Simulating the carbon balance in reclaimed forest ecosystems with the FORECAST model

Clive Welham

Forest Ecosystem Simulation Group
Department of Forest Sciences
University of British Columbia (clive.welham@ubc.ca)

UBC Forestry

and

FORRx Consulting Inc

and

3GreenTree Ecosystem Services Ltd
3960 Marine Avenue
Belcarra, BC V3H 4R9 (clive.welham@3greentree.com)

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Overall context:

Large emission sources are beginning to report their C footprint on an annual basis for a number of reasons: 1. They are mandated by government, 2. Shareholders are demanding disclosure of a company's risk to climate change, and 3. As part of corporate social responsibility initiatives.

From the perspective of CO_2 emissions, oil sands mining is a carbon intensive activity.

The intensity of C emissions can be mitigated through technological and process innovations.

However, reclamation is the only mining-related activity that directly removes atmospheric CO_2.

Principal objectives:

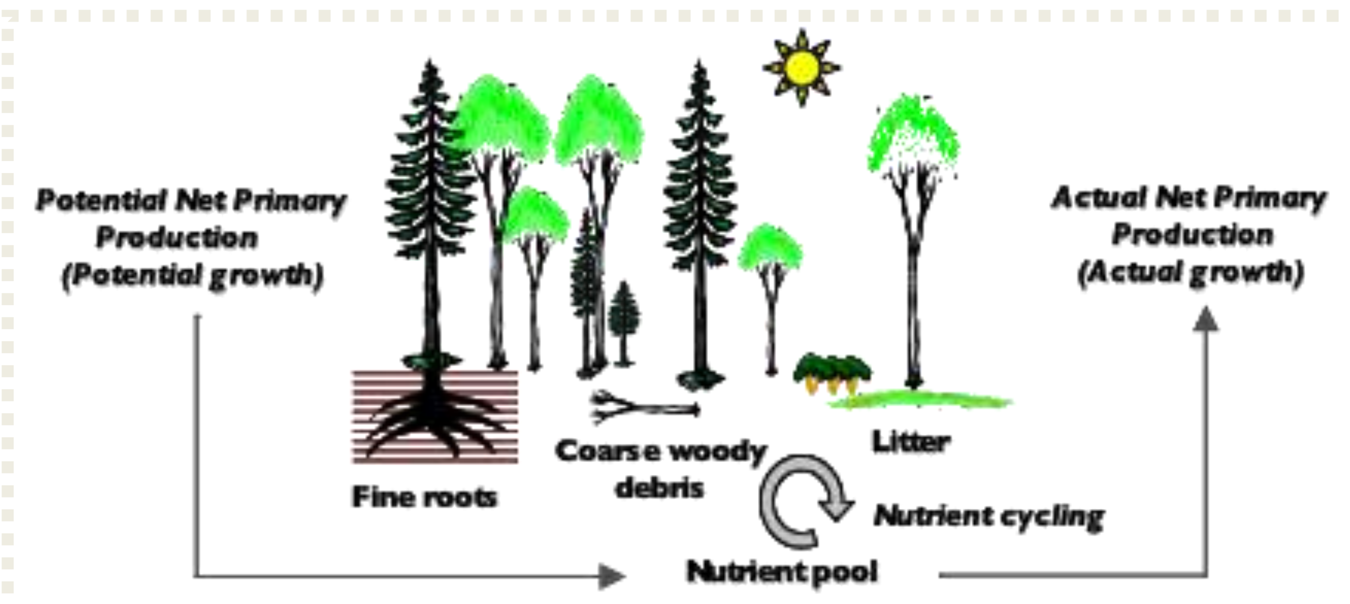
This modeling exercise has three principal objectives:

1. To simulate the carbon balance in a developing reclaimed upland forest ecosystem,
2. Explore the relative change in carbon pools over time, and
3. Compare the carbon balance of the reclaimed ecosystem to its natural analogue.

Methodology: Model description

Carbon balances were simulated using the ecosystem model, FORECAST

FORECAST is well-suited for the task because it can simulate the principal drivers of ecosystem development and productivity (light capture, nutrient cycling, competition, and available moisture).



FORECAST is also a well-established model:

- has been under development for almost 40 years
- has been documented in more than 45 refereed publications
- has been used in 4 Canadian provinces and five countries
- is used in forestry
- is used in oil sands mine reclamation (since 1999)
- is now being used to estimate carbon sequestration and carbon budgets in support of carbon reporting requirements and development of offset projects.

Methodology: Simulation protocol

1. FORECAST's capability to represent the carbon balance in local forest ecosystems was evaluated to demonstrate its suitability as a modeling tool

In this respect, the model was calibrated for an aspen-dominated stand (site index = 16) that originated from a stand-replacing fire, and included an understory community comprised of grass, small, medium, and tall shrubs.

Model output was then compared to literature values derived from plots located in fire-origin aspen-dominated stands within the region.

Methodology: Simulation protocol

2. Using the same calibration data set, FORECAST was then used to simulate a generalized reclamation scenario applicable to tailings sand reclamation, or 'good' to 'fair'-quality non saline-sodic overburden.

The coversoil was represented as a 50 cm peat:mineral mix layer, with an initial consistency of 105 t C ha^{-1} and 4200 kg N ha^{-1}.

Long-term trends in peat decomposition are not known and so two general patterns were simulated, termed **fast** and **slow decomposition**.

The general sequence of events in the simulated reclamation event were:

(a) Year 1, apply coversoil
(b) Year 2, plant aspen (2500 stems ha^{-1}; starting site index = 16*) and 'barley'
(c) Year 3, establish understory community
(d) Years 2 and 3, apply fertilizer

Simulations were run for 145 years.

* Equivalent to a '*b*' ecosite

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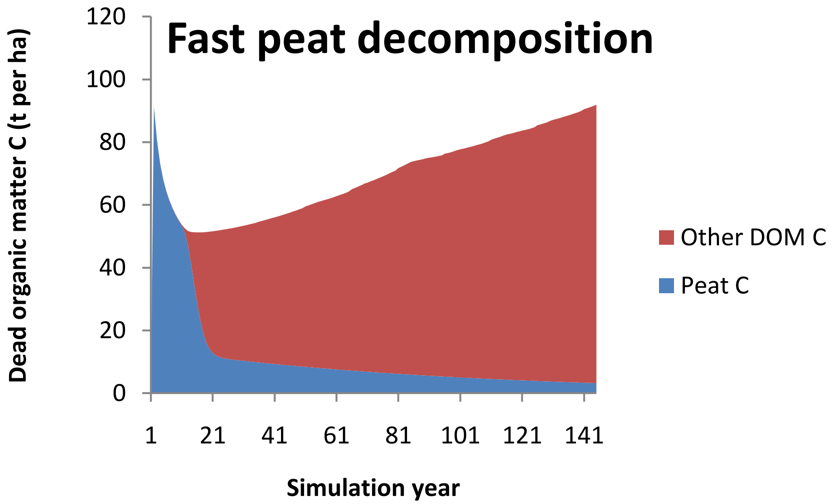
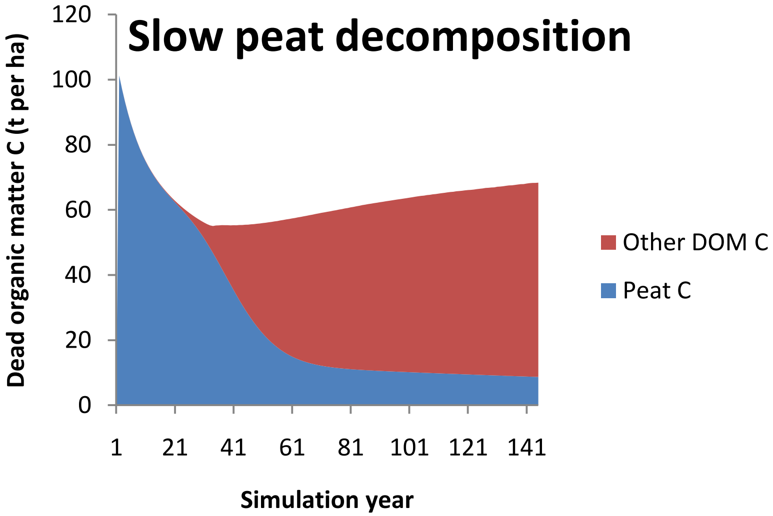
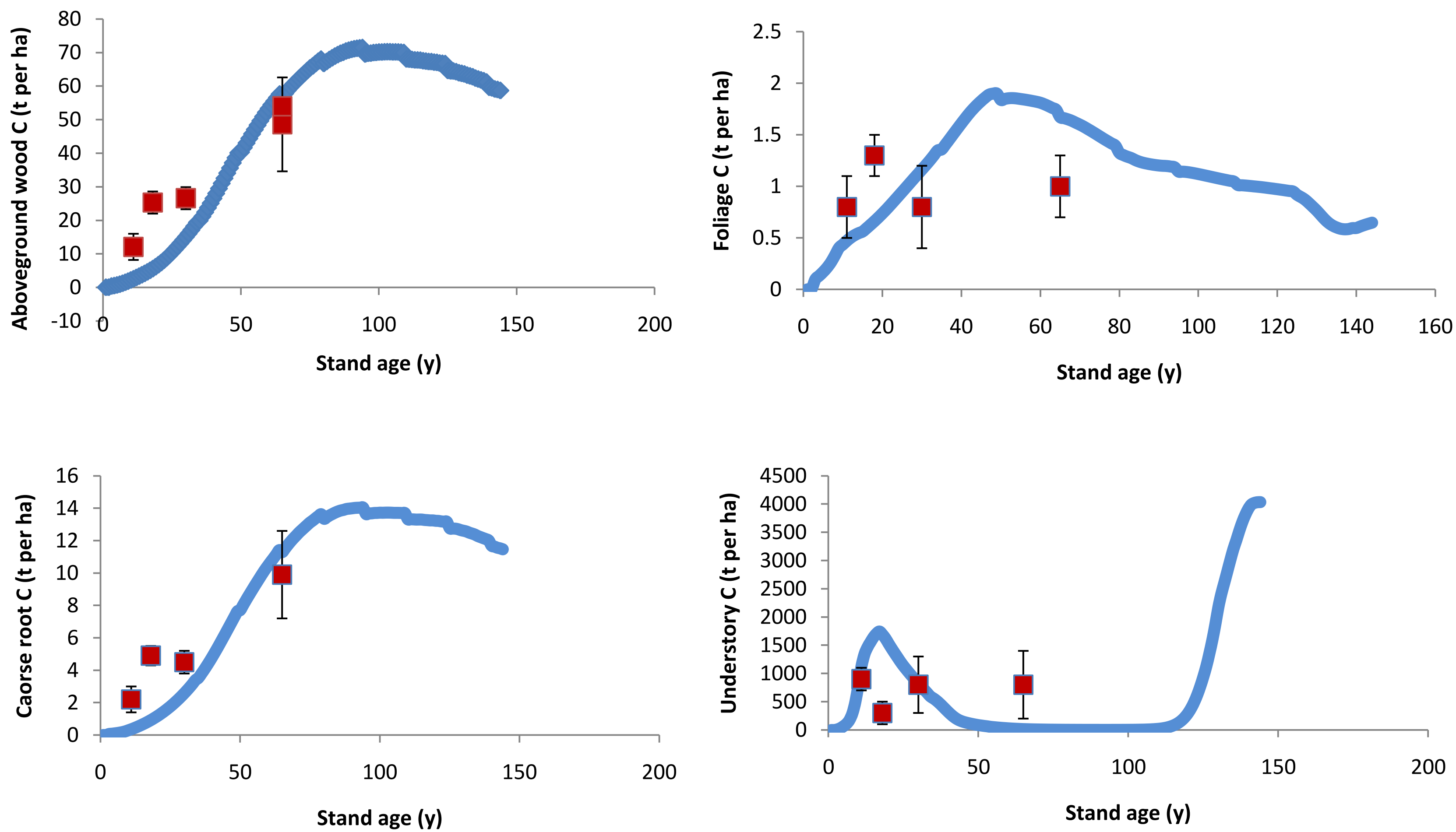




Results **1. Comparing FORECAST's projections of carbon balance in a natural aspen-dominated stand with empirical values**



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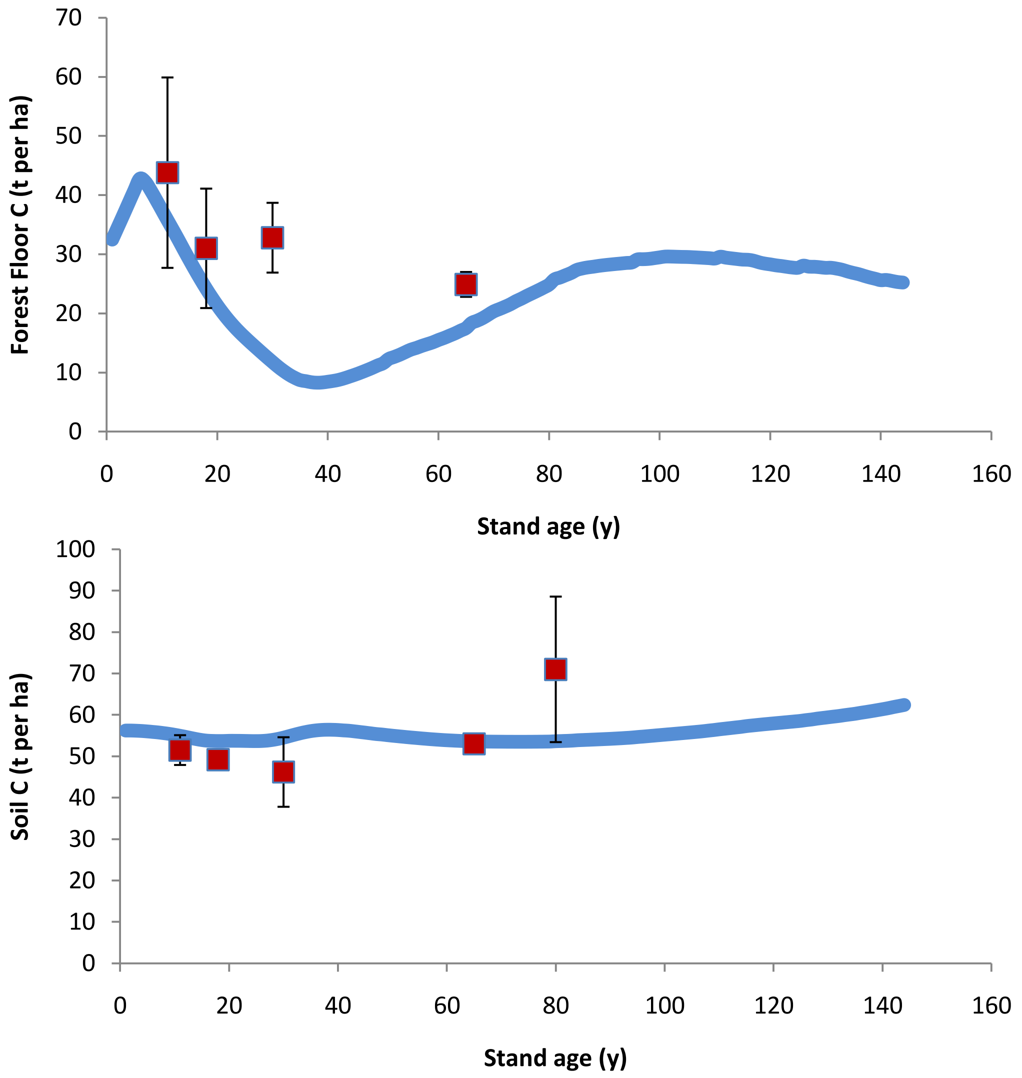
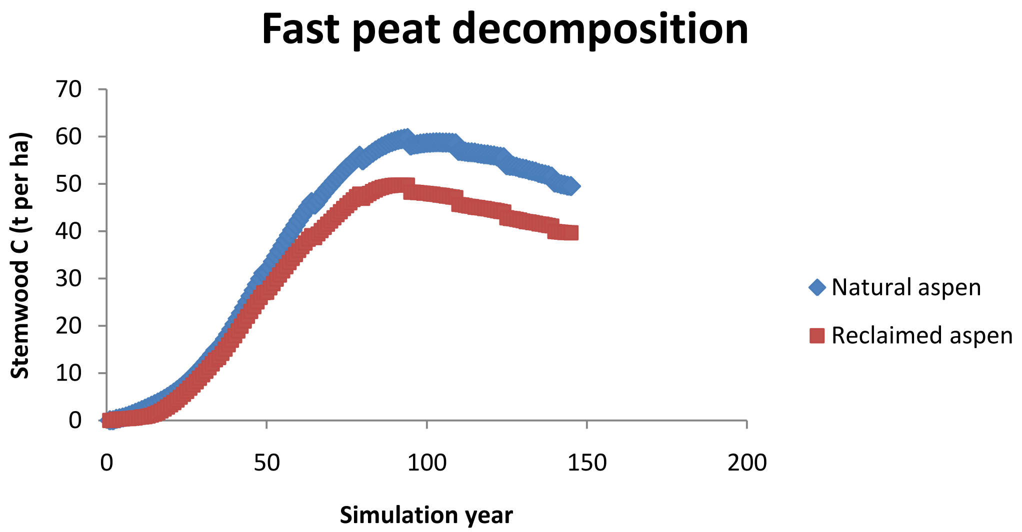
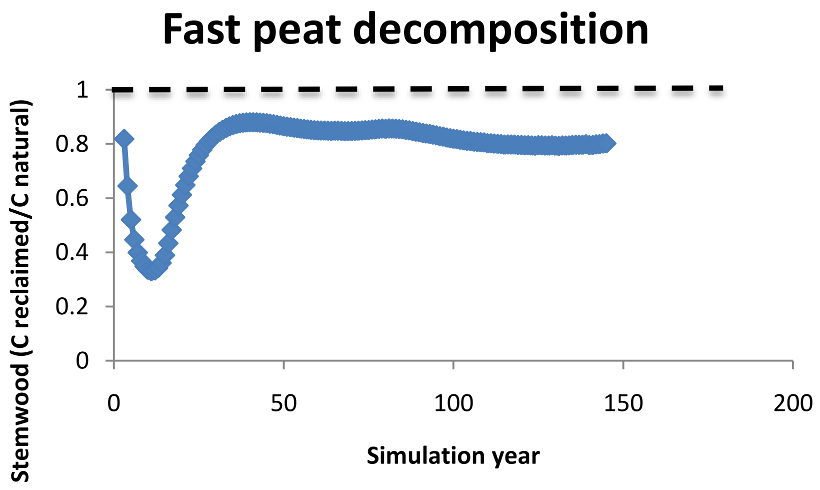


Results **2. Comparing FORECAST's projections of carbon balance in a reclaimed aspen-dominated stand with a natural stand**





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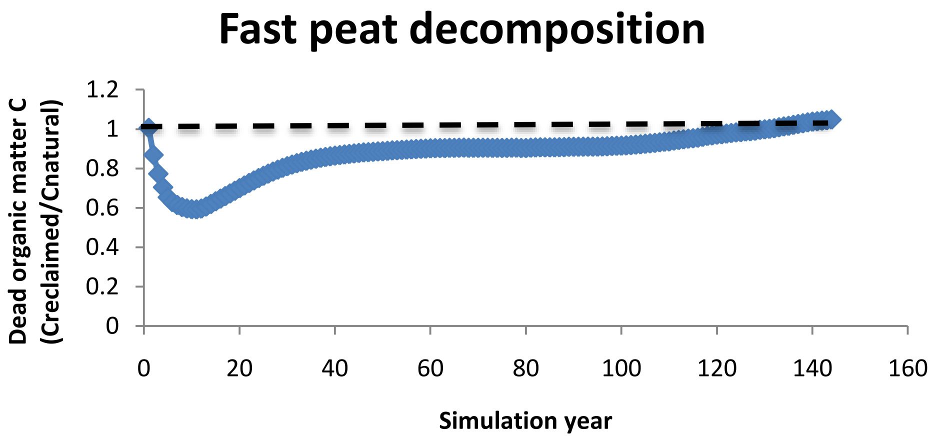

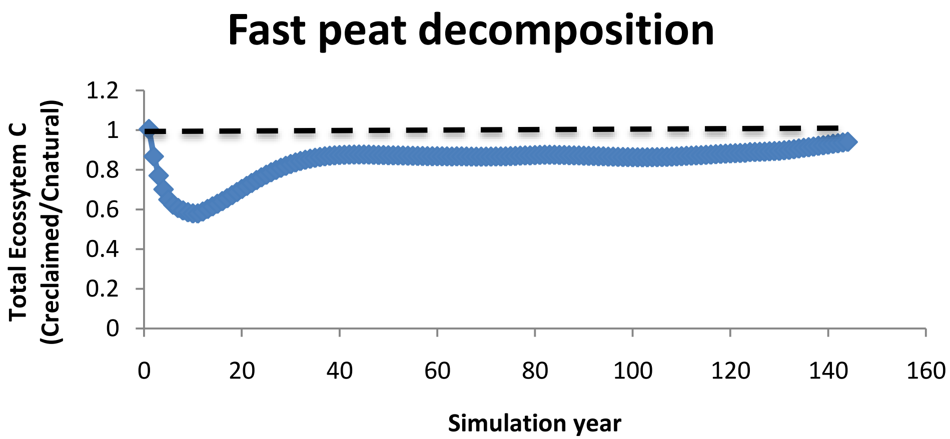

Results 2. Comparing FORECAST's projections of carbon balance in a reclaimed aspen-dominated stand with a natural stand

Conclusion:

If peat decomposition rates are 'fast', reclaimed aspen-dominated *b* ecosites sequester and accumulate carbon at levels similar to their simulated natural analogues

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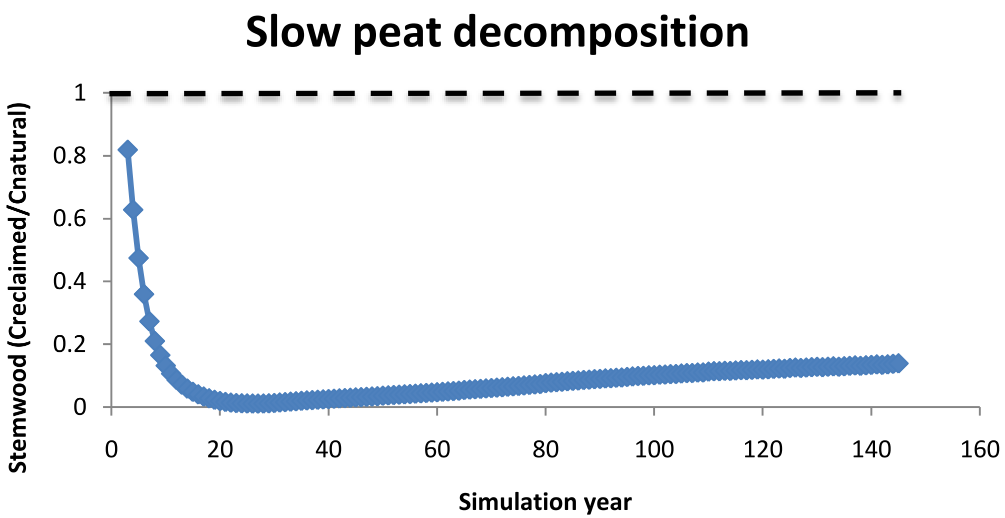

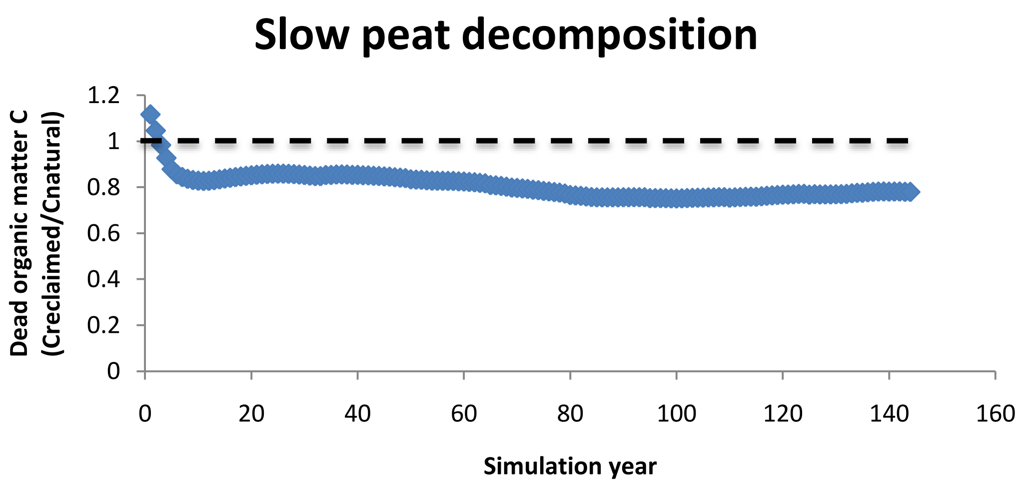

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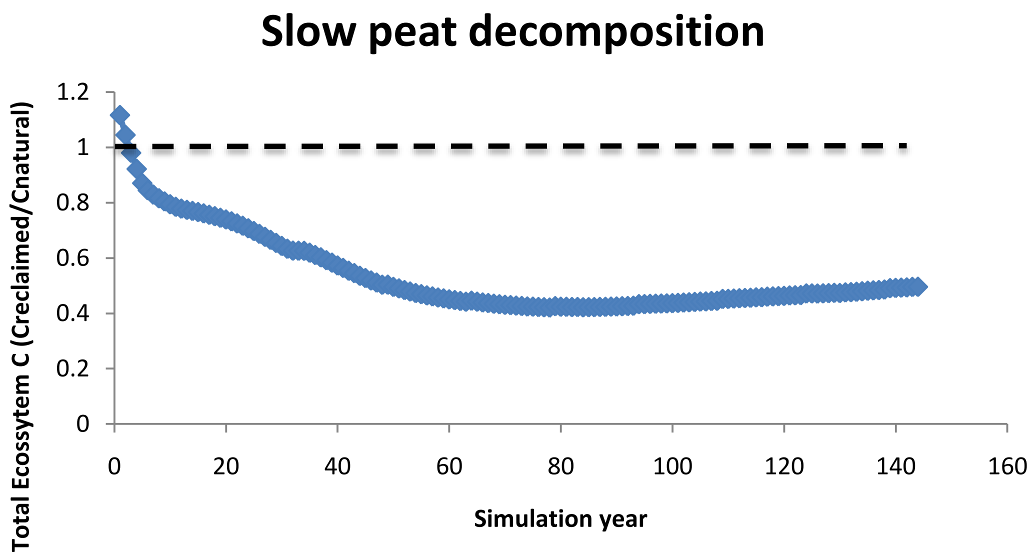


Results 2. Comparing FORECAST's projections of carbon balance in a reclaimed aspen-dominated stand with a natural stand

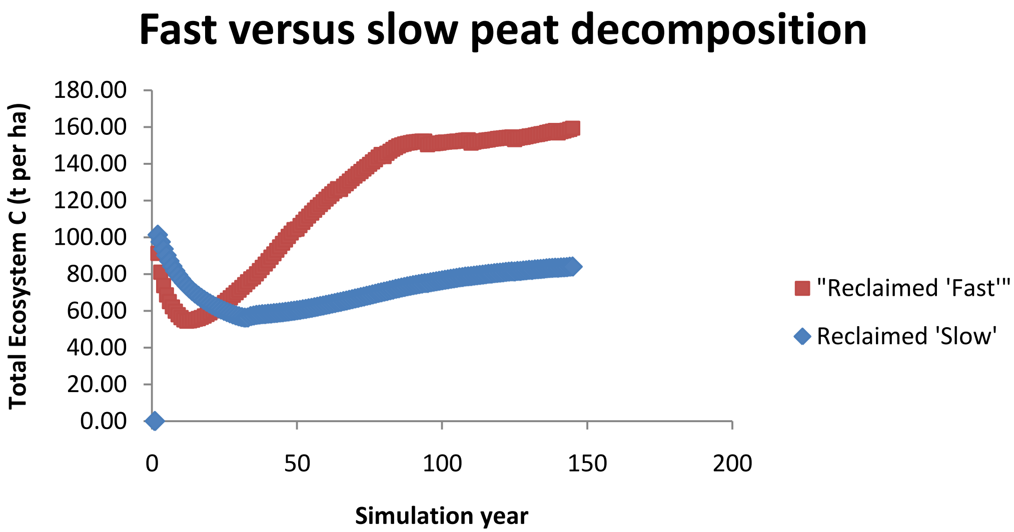
Conclusion:

If peat decomposition rates are 'slow', reclaimed aspen-dominated *b* ecosites sequester and accumulate carbon at levels that total about half of their simulated natural analogues

Overall conclusion:

Long-term peat decomposition rates are critical to the rate of carbon sequestration and storage in reclaimed ecosystems

How important is carbon sequestration and storage to the carbon balance over an entire mine footprint?



The maximum storage potential of a reclaimed mine footprint is very large (on 10,000 ha, for example, it totals between 3,000,000 to 6,000,000 t C).

However, reclamation occurs progressively and so the total storage potential is only realized over time. More importantly, the proper metric to calculate is the *annual rate of carbon accrual*.

What is the annual rate of carbon accrual on mine site with progressive reclamation?

Imperial Oil's Kearl Lake operation was used as a test case

Basic protocol:

1. Kearl Lake EIA documents were used to obtain information on reclamation practices from mine initiation to closure with respect to anticipated ecosite types, the time periods when each ecosite was to be reclaimed, and how much area a given ecosite was expected to occupy.
2. A series of FORECAST runs was conducted to simulate the productivity in each ecosite (expressed in units of carbon accrual) in accordance with the expected pattern of progressive reclamation. FORECAST used a peat decomposition rate intermediate between 'fast' and 'slow'.
3. The annual rate of total ecosystem carbon accrual was then calculated and converted to CO_2 equivalents.

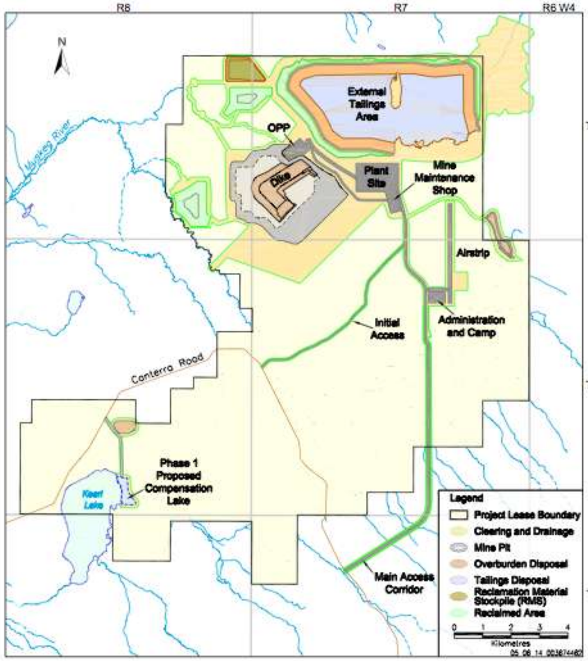


Figure 9-6: Mine Advance and Reclamation Activities – Years 2012 to 2016

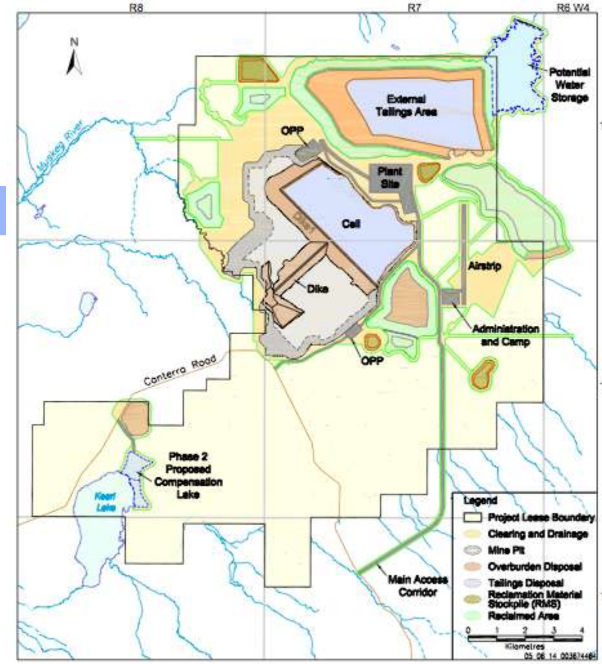


Figure 9-8: Mine Advance and Reclamation Activities – Years 2022 to 2026

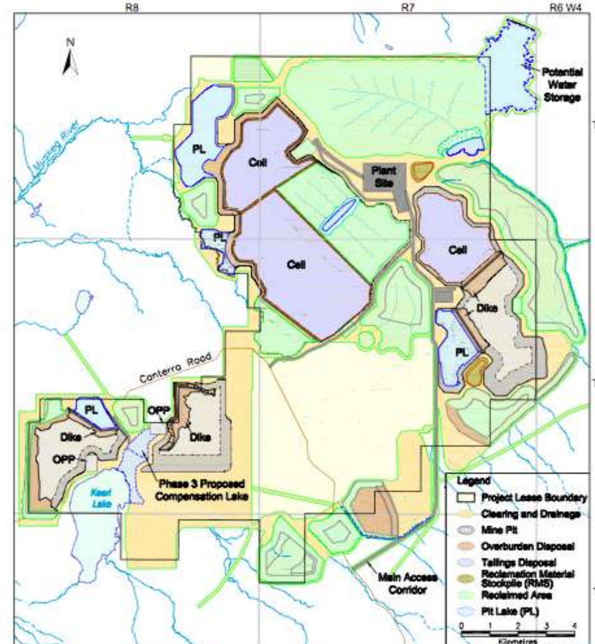


Figure 9-10: Mine Advance and Reclamation Activities – Years 2032 to 2041

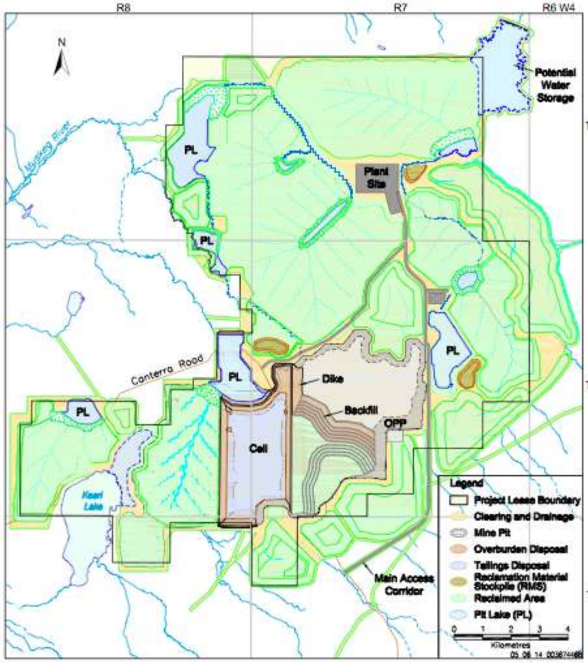
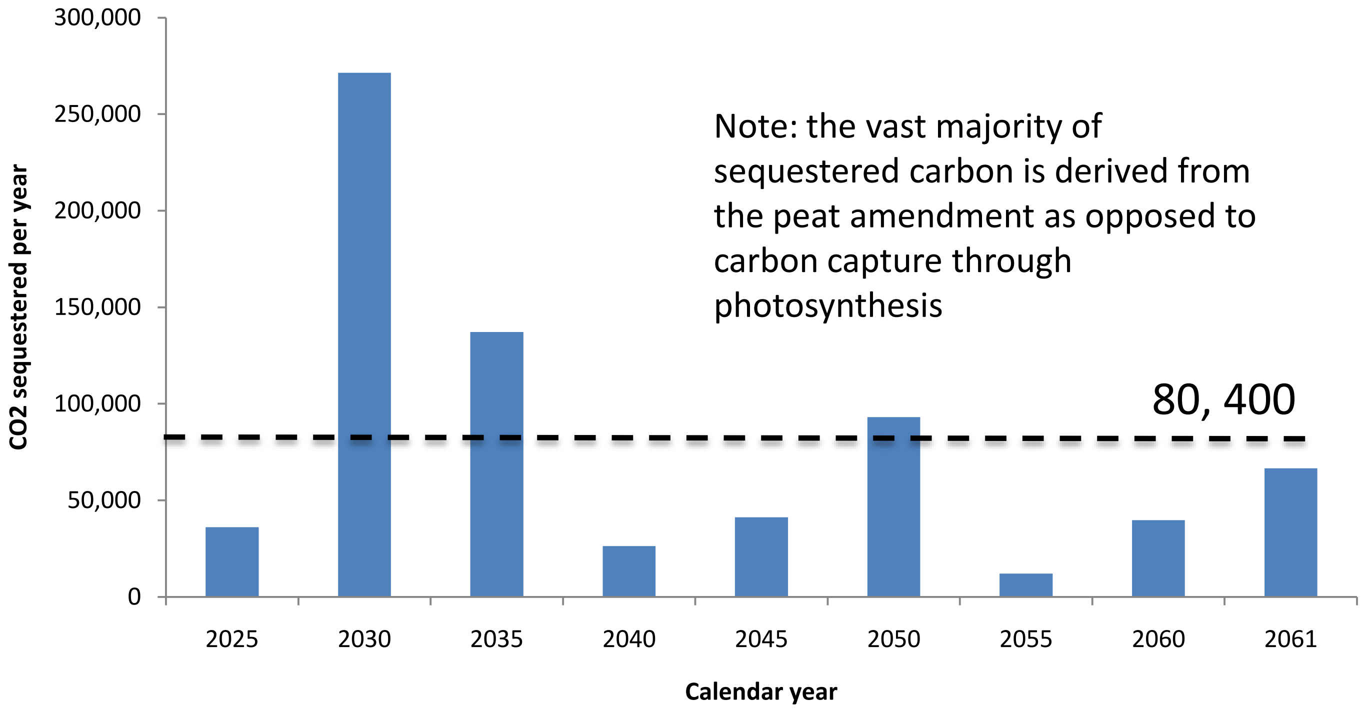


Figure 9-12: Mine Advance and Reclamation Activities – Years 2052 to 2060

What is the annual rate of carbon accrual on mine site with progressive reclamation?



To put this in perspective, a fully operational mine generates at least 8 million t of CO_2 per annum

Conclusion

In the Kearl Lake test case, an average of about 83,000 t CO_2 per ha were sequestered per annum as a result of reclamation. This, however, is only a relatively small fraction of total annual emissions.