forests

MDPI

Supplementary Figures (S1-S10)

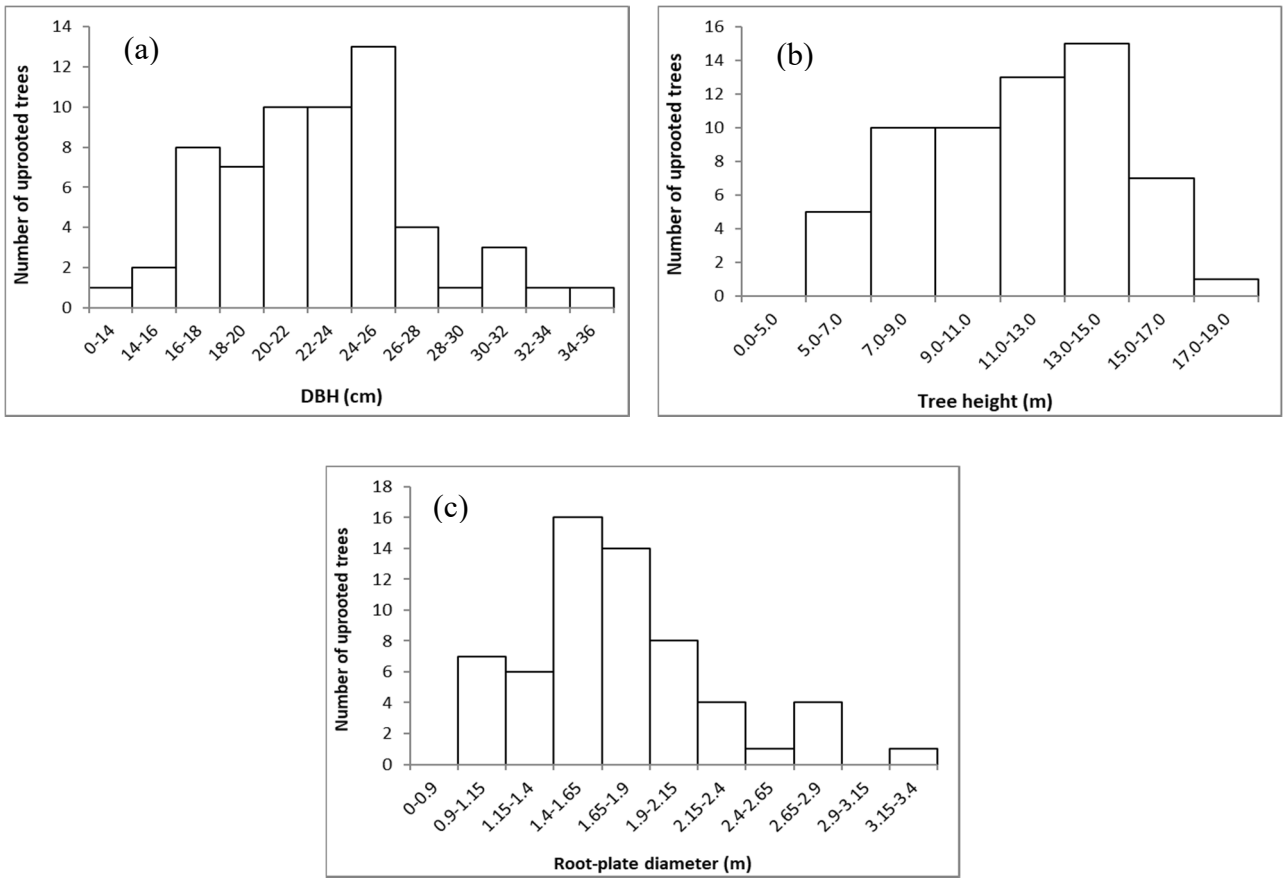

Fig. S1: Frequency of uprooted trees a) over the observed DBH range, b) over the observed tree height range, and c) over the observed root-plate diameter range

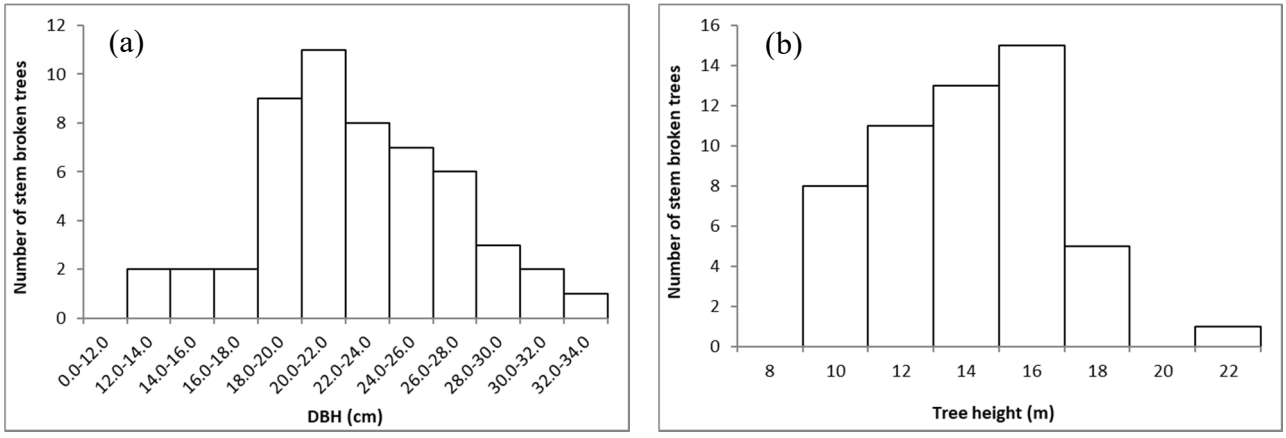

Fig. S2: Frequency of stem broken trees a) over the observed DBH range, and b) over the observed tree height range

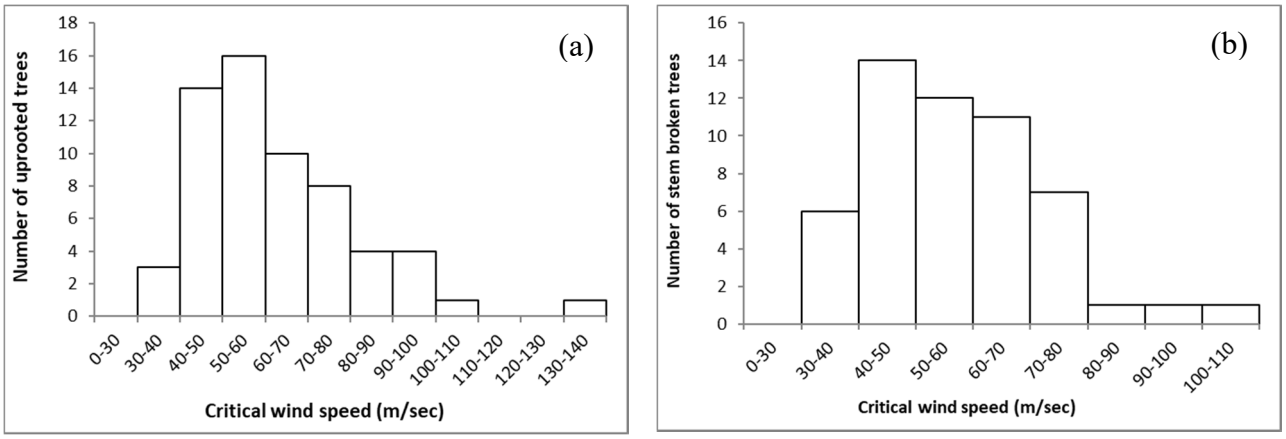

Fig. S3: Frequency of damaged trees over the observed V_c range a) uprooted trees, and b) stem broken trees

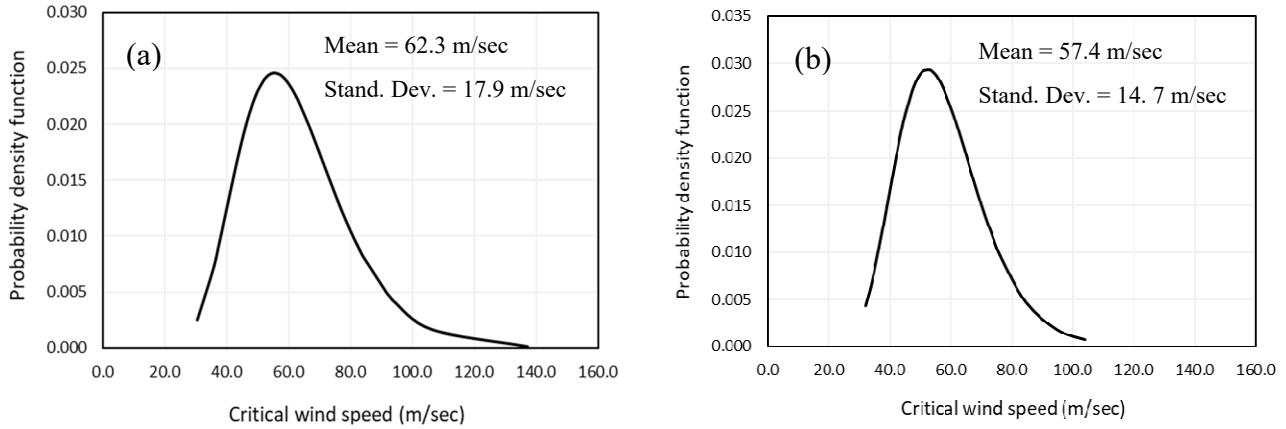

Fig. S4: Distribution of damaged trees over the observed V_c range a) uprooted trees, and b) Stem broken trees

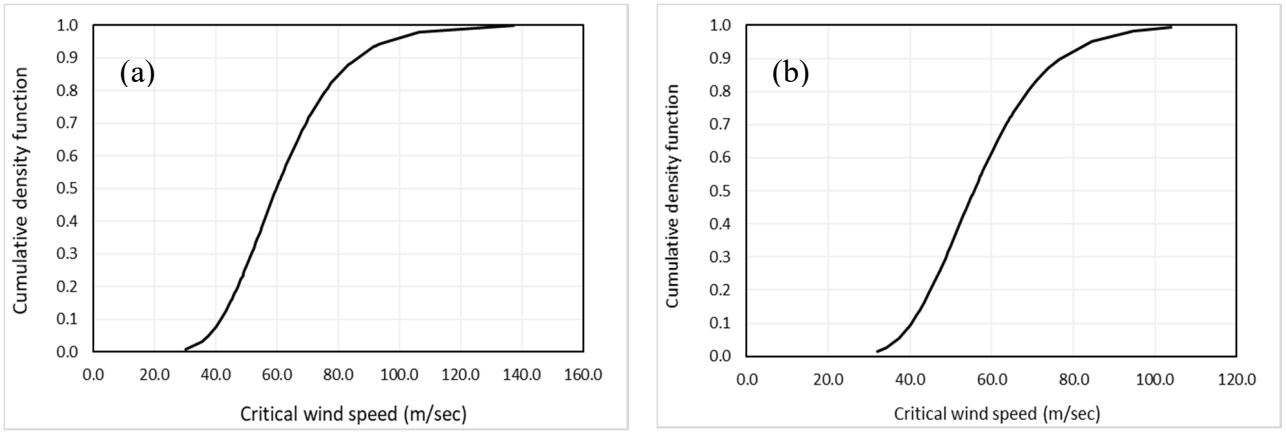

Fig. S5: Cumulative density function of damaged trees over the observed V_c range a) uprooted trees, and b) stem broken trees

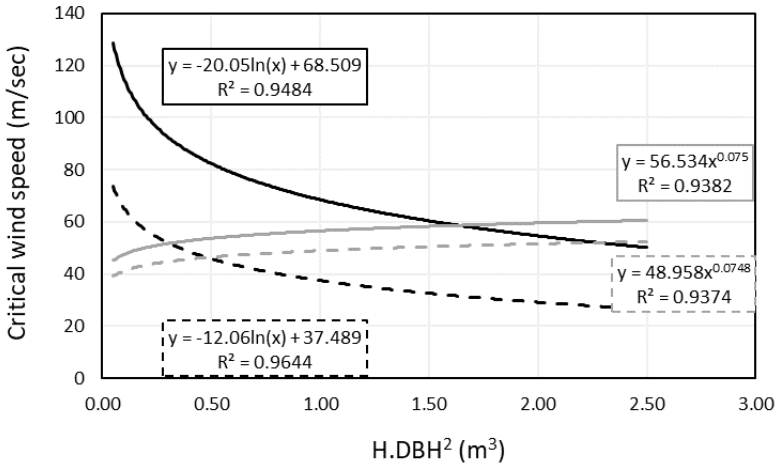

Fig. S6: Equations of the developed windthrow and stem breakage models

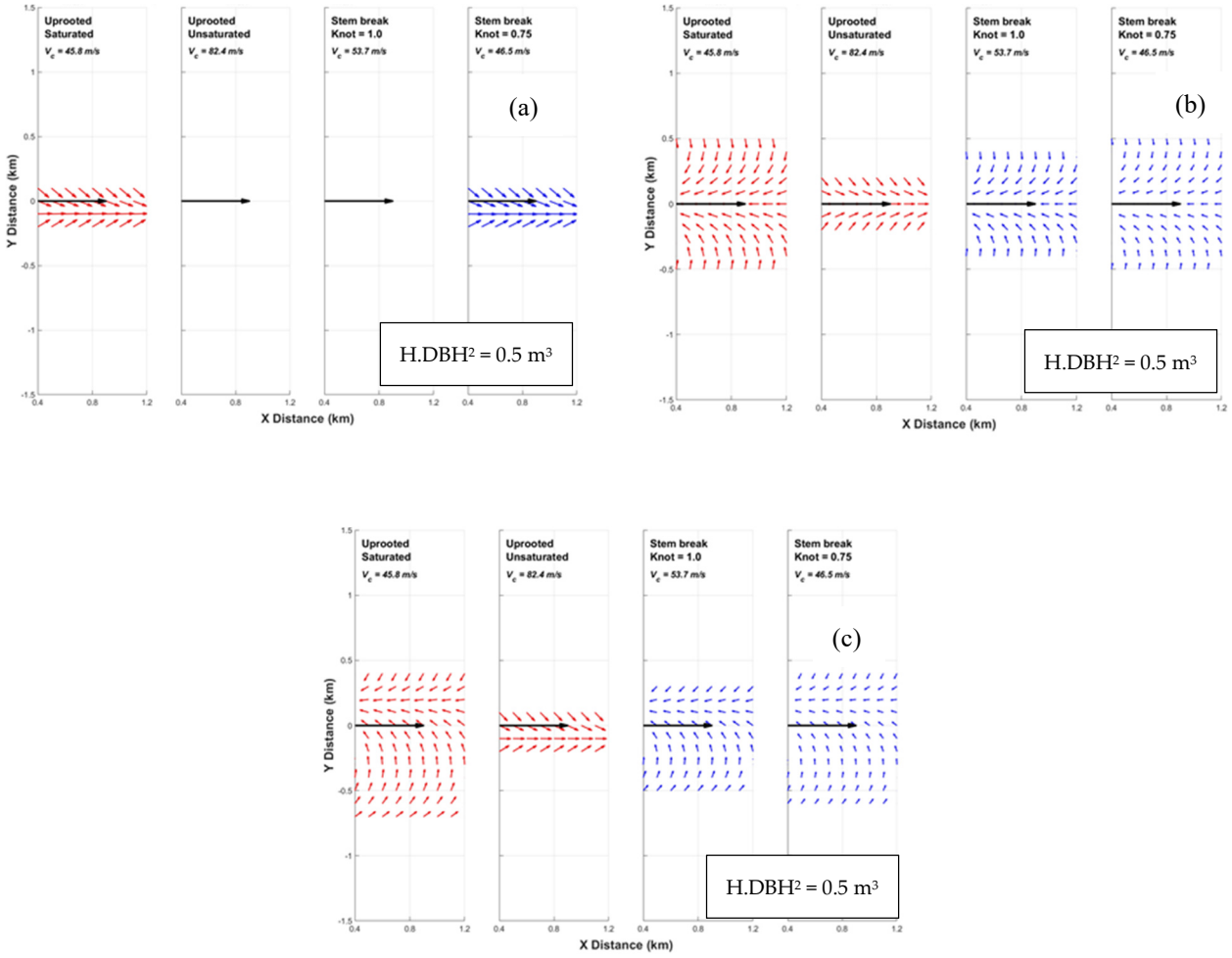

Fig. S7: Tree fall patterns with a vortex with R_{max} = 240 m and φ = 0.7, and tree volume H.DBH² = 0.5 m³, (a) α = 30º, G_{max} = 3 & V_{max} = 52 m/s, (b) α = 0º, G_{max} = 6 & V_{max} = 91 m/s, (c) α = 30º, G_{max} = 6 & V_{max} = 91 m/s

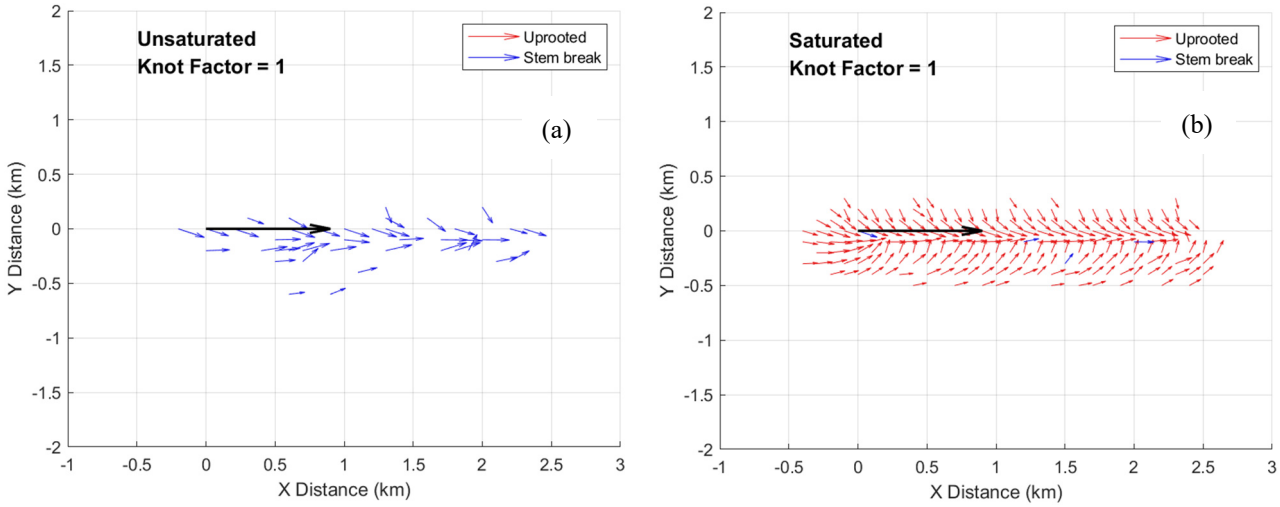

Fig. S8: Tree fall patterns with a translating vortex with V_{max} = 52 m/s, G_{max} = 3, R_{max} = 240 m, φ = 0.7, α = 30º and trees with random H.DBH^2 and knot factor = 1.0, (a) unsaturated soil and (b) saturated soil

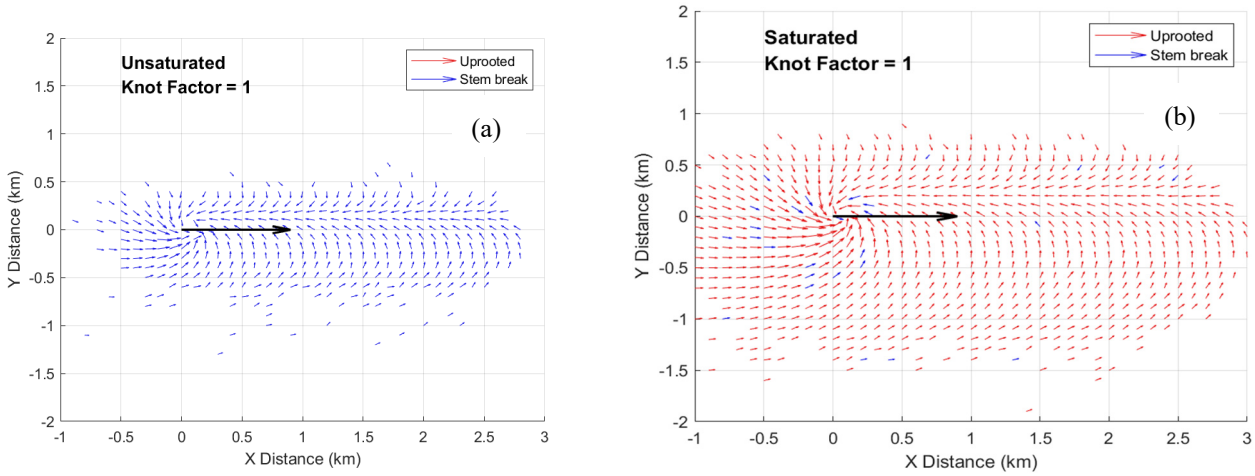

Fig. S9: Tree fall patterns with a translating vortex with V_{max} = 91 m/s, G_{max} = 6, R_{max} = 240 m, φ = 0.7, α = 30º and trees with random H.DBH^2 and knot factor = 1.0, (a) unsaturated soil and (b) saturated

(a)

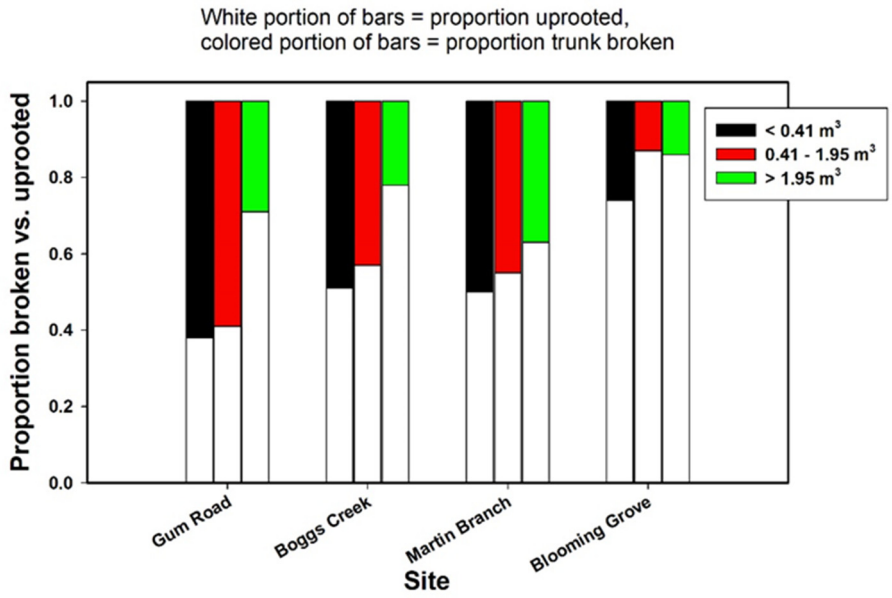

Fig. S10: Proportion of windthrown and stem broken trees in four US tornado events

Supplementary Tables (S1-S4)

Table S1: Uprooted trees data

Tree no.	Tree height (m)	DBH (cm)	Crown depth (m)	Crown diameter (m)	Root plate depth (m)	Root plate diameter (m)
1	13.6	33.0	5.0	3.9	1.0	1.5
2	8.7	26.0	6.2	3.6	0.8	2.9
3	15.0	31.0	5.5	4.8	0.9	2.0
4	15.7	35.0	5.3	4.4	1.0	2.7
5	16.0	27.0	5.4	4.0	0.9	2.9
6	15.5	30.0	8.0	5.8	1.0	2.0
7	13.9	26.0	6.9	4.3	0.8	1.8
8	17.6	25.0	8.1	4.9	0.8	1.7
9	14.8	28.0	5.7	5.0	0.8	2.1
10	13.7	24.0	6.5	3.2	0.7	2.2
11	13.8	22.0	5.2	3.8	0.7	2.0
12	16.3	23.0	5.8	4.0	0.7	1.7
13	12.1	27.0	5.9	3.9	0.7	1.9
14	14.9	31.0	4.1	6.0	0.8	3.3
15	13.8	21.0	7.2	4.8	0.6	1.8
16	7.1	16.0	3.4	3.0	0.4	1.7
17	7.2	19.0	2.8	3.2	0.4	1.5
18	10.1	25.0	3.4	3.0	0.5	1.9
19	5.7	21.0	3.3	2.0	0.4	2.0
20	6.1	16.0	3.2	2.3	0.3	1.1
21	6.4	17.0	2.2	2.8	0.3	1.1
22	12.2	23.0	5.3	4.2	0.5	1.6
23	8.8	23.0	4.4	3.0	0.3	1.2
24	9.7	23.0	4.4	3.0	0.2	1.0
25	8.5	17.0	3.0	2.4	0.4	1.5
26	5.4	14.0	2.3	1.8	0.3	1.1
27	15.0	25.0	4.2	2.9	0.6	2.7
28	9.3	18.0	3.7	2.7	0.3	1.4
29	10.4	21.0	3.0	3.2	0.4	1.8
30	10.8	17.0	4.5	3.7	0.4	1.6
31	8.7	24.0	3.8	3.7	0.4	1.5
32	14.8	22.0	3.9	3.9	0.5	1.8
33	15.7	21.0	3.6	3.5	0.5	1.4
34	15.5	23.0	8.6	6.8	0.5	1.5
35	16.2	26.0	4.9	3.4	0.4	1.7
36	12.9	23.0	6.4	4.6	0.4	1.5
37	11.9	25.0	5.9	4.5	0.4	1.7
38	14.1	25.0	7.5	3.1	0.4	1.3
39	8.0	18.0	2.4	5.2	0.3	0.9
40	12.4	25.0	5.4	3.3	0.4	1.5
41	11.2	26.0	6.2	5.4	0.6	2.5

Tree no.	Tree height (m)	DBH (cm)	Crown depth (m)	Crown diameter (m)	Root plate depth (m)	Root plate diameter (m)
42	11.0	20.0	5.5	4.0	0.4	1.6
43	11.6	18.0	4.2	3.8	0.6	2.3
44	13.1	21.0	7.1	4.6	0.5	2.0
45	9.9	19.0	4.4	3.6	0.4	1.2
46	12.9	32.0	5.1	6.8	0.6	2.4
47	9.6	20.0	3.6	4.2	0.7	1.8
48	10.3	22.0	3.0	2.8	0.4	1.5
49	12.0	23.0	2.7	2.6	0.4	2.0
50	12.3	22.0	3.4	2.6	0.4	1.6
51	8.7	18.0	3.5	3.8	0.3	1.1
52	7.9	20.0	2.5	2.6	0.3	1.4
53	13.0	27.0	3.7	4.9	0.6	1.9
54	14.9	24.0	4.7	2.7	0.7	1.8
55	9.0	19.0	4.2	2.7	0.3	1.2
56	12.2	21.0	4.4	5.1	0.3	1.1
57	14.0	26.0	6.9	5.0	0.6	1.6
58	10.0	19.0	5.4	3.8	0.4	2.0
59	5.4	17.0	2.9	3.4	0.4	1.3
60	11.9	25.0	2.4	4.6	0.4	1.7
61	12.1	26.0	4.7	3.8	0.5	2.2

Table S2: Uprooted trees used for windthrow model validation

Tree no.	Tree height (m)	DBH (cm)	Crown depth (m)	Crown diameter (m)	Root plate depth (m)	Root plate diameter (m)
1	7.6	16.0	3.3	3.1	0.2	1.3
2	8.2	17.1	3.6	3.2	0.3	1.4
3	8.9	18.2	3.8	3.3	0.3	1.4
4	10.5	21.0	4.3	3.6	0.4	1.6
5	12.2	23.7	4.9	3.9	0.5	1.8
6	13.8	26.5	5.4	4.2	0.7	2.0
7	15.4	29.3	5.9	4.5	0.8	2.1
8	17.1	32.0	6.5	4.8	0.9	2.3
9	18.7	34.8	7.0	5.1	1.0	2.5
10	20.4	37.6	7.6	5.5	1.1	2.7
11	22.0	40.4	8.1	5.8	1.2	2.8
12	23.6	43.1	8.6	6.1	1.3	3.0

Table S3: Stem broken trees data

Tree no.	Broken stem length (m)	Broken stem diameter (cm)	Crown depth (m)	Crown diameter (m)
1	12.7	30.6	6.0	6.5
2	7.9	22.0	4.0	3.4
3	10.8	22.0	4.5	3.7
4	11.7	25.3	3.3	3.0

Tree no.	Broken stem length (m)	Broken stem diameter (cm)	Crown depth (m)	Crown diameter (m)
5	8.2	23.8	3.1	2.1
6	12.4	29.4	4.5	4.0
7	14.6	28.6	5.5	4.8
8	11.8	23.4	3.7	2.9
9	13.7	26.0	5.2	3.3
10	11.6	21.3	4.8	3.8
11	9.4	20.6	3.7	2.8
12	9.1	18.2	3.8	4.5
13	14.6	20.9	7.0	4.6
14	13.6	26.4	4.3	4.2
15	14.3	28.6	3.6	2.7
16	18.6	31.5	7.9	5.6
17	11.8	24.2	3.3	2.9
18	12.4	21.5	5.5	3.6
19	12.2	26.4	6.2	5.1
20	13.0	23.7	4.4	4.1
21	13.8	23.1	4.1	4.0
22	11.5	21.7	3.6	3.4
23	11.1	25.5	5.3	3.6
24	15.6	26.4	6.1	5.8
25	13.9	27.9	5.4	4.1
26	9.7	25.1	4.3	3.6
27	13.6	32.1	4.0	3.3
28	13.2	24.2	3.6	3.5
29	10.8	15.5	3.5	2.8
30	13.6	23.5	4.7	3.9
31	10.9	18.0	2.2	3.8
32	14.0	25.3	5.0	4.7
33	8.7	19.8	3.3	3.0
34	13.0	19.9	4.6	4.3
35	14.0	18.0	4.3	3.5
36	11.2	26.4	3.7	3.6
37	15.0	19.8	4.1	3.2
38	8.0	18.9	5.0	4.4
39	9.6	22.0	3.5	2.9
40	10.2	27.5	3.5	2.7
41	9.2	17.6	2.3	3.3
42	8.1	22.4	3.9	4.0
43	9.3	22.7	4.0	2.8
44	7.9	18.7	3.1	2.9
45	7.9	16.2	3.1	2.2
46	13.0	23.1	4.5	3.9
47	11.3	21.6	3.3	2.8
48	11.5	18.7	2.3	2.6

Tree no.	Broken stem length (m)	Broken stem diameter (cm)	Crown depth (m)	Crown diameter (m)
49	9.9	20.7	3.8	3.4
50	6.8	12.7	2.7	3.3
51	9.0	15.6	2.9	3.6
52	8.2	13.4	4.3	2.2
53	9.0	21.2	3.0	3.5

Table S4: Stem broken trees used for stem breakage model validation

Tree no.	Broken stem length (m)	Broken stem diameter (cm)	Crown depth (m)	Crown diameter (m)
1	7.9	15.3	3.1	2.9
2	8.4	16.3	3.3	3.0
3	8.9	17.4	3.4	3.1
4	10.2	20.1	3.8	3.4
5	11.5	22.9	4.2	3.6
6	12.9	25.6	4.6	3.9
7	14.2	28.3	5.0	4.1
8	15.5	31.0	5.4	4.4
9	16.8	33.7	5.7	4.6
10	18.1	36.4	6.1	4.9
11	19.4	39.1	6.5	5.1
12	20.7	41.8	6.9	5.4