Tree Growth Submodels for the US Northern Forest

Results for Operational Versions

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Diameter Growth Submodel

Table 1: Results of diameter growth submodel, tested against an independent dataset. Diameter growth is measured in inches per year.

Species	***n***	***mean Δdbh***	***RMSE***	***nRMSE***	***MAE***	R^2
fir	15165	0.096	0.0524	0.546	0.0364	0.584
spruce	10580	0.091	0.0528	0.580	0.0383	0.536
soft maple	9048	0.090	0.0630	0.700	0.0454	0.312
hard maple	5292	0.092	0.0626	0.680	0.0462	0.339
cedar	5248	0.072	0.0484	0.672	0.0332	0.319
beech	4600	0.102	0.0607	0.595	0.0447	0.410
yellow birch	4070	0.104	0.0655	0.630	0.0497	0.404
paper birch	3800	0.057	0.0483	0.847	0.0359	0.351
hemlock	3287	0.128	0.0588	0.459	0.0439	0.511
white pine	2351	0.188	0.0971	0.516	0.0701	0.535
aspen	1848	0.151	0.0807	0.534	0.0597	0.451
ash	1708	0.101	0.0714	0.707	0.0497	0.369
other hardwood	1163	0.066	0.0590	0.894	0.0404	0.323
striped maple	1092	0.072	0.0476	0.661	0.0356	0.341
red oak	750	0.162	0.0818	0.505	0.0605	0.399
black cherry	504	0.112	0.0824	0.736	0.0593	0.294
hophornbeam	445	0.040	0.0541	1.353	0.0427	0.173
tamarack	382	0.115	0.0735	0.639	0.0552	0.545
norway spruce	216	0.089	0.0677	0.761	0.0463	0.656
elm	167	0.152	0.0969	0.638	0.0675	0.375
red pine	167	0.153	0.1139	0.744	0.0848	0.135
basswood	125	0.101	0.0714	0.707	0.0571	0.247
white oak	55	0.100	0.0704	0.704	0.0575	0.273
hickory	51	0.137	0.0933	0.681	0.0732	0.190
other softwood	40	0.070	0.0393	0.561	0.0301	0.281
scots pine	12	0.184	0.0890	0.484	0.0752	0.707
butternut	9	0.196	0.1743	0.889	0.1463	0.134
cottonwood	8	0.269	0.2575	0.957	0.1574	0.477
Combined	***72183***	***0.097***	***0.0604***	***0.623***	***0.0428***	***0.496***

Height Submodel

Table 2: Results of total height submodel, tested against an independent dataset. Height is measured in feet.

Species	***n***	***mean height***	***RMSE***	***nRMSE***	***MAE***	R^2
fir	8668	38.254	6.0615	0.158	4.7254	0.712
spruce	7998	44.119	6.5018	0.147	5.0940	0.765
soft maple	7053	52.514	7.7228	0.147	6.0505	0.623
hard maple	4261	55.905	8.1302	0.145	6.4092	0.628
cedar	4225	38.519	5.9381	0.154	4.5962	0.622
yellow birch	3308	49.283	7.7522	0.157	6.1210	0.593
beech	3207	45.380	8.2155	0.181	6.4265	0.579
paper birch	3022	46.149	6.8784	0.149	5.4216	0.639
hemlock	2919	45.026	8.3610	0.186	6.6048	0.701
white pine	2079	53.281	9.3608	0.176	7.3831	0.822
aspen	1715	57.675	8.3944	0.146	6.5089	0.665
ash	1423	54.040	8.8150	0.163	6.9018	0.651
red oak	599	57.940	9.3022	0.161	7.3396	0.530
other hardwood	537	35.838	9.6955	0.271	7.4841	0.388
black cherry	494	52.960	9.2482	0.175	7.2037	0.664
red pine	393	46.840	8.4569	0.181	7.2442	0.915
tamarack	276	56.931	10.4692	0.184	8.6219	0.812
hophornbeam	243	43.230	7.2770	0.168	5.8168	0.278
striped maple	215	32.670	6.2470	0.191	4.8724	0.681
elm	181	44.989	7.1845	0.160	5.7058	0.558
norway spruce	165	55.655	7.9446	0.143	6.1768	0.675
basswood	90	54.111	7.5438	0.139	5.6710	0.687
white oak	78	45.910	7.2185	0.157	5.4094	0.765
hickory	66	61.545	15.5868	0.253	13.3014	0.503
scots pine	65	51.923	11.2545	0.217	8.7622	0.430
other softwood	64	48.219	13.1091	0.272	10.1022	0.681
cottonwood	12	63.833	14.5137	0.227	11.4774	0.645
butternut	6	56.000	10.7062	0.191	7.9557	0.076
Combined	***53362***	***46.681***	***7.4671***	***0.160***	***5.7885***	***0.738***

Height Growth Submodel

Table 3: Results of height growth submodel, tested against an independent dataset. Height growth is measured in feet per year.

Species	***n***	***mean Δht***	***RMSE***	***nRMSE***	***MAE***	R^2
fir	7478	0.680	1.0329	1.519	0.7796	0.008
spruce	7439	0.427	1.0576	2.477	0.7843	0.000
soft maple	6831	0.326	1.4249	4.371	1.0954	0.004
cedar	4229	0.148	1.1538	7.796	0.8721	0.024
hard maple	4074	0.225	1.4427	6.412	1.1013	0.002
beech	3167	0.304	1.4059	4.625	1.0749	0.003
hemlock	3153	0.555	1.1023	1.986	0.8256	0.000
yellow birch	3065	0.364	1.4510	3.986	1.1075	0.004
paper birch	2614	0.128	1.4391	11.243	1.0947	0.005
white pine	2162	0.866	1.3530	1.562	1.0084	0.004
aspen	1487	0.635	1.5429	2.430	1.2025	0.003
ash	1333	0.380	1.5489	4.076	1.2107	0.002
red oak	767	0.609	1.5518	2.548	1.2164	0.020
other hardwood	443	0.431	1.2042	2.794	0.9206	0.000
black cherry	404	0.755	1.3431	1.779	1.0218	0.000
tamarack	404	0.768	1.3044	1.698	1.0255	0.013
hophornbeam	279	0.242	1.2902	5.331	0.9832	0.021
norway spruce	221	0.923	1.1295	1.224	0.8393	0.098
red pine	212	0.568	1.0897	1.918	0.8915	0.018
elm	154	0.868	1.2468	1.436	0.9696	0.000
striped maple	128	0.333	1.0965	3.293	0.8777	0.001
basswood	120	0.769	1.4976	1.947	1.1409	0.006
white oak	70	0.555	1.1386	2.052	0.8558	0.012
hickory	57	1.058	1.3366	1.263	0.9553	0.017
scots pine	40	-0.162	1.2725	-7.855	1.1382	0.154
butternut	9	0.840	1.3837	1.647	1.0679	0.220
cottonwood	4	0.789	1.1628	1.474	0.9614	0.643
other softwood	4	0.039	0.9683	24.828	0.8199	0.234
Combined	***50348***	***0.428***	***1.2822***	***2.996***	***0.9645***	***0.002***

Crown Ratio Change Submodel

Table 4: Results of crown ratio change submodel, tested against an independent dataset. Crown ratio change is measured in change of percent per year, with positive numbers indicating increasing crown ratios.

Species	***n***	***mean ΔCR***	***RMSE***	***nRMSE***	***MAE***	R^2
fir	15165	-1.151	3.0326	-2.635	2.3486	0.010
spruce	10580	-0.553	2.9367	-5.310	2.2625	0.003
soft maple	9048	0.030	2.5559	85.197	1.9481	0.012
hard maple	5292	0.128	2.6913	21.026	2.0492	0.020
cedar	5248	-0.223	3.2061	-14.377	2.4567	0.057
beech	4600	0.019	3.5787	188.353	2.7307	0.022
yellow birch	4070	-0.002	2.9180	-1459.000	2.2232	0.027
paper birch	3800	-0.241	2.4172	-10.030	1.8417	0.003
hemlock	3287	0.117	3.1991	27.343	2.4798	0.042
white pine	2351	-0.620	2.7964	-4.510	2.1421	0.003
aspen	1848	-0.212	2.5440	-12.000	1.9422	0.008
ash	1708	-0.196	2.5844	-13.186	1.9405	0.001
other hardwood	1163	-0.731	3.3557	-4.591	2.5649	0.021
striped maple	1092	-0.510	2.8748	-5.637	2.1762	0.011
red oak	750	0.605	2.6174	4.326	1.9350	0.076
black cherry	504	-0.292	2.3854	-8.169	1.7816	0.004
hophornbeam	445	-0.367	3.0676	-8.359	2.3894	0.005
tamarack	382	-0.468	2.8352	-6.058	2.2444	0.000
norway spruce	216	-0.333	2.6860	-8.066	2.0722	0.001
elm	167	-0.560	2.8857	-5.153	2.2877	0.000
red pine	167	-0.667	2.3757	-3.562	1.8691	0.134
basswood	125	-0.015	2.5354	-169.027	1.8886	0.003
white oak	55	-0.386	2.6739	-6.927	2.2777	0.012
hickory	51	-0.141	1.8380	-13.035	1.5079	0.001
other softwood	40	-0.292	1.7061	-5.843	1.1633	0.053
scots pine	12	-0.840	1.9206	-2.286	1.6098	0.060
butternut	9	-0.834	2.5043	-3.003	2.1618	0.572
cottonwood	8	-1.549	2.9940	-1.933	2.3391	0.029
Combined	***72183***	***-0.387***	***2.9217***	***-7.550***	***2.2295***	***0.001***

Survival Submodel

Where results depend on a positive class, the positive class is "lived".

Table 5: Overall accuracy estimates, calculated on independent data

	x
Accuracy	0.959
Kappa	0.131
AccuracyLower	0.957
AccuracyUpper	0.960
AccuracyNull	0.957
AccuracyPValue	0.020
McnemarPValue	0.000

Table 6: Accuracy estimates by class, calculated on independent data

	x
Sensitivity	0.998
Specificity	0.078
Pos Pred Value	0.960
Neg Pred Value	0.645
Precision	0.960
Recall	0.998
F1	0.979
Prevalence	0.957
Detection Rate	0.955
Detection Prevalence	0.995
Balanced Accuracy	0.538

Table 7: Confusion matrix. Columns are actual, observed outcomes; rows are predicted outcomes.

	died	lived
died	258	142
lived	3058	73841

The AUROC, calculated on independent data, was estimated to be 0.8135774, with a confidence interval between 0.8057681 and 0.8213867.