



Scotland's centre of expertise connecting climate change research and policy



Predicting the risk of wind damage to multiple forest types in a changing climate

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- 3. ClimateXChange, Scotland



Plan of Talk

Tools for supporting decisions on forest storm risk management

- Short background to forest wind damage in Europe
- Development of ForestGALES wind damage risk model
 - Development of risk model for uniform coniferous plantation
 - Addition of broad-leaved species
 - Application in different countries
 - Development of a single tree version for complex forest structures
- Integration of ForestGALES with other computer-based tools:
 - Integration within Excel spreadsheet
 - Integration in QGIS
 - Integration with airflow model
- Current/Future developments of ForestGALES
 - Library in R for integration in other DSS
 - Link with growth models and climate prediction
 - Link between single tree version and LiDAR survey data



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Storm 31 January 1953: Scotland

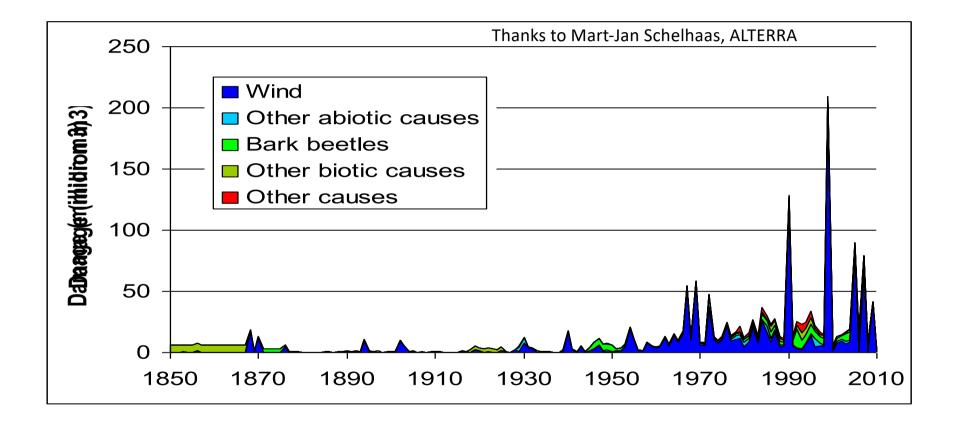




Storm Klaus 24th January 2009: Aquitaine

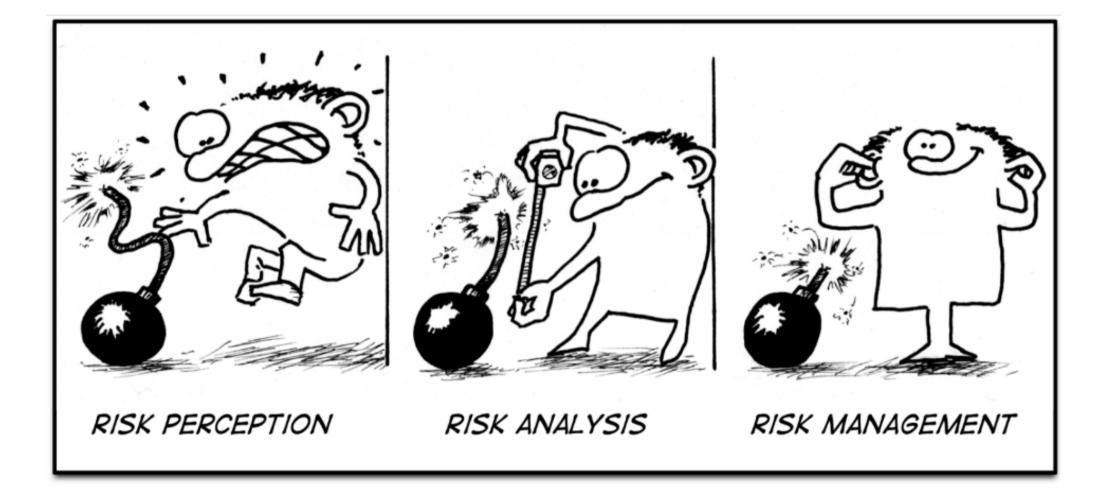








Risk Analysis and Management

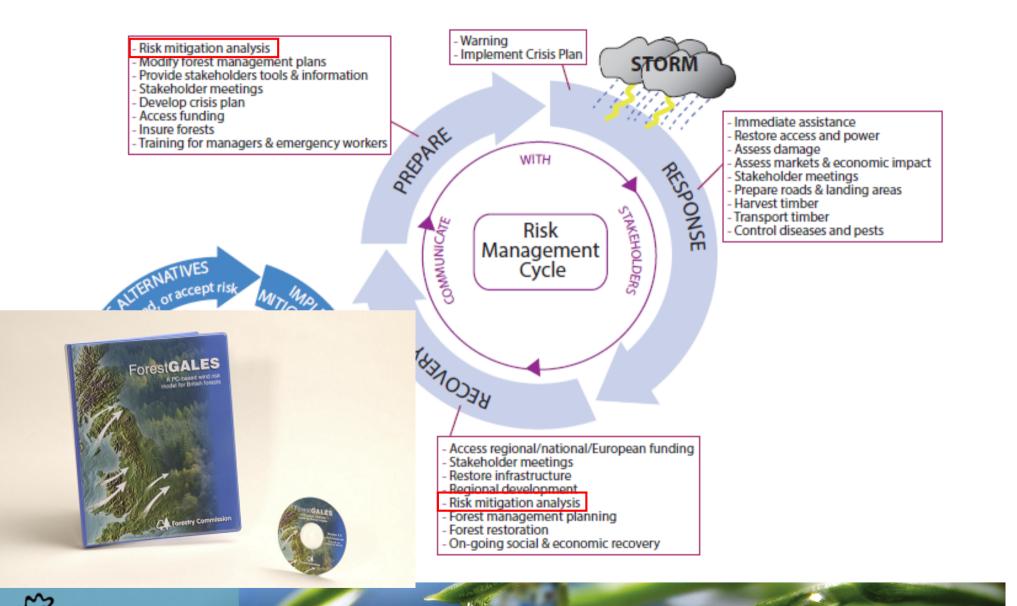




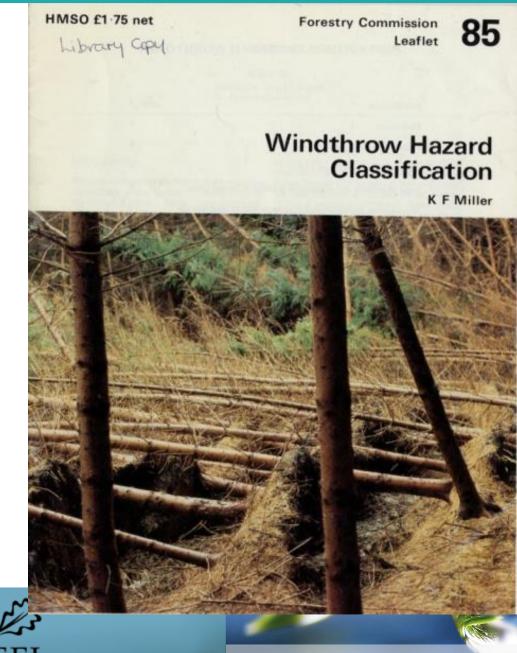
Risk Models in Risk Management

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EF



Windthrow Hazard Classification: Early Wind Damage DSS



Windiness Scores

-Region

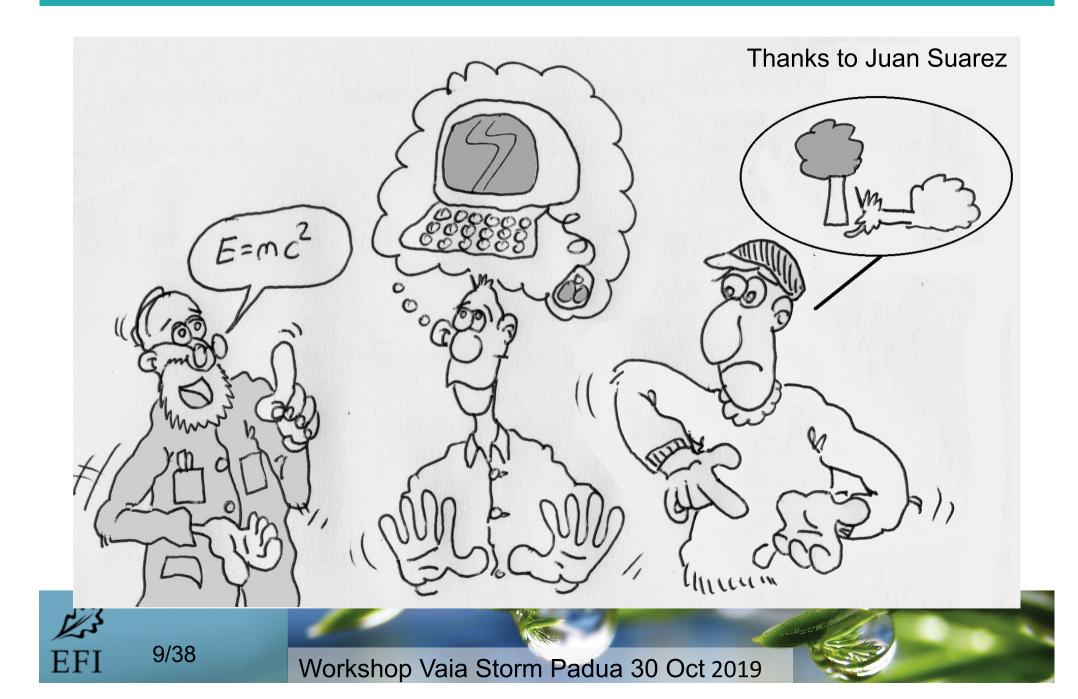
- -Elevation
- -Topographic Shelter

(Topex)

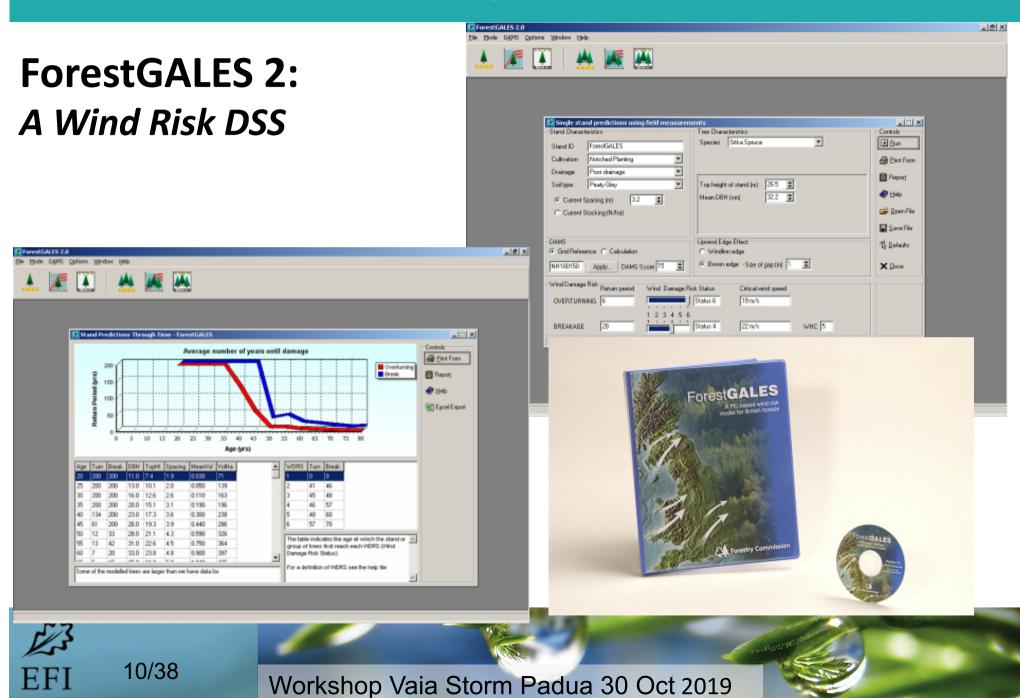
Soil Score

-Rooting Depth

Integrating knowledge: Decision Support Systems



ForestGALES: Modèle de Risque de Vent

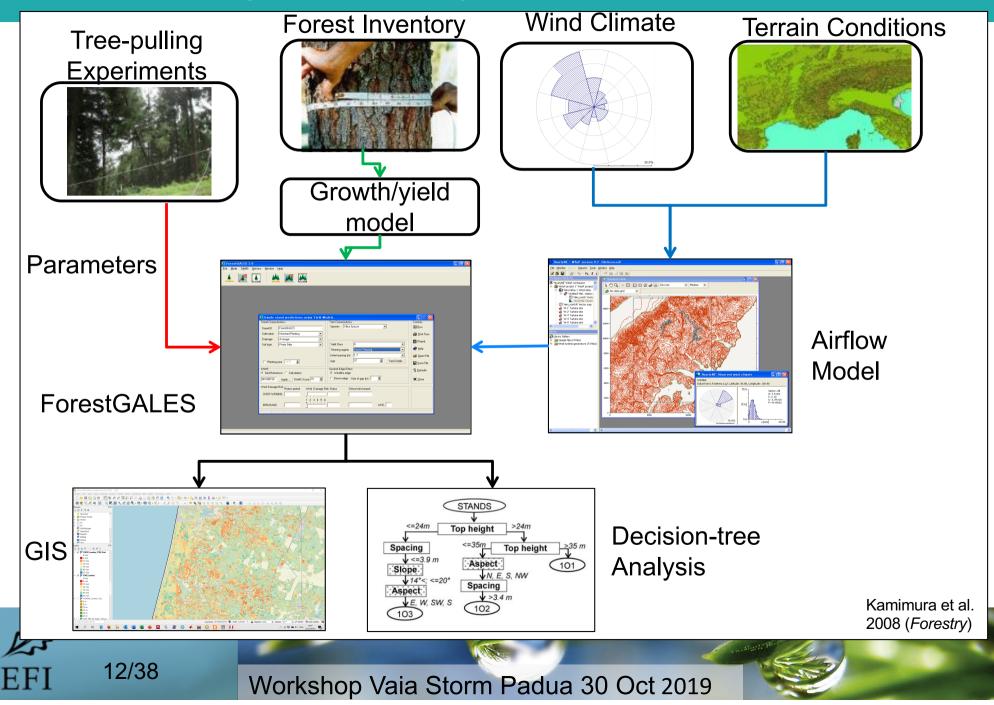


Versions of ForestGALES: Basaize 1.2 and ForêtTempête 1.1

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DERROCAR 200 ROTURA 200	CHABLIS 200 Status 1 1 '2 '3 '4' 5' 6' Status 1 RUPTURE 200	122.0 km/h 99.5 km/h	Probabilités		



ForestGALES Inputs and Outputs



ForestGALES for Complex Forest Stands

ForestGALES was only designed for uniform coniferous stands.

- 1. Needed to add broadleaved species
- Needed to be usable in complex forest stands (multi-species, multi-age)



Even-aged regular

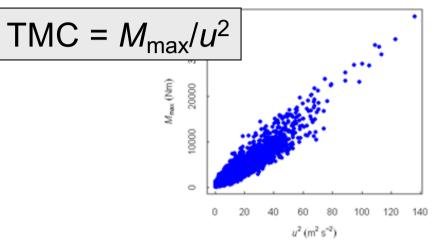


Uneven-aged irregular

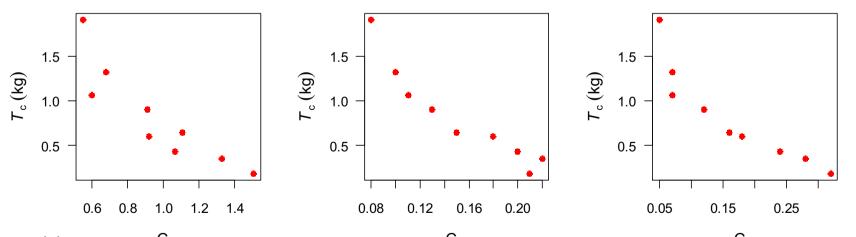


ForestGALES_TMC for Complex Forest Stands

New Method: Turning Moment Coefficient



TMC related to competition index



TMC = f(D, H)

8

6

8

2

4

6

 $D_{1,3}^2 H(m^3)$

8

10

 T_{c} (kg) 8



ForestGALES for Broadleaf Species

Birch



Beech



Oak



Silver birch Betula pendula

European beech Fagus sylvatica

Pedunculate oak *Quercus robur*



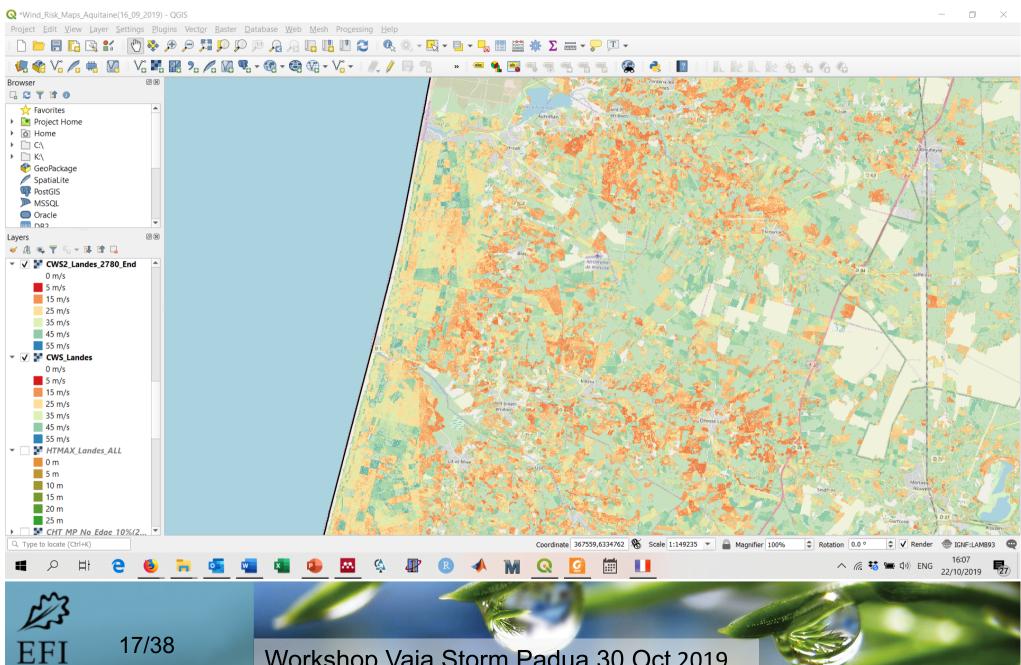
ForestGALES in Excel

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EFI

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	221	7.3666667	10.4			-2.53	43.05	2.783	1.276	Mineral	Shallow	No		5	22.8	17.7	33.4	26.8	0.0	0.1
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ForestGALES in QGIS

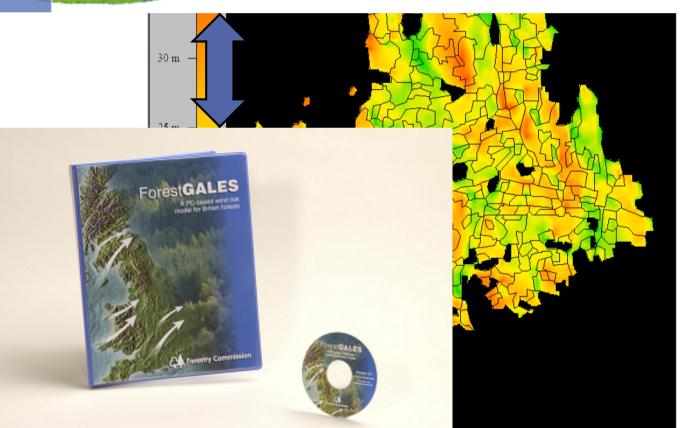


ForestGALES coupled with WAsP Airflow Model



WASP Wind resources for wind turbine production







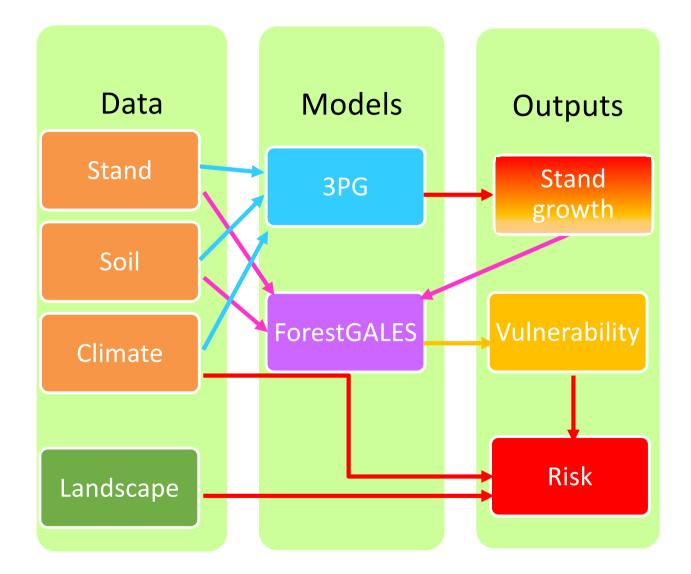
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Current/Future developments of ForestGALES

- FOSPREF-Wind:
 - Integration of ForestGALES R library with other models/DSS: Link with growth models and climate predictions
- Link between single tree version and LiDAR survey data







Models

3PG

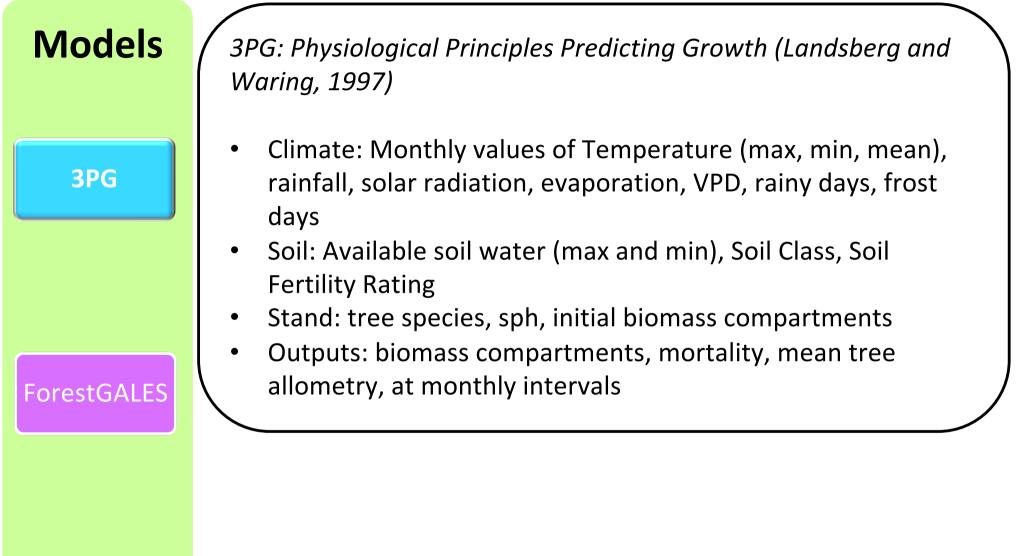
Xenakis et al., 2008. Sensitivity and uncertainty analysis from a coupled 3-PG and soil organic matter decomposition model. *Ecological modelling*, *219*(1-2), pp.1-16.

We know their parameter/input sensitivities

ForestGALES

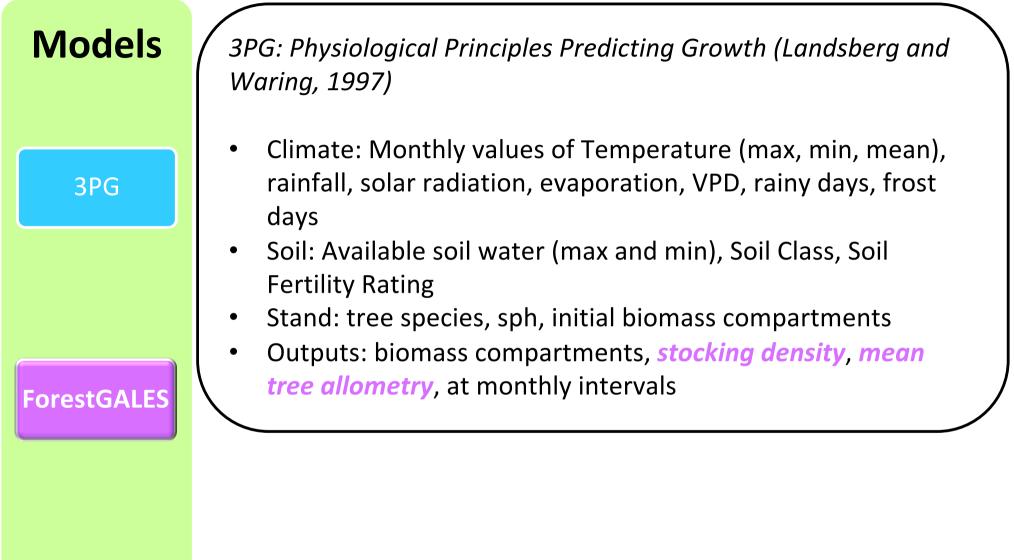
Locatelli et al., 2017. Variance-based sensitivity analysis of a wind risk model-Model behaviour and lessons for forest modelling. *Environmental modelling & software, 87*, pp.84-109.





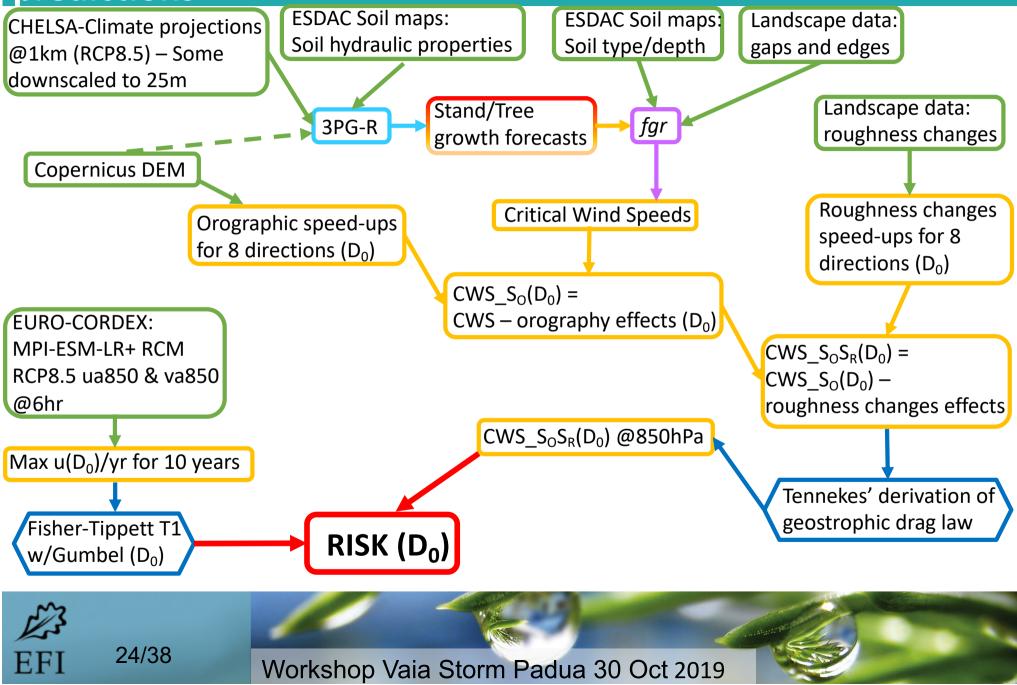


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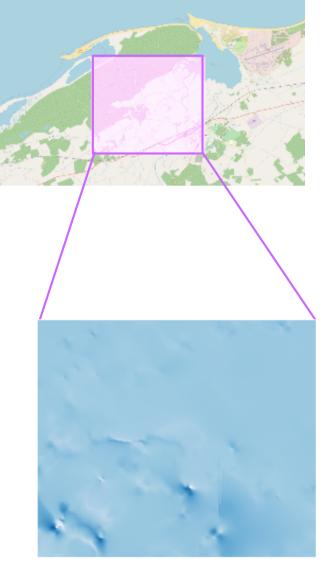
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Scottish case study area: coastal Scots Pine (*Pinus sylvestris*) forests in north Aberdeenshire

- Increased resolution of temperature CHELSA Climate 3PG input raster files with lapse rates
- 3PG functions extracted from existing FORTRAN code (Xenakis, 2007) and R shiny web app (Arias-Rodil et al.), rebuilt as R package: <u>https://github.com/drGeorgeXenakis/threePG</u>
- Calibrated 3PG-R for SP using FC permanent sample plots data
- ForestGALES complete R package ('fgr') released (both stand-level and individual tree methods): <u>https://github.com/tom-locatelli/fgr</u>
- Created QGIS Toolbox algorithm to run *fgr* within QGIS tested for Maritime Pine (*Pinus pinaster*) forests in Aquitaine, France
- Calculated orographic speed-ups maps for cardinal & intercardinal directions with WAsP (<u>https://www.wasp.dk/</u>)
- Coded and tested R functions for landscape-level aerodynamic roughness speed-ups and depth of boundary layer as a function of roughness changes



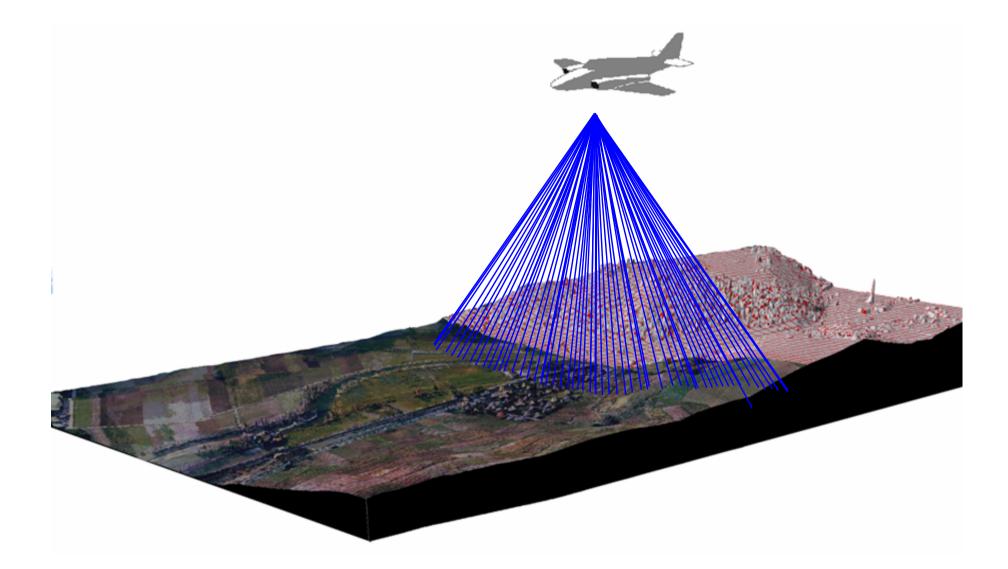


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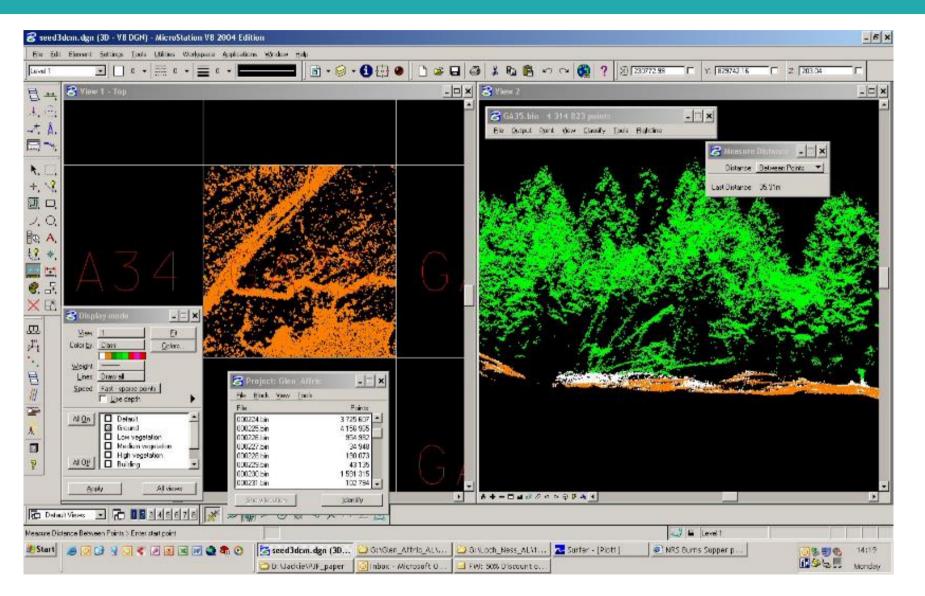
NEXT:

- Test aerodynamic roughness speed-ups scripts on raster files of land use change
- Package these scripts in a corollary R package to fgr (foRest.aiRflow?)
- Run the coupled models in R using EURO-CORDEX data
- Create QGIS Toolbox scripts to facilitate forest managers' planning operations



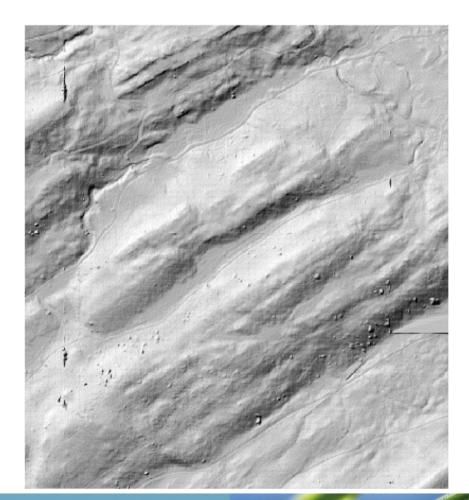




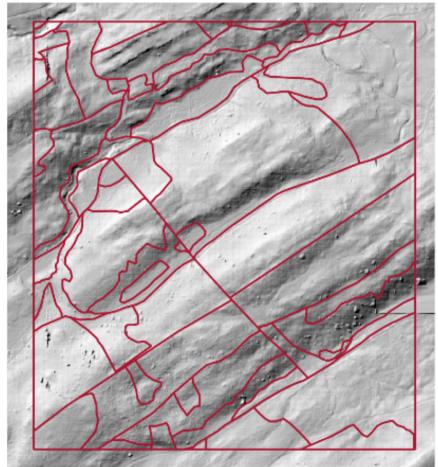




- Dem of surrounding area
- Fairly gentle
- Quite uniform predominant direction of valleys



- Management coupes only partially match topography
- Other characteristics might be important: soils, previous management history



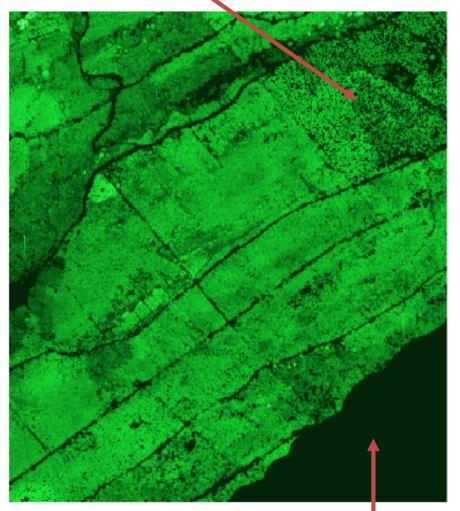


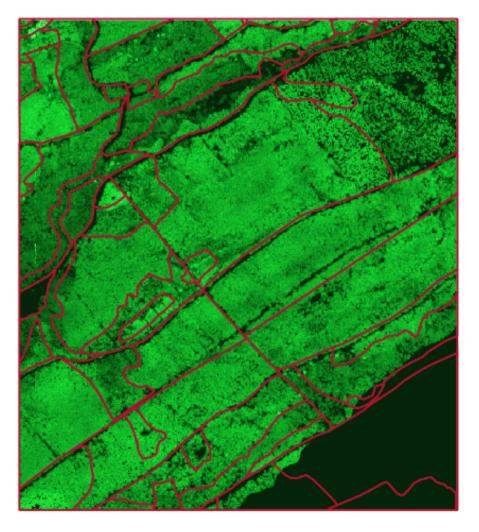
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Previous thinning

Forest in 2002

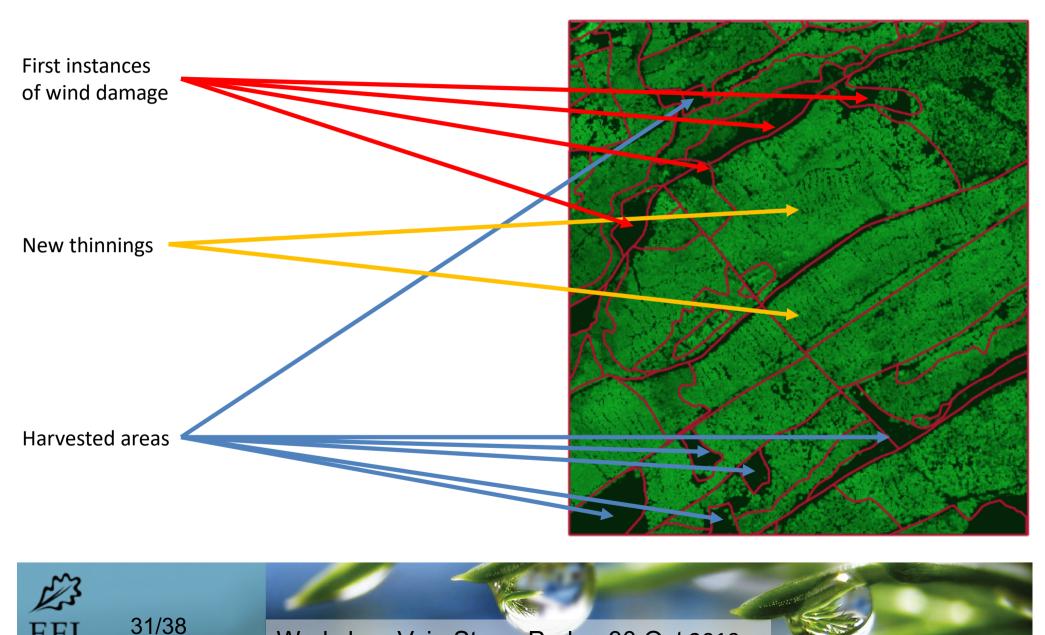




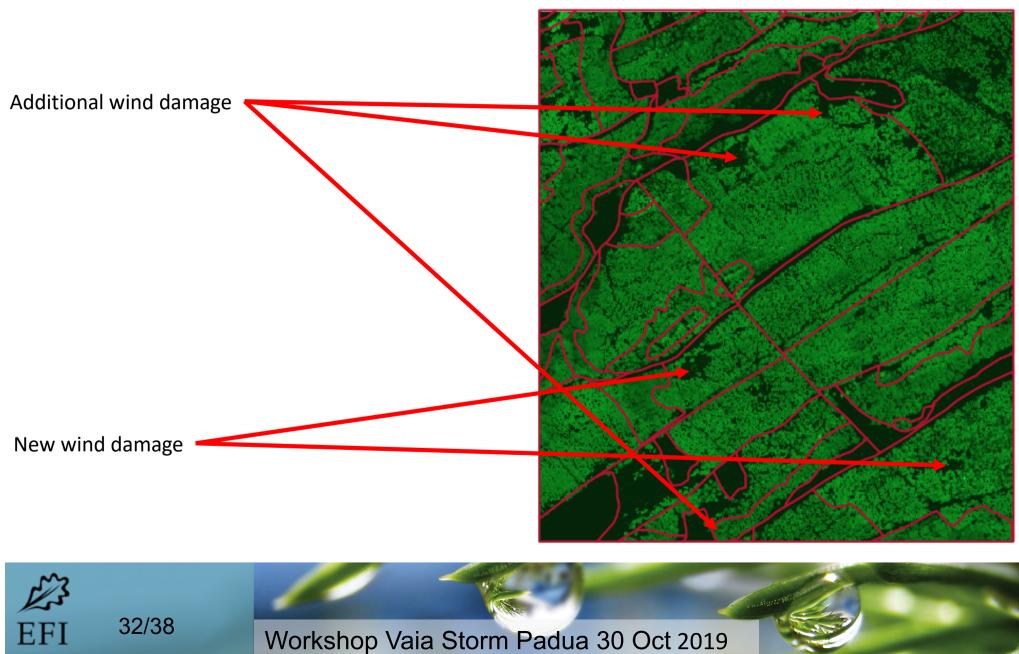
No data in 2002



Forest in 2006



Forest in 2008



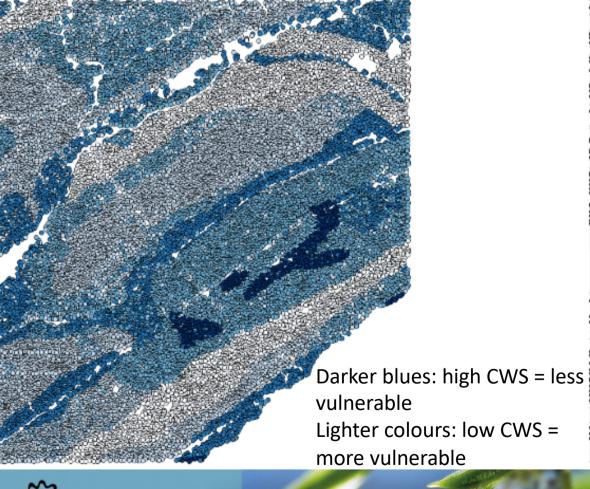
Forest in 2012

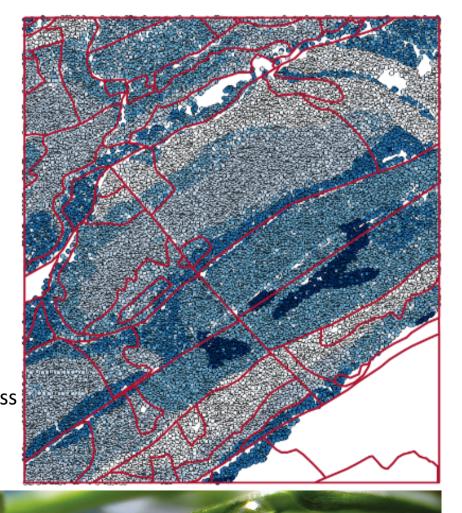


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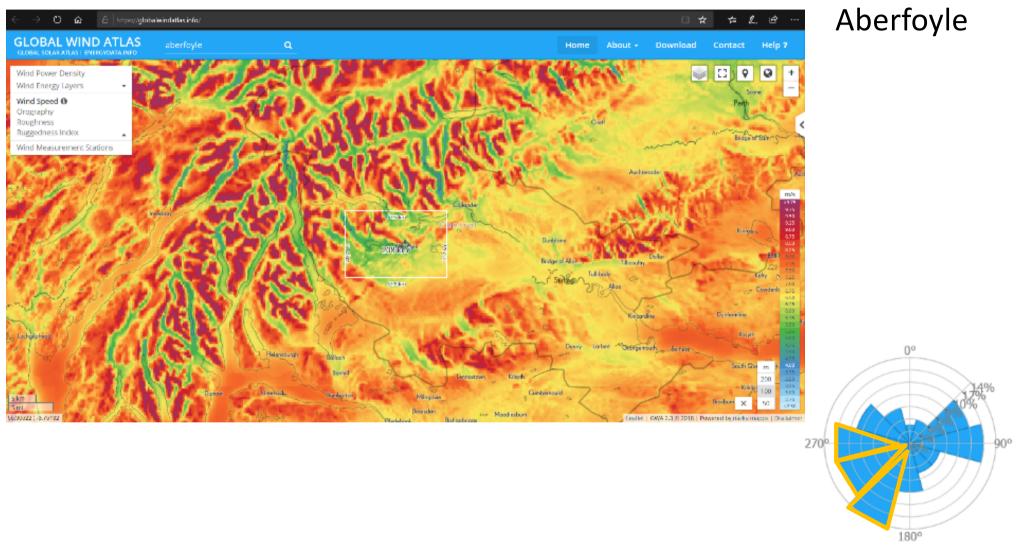
- Tree-level investigation allows discriminating tree vulnerability not only between but also within forest compartments
- Can help with planning management operations
- Can inform re-designing of management coupes



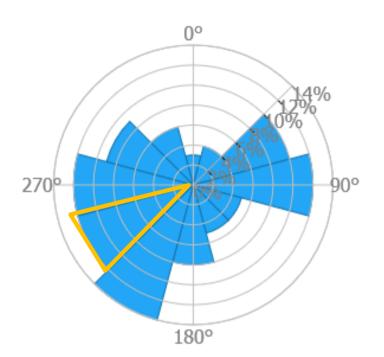


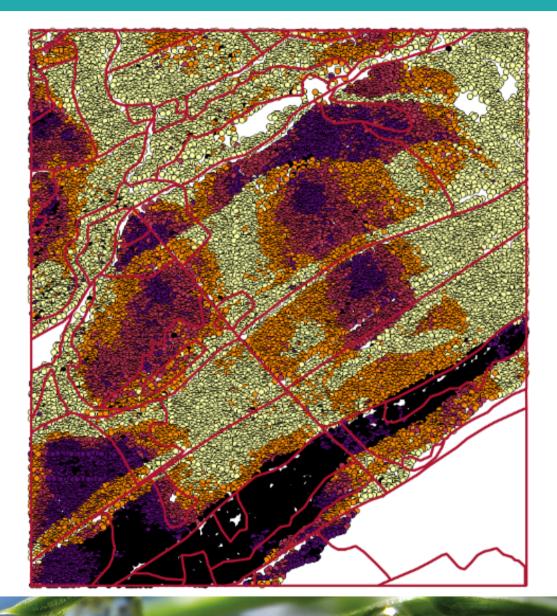


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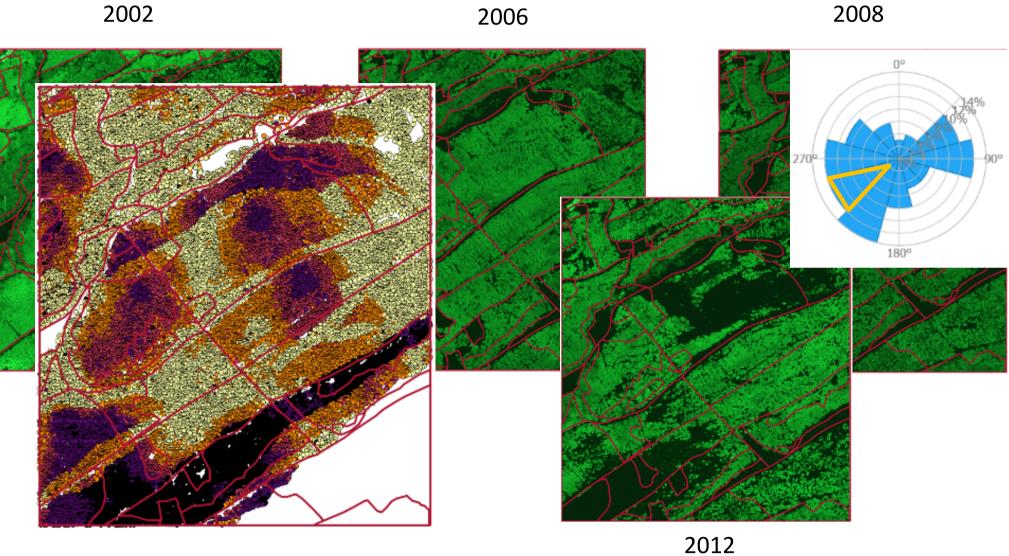






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Summary

To Date

- 1. ForestGALES wind risk model developed in UK for homogeneous conifer plantation
- 2. Model has been modified to work in France, Northern Spain, Canada (Quebec and BC), Japan, Denmark, New Zealand, USA, Brazil, etc.
- 3. New tree pulling experiments have added additional species including *Pinus pinaster, Fagus sylvatica, Pinus radiata, Eucalyptus globulus.* Other species parameterisations are based on data from other tree pulling experiments in other countries. Total of 20 species.
- 4. Model is available as "stand alone" version, integrated in Excel or as an R library.
- 5. Maps of wind risk in individual forests can be produced at stand level for current conditions and into the future using stand data, soil data, wind climate data and growth models.
- 6. With LiDAR data model can calculate wind damage risk to individual trees in a stand.
- 7. Model can be adapted for any country in the world with knowledge of species choice, soils and wind climate.

Current/Future

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- 1. Standardisation of tree resistance to overturning using database of tree-pulling from around the world.
- 2. Integration of the R version of ForestGALES with growth models and climate models to make predictions of the impact of a changing climate on wind risk
- 3. Validation of single tree ForestGALES through development of linkage with LiDAR data

