

Supplementary material

Table S1. Growth onset (DOY; 5% of yearly growth completed) for control and soil-heated balsam fir trees over a 12-yr period (2010–2021).

Trees		Years												Means
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
Control	101	145	154	150	144	156	148	154	160	153	165	163	145	153
	105	146	157	147	148	138	151	157	163	165	168	163	146	154
	111	156		155										156
	114	145	154	143	133	164	147	150	150	152	162	150	146	150
	121	145	154	143	133	137	150	158	151		162	151	146	148
	125	145	154	143										147
Heated	102	145	169	151										155
	104	145	158	146	153	163	150	155	155	156	162	163	145	154
	112	145	154	146	143	154	148	152	153	152	162	152	145	151
	115	145	158	146										150
	122	145	159	150	143	154	147	151	150		162	151		151
	124	145	159											152
Means														
Control		147	155	147	140	149	149	155	156	157	164	157	146	151
Heated		145	160	148	146	157	148	153	153	154	162	155	145	152
Overall		146	157	147	142	152	149	154	155	156	163	156	146	152

Table S2. Growth cessation (DOY; 95% of yearly growth completed) for control and soil-heated balsam fir trees over a 12-yr period (2010–2021).

Trees		Years												Means
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
Control	101	268	229	224	227	289	226	264	235	283	276	238	206	247
	105	258	233	229	296	292	227	297	289	285	268	277	217	264
	111	198		286										242
	114	251	234	223	216	245	224	239	231	313	248	220	222	239
	121	271	233	253	226	265	288	255	235		245	233	211	247
	125	249	231	199										226
Heated	102	273	248	225										249
	104	198	209	230	257	292	213	255	218	234	247	246	206	234
	112	252	233	224	222	246	224	297	217	234	231	216	206	234
	115	272	234	309										272
	122	257	233	224	247	246	240	253	235		247	233		242
	124	273	234											254
Means														
Control		249	232	236	241	273	241	264	248	294	259	242	214	248
Heated		254	232	242	242	261	226	268	223	234	242	232	206	240
Overall		252	232	239	242	268	235	266	237	270	252	238	211	244

Table S3. Growing season duration (days; from 5% to 95% of yearly growth completed) for control and soil-heated balsam fir trees over a 12-yr period (2010–2021).

Trees		Years												Means
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
Control	101	123	75	74	83	133	78	110	75	130	111	75	61	94
	105	112	76	82	148	154	76	140	126	120	100	114	71	110
	111	42		131										87
	114	106	80	80	83	81	77	89	81	161	86	70	76	89
	121	126	79	110	93	128	138	97	84		83	82	65	99
	125	104	77	56										79
Heated	102	128	79	74										94
	104	53	51	84	104	129	63	100	63	78	85	83	61	80
	112	107	79	78	79	92	76	145	64	82	69	64	61	83
	115	127	76	163										122
	122	112	74	74	104	92	93	102	85		85	82		90
	124	128	75											102
Means														
Control		102	77	89	102	124	92	109	92	137	95	85	68	96
Heated		109	72	95	96	104	77	116	71	80	80	76	61	88
Overall		106	75	92	99	116	86	112	83	114	88	81	66	93

Table S4. Total annual growth (μm) for control and soil-heated balsam fir trees over a 12-yr period (2010–2021).

Trees		Years												Means
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
Control	101	1715	2015	1658	1117	1042	1133	1312	1202	1187	1289	982	1376	1336
	105	1327	1285	957	427	435	535	700	849	670	704	634	571	758
	111	542		430										486
	114	2148	1773	1675	566	194	448	766	1491	1463	1143	1421	1354	1203
	121	1449	1241	1109	606	518	623	806	1628		1085	1370	959	1036
	125	2251	2047	1733										2010
Heated	102	532	295	411										412
	104	1505	1251	1597	737	793	961	1251	1505	1267	1226	1159	1167	1202
	112	1258	1476	1240	946	937	949	1061	1434	1551	1116	1394	1013	1198
	115	652	964	826										814
	122	1620	1592	1323	789	723	1994	2228	2932		2170	2088		1746
	124	543	605											574
Means														
Control		1572	1672	1260	679	547	685	896	1292	1107	1055	1102	1065	1115
Heated		1018	1031	1079	824	818	1301	1513	1957	1409	1504	1547	1090	1216
Overall		1295	1322	1178	741	663	949	1160	1577	1228	1248	1293	1073	1160

Table S5. Average daily growth rate ($\mu\text{m/day}$) for control and soil-heated balsam fir trees over a 12-yr period (2010–2021).

Trees		Years												Means
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
Control	101	13.9	26.9	22.4	13.5	7.8	14.5	11.9	16.0	9.1	11.6	13.1	22.6	15.3
	105	11.8	16.9	11.7	2.9	2.8	7.0	5.0	6.7	5.6	7.0	5.6	8.0	7.6
	111	12.9		3.3										8.1
	114	20.3	22.2	20.9	6.8	2.4	5.8	8.6	18.4	9.1	13.3	20.3	17.8	13.8
	121	11.5	15.7	10.1	6.5	4.0	4.5	8.3	19.4		13.1	16.7	14.8	11.3
	125	21.6	26.6	30.9										26.4
Heated	102	4.2	3.7	5.6										4.5
	104	28.4	24.5	19.0	7.1	6.1	15.2	12.5	23.9	16.2	14.4	14.0	19.1	16.7
	112	11.8	18.7	15.9	12.0	10.2	12.5	7.3	22.4	18.9	16.2	21.8	16.6	15.3
	115	5.1	12.7	5.1										7.6
	122	14.5	21.5	17.9	7.6	7.9	21.4	21.8	34.5		25.5	25.5		19.8
	124	4.2	8.1											6.2
Means														
Control		15.4	21.6	16.6	7.4	4.3	8.0	8.5	15.1	7.9	11.3	13.9	15.8	12.7
Heated		11.4	14.9	12.7	8.9	8.1	16.4	13.9	26.9	17.6	18.7	20.4	17.9	15.0
Overall		13.4	17.9	14.8	8.0	5.9	11.6	10.8	20.2	11.8	14.4	16.7	16.5	13.7

Table S6. Growth cessation (DOY; 80% of yearly growth completed) for control and soil-heated balsam fir trees over a 12-yr period (2010–2021).

Trees		Years												Means
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
Control	101	197	203	198	205	208	205	204	208	205	216	213	190	204
	105	197	199	189	192	211	204	205	218	207	220	194	179	201
	111	191		200										196
	114	199	202	187	191	209	200	204	202	205	215	196	195	200
	121	198	202	198	192	227	202	204	215		207	205	195	204
	125	199	207	187										198
Heated	102	190	234	199										208
	104	190	194	199	192	208	202	204	201	204	209	193	181	198
	112	191	194	197	191	206	199	200	197	195	200	193	187	196
	115	191	199	188										193
	122	197	202	199	205	208	209	224	216		219	208		209
	124	198	202											200
Means														
Control		197	203	193	195	214	203	204	211	206	215	202	190	202
Heated		193	204	196	196	207	203	209	205	200	209	198	184	200
Overall		195	204	195	195	211	203	206	208	203	212	200	188	201

Table S7. Growth cessation (DOY; 90% of yearly growth completed) for control and soil-heated balsam fir trees over a 12-yr period (2010–2021).

Trees		Years												Means
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
Control	101	216	217	219	215	245	224	209	217	217	231	218	206	220
	105	207	209	224	247	267	215	264	236	210	248	248	182	230
	111	194		227										211
	114	217	220	199	192	245	203	228	217	246	231	216	216	219
	121	251	220	224	216	254	225	239	225		216	213	206	226
	125	215	219	198										211
Heated	102	269	241	223										244
	104	194	203	224	221	228	204	252	217	207	232	218	195	216
	112	199	203	219	216	208	204	227	208	205	216	208	195	209
	115	252	203	225										227
	122	207	231	219	216	244	222	235	230		230	216		225
	124	268	233											251
Means														
Control		217	217	215	218	253	217	235	224	224	232	224	203	222
Heated		232	219	222	218	227	210	238	218	206	226	214	195	221
Overall		224	218	218	218	242	214	236	221	217	229	220	200	222

Table S8. Growing season duration (days; from 5% to 80% of yearly growth completed) for control and soil-heated balsam fir trees over a 12-yr period (2010–2021).

Trees		Years												Means
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
Control	101	52	49	48	61	52	57	50	48	52	51	50	45	51
	105	51	42	42	44	73	53	48	55	42	52	31	33	47
	111	35		45										40
	114	54	48	44	58	45	53	54	52	53	53	46	49	51
	121	53	48	55	59	90	52	46	64		45	54	49	56
	125	54	53	44										50
Heated	102	45	65	48										53
	104	45	36	53	39	45	52	49	46	48	47	30	36	44
	112	46	40	51	48	52	51	48	44	43	38	41	42	45
	115	46	41	42										43
	122	52	43	49	62	54	62	73	66		57	57		58
	124	53	43											48
Means														
Control		50	48	46	56	65	54	50	55	49	50	45	44	51
Heated		48	45	49	50	50	55	57	52	46	47	43	39	48
Overall		49	46	47	53	59	54	53	54	48	49	44	42	50

Table S9. Growing season duration (days; from 5% to 90% of yearly growth completed) for control and soil-heated balsam fir trees over a 12-yr period (2010–2021).

Trees		Years												Means
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
Control	101	71	63	69	71	89	76	55	57	64	66	55	61	66
	105	61	52	77	99	129	64	107	73	45	80	85	36	76
	111	38		72										55
	114	72	66	56	59	81	56	78	67	94	69	66	70	70
	121	106	66	81	83	117	75	81	74		54	62	60	78
	125	70	65	55										63
Heated	102	124	72	72										89
	104	49	45	78	68	65	54	97	62	51	70	55	50	62
	112	54	49	73	73	54	56	75	55	53	54	56	50	59
	115	107	45	79										77
	122	62	72	69	73	90	75	84	80		68	65		74
	124	123	74											99
Means														
Control		70	62	68	78	104	68	80	68	68	67	67	57	71
Heated		87	60	74	71	70	62	85	66	52	64	59	50	69
Overall		78	61	71	75	89	65	82	67	61	66	63	55	70

Table S10: Mixed between subjects (control/heated) and within subjects (years) analyze of variance of the trimmed means of parameters used to characterize growth phenology for 12 balsam fir trees over the 2010–2021 period, including the 5 trees that not survived from the combined drought and defoliation event occurring in 2012.

Effect	Onset		Cessation		Duration			Total	Rate
	5%	80%	90%	95%	80%	90%	95%		
Treatment	0.3	1.8	1.2	6.2*	2.7	1.5	7.5*	2.4	5.6*
Year	120***	38.0***	15.5***	129***	3.3*	3.3*	22.8***	3.1*	9.9***
Interaction	5.7**	0.7	1.8	102***	1.4	0.5	3.8*	1.0	1.2

Significance: * < 0.1, ** < 0.01, *** < 0.001

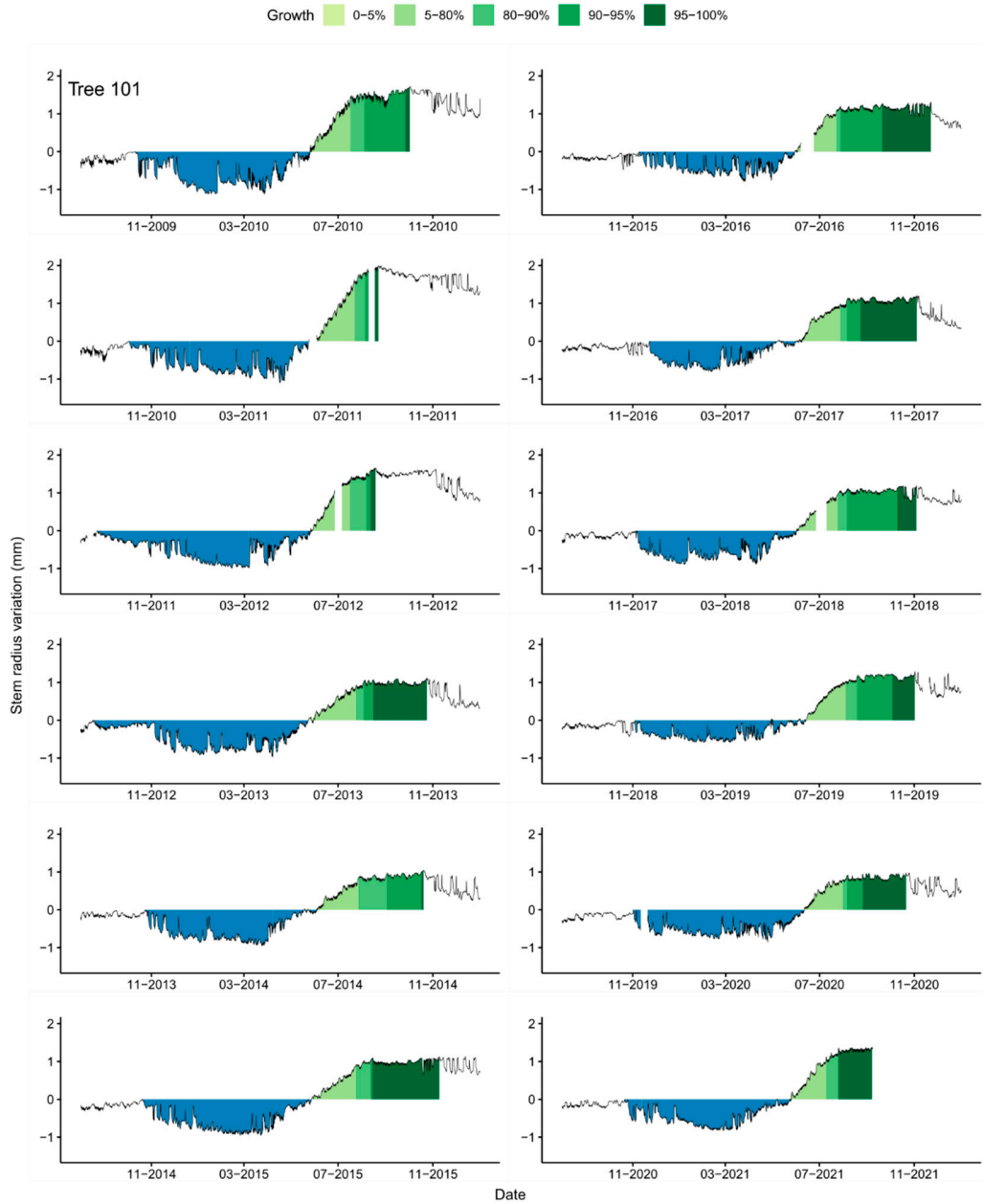


Figure S1: Characterization of growing season from stem radius variations of a balsam fir tree (no. 101) recorded by a dendrometer at a temporal resolution of 15 min over a twelve-year period. The green colors correspond to the DOY when 5%, 80%, 90%, 95% and 100% of the total annual growth is completed, while the blue area corresponds to the shrinking of the tree diameter in winter due to dehydration.

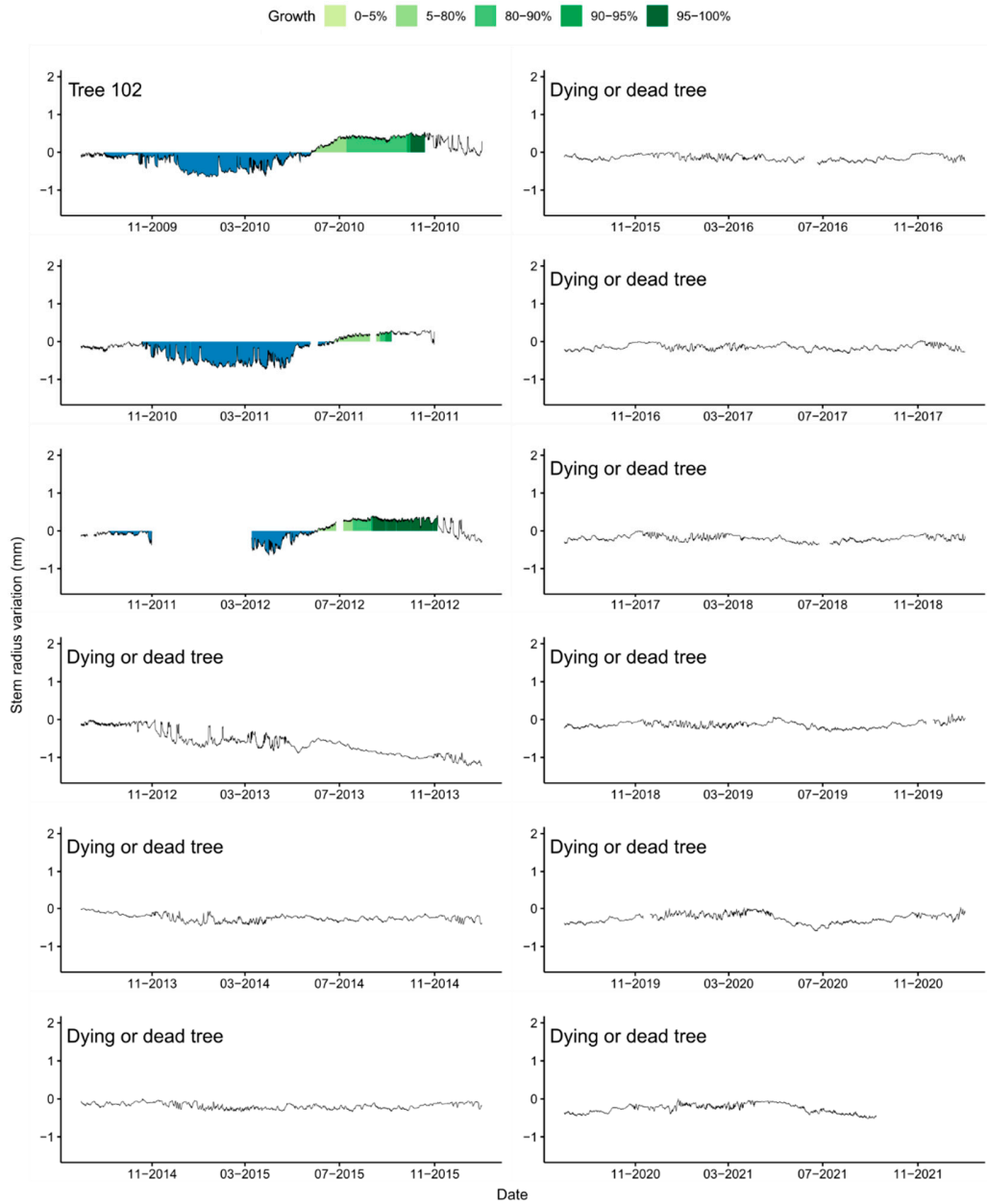


Figure S2: Characterization of growing season from stem radius variations of a balsam fir tree (no. 102) recorded by a dendrometer at a temporal resolution of 15 min over a twelve-year period. The green colors correspond to the DOY when 5%, 80%, 90%, 95% and 100% of the total annual growth is completed, while the blue area corresponds to the shrinking of the tree diameter in winter due to dehydration.

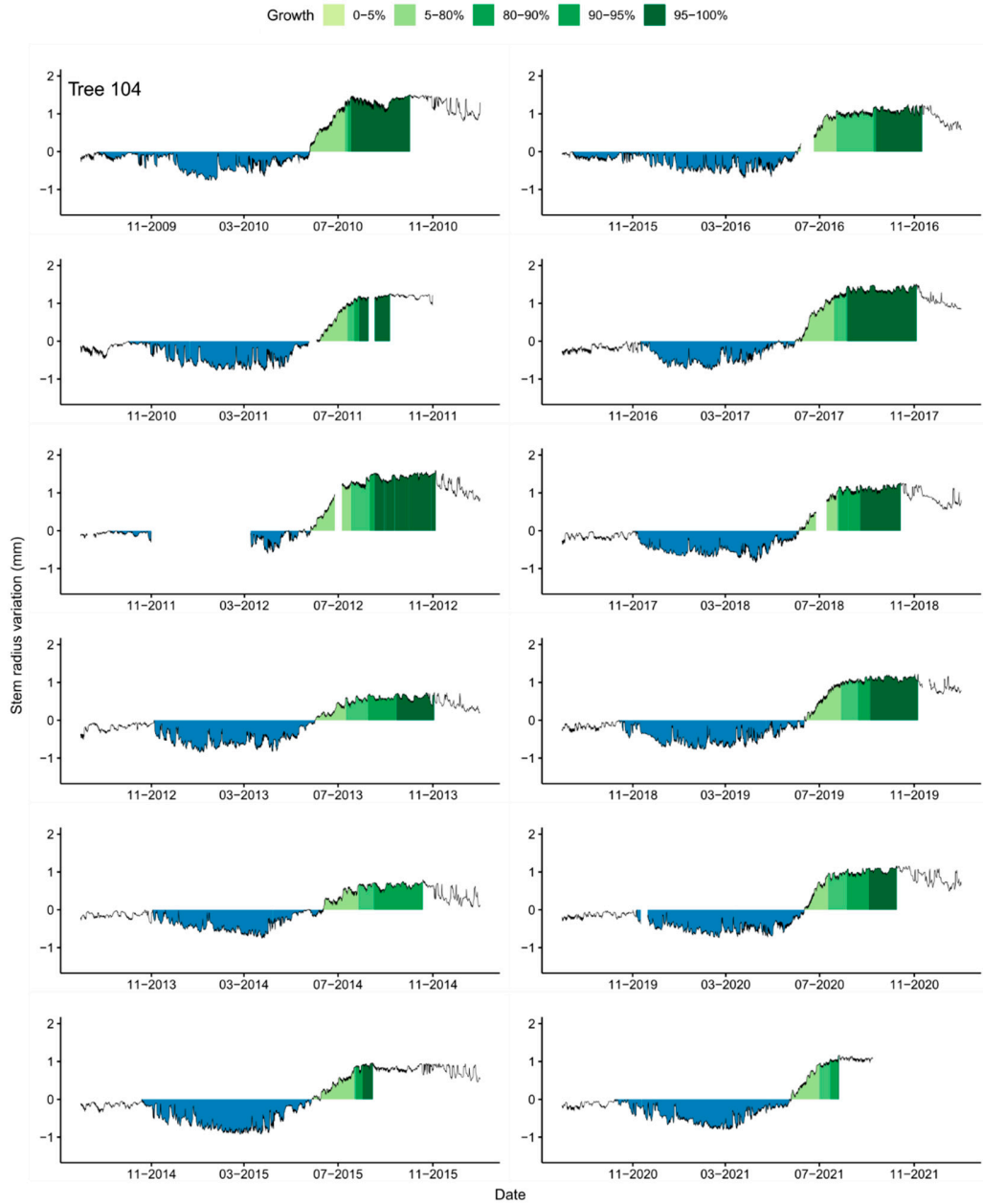


Figure S3: Characterization of growing season from stem radius variations of a balsam fir tree (no. 104) recorded by a dendrometer at a temporal resolution of 15 min over a twelve-year period. The green colors correspond to the DOY when 5%, 80%, 90%, 95% and 100% of the total annual growth is completed, while the blue area corresponds to the shrinking of the tree diameter in winter due to dehydration.

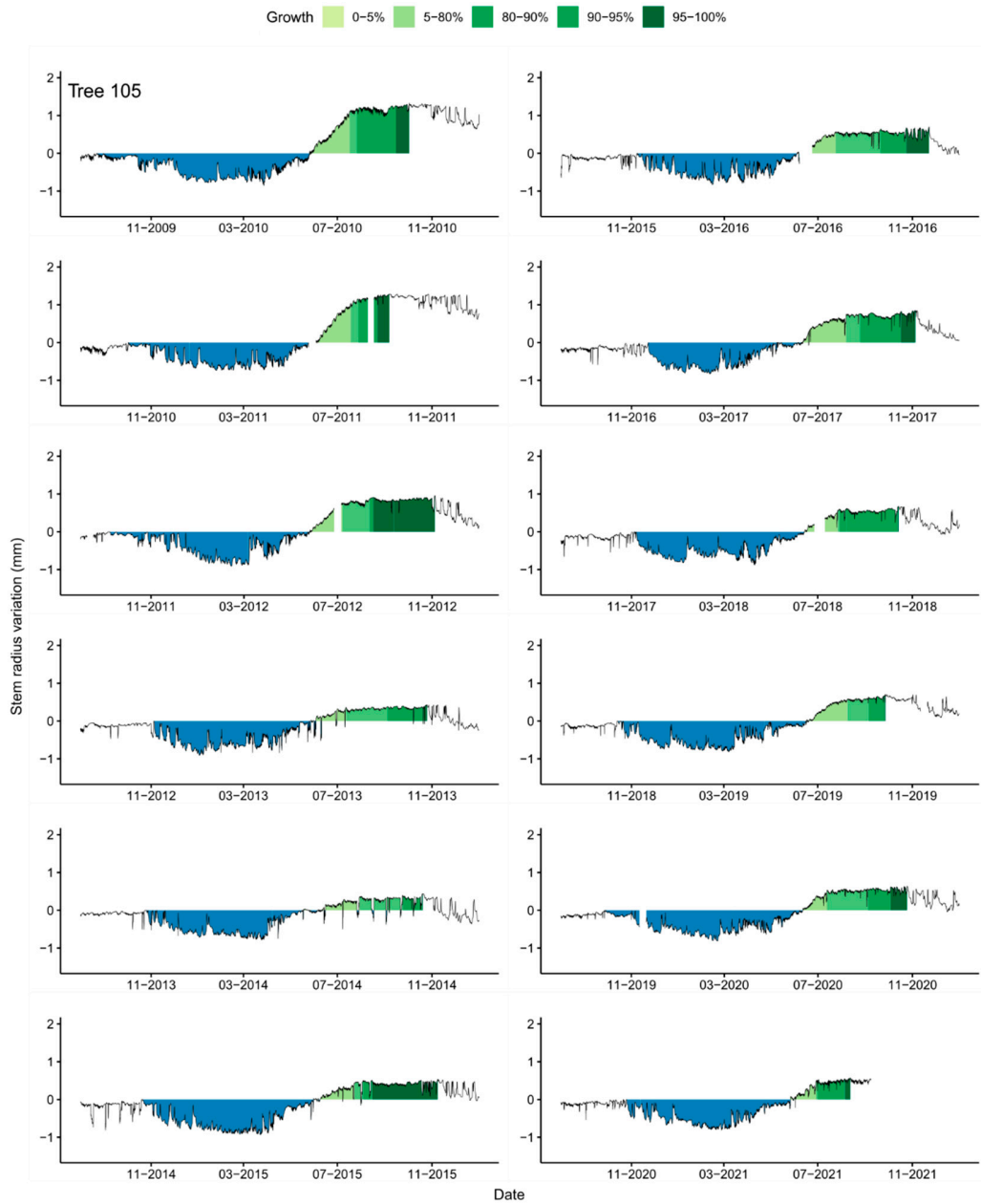


Figure S4: Characterization of growing season from stem radius variations of a balsam fir tree (no. 105) recorded by a dendrometer at a temporal resolution of 15 min over a twelve-year period. The green colors correspond to the DOY when 5%, 80%, 90%, 95% and 100% of the total annual growth is completed, while the blue area corresponds to the shrinking of the tree diameter in winter due to dehydration.

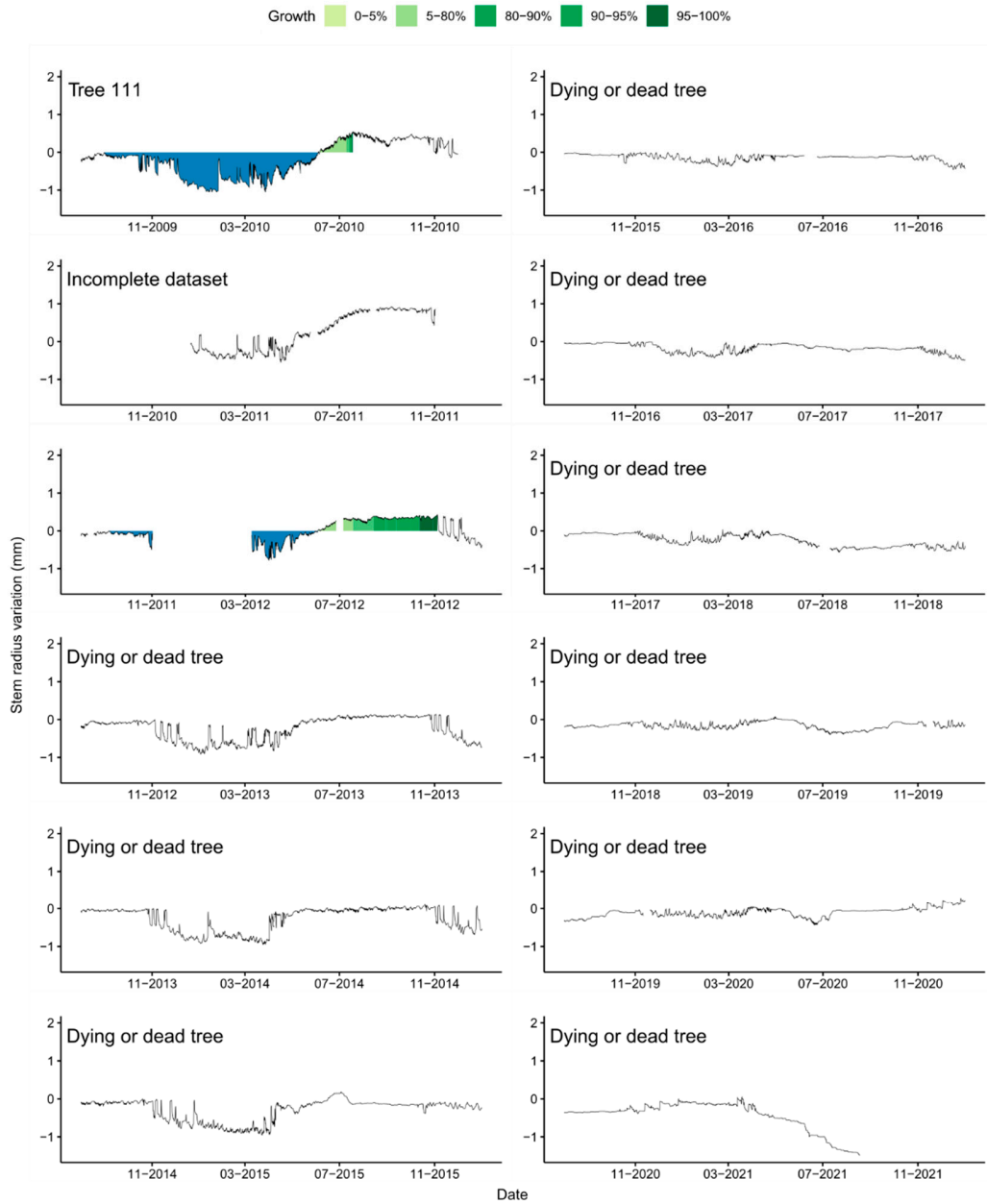


Figure S5: Characterization of growing season from stem radius variations of a balsam fir tree (no. 111) recorded by a dendrometer at a temporal resolution of 15 min over a twelve-year period. The green colors correspond to the DOY when 5%, 80%, 90%, 95% and 100% of the total annual growth is completed, while the blue area corresponds to the shrinking of the tree diameter in winter due to dehydration.

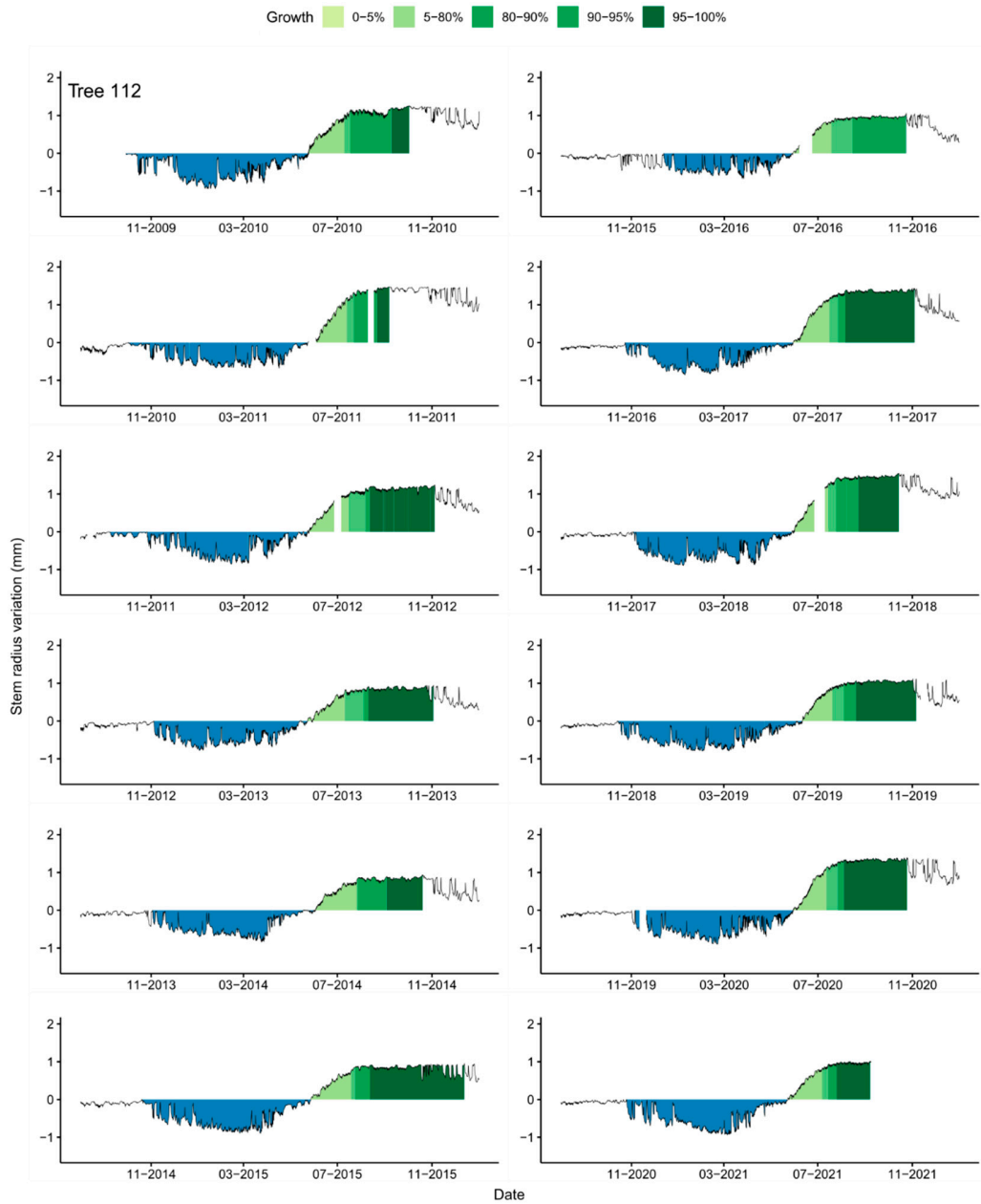


Figure S6: Characterization of growing season from stem radius variations of a balsam fir tree (no. 112) recorded by a dendrometer at a temporal resolution of 15 min over a twelve-year period. The green colors correspond to the DOY when 5%, 80%, 90%, 95% and 100% of the total annual growth is completed, while the blue area corresponds to the shrinking of the tree diameter in winter due to dehydration.

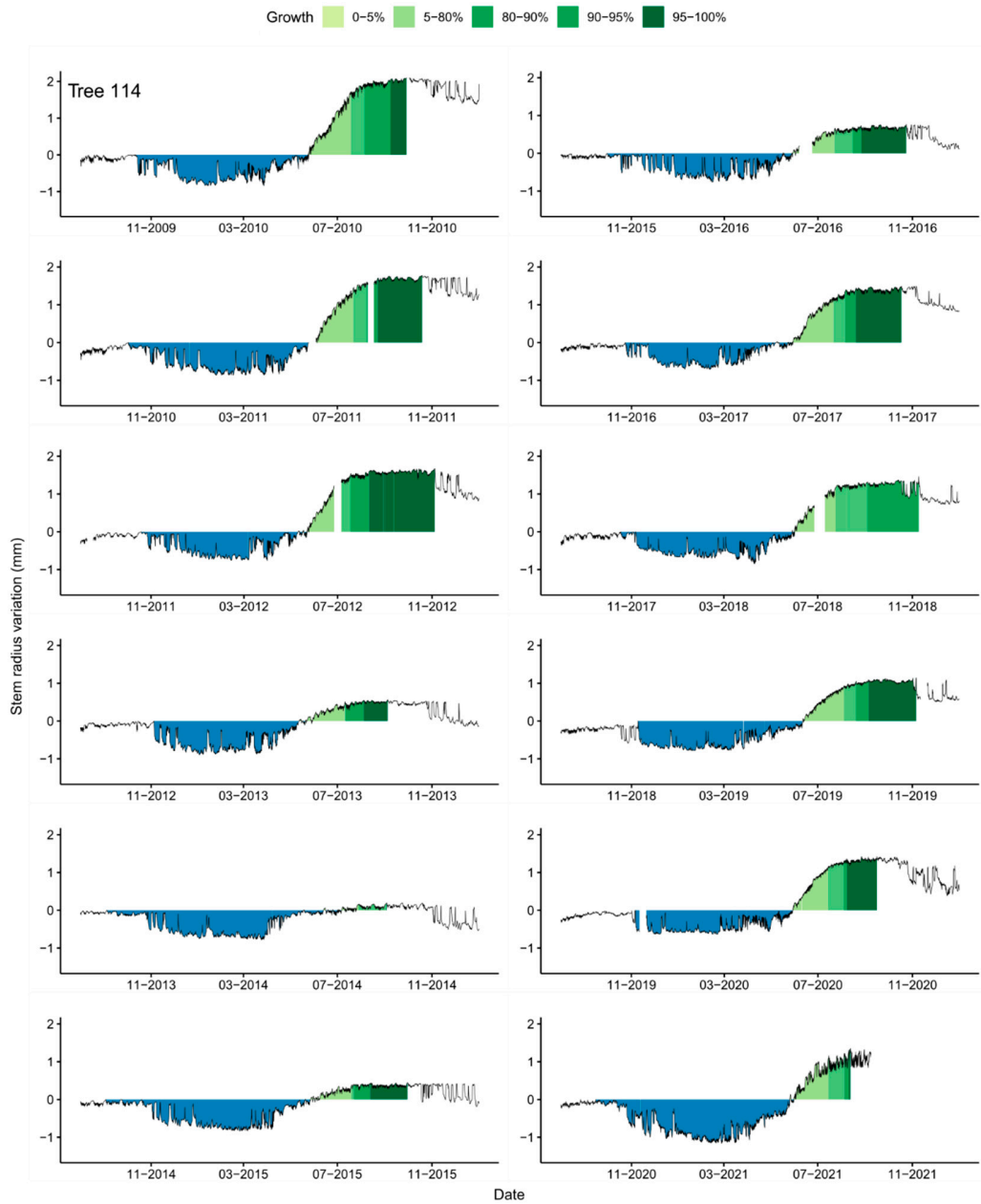


Figure S7: Characterization of growing season from stem radius variations of a balsam fir tree (no. 114) recorded by a dendrometer at a temporal resolution of 15 min over a twelve-year period. The green colors correspond to the DOY when 5%, 80%, 90%, 95% and 100% of the total annual growth is completed, while the blue area corresponds to the shrinking of the tree diameter in winter due to dehydration.

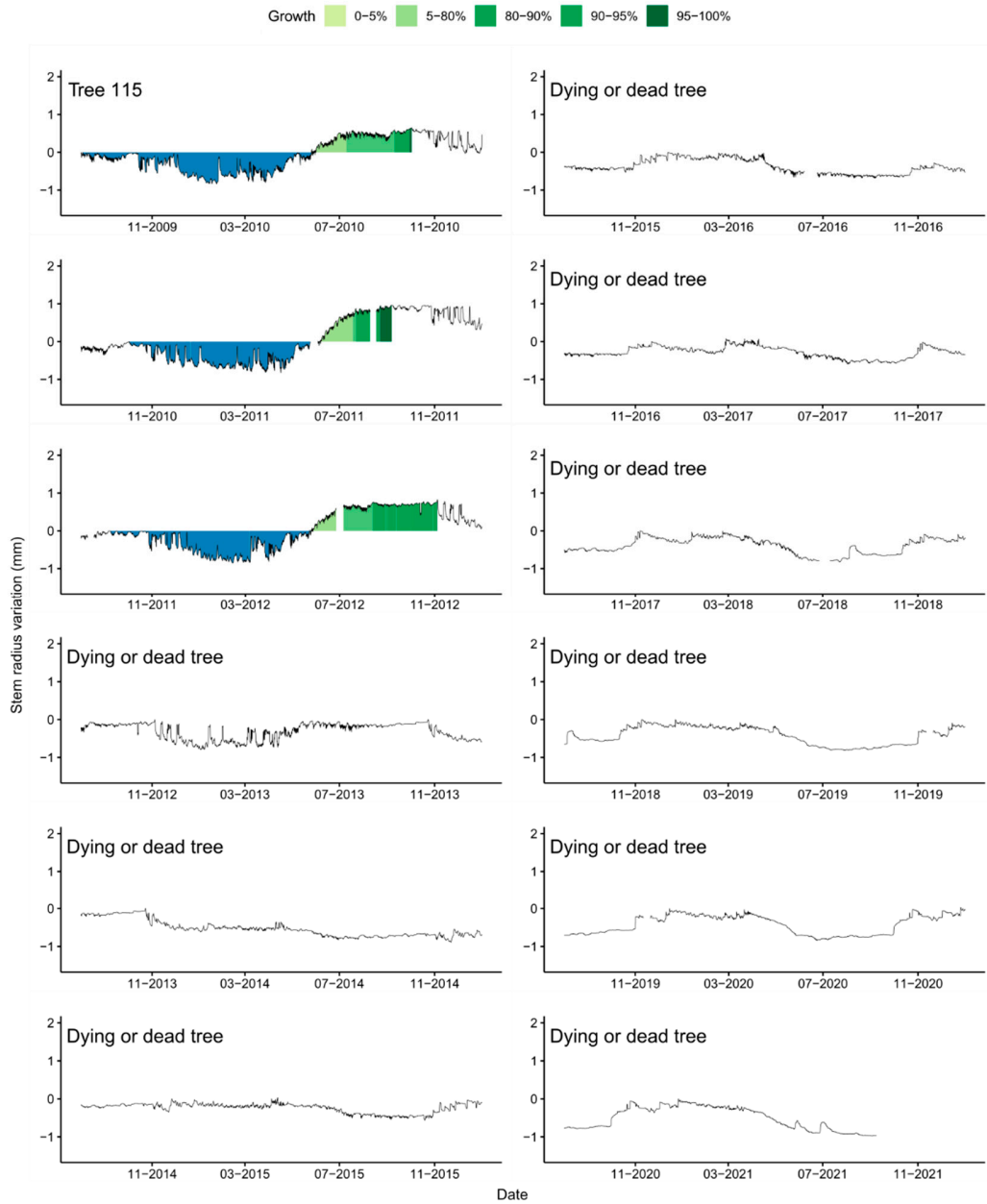


Figure S8: Characterization of growing season from stem radius variations of a balsam fir tree (no. 115) recorded by a dendrometer at a temporal resolution of 15 min over a twelve-year period. The green colors correspond to the DOY when 5%, 80%, 90%, 95% and 100% of the total annual growth is completed, while the blue area corresponds to the shrinking of the tree diameter in winter due to dehydration.

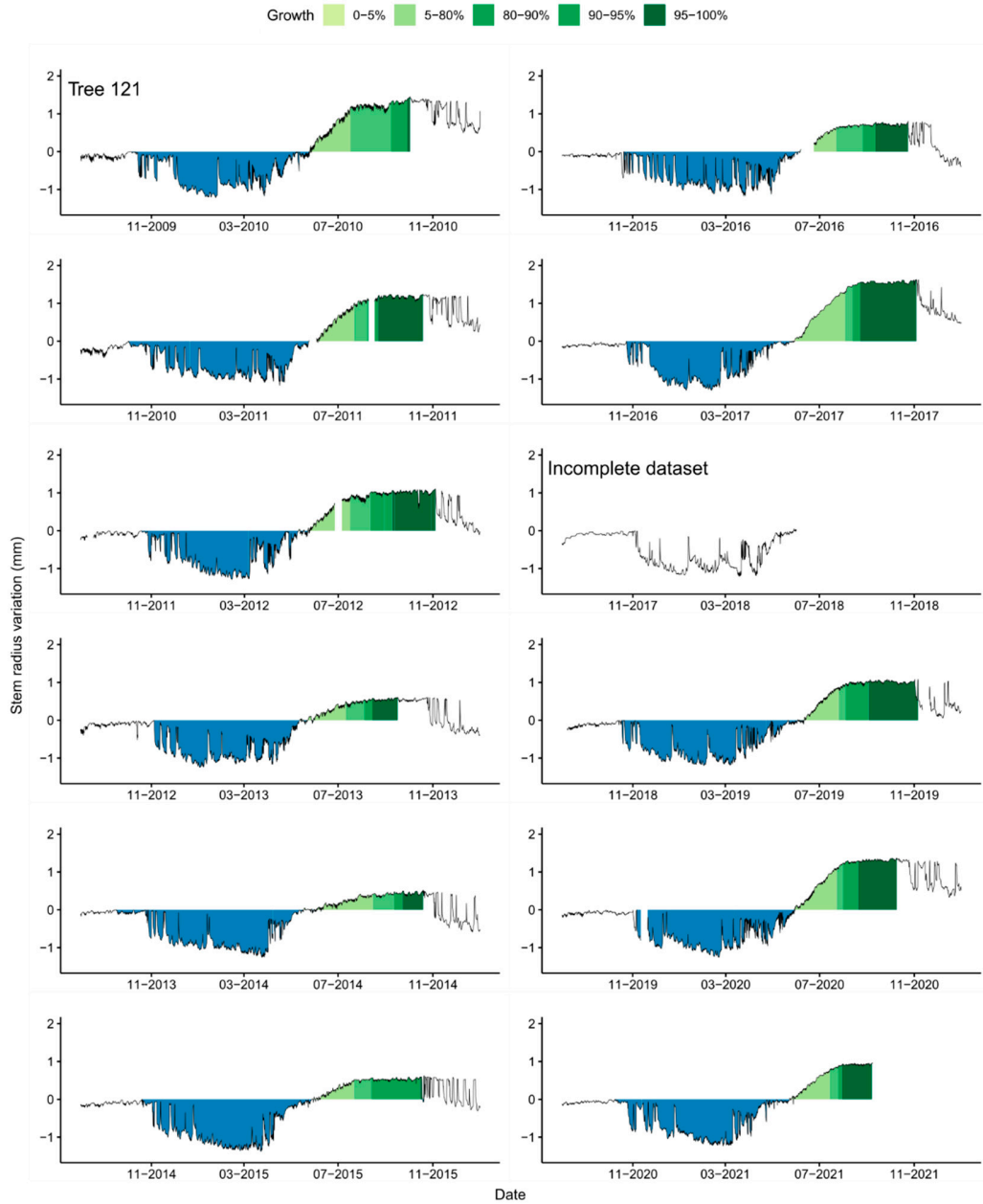


Figure S9: Characterization of growing season from stem radius variations of a balsam fir tree (no. 121) recorded by a dendrometer at a temporal resolution of 15 min over a twelve-year period. The green colors correspond to the DOY when 5%, 80%, 90%, 95% and 100% of the total annual growth is completed, while the blue area corresponds to the shrinking of the tree diameter in winter due to dehydration.

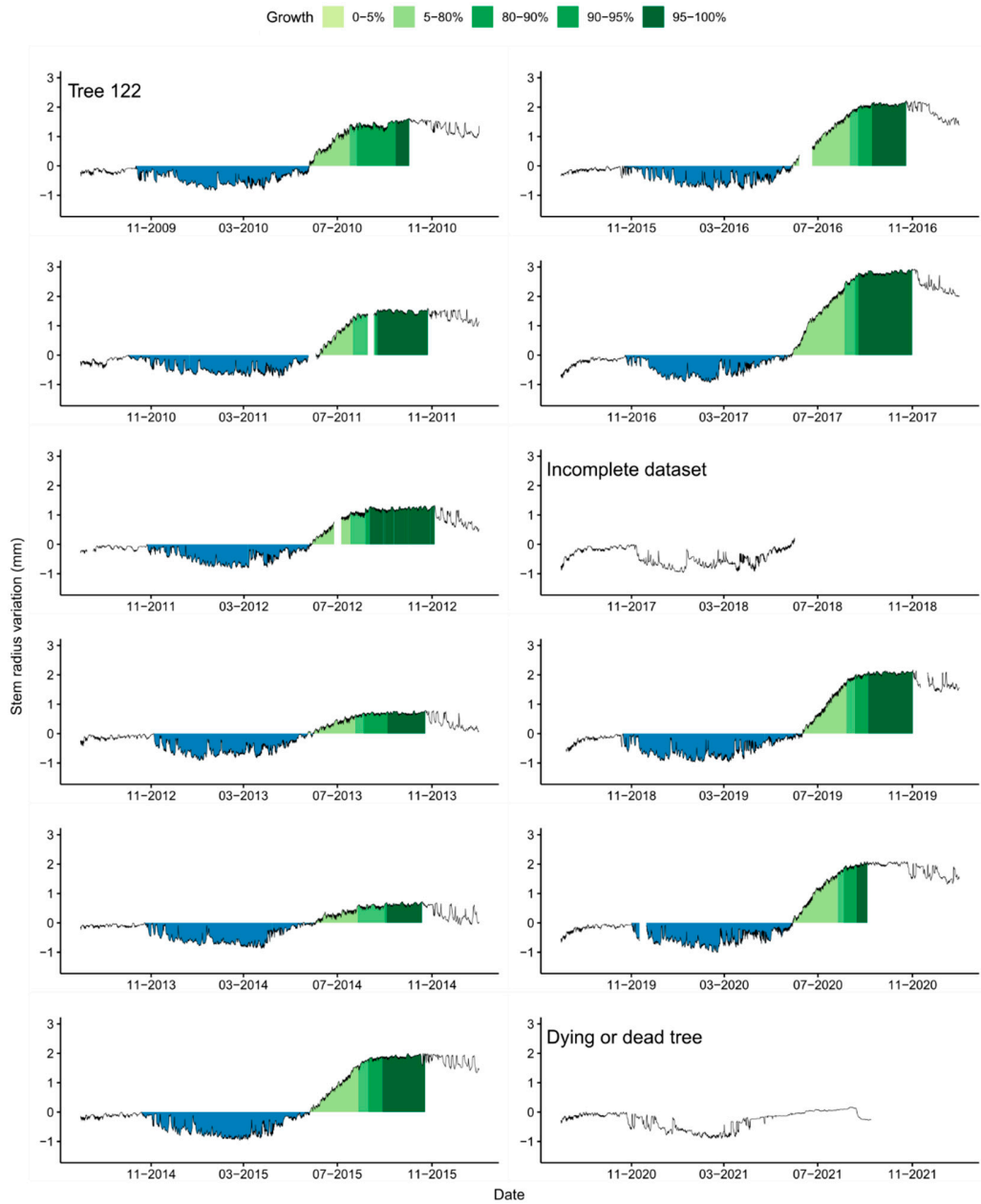


Figure S10: Characterization of growing season from stem radius variations of a balsam fir tree (no. 122) recorded by a dendrometer at a temporal resolution of 15 min over a twelve-year period. The green colors correspond to the DOY when 5%, 80%, 90%, 95% and 100% of the total annual growth is completed, while the blue area corresponds to the shrinking of the tree diameter in winter due to dehydration.

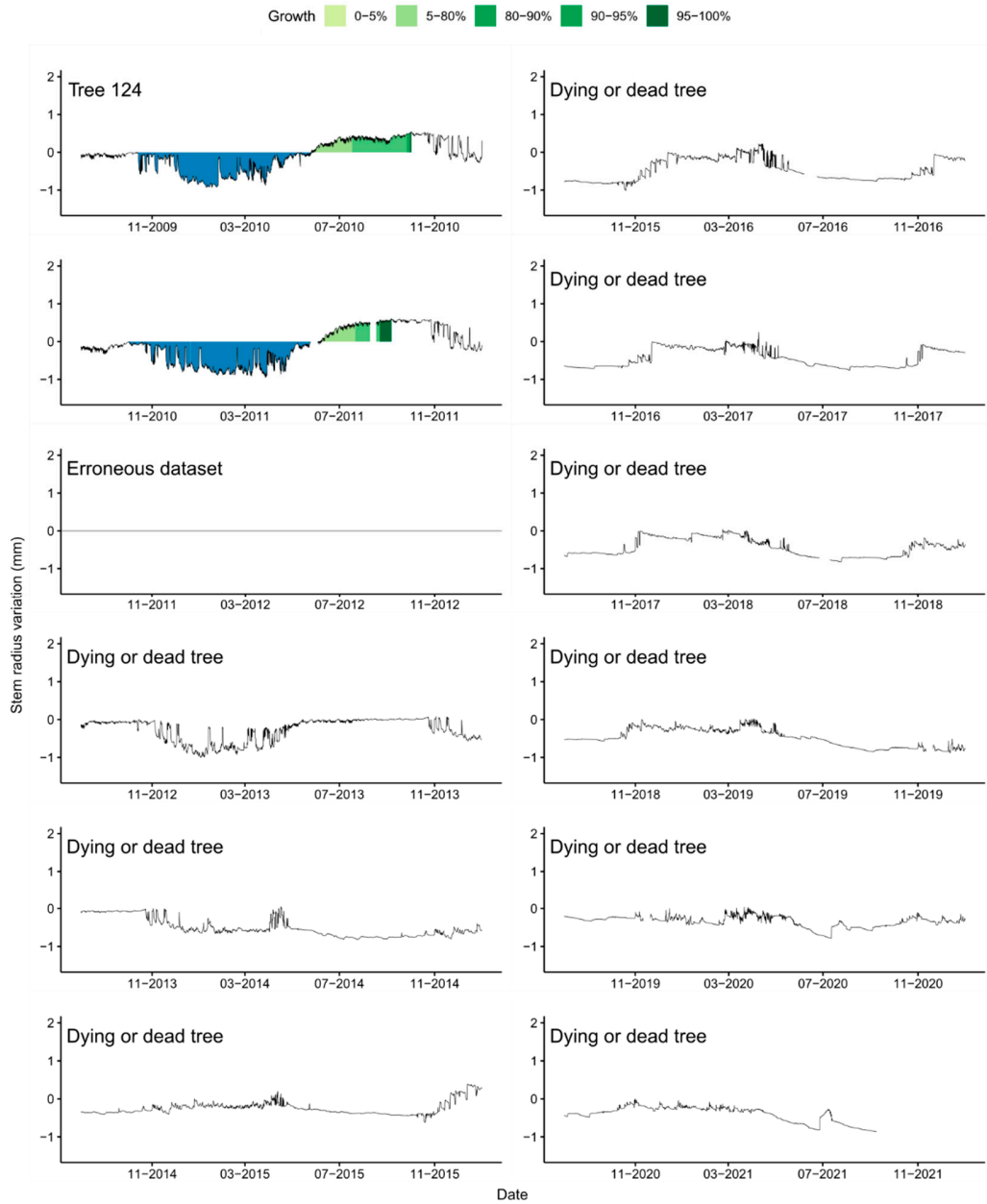


Figure S11: Characterization of growing season from stem radius variations of a balsam fir tree (no. 124) recorded by a dendrometer at a temporal resolution of 15 min over a twelve-year period. The green colors correspond to the DOY when 5%, 80%, 90%, 95% and 100% of the total annual growth is completed, while the blue area corresponds to the shrinking of the tree diameter in winter due to dehydration.

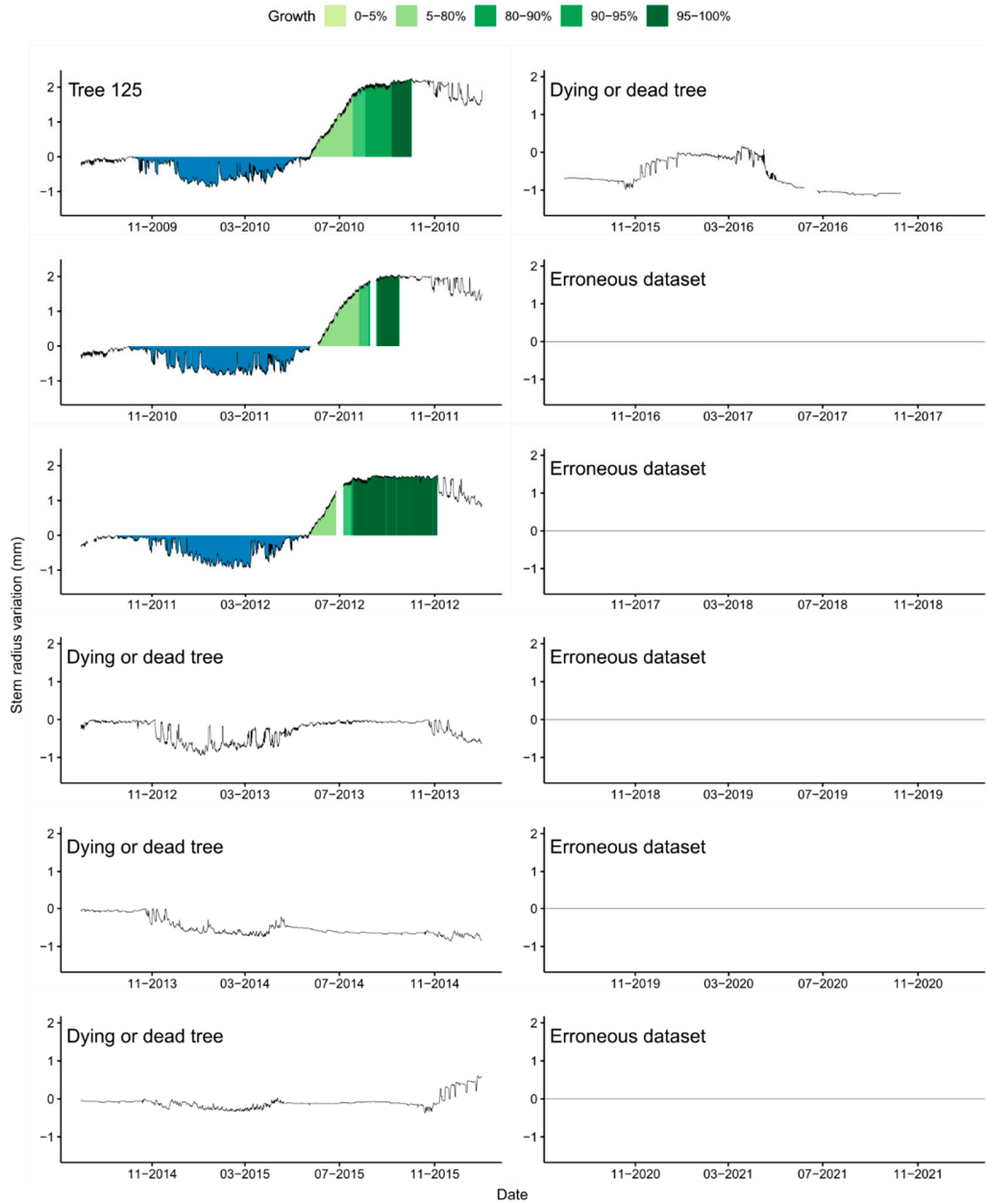


Figure S12: Characterization of growing season from stem radius variations of a balsam fir tree (no. 125) recorded by a dendrometer at a temporal resolution of 15 min over a twelve-year period. The green colors correspond to the DOY when 5%, 80%, 90%, 95% and 100% of the total annual growth is completed, while the blue area corresponds to the shrinking of the tree diameter in winter due to dehydration.