

Management of Wind Damage to Forests

Barry Gardiner

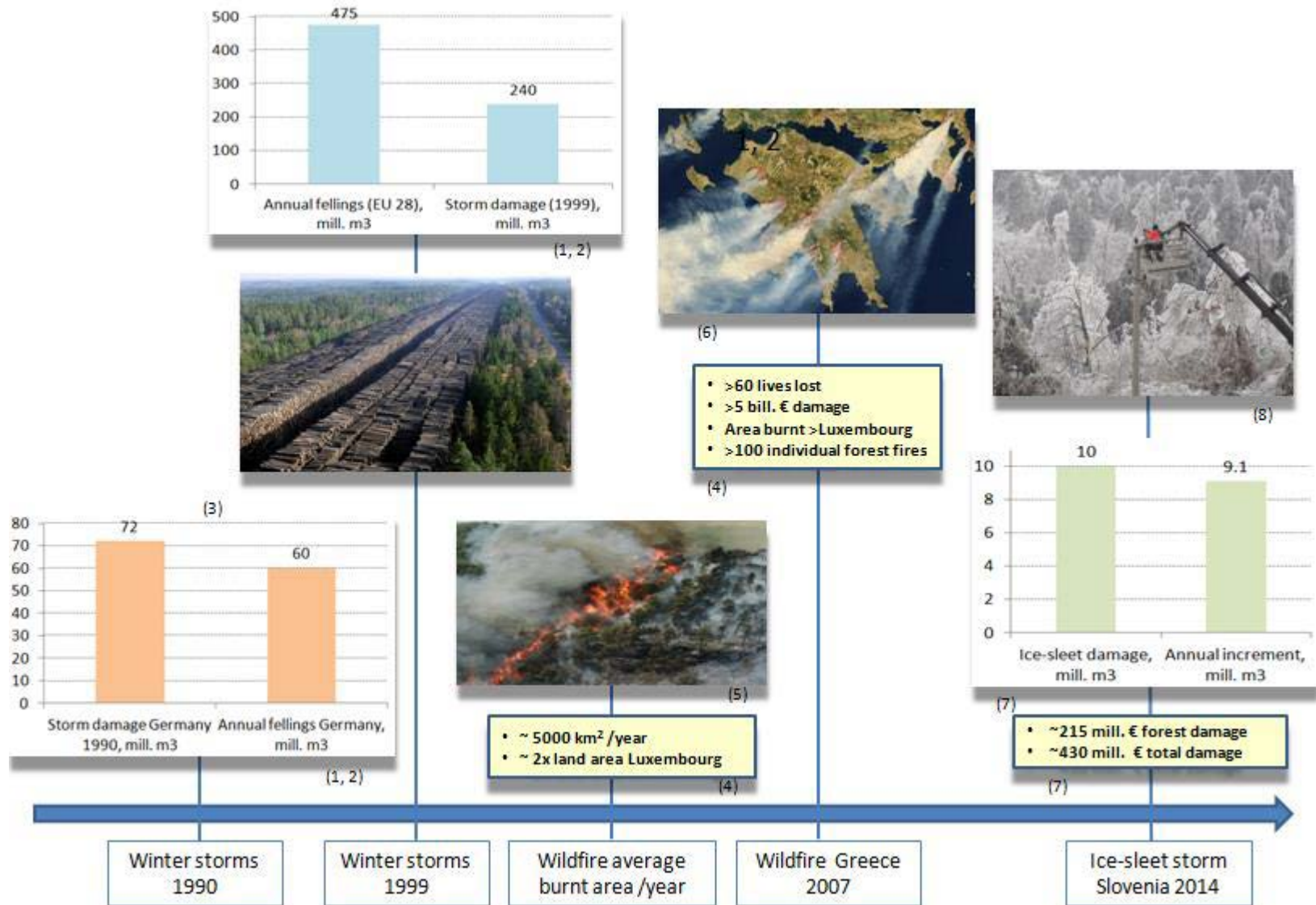
European Forest Institute, Cestas, France



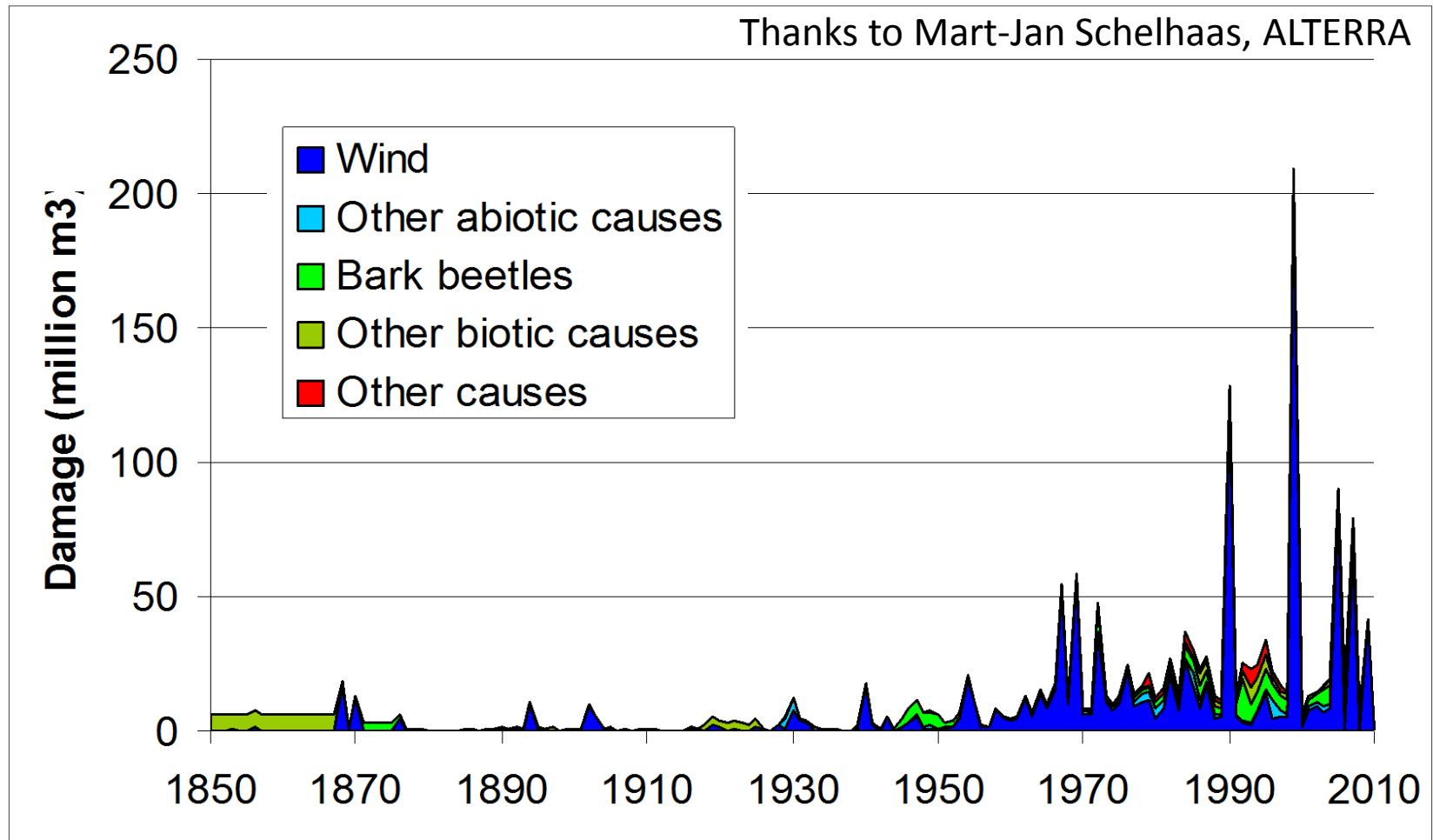
- Wind as the major disturbance in European forests
- Impacts of wind damage
- Risk management in forestry
- Factors affecting forest vulnerability to wind
- Development of tree/stand level risk model (ForestGALES)
- Validation of the wind risk model
- Modelling forest risk at stand/regional/European scale
- Potential impact of the changing climate on wind risk to forests
- Summary



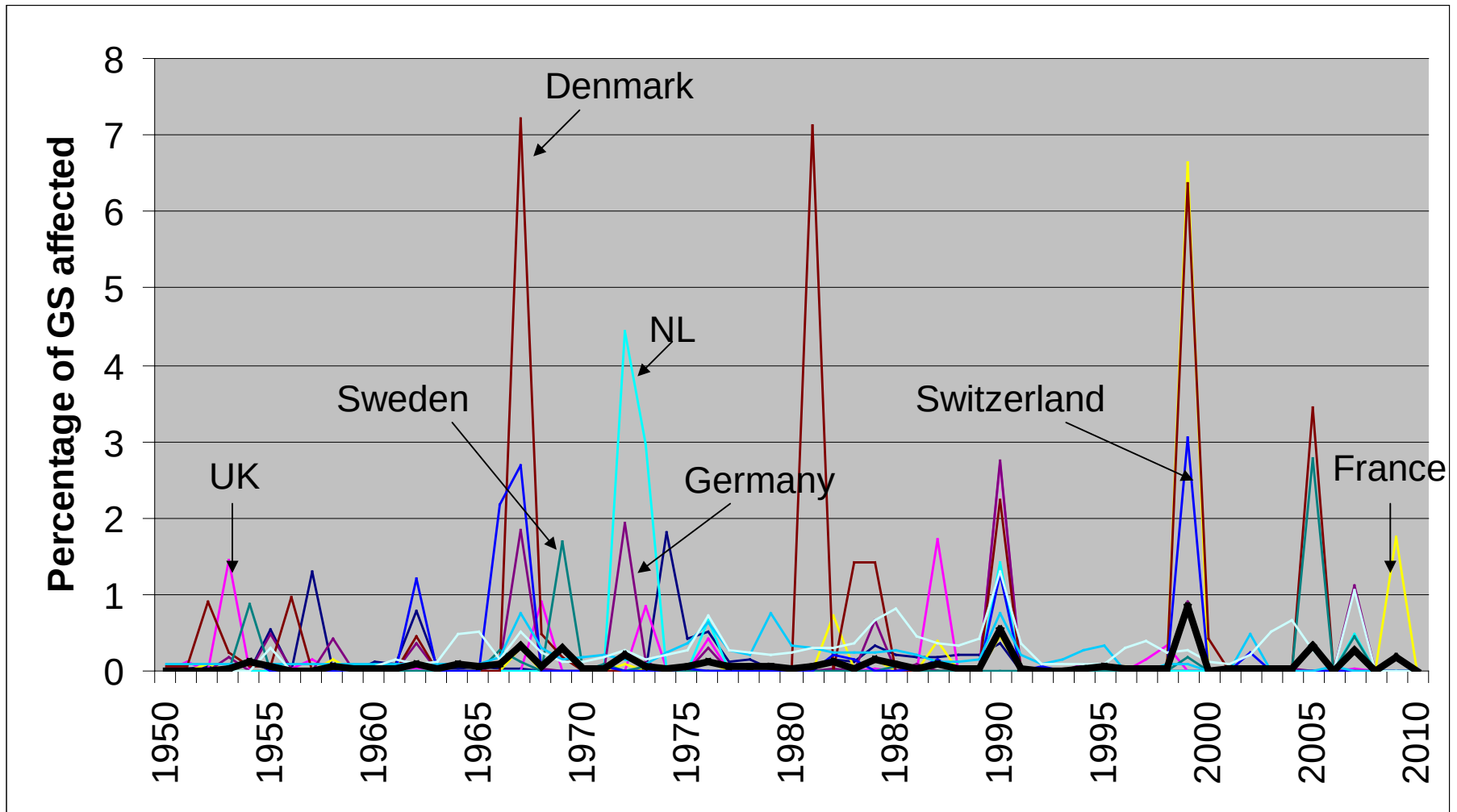
Damage Trends in European Forests



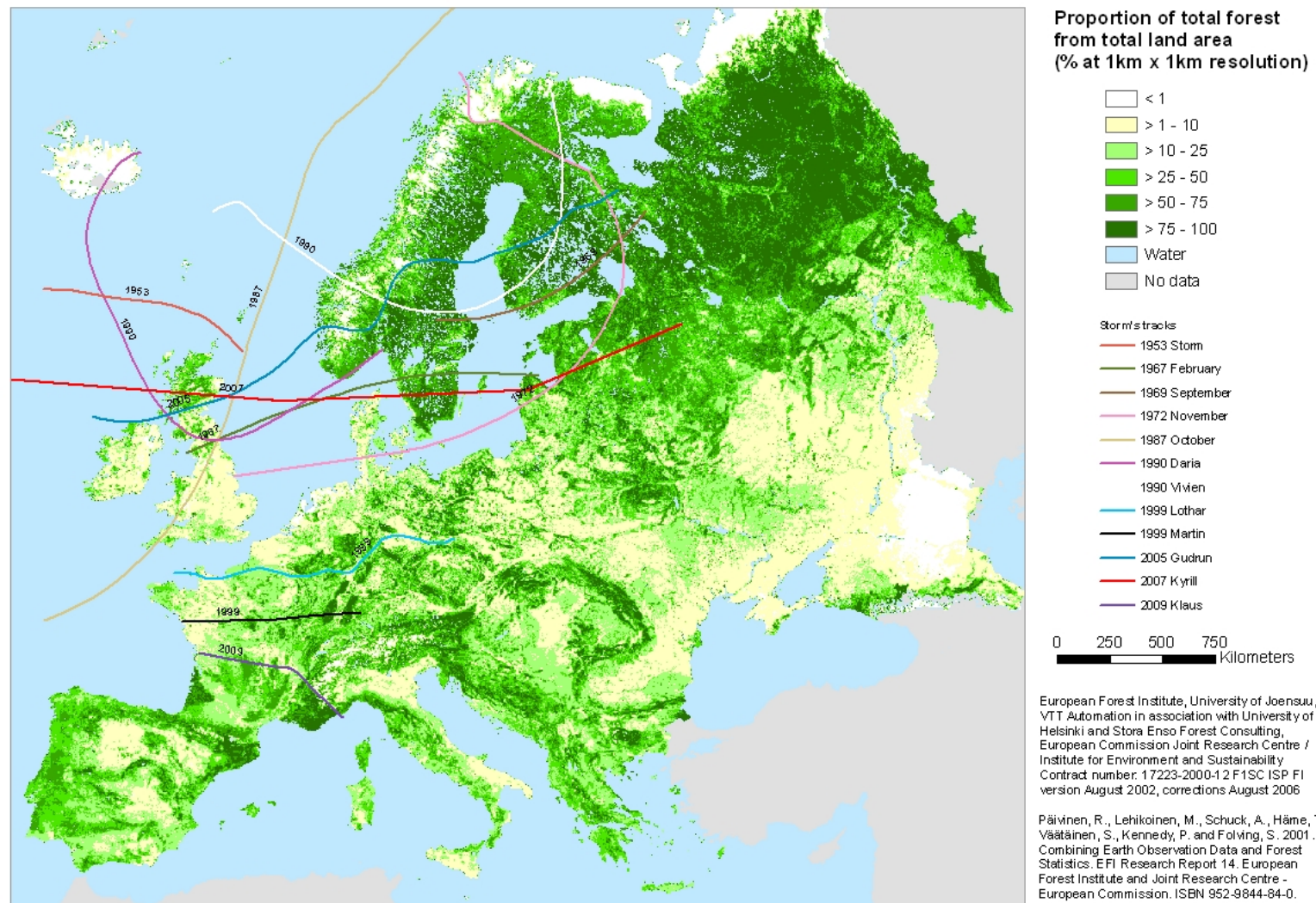
Damage Trends in European Forests



Storm Damage as Percentage of Growing Stock

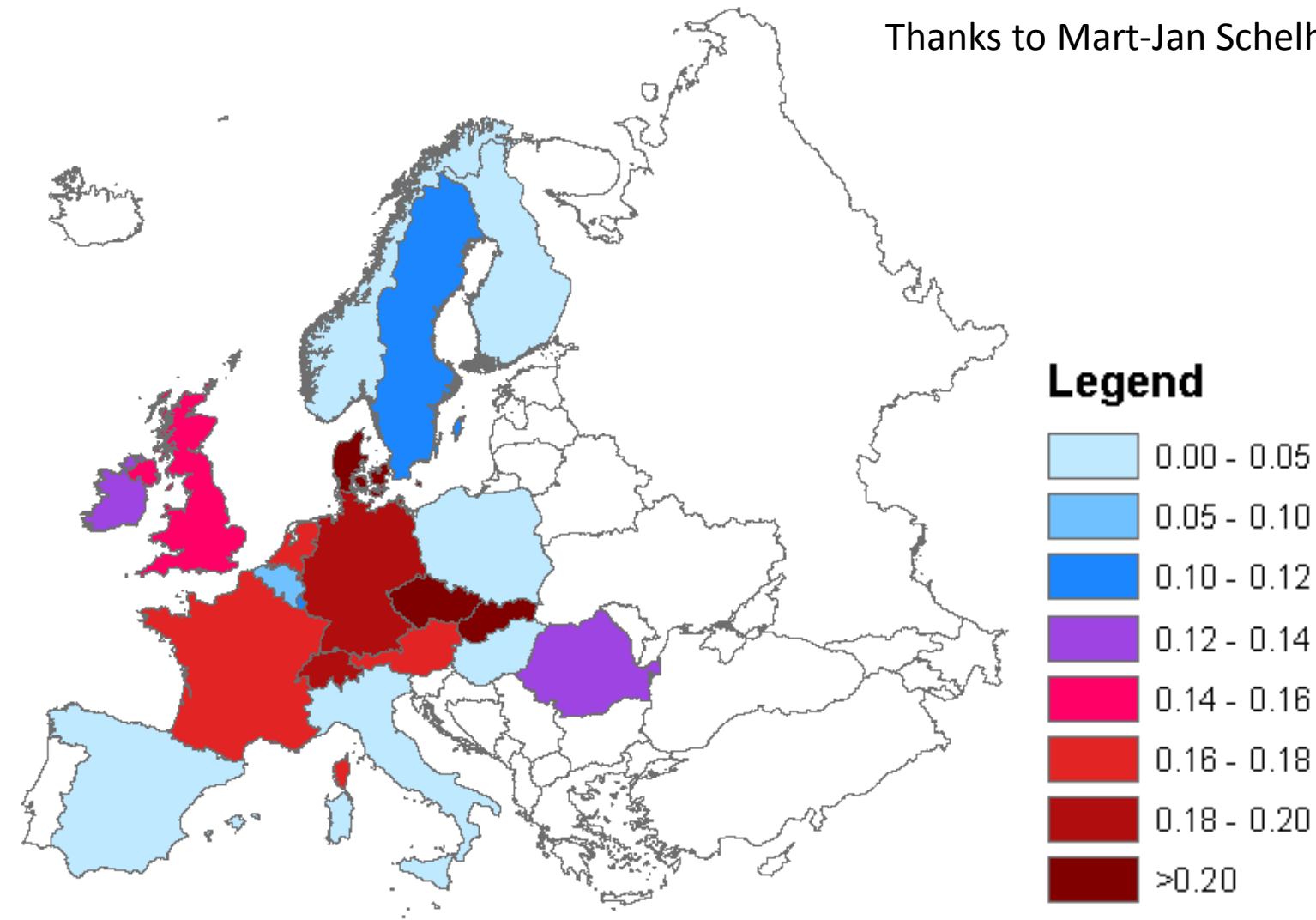


Some Major Storm Tracks and Areas Affected



Annual Wind Damage Levels (% Growing Stock)

Thanks to Mart-Jan Schelhaas, ALTERRA





- **Forest fires:**

In 2005, Portugal: 800 million € worth damage and 13 casualties

In 2007, Greece: 5 billion € worth damage and 64 casualties

- **Storms:**

Responsible for more than 50% of all damage by volume in Europe:

- In 1999, France: 180 millions m³ were destroyed = 6 billion €
- In 2005, Sweden: 75 millions m³ were destroyed = 2.4 billion €

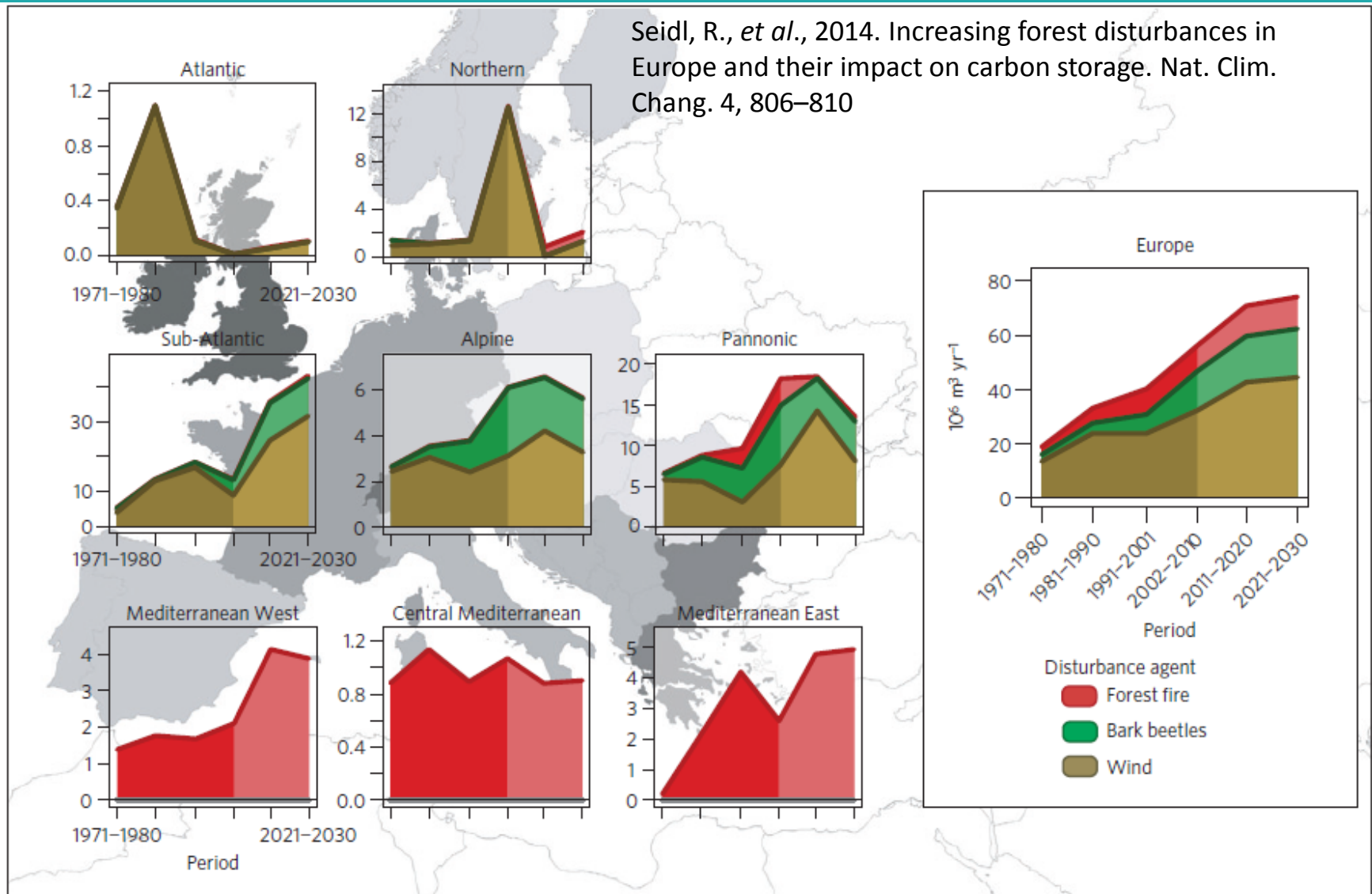
- **Pests and diseases:**

About 2.7% of the forest area in Europe is adversely affected by insects and diseases (new species entering Europe due to climate change)

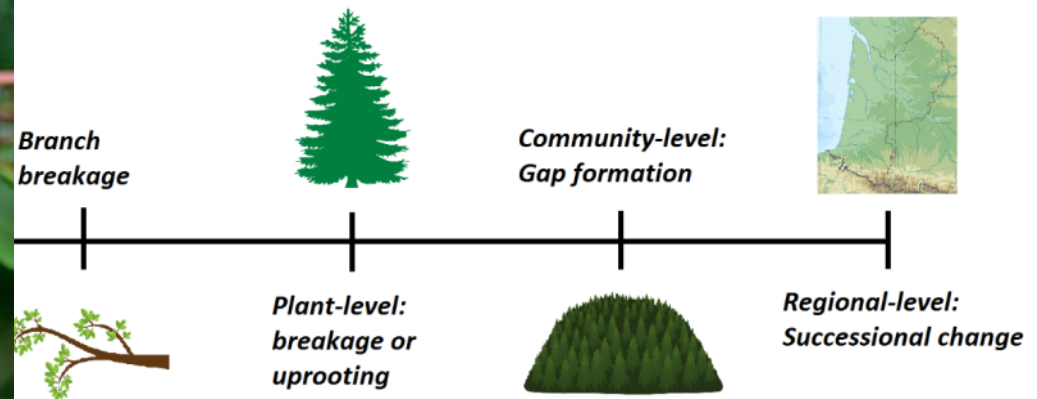


Damage Trends in European Forests

Seidl, R., *et al.*, 2014. Increasing forest disturbances in Europe and their impact on carbon storage. *Nat. Clim. Chang.* 4, 806–810



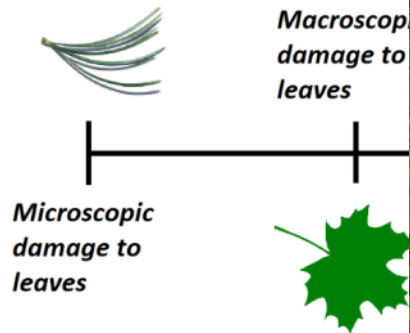
Wind Damage: Leaf/Needle Damage

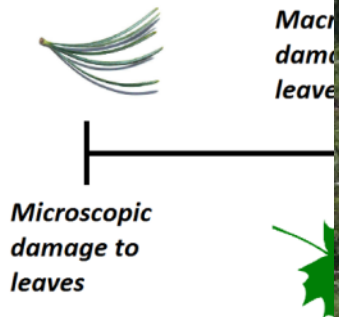


Wind Damage: Defoliation/Branch Breakage



Wind Damage: Individual to Group





Wind Damage during a Storm



Snow/Ice Damage: Tree Bending







Forest Ecology and Management 135 (2000) 261–277

Forest Ecology
and
Management

www.elsevier.com/locate/foreco

Management of forests to reduce the risk of abiotic damage — a review with particular reference to the effects of strong winds

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RISK MANAGEMENT

RISK MANAGEMENT

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Managing Wind Risk: Risk Management/Mitigation Cycles

- **Risk mitigation analysis**

- Modify forest management
- Provide stakeholders to access information
- Stakeholder meetings
- Develop crisis plan
- Access funding
- Insure forests
- Training for managers & emergency workers

- Warning

- Implement Crisis Plan

- State assistance

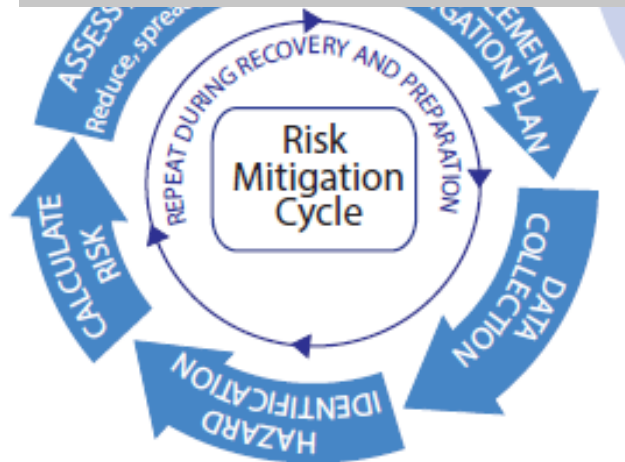
- Access and power

- Assess damage
- Assess markets & economic impact
- Stakeholder meetings
- Prepare roads & landing areas
- Harvest timber
- Transport timber

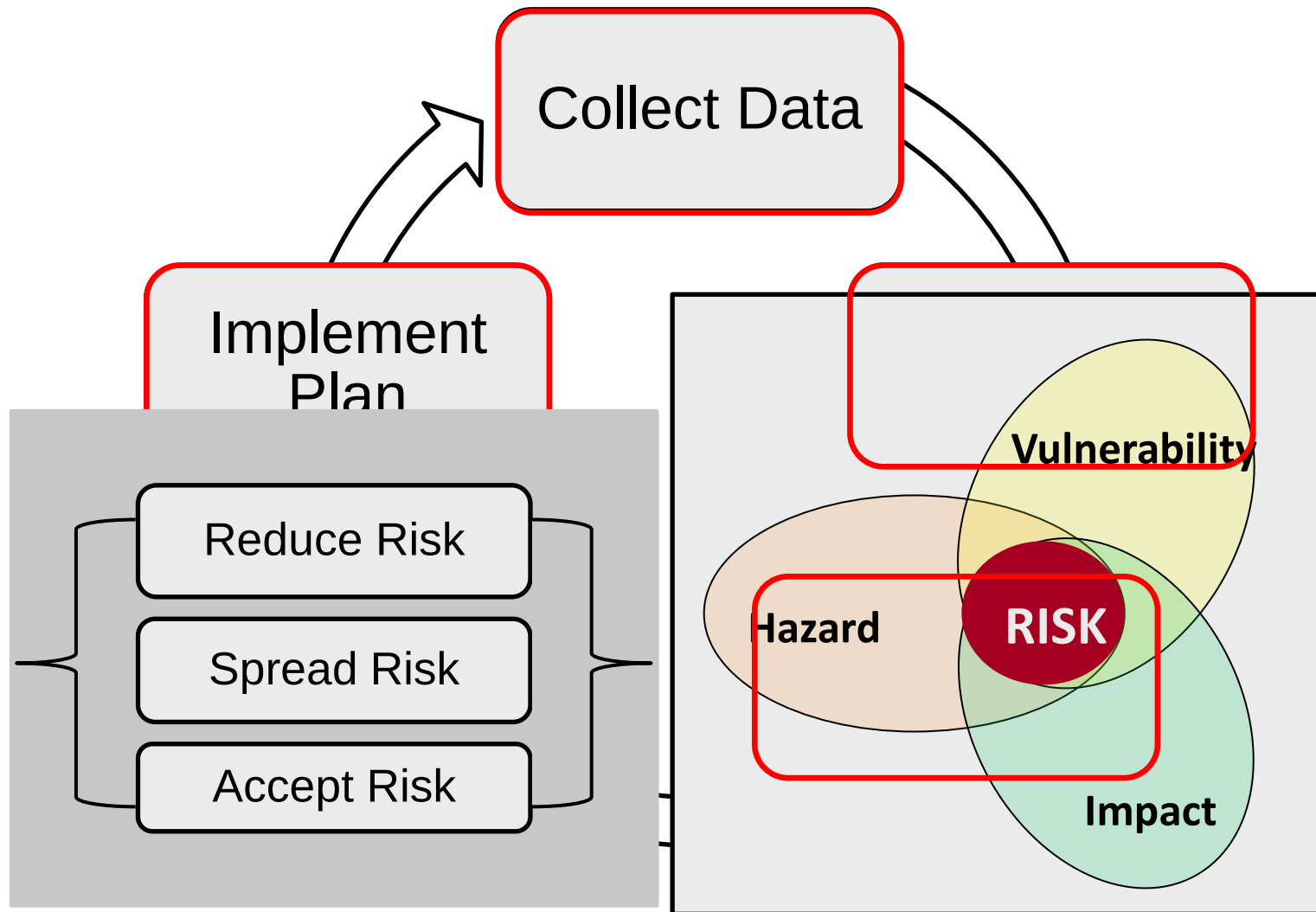
is regional/national/European

funding

- Stakeholder meetings
- Restore infrastructure
- Regional development
- **Risk mitigation analysis**
- Stakeholder meetings
- Forest management planning
- Forest restoration
- Transport timber
- On-going social & economic recovery



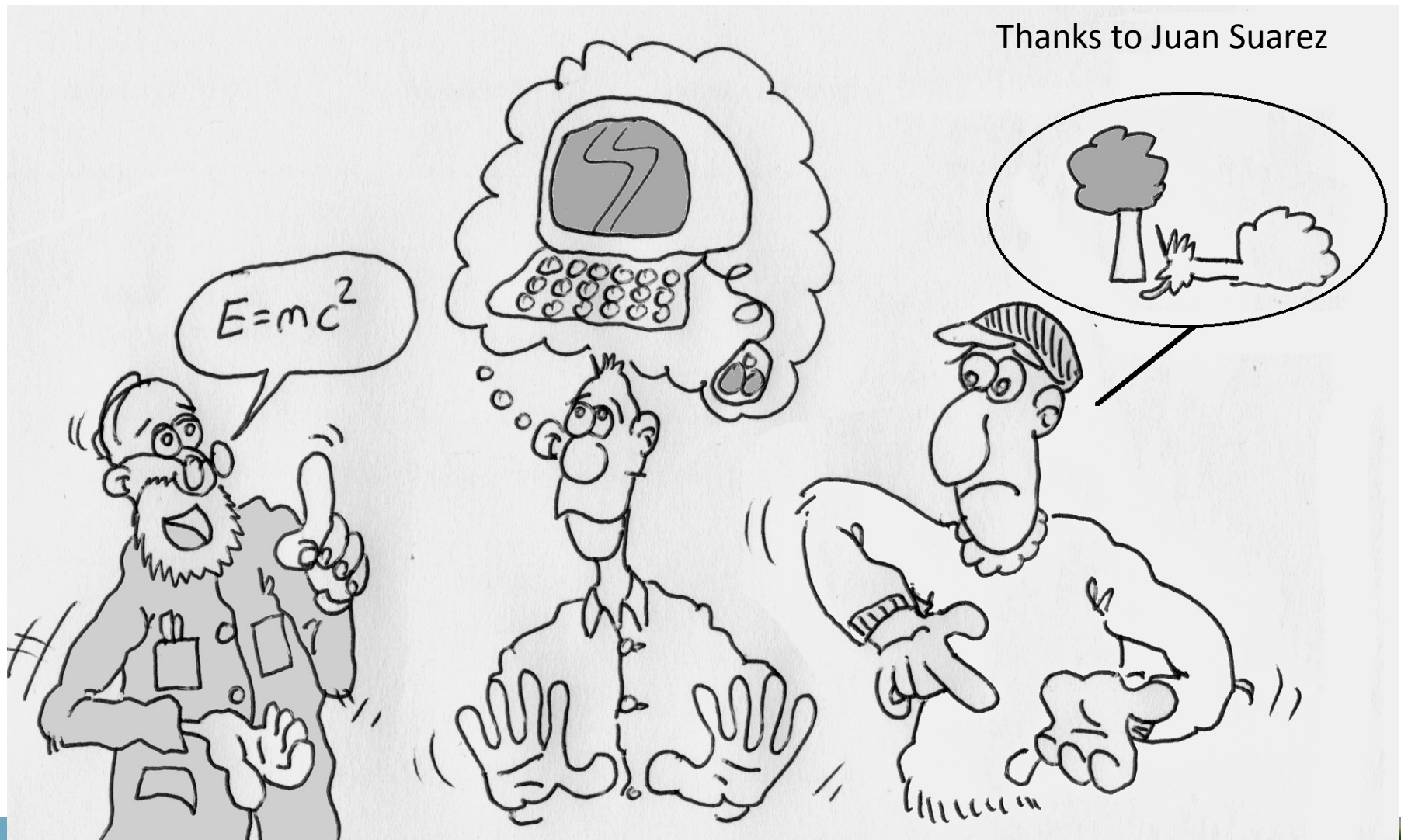
Managing Wind Risk: Risk Mitigation Cycle



Managing Wind Risk: Manuals/Books/Web pages



Managing Wind Risk: Decision Support System



ForestGALES Forest Wind Risk Model

ForestGALES 2.1

File Mode DAMS Options Window Help

Single stand predictions using Yield Models

Stand Characteristics

Stand ID: ForestGALES

Cultivation: Shallow Ploughing < 45cm

Drainage: Average

Soil type: Peaty Gley

☐ Planting year: 1970

Tree Characteristics

Species: Sitka Spruce

Yield Class: 14

Thinning regime: Line Thinning with no delay

Initial spacing (m): 1.7

Age: 37

Tree Details

DAMS

☒ Grid Reference ☐ Calculation

NH180150 Apply... DAMS Score: 15

Upwind Edge Effect

☒ Windfirm edge

☐ Brown edge - Size of gap (m): 0

Wind Damage Risk

Return period: 24

Wind Damage Risk Status: Status 4

Critical wind speed: 48 mph

OVERTURNING

BREAKAGE: 188

1 2 3 4 5 6

Status 1

53 mph

WHC: 5

Controls

Run

Print Form

Report

Help

Open File

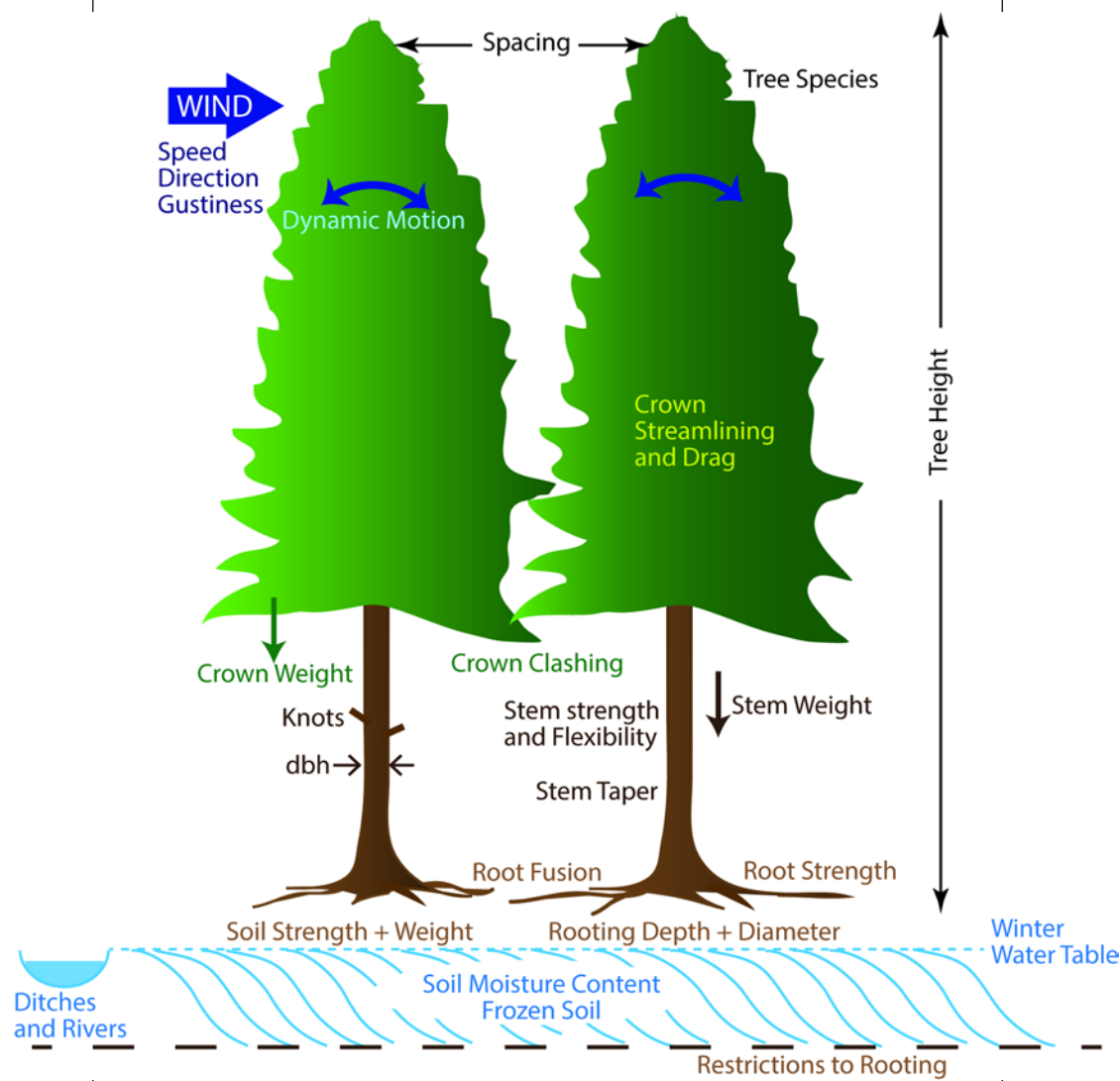
Save File

Defaults

Close



Developing a Risk Model: Factors Affecting Wind Risk of Trees



Factors Affecting Wind Risk of Trees: Forest Edges



Factors Affecting Wind Risk to Trees: Damage Propagation



Factors Affecting Wind Risk of Trees: Thinning



Factors Affecting Wind Risk of Trees: Gaps

Resultant bending moment coefficient



12

Size of clearing/h

Factors Affecting Wind Risk of Trees: Streamlining



Factors Affecting Wind Risk of Trees: Tree Species

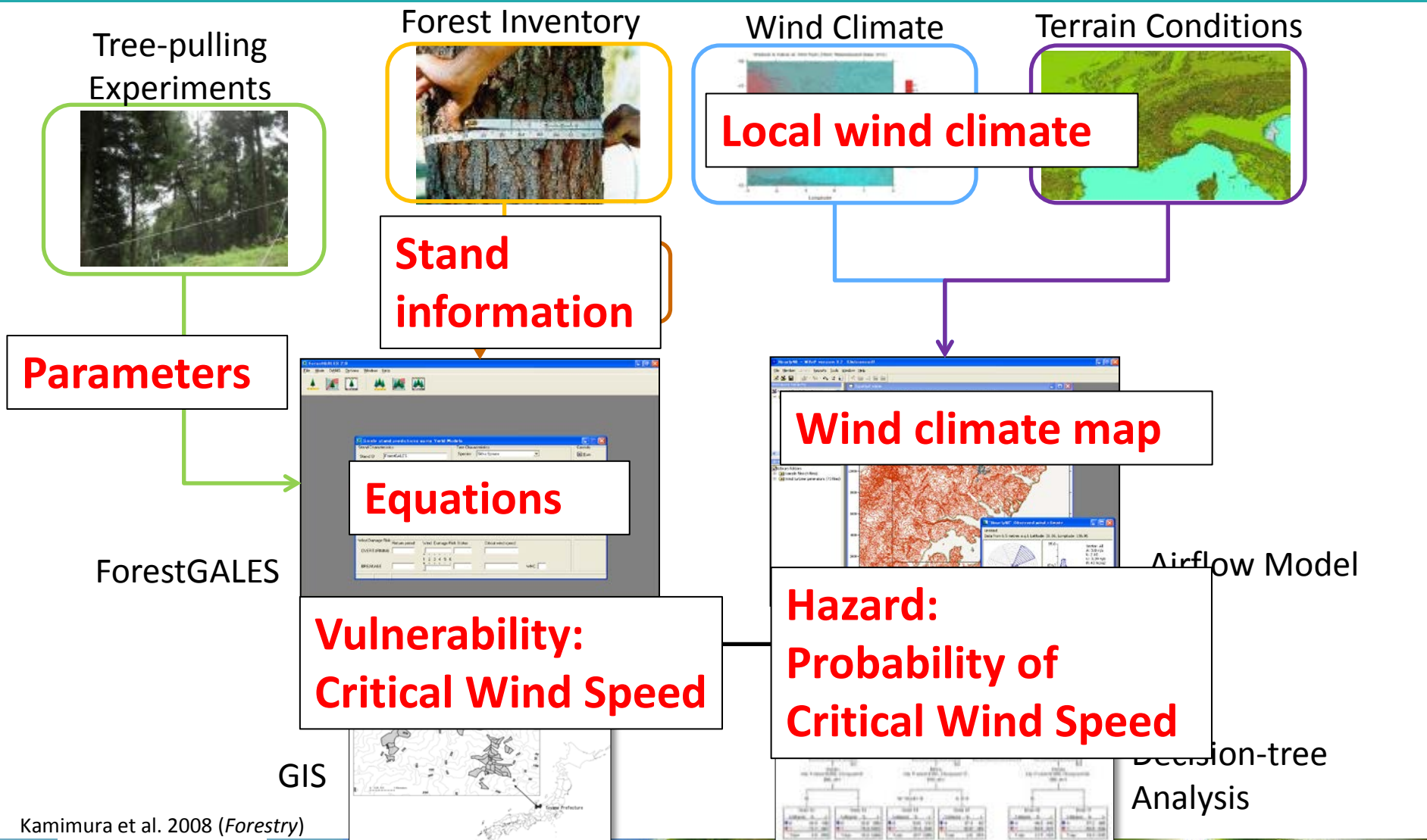
Table 1. A ranking of the vulnerability of important tree species of European forests to wind damage. Adapted from Colin et al (2009).

Vulnerable	Intermediate	Resistant
<i>Picea abies</i>	<i>Pinus nigra</i>	<i>Larix decidua</i>
<i>Picea sitchensis</i>	<i>Pinus nigra</i> ssp <i>laricio</i>	<i>Abies alba</i>
<i>Pinus pinaster</i>	<i>Pinus sylvestris</i>	<i>Cedrus atlantica</i>
<i>Pseudotsuga menziesii</i>	<i>Fagus sylvatica</i>	<i>Quercus robur</i>
<i>Pinus contorta</i>	<i>Prunus avium</i>	<i>Quercus petraea</i>
<i>Populus nigra</i> , <i>P. trichocarpa</i> , and hybrids	<i>Betula pendula</i>	<i>Tilia cordata</i>
<i>Populus tremula</i>	<i>Betula pubescens</i>	<i>Carpinus betulus</i>
<i>Pinus radiata</i>	<i>Castanea sativa</i>	<i>Fraxinus excelsior</i>
<i>Eucalyptus globulus</i>		<i>Acer pseudoplatanus</i>

Factors Affecting Wind Risk of Trees: Terrain

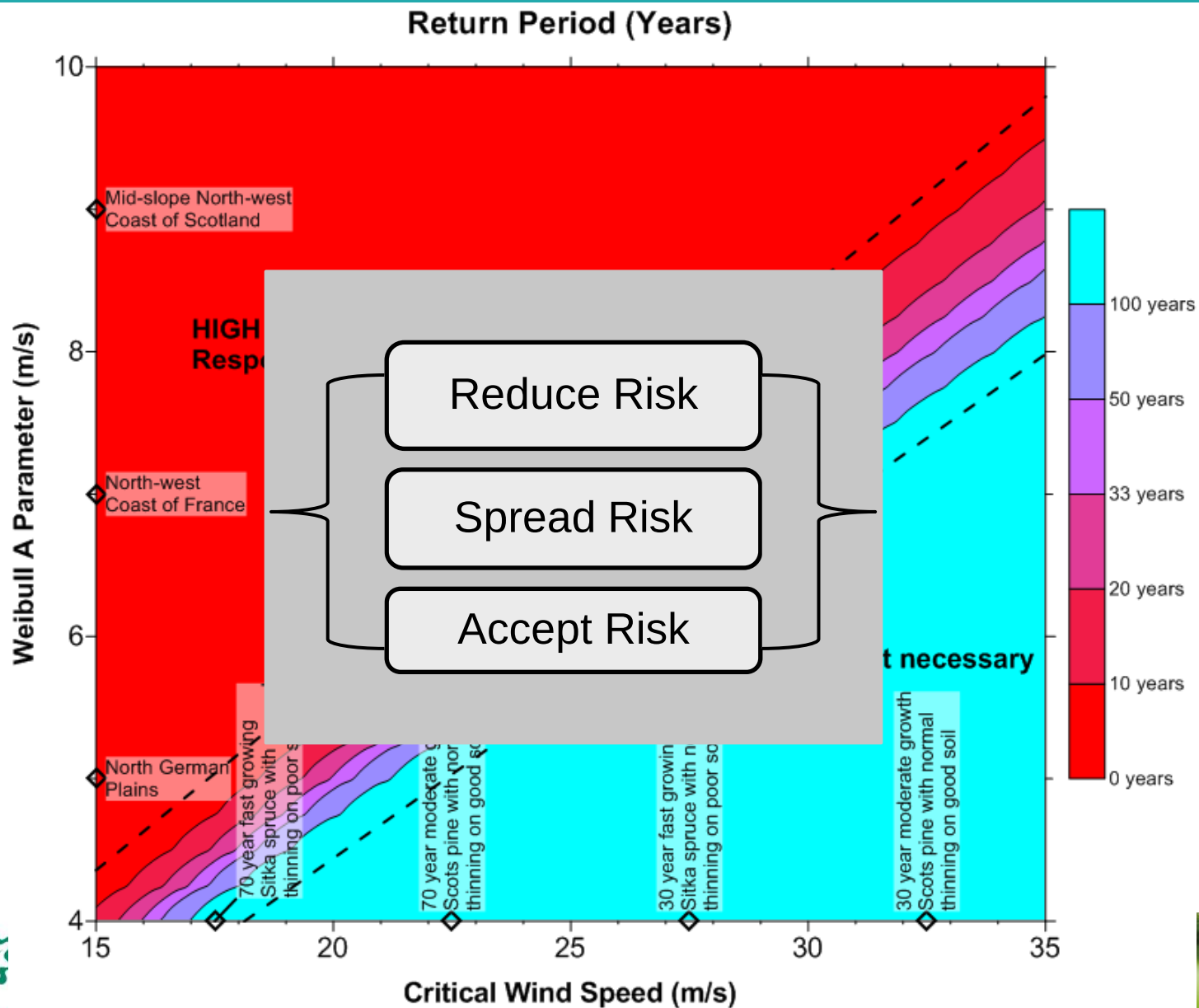


ForestGALES: Information Flow



Kamimura et al. 2008 (Forestry)

Managing Wind Risk: Decision Making



ForestGALES: Validation Locations

Aberfoyle, Scotland

- Storm on 3 January 2012
- Main tree species: Sitka spruce

Aquitaine, France

- Storm Martin (27 December 1999) & Klaus (24 January 2009)
- Main tree species: Maritime pine

Basque Country, Spain

- Storm Klaus (24 January 2009)
- Storm Xynthia (27 February 2010)
- Main tree species: Radiata pine



ForestGALES Validation: Climatology/Topography/Species

Wind damage in different wind climate, topography, and tree species



Aberfoyle
(Scotland)

- High wind exposure
- Moderate topography
- Sitka spruce



Aquitaine
(France)

- Moderate wind exposure
- Flat topography
- Maritime pine



Basque
(Spain)

- Moderate wind exposure
- Severe topography
- Radiata pine

ForestGALES Validation: Damage in Forests

Aberfoyle, Scotland

Sitka spruce (50%)

3 January 2012



By Sophie Hale

Aquitaine, France

Maritime pine

24 January 2009(Klaus)



By Christophe Orazio

Basque Country

Radiata pine

24 January 2009

27 February 2010



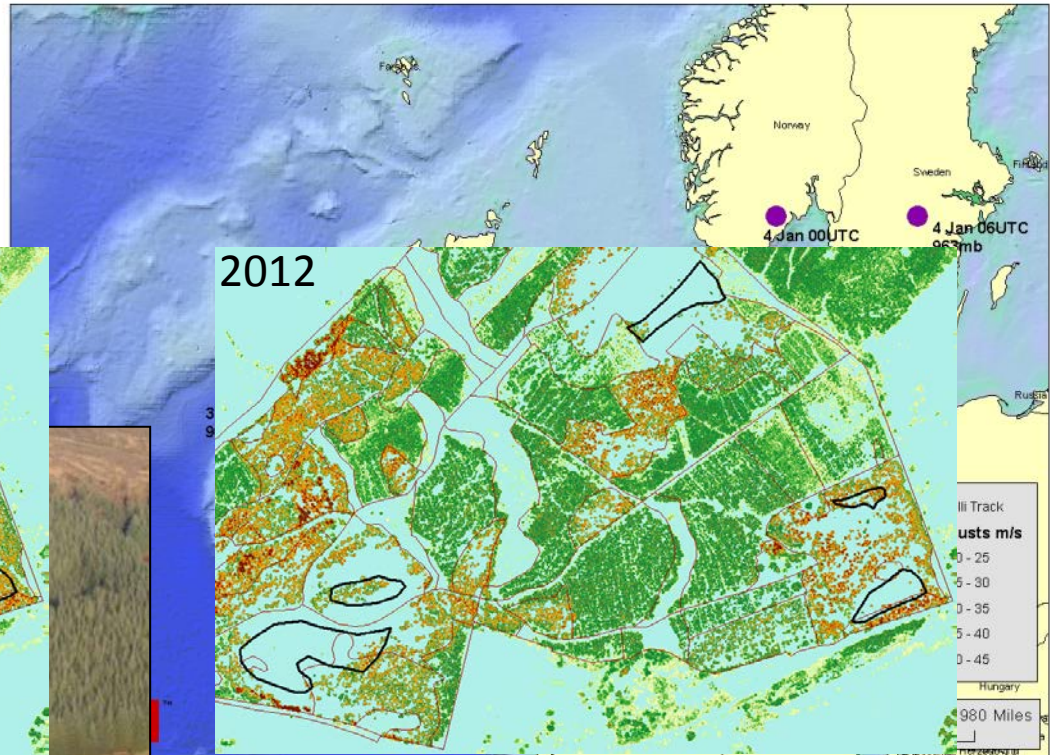
Xintia



Klaus



ForestGALES: Validation in Scotland



ForestGALES: Validation in Scotland

Environmental Modelling & Software 68 (2015) 27–41



Contents lists available at ScienceDirect

Environmental Modelling & Software

journal homepage: www.elsevier.com/locate/envsoft



Comparison and validation of three versions of a forest wind risk model



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(a)



ARTICLE

Mechanistic and statistical approaches to predicting wind damage to individual maritime pine (*Pinus pinaster*) trees in forests

Kana Kamimura, Barry Gardiner, Sylvain Dupont, Dominique Guyon, and Céline Meredieu

Abstract: Maritime pine (*Pinus pinaster* Aiton) forests in the Aquitaine region, southwestern France, suffered catastrophic damage from storms Martin (1999) and Klaus (2009), and more damage is expected in the future due to forest structural change and climate change. Thus, developing risk assessment methods is one of the keys to finding forest management strategies to reduce future damage. In this paper, we evaluated two approaches to calculate wind damage risk to individual trees using data from different damage data sets from two storm events. Airflow models were coupled either with a mechanistic model (GALES) or a bias-reduced logistic regression model to discriminate between damaged and undamaged trees. The mechanistic approach was found to successfully discriminate the trees for different storms but only in locations with soil conditions similar to where the model parameters were obtained from previous field experiments. The statistical approach successfully discriminated the trees only when applied to similar data as that used for creating the models, but it did not work at an acceptable level for other data sets. One variable, decade of stand establishment, was a significant variable in all statistical models, suggesting that site preparation and tree establishment could be a key factor related to wind damage in this region.

Key words: tree wind damage, GALES, logistic regression, airflow models.

Résumé : Les forêts d'Aquitaine de Pin maritime (*Pinus pinaster* Aiton) du sud-ouest de la France ont souffert de deux tempêtes majeures, Martin (1999) et Klaus (2009) et de nouveaux dégâts sont attendus dans le futur en raison de changements dans la structure forestière et à cause du changement climatique. C'est pour cela que le développement d'une méthode d'évaluation des risques liés aux tempêtes est une des clés pour développer de nouvelles stratégies d'aménagement pour réduire les risques à venir. Dans ce papier, nous avons évalué deux approches pour calculer le risque au niveau des arbres individuels en utilisant deux jeux de données provenant des deux dernières tempêtes. Des modèles de simulation atmosphériques ont été couplés soit à un modèle mécaniste de prévision des dégâts (GALES) soit à un modèle de régression logistique avec réduction du biais de façon à distinguer les arbres endommagés ou non. L'approche mécaniste permet de distinguer avec succès les catégories d'arbres lors des deux tempêtes mais seulement pour les conditions pédologiques des données qui ont servi à la calibration des paramètres du modèle. L'approche statistique permet elle aussi de discriminer les catégories d'arbres avec succès uniquement pour les conditions de calibration mais elle ne fonctionne pas pour d'autres jeux de données. Une variable, la décennie d'installation des peuplements, est significative pour tous les différents modèles statistiques, suggérant que les techniques de préparation du sol et de régénération pourraient faire parties des facteurs clés en relation avec les dégâts dus au vent dans cette région.

Mots-clés : dommages aux arbres causés par le vent, GALES, régression logistique, modèles d'écoulement d'air.

1. Introduction

Strong winds during storms can cause catastrophic damage to forests. In the last two decades, two storm events caused substantial damage to maritime pine (*Pinus pinaster* Aiton) planted forests in the Aquitaine region, southwestern France (specifically in the Landes de Gascogne and Dunes atlantiques areas, Fig. 1). Storm Martin on 27 December 1999 resulted in approximately 26 million m³ of timber loss, which was equivalent to the general harvested volume for 3.5 years in maritime pine forests in southwestern France (Cucchi et al. 2004). Ten years later, storm Klaus on 24 January 2009 damaged approximately 37 million m³ of maritime pine trees further south in the region (Colin et al. 2010). This led to losses of approximately €1800 million in the forestry sector, which was almost 60% of total economic losses in France that year

(Commission des affaires économiques 2009). These storms are predicted by some researchers to become more intense although less frequent in the future (e.g., Marcos et al. 2011; Feser et al. 2015), and further catastrophic damage in these maritime pine forests is likely to occur. It is thus important to understand the direct causes leading to damage occurrence and to develop methodologies to assess and predict the risk of damage to sustainably manage the forests.

There are several key factors associated with wind damage based on previous studies. The main biotic factors are tree dimensions, tree species, absence or presence of leaves, and tree acclimation to the new environment, and the main abiotic factors are soil type, terrain conditions, and wind speed (e.g., Gardiner and Quine 2000; Mitchell 2013). For instance, wind damage has been

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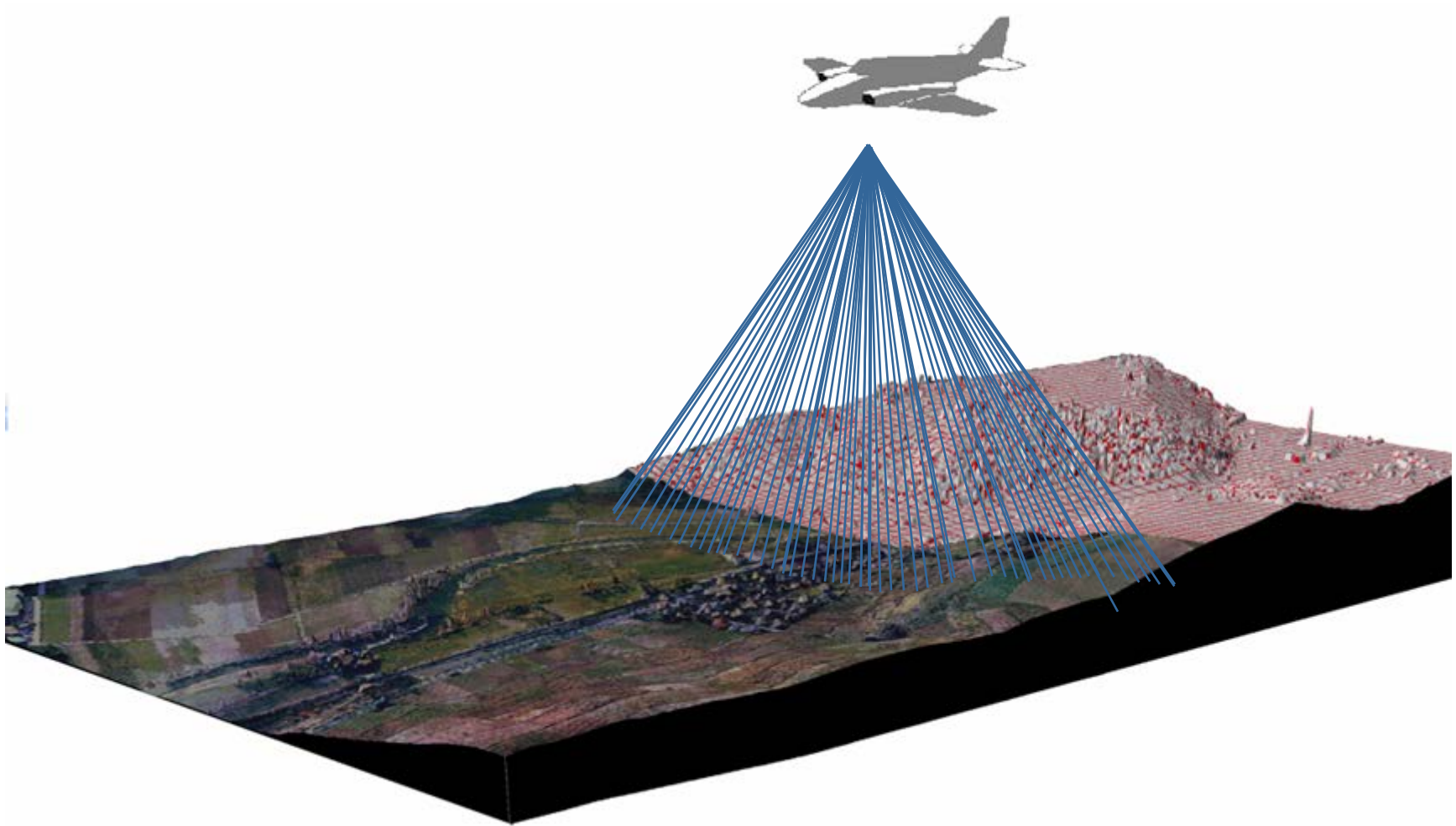
Published at www.nrcresearchpress.com/cjfr on 19 October 2015.



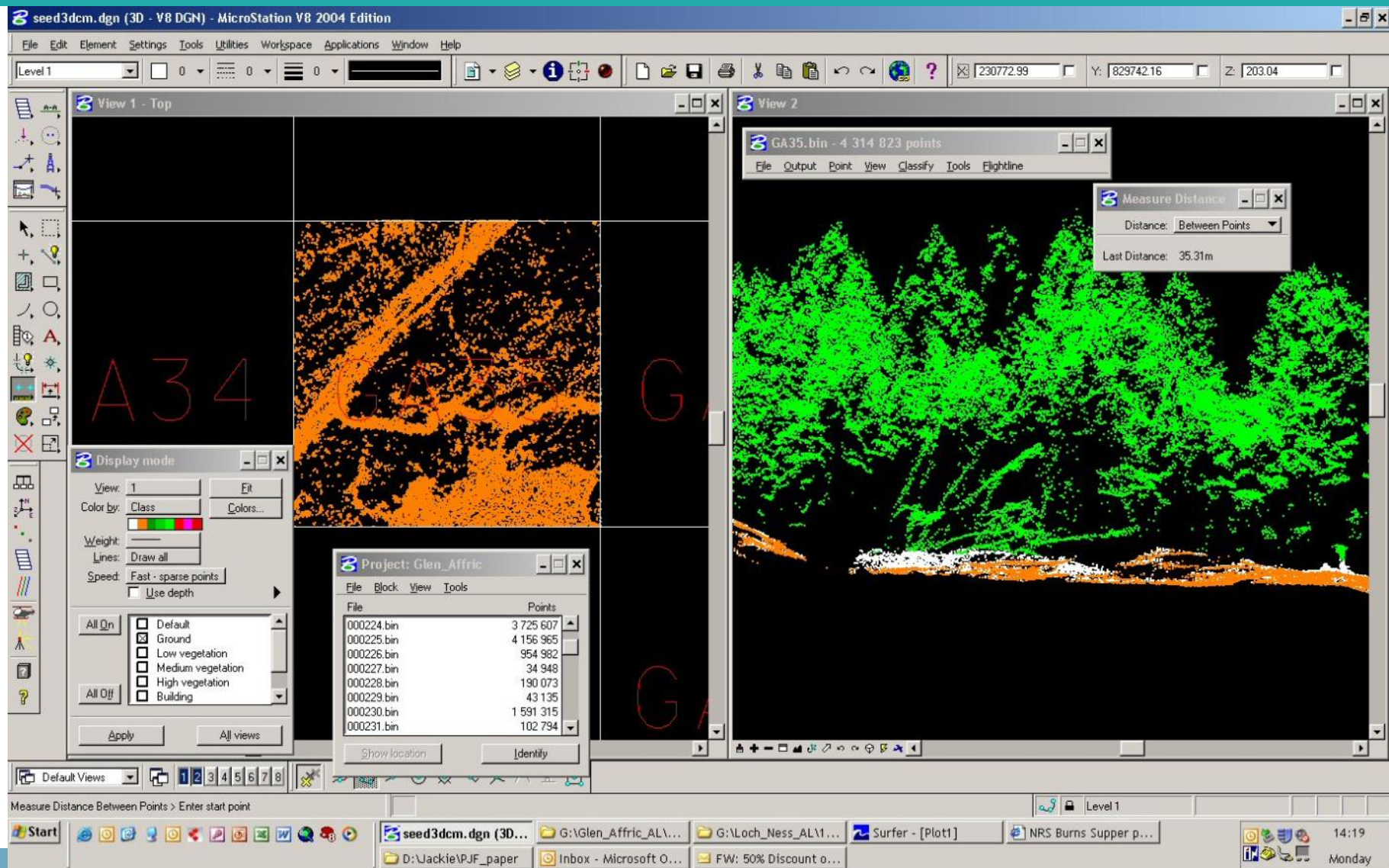
140 Kilometers



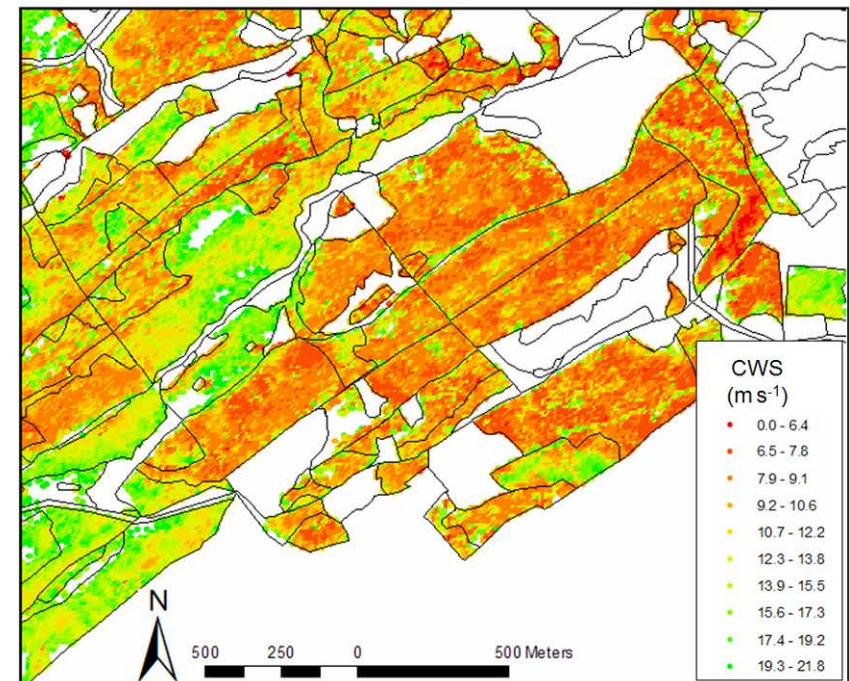
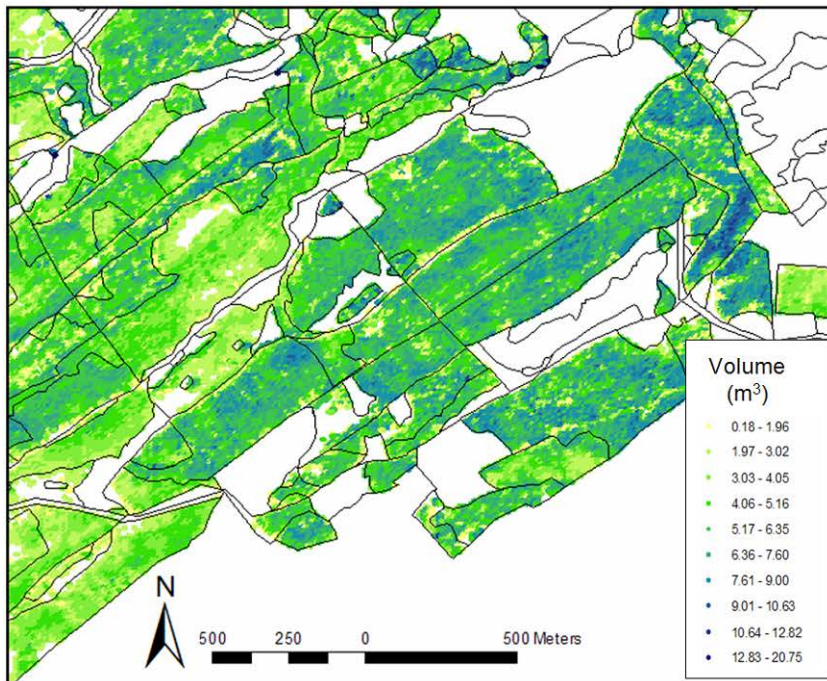
Modelling Wind Risk at Regional Level: Airborne LiDAR



Modelling Wind Risk at Regional Level: Airborne LiDAR



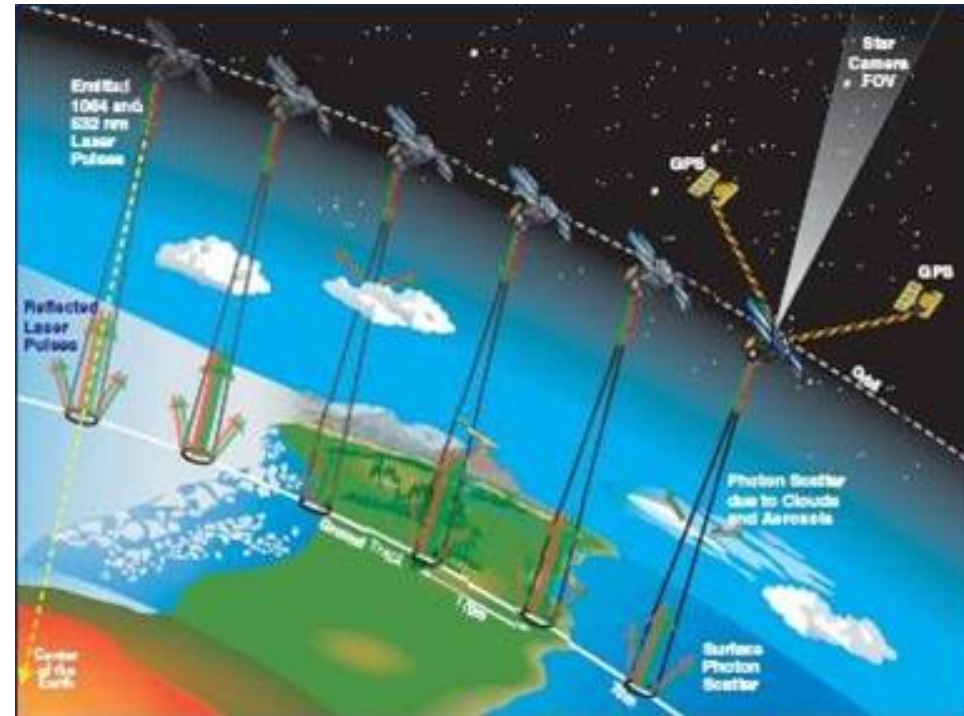
Modelling Wind Risk at Regional Level: Airborne LiDAR



Modelling Wind Risk at National/European Level : ICESat

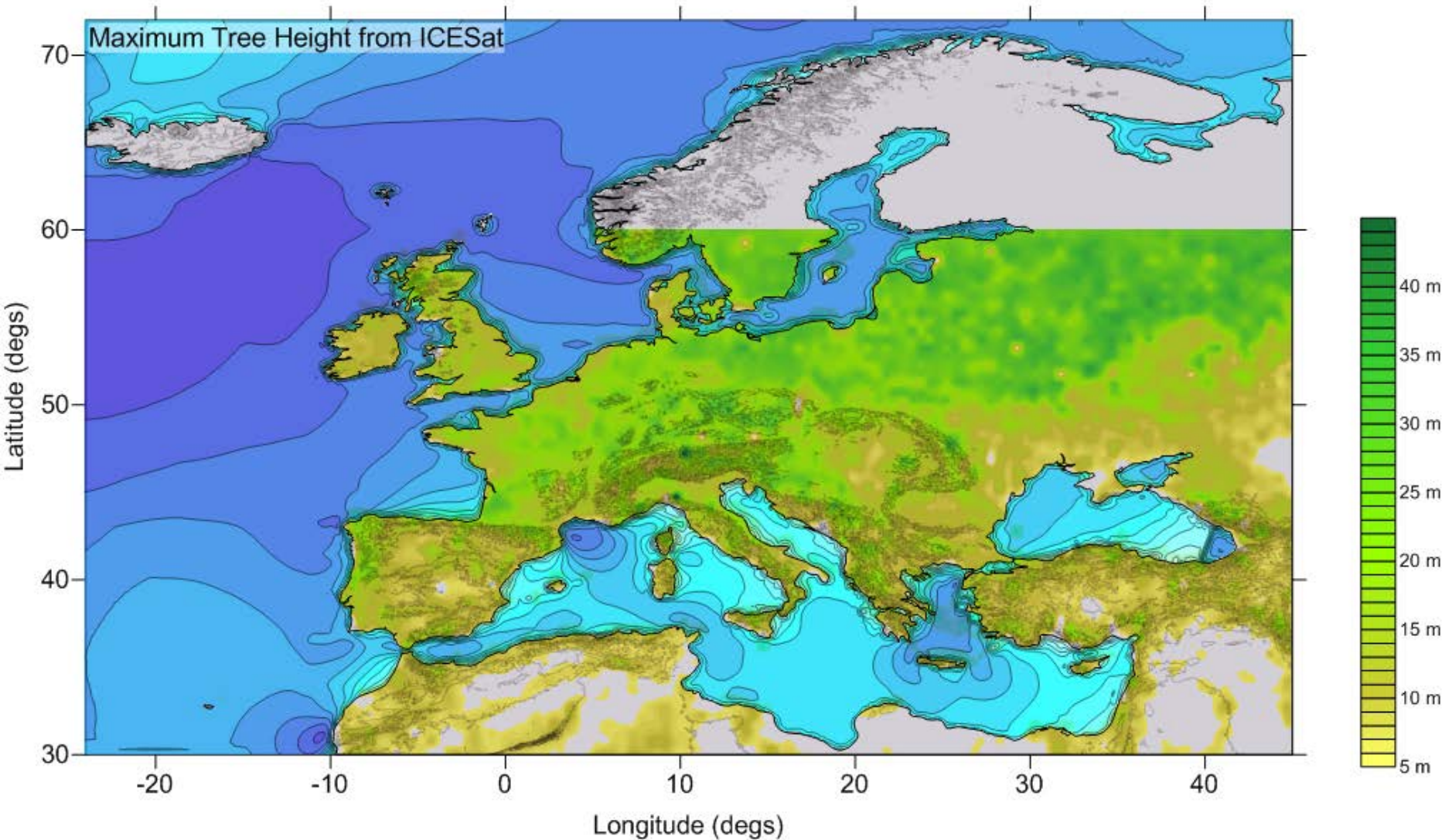
Potential of Full Waveform Satellite Lidar:

- Forest parameter retrieval
- Application at a regional and national scale
- 172 m between footprint centres
- Approximately 64m diameter footprints

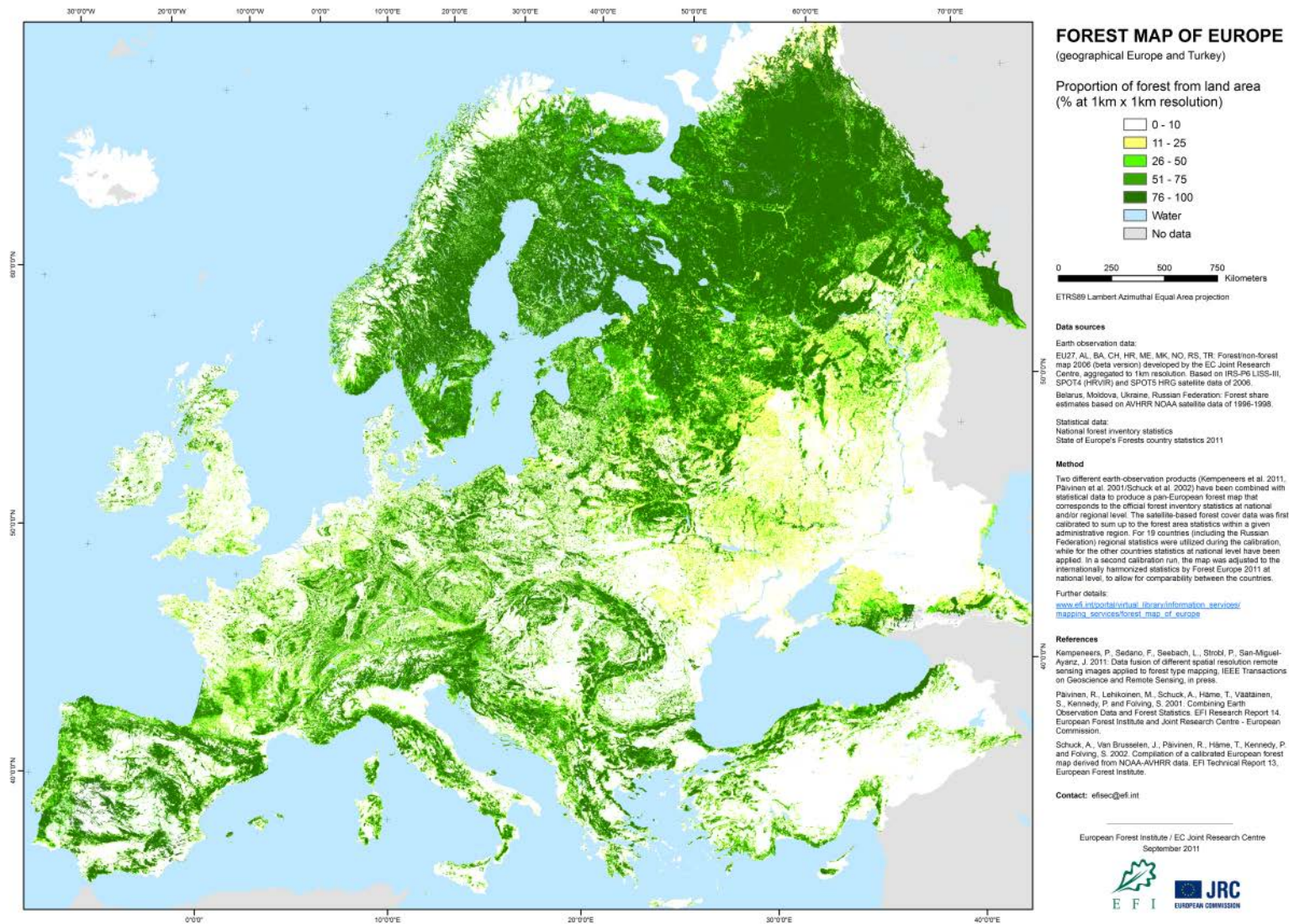


ICESat ice sheet elevation and cloud cover
Source: <http://icesat.gsfc.nasa.gov/>

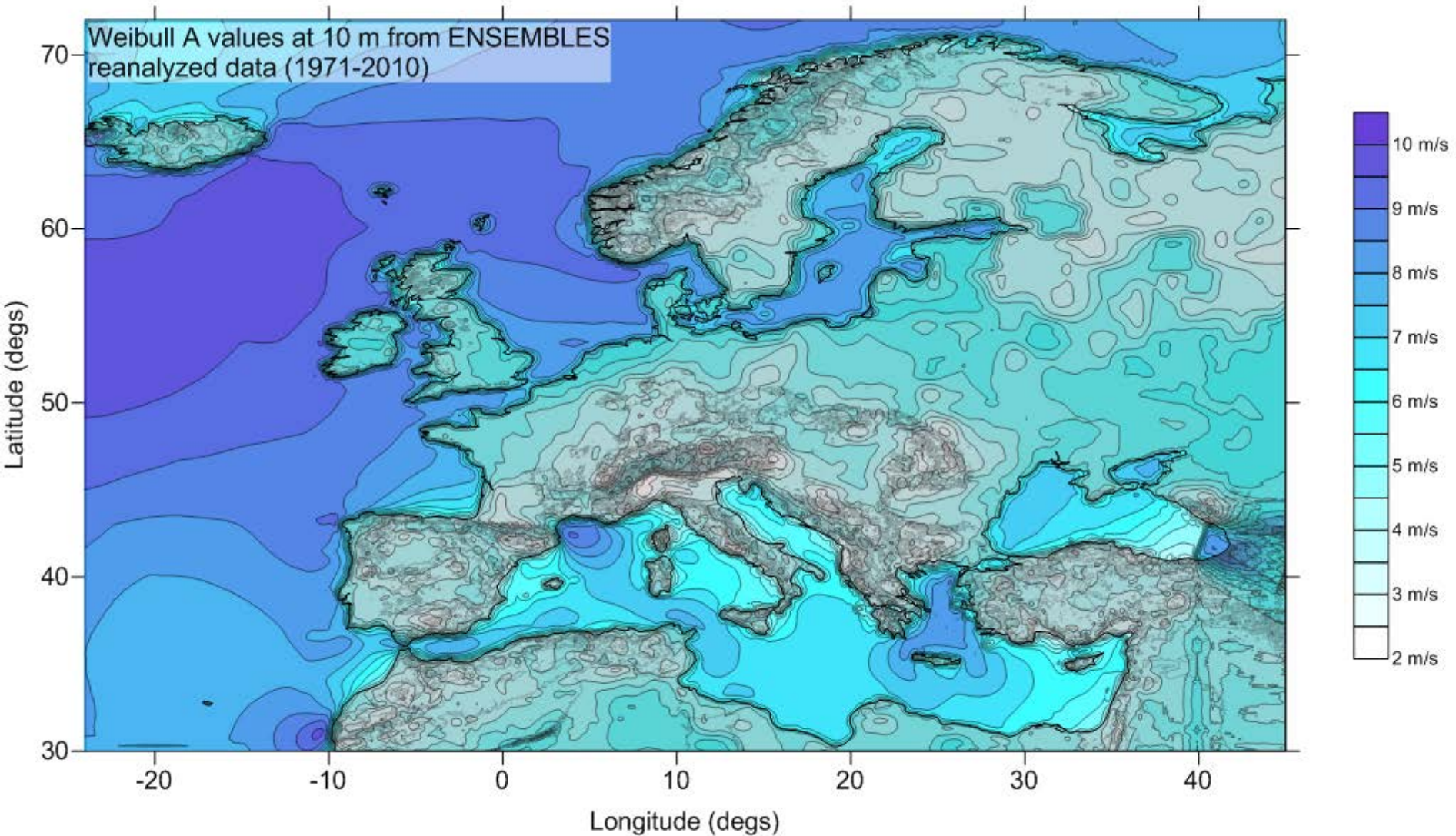
Modelling Wind Risk at National/European Level: ICESat Data



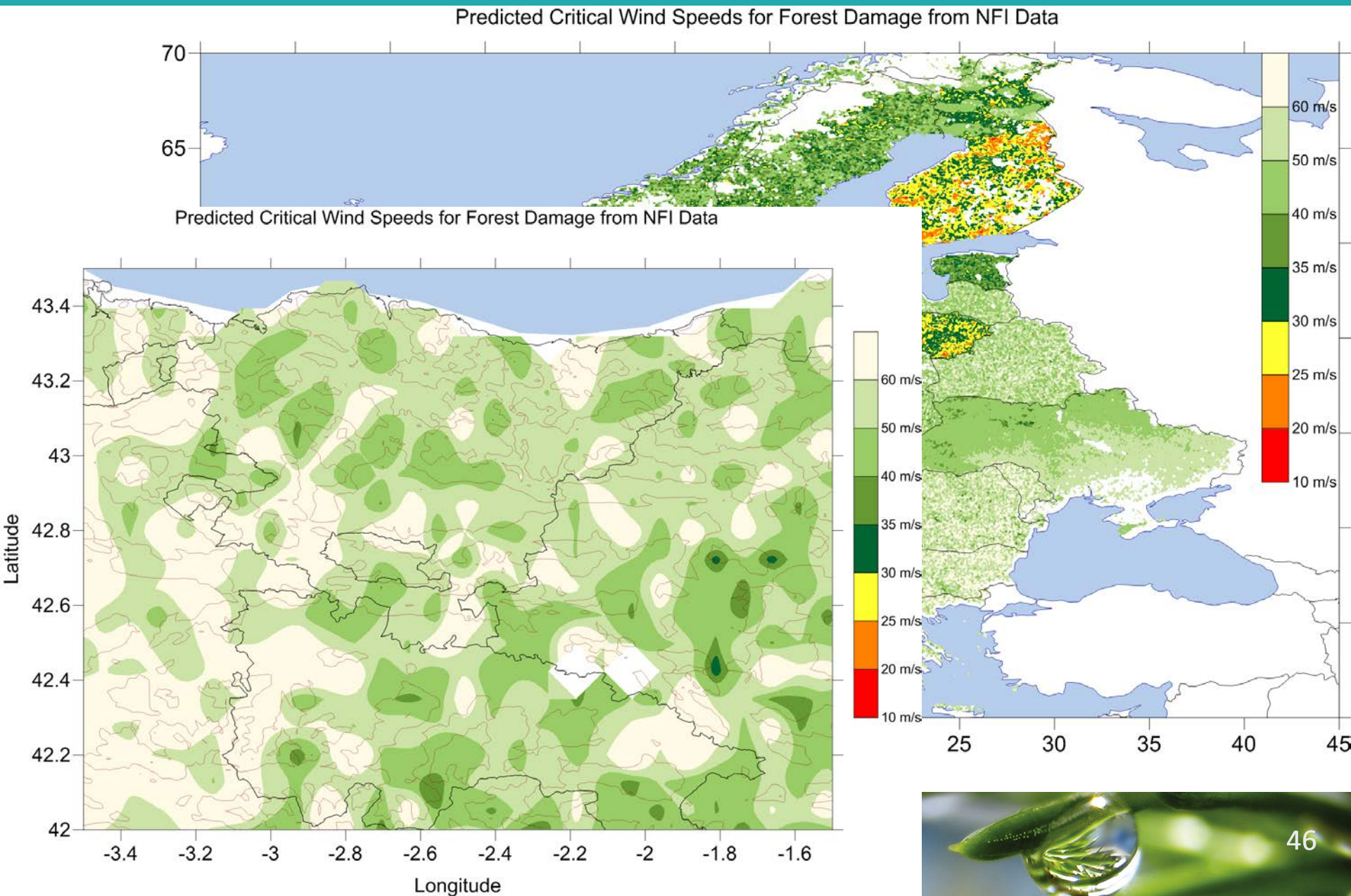
EFISCEN-Space: Forest Cover



Modelling Wind Risk at National/European Level



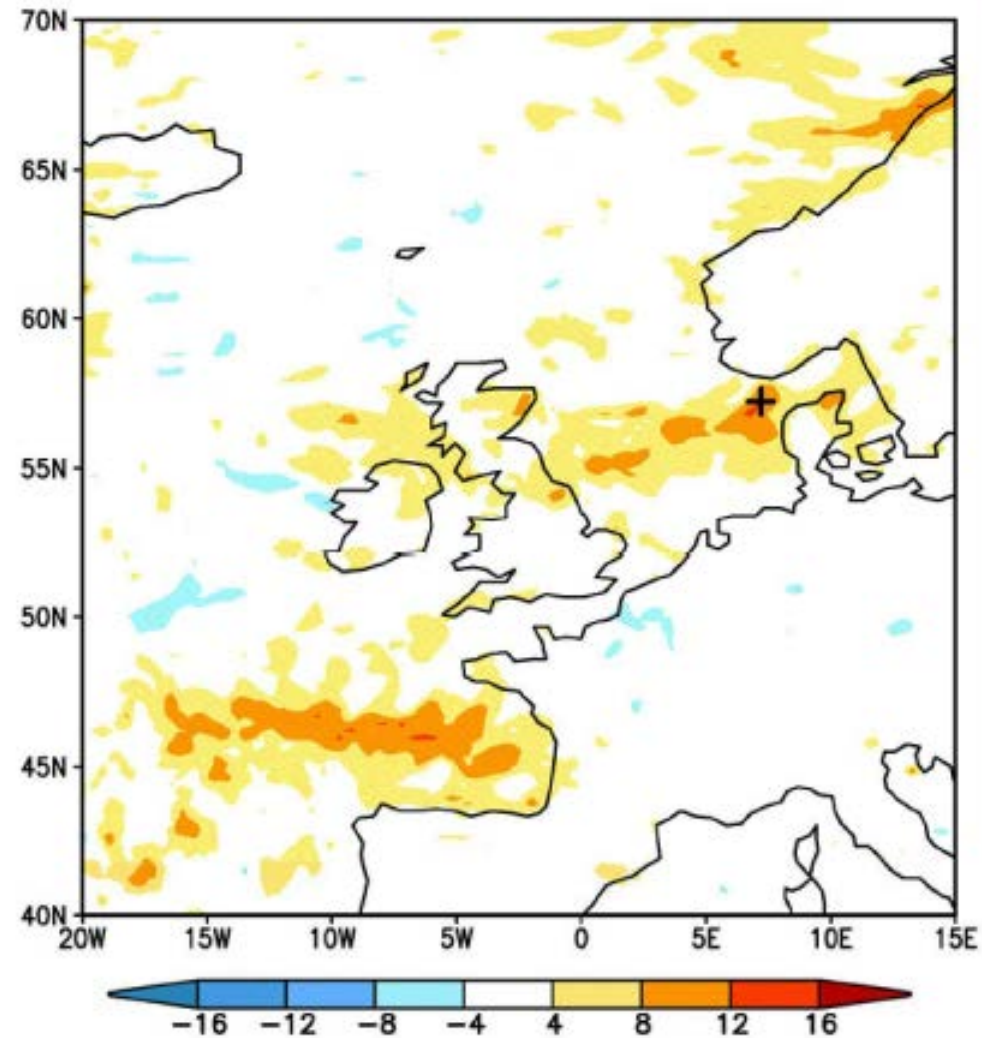
Modelling Wind Risk at National/European Level



Wind Risk in Changing Climate



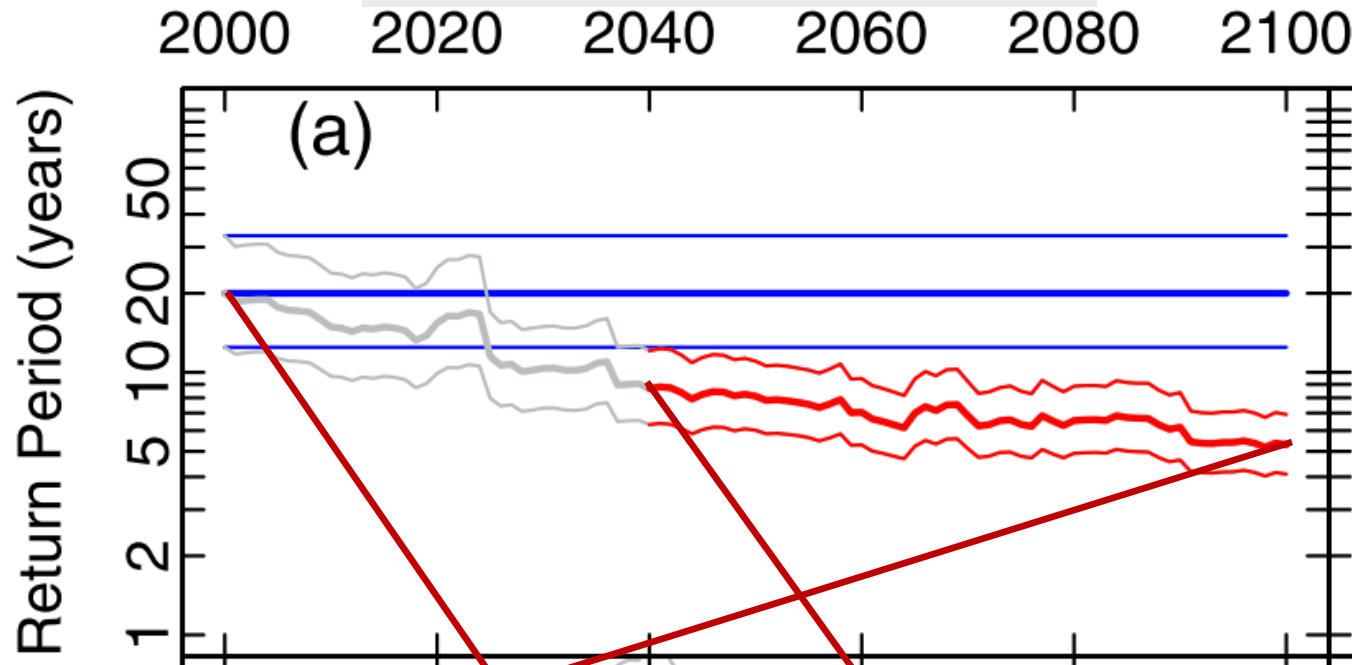
Wind speed change (m s^{-1})
for the period (Aug.-Oct.)



Haarsma et al, 2013. Geophysical Research Letters. Volume 40, Issue 9

Wind Risk in Changing Climate

Projected change to return period of strong storms in UK
(A1B scenario)

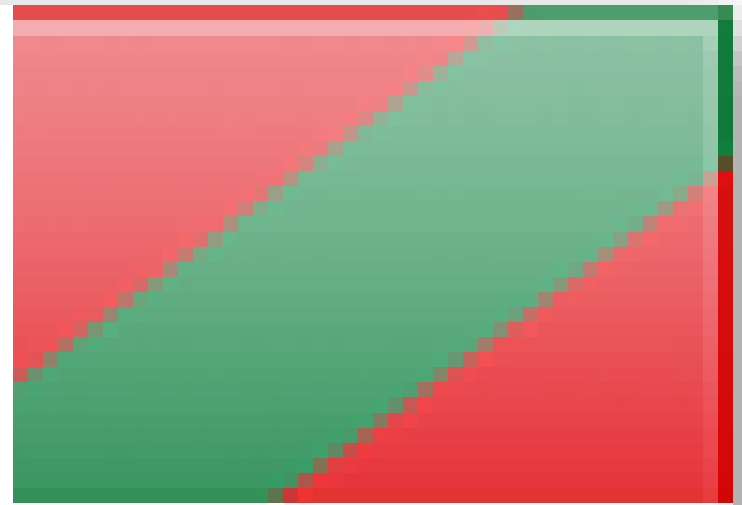
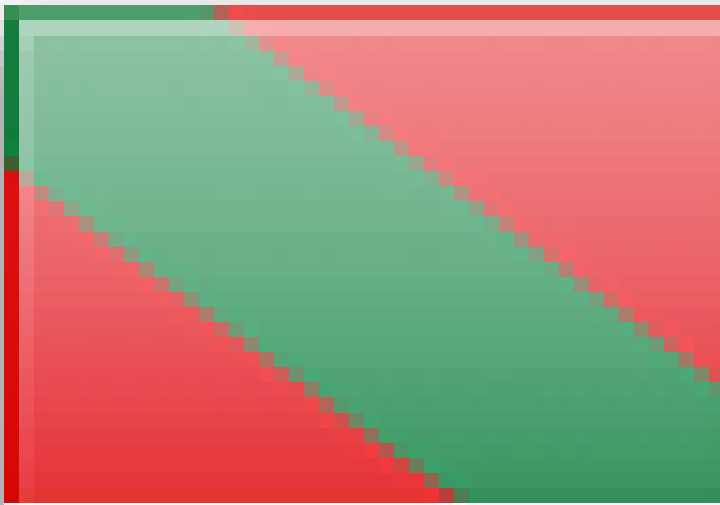


(Della-Marta & Pinto, Geophysical Research Letters Vol. 36, 2009).

Summary of Presentation

- Wind damage is the major disturbance in temperate and boreal forests
- Wind damage is increasing in direct correlation to the increase in European forest growing stock but also due to climatic change
- It is crucial to have a risk management plan and a risk mitigation plan as part of forest management
- Wind risk models are available for predicting the vulnerability of forests and new species are being added all the time
- LiDAR gives unprecedented levels of data as model input
- Possible to make initial predictions of forest vulnerability and risk at regional scale across Europe





Thank You

