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Interdependent dynamics of C, N, P and water in reclaimed soil profiles from the Athabasca Oil Sands Region

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Oil sands in Canada represent the third largest oil reserves in the world, with the Athabasca Oil Sands being the single largest deposit of bitumen. Post-mining land reclamation of this area involves the reconstruction of soil profiles able to support a mosaic of boreal forest communities similar to those that existed prior to disturbance. However, the use of coarse-textured reclamation materials to recreate forest ecosystems constitutes a challenge in terms of water and nutrient availability.

This work aimed to examine the links between the dynamics of C, N, P and water in reclaimed coarse-textured soils constructed with two cover soils (peat-mineral mix and forest floor mix) underlain by three mineral materials, including a blended B/C subsoil reclamation material, lean oil sands overburden substrate and tailing sands (residual sands following bitumen extraction). The retention potential of each material for mineral N and P was measured using a batch sorption experiment. A 325-day lab-incubation experiment was conducted in order to compare the organic matter mineralization rates and the release of N and P between the two covering materials. A 5-day column leaching experiment was also designed to determine the retention/redistribution of water, N and P in reclaimed soil profiles up to 1.2-m depth following intense rain events. The influence of fertilizer addition on the overall dynamics of soil C, N and P was also tested using 15N-labelling to distinguish between fertilizer-N and N mineralized from the original soil organic matter.

The release of mineral N over time was directly dependent on the rate of organic matter mineralization in the two cover soils, while abiotic processes were shown to control the release of water-soluble P. Following an intense rainfall, the peat-mineral mix was able to retain a significant part of the initial plant-available mineral N within the top 20 cm of the reclaimed soil profiles, while most of the initially available mineral N in the forest floor mix was leached further down. Compared to the redistribution of water with depth, the flow of N down the soil profiles was slower and more restricted by the presence of textural discontinuities between the sandy subsoil and the tailing sands or lean oil sands. The addition of ammonium-N through fertilizer addition on the soil surface did not modify the available mineral N profile below the 20 cm, suggesting that most of the fertilizer-N remained in the cover soil. Overall, our results highlight the importance of taking into account not only the quality and degradability of organic matter contained in the reclaimed topsoil, but also the hydrodynamics of the whole soil profiles when predicting the evolution of plant-available N and P pools in reclaimed coarse-textured soils.