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MORE LAKE STATES TREE SURVIVAL PREDICTIONS

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ABSTRACT.—Species coefficients are reported for predicting individual tree survival for nine Lake States species, supplementing a previous report for 10 species. Tree attributes are diameter growth rate and diameter at breast height. Regional and local performances are summarized.

KEY WORDS: Mortality rates, mortality models, survival model, mortality coefficients, tree risk.

This note presents annual survival prediction coefficients for nine important Lake States tree species and describes the supporting data and tests. Its organization, computations, and tables parallel those of Buchman's (1983) report for 10 other tree species. The underlying mathematical model was presented by Buchman *et al.* (1983).

The data base for each species consisted of at least 1,000 tree-records and more than 3,000 for four species (table 1). For five species, the interval between tree measurements was no more than 6 years. However, for white spruce, black spruce, northern white-cedar, and hickory, the measurements were separated by 10 to 13 years.

The coefficients for individual species (table 2) were computed using diameter-growth-rate (DGR) data from trees well distributed over the growth-rate range. However, the diameter (DBH) distribution was not as extensive (table 4); there were few, if any, records for trees less than 4.6 inches DBH for northern white-cedar, hemlock, yellow birch, white oak, red oak, and hickory.

RESULTS

The "regional" performance of the model for each species is shown for DGR (table 3) and DBH (table 4) using data from across the Lake States. Tree-record data were assembled into 12 DGR classes for each species; 90 of these classes had 50 or more records each (table 3). In 23 of these classes the predicted annual survival rate differs from the calculated rate by more than 0.005; in 5 classes the difference is greater than 0.01. The 23 classes are concentrated among the slow-growing trees but show no positive or negative difference pattern.

Tree-record data were assembled into 21 DBH classes by species; 91 of these classes had 50 or more records each (table 4). In 13 of these classes, scattered among the DBH classes, the predicted annual survival rate differs from the calculated rate by more than 0.005. Four classes have a difference greater than 0.01. Only three of the nine species had many trees less than 4.6 inches DBH.

"Local" performance of the model is shown within at least two individual stands for each species (table 5). In each stand, the number of trees observed alive at the time of remeasurement was compared with the calculated survival based on the model and the number of years in the remeasurement interval. The largest discrepancy, based on the annual survival rate, is found on the third line for white spruce where the difference is 0.036. With 30 of 33 trees surviving for 7 years, the actual annual rate is 0.986 while the

predicted rate based on 23 surviving is 0.950. For 42 of the 52 stands, the actual annual survival rate was within 0.01 of the rate calculated from the predicted survival.

DISCUSSION

The coefficients calculated for each of these nine tree species were based on more than 1,000 tree records from across the Lake States. All growth classes were well represented in this base. There was poor representation for the small diameter trees for six species. This base is not as strong as that for the previous 10-species report (Buchman 1983).

The model shows close agreement between predicted and calculated annual survival rates. The main differences encountered were among the slow-growing trees. However, these differences were generally offset by opposite differences from adjoining DGR classes. The DBH classes showing large differences were well scattered among species over the DBH range.

The model's performance within stands showed the predicted number of trees surviving equaled the actual count in 22 of 52 stands. The annual survival rate errors for the 30 remaining stands were generally less than 0.01 and the result of underestimating survival.

LITERATURE CITED

Buchman, R. G. Survival predictions for major Lake States tree species. Res. Pap. NC-233. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1983 7 p.

Buchman, R. G.; Pederson, S. P.; Walters, N. R. A tree survival model with application to species of the Great Lakes region. Can. J. For. Res. 13(4); 601-608; 1983.

Table 1.--Tree survival data sources

(In number of tree records)

Tree species	Total	North Central Minnesota (research)	Minnesota Wisconsin (BIA)	Wisconsin (timber harvest forest)	Wisconsin (private woodlot)	Wisconsin (forest industry)	North West Wisconsin (research)	North East Wisconsin (research)	Upper Michigan (DNR)	Lower Michigan (research)
White spruce	3,548	7	0	0	0	0	601	2,940	0	0
Black spruce	3,546	1,782	0	0	0	0	0	845	919	0
N. white-cedar	1,958	0	476	0	0	0	0	0	1,482	0
Hemlock	1,447	0	625	570	0	0	0	252	0	0
Yellow birch	1,129	0	0	380	0	252	0	497	0	0
White ash	2,818	0	0	261	166	165	0	2,226	0	0
White oak	1,258	62	0	173	1,023	0	0	0	0	0
Red oak	3,378	9	0	940	1,941	291	0	140	0	57
Hickory	3,573	0	0	88	3,485	0	0	0	0	0

1 Number of tree records, several records for some trees.

Table 2.--Model[1] coefficients for predicting annual tree survival from diameter growth rate (DGR) and diameter at breast height (DBH)

Species	b_1	b_2	b_3	b_4	b_5	b_6	b_7
White spruce	0.9994	0.9724E+0	0.3142E+3	0.1915E+1	0.2839E+0	0.1302E+1	0.1683E+0
Black spruce	.9946	.1699E+1	.5378E+2	.1219E+1	.6828E+0	.9598E+0	.2250E+0
N. white-cedar	.9990	.2208E+1	.8674E+2	.1000E+1	.1931E+0	.1588E+1	.2157E+0
Hemlock	.9991	.3076E+1	.2714E+2	.1101E+1	.6678E-1	.3491E+1	.4888E+0
Yellow birch	.9975	.2203E+1	.1911E+2	.8298E+0	.1517E+1	.2169E+1	.7958E+0
White ash	.9992	.1315E+1	.1393E+4	.2484E+1	.3413E-1	.4970E+1	.8110E+0
White oak	.9994	.2291E+1	.1000E+4	.1850E+1	.6576E-1	.4228E+1	.7366E+0
Red oak	.9977	.5639E+0	.2909E+2	.1137E+1	.1004E-1	.3834E+1	.3177E+0
Hickory	.9980	.2012E+1	.3140E+3	.2452E+1	.1149E-1	.4102E+1	.3479E+0

1 $SR = b_1 - [1/(1+e^n)]$
where n is $b_2 + b_3 \cdot DGR^{b4} + b_5 \cdot (DBH - 1)^{b6} \cdot e^{-b7} \cdot (DBH-1)$
and $b_1, \ldots, b_7$ are species constants.

Table 3.--Measured and predicted annual tree survival rates by diameter growth rate (DGR) for nine Lake States tree species

DGR[1] (in/yr)	Survival rate[2]	White spruce	Black spruce	N.white-cedar	Hemlock	Yellow birch	White ash	White oak	Red oak	Hickory
0.00	Mea.	0.8105	0.9289	0.9612	0.9939	0.9497	0.9084	0.9625	0.8555	0.9919
	Pre.	.8286	.9278	.9562	.9884	.9415	.9031	.9648	.8698	.9908
	Base[3]	214	119	57	111	61	58	43	37	1,429
.02	Mea.	.8448	.9537	.9942	.9862	.9546	.8948	.9795	.9138	1.0000
	Pre.	.8467	.9503	.9856	.9924	.9719	.9172	.9800	.9371	.9580
	Base	215	224	111	46	47	32	66	66	6
.04	Mea.	.9026	.9668	.9921	.9949	.9800	.9461	.9980	.9490	1.0000
	Pre.	.8849	.9676	.9953	.9937	.9798	.9346	.9952	.9510	.9705
	Base	252	423	203	121	91	119	108	136	13
.06	Mea.	.9387	.9816	.9973	.9938	.9894	.9931	.9974	.9805	1.0000
	Pre.	.9313	.9797	.9983	.9956	.9874	.9730	.9991	.9757	.9766
	Base	253	503	484	186	110	95	162	204	12
.08	Mea.	.9741	.9853	.9979	.9960	.9910	.9853	.9989	.9881	1.0000
	Pre.	.9742	.9869	.9989	.9967	.9905	.9893	.9994	.9833	.9900
	Base	252	494	273	166	125	186	192	305	13
.10	Mea.	.9921	.9906	.9989	.9956	.9865	.9970	1.0000	.9915	.9978
	Pre.	.9922	.9910	.9990	.9975	.9933	.9980	.9994	.9900	.9963
	Base	350	611	411	280	167	221	189	439	1,718
.12	Mea.	.9970	.9968	.9992	1.0000	1.0000	.9983	1.0000	.9959	1.0000
	Pre.	.9982	.9930	.9990	.9982	.9945	.9991	.9994	.9935	.9878
	Base	228	361	117	78	78	116	137	355	3
.14	Mea.	.9982	.9966	1.0000	.9939	.9947	.9958	1.0000	.9955	1.0000
	Pre.	.9991	.9938	.9990	.9982	.9956	.9992	.9994	.9949	.9934
	Base	271	383	96	100	127	260	123	372	10
.16	Mea.	.9996	.9953	1.0000	1.0000	1.0000	.9990	.9975	.9993	1.0000
	Pre.	.9994	.9943	.9990	.9985	.9962	.9992	.9994	.9960	.9947
	Base	304	212	99	111	75	210	82	321	5
.18	Mea.	.9995	.9900	.9967	1.0000	1.0000	1.0000	1.0000	.9968	1.0000
	Pre.	.9994	.9945	.9990	.9988	.9966	.9992	.9994	.9967	.9979
	Base	270	109	27	66	68	246	61	332	7
.20	Mea.	.9993	.9912	.9982	.9976	1.0000	.9989	1.0000	.9991	.9947
	Pre.	.9994	.9946	.9990	.9989	.9969	.9992	.9994	.9972	.9980
	Base	605	56	47	91	73	357	43	246	330
Rest[4]	Mea.	.9998	.9878	1.0000	1.0000	.9958	.9991	.9961	.9980	1.0000
	Pre.	.9994	.9946	.9990	.9990	.9973	.9992	.9994	.9975	.9980
	Base	605	51	33	91	107	918	52	565	27

[1] Upper limit of DGR interval, first interval contains trees of no measurable growth.
[2] Measured annual survival rate and the predicted annual survival rate.
[3] Number of tree records.
[4] Includes all trees growing more than 0.2 inch per year.

Table 4.--Measured and predicted annual tree survival rates by diameter class (DBH) for nine Lake States tree species

DBH[1] (in)	Survival rate[2]	White spruce	Black spruce	N.white-cedar	Hemlock	Yellow birch	White ash	White oak	Red oak	Hickory
1	Mea.	0.8085	0.9588						0	
	Pre.	.8230	.9436						.6873	
	Base[3]	29	13	0	0	0	0	0	3	0
2	Mea.	.8349	.9827				0.8661		0	1.0000
	Pre.	.8645	.9752				.8359		.7821	.9252
	Base	272	160	0	0	0	13	0	7	8
3	Mea.	.9349	.9907				.8620		0	1.0000
	Pre.	.9409	.9829				.8929		.8248	.9655
	Base	575	439	0	0	0	35	0	10	5
4	Mea.	.9803	.9900			.8776	.9597		.7324	1.0000
	Pre.	.9764	.9865			.9904	.9454		.8706	.9571
	Base	891	451	0	0	7	111	0	17	12
5	Mea.	.9943	.9818	.9965	.9945	.9871	.9782	.9790	.9115	1.0000
	Pre.	.9911	.9805	.9929	.9923	.9871	.9804	.9845	.9109	.9575
	Base	741	484	115	109	125	209	13	47	8
6	Mea.	.9995	.9826	.9977	.9923	.9873	.9944	1.0000	.9737	.9727
	Pre.	.9971	.9831	.9970	.9959	.9915	.9938	.9837	.9535	.9744
	Base	487	836	538	174	228	321	7	93	7
7	Mea.	.9995	.9781	.9982	.9933	.9894	.9972	.9918	.9699	.9929
	Pre.	.9981	.9840	.9974	.9967	.9904	.9973	.9940	.9706	.9890
	Base	288	608	411	164	193	390	53	123	577
8	Mea.	.9987	.9847	.9973	.9986	.9864	.9980	.9943	.9971	.9943
	Pre.	.9988	.9840	.9976	.9972	.9892	.9981	.9960	.9841	.9934
	Base	132	286	305	146	134	423	112	152	954
9	Mea.	.9959	.9813	.9960	.9938	.9897	.9978	.9957	.9891	.9958
	Pre.	.9989	.9834	.9970	.9974	.9862	.9976	.9973	.9877	.9957
	Base	93	156	188	135	128	362	145	166	840
10	Mea.	1.0000	.9897	.9950	.9982	.9932	.9981	1.0000	.9925	.9975
	Pre.	.9957	.9838	.9974	.9974	.9904	.9972	.9979	.9911	.9969
	Base	26	73	119	122	99	325	176	241	437
11	Mea.	.9834	.9761	.9923	1.0000	.9925	.9968	1.0000	.9956	.9960
	Pre.	.9848	.9864	.9956	.9970	.9893	.9965	.9985	.9940	.9973
	Base	14	26	119	135	59	249	123	309	298
12	Mea.		.9830	.9966	.9978	1.0000	.9987	.9983	.9903	.9931
	Pre.		.9836	.9959	.9970	.9919	.9976	.9972	.9942	.9974
	Base	0	14	63	92	32	159	126	300	177
13	Mea.			.9945	.9969	.9885	.9975	1.0000	.9959	.9948
	Pre.			.9988	.9972	.9874	.9990	.9985	.9952	.9975
	Base	0	0	36	74	38	81	76	319	110
14	Mea.			1.0000	1.0000	.9908	.9964	.9975	.9963	1.0000
	Pre.			.9971	.9969	.9841	.9970	.9992	.9949	.9974
	Base	0	0	21	82	26	59	83	286	73
15	Mea.			.9878	.9963	.9963	.9940	.9927	.9991	1.0000
	Pre.			.9986	.9964	.9868	.9946	.9954	.9953	.9973
	Base	0	0	43	64	59	34	86	227	44
16	Mea.				.9966		.9906	1.0000	.9948	1.0000
	Pre.				.9968		.9990	.9984	.9951	.9975
	Base	0	0	0	61	0	47	58	242	23
17	Mea.				.9917			1.0000	.9989	
	Pre.				.9962			.9988	.9948	
	Base	0	0	0	26	0	0	37	192	0
18	Mea.				1.0000			1.0000	.9974	
	Pre.				.9969			.9977	.9946	
	Base	0	0	0	15	0	0	31	160	0
19	Mea.				.9965			1.0000	.9901	
	Pre.				.9960			.9982	.9948	
	Base	0	0	0	48	0	0	34	128	0
20	Mea.							.9861	1.0000	
	Pre.							.9980	.9941	
	Base	0	0	0	0	0	0	15	96	0
21	Mea.							.9925	.9973	
	Pre.							.9986	.9928	
	Base	0	0	0	0	0	0	81	78	0

1 Midpoint of DBH interval, last entry for a species includes that DBH and larger trees.
2 Measured annual survival rate and predicted annual rate.
3 Number of tree records.

Table 5.--Performance of survival rate prediction model for selected forest areas

Stand description									Survival results					
SP[1]	Area and origin[2]			Plots	SP[3] SI	Basal area All	Basal area SP	DBH SP	Beg. obs.	End obs.	End pre.	Yrs[4]	Std dev.[5]	Slope
				No.	Ft	Ft²/ac		In.	---No. of trees---					
WS	EC	WISC	RP	12	65	202	202	5.4	1,277	966	966	10	.2833E+2	0.940
	NE	WISC	RN	6	--	100	2	2.8	25	25	24	5	.2870E+1	1.072
	NE	WISC	RN	7	--	153	5	4.7	33	30	23	7	.6050E+1	1.573
	NW	WISC	RP	20	55	134	134	6.0	612	566	549	3	.2343E+2	0.907
BS	NE	WISC	RN	14	--	93	10	4.1	99	93	89	6	.1396E+2	0.906
	NE	WISC	RN	10	41	76	19	6.8	81	73	68	8	.1648E+2	0.842
	NC	MINN	RN	12	33	80	76	3.8	886	883	842	6	.1923E+2	0.949
	NE	MINN	RN	45	--	70	31	7.2	117	101	100	7	.1808E+2	0.970
	UP	MICH	SN	30	--	74	16	7.2	49	35	42	9	.1796E+2	0.760
	UP	MICH	SN	32	--	52	17	7.0	63	53	51	11	.1044E+2	1.002
	UP	MICH	SN	24	--	82	19	7.2	70	58	56	12	.1212E+2	0.861
WC	EC	WISC	FN	9	--	137	68	8.1	178	177	173	5	.3140E+1	0.983
	UP	MICH	SN	48	--	106	69	7.7	199	193	193	12	.6810E+1	0.972
HL	NE	WISC	TN	5	--	80	22	10.9	32	32	31	7	.4200E+0	0.983
	NE	WISC	TN	4	--	83	22	11.5	25	25	24	6	.6100E+0	0.978
	NE	WISC	RN	23	--	96	16	10.9	25	23	23	4	.1700E+0	0.993
	NE	WISC	RN	12	--	97	15	13.5	13	13	13	3	.1600E+0	0.985
	NE	WISC	RN	8	--	70	6	12.9	6	6	6	6	.1100E+0	0.974
	NE	WISC	RN	8	--	106	12	13.2	13	13	13	3	.6300E+0	0.996
	EC	WISC	FN	21	--	158	88	10.4	127	120	123	8	.7500E+1	0.962
YB	NE	WISC	TN	5	65	81	8	9.8	15	15	15	7	.2300E+0	0.980
	NE	WISC	TN	5	65	84	9	11.9	12	12	11	6	.8300E+0	0.929
	NE	WISC	RN	33	65	94	14	9.3	35	32	34	4	.6250E+1	1.074
	NE	WISC	RN	25	65	93	14	10.5	24	24	23	3	.1090E+1	0.965
		WISC	IN	22	--	72	12	9.3	27	25	24	5	.4130E+1	0.959
		WISC	IN	46	--	67	9	8.6	24	23	22	5	.2720E+1	0.918
WA	NE	WISC	WN	12	80	91	21	9.0	49	48	48	6	.2480E+1	0.982
	NE	WISC	WN	12	80	108	25	10.1	48	48	46	5	.2690E+1	0.962
	NE	WISC	RN	36	70	93	13	9.4	28	28	27	4	.1520E+1	0.986
	NE	WISC	RN	34	70	90	18	11.8	24	24	24	3	.4600E+0	0.984
	NE	WISC	RN	19	76	56	7	9.7	13	13	13	6	.5200E+0	1.011
	NE	WISC	RN	21	76	82	10	11.7	12	12	12	3	.5200E+0	0.980
		WISC	IN	15	--	74	5	7.0	14	14	13	5	.1720E+1	0.918
		WISC	IN	37	--	67	8	8.0	23	22	22	5	.1560E+1	0.988
WO	SE	WISC	WN	11	--	89	36	11.6	47	45	47	4	.2320E+1	0.973
	SE	WISC	WN	10	--	93	40	11.8	50	50	50	4	.3200E+0	0.999
	WC	WISC	TN	7	--	119	43	10.7	68	66	66	3	.2190E+1	1.011
	SE	WISC	WN	5	--	83	47	16.8	30	29	30	4	.2200E+1	1.029
	SE	WISC	WN	5	--	95	51	17.2	31	31	31	4	.0300E+0	1.000
RO	NW	WISC	TN	8	73	109	44	10.2	86	83	83	2	.5990E+1	1.022
	NW	WISC	TN	8	73	112	47	10.6	83	81	79	4	.4300E+1	0.938
	SE	WISC	TN	8	60	104	65	12.1	73	71	68	4	.3540E+1	0.928
	SE	WISC	TN	8	60	103	69	12.6	71	69	66	5	.3510E+1	0.952
	WC	WISC	TN	9	62	123	103	14.3	87	86	84	3	.2870E+1	0.945
	SE	WISC	WN	46	--	94	54	14.7	44	43	43	4	.2600E+1	0.969
	SE	WISC	WN	40	--	97	56	15.4	42	40	40	4	.3030E+1	0.981
		WISC	IN	21	--	57	17	8.8	46	45	42	5	.6980E+1	0.874
		WISC	IN	21	--	74	22	8.4	54	53	49	5	.6860E+1	0.885
HK	SE	WISC	WN	50	--	84	7	8.8	16	16	16	4	.1010E+1	0.981
	SE	WISC	WN	50	--	86	9	9.2	19	18	18	4	.7200E+0	0.980
	SE	WISC	WN	6	--	56	10	11.5	13	12	12	4	.1910E+1	1.199
	SE	WISC	WN	8	--	69	10	11.2	13	13	13	4	.1100E+0	0.985

1 Species:
WS (white spruce)
BS (black spruce)
WC (northern white cedar)
HL (hemlock)
YB (yelllow birch)
WA (white ash)
WO (white oak)
RO (red oak)
HK (hickory)

2 Origin:

Column 1	Column 2
F (federal)	N (natural stand)
I (industry - private)	P (plantation)
R (research)	
S (state DNR)	
T (timber harvest forest)	
W (woodlot - individual)	

3 Site index at age 50 is given for species being analyzed when uniform value was obtained among the plots.

4 Years in the interval between measuring DGR and DBH and recording status; i.e., the projection interval.

5 Standard deviation among the plots within the stand.

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