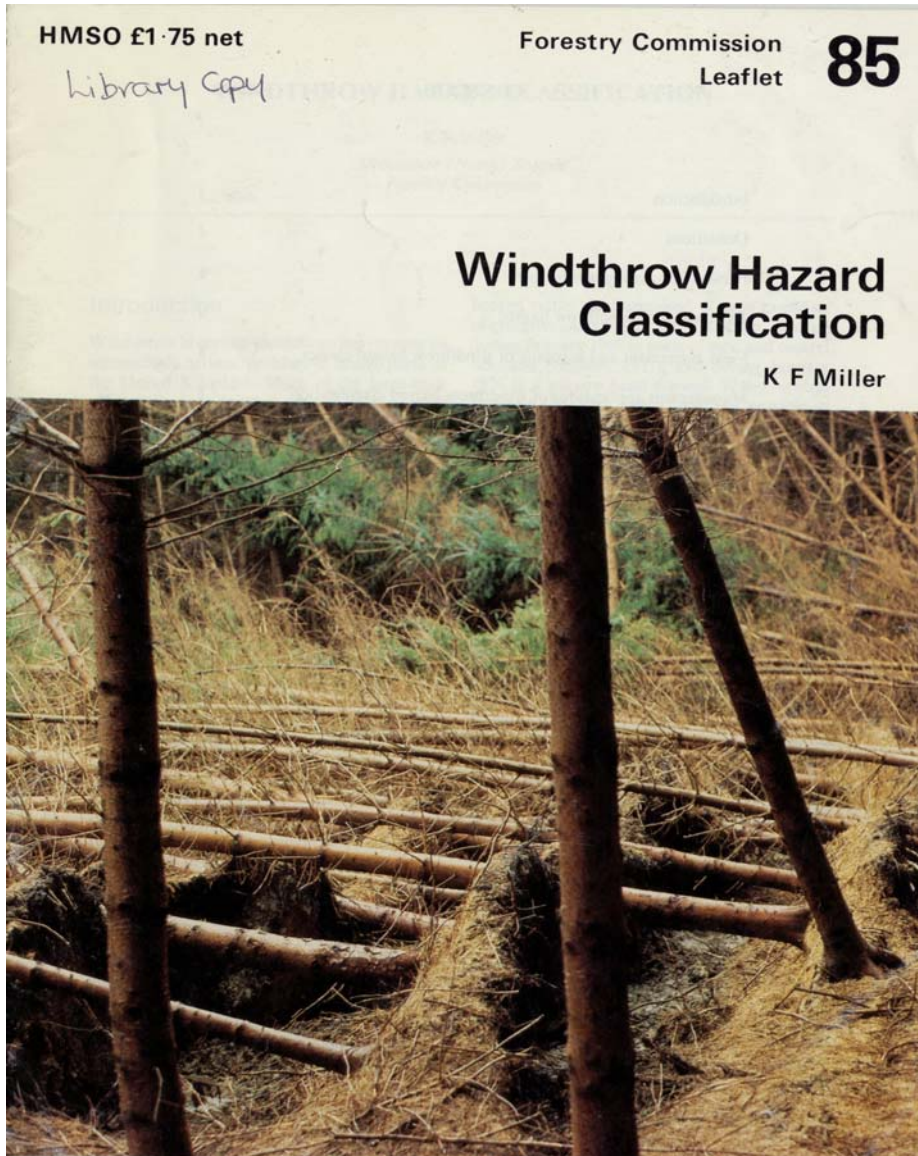


# ForestGALES

**Barry Gardiner and  
Sophie Hale**

**Forest Research,  
Roslin, Scotland, UK**

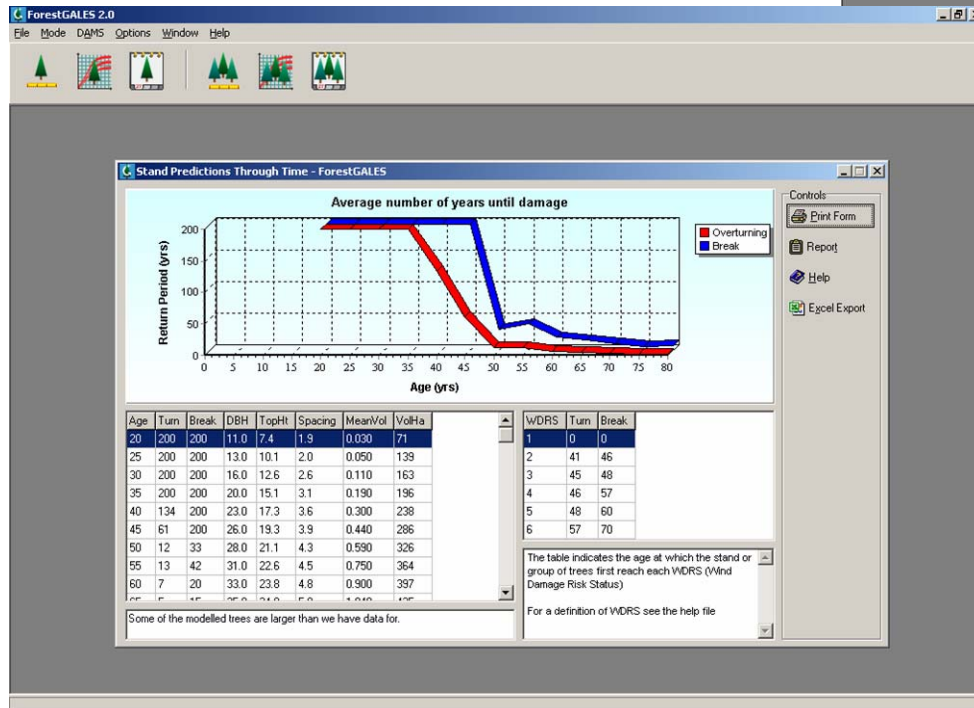
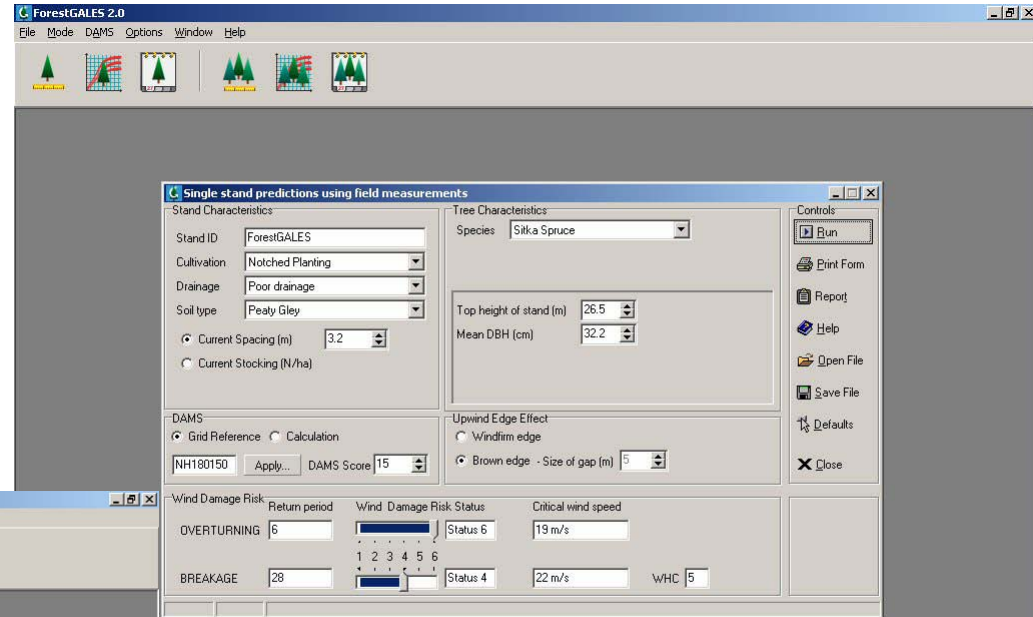




## Windthrow Hazard Classification

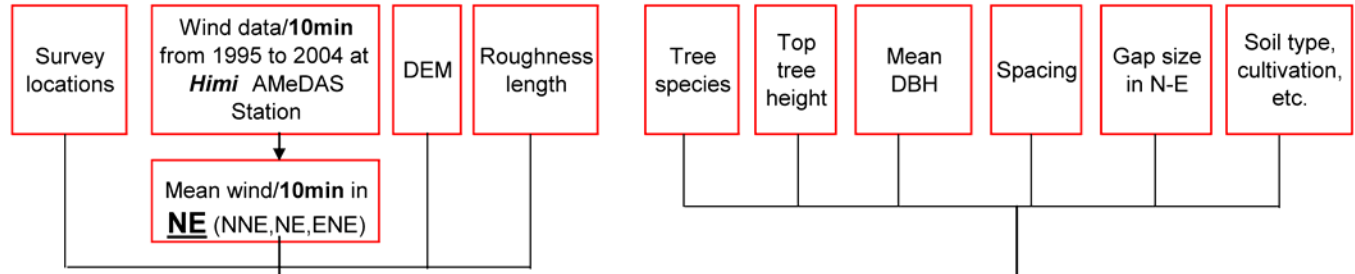
- Windiness Scores
  - Region
  - Elevation
  - Topographic Shelter (Topex)
- Soil Score
  - Rooting Depth

## ForestGALES 2: A Wind Risk Management Model (WRMM)

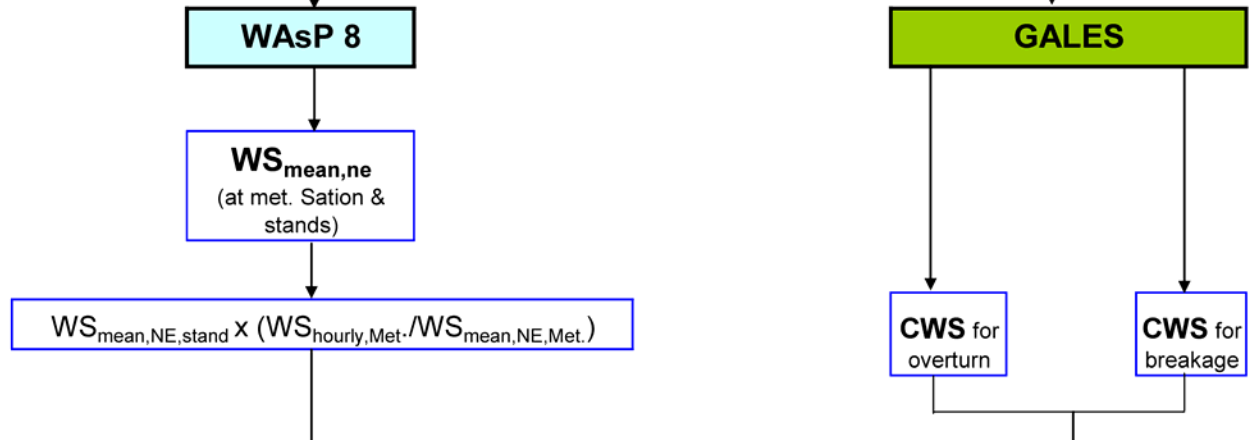


# Wind Risk Management Model: *ForestTYPHOON*

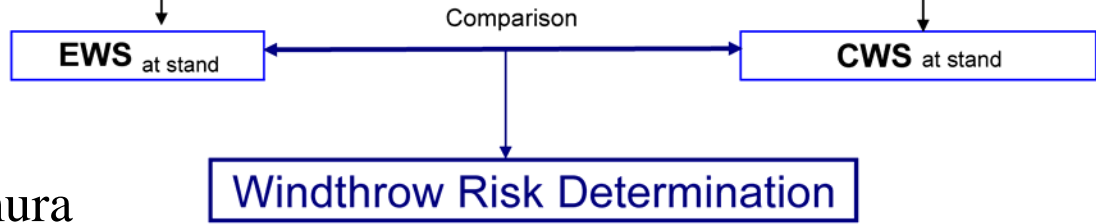
INPUT



SIMULATION



OUTPUT



courtesy Kana Kamimura

## Other Wind Damage Mechanistic Modelling

WRM Tool	CWS Model	Wind Climate	Tree Species	Country/Region	References
WINDA	HWIND	WAsP	Norway Spruce, Scots pine, birch	Scandinavia	Blennow and Sallnas (2004)
GEO-SIMA-HWIND	HWIND	Climate Data	Norway Spruce, Scots pine, birch	Scandinavia	Zeng et al. (2007b)
ForestGALES	GALES	DAMS	Most European commercial conifer species	UK	Gardiner et al. (2000) Gardiner et al. (2004)
ForestTYPHOON	GALES	WAsP	Hinoki, sugi and Japanese larch	Japan	Kamimura et al. (2008)
FORGEM-W	HWIND	Climate Data	Douglas fir	Netherlands	Schelhaas et al. (2007)
STORMFALD	GALES	Climate Data	Most European commercial conifer species	Denmark	Mikklesen (2007)
CAPSIS-FOREOLE	FOREOLE	Climate Data	Norway Spruce	France	Ancelin et al. (2004)
ForêtVENT	GALES	Climate Data	Black spruce, Jack pine, Balsam fir,	Quebec, Canada	Ruel et al., (2000)
CAPSIS-GALES	GALES	Climate Data	Maritime pine	Aquitaine, France	Cucchi et al. (2005)
WINDFIRM	ForestGALES_BC	Mesoscale airflow model	Western hemlock, Western red cedar, interior spruce and lodgepole pine	British Columbia, Canada	Di Lucca et al. (2007) Byrne (2005)

## Key Equations in GALES

$$uh_{over} = \frac{1}{kD} \left[ \frac{C_{reg} SW}{\rho G d} \right]^{\frac{1}{2}} \left[ \frac{1}{f_{edge} f_{CW}} \right]^{\frac{1}{2}} \ln \left( \frac{h-d}{z_0} \right)$$

$$uh_{break} = \frac{1}{kD} \left[ \frac{\pi \times MOR \times dbh^3}{32 \rho G (d - 1.3)} \right]^{\frac{1}{2}} \left[ \frac{f_{knot}}{f_{edge} f_{CW}} \right]^{\frac{1}{2}} \ln \left( \frac{h-d}{z_0} \right)$$

$$aef = 1 - \exp(-\exp(5(1 - uh_{crit}^2 / (AU)^2)))$$

$$\text{where } U = -0.59k^3 + 4.435k^2 - 11.863k + 13.57$$

## Pros and Cons of Current Mechanistic Models

Strengths	Weaknesses
Can predict the risk of wind damage at stand, forest and national scale	Cannot deal with complex forest structures
Uniform coniferous plantations	Wind climate modelling
Synthesises our existing knowledge (objective)	Comparison of individual stands needs to be treated with care
Shows impact of silviculture, cultivation and species choice	Not able to predict risk for broadleaves
Shows change of risk through life of crop	Sensitive to data input (particularly dbh and spacing)
At its best is correct ~70% of time (needs quality data)	Exact timing of catastrophic wind damage (no one can predict this!)
Planning forest operations (thinning, harvesting, roads)	Can persuade people to stop thinking!
Have developed objective management tools for many parts of the world	Almost nobody is using them operationally

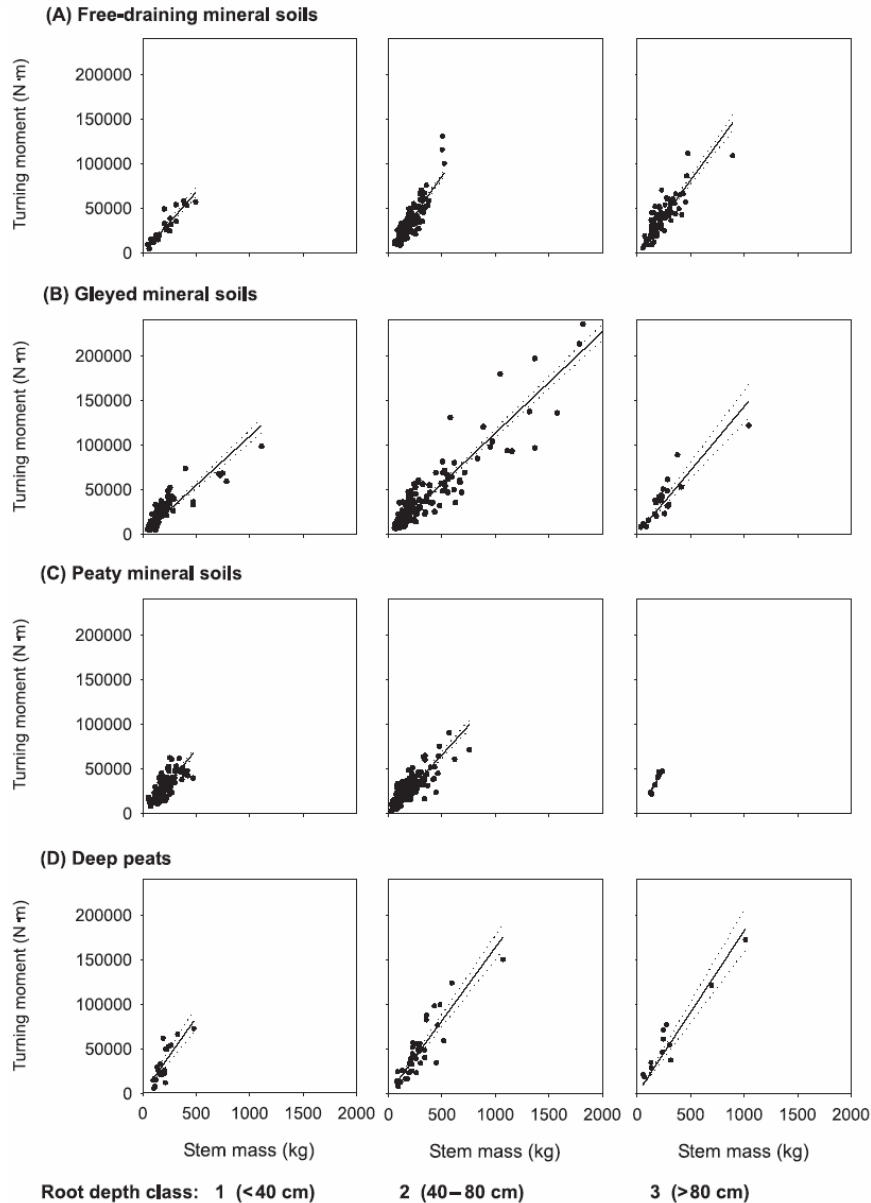
## What Next for ForestGALES?

- Modify to calculate risk to individual trees in order to deal with more complex stands. Previous assumptions may no longer be valid
- Modelling of resistance to overturning needs to move to more rational basis than regression against stem weight
- Need to improve prediction of gust loading in forest. LES can do this but computationally expensive and difficult to set up
- Need to account for adaptive response of trees, in particular following changes to stand conditions
- Need for better (and accessible) airflow models in forested complex terrain.
- Models need to be linked in any easy to use format for real use to be made of them. GIS, Decision Trees, etc. Need to consider end-user requirements

## What Has Improved since 2000

- Better soil rooting classification which brings logical structure to tree pulling
- LES models are capable of fully simulating flow over forests and wind loading on trees
- Possible to predict wind loading on individual trees using competition indices
- Understand the impact of crown clashing much better
- FEM modelling has improved description of dynamic behaviour of trees
- Airflow models able to predict flow in complex forested terrain are now becoming available

## Regressions Using Soil Type and Rooting Depth



- Logical structure that depends only on soil type and rooting depth
- Evidence for adaptation by trees in response to wind climate

**Table 5.** Soil group and rooting depth, coefficient of regression line ( $C_{reg}$ ), number of samples (number of sites is given in parentheses),  $p$  value for the comparison with the equivalent regression for Sitka spruce, and standard error (SE), for each species.

Species	Soil group	$C_{reg}$			No. of samples (sites)			$P$			SE		
		<40 cm	40–80 cm	>80 cm	<40 cm	40–80 cm	>80 cm	<40 cm	40–80 cm	>80 cm	<40 cm	40–80 cm	>80 cm
CP	A	105.1	125.5*	131.0	1(1)	31(2)	24(3)	0.17	<0.01	0.10	24.8	10.3	12.7
	B		129.5			27(2)			0.39			21.9	
	C												
	D												
DF	A		197.9*	165.6		16(2)	15(2)		<0.001	0.39		10.1	11.9
	B	197.4	156.9		2(1)	6(1)		0.22	0.17		70.3	51.8	
	C												
	D												
EL	A		177.5	147.7		1(1)	23(2)		0.65	0.77		33.4	21.4
	B												
	C												
	D												
GF	A			212.9*			10(2)				<0.001		15.3
	B	166.0*	193.0*	173.1	8(2)	8(2)	3(1)	<0.05	<0.05	0.66	24.4	25.4	27.7
	C		135.2	128.5*		2(1)	6(1)		0.77		<0.001	31.9	9.0
	D												
JL	A	177.1	182.8	168.2	1(1)	12(1)	31(3)	0.29	0.19	0.35	30.9	14.7	13.6
	B												
	C												
	D												
LP	A	137.9	142.6*	140.1	6(4)	63(6)	25(6)	0.77	<0.05	0.33	12.8	7.3	12.8
	B		137.8	148.5		15(2)	5(2)		0.31	0.61		26.3	21.4
	C	94.1	119.0	123.2*	1(1)	12(1)	6(1)	0.72	0.78	<0.001	95.7	24.9	9.7
	D		141.3	132.2*		7(1)	19(2)		0.73	<0.001		42.9	15.6
NF	A			107.5			8(1)			0.07			24.7
	B												
	C	78.5	105.6	195.8	2(1)	5(1)	1(1)	0.34	0.48	0.78	51.9	28.1	20.9
	D												
NS	A	127.8	154.6	160.9	7(1)	22(2)	22(4)	0.67	0.72	0.63	32.7	19.2	12.4
	B	62.9*	114.2		24(3)	64(5)		<0.001	0.73		9.5	9.9	
	C												
	D												
RC	A												
	B		171.7	193.9		6(1)	2(1)		0.13	0.41		40.2	38.9
	C												
	D												
SP	A	124.1	146.4	141.3	5(3)	71(5)	40(5)	0.31	0.17	0.27	15.4	9.6	9.6
	B												
	C												
	D												
SS	A	142.4	162.0	154.0	31(8)	149(12)	101(13)	—	—	—	8.6	6.1	6.4
	B	111.0	110.6	160.2	109(12)		24(7)	—	—	—	6.4	3.7	8.9
	C	129.0	126.0	202.4	120(7)	191(14)	8(3)	—	—	—	8.6	6.6	9.5
	D	180.6	156.7	189.9	19(5)	137(8)	13(6)	—	—	—	20.2	10.4	11.8
WH	A	109.9	141.2	168.7	5(2)	7(1)	8(1)	0.14	0.36	0.52	19.5	21.6	22.1
	B	126.0	152.2		12(2)	10(3)		0.70	0.13		36.6	27.2	
	C												
	D												

Note: Coefficients significantly different ( $p < 0.05$ ) from Sitka spruce are indicated with an asterisk. Trees were excluded if they snapped during tree pulling or if root rot was recorded. Soil group codes are given in Table 1.

**New Regressions  
(will use in FG 2.3 Demo)**

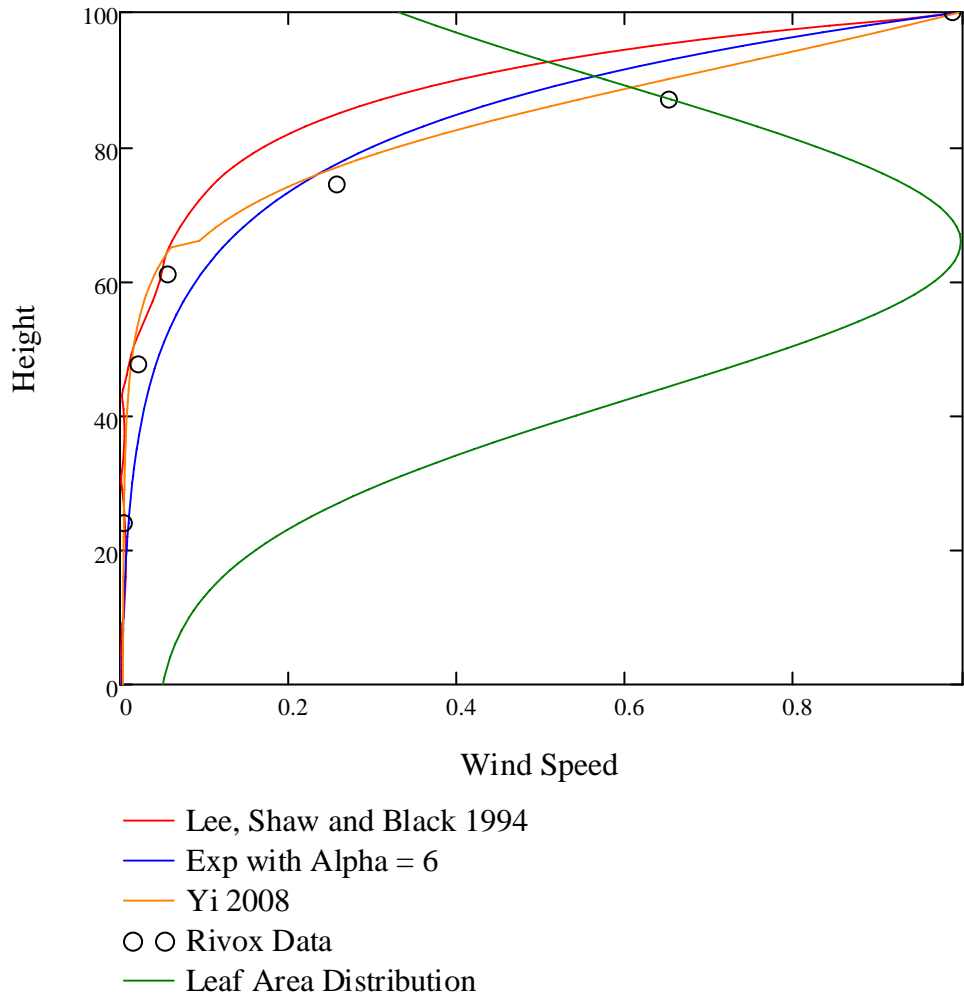
## New Drag Measurements

- A number of new drag measurements have been made in the wind tunnel
- Rationalisation of existing and new drag measurements
- Drag coefficients still not known for many species, particularly broadleaves.



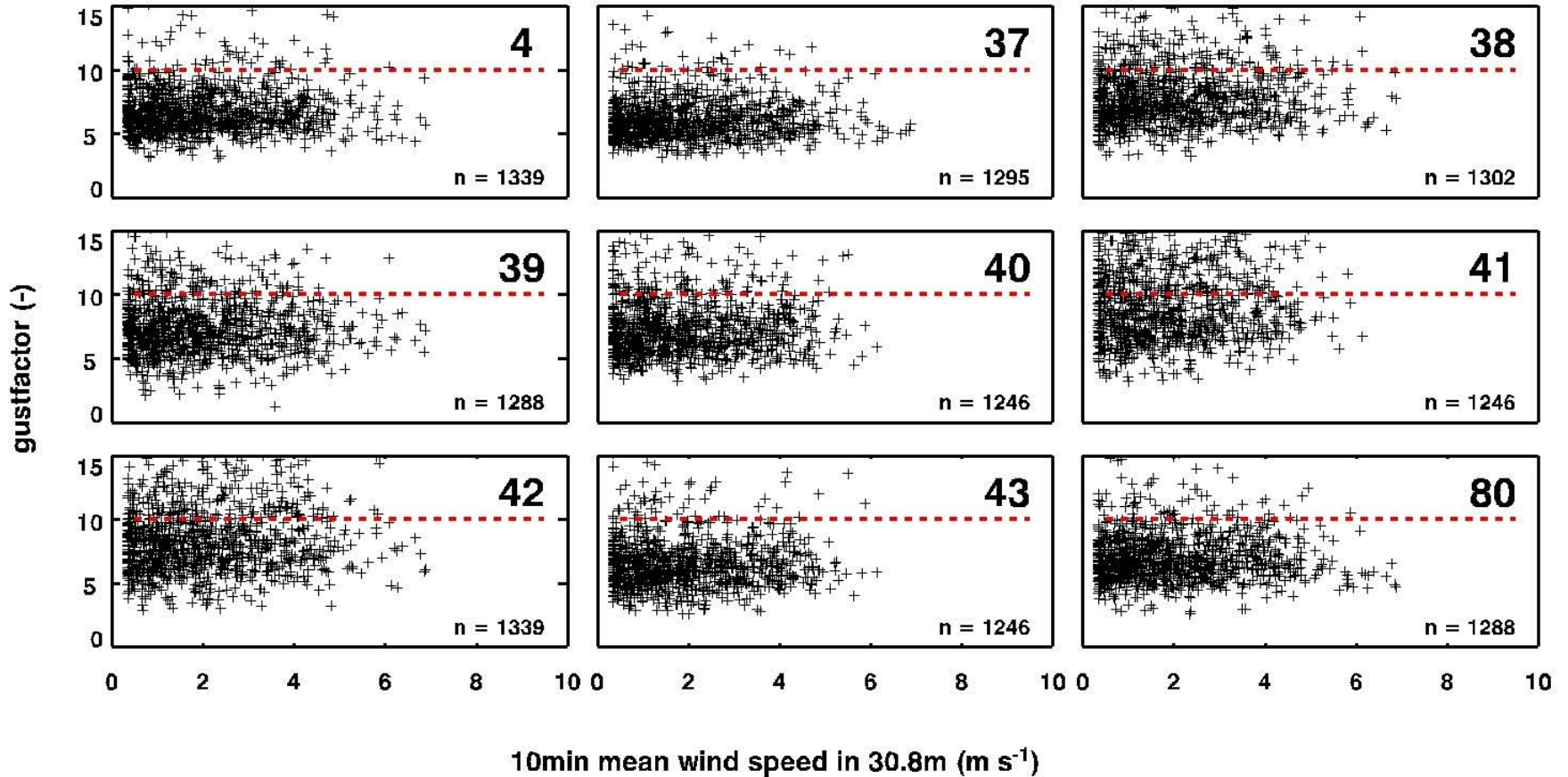
## Velocity Profiles

Wind Profiles in Canopy (Rivox)



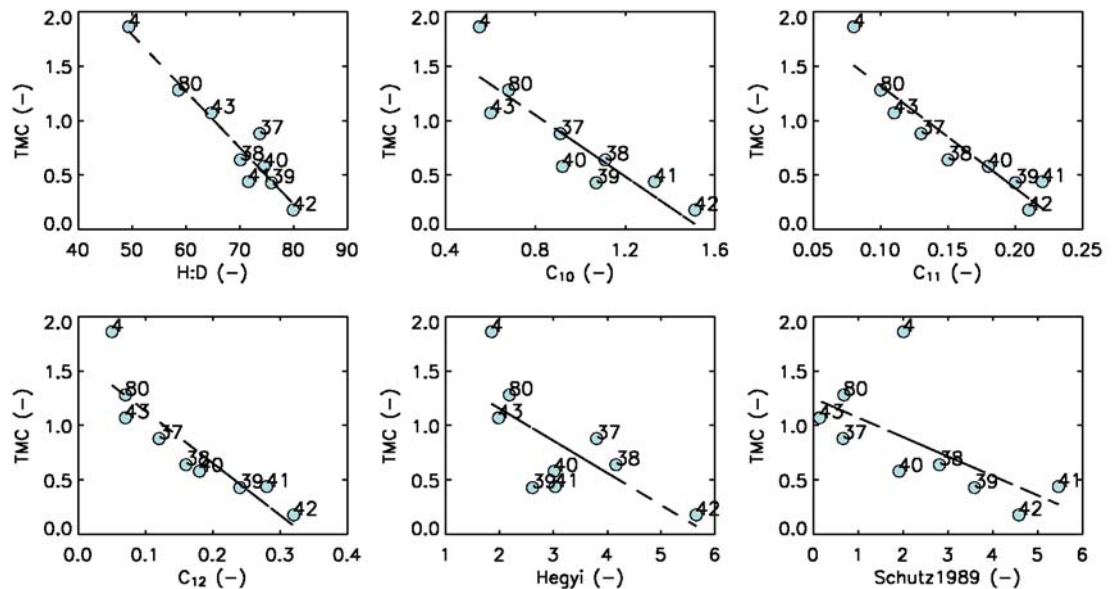
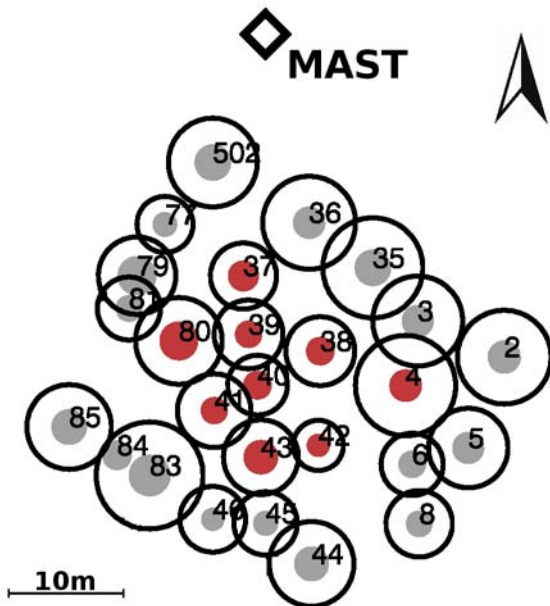
- Present models uses empirical fits
- Empirical fits are based on uniform forest data
- Need to be able to predict wind profiles in more complex forest types
- Make use of 1D or 2D airflow models with proper canopy leaf area description

# New Measurements of Gust Factors



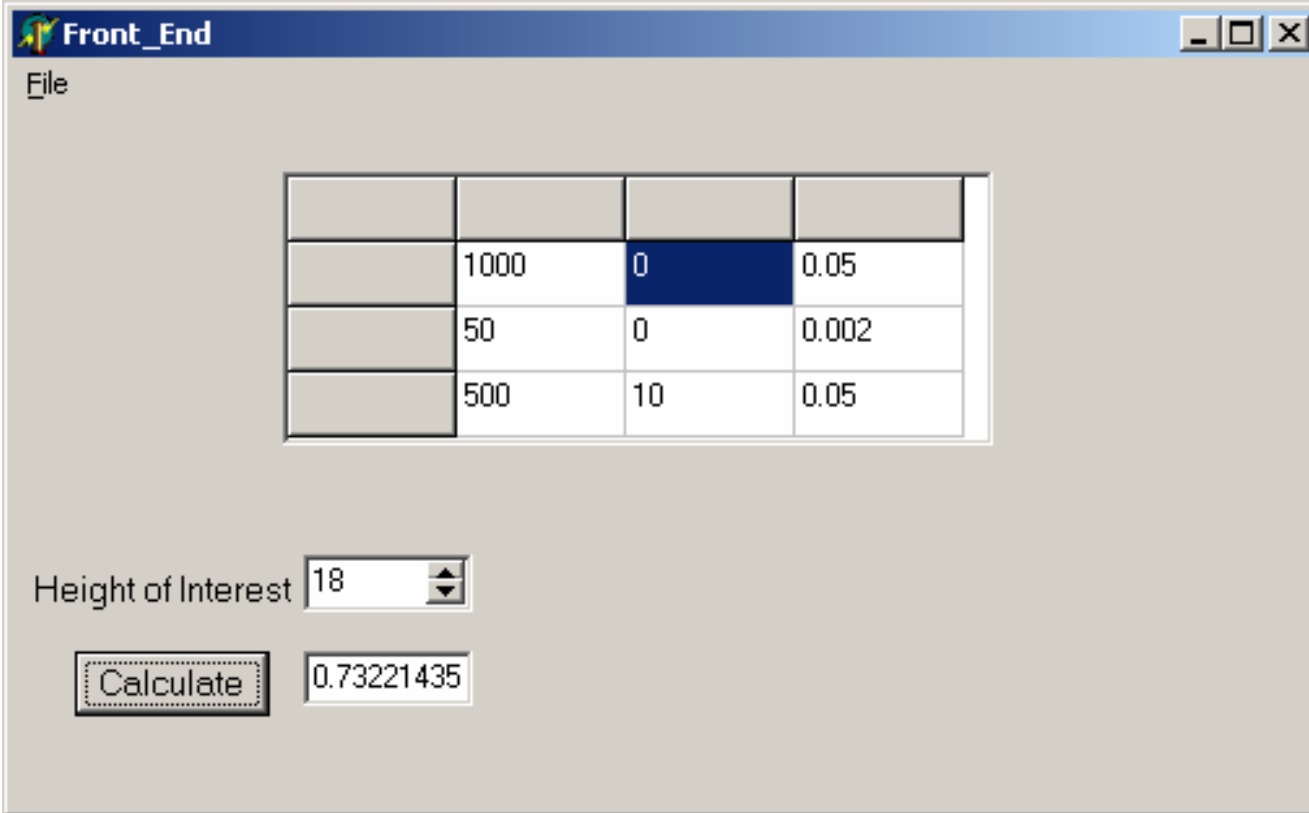
courtesy Axel Wellpott

# Wind Loading for Individual Trees



courtesy Axel Wellpott

## Model to Calculate the Effect of Upwind Land Use



The screenshot shows a software window titled "Front\_End" with a "File" menu. It contains a table with four columns and four rows. The second row is highlighted in blue. Below the table, there is a "Height of Interest" label with a spin box set to "18". A "Calculate" button is next to a text box displaying the result "0.73221435".

	1000	0	0.05
	50	0	0.002
	500	10	0.05

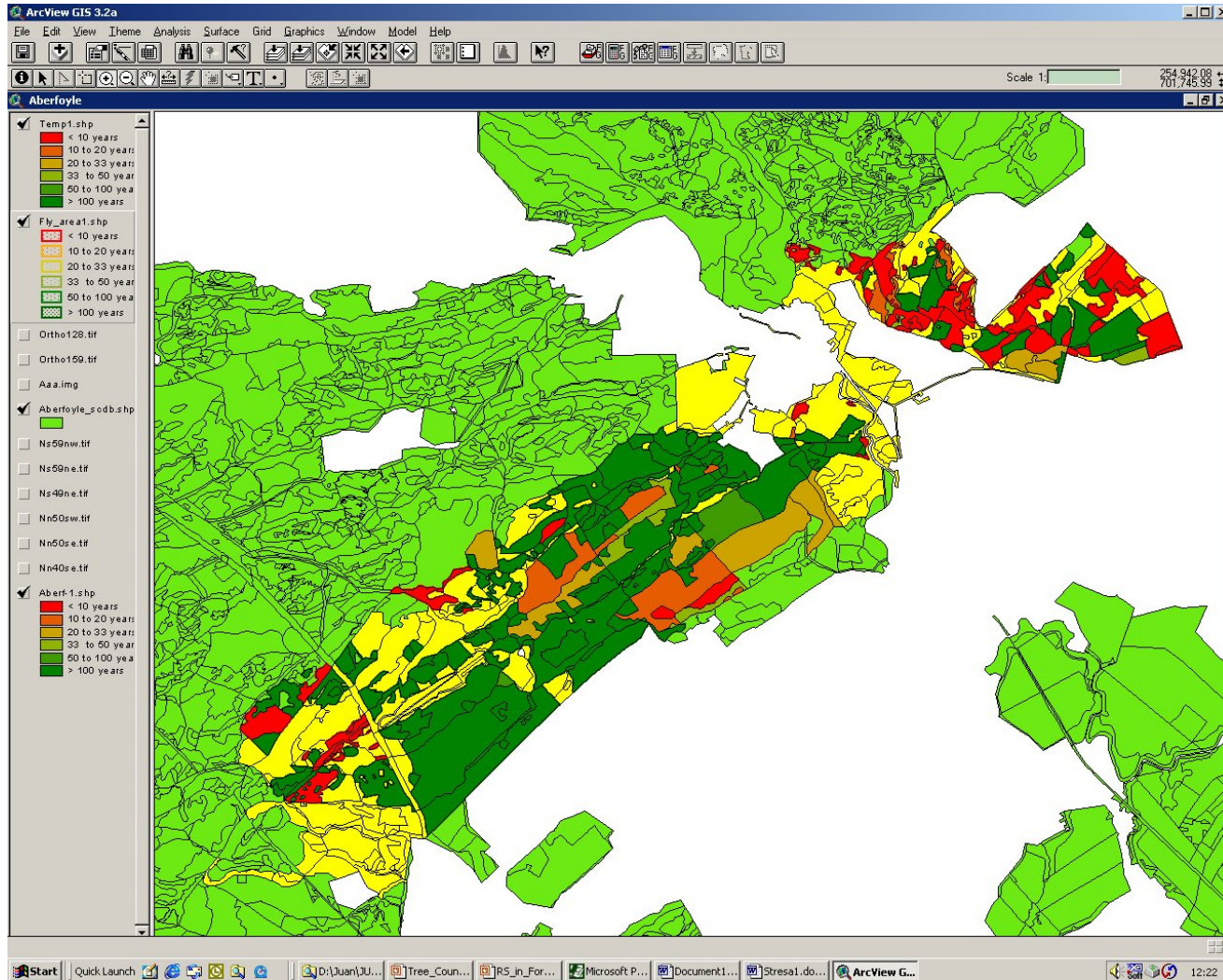
Height of Interest: 18

Calculate: 0.73221435

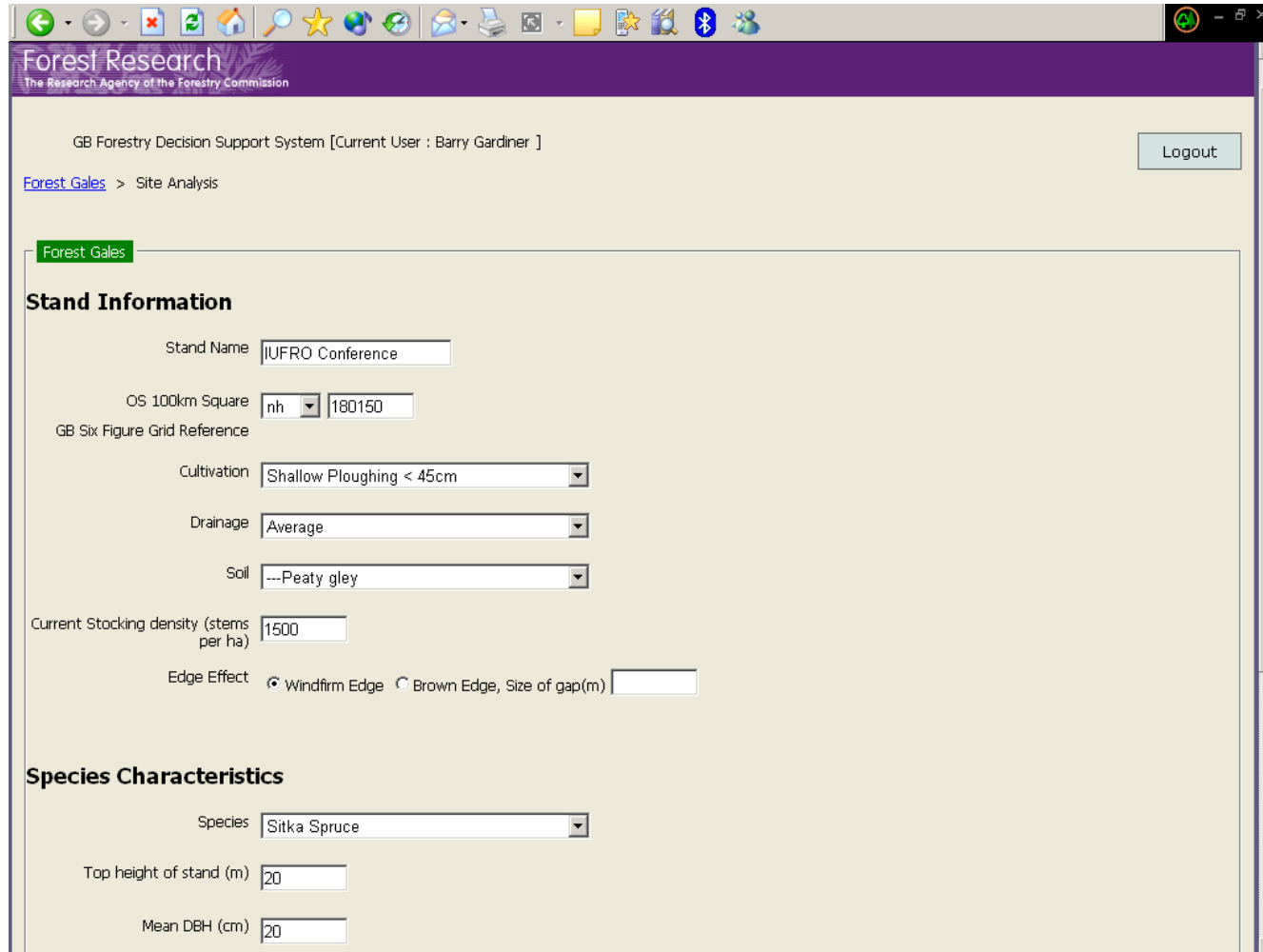
## Where is ForestGALES going?

- GIS
  - Short Term: Calculation of current risk on annual basis
  - Long Term: Full implementation within ArcView.
- WEB
  - Short Term: Basic version on WEB @ <https://www.eforestry.gov.uk/forestdss>
  - Long Term: Full version available plus downloadable versions
- Research Version
  - Short Term: Reprogrammed to make all parameters available within external text files
  - Long Term: Versions available as dll, java code and Excel(?)
- ForestGALES3 (Multi structured stand version)

# ForestGALES Linked to GIS



# ForestGALES on the WEB



Forest Research  
The Research Agency of the Forestry Commission

GB Forestry Decision Support System [Current User : Barry Gardiner ] Logout

[Forest Gales](#) > Site Analysis

**Forest Gales**

**Stand Information**

Stand Name

OS 100km Square

GB Six Figure Grid Reference

Cultivation

Drainage

Soil

Current Stocking density (stems per ha)

Edge Effect  Windfirm Edge  Brown Edge, Size of gap(m)

**Species Characteristics**

Species

Top height of stand (m)

Mean DBH (cm)

<https://www.eforestry.gov.uk/forestdss>

## Challenge for Wind Risk Mechanistic Modelling

- Modelling airflow in complex stands
- Characterising complex stands in useable ways
- Predicting extreme loading on individual trees
- Including broadleaves
- Dealing with changing risk during storm as stands fail
- Including tree acclimatisation following disturbance (thinning, felling, road construction, etc.)
- Linking CWS Models to Wind Climate Models
- Keeping things simple enough to be useable

# Forest wind damage modelling workshop

