Title and description:
Soil and Landscape Factors Influencing Forest Production Following Natural and Human-induced Disturbance; Pennock, Dr. D. J.; 1997; Department of Soil Science, University of Saskatchewan, Saskatoon, Sk; 74 pages

Excerpt from file:

1. INTRODUCTION

The effects of clear-cut harvest of forest products on soils and related ecosystem components have been widely studied. Although several common effects have been established in these studies, the specific effects of clear-cutting on soils of any given region have proved to be difficult to predict. The objectives of our research were to i) develop a soil-landscape model for Mid-Boreal Upland Ecoregion contained within the Prince Albert Model Forest, ii) to use this model to develop a baseline of soil conditions within mature Mixedwood and non-Mixedwood forests and iii) to assess the impact of clear-cut forest harvest on the soil and landsurface.

Clear-cutting affects the rates of most soil processes operating within forested landscapes. One immediate impact of clear-cutting on nutrient and chemical flux is the loss of nutrients through removal of the biomass. The potential losses through biomass removal differ depending on the harvest method, management of the slash after harvest, and the specific nutrients involved. At a site similar to those discussed in our research, Alban and Perala (1990) examined the proportion of total nutrient reserves removed in whole-tree harvest of aspen; nutrient removal due to harvest comprised 5% of nitrogen reserves, 2% of phosphorus reserves, and 11%, 8%, and 2% of potassium, calcium, and magnesium reserves, respectively. The percentage of the reserves lost through harvest differs depending on soil type (e.g., Gordon, 1983; Timmer *et al.*, 1983); nonetheless nutrient export through harvest is appreciable.

A second immediate impact is on the physical properties of the soil surface and subsoil; these impacts occur primarily due to the ground pressure exerted by mechanical harvest systems (Greacen and Sands, 1980). The physical disturbance commonly increases the bulls density and soil strength and reduces the infiltration capacity, all of which affect the partitioning of water at the soil-atmosphere interface. The physical impacts are primarily concentrated in heavily used areas within the harvest block (e.g., skidder trails and landings); the landscape-wide impact tends to be less significant (Hatchell *et al.*, 1970).

The loss of the forest cover (and possible disruption of the ground cover) changes both the microclimatic and hydrological contexts within which the soil processes are operating. The removal of the forest canopy (and an appreciable percentage of the ground cover) increases the radiation reaching the soil surface and hence soil temperatures rise after clear-cutting.

Probably the most significant impact of clear-cutting from a soil quality perspective, however, is on the hydrological processes operating at the site. In a review of clear-cutting impacts in a range of environments, Neary and Hornbeck (1994) found a median water yield increase of 48% in the first year after clear-cutting; this increase is largely attributable to the impact of biomass removal on reduced transpiration rates. This increase in water yield becomes apparent as either an increase in surface runoff (and possibly in related water erosion) or as increases in the recharge of groundwater; the partitioning between the two depends on the physical nature of the soils, the degree of disturbance associated with the clear-cutting, and the nature of the landscape itself (e.g., the slope gradient and continuity).

For coniferous forest stands in the Model Forest Region, Kachanoski and de Jong (1982) showed that the effects of clear-cutting on the hydrological cycle were most evident in the snow-melt period. They found that clear-cutting increased hillslope water yield fivefold during the snowmelt period in the year following clear-cutting. Some effects were, however, evident throughout the growing season - for example, drainage through the soil was twice as high in the clear-cut sites as in the mature forested sites. Hence the potential for both surface and sub-surface transfers of solutes and colloidal material is much higher after clear-cutting.

The increased soil temperatures, radiation levels, and soil moisture combine to increase the mineralization rate of organic materials in the soil; however increased additions and decomposition of slash and incorporation of the surface organic layer into the mineral soil during harvest may, in some cases, increase soil organic matter levels. In a recent review of the literature available, Johnson (1992) concluded that the changes in soil organic matter in temperate and boreal forests due to harvest are generally on the order of ± 10% of pre-harvest levels.

The increase in vertical and lateral water movement through the soil greatly increases the potential for leaching of soluble soil components, and these leaching losses have been identified as a major consequence of clear-cutting (Johnson, 1994). Higher mobility and losses of both cations (e.g., NH_4^+, K^+, and especially Ca^{2+}) and anions (e.g., NO_3^- and $H_2PO_4^-$) are commonly observed after clear-cutting (Krause and Ramlal, 1986; Johnson, 1994).

The increased leaching of nutrients is commonly believed to be highest in the first few years after clear-cutting (e.g., Gordon, 1983; Alban and Perala, 1990). When the groundcover and regenerating tree species are established, transpiration rates increase and the water available for leaching decreases; as well, increased ion uptake by plants decreases the ions available for leaching. Hence Alban and Perala (1990) argue that accelerated leaching of nutrients below the rooting zone is often a short-lived phenomenon.

Previous studies have identified a range of possible impacts of clear-cutting on soil functions: physical impacts of mechanical harvesting systems; disruption of chemical and nutrient cycles leading to accelerated loss of ions by biomass removal and changes in addition and decomposition of organic residues; and disruption of the partitioning of water within the ecosystem through changes in transpiration rates. The indicators chosen in our study were selected to assess the impact of these disturbances on soil functions in the Mixedwood forest of Central Saskatchewan.

The existing literature also provides a range of approaches which can be used to assess the effects of forest harvest on soil condition. Doran and Parkin (1994) discuss two of the most common methods for establishing reference conditions against which the observed levels of soil quality indicators can be compared. The first is to use the soil characteristics of an undisturbed soil to establish reference conditions; the second is to compare the observed characteristics with a range of conditions which have been established to maximize productivity and environmental performance. The latter approach presupposes a thorough understanding of the optimum functioning of the soil, and for the Mixedwood forest of central Saskatchewan this understanding is lacking; hence we compare our observed levels of soil indicators after clear-cutting to conditions which exist in analogous mature Mixedwood forests in the region. These reference conditions are then compared with the soil quality conditions observed in the disturbed ecosystem.

As discussed above, the literature suggests that the rate of change in soil quality conditions due to clear-cutting is greatest immediately after the harvest, and that a reduced rate of change occurs in the medium- and long-term. Two major assumptions underlie the application of the undisturbed/disturbed comparison approach (Dyck and Cole, 1994): that all of the ecosystems under study were identical at time zero and have not been selectively affected by biological factors since time zero; and that climate has not changed and is similar for all sites used in the comparison. The requirement for an identical starting point appears unlikely under field conditions, but the onus is on the researcher to demonstrate at least a strong similarity among the research sites.