Using the Tree and Stand Simulator (TASS) model to predict the effect of stand management on quantity and value of carbon and biomass in British Columbia, Canada

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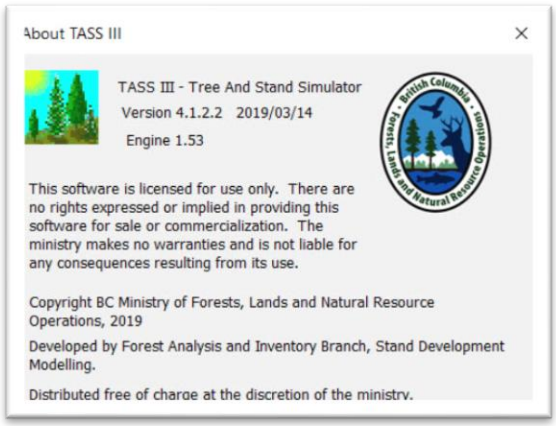

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Abstract

The Tree and Stand Simulator (TASS) model enables forest managers and timber supply analysts to explore the effects of stand management on quantity and value of carbon and biomass in British Columbia, Canada. TASS is a spatially explicit, individual tree model that provides key growth and yield estimates for the managed forests of British Columbia. It incorporates individual tree biomass equations to predict stand biomass and carbon yields under different management scenarios. The poster presentation demonstrates the use and operational applications of TASS with the emphasis on carbon yield and economic return forecasting.

Why is it important?

British Columbia has vast forests that can help fight climate change by affecting atmospheric concentrations of carbon dioxide (CO_2) due to trees' ability to absorb and store carbon as they grow. The province has a Forest Carbon Strategy that outlines current and planned strategies to manage forest carbon and improve the sustainability of B.C. forests, communities and industry while mitigating the effects of climate change. It includes forest carbon management options that satisfy diverse values including carbon, biodiversity, water, fish and wildlife, as well as, socio-economic values generated by harvesting, processing and manufacturing wood products. One of the key goals of the Strategy is the simulation modelling of forest carbon and natural resource values to assess management options under a changing climate, and to support provincial research and policy development.

How?

The Tree And Stand Simulator (TASS) (Mitchell, 1969; 1975) model is used in British Columbia to explore stand level management impacts on the quantity and value of carbon and biomass for commercial tree species in second-growth forests. A new third generation of TASS incorporates the modelling of stands with complex vertical structure and multiple species by introducing innovative simulation techniques, including dynamic light modelling to regulate growth and mortality. It is a spatially explicit (distance dependent), individual tree growth and yield model that simulates the growth of trees and stands in three dimensions. It currently simulates lodgepole pine, ***Pinus contorta var. latifolia,*** and white spruce, ***Picea glauca,*** in pure and mixed stands. Additional tree species are currently being added. TASS predicts silvicultural treatment response through the modelling of individual tree crown dynamics and its linkage to bole growth and wood quality. The focus on crown dynamics makes TASS particularly well suited for predicting response to treatments such as espacement, fertilization, pruning, pre-commercial and commercial thinning.

TASS computes the above-ground biomass for each live and dead tree using diameter at breast height (DBH) and height-based individual tree biomass equations developed by Lambert et al. (2005) and Ung et al. (2008), as follows:

(1) $$y_i = \beta_{ik} D^{\beta ik} H^{\beta ik} + \varepsilon_i$$

where y_i is the dry biomass of component *i* for either: stem wood, stem bark, foliage or branches (kg), *D* is (DBH, cm), *H* is total tree height (m), β_{ik} are the parameter estimates (*i* is as above, *k* = 0, 1 or 2), and ε_i is the error term for the component *i*. Total above-ground biomass is calculated as the sum of the stem wood, bark, foliage and branch biomass. The total below-ground root biomass for each tree is calculated as a function of the total above-ground biomass using the equations developed by Li et al. (2003) for all softwoods and hardwoods. The equation forms are:

(2) $$RB_s = 0.222 AB_s$$ (3) $$RB_h = 1.576 AB_h^{0.615}$$

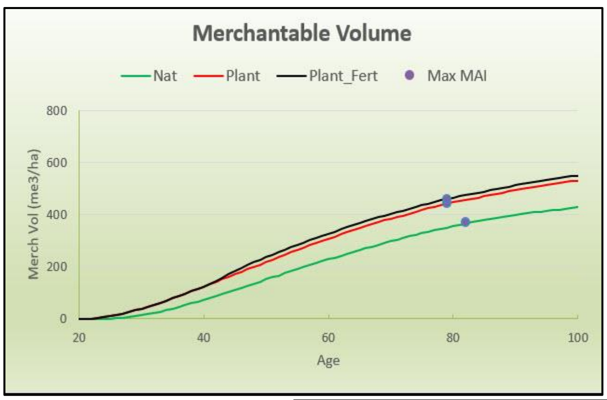
where *RB* and *AB* are root and above-ground biomass (kg) respectively, (subscript *s* denotes the softwood species group, and *h* is the hardwood species group). A conversion factor for temperate zones of 0.5 g C/g (Mattheus, 1993; Lamlom and Savidge, 2003) is used to convert biomass to carbon stock for each individual tree component, and carbon stock is multiplied by 3.67 to convert to carbon dioxide equivalent (CO_{2e}). The individual tree biomass calculated in TASS is aggregated into stand level yield tables reporting the live biomass stock and dead biomass stock change in oven dry units (O.D. tonnes/ha) for the bark, branches, foliage, stem wood, roots, and total (above- and below-ground) stand components. Similarly, it reports the live and dead carbon stock change in oven dry units (O.D. tonnes/ha) and CO_{2e} in tonnes per hectare for the same tree components.

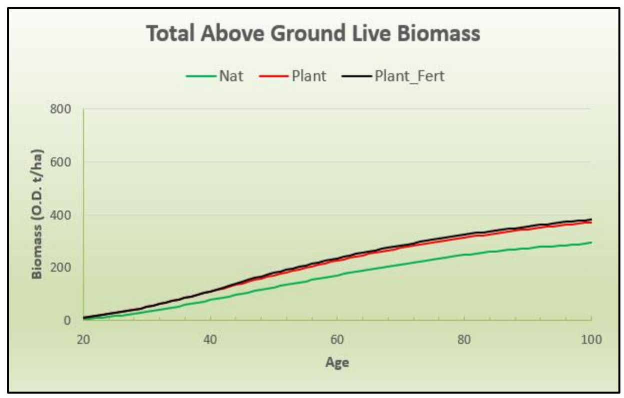
Example

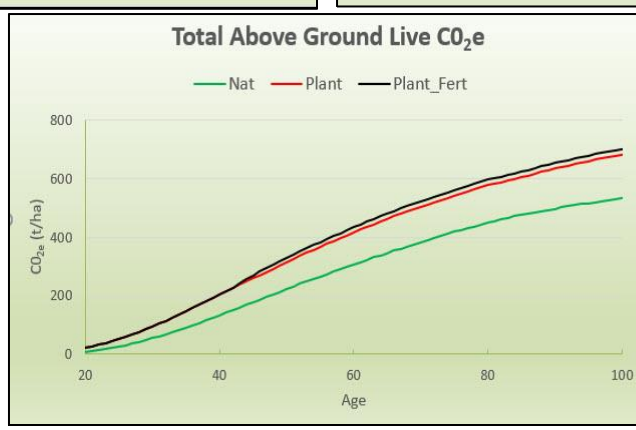
How does natural regeneration, planting and fertilization affect the production of merchantable volume, biomass, $C0_{2e}$, harvest age and economic return?

To answer this question we used TASS to generate merchantable volume, biomass and CO_{2e} products, and companion software called Financial Analysis of $ilviculture Investment and Economic Return (FAN$IER) to generate Site Value under four CO_{2e} price options (i.e. 20, 40, 60 and 80 CAN$/t$CO_{2e}$) using a discount rate of 4%. Analyses were run on three Lodgepole pine stands (i.e. naturally regenerated, planted and planted and fertilized at age 40) with the same initial density of 1200 trees per ha. growing on a site index of 20m. Site Value (SV) is the net present value of an infinite series of identical regimes; it enables comparisons involving different rotation ages. The costs used in the analyses were based on long-term local averages for Kamloops B.C.

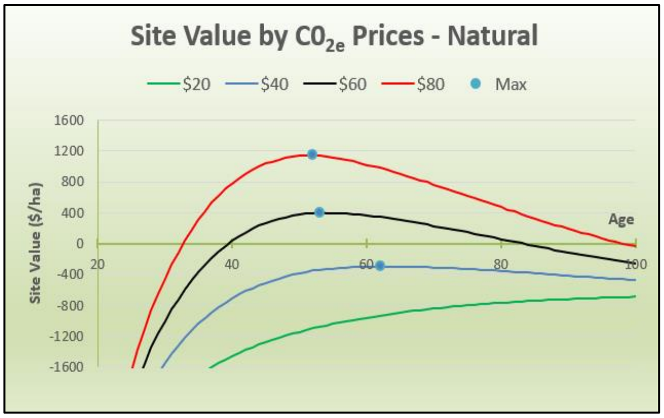
3-D images generated by TASS for the planted and naturally regenerated regimes at age 100.

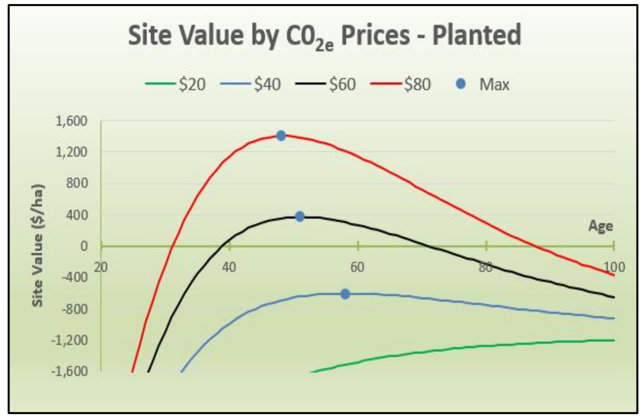


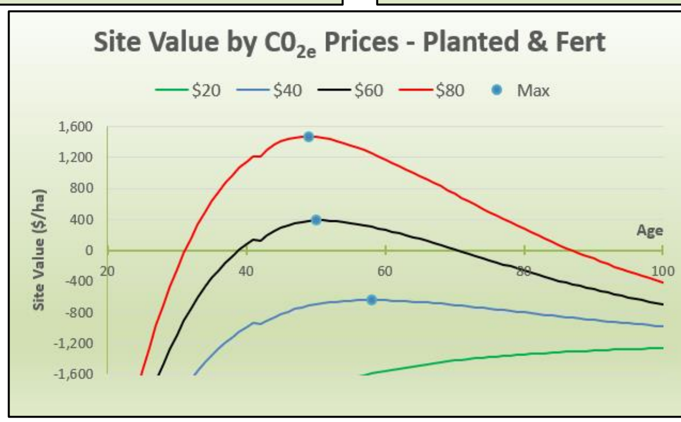




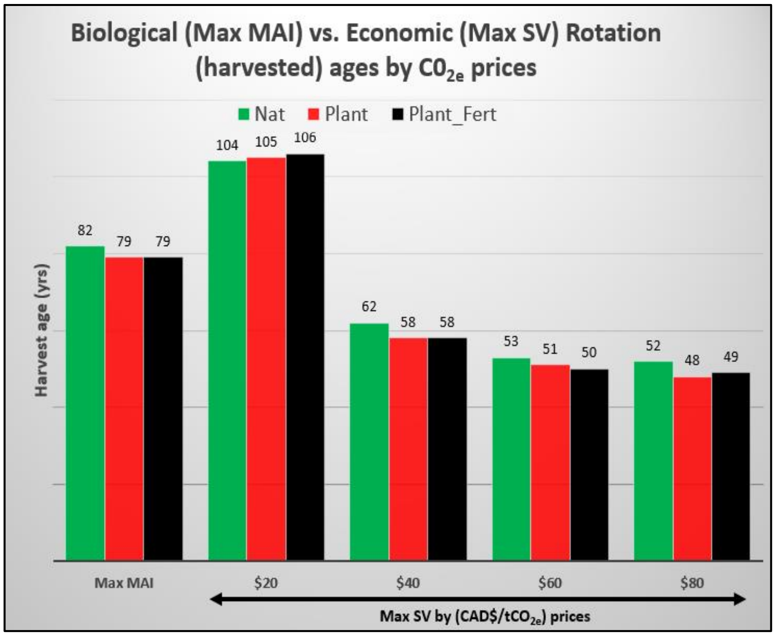
These three figures show merchantable volume (12.5+ cm DBH), total above ground live biomass and associated CO_{2e} for each of the three regimes. Max MAI (blue dots) reflects the biological rotation age of each regime, i.e., the age of maximum mean annual increment (MAI) for merchantable volume. Max MAI for the natural regeneration regime was 82 years and 79 years for both planted regimes. At age 80, a common harvest age in B.C., results indicate that the planted and fertilized regime is the most productive. It generated an additional 104 m^3/ha of merchantable volume, 77 O.D. tonnes/ha of biomass and 141 tonnes/ha of CO_{2e} over the natural regeneration regime.



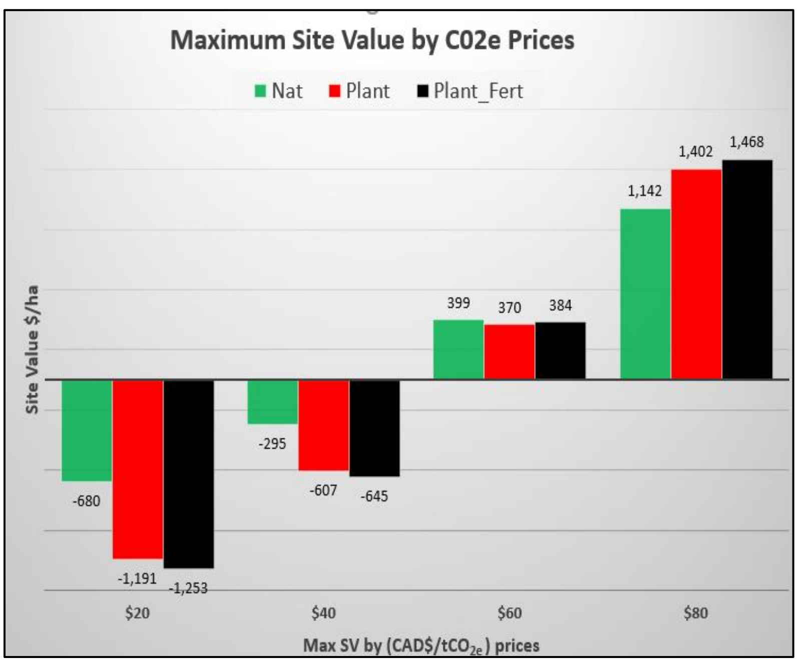




These figures show Site Value (SV, also known as soil expectation value or land rent) over age for each regime, at four CO_{2e} prices for the natural, planted and planted and fertilized regimes. SV is the net present value of an infinite series of identical regimes; it enables comparisons involving different rotation ages. As expected, SV is directly proportional to CO_{2e} price. Blue dots (Max) indicate the harvest ages which maximize SV, i.e., the economic rotation age. In all cases, economic rotation ages decrease as CO_{2e} prices increase.



This figure compares biological (Max MAI) versus economic (Max SV) rotation (harvest) ages at four CO_{2e} prices, for the three regimes. The average biological rotation for all the regimes was 80 years, while economic rotations averaged 105, 59, 51 and 50 years across the four CO_{2e} prices of 20, 40, 60 and 80 \$/tCO_{2e} respectively. The economic rotation occurs earlier than the biological rotation when the CO_{2e} prices are 40 \$/tCO_{2e} or higher.



This figure shows that the maximum SVs were negative (costs exceed product value) for all the regimes unless CO_{2e} prices are 60 \$/tCO_{2e} or higher.

Conclusion

In summary, TASS in combination with FAN$IER, enables B.C. forest managers to assess the economics of silviculture investments relative to biomass and CO_{2e} production. Such analyses consider both costs associated with the regeneration and stand tending, and potential future prices of these forest products. This poster demonstrates that planting plus fertilization can produce higher merchantable volumes, biomass, and CO_{2e} yields than natural regeneration or planting alone. Financial analyses indicated positive Site Values for both planted regimes when CO_{2e} prices are 60 $/t$CO_{2e}$ or higher. Site Value is directly proportional to CO_{2e} price. Using these tools will help guide forest management decision making in response to climate change.

References

Lambert, M.-C., Ung C.-H. and Raulier F. 1996. Canadian national tree biomass above ground biomass equations. Can. J. For. Res. 35:1996-2018.

Lamlom, S.H., and R.A. Savidge 2003. A reassessment of carbon content in wood: variation within and between 41 North American species. Biomass Bioenergy 25, 381-388.

Li, Z.; Kurz, W.A.; Apps, M.J.; Beukema, S.J. 2003 Belowground biomass dynamics in the Carbon Budget Model of the Canadian Forest Sector: recent improvements and implications for the estimation of NPP and NEP. 2003. Canadian Journal of Forest Research 33: 126-136.

Matthews, G. 1993. The carbon contents of trees. Forestry Commission, Surrey, UK.

Mitchell, K. J. 1969. Simulation of the growth of even-aged stands of white spruce. *In* Yale Univ. School of Forestry Bull. No. 75, Yale University, New Haven, Conn.

Mitchell, K. J. 1975. Dynamics and simulated yield of Douglas-fir. Forest Science Monography 17.

Ung, C.-H., Bernier, P. and Guo, X.-J. 2008. Canadian national biomass equations: new parameter estimates that include British Columbia data. Can. J. For. Res. 38:1123-1132.

Growth and Yield Modelling – Province of British Columbia

Tree and Stand Simulator (TASS)

Financial Analysis of $ilviculture Investment and Economic Return (FAN$IER)

Forest Carbon Strategy