (control and drained sites) before treatment.

Taulukko 1: keskimääräisiä turpeen ominaisuuksia ja puustotunnuksia tutkimusalueella (ojitettu alue ja ojittamaton vertailuala) ennen kuivatusta.

	Peat		Stand		
Treatment	Thickness (m)	pH	Age (year)	Diameter (cm)	Height (m)
Control	0.45	3.5	48	11.1	11.2
Drained	1.00	3.3	94	11.0	11.7

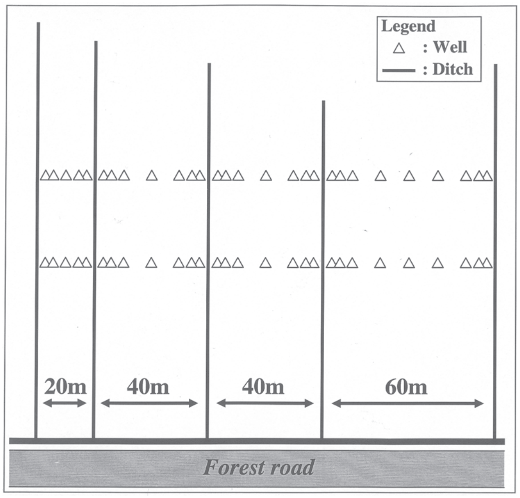

Fig. 1: Drainage and sampling design of the water table level on treated site on the study area.

Kuva 1. Ojien ja pohjaveden mittauskaivojen sijainti tutkimusalueella

Water table level was measured in individual wells that were constructed from plastic tubes (20 mm inner-diameter) perforated at the base with 5 mm diameter holes and inserted 1 to 1.5 m into the soil. Two rows of wells were located 20 m apart and parallel to the roadside ditch. Tubes within each row were located at 3, 6, 10, 20 and 30 m from each ditch, where spacing permitted (Fig. 1). The wells were visibly identified on site and mapped in order to replace them in case of damage during harvesting. The depth of the water table level was measured using a home-made electrical buzzer probe that signalled contact with water. Prior to any treatment, water table level was measured from September 15th to November 1st in 1986 on both sites. Following the drainage, measurements were made during the growing season, normally from the beginning of May to the end of October. This was done twice weekly from 1987 to 1989 and once weekly until 2000 except in 1991, 1992 and 1995 when no measurements were taken. In 1999 measurements were done bi-weekly. The elevation of the well above the peat was measured every year so that the water table level was referenced to the peat surface.

Pre-drainage water table levels were used by Belleau et al. (1992) to produce a calibration curve

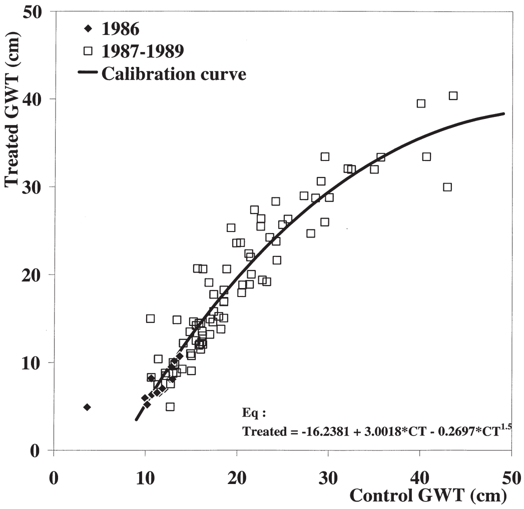

Fig. 2: Calibration curve of the water table level (GWT) for the treated site without drainage effect and the water table of the control site. Treated water table from 1986 was collected before drainage. From 1987 to 1989, it was collected after drainage in the 60 m spacing, from the well located at 30 m from the closest ditch.

Kuva 2. Pohjaveden pinnan tason (GWT) kalibrointikäyrä tutkittavalle ojitusalueelle ennen ojitusta sekä havainnot luonnontilaisen vertailualueen pohjaveden pinnan tasosta. Ojitusta edeltävä pohjaveden pinnan taso mitattiin vuonna 1986. Ojituksen jälkeen pohjaveden pinnan tasoa seurattiin vuosina 1987–1989, jolloin mittaukset tehtiin 60 m:n levyiseltä saralta 30 m:n etäisyydeltä ojasta .

for this same study area. It was used to take into account the differences in water table fluctuations and tree stand characteristics naturally occurring between the control and the treated sites. However, the curve had to be adjusted for deeper water table levels because it was relatively high during the period the calibration of 1986. At the centre of the 60 m spacing, the water table drawdown caused by drainage was negligible. Therefore, the 1987 to 1989 summer data from this location was used to establish a new calibration curve (Fig. 2). This curve was later used to predict the water table level for the treated site if no treatment was applied (PWTno) using the water table level of the control site. The possible bias caused by this calculation would give a slight underestimation of the drainage effects. However, it had no effect on the comparison of water table levels before and after harvesting.

Correlation of repeated observations of the same wells was evaluated in a random parameter regression model analysing the water table level following drainage and clearcutting. This statistical design was similar to Hökkä et al. (2000). Fixed variables included the following: predicted water table level if no treatment was applied (covariate), distance to the closest ditch (3, 6, 10, 20 and 30 m), spacing between ditches (20, 40, 60 m), and period of observation (drained: 1987–1996 and harvested: 1997–2000). Random variables were: direction to the closest ditch, row number, well number, year within a period and date of measure. The complete model was tested so that all possible interactions between the four fixed variables were included. Statistical analyses were done with the MIXED procedure of the SAS/STAT software, Version 8.2 of the SAS System for Windows (SAS 1999).

Results and Discussion

The model tested showed a significant difference ($p = 0.0012$) for the highest interaction which included all of the four fixed variables. This interaction has been illustrated separately for each of the three spacing (Fig. 3).

The first period of observation (1987–1996) was used to evaluate the water table fluctuations following drainage. The water table at 3 m from the ditch was lower for each of the spacing. The lowering of the water table at 6, 10 and 20 m from the ditch decreased as the spacing between ditches increased (Fig. 3). The high degree of decomposition of the peat below 10 cm reduced the hydraulic conductivity (Plamondon & Belleau 1991) and consequently the water table lowering away from the ditch.

The second period of observation (1997–2000) was used to indicate watering-up following timber harvest. To do this, we compared the predicted water table of this second period to the calibration curve. Watering-up was not observed within the 20 m spacing (Fig. 3). For the 40 and the 60 m spacing, no watering-up was observed at 3 m from the ditch while at 6 m from the ditch, the water table was close to the calibration curve. At 10, 20 and 30 m from the ditch, watering-up

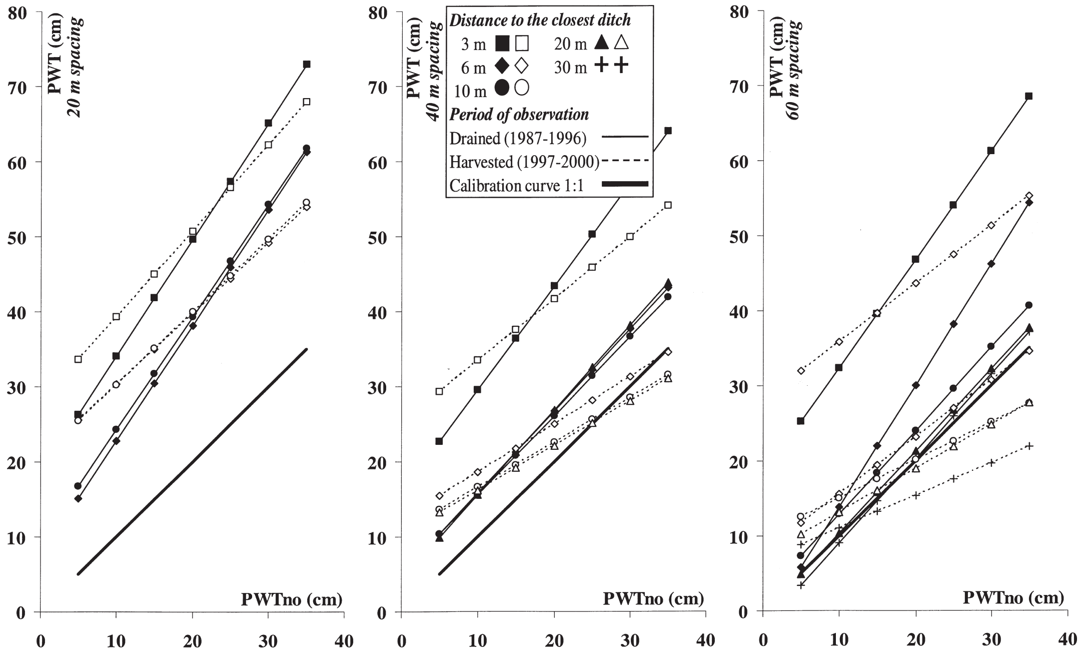

Fig. 3: Predicted water table level (PWT) following drainage and timber harvesting of a forested peatland site in function of ditch spacing, distance to the closest ditch, period of observation and predicted water table level if no treatment was applied (PWTno).

Kuva 3. Ennustettu suon pohjaveden pinnan taso (PWT) ojituksen ja hakkuun jälkeen. Selittävinä muuttujina sarkaleveys, etäisyys lähimmästä ojasta, seurantajakso ja ennustettu pohjaveden pinnan taso ilman käsittelyjä (PWTno)

was observed mostly during dry episodes (low predicted water table if no treatment was applied) and it was more important for the 60 m spacing than the 40 m spacing. These results were similar to Heikurainen & Päivänen (1970) and Päivänen (1980) who observed significant watering-up after the clearcutting of drained peatlands, for ditch spacing of 50 m and 70 m.

Fluctuations of the water table were more important for the first period of observation than for the second period of observation (Fig. 3). Reduced water table fluctuations were also observed after the harvesting of drained stands in Finland (Heikurainen & Päivänen 1970, Päivänen 1980).

When drainage was able to lower the water table level by more than 10 cm, watering-up did not occur and the variability of the water table fluctuation was reduced. Watering-up was evident in locations where drainage was inefficient. The most problematic drainage patterns were found at distances more than 6 m from the ditch in the 40 and 60 m spacings. To enhance regeneration and growth conditions, drawdown by drainage should ideally be over 10 cm to compensate the subsequent watering-up due to harvesting. The significant water table drawdown caused by drainage and the reduced water table fluctuation caused by harvesting within the 20 m ditch spacing would create the most favourable tree growth conditions on the study site.

Every measurement location within the 20m spacing offered a constantly lower water table than the situation where no treatment was applied, even after clearcutting. Prescribing a drainage network that lowers the water table by at least 10 cm throughout the whole spacing should be the best way to reduce the impact of the watering-up after harvesting. Furthermore, this prescription needs to be adapted to individual peatland soil and stand characteristics. The origin, the nature and the state of decomposition of the organic mater, as well as the amount of biomass removed from the site are important factors that might have an effect on the magnitude of the watering-up after harvesting.

Conclusions

This study quantified the water table level at 5 different distances from a ditch for three different ditch spacing in an old stagnant black spruce stand growing on highly decomposed *Sphagnum* peat that was drained 10 years before clearcutting. The amount that the water table rose following clearcutting was different depending on the distance from the drainage ditch and the space between ditches. Watering-up occurred when drainage was unable to lower the water table level by more than 10 cm. When drainage was able to lower the water table level by 10 cm and more, watering-up did not occur and the variability of the water table fluctuation was reduced.

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Tiivistelmä:

Vedenpinnan nousu avohakkuun jälkeen ojitetulla puustoisella suolla

Avohakkuun vaikutusta ojitusalueen pohjavedenpinnan tasoon tutkittiin mustakuusivaltaisella (*Picea mariana* (Mill.) B.S.P.) suolla Quebecissä Kanadassa. Koejärjestelyyn sisältyi sekä ojittamaton ja hakkaamaton vertailualue että ojitusalue, jossa vertailtiin kolmea eri sarkaleveyttä (20 m, 40 m ja 60 m). Ojitus tehtiin vuonna 1987 ja puuston poisto suoritettiin vuonna 1997. Pohjavedenpinnan taso mitattiin viideltä eri etäisyydeltä ojasta. Hakkuunjälkeistä pohjavedenpinnan tasoa vertailtiin sekä ennen hakkuuta että ennen ojitusta vallinneeseen tilanteeseen. Tulokset osoittivat, että suon pohjavedenpinta ei noussut avohakkuun jälkeen merkittävästi, mikäli sitä oli saatu alennettua hakkuuta edeltävällä ojituksella vähintään 10 cm. Tämä riittävä kuivatusvaikutus aikaansaatiin koko saran leveydeltä, mikäli käytettiin 20 m:n sarkaleveyttä. Leveämmillä sarkaleveyksillä riittävä kuivatusvaikutus aikaansaatiin 6 m:n etäisyydellä ojan molemmin puolin. Pohjavedenpinnan vaihtelu pieneni myös hakkuun jälkeen.

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