Forest Research

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

Interreg Sudoe
PLURIFOR

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

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Plan of Talk

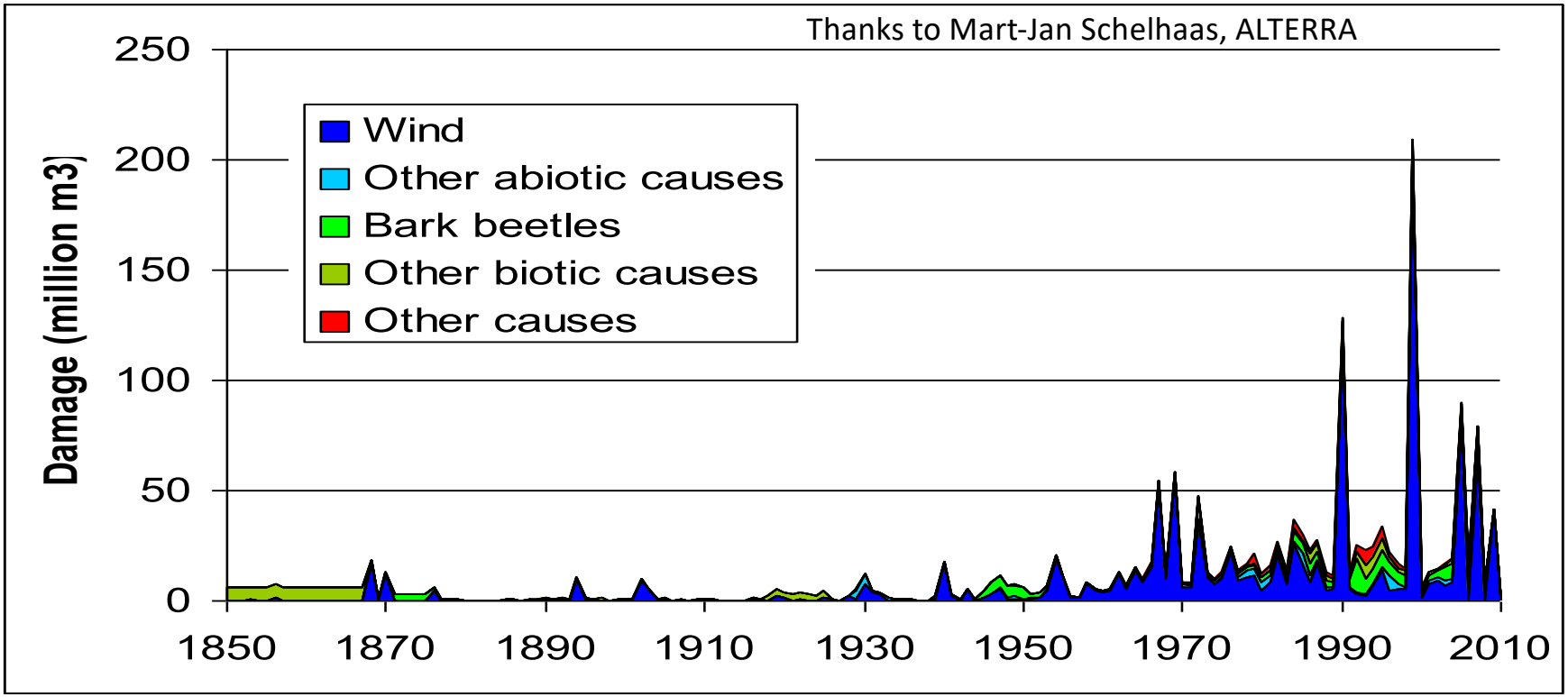
Tools for supporting decisions on forest storm risk management

- 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

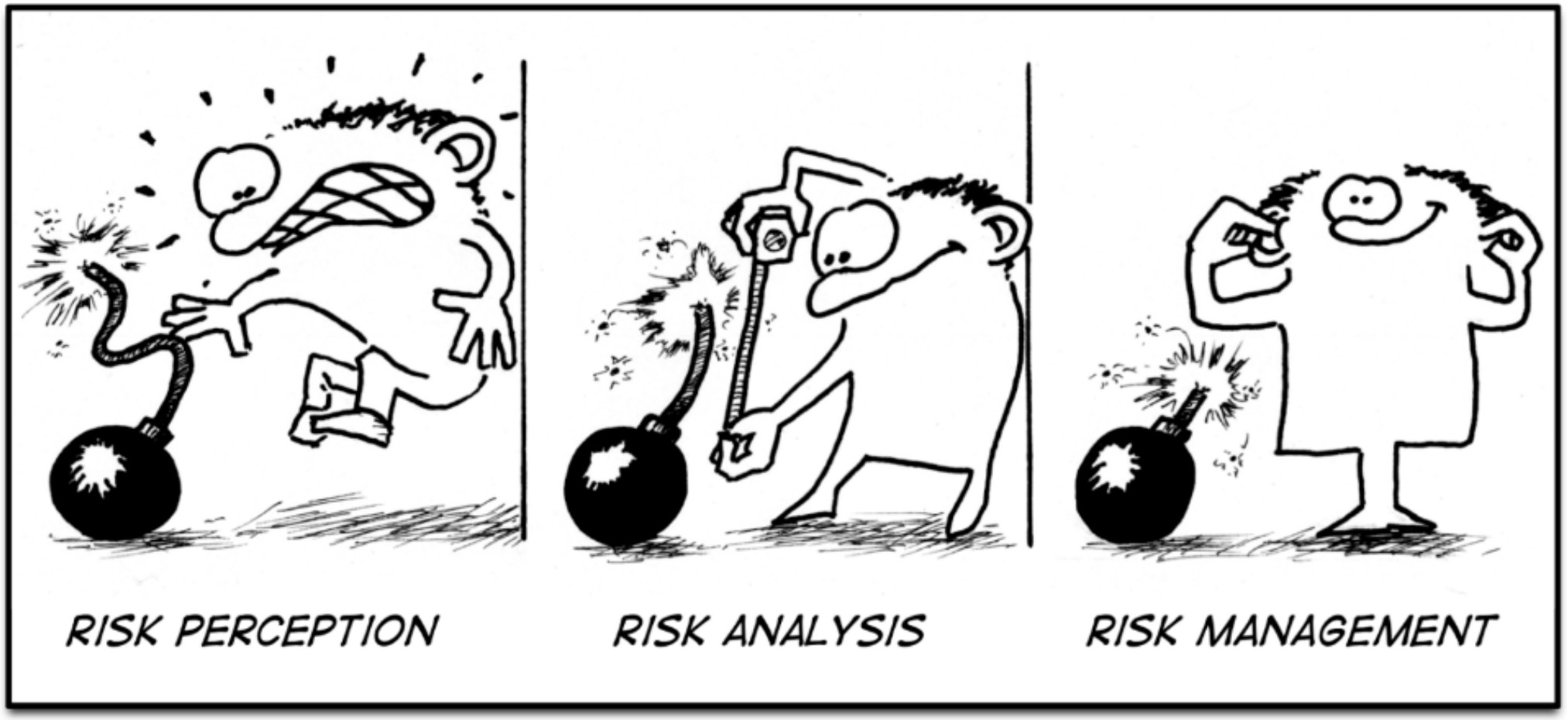
Storm 31 January 1953: Scotland

Storm Klaus 24th January 2009: Aquitaine

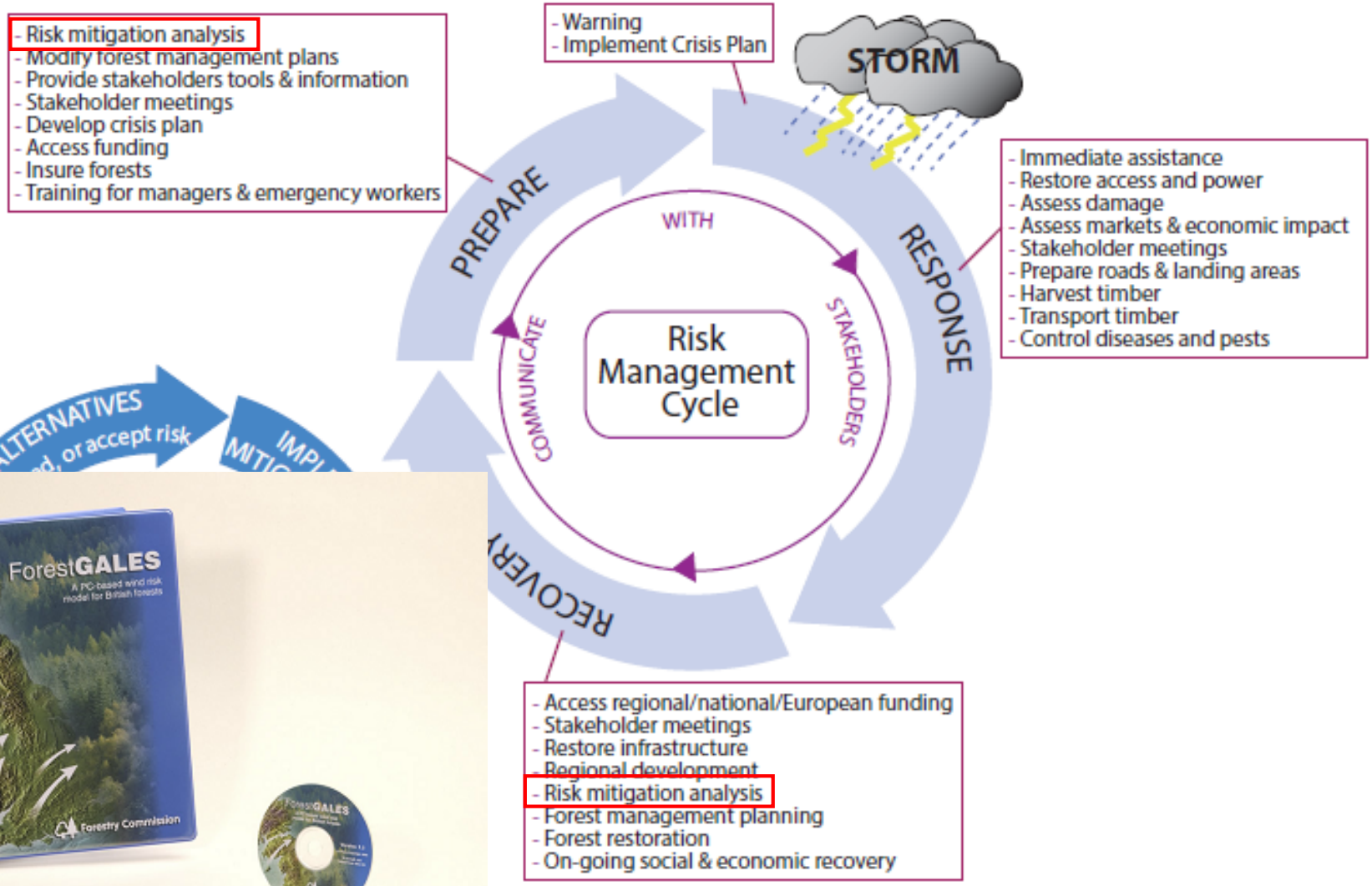
Damage Trends in European Forests



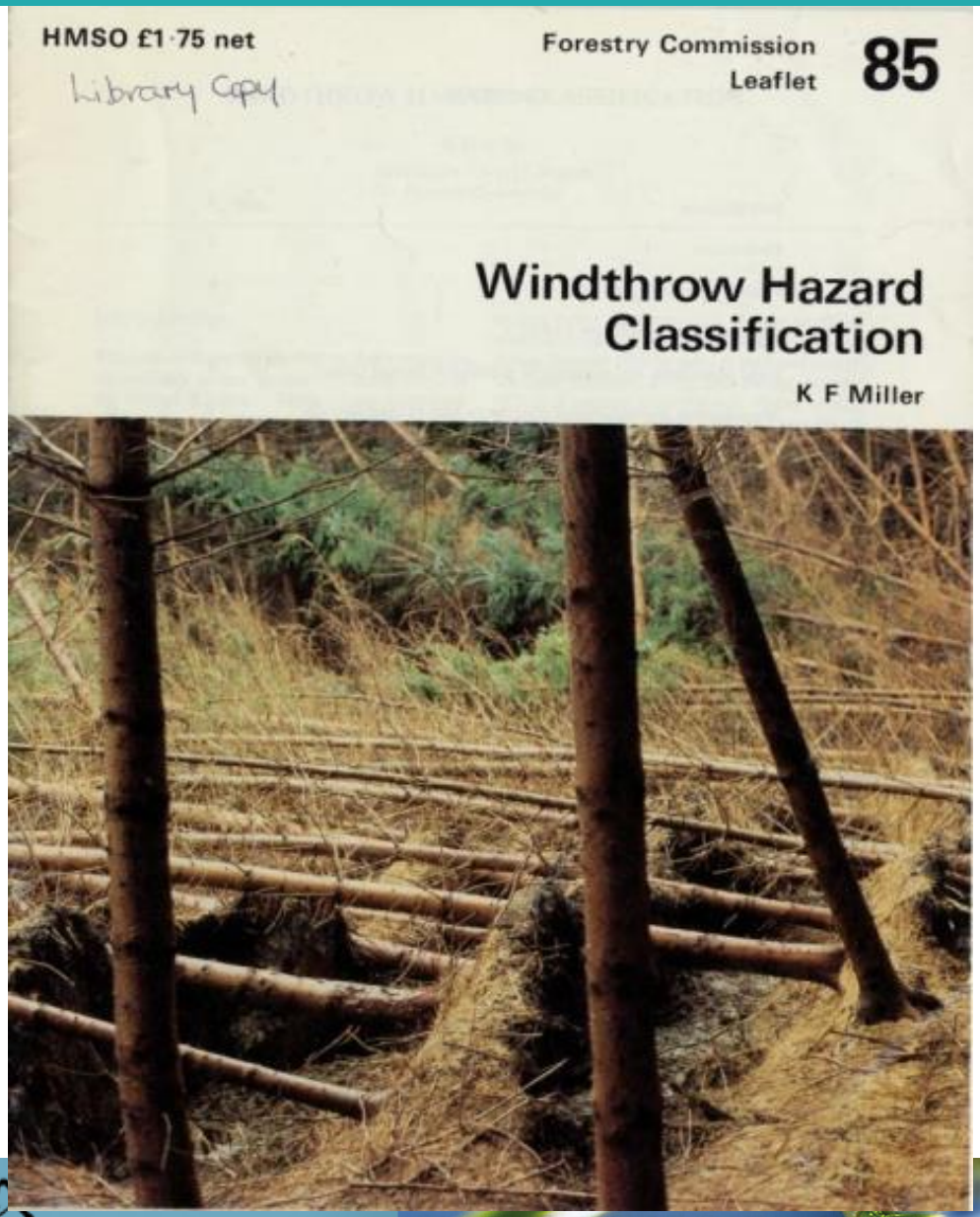
Risk Analysis and Management



Risk Models in Risk Management

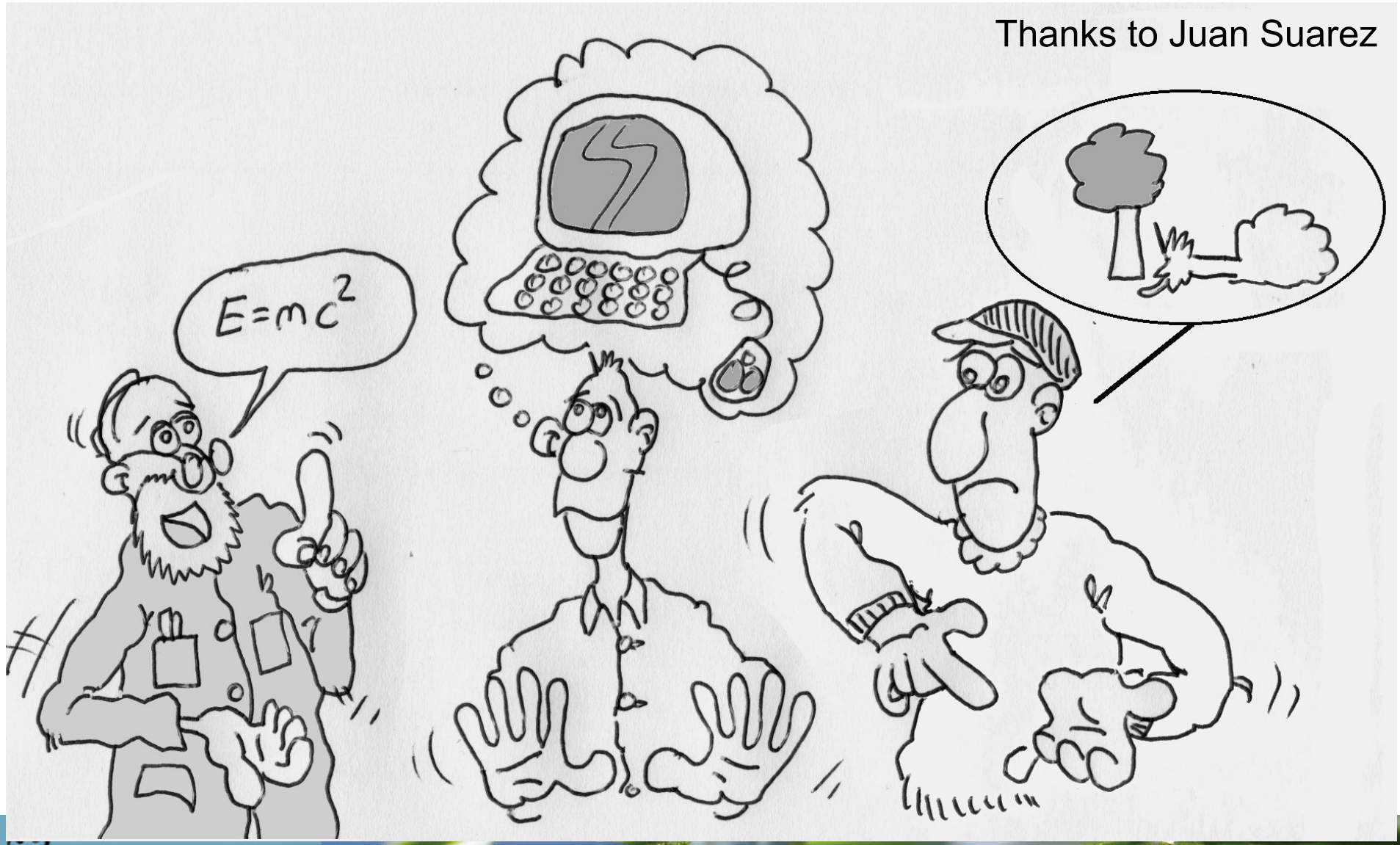


Windthrow Hazard Classification: Early Wind Damage DSS



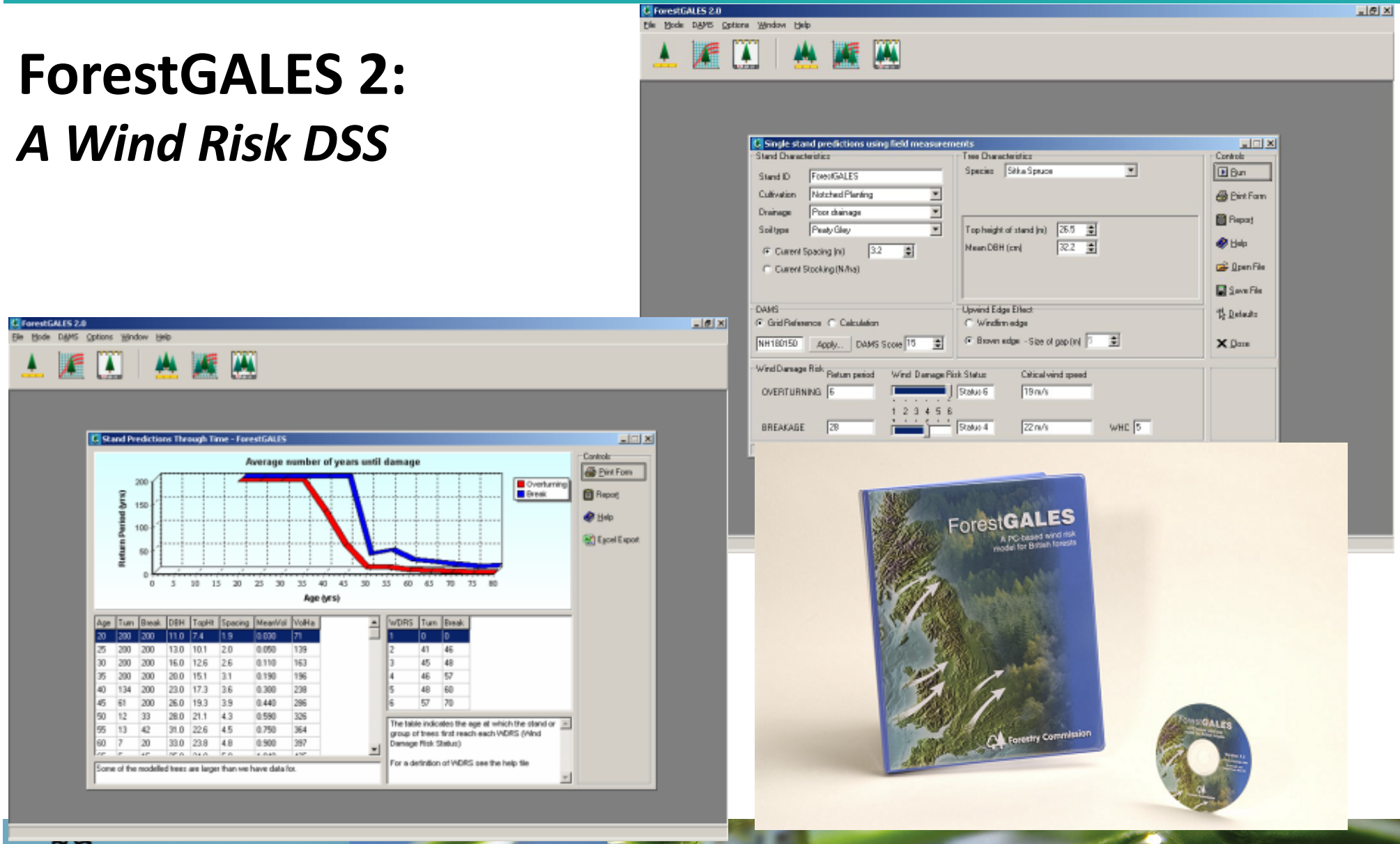
- Windiness Scores
  - Region
  - Elevation
  - Topographic Shelter (Topex)
- Soil Score
  - Rooting Depth

Integrating knowledge: Decision Support Systems

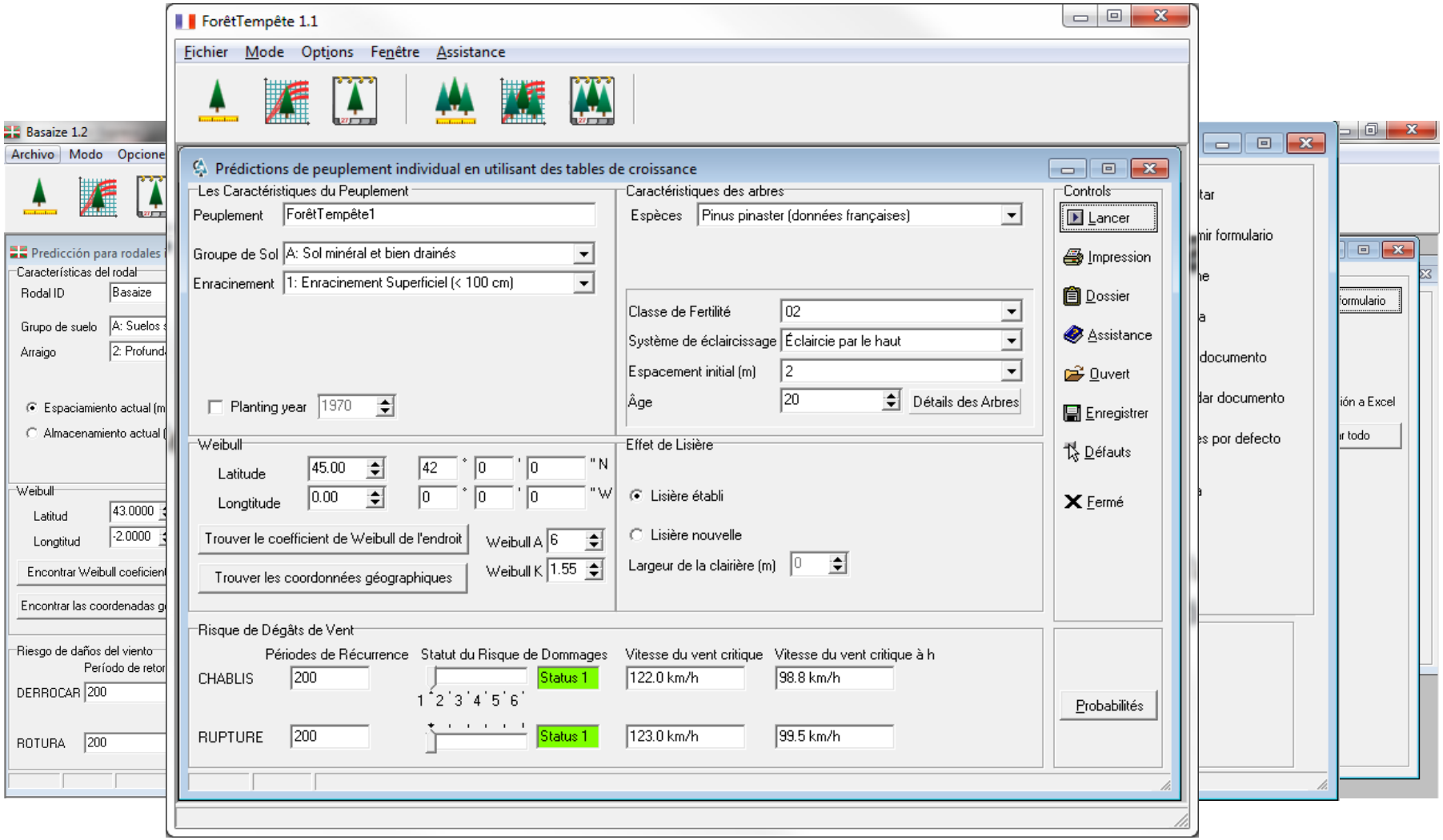


ForestGALES: Modèle de Risque de Vent

ForestGALES 2:
A Wind Risk DSS



Versions of ForestGALES: Basaize 1.2 and ForêtTempête 1.1



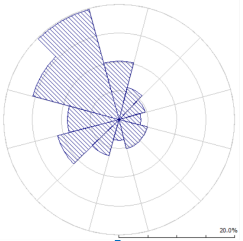
ForestGALES Inputs and Outputs

Tree-pulling Experiments

Forest Inventory

Growth/yield model

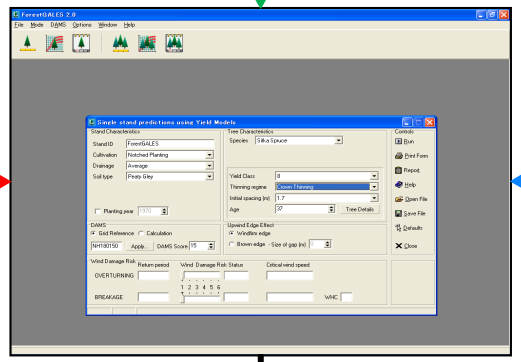
Wind Climate

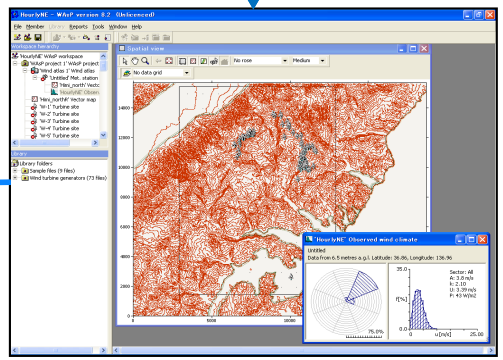


Terrain Conditions

Parameters

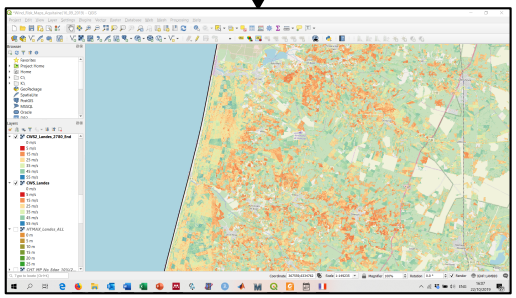
ForestGALES

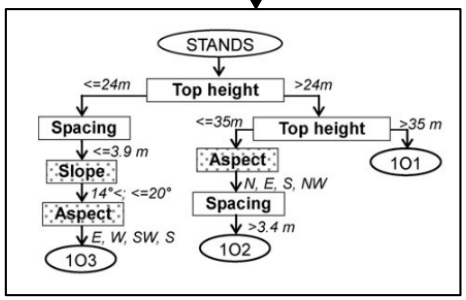




Airflow Model

GIS





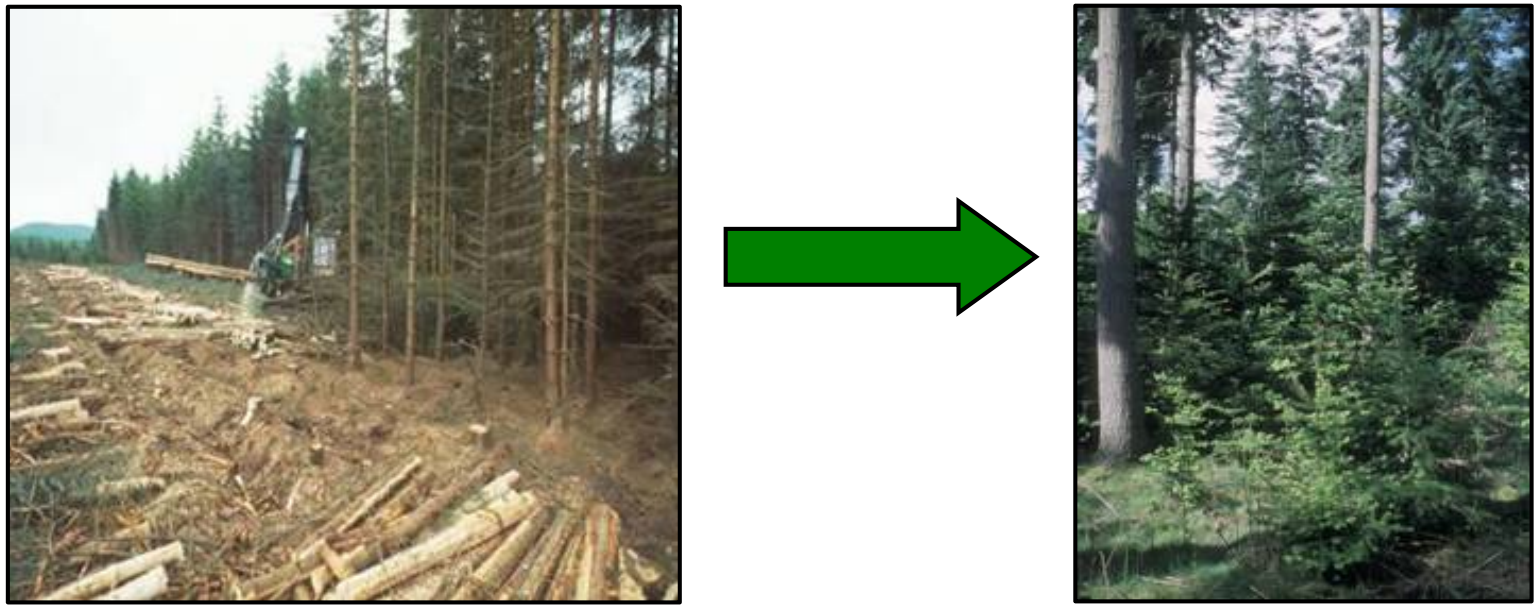
Decision-tree Analysis

Kamimura et al. 2008 (*Forestry*)

ForestGALES for Complex Forest Stands

ForestGALES was only designed for uniform coniferous stands.

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



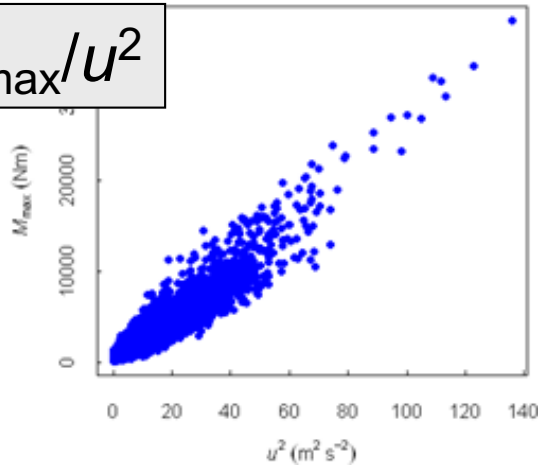
Even-aged regular

Uneven-aged irregular

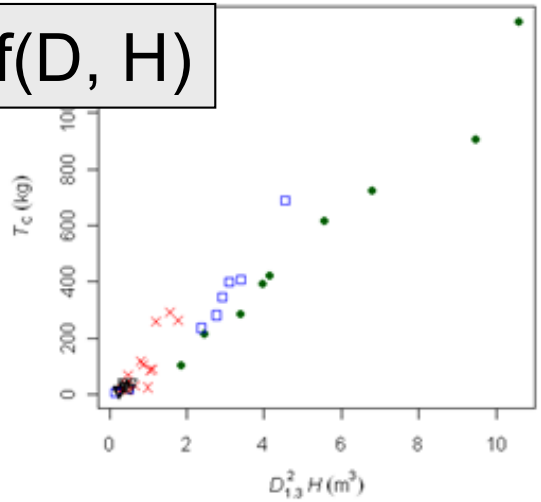
ForestGALES_TMC for Complex Forest Stands

New Method: Turning Moment Coefficient

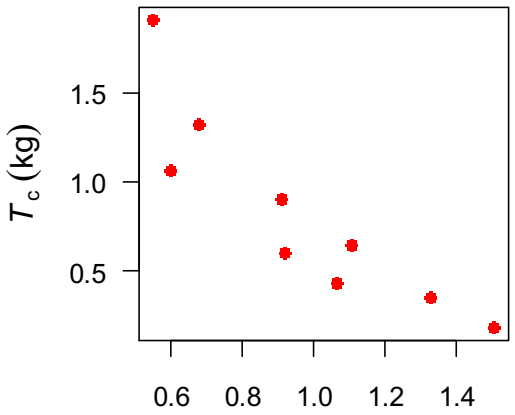
TMC = M_{max}/u^2

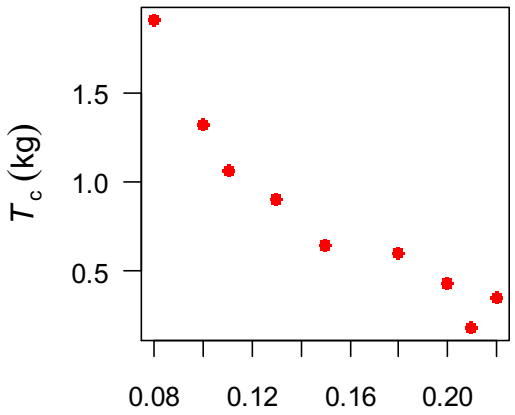


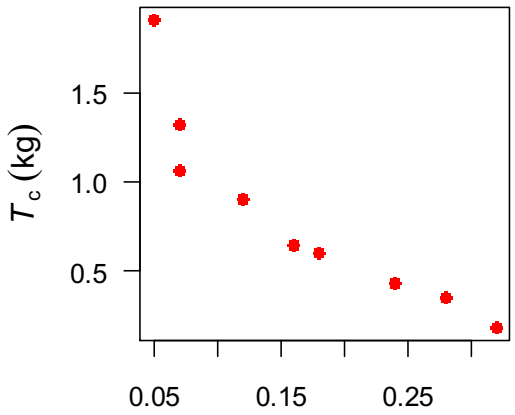
TMC = f(D, H)



TMC related to competition index



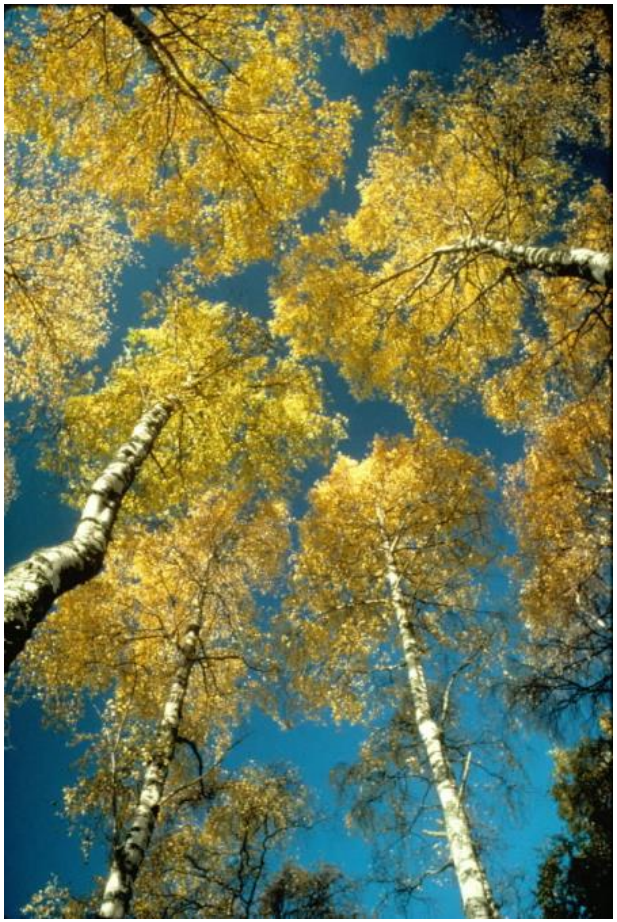




EFI

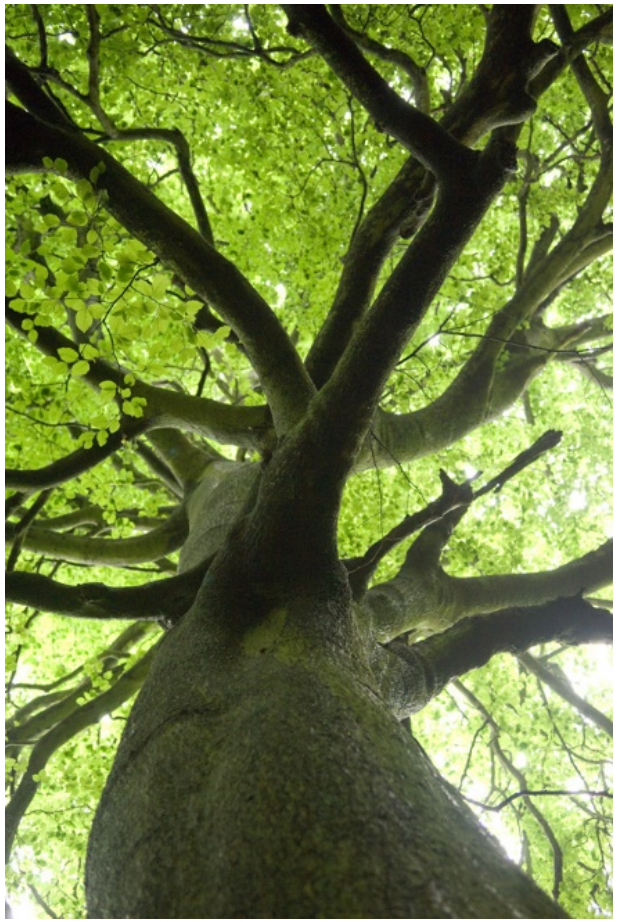
ForestGALES for Broadleaf Species

Birch



Silver birch
Betula pendula

Beech

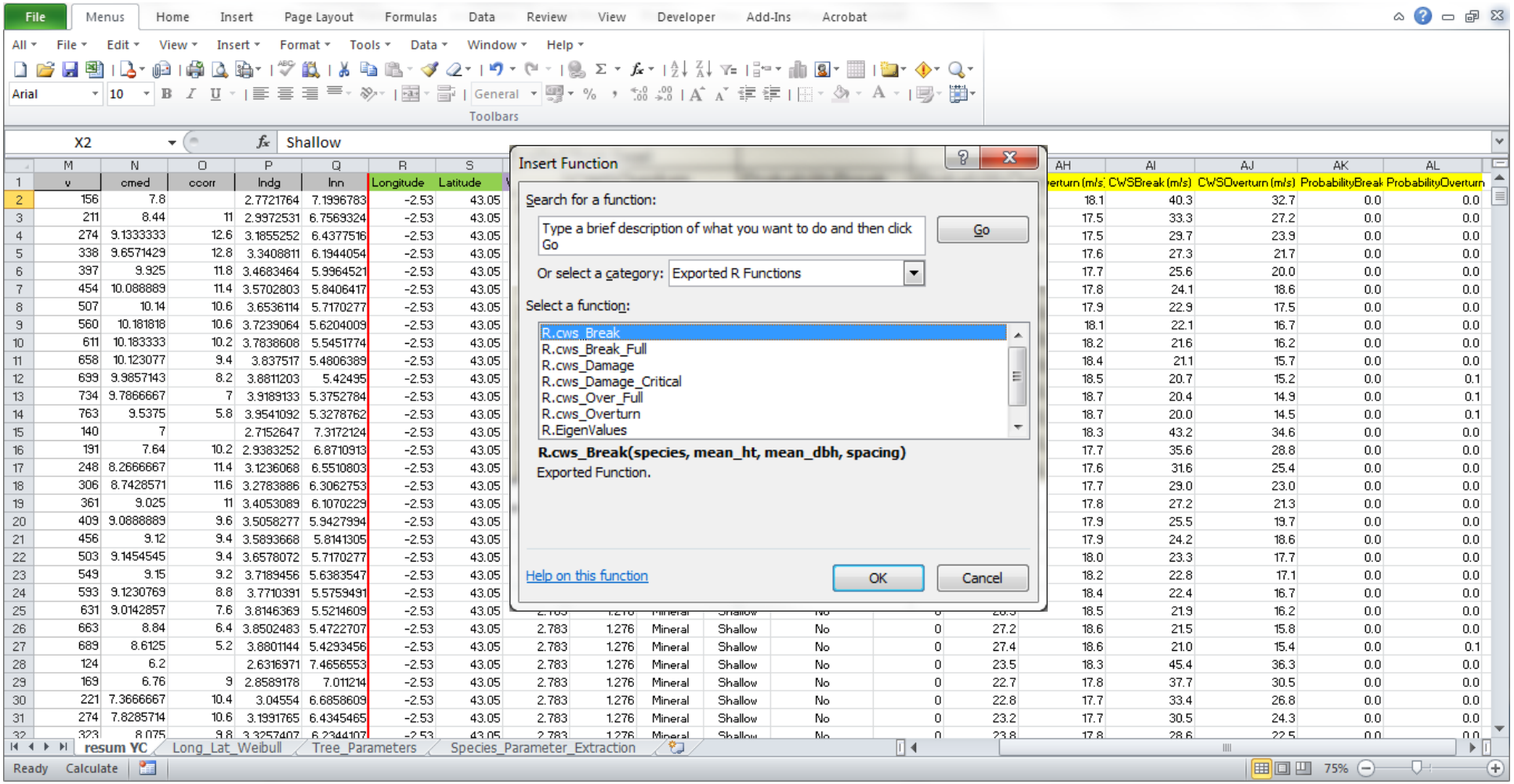


European beech
Fagus sylvatica

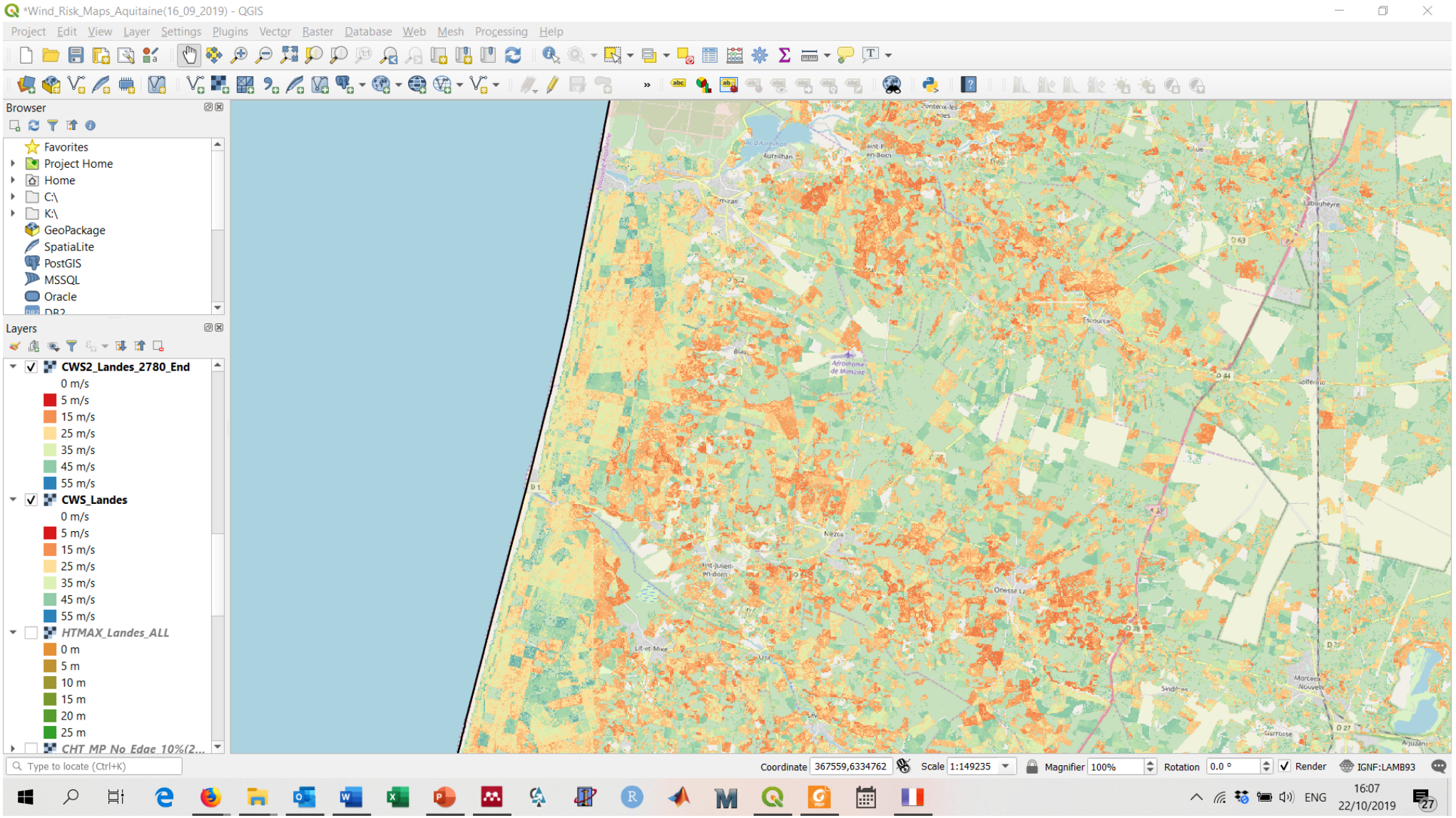
Oak

Pedunculate oak
Quercus robur

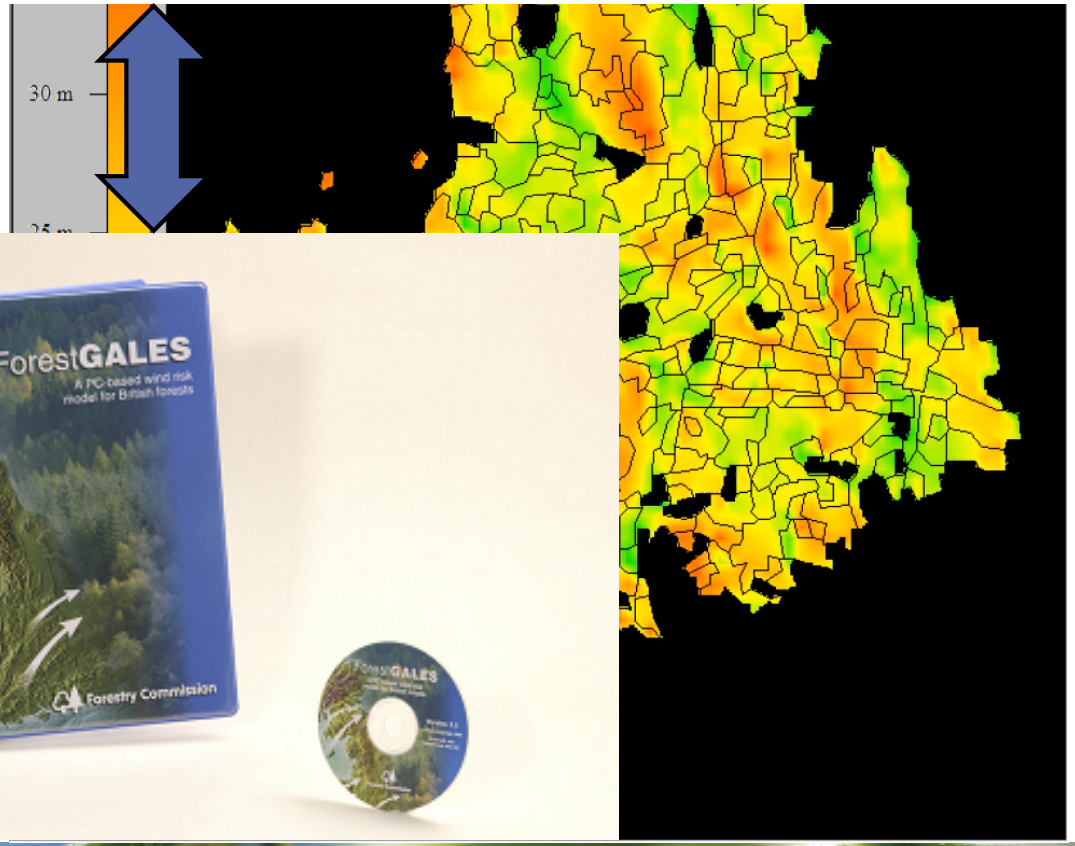
ForestGALES in Excel



ForestGALES in QGIS



ForestGALES coupled with WAsP Airflow Model

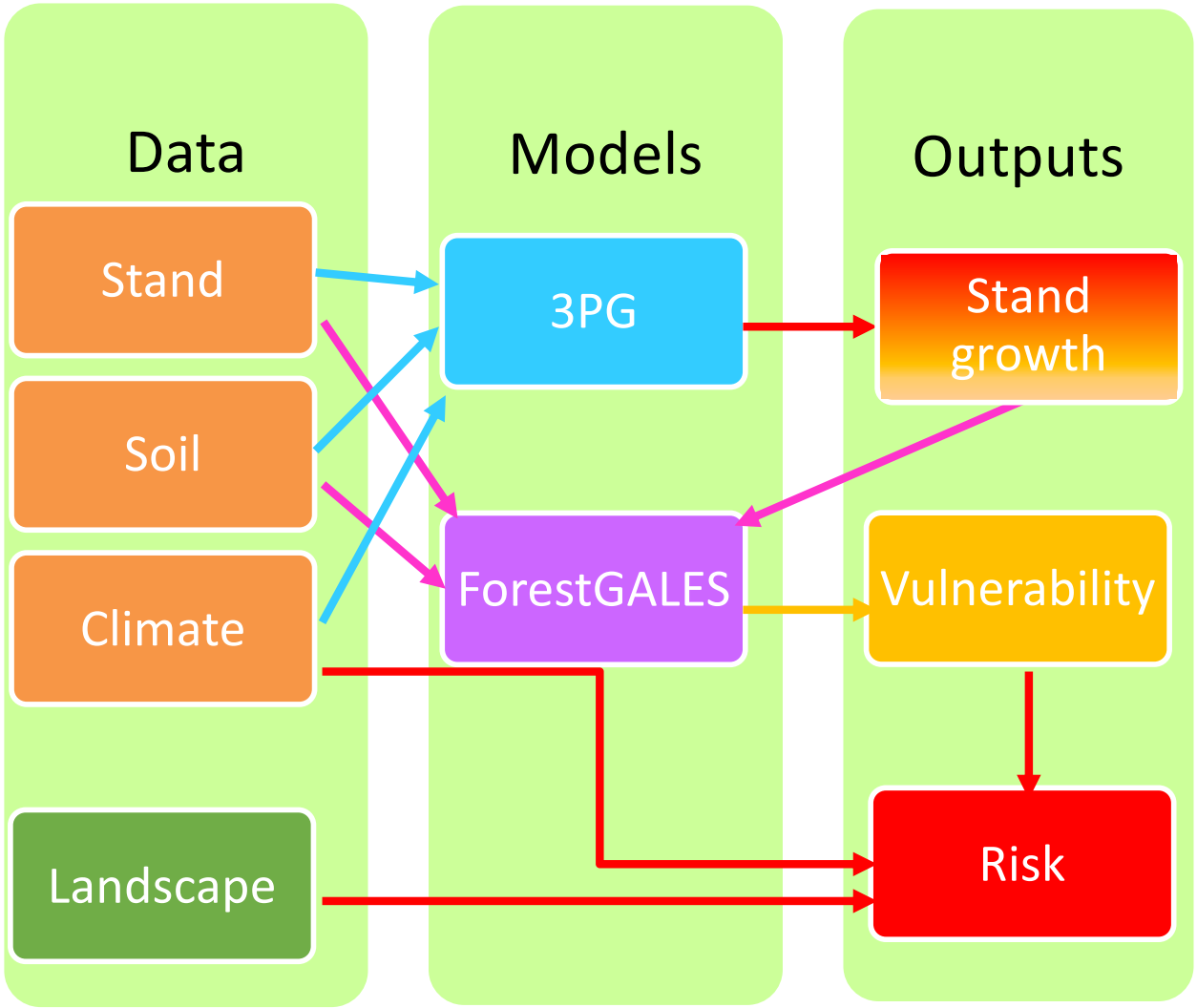


Current/Future developments of ForestGALES

- 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

FOSPREF-Wind - Link with growth models and climate predictions



FOSPREF-Wind - Link with growth models and climate predictions

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.

FOSPREF-Wind - Link with growth models and climate predictions

Models

3PG

ForestGALES

3PG: Physiological Principles Predicting Growth (Landsberg and Waring, 1997)

- Climate: Monthly values of Temperature (max, min, mean), rainfall, solar radiation, evaporation, VPD, rainy days, frost days
- Soil: Available soil water (max and min), Soil Class, Soil Fertility Rating
- Stand: tree species, sph, initial biomass compartments
- Outputs: biomass compartments, mortality, mean tree allometry, at monthly intervals

FOSPREF-Wind - Link with growth models and climate predictions

Models

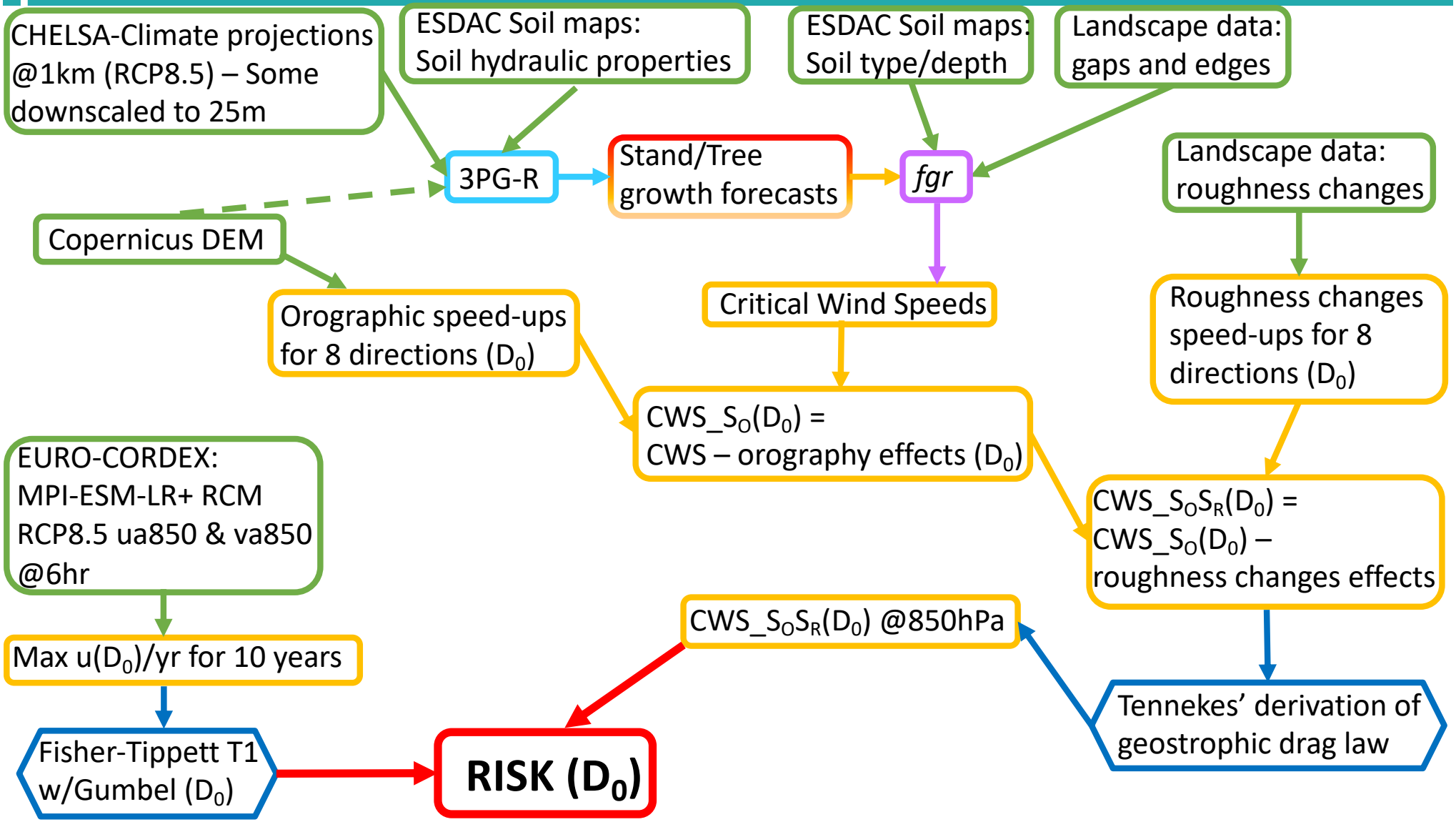
3PG

ForestGALES

3PG: Physiological Principles Predicting Growth (Landsberg and Waring, 1997)

- Climate: Monthly values of Temperature (max, min, mean), rainfall, solar radiation, evaporation, VPD, rainy days, frost days
- Soil: Available soil water (max and min), Soil Class, Soil Fertility Rating
- Stand: tree species, sph, initial biomass compartments
- Outputs: biomass compartments, ***stocking density***, ***mean tree allometry***, at monthly intervals

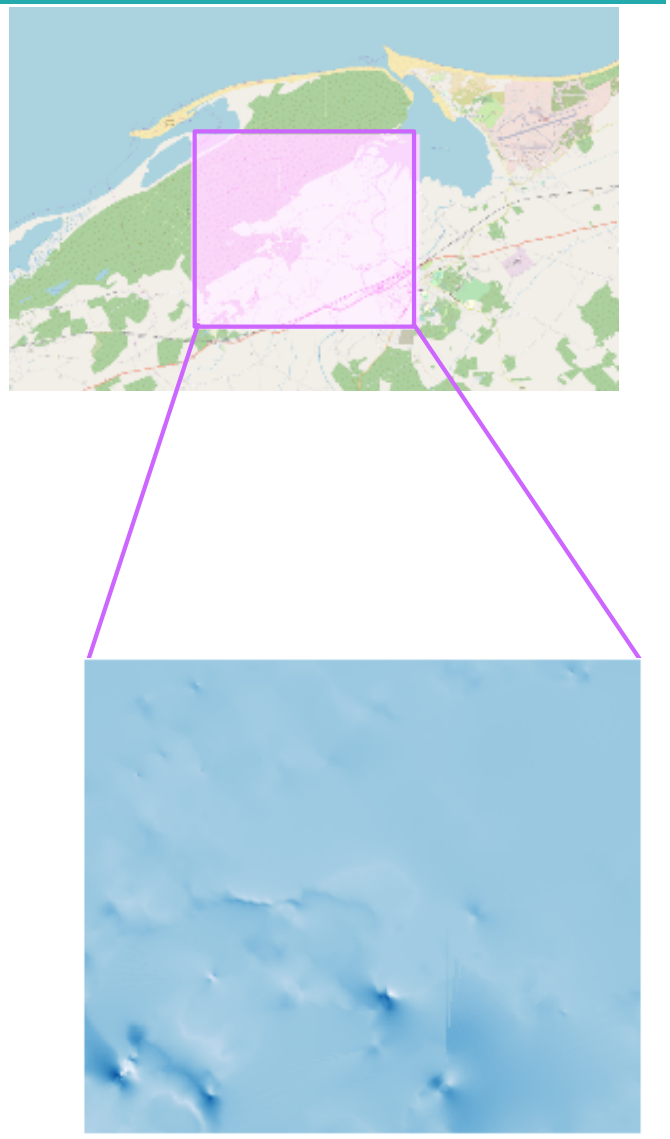
FOSPREF-Wind - Link with growth models and climate predictions



FOSPREF-Wind - Link with growth models and climate predictions

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: https://github.com/drGeorgeXenakis/threePG
- Calibrated 3PG-R for SP using FC permanent sample plots data
- ForestGALES complete R package (‘*fgr*’) released (both stand-level and individual tree methods): https://github.com/tom-locatelli/fgr
- 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 (https://www.wasp.dk/)
- Coded and tested R functions for landscape-level aerodynamic roughness speed-ups and depth of boundary layer as a function of roughness changes

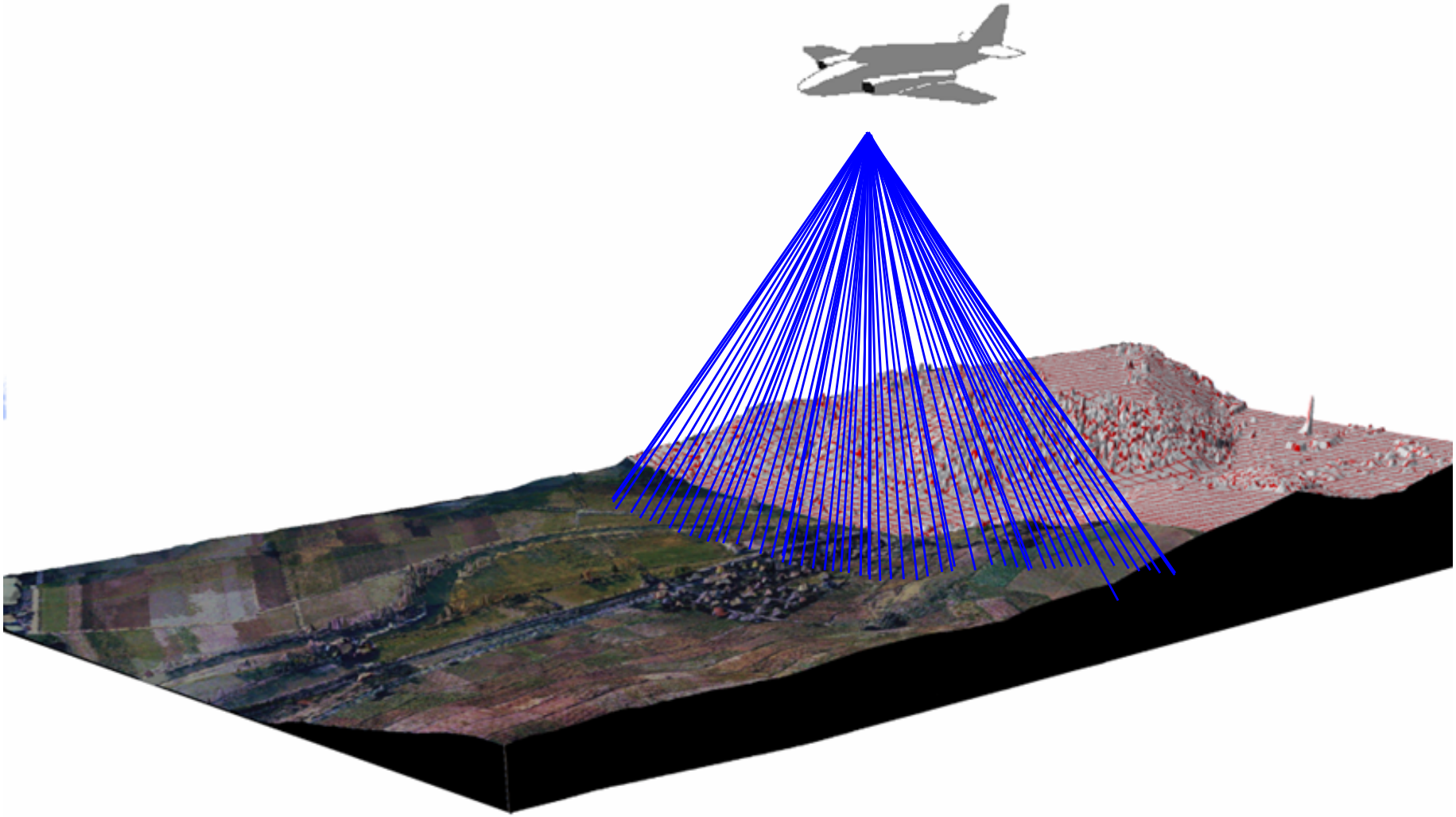


FOSPREF-Wind - Link with growth models and climate predictions

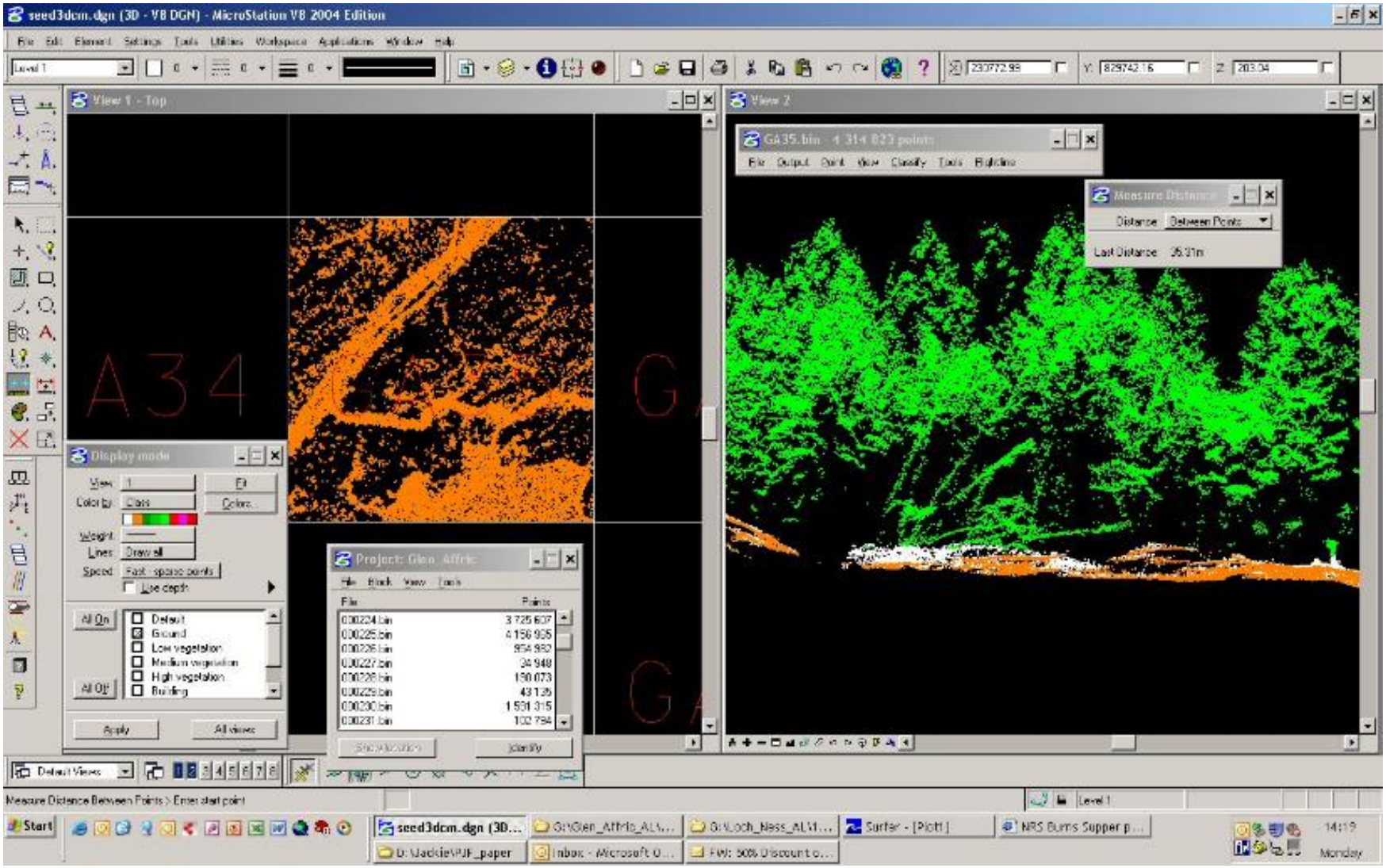
NEXT:

- 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

Link between single tree version and LiDAR survey data

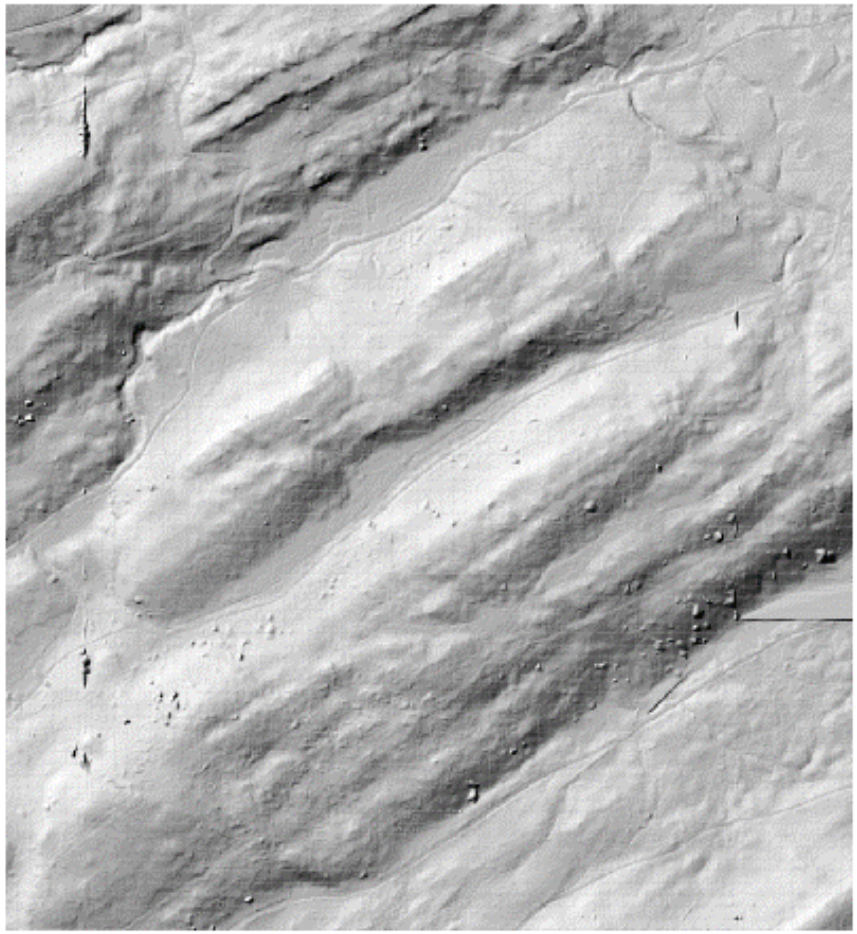


Link between single tree version and LiDAR survey data

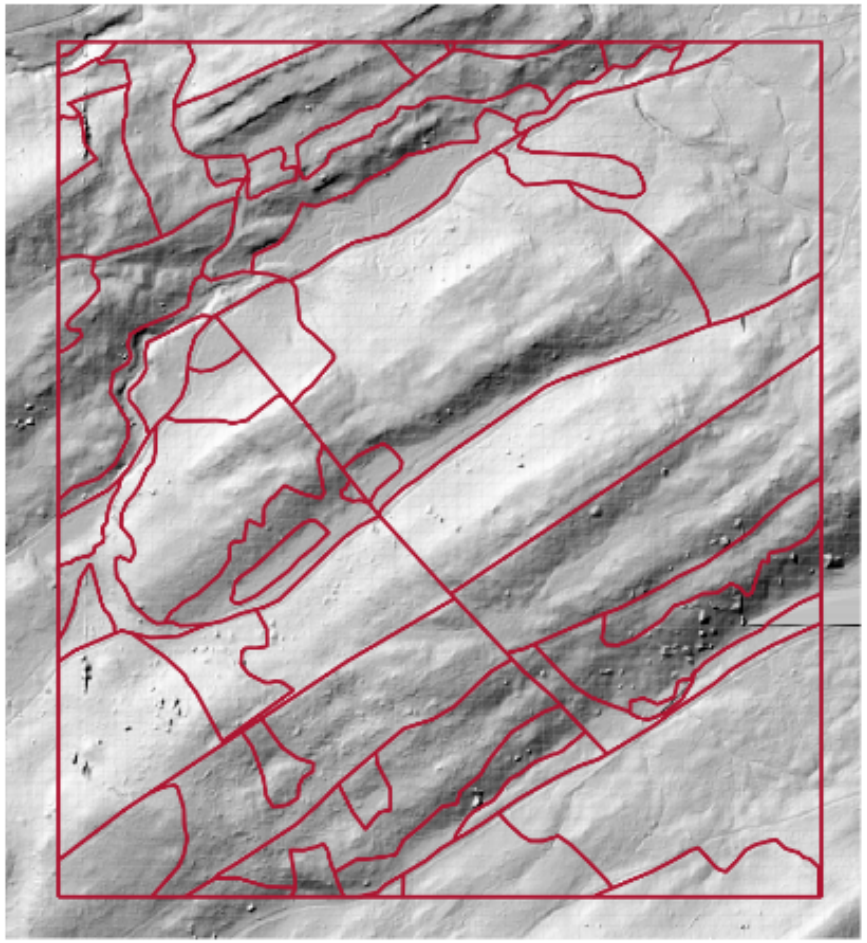


Link between single tree version and LiDAR survey data

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

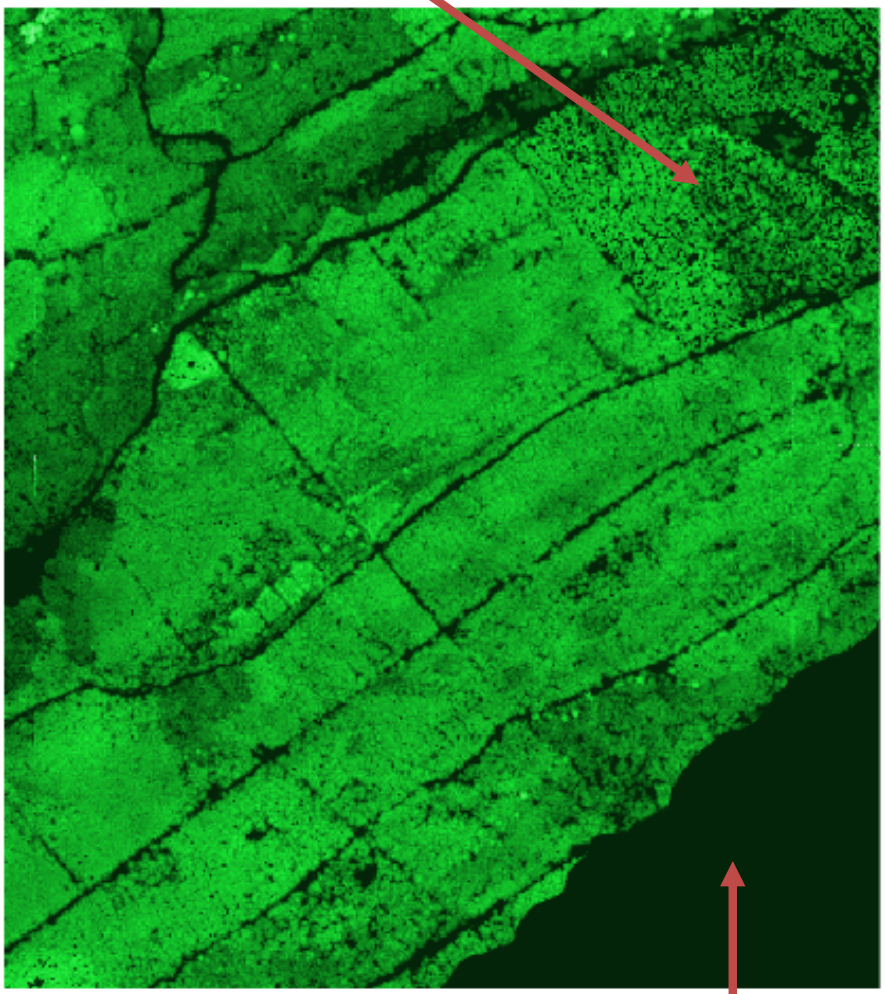


- Management coupes only partially match topography
- Other characteristics might be important: soils, previous management history



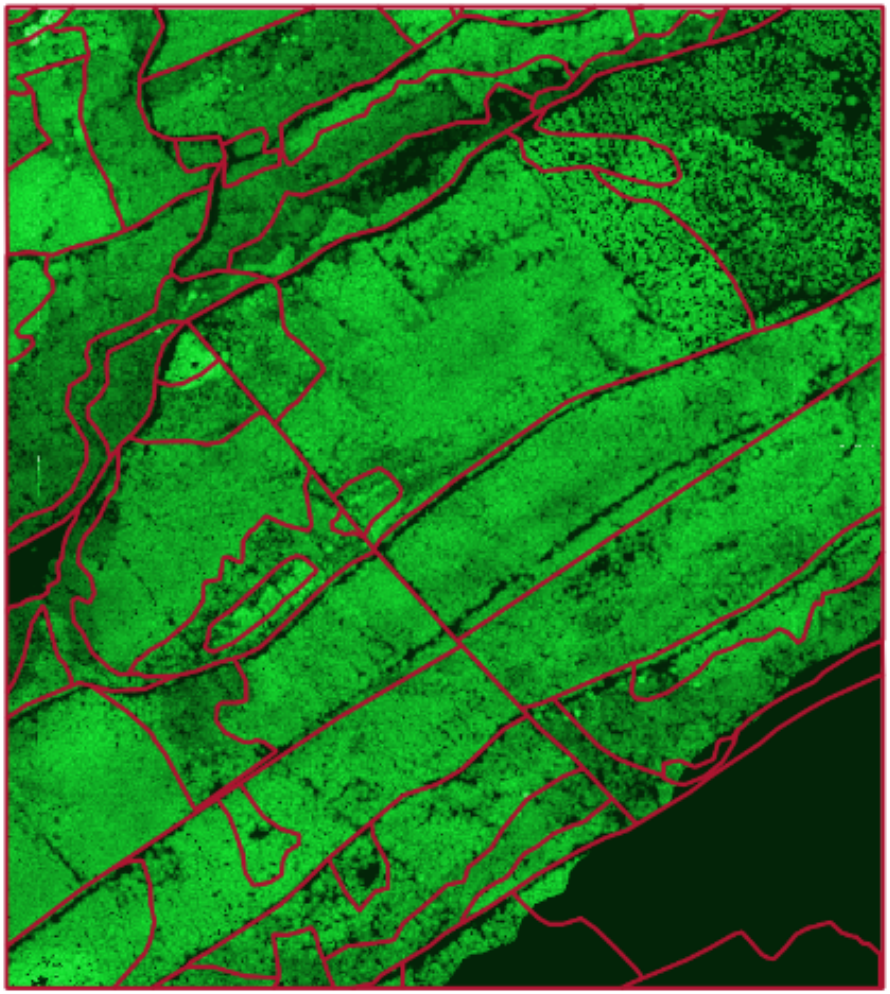
Link between single tree version and LiDAR survey data

Previous thinning



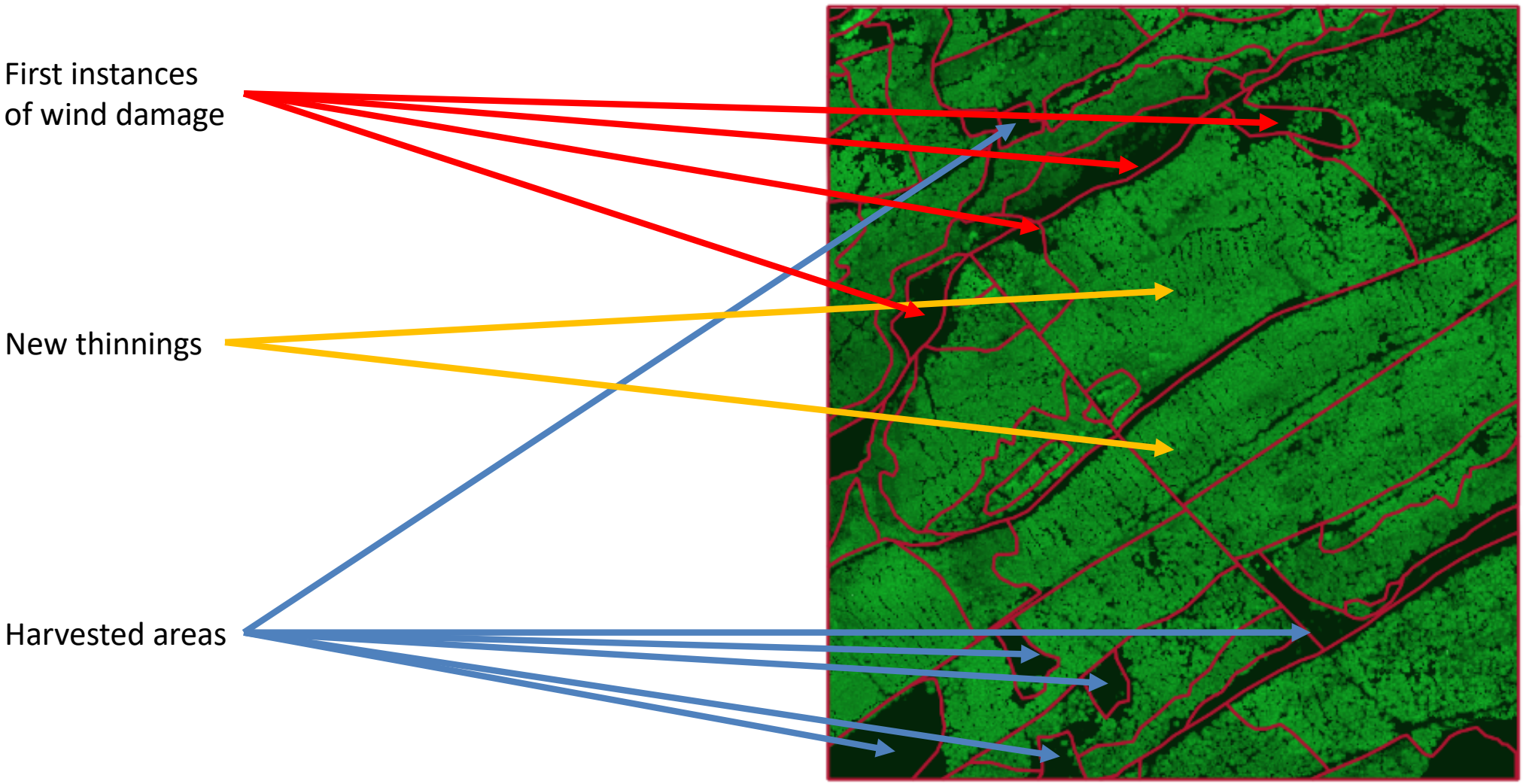
No data in 2002

Forest in 2002



Link between single tree version and LiDAR survey data

Forest in 2006

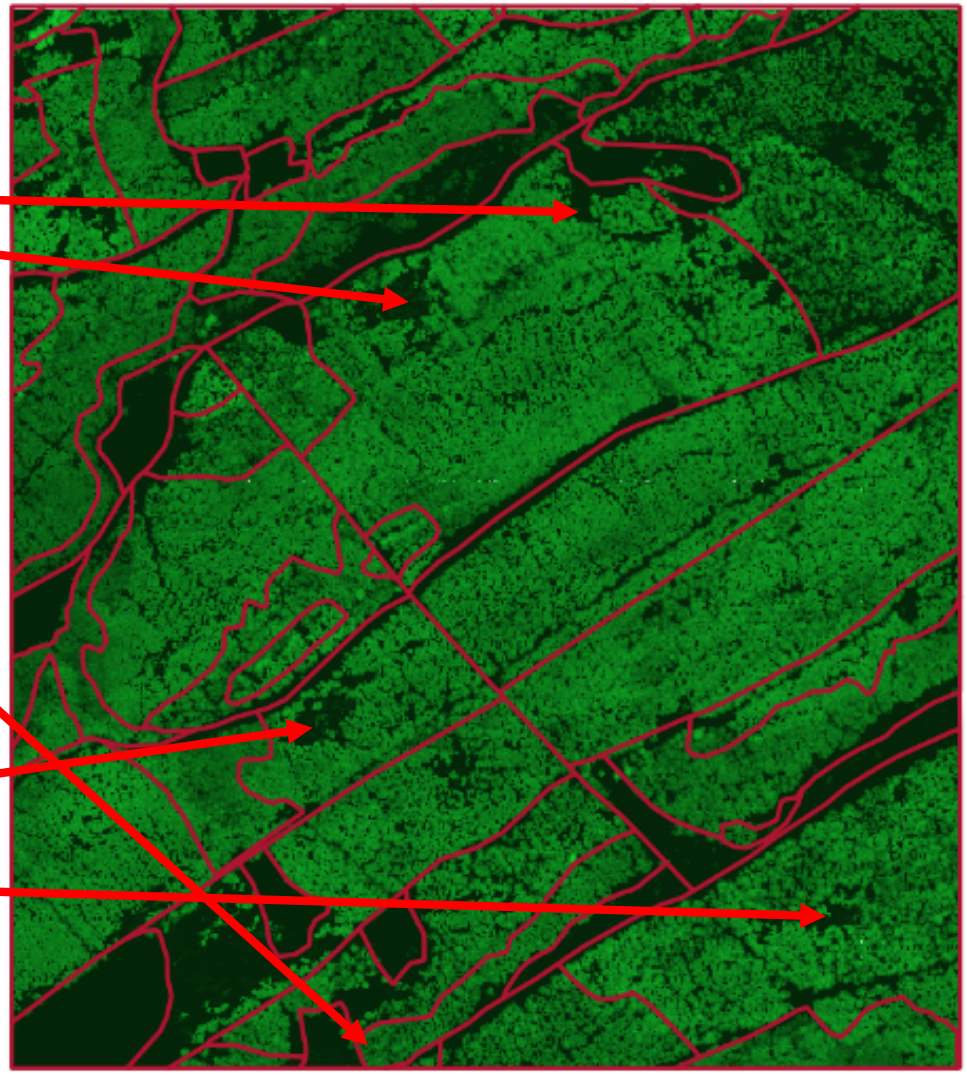


Link between single tree version and LiDAR survey data

Forest in 2008

Additional wind damage

New wind damage

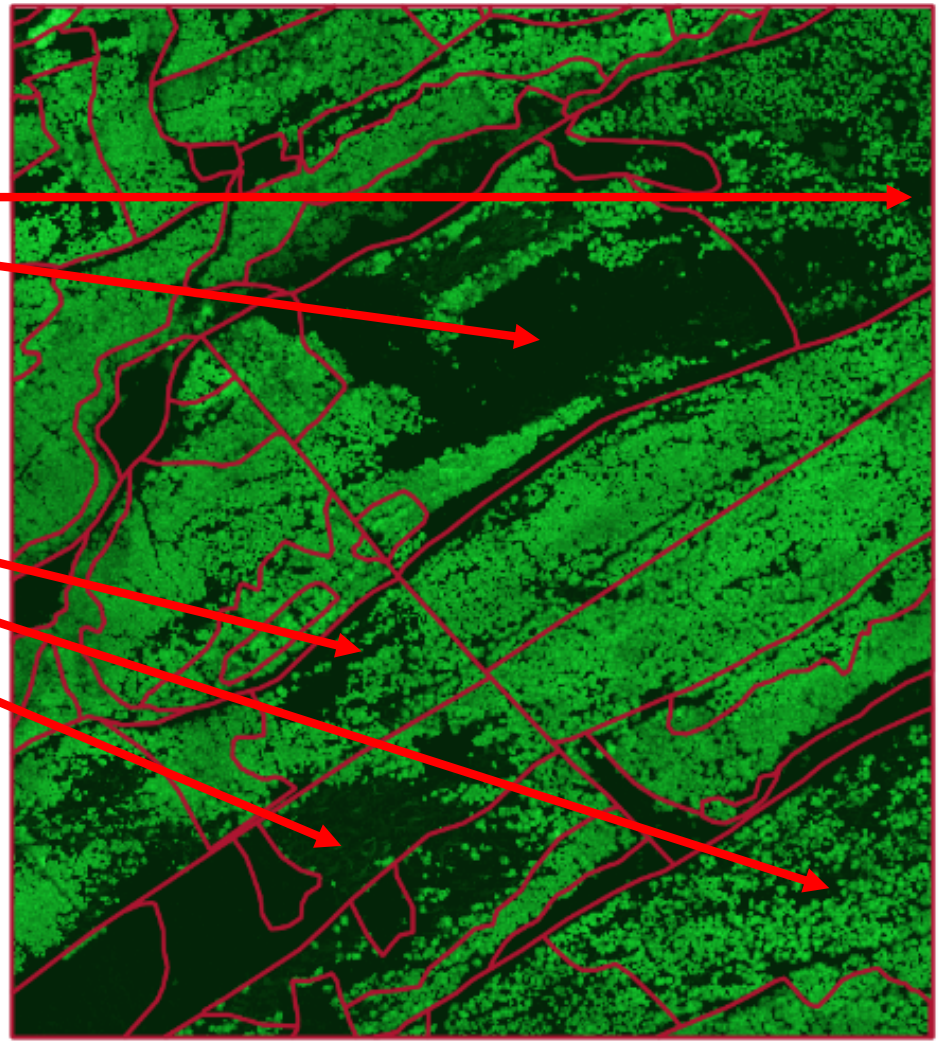


Link between single tree version and LiDAR survey data

Forest in 2012

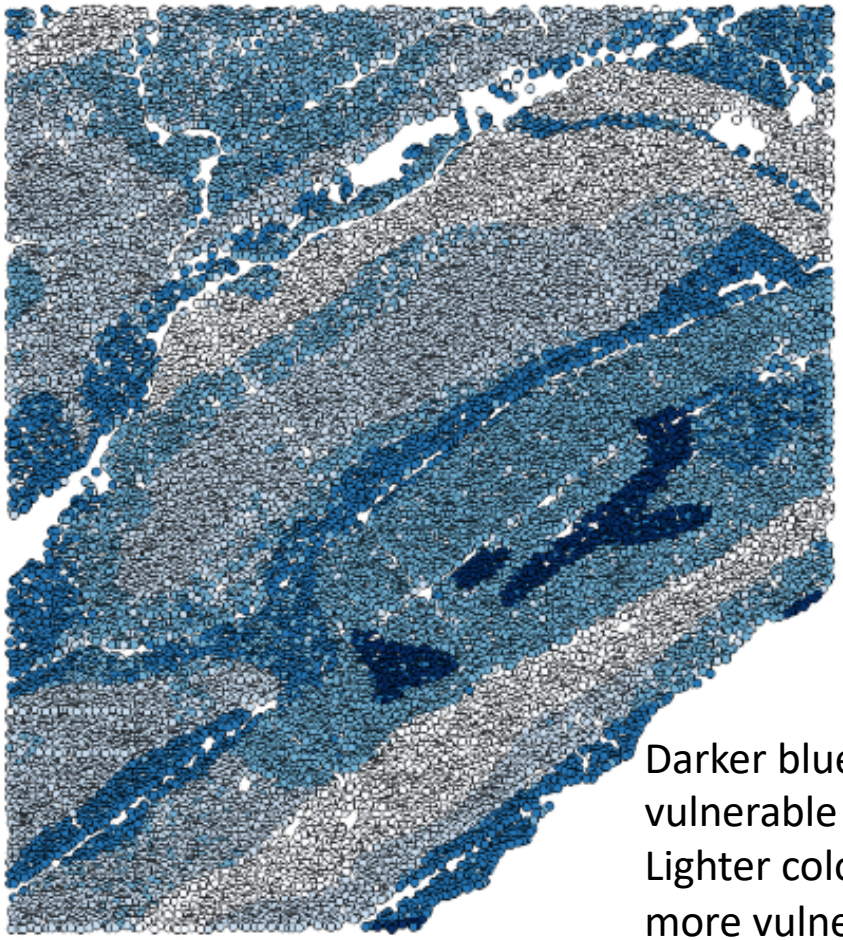
Stands opened/destabilised by previous damage/harvests/thinnings

Catastrophic wind damage propagation

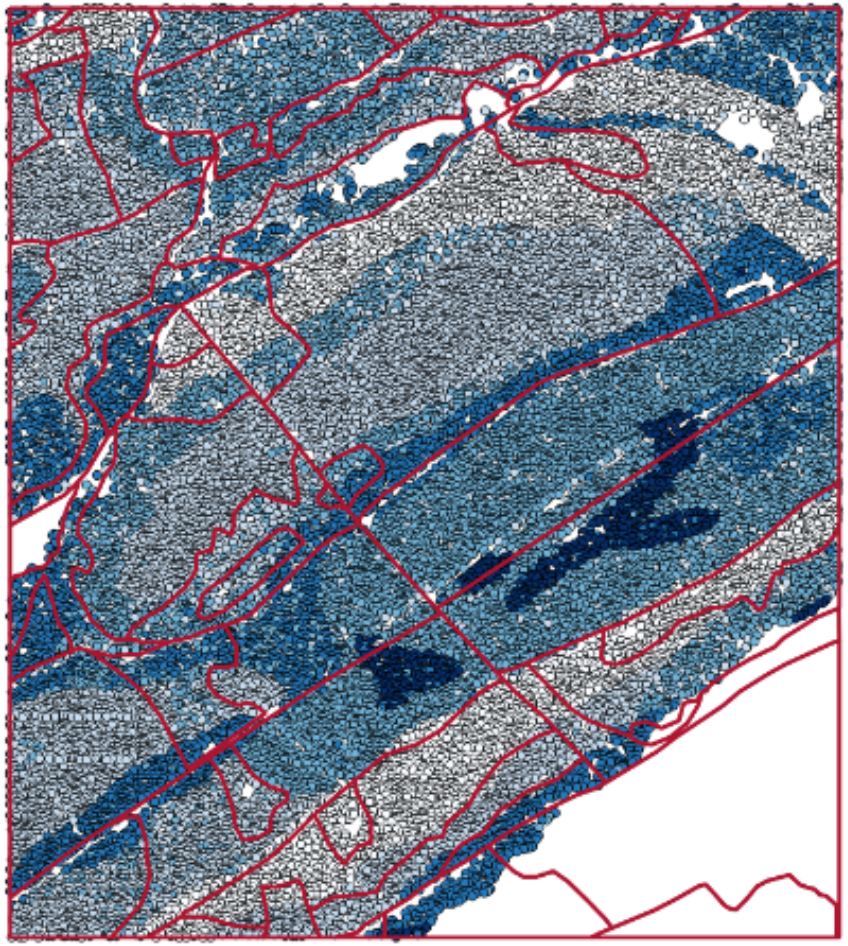


Link between single tree version and LiDAR survey data

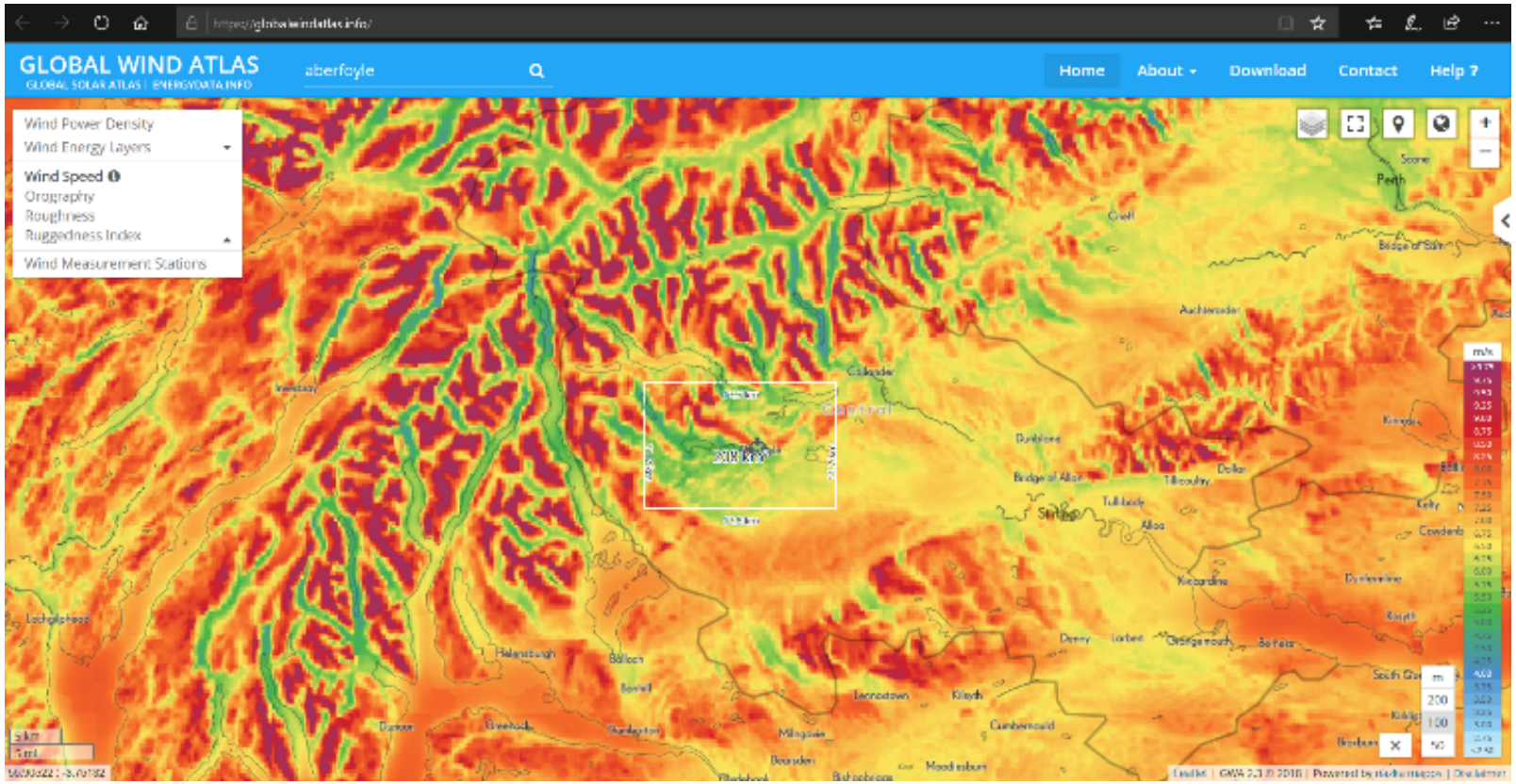
- Tree-level investigation allows discriminating tree vulnerability not only between but also within forest compartments
- Can help with planning management operations
- Can inform re-designing of management coupes



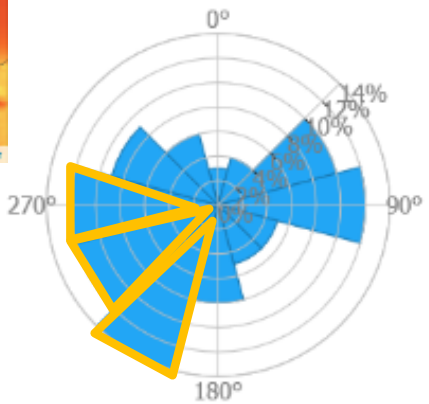
Darker blues: high CWS = less vulnerable
Lighter colours: low CWS = more vulnerable



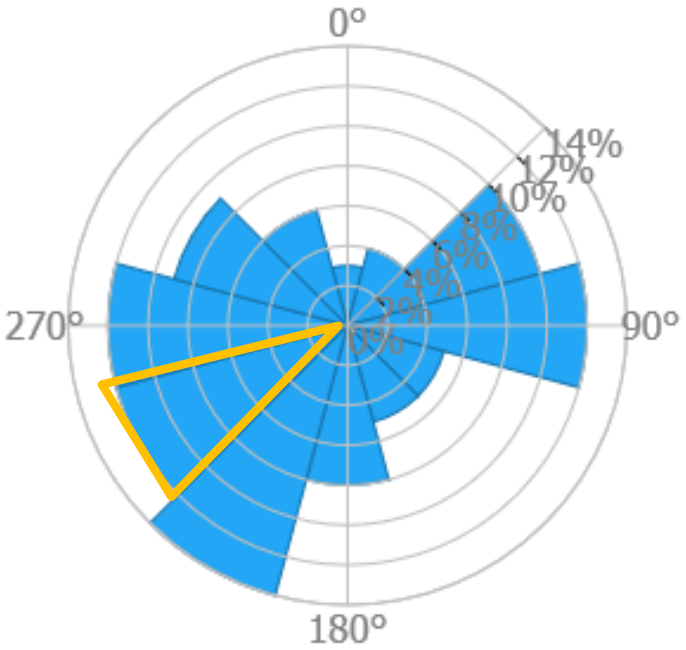
Link between single tree version and LiDAR survey data

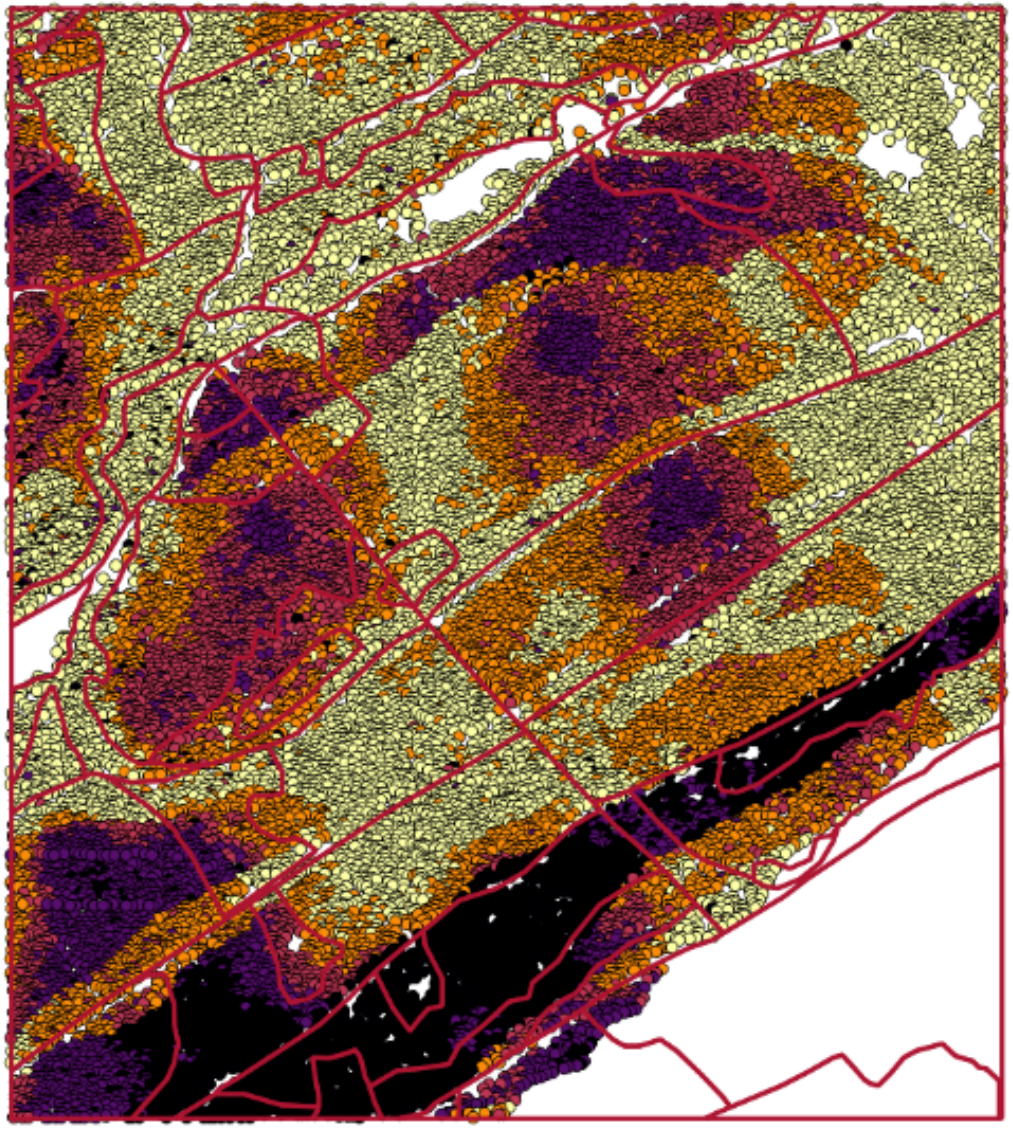


Aberfoyle



Link between single tree version and LiDAR survey data



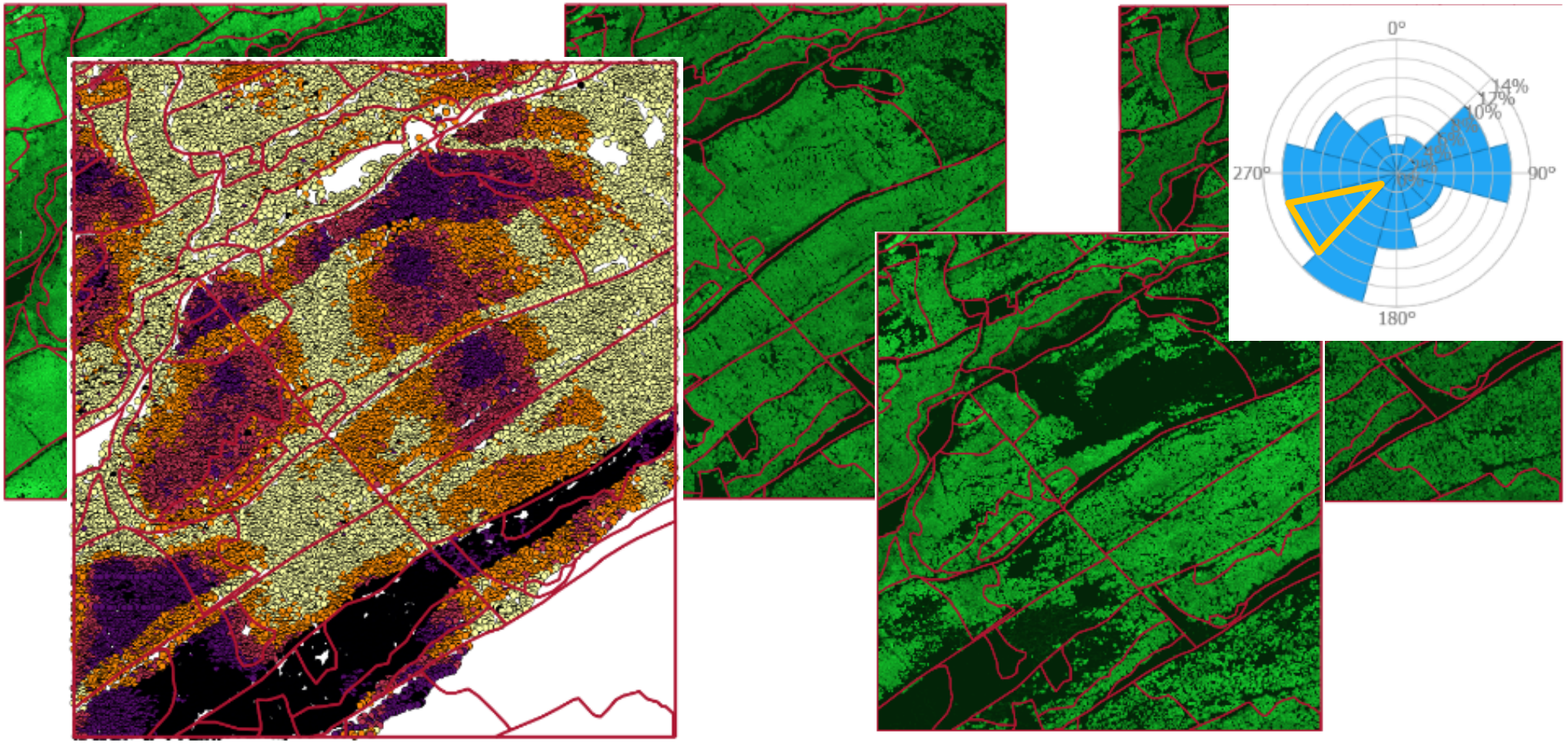


Link between single tree version and LiDAR survey data

2002

2006

2008



2012

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

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