Tree-pulling Experiments in Japan

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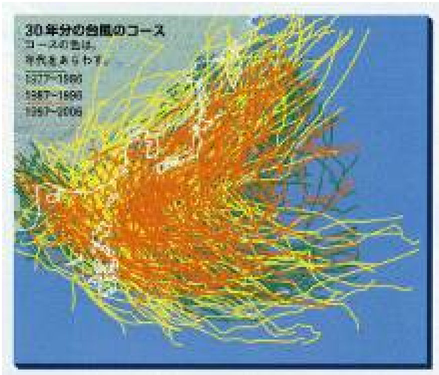
1. Wind damage in Japan

1. History of damage

Year	Damaged timber or area	Main location	Causes
1954	300,000 m^3	South & North	Typhoon
1959	4,100,000 m^3	South & North	Typhoon
1991	11,000,000 m^3	South	Typhoon
2004	22,000,000 m^3	many	Typhoons (south & central) Extratropical storm (north)
2006	5,541 ha	North	Extratropical storm

1. Wind damage in Japan

1. Main causes:
   - Typhoons (tropical cyclone)



Characteristics:

•an eye at the centre with low pressure

•a large counterclockwise revolving vortex

•usually move at between 5 and 15 m/s

•with **strong wind** (> 17.2m/s) and **heavy rainfall**

Fig. 1. Courses of typhoons passing on Japan from 1977 to 2006 (Cited from “Newton (October 2008)”)

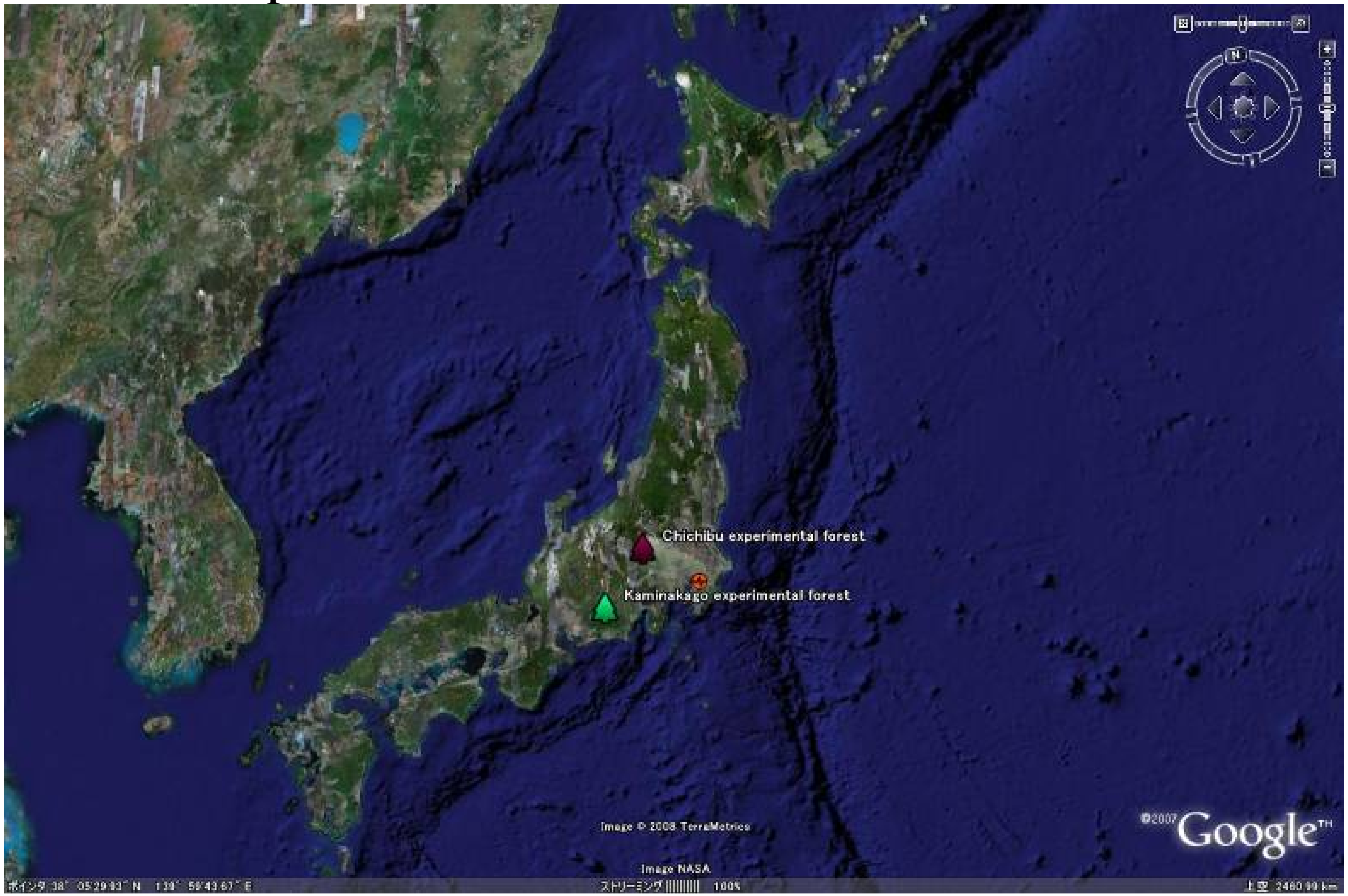
   - Storms (Extratropical cyclone)
     - With strong wind on large area
     - Typhoons often change to extratropical cyclone, then it is disappeared
     - But sometimes extratropical cyclone makes stronger wind than typhoon

2. Purposes of tree-pulling experiments

1. To understand tree & stand vulnerabilities
   - depending on tree characteristics
   - depending on tree position (inside or edge of forests)
2. To understand failures mechanisms (uprooting or stem breakage)
   - both types of failure are common
   - ruptured trees would be more serious than uprooting due to reduced log quality
3. To develop mechanistic approaches
   - determining differences of vulnerability among tree species and site locations

3. Methods

1. Site description



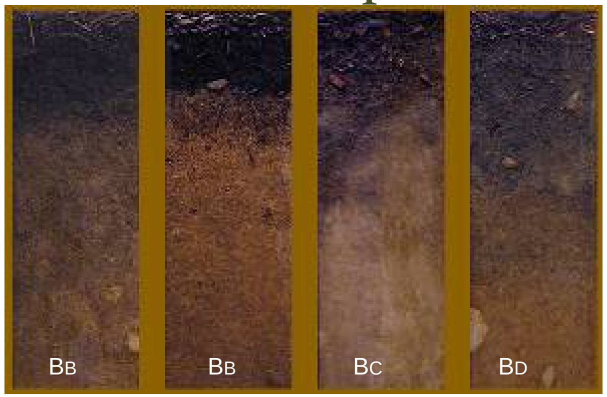
3. Methods

Chichibu experimental forest (2005)
University of Tokyo

Kamiatago experimental forest (2008)
Shizuoka University

3. Methods

2. Soil type: Brown earth soil
    1. Most popular soil type on Japanese mountains except Hokkaido Island
    2. Brown color
    3. Acid or weak acid
    4. Many varieties of characteristics



3. Target tree species

<u>Sugi</u> *Cryptomeria japonica*: Deep root, preferring soil with wet and much organic matter, tolerant of shade

<u>Hinoki</u> *Chanaecyparis obtusa*: slightly shallow root, preparing dry soil. and much organic matter, tolerant of shade

4. Procedures

- Tree-pulling experiments
  - Mostly adapting British procedure except winch method
    Power shovel or small skidder was used
    ➡ good to reduce time, but need forest engineers

- Calculating the max turning moment & MOR

- Analysis
  - Overturning
    - Correlation
      - Tree characteristics vs. TM_{total}
    - General linear morels
  - Breakage

Calculating the turning moment at stem base and MOR

I) $TM_{max,total} = TM_{max,applied} + TM_{max,gravity}$ (Nm)

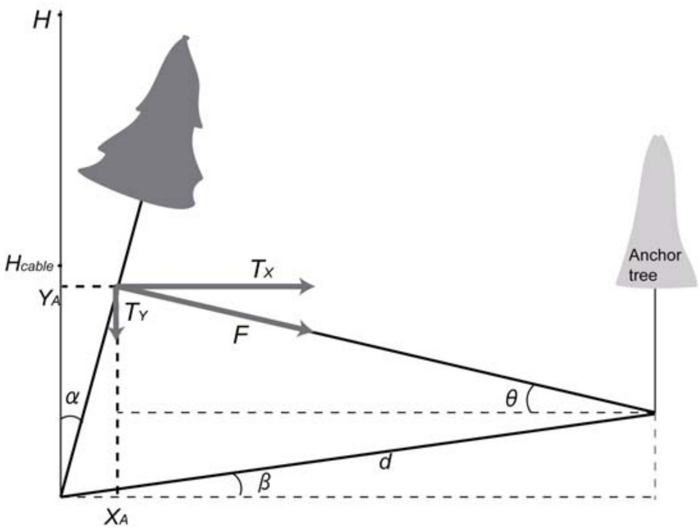
$$TM_{\max,applied} = T_X Y_A + T_Y X_A$$

$$T_X = F\cos\theta$$

$$T_Y = F\sin\theta$$

$$X_A = H_{cable}\sin\alpha$$

$$Y_A = H_{cable}\cos\alpha$$



$$TM_{\max,gravity} = W_S X_S + W_C X_C$$

W_S: weight (kg) of the lower part of the stem
X_S: centre of gravity
W_C: weight of the crown
X_C: centre of the gravity of the crown

II) Modulus of Rapture (MOR) (Pa)

$$MOR = \frac{32 TM_{\max,total}}{\pi {D_r}^3}$$

D_r: stem diameter at the ruptured part

4. Results

1. Tree-pulling experiments

Table 1. Basic statistics of pulled sugi and hinoki trees in Chichibu and Kamiatago forests

Sites	Species	Failure type	N	Age (year)	Tree height (m)	Crown depth (m)	dbh (cm)	Root-soil plate width (m)	Max root-soil plate depth (m)	Crown weight (kg)	Stem weight (kg)	Tmtotal (Nm)	Stem deflection (degree)	MOR (MPa)
Chichibu	sugi	Overturn	6	28.8 (5.9)	15.5 (1.6)	8.0 (1.2)	20.6 (3.4)	1.8 (0.4)	1.2 (0.1)	141.5 (67.0)	265.8 (93.3)	75,280.3 (33,349.2)	15.8 (1.8)	-
		Breakage	4	28.0 (6.8)	16.8 (2.6)	9.3 (1.7)	19.7 (3.4)	-	-	141.5 (47.9)	268.0 (112.6)	39,488.4 (14,660.0)	16.6 (3.4)	42.5 (4.5)
Chichibu	hinoki	Overturn	7	28.3 (3.9)	12.0 (1.3)	6.7 (0.3)	14.0 (1.9)	1.7 (0.3)	1.1 (0.1)	93.1 (23.4)	132.1 (42.0)	29,747.2 (12,347.5)	21.1 (4.6)	-
		Breakage	1	47	17.6	7	27	-	-	188.6	418.2	138,175.20	15	71.6
Kamiatago	hinoki	Overturn	14	51 (4.8)	17.6 (0.7)	7.8 (0.6)	26.3 (2.1)	2.0 (0.1)	1.1 (0.1)	175.4 (30.4)		82,978.8 (13,562.2)	16.3 (1.6)	
		Breakage	3	42.7 (11.7)	17.6 (0.9)	8.7 (0.6)	22.7 (1.2)	1.6*	0.8*	159.8		88,256.4 (17,778.8)	25.7 (3.9)	47.4 (6.9)

( ) is standard error of mean

* Root-soil plate of a broken hinoki was measured.

Sites	Species	Failure type	N	Height/dbh (%)	dbh^2h (m^3)
Chichibu	sugi	Overturn	6	78.5 (4.3)	0.9 (0.3)
		Breakage	4	86.2 (2.6)	0.8 (0.4)
Chichibu	hinoki	Overturn	7	71.7 (7.1)	0.4 (0.1)
		Breakage	1	65.1	1.3
Kamiatago	hinoki	Overturn	14	70.9 (4.4)	1.4 (0.2)
		Breakage	3	77.6 (2.4)	0.9 (0.1)

( ) is standard error of mean

2. Statistical analysis

- Correlation

Table 2. Pearson correlation between tree characteristics & maximum turning moment at stem base

Sites	Species	Failure type	N	dbh	Tree height	Root-soil plate width	Max root-soil plate depth	Stem weight	Tree weight	dbh^2h	Height/dbh
Chichibu	sugi	Overturn	6	.905*	.930**	.871*	.110	.916*	.849*	.895*	-.716
		Breakage	4	.998**	.983*	-	-	.986*	.995**	.979*	-.798
Chichibu	hinoki	Overturn	7	.587	.994**	.761*	.886**	.974**	.996**	.989**	-.290
		Breakage	1	-	-	-	-	-	-	-	-
Kamiatago	hinoki	Overturn	14	.959**	.644*	.205	.728**	-	.954**	.936**	-.859**
		Breakage	3	.972	.695	-	-	-	.997	.908	-.523

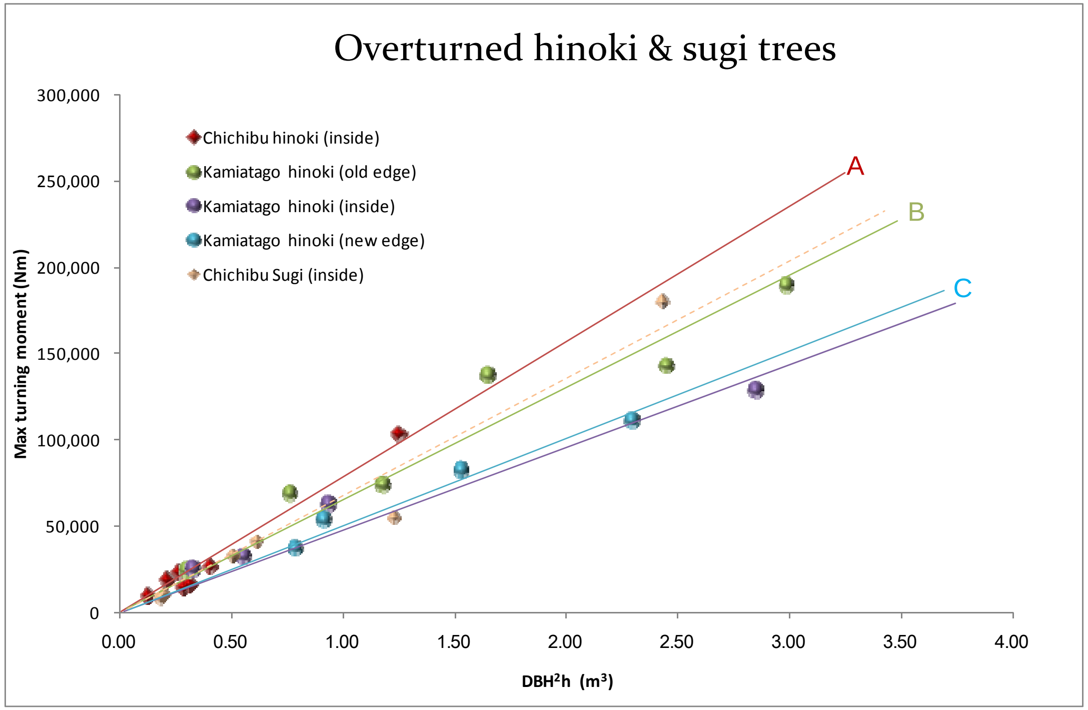
*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

The turning moment at stem base and dbh^2h & tree weight (stem weight) are strongly correlated.

4. Results

- Overturning: Linear regression models depending on position



Sites	Species	Locations	N	Models	R^2
Chichibu	sugi	Inside	6	86,902×dbh^{2}h	0.901
Chichibu	hinoki	Inside	7	78,695×dbh^{2}h	0.984
Kamiatago	hinoki	Inside	4	47,824×dbh^{2}h	0.977
		Edge (new)	4	50,575×dbh^{2}h	0.995
		Edge (old)	6	65118×dbh^{2}h	0.982

- Linear regression models depending on species

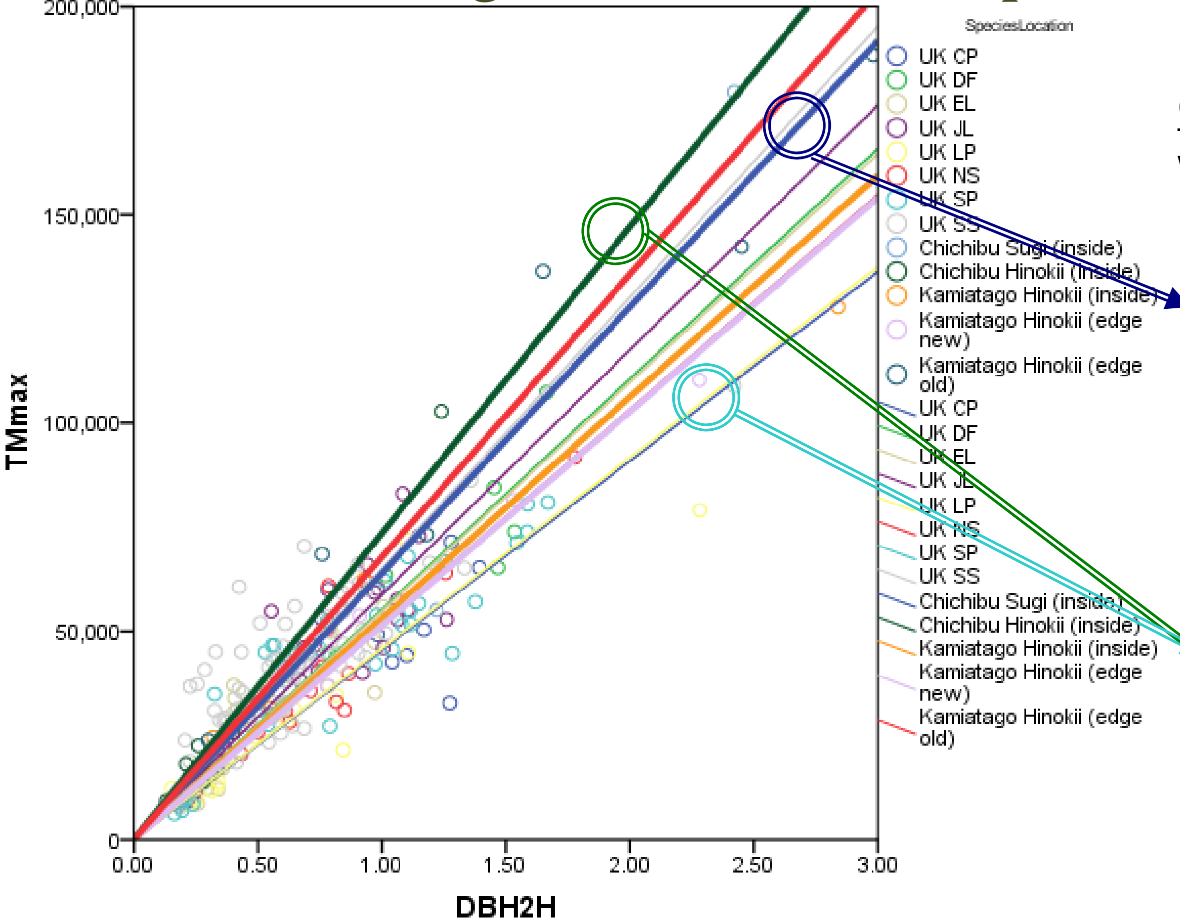


Figure 2: Linear relationship between applied turning moment and DBH2H of overturned sugi, hinoki, and tree species with more than 80 cm of root-soil plate depth in soil type A (mineral soil) in British tree-pulling database.

General Linear Model (GLM) was used to compare models between species.

Eg.1: SS vs. sugi

1 model *Sig.* = 0

2 models *Sig.* = 0.09

•*Models of SS and sugi are preferable to be one model at 0.05 level.*

•*Thus, vulnerabilities against overturning are not statistically different.*

Eg.2: CP vs. hinoki (Chichibu)

1 model *Sig.* = 0

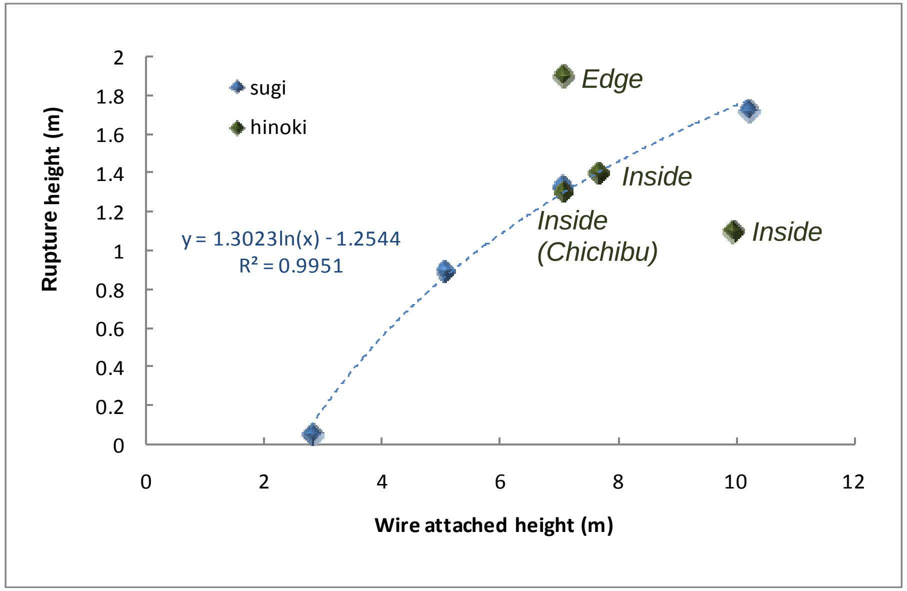
2 models *Sig.* = 0.001

•*It is hard to statistically show that these models are different or not.*

•*More data would be necessary.*

4. Results

3. Breakage: Demonstrated rupture vs. Real rupture



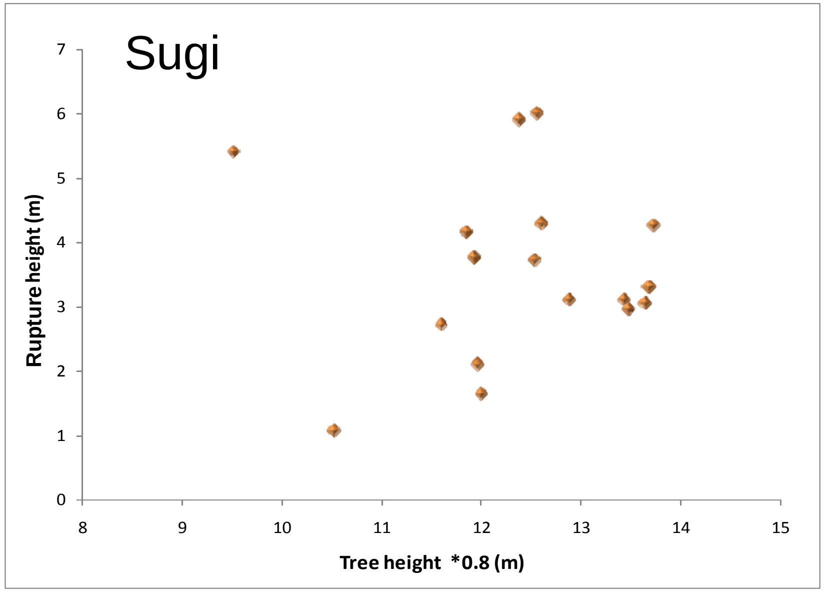


Figure 3: Ruptured sugi and hinoki in the tree-pulling experiments in Chichibu & Kamiatago

Figure 4: Relationship between rapture height and tree height*0.8 caused by a typhoon in Kyusyu Island in 1991 (Data was provided by Dr. Chiba at FFPRI.)

5. Questions

To improve procedures of tree-pulling experiments,

1. **Overturning**: Although main factors, such as root-soil plate depth and soil type, are similar, various types of stability (dbh^{2}h against the turning moment) were found.
   - Are other supportive data required?
     - E.g. Measuring water content and stiffness in the soil
2. **Breakage**: Ruptured trees can be used to calculate MOR based on the hypothesis of uniform stress on the stem (Morgan and Cannell, 1994).
   - Can this assumption used for any tree species and conditions?
     - E.g. Trees with very strong stem and root system (eg. hinoki) or on very steep terrain

Conference Information

International conference on

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Main sections are:

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- ✓ Disaster damage reduction
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- ✓ Mathematical modelling
- ✓ Application of remote sensing and geographic information
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