Carbon and Nitrogen Dynamics Associated with Post-wildfire Stand Development for Jack Pine-Dominated Sites in Northwestern Ontario

Dave Morris, Laura Edgington, Dan Duckert and Martin Kwiaton
Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research
c/o Lakehead University, Thunder Bay, ON, CAN P7B 5E1 (Dave.M.Morris@Ontario.ca)

Introduction

Clearcut harvesting, using the full-tree logging method, represents the standard operating practice in boreal conifer (jack pine, upland black spruce) stands throughout northwestern Ontario. The underlying premise supporting the use of this logging method is that it emulates the natural renewal mechanism (*i.e.*, large-scale wildfires) for these boreal forest systems. Although spatial patterns (*e.g.*, size and configuration), at a landscape level, may be comparable, little work has been done to confirm that important ecological processes (*e.g.*, nutrient retention and cycling) are not being adversely altered, ultimately, impacting long-term site productivity.

As a first step in this fire vs. logging evaluation, the current study was designed: 1) to compare and contrast C and N soil reserves, microclimate conditions, and N mineralization rates for recently logged (full-tree harvest), burned (wildfire), and salvage logged (wildfire followed by full-tree logging) sites, and 2) to develop natural disturbance benchmarks for important ecological processes (*i.e.*, C sequestration and N mineralization rates) utilizing a jack pine-dominated chronosequence.

Methods

Study Site Description

The study area is located approximately 50 km north of Ignace, ON (49° 50' N ; 91° 20' W). A total of 15 sites, ranging in age since disturbance from 5 to 125 years (Figure 1), were selected from a broader plot array for the determination of C and N pools.

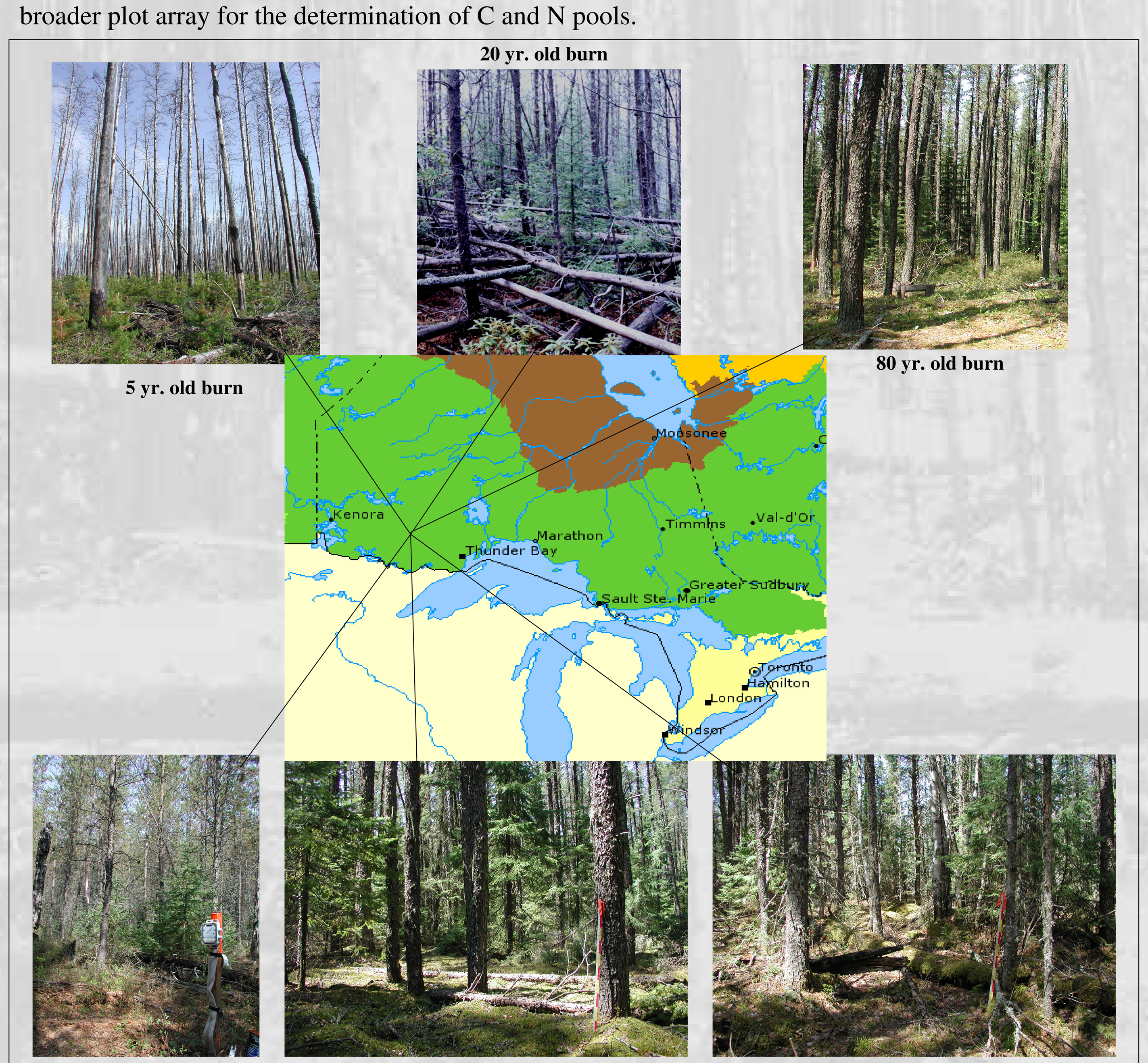

Figure 1. Study area location.

These sites are characteristically dominated by fully stocked jack pine stands with an understory of feathermoss, lichen, and conifer litter. The soils for all of the study sites represent well-drained, outwash sands, with fully developed Orthic Humo-Ferric Podzolic profiles (Figure 2).

Figure 2. Soil profile development.

Field and laboratory Procedures

A total of 12 – 200m^2 tree inventory plots were established on each site. Up to 18 – 1m^2 lesser vegetation quadrats (percent cover by species) were also established to characterize the shrub, herb, and moss layers. Soil pits were dug at the centre of 6 inventory plots to describe the physical and chemical properties of the soil profiles. In addition, 9 CWD transects (2m x 15m) were randomly located at each site. Coarse wood within each transect was classified according to position and decay class.

In situ N mineralization rates (buried bag technique) were determined for 6 of the study sites, corresponding with 3 different age/stand development stages (regen – 5 years; crown closure – 20 years; steady state – 75 years). Soil samples were collected (T0 samples) and incubated (30 day incubations during the growing season + overwinter) at 9 locations at each site, with samples corresponding to 4 soil layers (forest floor, Ae, Bf, Bfj). Standard 2M KCl extractions were done on all samples, in duplicate, and run on a TrAAcs for NH_4 and NO_3 determinations.

Results and Discussion

Carbon Dynamics

Changes in Carbon Pools over Time

As expected, total carbon storage increased substantially with stand age (Figure 3a) (140 to 300 T • ha^{-1}) largely the result of C accumulation in tree biomass (0 to a maximum of 115 T • ha^{-1} at 90 years after disturbance). Soil carbon reserves also increased with stand age (60 to 100 T • ha^{-1}), due primarily to the build up of the forest humus layer (16 to 56 T • ha^{-1}). Mineral soil C, on the other hand, tended to be more stable maintaining a pool size of approximately 40 T • ha^{-1} over the 125-year chronosequence.

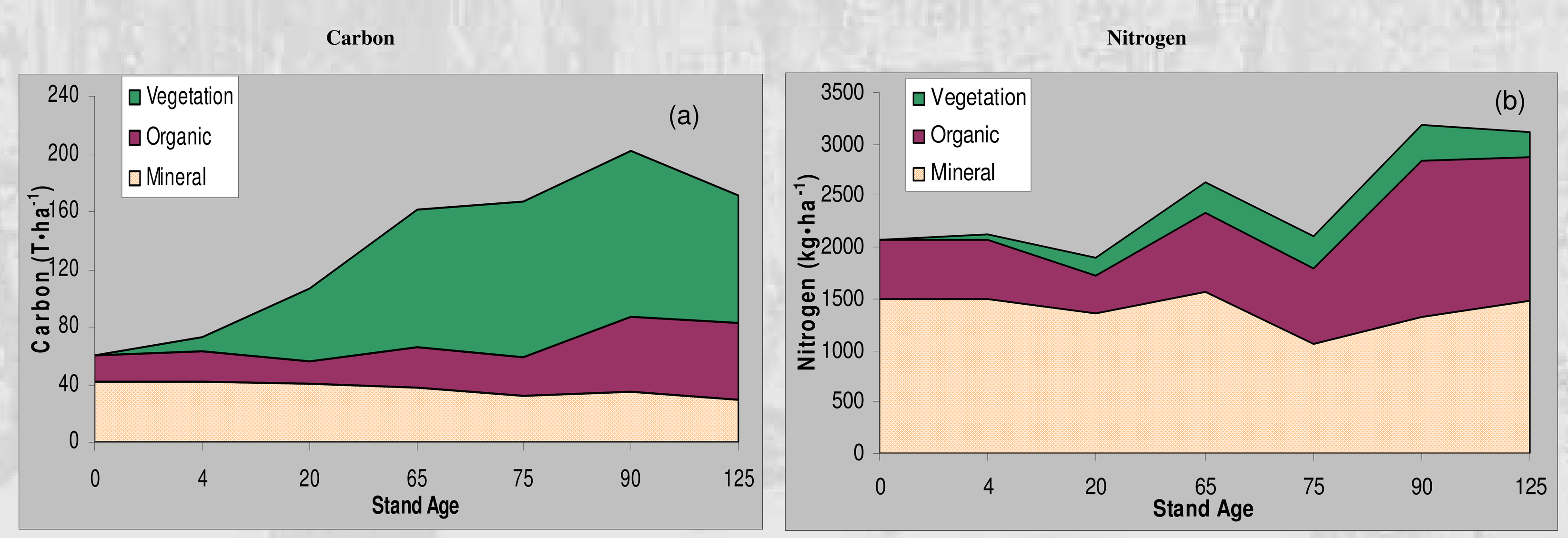

Figure 3. Carbon and nitrogen pools across a jack pine, upland black spruce ecosite.

Coarse Woody Debris

After an initial drop in the total carbon pool associated with CW (consumption by the fire), total pool tended to stabilize by Year 40 at approximately 100 T • ha^{-1} (Figure 4). Dynamic shifts, however, do occur between CWD compartments in response to important stand development periods. After wildfire, a large portion (85%) of the tree biomass C is retained on site as standing dead. A substantial portion moves into the DWD surface pool by Year 20, and eventually moves into the DWD buried pool (Year 40). Tree biomass, on the other hand, builds rapidly after stand initiation until Year 40 where self-thinning results in an increase in the standing dead pool.

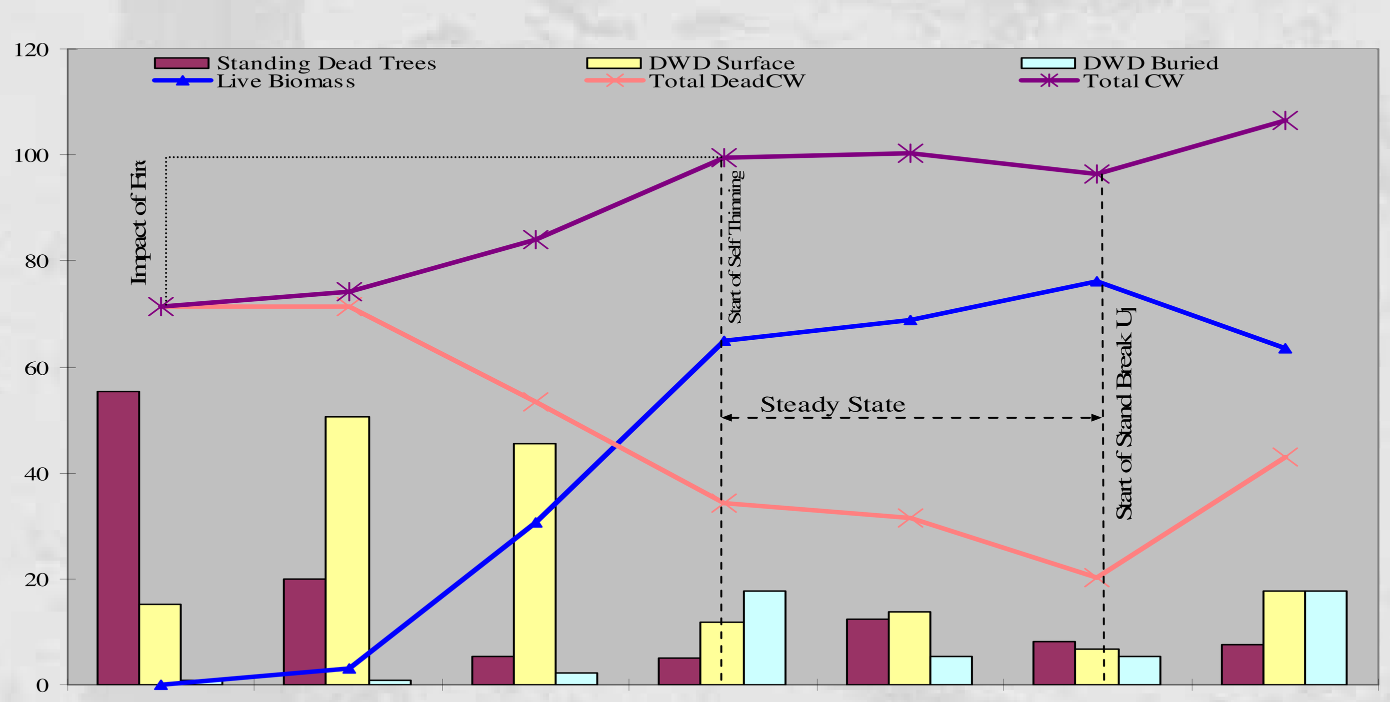

Figure 4. Distribution of coarse wood across a jack pine, upland black spruce ecosite.

Nitrogen Dynamics

Changes in Nitrogen Pools over Time

In terms of nitrogen, only a small percentage (<10%) of the N pool was associated with tree biomass during any time sequence (Figure 3b). The largest store of N in these systems was in the mineral soil layers. There does appear to be a definite pattern of rapidly decreasing N soil reserves for nearly 20 years after wildfire (2900 kg•ha^{-1} at Time 0 to 1460 kg•ha^{-1} at Year 20), presumably due to increased leaching. This decrease is followed by an extended period of gradual increase in both the soil organic and mineral layers to a maximum reserve of 3600 kg•ha^{-1} by Year 90.

N-mineralization Rates

In terms of available pool, N mineralization rates immediately after the fire peaked at (> 30 kg•ha^{-1}•yr^{-1}), but dropped as the stands approached crown closure (22 kg•ha^{-1}•yr^{-1}), followed by a slight increase to a stable level of 25 kg•ha^{-1}•yr^{-1} (Figure 5). For the most part, the available N pool was dominated by NH4+ - N (> 90%). A significant pulse of NO3- - N (5 kg•ha^{-1}•yr^{-1}) was detected at the recently burned site. This nitrate production occurred, exclusively, in the deeper B horizon.

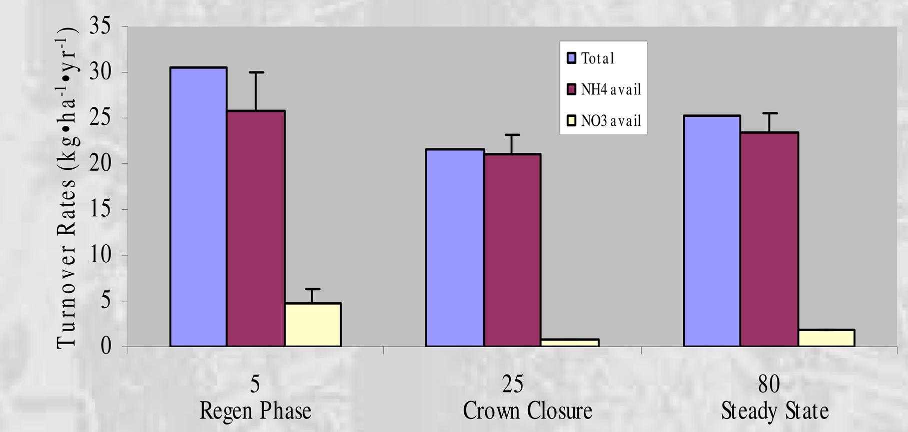

Figure 5. Changes in annual N mineralization rates during stand development.

Estimates of N mineralization (growing season) suggested that the salvage treatment was generating substantially higher rates (nearly double) than the other two treatments (Figure 6). As might be expected, N mineralization rates were highest in the organic layer (20.3 kg•ha^{-1}•yr^{-1}), and decreased with soil depth to below 2 kg•ha^{-1}•yr^{-1}.

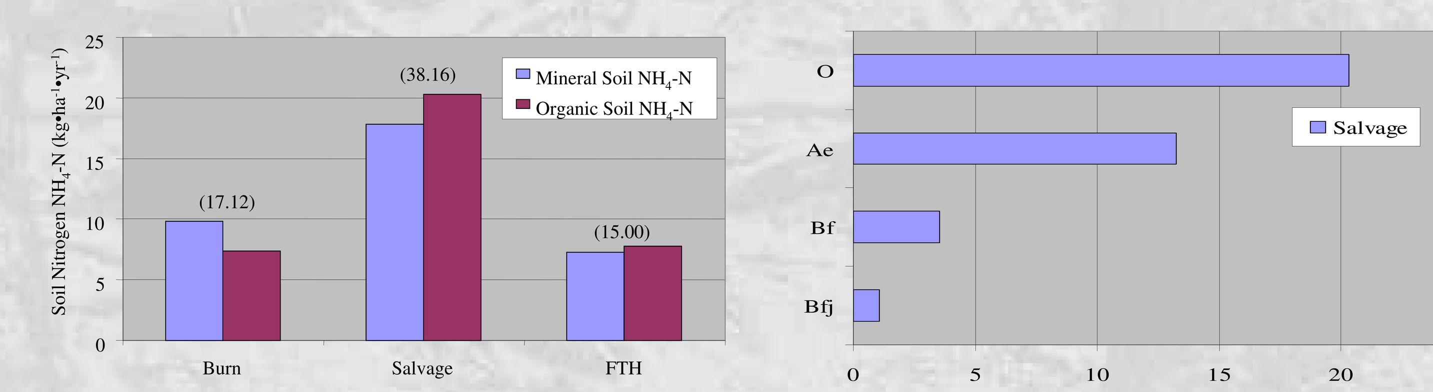

Figure 6. Growing season N mineralization rates, by renewal treatment.

The greatest mineralization rates occurred in the salvage treatment at the end of June in both the mineral and organic layers (reaching 0.29 and 0.41 kg NH4-N•ha^{-1}•day^{-1} for mineral and organic layers, respectively) (Figure 7). All three treatments experienced the highest rates at this time of year with the mineral soil at the burn site being the only exception. The lowest rates of turnover occurred at the end of July. This may be due to generally drier soil conditions.

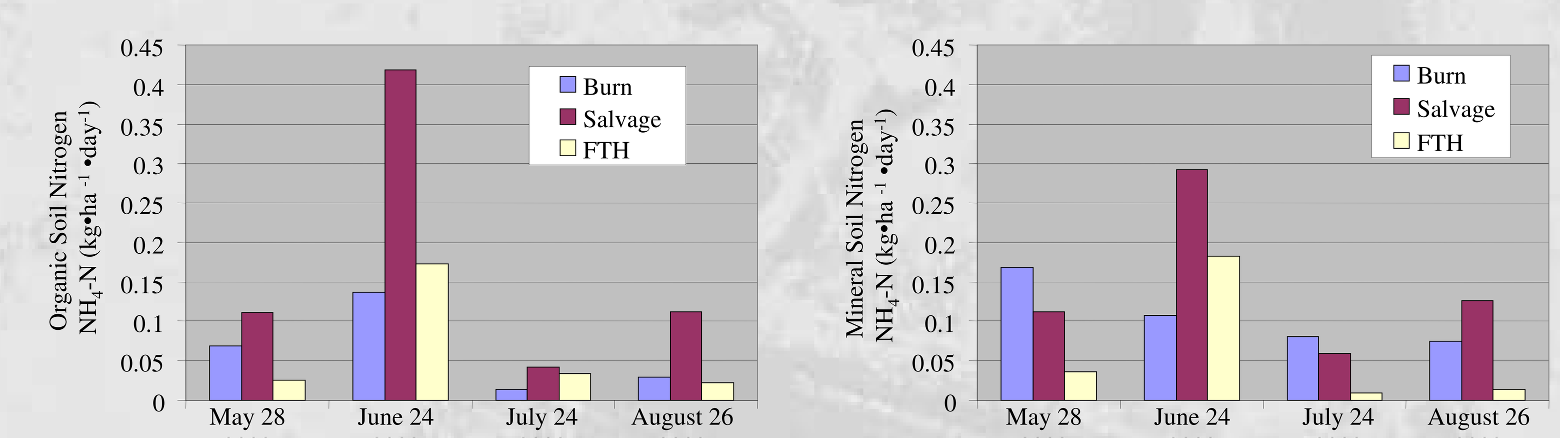

Figure 7. Seasonal patterns in N mineralization rates, by renewal treatment.