Summary of:
Quantification of Hydrological Pathways in the Prince Albert Model Forest 1994/95 Annual Report 1995/96 Annual Report; Pomeroy, J. W.; Granger, R. J.; Hedstrom, N.; Toth, B.; Parvianen, J.; Pietroniro, A.; 1996; Prince Albert Model Forest Assoc. Inc., Prince Albert, Saskatchewan. 98 p.

Executive Summary

Boreal Forest Self-regulation of Hydrology and Climate

1) The boreal forest sustains itself by regulating water and climate.
2) Boreal ecoystems have adapted to perform this role and to thrive under certain hydrological regimes which are sustained in the forest.
3) Forest stands altered by harvesting will manage water and climate in a different manner than do undisturbed areas.
4) The extent to which water and climate management is disturbed and the recovery time have been unknown for the boreal forest.

Prince Albert Model Forest Hydrology

1) The PAMF is extremely sensitive to surface water and climate conditions.
2) Balanced on a climatic margin between the semi-arid prairie and the cool boreal/subarctic, the PAMF is regularly threatened by water shortages or low temperatures.
3) The mixed-wood aspen/spruce forest stabilizes the PAMF with special characteristics which allow it to maximize protective snowcover in winter and minimize evaporation and heating in summer.

Evaporation of Snow from Conifers

1) Conifer stands intercept over 50% of winter snowfall. Because intercepted snow is exposed to dry winds, about half of it evaporates. Winter evaporation causes 1/3 of snowfall over conifers to never reach the ground and contribute to snowmelt.
2) To measure snow interception a full-size pine tree was hung from a weigh-scale. The change in weight of tree + snow shows the amount of snow intercepted and evaporated.
3) The energy used in evaporation (latent heat) comes from net radiation (balance of solar and thermal radiation) and sensible heat (atmospheric heat). These values change with snow on the canopy and between forest and a nearby frozen lake.

Snow Accumulation and Melt in the Model Forest

1) Winter evaporation removes snow from coniferous stands, however mixed-wood and clear-cuts hold the snow quite well. In 1994 there was 75% more snow in mixed-woods and clear-cuts than in coniferous forests at the time snowmelt began. Snow melted faster in open areas than under the conifers because of greater exposure to net radiation and sensible heat. The coniferous forests sheltered their shallow snowpacks from rapid melt.
2) A satellite derived map of landcover shows extensive, open clearcut areas outside of Prince Albert National Park and a mosaic of mixed-woods and coniferous forest within.
Summer Temperatures and Vegetation in the PAMF

1) Peak surface temperatures are strongly influenced by vegetation. The daytime clear-cut temperature is much higher than those at other sites because of its lack of

mature boreal forest vegetation. Less incoming energy is used in the clear-cut for evapotranspiration and more for heating the soil and the air.
2) Satellite data can be used to index surface temperature and vegetation amount and vigour by indices. There is an inverse relationship between vegetation and thermal indices because more incoming energy is used for surface heating in poorly vegetated areas. Full boreal forest vegetation remains relatively cool, particularly the mixed-wood.

Summer Energy Balance. PAMF

1) Converting the energy flows into monthly equivalent amounts of water in millimetres provides a useful comparison of vegetation. An alternative is to express how the vegetation uses its net radiation.
2) The pine receives the most net radiation with the clear-cut and mixed-wood receiving the least.
3) Surface air heating (sensible heat) is least at the mixed-wood, soils receive the most heat at the clearcut and regrowth sites.
4) Latent heat or evapotranspiration is lowest at the clearcut and higher for older clearcuts and mixed and pine forests. The mixed-wood directs the most net radiation to evapotranspiration.
5) In many respects the 12 year old regrowth clearcut is beginning to resemble the pine forest, though the recent clearcut is still subject to poor transpiration and extreme surface heating.

CONCLUSIONS

1) Natural mixed and coniferous forests moderate the local climate in winter and summer. In particular the mixed-wood forest provides a favourable water status and directs incoming water and energy fluxes to evapotranspiration.
2) Removal of natural vegetation by clear-cutting dramatically changes the status and fluxes of water and energy producing a more harsh climate with lower evapotranspiration rates. Strong evidence of partial recovery was shown for a planted, 12-year old clearcut.

1994/95 Annual Report

ABSTRACT

The National Hydrology Research Institute is investigating snow accumulation, snow melt, infiltration, evaporation, runoff and hydrological modelling in the Model Forest to document the self-regulation of water supply, nutrients and climate by boreal forests and the effect of forest harvesting on this self regulation. Research sites have been established in undisturbed sites in the Beartrap Creek watershed of Prince Albert National Park, and harvested sites in the Bittern Creek and Waskesiu River watersheds near Montreal Lake. Year-round measurements of net radiation, shortwave radiation, ground heat flux, wind speed, air temperature, humidity, soil temperature, evaporation and precipitation are made at each site. In winter, frozen and unfrozen water content in soils, weekly snowcover, snow chemistry, snowfall and intercepted snow on a full-size and a recently planted jack pine tree are measured. In spring and summer, continuous above and sub-canopy rainfall, stem-flow and soil moisture are measured. Eddy-correlation units for direct measurement of evaporation and atmospheric heat flux were deployed periodically in both summer and winter.

The spruce and pine forests lost 32% of their annual snowfall to sublimation of snow intercepted by the forest canopy; these losses did not occur from the grass areas or

recent clearcuts and much smaller losses occurred from the mixed-wood sites. Of 33 kg of snow intercepted on a jack pine tree from January to March, 1994, 24 kg of this snow sublimated with only 9 kg reaching the ground. Snowcover caused the fluxes of heat and net radiation to differ substantially between forested and non-forested surfaces. Net radiation was negative over open snow-covered surfaces and strongly positive over the pine canopy. Heat fluxes were usually downwards to snow-covered clearings and to snow-covered pine canopies but away from-the pine canopy when it was snow-free. Evaporation consumed 55% of net radiation when the pine canopy was snow-free, but evaporation from snow-covered pine canopies consumed energy equivalent to 240% of net radiation. The presence of sublimating, intercepted snow caused the daily evaporation to increase five-fold over the snow-free condition for roughly constant net radiation fluxes.

Stem flow of rain-water down the trunks of aspen trees contributed large amounts of water directly to the root system and began when rainfall amounts in an individual storm exceeded 5 mm. There is a similar threshold rainfall for throughflow in the mixed-wood, pine and regenerating canopies (5-7 mm) but under the spruce canopy the threshold is over 12 mm and no threshold was observed in the recent clearcut. For mature sites only rainfall amounts in excess of about 5 mm will contribute directly to enhancing soil moisture in the rooting zone of fully-leafed canopies. The differences in albedo between the various forest cover types are significant The increased energy absorption at the conifer sites (in particular the natural pine stand) means that more energy is available for evapotranspiration as well as for heating the air and the soil. The cleared site surface temperature on clear days reaches daytime values 10 to 150C greater than the other sites. In May the maximum surface temperature at the clearcut frequently exceeded the critical value for seedline survival of 350C. As can be expected, with less net energy received, a smaller leaf and rooting area and less interception of water, the cleared site showed a significantly lower evapotranspiration component than did the other sites. Consequently more surface heating is observed, as reflected in the larger soil heat flux and sensible heat flux components. The sites with a complete forest cover efficiently converted 61 - 68% of the incoming energy to latent heat, while at the clearcut site this component represented only 49%. As was demonstrated with the surface heating, this difference in the partitioning of energy has a significant impact on the local climate. These results are being applied to the Model Forest using a satellite-derived landcover classification and a GIS to distribute water and energy fluxes by landcover type.

A comparison of satellite temperature and vegetation data for the Pine and Regenerating sites shows that though the regenerating vegetation has almost recovered its mass, it has not yet fully recovered its ability to effectively manage the energy and water that it receives. This will help us to establish the role of undisturbed landcover in sustaining water and energy cycles in the boreal forest, calculate changes to hydrology and climate from changes in landcover and estimate recovery times for harvested landscapes.

1995/96 Annual Report

ABSTRACT

The National Hydrology Research Institute is investigating snow accumulation, snow melt, infiltration, evaporation, runoff and hydrological modelling in the Model Forest to document the self-regulation of hydrology by boreal forests and the effect of disturbance on this self-regulation. The objectives are to:

1) quantify the fluxes and states of water, water-borne nutrients and energy in the

major landscape elements of undisturbed and harvested forests,
2) specify the interaction of water and energy fluxes in undisturbed, disturbed and regenerating landscapes, and
3) develop process-based, distributed models of forest hydrology that may be used to assess the water supply, nutrient level and surface micro-climate impacts of forest harvesting, forest fires and vegetation successional change.

A series of six instrumented sites have been established, measuring hundreds of hydrological parameters in order to determine the hydrological functions that are influential to the critical levels of water, nutrient and energy supply for forest ecosystem productivity. Canopy cover is an extremely important factor. When canopy is reduced, snow accumulation increases and melt occurs faster and earlier. Denser canopy cover also promotes the aerodynamic transfer of moisture from the forest. The combination of incomplete functioning in the soil-root system and reduced canopy results in lower transpiration from clearcut areas during drought and therefore extremely high surface temperatures. In periods of water excess these regenerating areas consume more water than do mature forests. The mature boreal forest regulates its climate and water supply and this system must recover for clearcut areas to do the same.