The Carbon Cycle, Mosses and our Forests **by Anne Mills**[1]
Some Nature Notes:

Photosynthesis in green plants is a process by which carbon dioxide (CO_2), water and solar energy are transformed into complex organic compounds that contain carbon, hydrogen and oxygen with the release of oxygen gas and water vapour into the atmosphere. The reverse occurs in respiration when those carbon-containing compounds are broken down into their component parts – to water and CO_2 with the release of energy. This process is called the *carbon cycle*.

About 10,000 years ago after the last glaciers retreated, the rocks that were left behind were weathered by freeze-thaw action and by chemical and mechanical breakdown by lichens and mosses. Soils that accumulated as a result of these activities eventually became partitioned into layers called *horizons,* each of which was further modified by the plants growing there; shrubs, trees and grasses.

The top layer is exposed to the elements and is composed of dead material; leaf litter, twigs, dead branches, below which is a thin layer of decomposing material. These above-ground layers are called *organic horizons* and include a narrow band of humus. Below this layer are three main *horizons,* each with a distinct profile and function and varying in depth and composition. **Horizon A** is rich in dead and decaying organic materials being broken down mainly by bacteria and fungi but also by a host of small and larger soil organisms such as ants, earthworms, moles, mites, millipedes and centipedes, wingless insects, ground beetles and many more. Given enough time the soil created has a mix of small particles that retain nutrients and large particles that give the soil good drainage. Horizon A contains more carbon than lower layers, crucial to the growth of healthy forests. Plant roots tap into this rich layer where nutrients for plant growth are located – calcium, phosphorus, nitrogen.

Horizon B is called the subsoil layer which includes small amounts of organic material that move down from horizon A carried there by rainwater in a process called *leaching*. It is less weathered than A and is a layer in which minerals and clays accumulate.

Horizon C below B is composed mostly of rocky material subject to weathering and is the source of new soil for the top layer. This process happens when rocks and stones are found on the soil surface where there was none the year before. This is due to the freeze-thaw cycle.

Below these 3 layers is *bedrock*. The depth from the organic horizon to bedrock may be only about 140 cm (about 4.5 feet) so disruption of the top layers results in a change in the dynamics of the horizons below the surface. These disruptions can take the form of land clearing for agriculture, mining, and forestry to name a few.

Where do mosses (Bryophytes) fit into the picture? These small plants are often neglected in the forest scenario yet they play a significant role in keeping carbon, mineral nutrients and water in forest ecosystems and are a major contributor to *carbon storage*. For most of us, *bryophytes* (mosses, liverworts and hornworts) are just *there*; "background noise" and are largely ignored but they play an important role in forest ecology. Mosses have been around for over 450 million years and are considered to be the forerunners of modern day vascular plants. They photosynthesize like other plants and can grow on surfaces where herbs and woody plants cannot. They are different because they have no water-conducting tissues, no true roots only hair-like structures called *rhizoids* that anchor them to their substrata, and their stems and leaves have no waxy coating, so water, nutrients, CO_2 and O_2 diffuse freely across the moist surfaces of the whole plant. Hence they have remained small and most are found in cool, damp, shaded areas although they have populated just about every habitat on the planet; the Arctic, Antarctica, deserts, the tropics, salt water estuaries but not oceans. Consider them to be the "amphibians" of the plant world. They are at the mercy of their surroundings but have been

successful on land in part because they can make use of low light levels to produce enough photosynthesis to promote new growth and have the enviable capacity to carry their own external water supply. The fact that they can use low light intensities means that they can sequester more carbon than many vascular plants. Bryophytes, for the most part, live close to the substratum where they grow, within a thin boundary layer high in CO_2 and where air disturbance is less than in their surroundings.

Mosses, especially *Sphagnum* (peat or bog moss) occupy 1% of the earth's surface and hold more carbon below in peat than do tropical rainforests above ground in wood. Eighty percent of all peatlands in temperate and boreal areas of the northern hemisphere store 15-30% of the global soil carbon as peat. (Limpens et al., 2008). Mosses growing on the ground in forests protect valuable soil nutrients, prevent soil runoff, filter toxins from the air and land, trap dust and debris for future soils, provide a nursery for the germination of some seeds while deterring invasive plants from taking hold. Forest clearcutting in temperate and boreal forests has a profound negative effect on this forest complexity. Bared soil is subject to runoff taking with it the soil that contains the very nutrients trees and other plants depend for healthy growth, and regrowth of new forests. That runoff winds up in lakes, rivers, streams and the ocean where it may never be available to plants for millions of years.

After a forest is clearcut either wholesale or in patches the soil profile changes and it takes hundreds of years for them to replace what is lost, if ever. In addition at least eighty-five percent of all plants have particular types of fungi associated with their roots called mycorrhizae. Mycorrhizae that penetrate roots are called endomycorrhizae and those that form a sheath around the roots are called ectomycorrhizae. Some of these fungi are generalists and others specific to particular plants. Either way they are important for seedling growth and the transfer of such nutrients as phosphorus from the soil to the plants and organic carbon to the fungus. In particular, both temperate and boreal forests depend on these fungi. Trees growing in temperate regions in poor soils like those in Nova Scotia, depend almost exclusively on ectomycorrhizal fungi that help protect them from harsh growing conditions and provide a connection between the plant roots and the fungus and between adjacent tree roots as well. Enzymes released by the fungi help break down organic matter in the soil and those resulting nutrients can then be taken up by plants. Conifers, beech, birch, oaks etc. depend on ectomycorrhizal fungi. Forest clearcutting destroys these fungi present in the soil, and upsets a delicate balance of fungi, bacteria and soil organisms and the source of carbon so important for healthy forests and colonization of replacement trees. Forest disturbance for forest floor bryophytes changes many variables; heat, light, moisture, burial under slash, removal of dead wood, changes in their well-established microclimate. Studies have shown that biodiversity decreases dramatically after tree harvest especially for liverworts for the reasons stated above, and that the tree clumps left as legacy trees are insufficient in size for recruitment and recolonization of new bryophytes and to maintain the diversity found in undisturbed forests. Nelson et al. (2005) and Ross-Davis et al. (2002).

The Last Word

Nova Scotia can learn much from countries like Finland, Sweden and Switzerland on how to derive economic benefits from the remaining forests in the province and at the same time keep those forests in a healthy state by looking at long-term forestry planning. As I drive the highways across the province all I see are clearcuts and the scene from the air is even more bleak. Truckloads of logs roar by going where? And more and more new logging roads are being cut into the forests. Recent cutting along one of the 100 series highways showed a steep slope down to a waterway logged over. And I haven't even mentioned what happens to the nitrogen cycle, the hydrological cycle, dead wood and its values to the forest, the birds that return to the province in spring with their usual nesting sites gone, and the mammals that require large tracts of land to breed, feed and live. It is time to change the forestry practices in Nova Scotia to maintain a healthy ecosystem for future trees, bryophytes, lichens, fungi, bacteria and soil organisms. It can be done!

References
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Ross-Davis, Amy L. & Katherine A. Frego. 2002. Comaprison of plantations and naturally regenerated clearcuts in the Acadian Forest: forest floor bryophyte community and habitat features. Can. J. Bot. 80: 21-33.

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Photos taken off and along highway 103 between Mahone Bay and Chester Basin March 18, 2017

Logging machinery off route 103

Intact forest on the road to a logged over area

An older logged area with new cuts to the west

Exposed tree roots in horizon A

A small legacy clump of white pine

A new road to the new cut in photo above

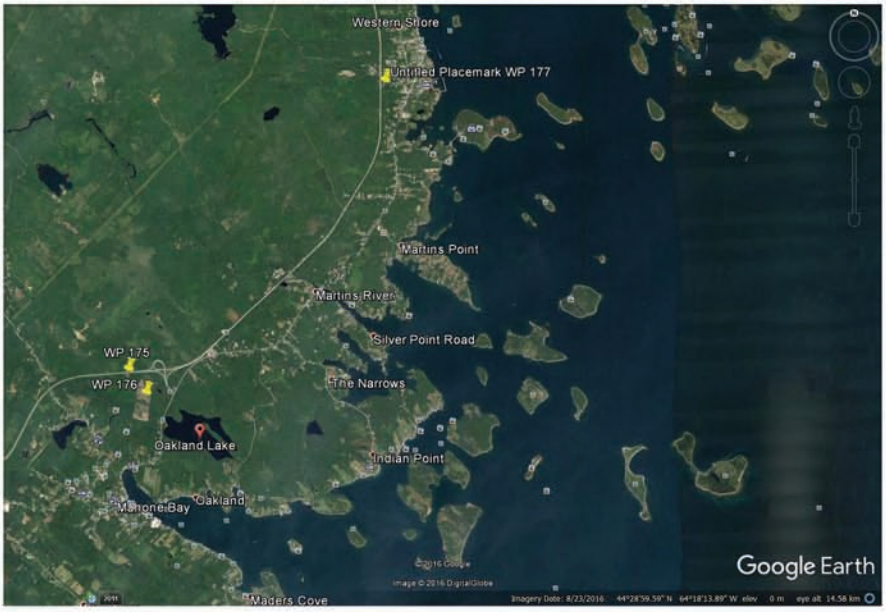
Red maple bark with *Neckera pennata* on bark

Red spruce log about 80 years old

Recent cleared area along 103 in plain view!

Loading “sticks” N side of 103

Sheer volume of cut logs from new cut off hwy 103



Hwy 103 locations