Forest Sciences

Prince Rupert Forest Region

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Canopy Interception in a Hypermaritime Forest on the North Coast of British Columbia

Research Issue Groups:

Forest Biology
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Introduction

Canopy interception plays an important role in determining the amount of rainfall reaching the forest floor. During a rainfall event, water either penetrates the canopy falling directly to the understory of the forest floor, or is intercepted by the canopy. From there it can drip to the ground surface, flow down tree stems, or be held and evaporated. The portion that falls directly to the ground or drips from the canopy is termed throughfall. Rainfall that is intercepted and flows down the tree trunk is known as stemflow, and the remainder is called interception. The amount of rainfall intercepted by a forest canopy depends on storm size, intensity, duration, rainfall frequency, forest structure, tree species and architecture, tree age, tree density, and epiphytic growth such as moss and lichens (Crockford and Richardson 1990; Calder 1998; Spittlehouse 1998). Depending on these conditions, canopy interception can account for 15 to 35% of annual rainfall.

The removal of the forest canopy in a wet environment will introduce more water to already saturated soils. Before any harvesting occurs it is important to know the role of the forest canopy in the water cycle and to determine the effects of this extra input of water. Potential effects of increased water include: larger peak water flows, decreased slope stability, road and streambank erosion, and damage to fish habitat (Spittlehouse 1998). The ecology of the site could also be affected; this includes a higher water table leading to regeneration problems, lower tree productivity, and paludification (peatland formation).

This research is part of the HyP^3 Project (Pattern, Process and Productivity in Hypermaritime Forests) initiated in the North Coast Forest District in 1997 to develop ecologically based guidelines for the management of lower productivity cedar-dominated forests on north coastal B.C. (see Extension Note 38, Banner and Shaw 1999 for project details). These forests are currently outside the operable land base.   At present there is considerable uncertainty regarding the feasibility and sustainability of harvesting these wet, slow growing forests. One of the goals of the research project is to document the ecology and hydrology of the blanket bog

– upland forest complex of the CWHvh2.

This extension note documents:

- interception, throughfall and stemflow as a percentage of total rainfall.
- interception, throughfall and stemflow in relation to weather conditions, storm size and storm intensity.
- the potential effects of changes in the interception rate due to harvesting.

Two locations were used as study areas, one in Diana Lake Provincial Park, 15 km southeast of Prince Rupert, and the second on Smith Island, 20 km south of Prince Rupert (Figure 1). The areas were selected as being representative of the forest type being studied. Both watersheds are located in the Coastal Western Hemlock biogeoclimatic zone, Very Wet Hypermaritime subzone – Central variant (CWHvh2); (Banner et al. 1993). Forests in the watersheds are comprised primarily of western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), yellow cedar (*Chamaecyparis nootkatensis*) and amabilis fir (*Abies amabilis*); shore pine (*Pinus contorta* var. *contorta*), mountain hemlock (*Tsuga mertensiana*) and Sitka spruce (*Picea sitchensis*) also occur. Instrumentation was located at 72 m elevation on a southeast facing slope at Diana Lake, and at 52 m on a northeast facing slope at Smith Island. Both canopy interception sites were representative of the 01 Western redcedar-Western hemlock-Salal site series (Banner et al. 1993).

Climate

At Prince Rupert airport (34 m elev.) mean daily temperature is 6.9°C (Environment Canada 1998). Mean daily temperature is 13.3°C during August, the warmest month, and 0.8°C during January, the coldest month. Mean annual precipitation is 2,552 mm, of which 94% is rain; on average there are 223 days per year with measurable rainfall. Mean annual snowfall is 152 cm and on average there are 29 days per year with measurable snowfall. Fog occurs on an average of 34 days per year, with a high number of days with fog per month in July (5 days), August (8 days) and September (7 days).

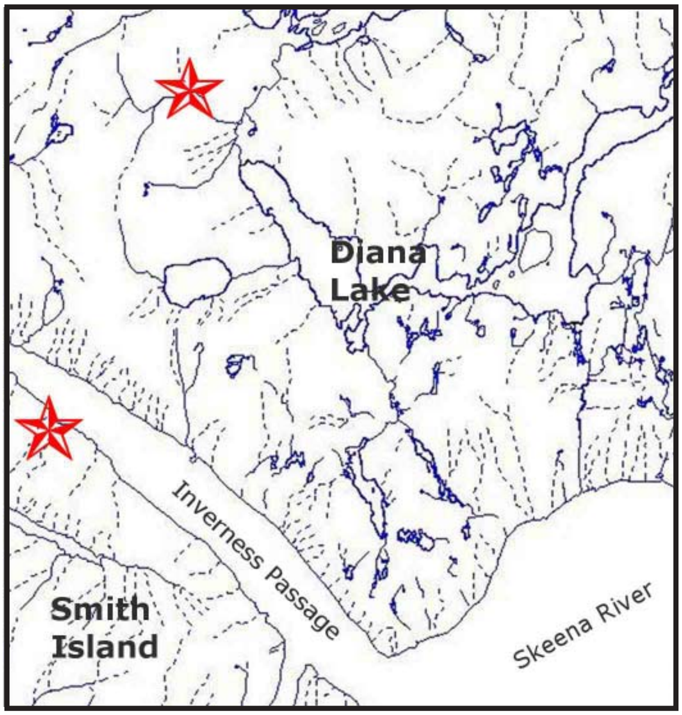

Figure 1. Location map of Diana Lake and Smith Island study sites.

Study Description

Stand characteristics were determined using standard prism (variable radius) cruise plots for stems over 7.5 cm DBH (Diameter Breast Height) and fixed area plots for stems under 7.5 cm DBH. Total rainfall for each site was recorded by a raingauge located in a nearby non-forested bog area. Ten throughfall units were located beneath the forest canopy at each site. Throughfall units consisted of a stainless steel trough (5 m long, 0.1 m wide, 0.1m deep, at an angle of 10° from the horizontal) that drained into a tipping bucket gauge recorder (Figure 2). The tipping bucket recorders were initially set up below five throughfall troughs at each site and then moved to the other five throughfall troughs.

Stemflow was measured on fifteen trees of various diameters, heights, and species at each site using a 10 mm wide collar that made one and a half turns around a tree at breast height. Tipping bucket recorders measured stemflow on two trees at each site, with stemflow on the remaining trees collected in manually emptied standpipes. The volume of water collected was converted to mm^3 and then multiplied by stand density (stems/ha) for that species, and divided by the area of a hectare to give stemflow in mm's (Spittlehouse 1998). Total stemflow was calculated as a weighted average of the stemflow for each size class for dead and living trees.

Canopy interception was calculated as the difference between

Figure 2. Throughfall measurement troughs located at Diana Lake.

incoming rainfall at the non-forested bog site and the amount of rainfall reaching the forest floor as throughfall and stemflow. Interception was calculated by rainfall event, assuming a constant stemflow of 1.2% at Smith Island and 0.8% at Diana Lake. Canopy closure measurements by hemispherical photography used three evenly spaced measurements over the length of each trough; these were averaged to determine the percent open sky above each trough.

For this study, stemflow, throughfall, and interception were calculated during the ice and snow-free months of May to November for each year. Throughfall and stemflow were first summarized on a monthly basis to estimate interception for the study period. Following this, throughfall, stemflow and interception were investigated as functions of individual rainfall events. A rainfall event or storm was defined as a period of rain separated by at least four rain-free hours from the next rain event.

Results and Discussion

Forest Stand Characteristics

The forest stands at the Smith Island and Diana Lake sites were 250 to 300 years old, comprised of many different species, and had total densities of 2614 and 4499 stems/ha respectively (Table 1). The number of stems per hectare was greater at Diana Lake than at Smith Island, with the main difference between stands being the number of small trees in both live and dead tree categories. The two study areas are very comparable in terms of the density of stems greater than 17.5 cm DBH (485 stems/ha at Smith Island and 498 stems/ha at Diana Lake). The average canopy closure was 91% at Diana Lake and 79% at Smith Island.

Over the combined ice-free monitoring periods (May to Nov. 1999 – 2001), 6521 mm of rain fell at Smith Island, while 6969 mm of rain fell at Diana Lake (Table 2). The differences in total rainfall and storm size at each site are related to topography and wind patterns (Maloney et al. 2002).

Stemflow

Stand stemflow as a percentage of total rainfall averaged approximately 1% at both Smith Island and Diana Lake (Table 2). Small differences in monthly stemflow

Table 1. Species composition of forest stands at the Smith Island and Diana Lake study sites.

	Smith Island					Diana Lake				
Tree Species	Stems/ha by DBH (cm) class				% of total	Stems/ha by DBH (cm) class				% of total
	<7.5	7.5-17.5	>17.5	Total		<7.5	7.5-17.5	>17.5	Total	
Western hemlock	1000	188.5	69.6	1258.1	48	1700	345.7	77.5	2123.2	47
Redcedar	300	131.2	200.9	632.1	24	200	34.8	224.9	459.7	10
Sitka spruce		22.8		22.8	1		483.6	1.4	485.0	11
Yellow cedar			58.3	58.3	2		29.9	62.0	91.9	2
Amabilis fir								18.5	18.5	0
Shore pine								5.5	5.5	0
Live useless			13.1	13.1	1		248.0		248.0	6
Total live	1300	342.5	341.9	1984.4	76	1900	1142.0	389.8	3431.8	76
Total dead	300	186.9	142.7	629.6	24	800	158.7	108.1	1066.8	24
Total	1600	529.4	484.6	2614.0		2700	1300.7	497.9	4498.6	

Table 2. Annual rainfall, throughfall, stemflow, and interception at Smith island and Diana Lake study sites for the May to November periods in 1999, 2000, and 2001.

	Smith Island				Diana Lake			
	Total rainfall (mm)	Canopy throughfall (mm)	Stemflow (mm)	Interception (mm)	Total rainfall (mm)	Canopy throughfall (mm)	Stemflow (mm)	Interception (mm)
1999	2133	1443	22.9	667[a]	2156	1673	17.6	465[a]
2000	1793	1345	21.0	427	1800	1429	15.5	356
2001	1659	1308	22.1	329	1873	1446	15.6	412
Ave	1862	1366	22.0	474	1943	1516	16.2	411
%		73.4	1.2	25.5		78.0	0.8	21.2

[a] – Location of throughfall troughs changed to 5 new locations for 2000 and 2001 to account for canopy variability.

are likely due to factors such as canopy state (dry or wet) and rainfall intensity and angle (Crockford and Richardson 2000).

Trees greater than 17.5 cm DBH produced a greater amount of stemflow than their proportion of the stand at both sites, with dead trees having the opposite result, although basal area of each tree class was not considered (Table 3). This reflects the relative amount of crown area available to intercept water by these two categories of trees. The results from the smaller trees classes are mixed, making interpretation difficult.

Although stemflow is a small component of forest hydrology, it plays an important role in directing water to tree roots. While the added water may not be important in the hypermaritime, stemflow may be enriched with nutrients from tree canopies and trunks. So although stemflow is a small component of total water input, it has been shown to have a larger effect on the quality of water entering the soil (Johnson 1990).

Interception

Average annual interception was 25% at Smith Island and 21% at Diana Lake (Table 2). These results are similar to Spittlehouse (1998) who found interception to be 30% for mature coastal hemlock forests on Vancouver Island, and Beaudry and Sagar (1995) who found interception to be 21.2% for a coastal cedar-hemlock forest 25 km north of Prince Rupert, BC. Interception was greater at the Smith Island site even though canopy closure was greater at Diana Lake.

Monthly interception at Smith Island ranged from 12.1% to 46.1%, and at Diana Lake from 15.1% to 39.3% (Table 4). Maximum interception was observed during the dry summer months, and minimum interception during the wettest months. During June 2001, a very dry month, interception at Smith Island was 46.1% of total rainfall, and at Diana Lake it was 39.3%. During the very wet October 2001 (>500 mm rainfall), 12.1% of rainfall was intercepted at Smith Island and 15.1% at Diana Lake.

For individual single rainfall events, interception varied from nearly zero to 100 per cent (Figure 3), with the variability due to the size, length, and intensity of the rainfall event, and timing relative to other events. Interception was found to decrease with both event intensity and event duration, especially for medium and long duration events (Table 5). Interception was lowest for events of long duration, regardless of intensity or canopy state. Interception was the greatest and stemflow and throughfall were the lowest during low intensity, short duration events regardless of the canopy saturation level. For short duration, low intensity events, interception was

Table 3. Production of stemflow by trees size class based on cruise data.

Tree Class	Smith Island			Diana Lake		
	# of sample trees	% of trees in class in stand	% of stemflow	# of sample trees	% of trees in class in stand	% of stemflow
DBH <7.5	3	50	52	4	42	35
DBH 7.5-17.5	2	13	1	3	26	33
DBH >17.5	8	13	30	5	9	20
Dead trees	4	24	17	3	23	12

Table 4. Maximum, minimum monthly interception as a percentage of rainfall at the Smith Island and Diana Lake study sites, from May to November months in 1999, 2000, and 2001.

	Smith Island			Diana Lake		
	Total rainfall (mm)	Interception (mm)	Interception (%)	Total rainfall (mm)	Interception (mm)	Interception (%)
Maximum	515.5	62.3	12.1	607.5	91.7	15.1
Minimum	60.5	27.9	46.1	73.5	28.9	39.3

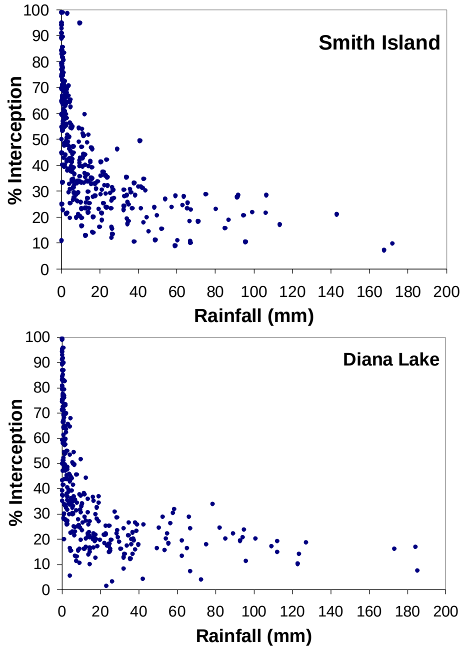

Figure 3. Interception as a percentage of rainfall, by rainfall event at Smith Island and Diana Lake.

roughly 62 - 70% at Smith Island and 69% at Diana Lake. For long duration, low intensity events, interception was roughly 30% at Smith Island and 22% at Diana Lake.

The wet or dry condition of the canopy prior to the event did not have a major affect on interception. In a dry canopy, throughfall begins shortly after the start of a storm event, while there was a delay in stemflow until the canopy was saturated.

Potential Management Implications

The amount of water received on the ground following harvest will increase because of decreased canopy interception. At the two study sites, the canopy intercepted between 20 and 25% of average annual rainfall (for the May to Nov. ice and snow free study period). Removal of the canopy will result in an increase in the amount of water that must be removed from the site through existing hydrological processes. The hydrological consequences of decreased interception following canopy removal could include: a decrease in time to peak stream flows after a storm, an increase in peakflow volume, an increase in water table height, and increased erosion as more overland flow may occur due to natural drainage pipes reaching capacity sooner. Although the increased erosion of organic soils after disturbance is possible, due to their high water retention and low cohesion, the relatively gentle slopes on which these low productivity forests occur will experience lower surface water runoff velocities and thus lower off-site sediment transport than steeper hillslopes.

The introduction of additional water to a drainage system can be problematic, however, use of the current watershed assessment procedures for road building and bridge engineering can provide adequate management solutions. By knowing the area of the harvested unit and the watershed's discharge characteristics, the increase in peakflow can be identified and considered in management plans.

Table 5. Rainfall interception sorted by canopy condition, event intensity and event length.

Canopy condition	Intensity (mm/hr)	Event length (hrs)	Smith Island		Diana Lake	
			n	Interception average (%)	n	Interception average (%)
Wet (<24 hrs without rain)	Low (<=mm/hr)	<5	117	62	78	69
		5 to 24	108	41	104	30
		>24	29	30	19	22
	High (>1mm/hr)	<5	6	37	4	28
		5 to 24	38	24	26	17
		>24	31	19	32	18
Dry (>24 hrs without rain)	Low (<=1mm/hr)	<5	45	70	20	69
		5 to 24	21	41	24	28
		>24	4	30	6	21
	High (>1mm/hr)	<5	0	-	2	43
		5 to 24	14	28	11	24
		>24	9	23	11	19

A rise in the water table, a process called 'watering up', has been shown to occur in other areas with forested wetlands following harvesting, especially where the water table is not already near the surface (Dubé et al. 1995). This process could lead to problems in regeneration establishment on the wetter soils. It may be possible to enhance regeneration using site preparation treatments such as soil mixing and mounding (Shaw and Banner 2001). Experience with mounding treatments on these sites has shown that it is important not to create large depressions beside each mound. These depressions can form pools that facilitate Sphagnum moss growth and paludification (Asada et al. 2002). If forest regeneration is successful, canopy interception will begin to increase again as trees grow and form a closed canopy. Although hydrologic recovery data from the hypermaritime north coast is very scarce, relatively fast growing New Zealand Radiata pine (*Pinus radiata*) plantations have been shown to return to preharvest runoff conditions within 10 years of replanting (Fahey and Jackson 1997).

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