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# The effect of *in situ* evaporation on perceived snow distribution in partially clear-cut forests

by

Robert H. Swanson[1]

## Introduction

The use of models to simulate the hydrologic response of partially forested watersheds is a becoming more commonplace. The U.S. Forest Service WRENSS procedure (Troendle and Leaf 1980), which is based on the WATBAL model (Leaf and Brink 1973) in snow dominated regions, is widely used in Canada and the western United States to estimate the effect of various clear-cutting practices on water available for streamflow. One of the key featur of WRENSS is a curve (Figure 1a) that describes the relationship between clear-cut dimensions and snow accumulation at maximum snowpack. The published curve was derived principa ly from Colorado and Wyoming data; we have confirmed the general shape of this curve in Alberta as well (Figure 1b). The curves of Figure 1 are used in WRENSS to apportion the sn data obtained from precipitation records to either clear-cuts or treed areas in a partiall harvested watershed. Since these curves are a reasonably accurate portrayal of the areal distribution of snow at the beginning of the melt season, the results obtained from WRENSS are a reasonably accurate estimate of water available for streamflow.

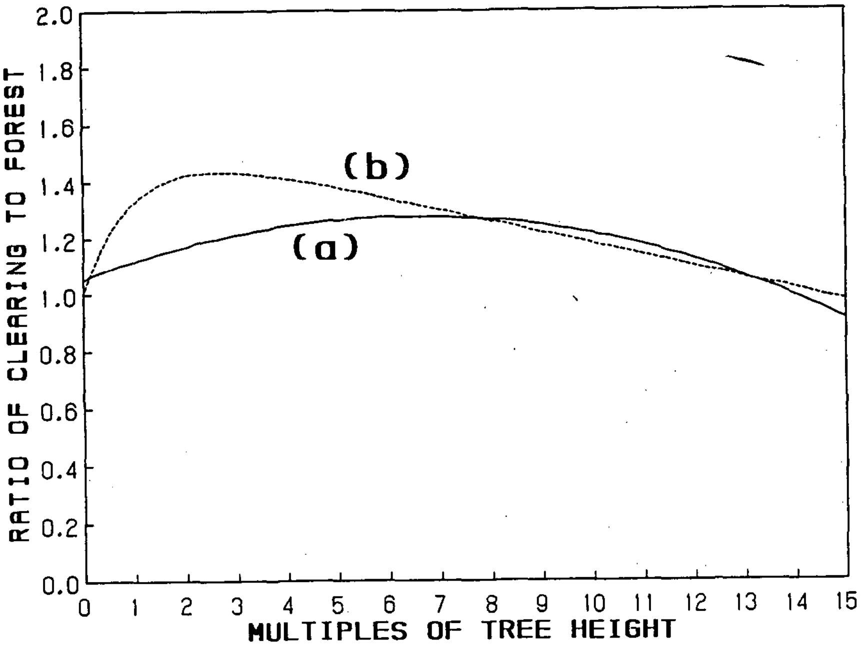

Figure 1. Snow retention as a function of clear-cut size: (a) Original WRENSS after Troendle and Leaf (1980); (b) Snow distribution as determined from James River microclimate site in Alberta.

## Interpretation of peak-snowpack accumulation data

It is possible that a distribution function, such as those in Figure 1, may work well but be incorrectly interpreted as to the processes acting on snow accumulation. The greater amount of snow accumulated in clearings than under the surrounding trees has been variously attributed to lack of interception, aerodynamic trapping or redistribution of

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intercepted snow (Gary 1974, Hoover and Leaf 1967, Meiman 1987, Wheeler 1987). However, snow is a buoyant crystalline material and in the process of falling through moving air and accumulation it undergoes processes somewhat analogous to sediment transport by water and deposition in a river. Both are significantly affected by the dynamics and state of the transporting fluid near any boundary. Similar to sediment measurements in a river, point measurements of snow on the ground are a single measurement that is the momentary integrated result of several complex deposition and loss processes.

Early research on small plots attributed differential snow accumulation between cut and uncut forest entirely to the vaporization of snow intercepted by the forest canopy (Wilm and Dunford 1948; Goodell 1959). Hoover and Leaf (1967) postulated that the aerodynamics of forest openings during and after snowfall episodes also significantly influenced snow accumulation in those areas directly exposed to wind. Golding and Swanson (1986), Figure 2, found in Alberta, that apparent ablation of snow in the clearings and under the canopy on the east, west and north sides of clearings contributed significantly to the differences between accumulated snow in openings and the surrounding forest that one ascertains from snow survey data.

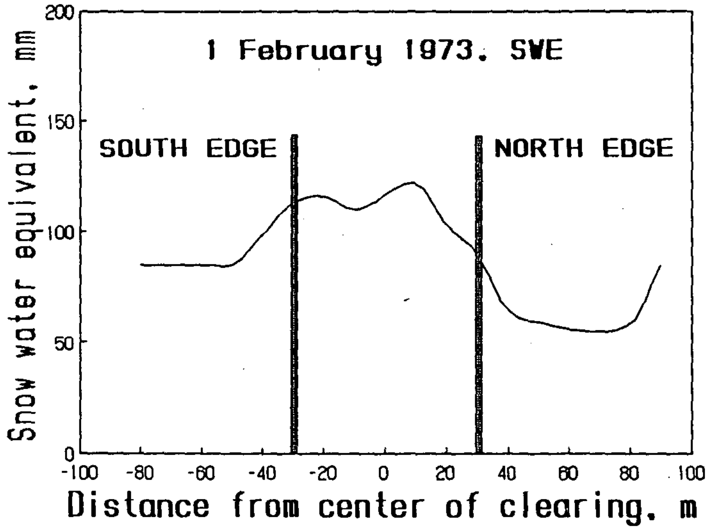


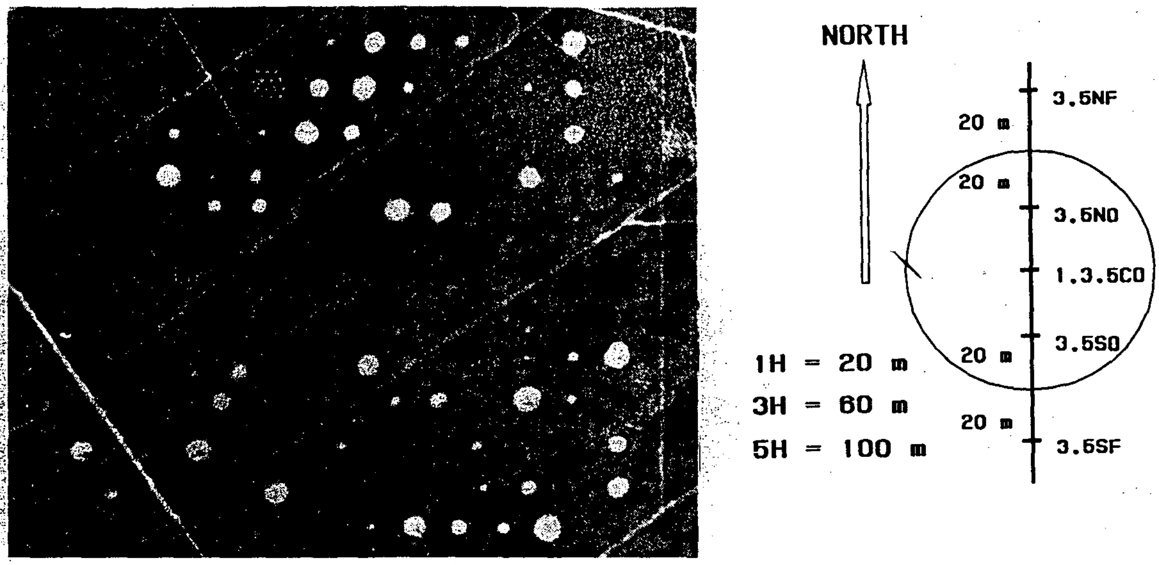
Figure 2. North-south profile of snow water equivalent in 3 tree-height diameter clearing at the James River microclimate study site, Alberta, February 1973 (After Golding and Swanson 1986).

In this paper I examine evaporation from the surface of the accumulated snowpack. My purpose is to estimate how much of the differential accumulation noted could be attributed to evaporation or sublimation from the snowpack. Pan evaporation measurements from snow in clearings and from under the immediately adjacent surrounding forest canopy are used to estimate the amount of snow lost by <u>in situ</u> evaporation. If the lessor amount of snow noted on the north side (Figure 2) is primarily evaporation, then this is a loss that must be accounted for in the application of watershed management techniques. However, if it is primarily melt, than the water is still available for on-site use by vegetation or streamflow.

## <u>Snow evaporation study at James River microclimate site</u>

The James River microclimate study area (Figure 3a) is located approximately 100 km northwest of Calgary, near Rocky Mountain House, Alberta. The terrain is essentially level with little topographic relief. The forest consists of 100 year old, 20 m tall lodgepole pine, approximately 1200 trees ha$^{-1}$. Ten replicates of ten plots, (Figure 3a, 1 uncut, 9 circular clear-cuts ranging from 5 to 120 m diameter) were established on a 200 x 200 m grid in 1970 - 1972. Intensive snow water equivalent (SWE) measurements were made from January to April in 1973 and from mid-March to April in 1974-76 (Golding and Swanson 1978). The evaporation study reported here occurred 12 years later: January 30 to March 15, 1985.

The snow water equivalent patterns reported by Golding and Swanson (1986) were general similar within all clearings of a given size. Quite likely, the evaporation patters woul also be generally similar. Even so, it would have been desirable to replicate instrument but I did not have a sufficient number of climatic instruments, nor manpower to weigh the evaporation pans, to do so for the study reported here.



(a) (b)

Figure 3. (a) James River microclimate study site. (b) Location of evaporation pans in t clearings. In the 3 and 5 tree-height (H = 20 m) diameter clearings, 5 group pans were placed along a North-South transect; (NF) at 1 H into the north forest, (NO) 1 H into the clearing from the north edge, (CO) at the cente clearing, (SO) 1 H into the clearing from the south edge, and (SF) 1 H into forest from the south edge.

The evaporation pan instrumentation at each location, Figure 3b, was identical. Aluminum baking pans (E-Z Por Corp, Wheeling, Illinois, "Smarty Pans") were used for the evaporation measurements because: 1) West (1959) indicated that the evaporation from ei polyethylene or metal pans was identical; 2) My budget was limited and I had about 100 these pans that were left behind be a previous scientist. Five 20 cm diameter, 4 cm dee aluminum pans (4 filled with snow flush to the pan surface, one empty to indicate snowfa or blowing snow) were placed in the snowpack, the pan surface flush with the snow surfac Each pan was weighed to the nearest 0.1 g (0.03 mm evaporation or condensation) on a tri beam balance at the start of each data period (usually between 1100 to 1400 hours). The were then reweighed at least once and occasionally twice daily, starting at 1000 on the day and for 3 subsequent days. The pans were refilled and reweighed before replacing in snowpack if the surface of the snow in the pan was more than 1-2 mm below the rim of the pan. If snow was found in the empty control pan (either as the result of wind transport snowfall), the data for that period were discarded. I generally obtained two days of "g data during each of the four data periods.

I also installed an anemometer at 2 m above the snow pack and a shielded non-aspirat combination air temperature and relative humidity sensor at approximately 1 m above the surface at all evaporation pan sites. The site in the center of the clearing was also equipped with a CSIRO net radiometer at 1 m above the snow surface. Data from all sens in each clearing were recorded at hourly intervals on a single Campbell Scientific CR21 micrologger using multiplexed sampling scheme that interrogated each sensor set for 12 minutes within each hour. The climatic data from these sensors are not reported here. I my intent eventually to use these data to provide a better empirical description of the complex-to-handle-theoretically 3-dimensional energy and mass transfer situation that th edges of clearings represent.

### Discussion of data in light of snow distribution

My evaporation results (estimated total for 100 days: non north edge forest 18 mm, open 31 mm) tend to confirm the magnitude of those of West (1959) (West: forest 17 mm, open 30 mm, January-April). They also suggest that the winter rate of Wilm and Dunford (1948) is much to low, even under dense lodgepole pine canopy. Actually, Wilm and Dunford (1948) report results of 16, -23, 16, and 15 mm for the four winters they evaluated. I am inclined to discard their -23 mm of condensation as being an error in measurement. The average for the other 3 years, 16 mm, is very close to the 18 that I estimate for a 100 day winter evaporation period (Table 1, 0H and 1H sites).

Table 1. Evaporation in mm/day from aluminum pans placed flush with snow surface. 0F means no clearing in forest; 1CO is center of 1-tree height circular opening; 3SF is 1-tree height into forest on south edge of 3 tree-height circular clearing; 3SO is 1 tree-height into opening from south edge of clearing; similarly for N (north edge) and 5 (5 tree-height circular clearing). LC designates an average sample obtained with two 5-pan groups in a clear-cut >20H in the windward direction. The * means that some melt water was noted in the pan when weighed. Each set of data is the average for 4 pans (except for LC which is the average of 8 pans).

| Da/Mo 1985 | 0F | 1CO | 3SF | 3SO | 3CO | 3NO | 3NF | 5SF | 5SO | 5CO | 5NO | 5NF | LC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30/01-02/02 | 0.03 | 0.00 | 0.08 | 0.12 | 0.14 | 0.02 | 0.05 | 0.14 | 0.26 | 0.09 | 0.07 | 0.11 | NA |
| 12/02-15/02 | 0.30 | 0.33 | 0.21* | 0.46 | 0.34 | 0.36* | 0.41* | 0.26* | 0.25 | 0.42 | 0.42 | 0.65 | 0.95 |
| 26/02-28/02 | 0.16 | 0.16 | 0.15 | 0.26 | 0.30 | 0.21 | 0.26 | 0.31 | 0.35 | 0.37 | 0.37 | 0.36 | 0.85* |
| 12/03-15/03 | 0.25 | 0.22 | 0.29 | 0.39* | 0.42* | 0.43* | 0.49* | 0.34 | 0.39* | 0.47* | 0.47* | 0.55* | 0.82* |
| AVERAGE | 0.18 | 0.18 | 0.18 | 0.31 | 0.30 | 0.26 | 0.30 | 0.26 | 0.31 | 0.34 | 0.33 | 0.42 | 0.87 |
| mm/100 days | 18 | 18 | 18 | 31 | 30 | 26 | 30 | 26 | 31 | 34 | 33 | 42 | 87 |

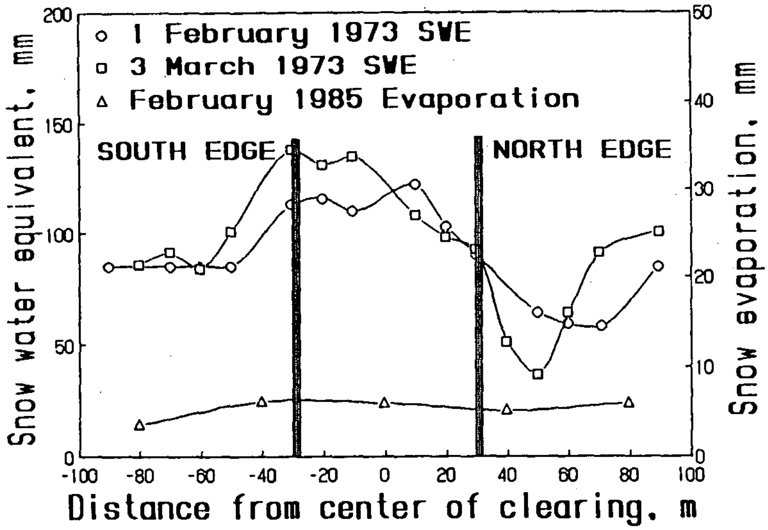


Figure 4. South to north profiles of snow water equivalent (1973 measurements) and evaporation from snow (1985 measurements), both in millimeters. Note that the snow near north edge of the clearing in March is less than that measured one month earlier.

The evaporation that I measured accounts for less than one-third of the incoming precipitation. The precipitation in February 1973 was 25 mm, which occurred during 6 days. If I assume that the evaporation rates (Table 1) determined for snow-free days during February 1985, are applicable to the 22 snow-free days in February 1973, then evaporation from the snowpack would account for 4 mm of evaporation under the canopy and 7 mm near the north edge of the 3 H clearing. Since the SWE near the north edge of the clearing at the March 1973 snow survey is actually less than the amount that was there in February 1973 (Figure 4), and only 7 mm of the incoming 25 mm precipitation is estimated to have evaporated, the remaining 18 to 21 mm is unaccounted for. Some of it probably melted. However, some of the difference in accumulation might also be due to differential vaporization of intercepted snow caught in the canopy of the trees surrounding the clearing. The temperature of the canopy on the sunlit sides may be high enough to support much higher rates of vaporization than on the shaded side(s). For instance, on a clear day, March 9, 1983, at approximately 1530 hours, I used a Barnes PRT-10 infrared thermometer to measure the temperature of the bottom of the canopy of 20 m tall lodgepole pine at 20 m from the edges of a different 3 tree-height diameter circular clearing in the same study area of: 9 to 11 °C south side; 10 to 12 °C west side; 12 to 14 °C north side; and 12 to 14 °C east side. The canopy temperature of the edges facing the clearing were: 10 to 12 °C south; 8 to 10 °C west; 18 to 19 °C north; 16 to 18 °C east.

## Discussion and conclusions

As indicated by Golding and Swanson (1986), evaporation and melt appear to be primarily radiation driven at the edges and under the canopy. The south-facing wall of trees on the north side of a clearing, (and the east or west facing walls to a lesser extent) absorbs both direct and reflected solar radiation. The heated canopy re-radiates energy in the long wave bands that are absorbed by snow that "sees" the canopy. Most of the absorbed energy warms and melts the snowpack. I did not measure the amount of melt that occurred. However, a similar study carried out at a different set of clearings on this site in April 1984 found that the ratio of melt to evaporation was nearly 10:1 (Berry 1985).

During this evaporation study, I visually noted saturated snow from about 20 meters inside the north edge of the clearing to about 40 to 60 meters (2 - 3 tree heights) into the trees on the north edge of both the 60 and 100 m diameter clearings.

These results indicate that 10 to 20 mm of the winter season difference in SWE between clearings and adjacent forest may be attributed to higher evaporation rates under the sunlit edges. A significant remainder of the difference in SWE might be attributed to melt, but some may be due to differential interception loss as well.

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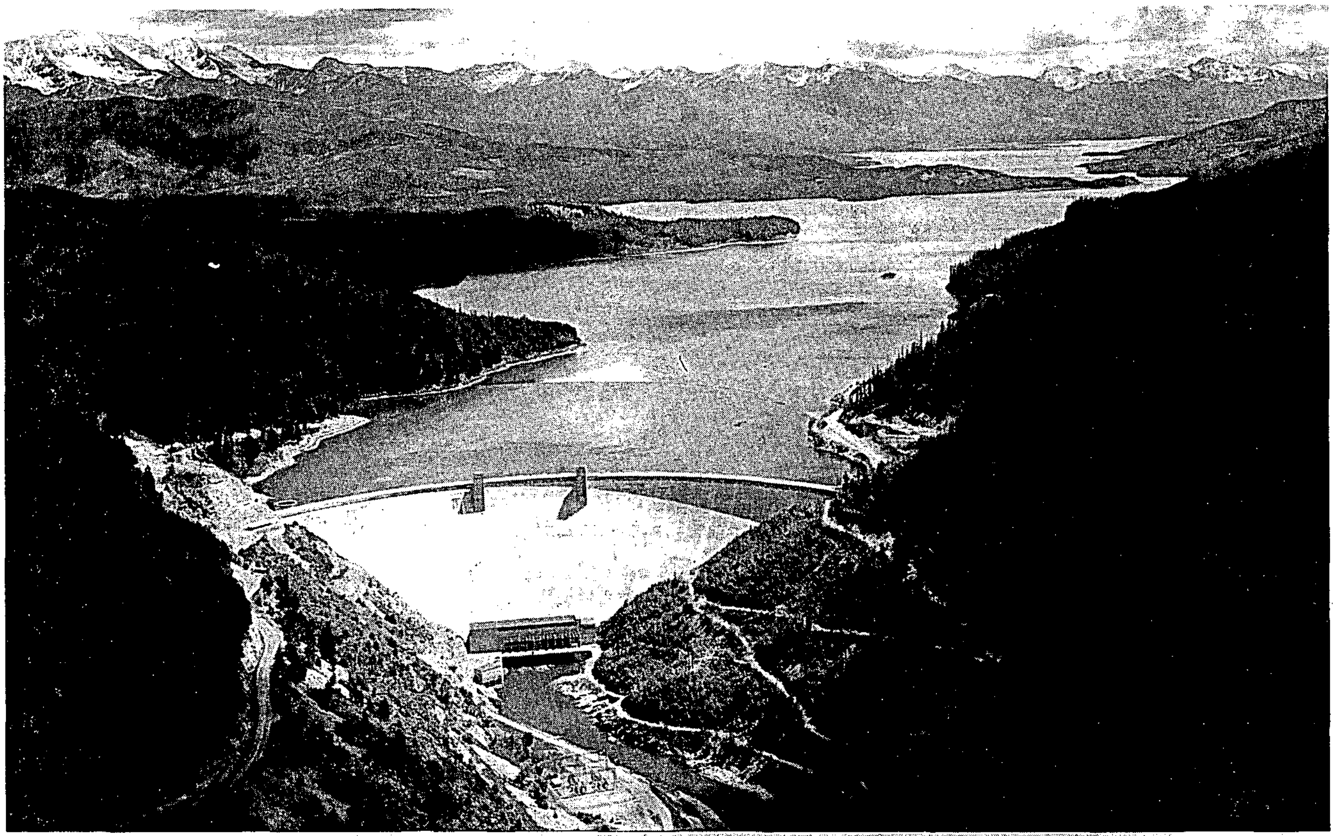

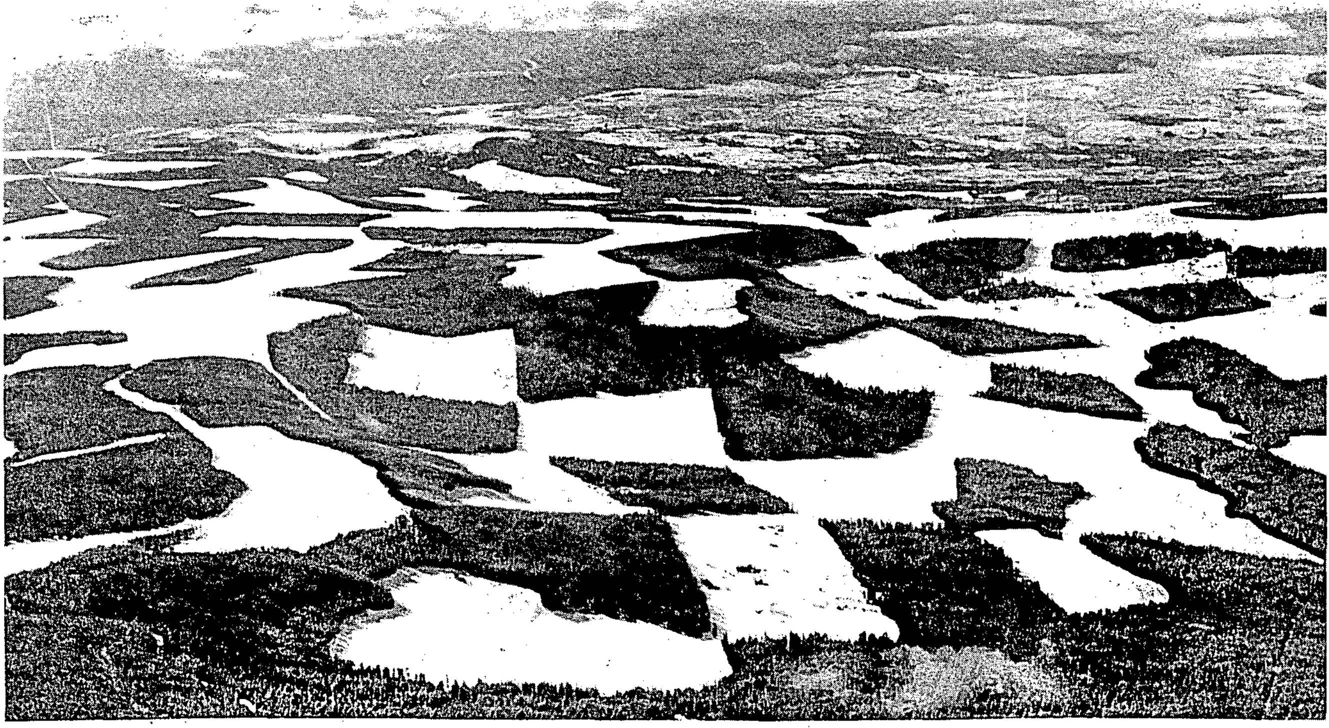

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