EXPLORING THE CANOPY QUANTUM EFFICIENCY PARAMETER USING 3-PG IN SHELTERBELTS

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To use shelterbelts for climate change mitigation planning, carbon sequestration over time needs to be precisely predicted according to the environment, age, species and management. Model 3-PG is a hybrid forestry model that accounts for these factors and was used to model shelterbelt growth in past studies. However, an accurate accounting of specific growth conditions was missing, due to the lack of input data. We retrieved diameter growth data from increment cores and use it in this study. Our goal was to test model reliability when fitting with increment core data as input variables. The second goal was to test how geographically specific fitting needs to be for reliable modeling, tree-, site- or regionally-specific. The third goal of this study was to test modeling reliability over the years of a tree's life. Carbon stocks were therefore estimated at tree-, site- and regionally-specific scales, and the results were compared.

METHODS

Twenty-nine trees of the six main shelterbelt species were cut and sampled for total height, diameter at breast height, diameter at every one metre up to the total tree height, leaf area, branch and foliage biomass, spacing between trees and lines of trees, and crown width. The 3-PG model was fitted tree-specifically, and validated by varying the canopy quantum efficiency parameter site-specifically and regional-specifically for each species. Tree, site and regional modeling were assessed by the root mean square error (RMSE), bias, and coefficient of determination (R^2). Tree fitting was also assessed at every five-year age class to assess modeling reliability through time.

RESULTS

Increment core-related data was proven reliable as input data for the 3-PG model. The most precise modeling was tree-specific, not very divergent from the local-specific modeling (Table 1, Figure 1). The worst modeling was regionally specific (Table 1, Figure 1). Modeling precision decreased through time from the last measured diameter (near the bark) towards the pith (Table 2).

IMPLICATIONS

Increment core-related data was reliable as an input in the 3-PG model, even though accuracy decreased through time from the rings near the bark, towards the pith. This means that more data is available for carbon stock modeling. More carbon sequestration modeling implies a better ability to plan for future climatic change.

Table 1 - Average alpha, root mean square error (RMSE), bias, and coefficient of determination (R^2) for predicted DBH. Note: The standard deviation for tree fitting, local, and regional value validations are listed beside each calculation in parentheses; Green ash (GA), Manitoba maple (MM), white spruce (WS), caragana (CG) and hybrid poplar (HP) trees sampled in SK, Canada.

	Species	alpha	RMSE	Bias	R^2
Tree	GA	0.0098 (0.0038)	10.53 (3.45)	-9.54 (18.63)	0.97 (0.03)
	SP	0.011	12.6	20.88	0.98
	MM	0.0077 (0.0015)	39.07 (26.39)	-30.56(81.78)	0.99 (0.01)
	WS	0.0175 (0.0098)	23.75 (12.00)	-65.19 (89.76)	0.97 (0.02)
	CG	0.0033 (0.0012)	25.56 (9.25)	26.39 (7.38)	0.87 (0.05)
	HP	0.0306 (0.0186)	11.98 (8.16)	-0.67(12.72)	0.98 (0.03)
	Average		20.58	-9.78	0.96
Local	GA	0.012 (0)	12.23 (0.59)	-10.36 (21.58)	0.97 (0.04)
	SP				
	MM	0.007 (0.01)	28.64 (15.62)	-5.11 (34.36)	0.99 (0.01)
	WS	0.019 (0.02)	114.07 (128.73)	-94.12 (238.20)	0.96 (0.05)
	CG	0.0042 (0.01)	41.54 (6.37)	29.3 (29.30)	0.20 (0.06)
	HP	0.027 (0.02)	58.35 (48.74)	-23.19 (89.57)	0.98 (0.02)
	Average		50.97	-20.70	0.78
Regional	GA	0.03	137.58 (90.66)	-197.38 (128.68)	0.97 (0.03)
	SP	0.05	229.42	-252.62	0.99
	MM	0.03	198.98 (65.81)	-220.07 (75.09)	0.99 (0.01)
	WS	0.05	262.65 (182.61)	-537.44 (289.35)	0.95 (0.05)
	CG	0.0177	444.98 (240.45)	-432.81 (377.14)	0.20 (0.08)
	HP	0.03	60.92(104.08)	-50.44 (152.18)	0.97 (0.03)
	Average		222.42	-281.79	0.85

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Tree and local-specific fittings were considered reliable for carbon stock modeling, meaning that farm-specific carbon footprints can be calculated in a practical manner, as described in this study. Farm specific carbon

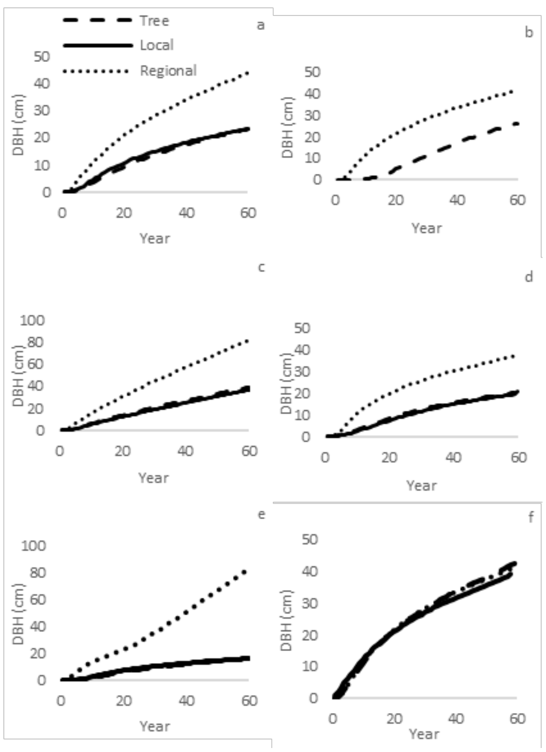

Figure 1 - Figure 5.2 - Predicted diameters over time for each species for fitting, local, and regional validations. The trees are, a) Green ash (n=3); b) Scots pine (n=1); c) Manitoba maple (n=3); d) White spruce (n=10); e) Caragana (n=4); f) Hybrid poplar (n=8). Note: n = number of trees from each species.

Table 2 - RMSE for trees at each 5-year age class into the past. Note: the number of trees used in the average calculation for that class is in parentheses. If there are no parentheses, it indicates that only one tree was used for the calculation.

	RMSE								
Age	45	40	35	30	25	20	15	10	5
8									10.71
12								8.07	4.91
13								18. 85 (2)	11.31
14								6.23	6.49
15								23.16	11.21
18							29.57	19.64	16.04
20						17.08	16. 29 (2)	13.38	9.35
21						24.42	21.45	10.44	9.22
23						24.13 (2)	18.50	11.05	11.48
25					11.39	39.39 (2)	33.12	29.32	24.65
26							21.09	12.44	7.26
28					7.63	7.11	6.84	5.48	4.26
29					16.00 (2)	10.76	9.01	8.59	8.38
30				20.85 (2)	17.07	14.89	12.88	12.17	12.70
36						22.33	12.76	8.85	10.32
39			22.53	21.20	19.00	17.70	17.60	19.25	22.49
43		31.11	29.33	25.59	21.04	16.52	12.59	9.45	2.84
46		12.60	11.20	8.85	6.68	5.81	6.06	5.62	4.03
47		34.28 (2)	24.32	19.75	16.01	13.34	11.23	9.41	8.39
48					13.57	4.44	2.74	2.89	3.30
49	14.4	13.71	12.88	12.53	12.34	12.76	13.79	14.95	15.20
56		6.63	5.32	4.65	4.74	4.88	5.22	5.38	5.76
Average	14.44	16.01	17.60	15.43	12.95	13.23	14.65	11.79	10.01

footprints can support policies rewarding farmers for sequestering carbon or to create a carbon market to benefit negative emissions, for example. If applied, those policies can motivate farmers to plant trees, mitigate climate change more efficiently, and raise the popularity of carbon pricing policies.

The 3-PG modeling was accurate to model shelterbelt carbon stocks and is especially beneficial since the model accounts for environmental variables that are changing beyond the known records into the future. This robust model with local-specific fittings makes this method dependable and safe to be used through the years across a wide geographic range.

FURTHER READING: Mayrinck, R. C. (2021). PhD dissertation, University of Saskatchewan.

CONTACT FOR MORE INFORMATION: SASKAGROFORESTRY.CA/

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