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Implementing quantitative pest risk analyses in planted forest: the case study of the pine processionary moth

Régolini M., Dulaurent A.-M., Jacquet J.S., Meredieu C., Orazio C., Piou D., Samalens J.C., Jactel H.

→ **Climate change** and increase in **global trade** trigger new forest risks, especially biotic risks

- Higher intensity and frequency of pest outbreaks, expansion of their natural range
- Increasing introduction and establishment of invasive species



Raise concern for forest health & need to better evaluate risk in this changing world

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability} \times \text{Impact}$$

↙
Cause of damage
(windstorm, pest
insect)

↓
Susceptibility of tree
or stand to hazard

↘
Values at stake =
socioeconomic
impact of damage

→ To make a risk analysis we need to combine information about

- the likelihood of hazard (spatiotemporal dynamics of pest population)
- the level of tree/stand resistance to hazard
- the cost of damage

→ However such comprehensive risk analysis are rarely made due to a lack of knowledge or data

INTRODUCTION

→ Pine processionary moth (PPM) on maritime pine in South-West France as an example

- PPM is the main **pine defoliator** in the mediterranean Basin (including SW France).

Frequent defoliations (cyclic epidemics) are causing significant growth reduction (Jacquet J.-S., 2012), and **then economic losses** thus questioning the relevance of pesticide application (Gatto et al., 2008)

- **Well-studied insect** (more than 30 years of research)
- **Long-term monitored insect** by the Forest Health Department (since 1980)

➔ **Relevant case study for full risk analysis**

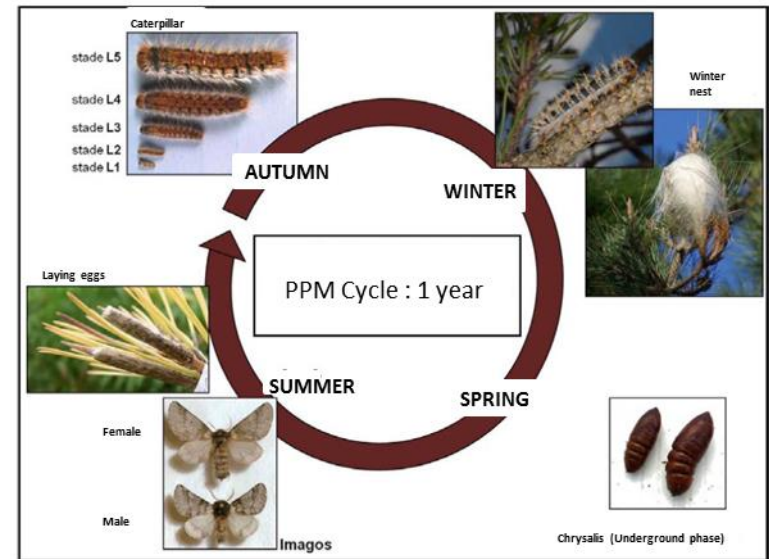


Figure by A.-M. Dulaurent, 2010



Photo By I. Van Halder



Hazard X Vulnerability X Impact



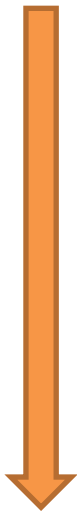
Based on past outbreaks records

Patterns of individual tree and stand level PPM infestation

Relationship between PPM defoliation and tree growth loss



Hazard X Vulnerability X Impact



Based on past outbreaks records



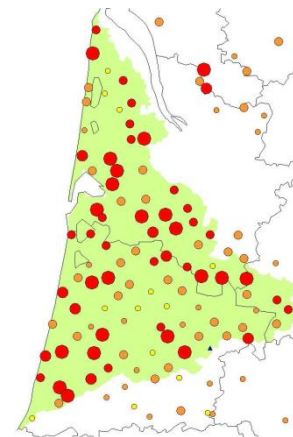
Patterns of individual tree and stand level PPM infestation



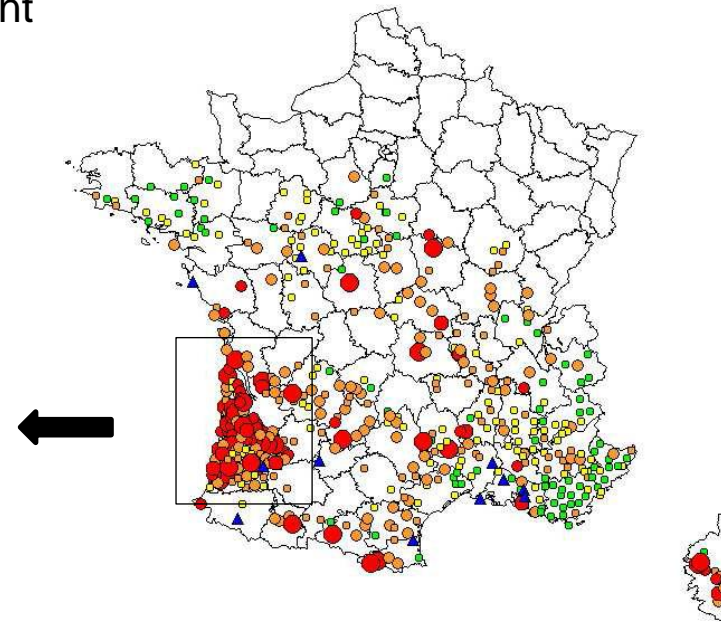
Relationship between PPM defoliation and tree growth loss



The temporal occurrence of PPM has been monitored for **the last 30 years** by the Forest Health Department using standardized protocol in permanent plots.

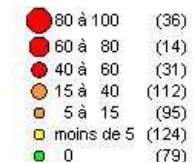


South-Western France



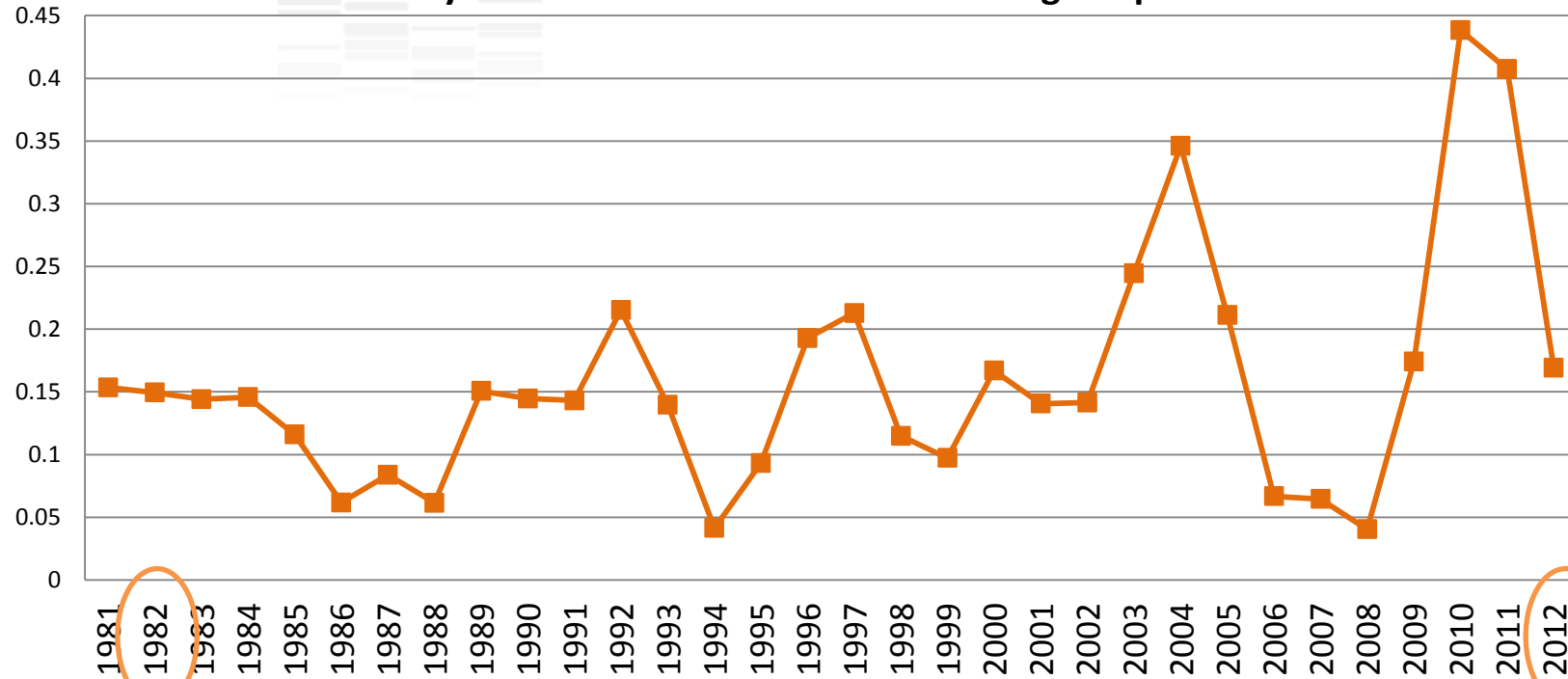
PPM network-Winter 2009-2010

Percentage of defoliated tree per plot



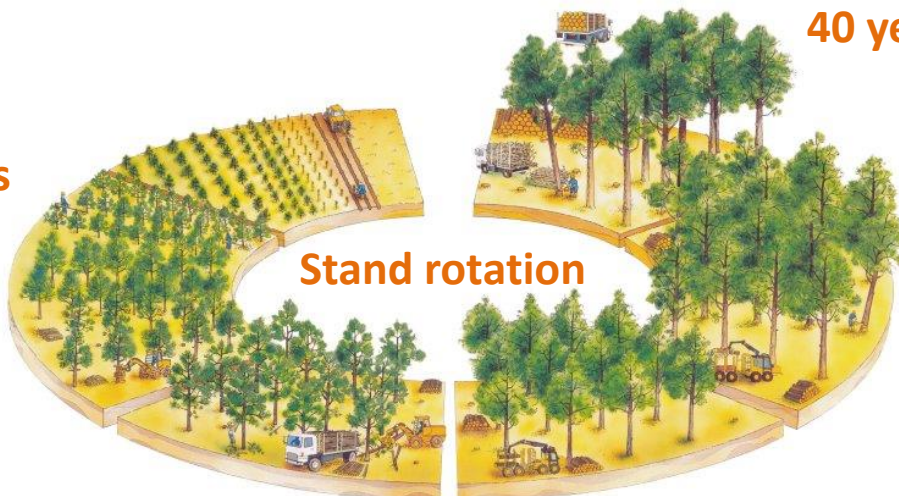
▲ Treatment against PPM

Outbreaks cycle of PPM in the Landes de Gascogne : percent of infested trees



10 years

40 years



PPM hazard : maritime pine trees can experience at least 5 PPM outbreaks before the final harvesting



Hazard X **Vulnerability** X Impact



Based on past outbreaks records

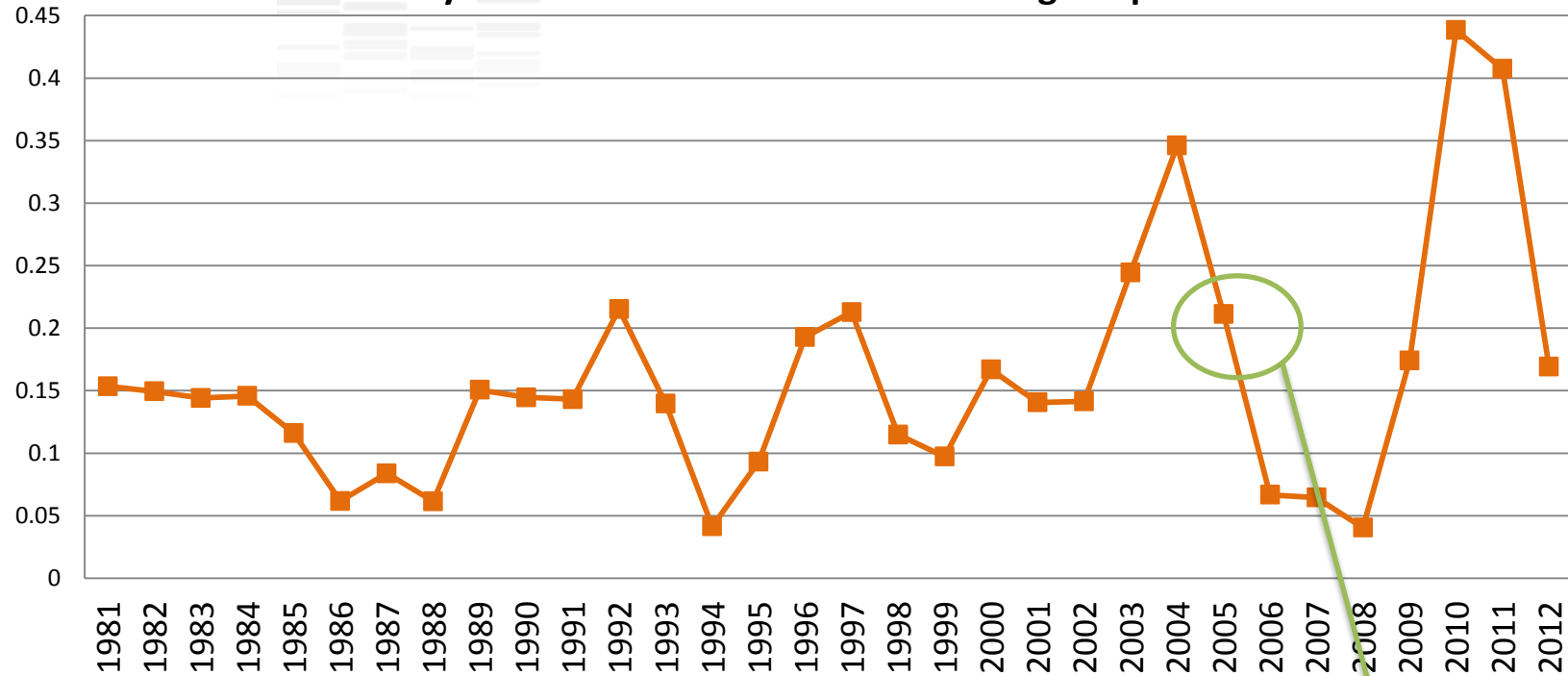


Patterns of individual tree and stand level PPM infestation



Relationship between PPM defoliation and tree growth loss

Outbreaks cycle of PPM in the Landes de Gascogne : percent of infested trees

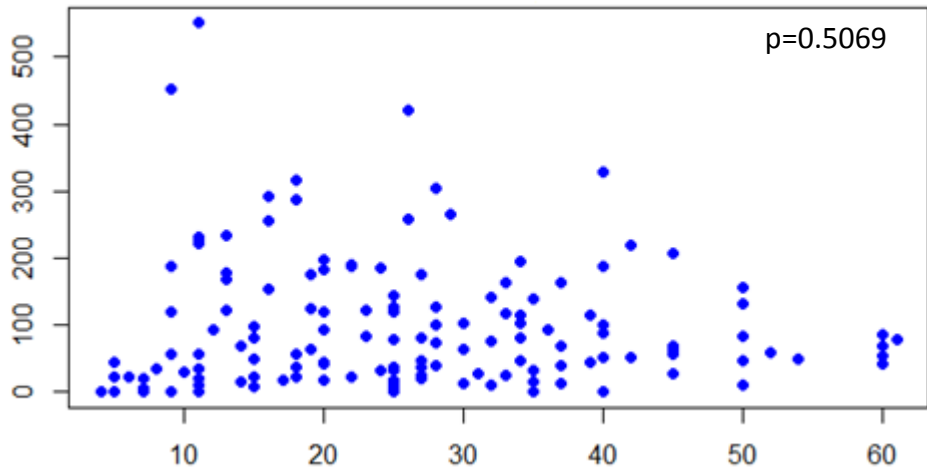


2005 : year of our study

→ Age

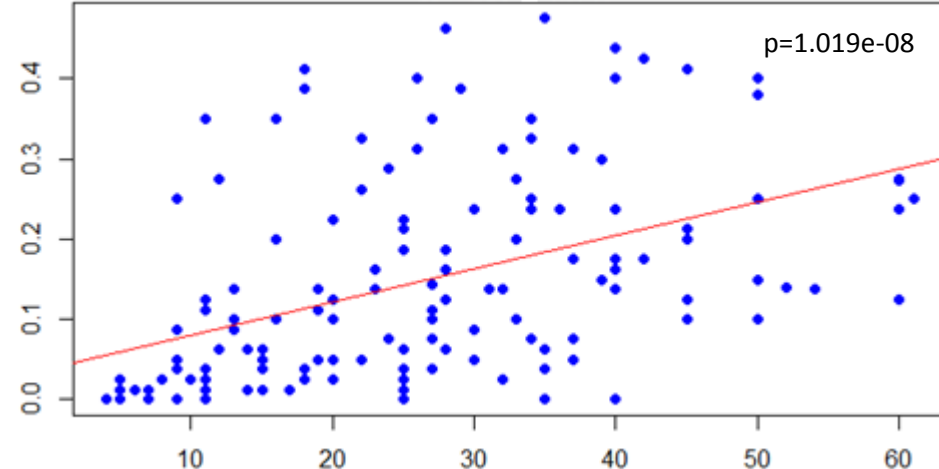


PPM population density = number of nests.ha-1



Stand age in 2005

Percentage of infested trees

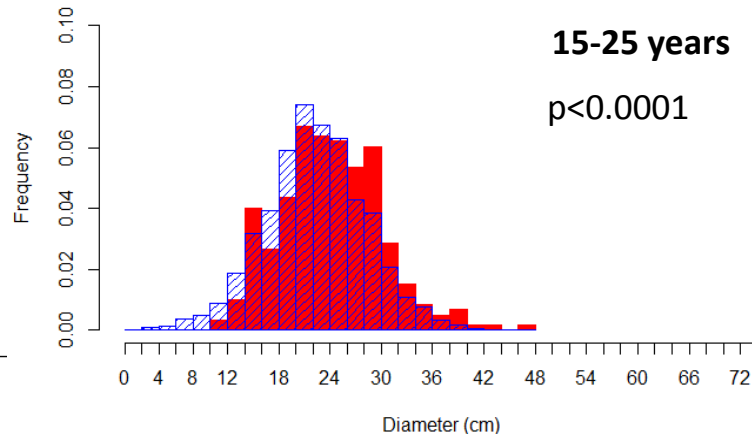
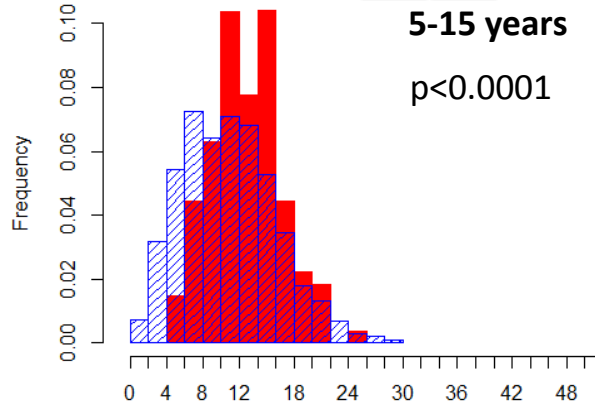


Stand age in 2005

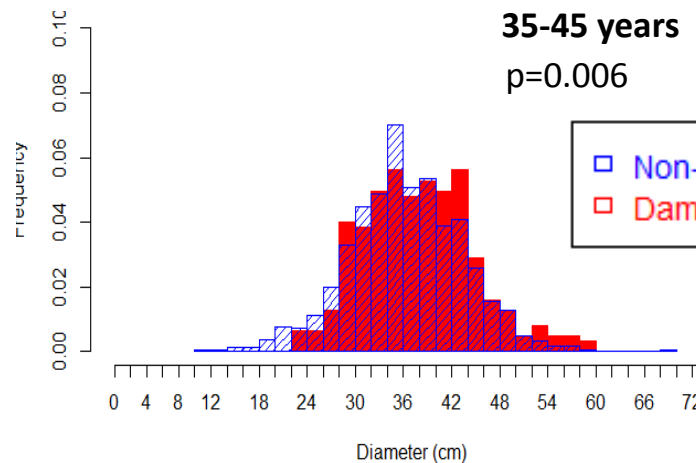
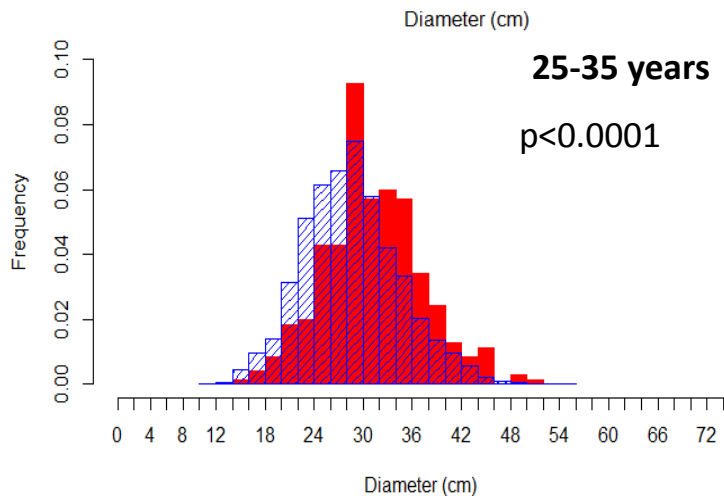
Population density remains constant irrespective of stand age.
 Percentage of infested trees increases with stand age due to lower tree density in older stands

→ Age X Size

(data from thesis : J.-C. Samalens, 2009 and A.-M. Dulaurent, 2010)



Frequency distribution of tree diameters for infested vs. non-infested maritime pine trees by PPM for 4 classes of stand age (Kolmogorov Smirnov test)



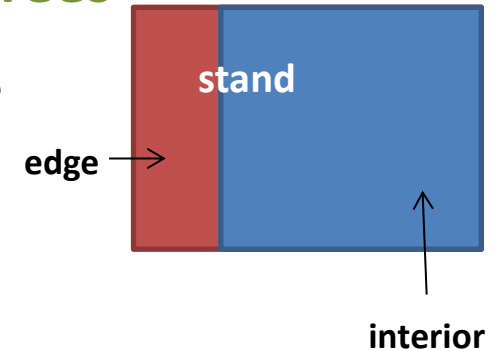
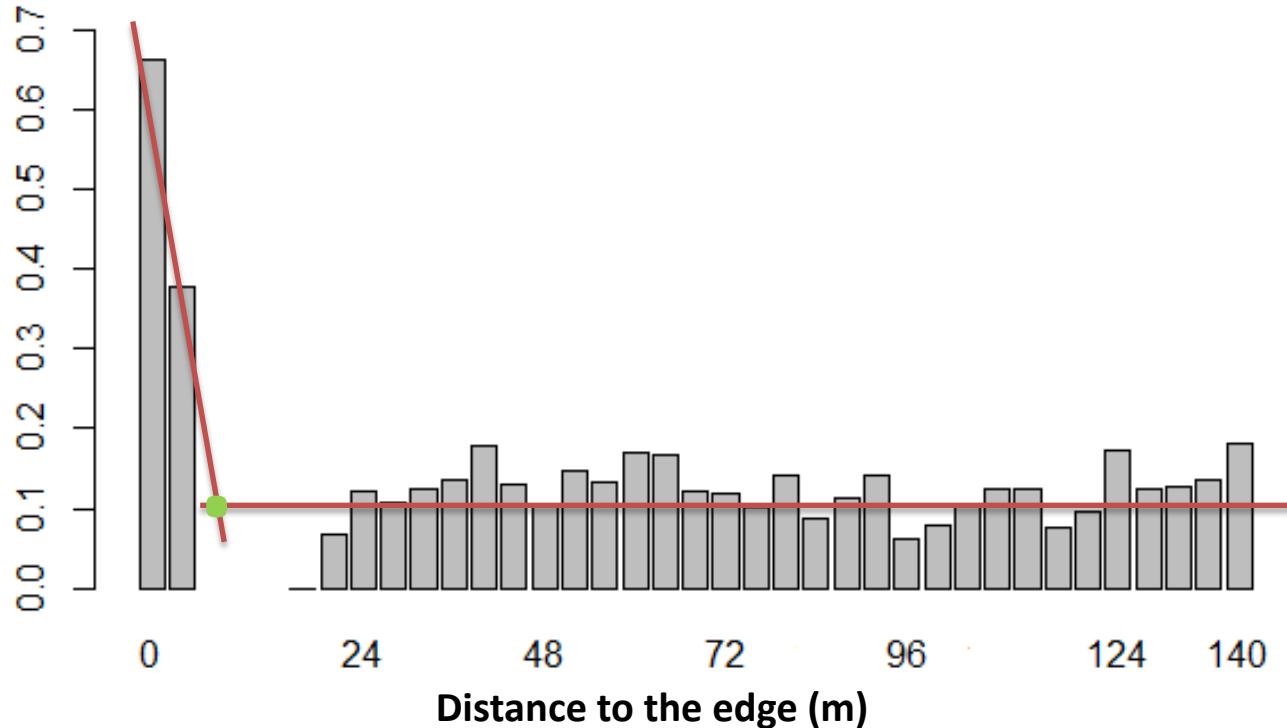
□ Non-damaged trees (no nest)
□ Damaged trees (at least one nest)



Taller trees are more likely to be infested by PPM regardless of their age

→ Tree location in the stand : edge vs. interior trees

Average number of nests per tree depending on tree distance to the edge

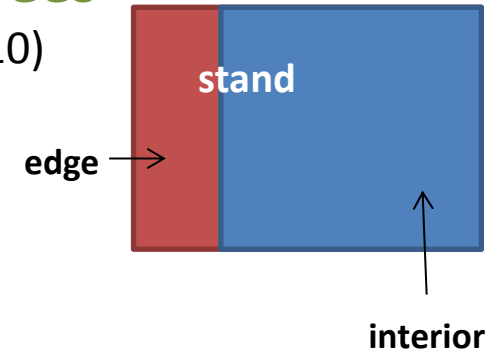
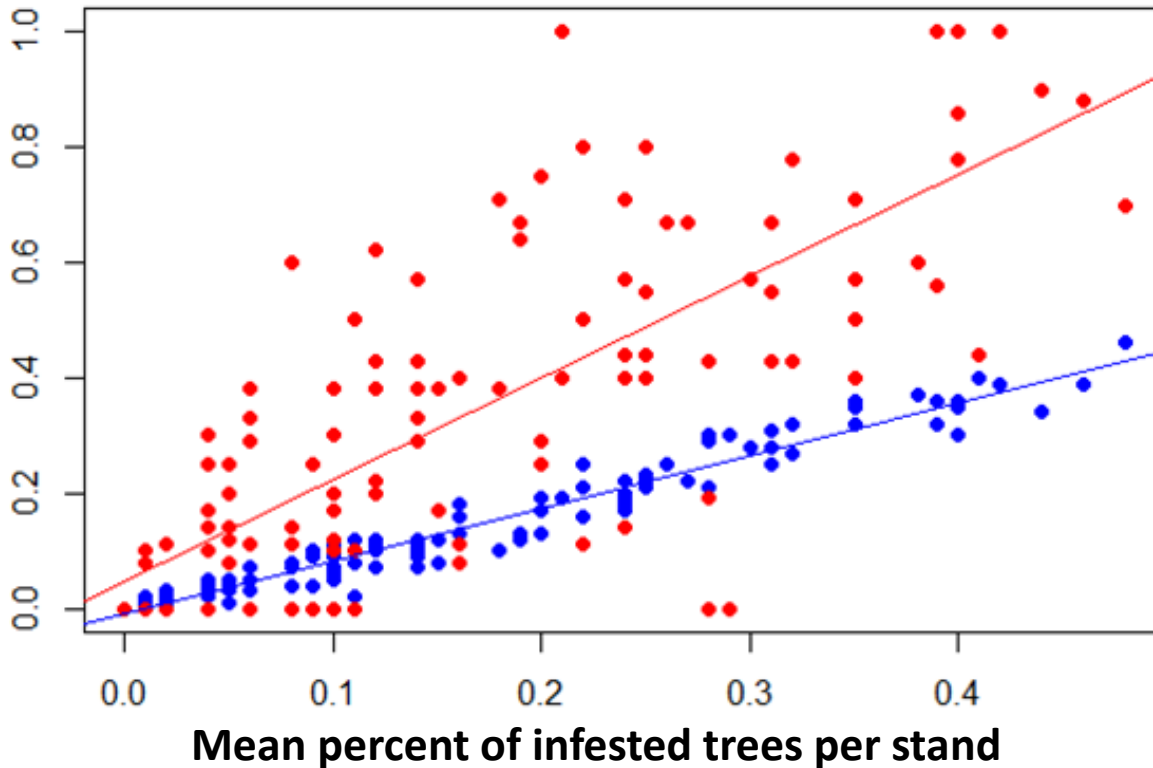


Breakpoint = 7.55 ± 0.55 m demonstrating an edge effect ending after the 2nd row

→ Tree location in the stand : edge vs. interior trees

(data from thesis : J.-C. Samalens, 2009 and A.-M. Dulaurent, 2010)

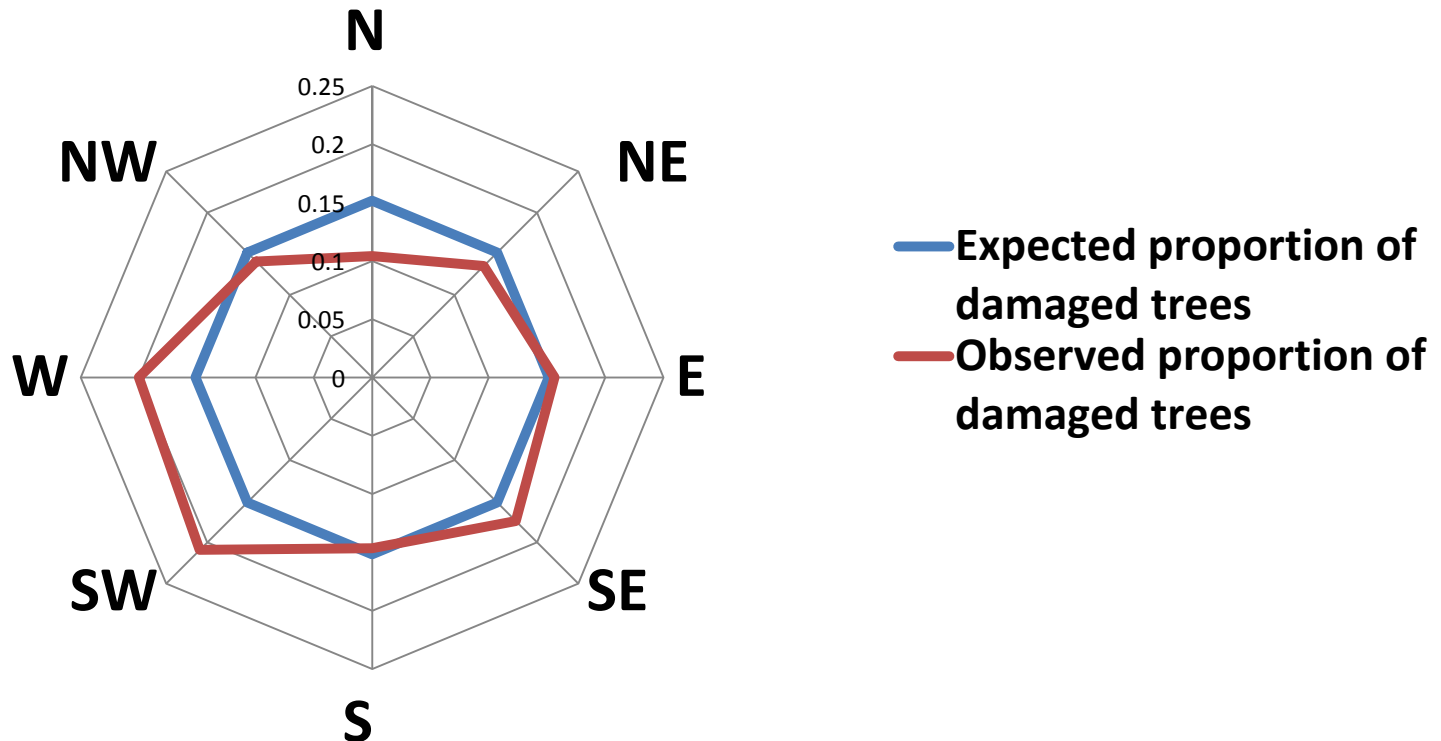
Relationship between mean stand percent of infested trees and interior and edge percent of infested trees



→ Tree location in the stand : edge aspect

(data from thesis : J.-C. Samalens, 2009 and A.-M. Dulaurent, 2010)

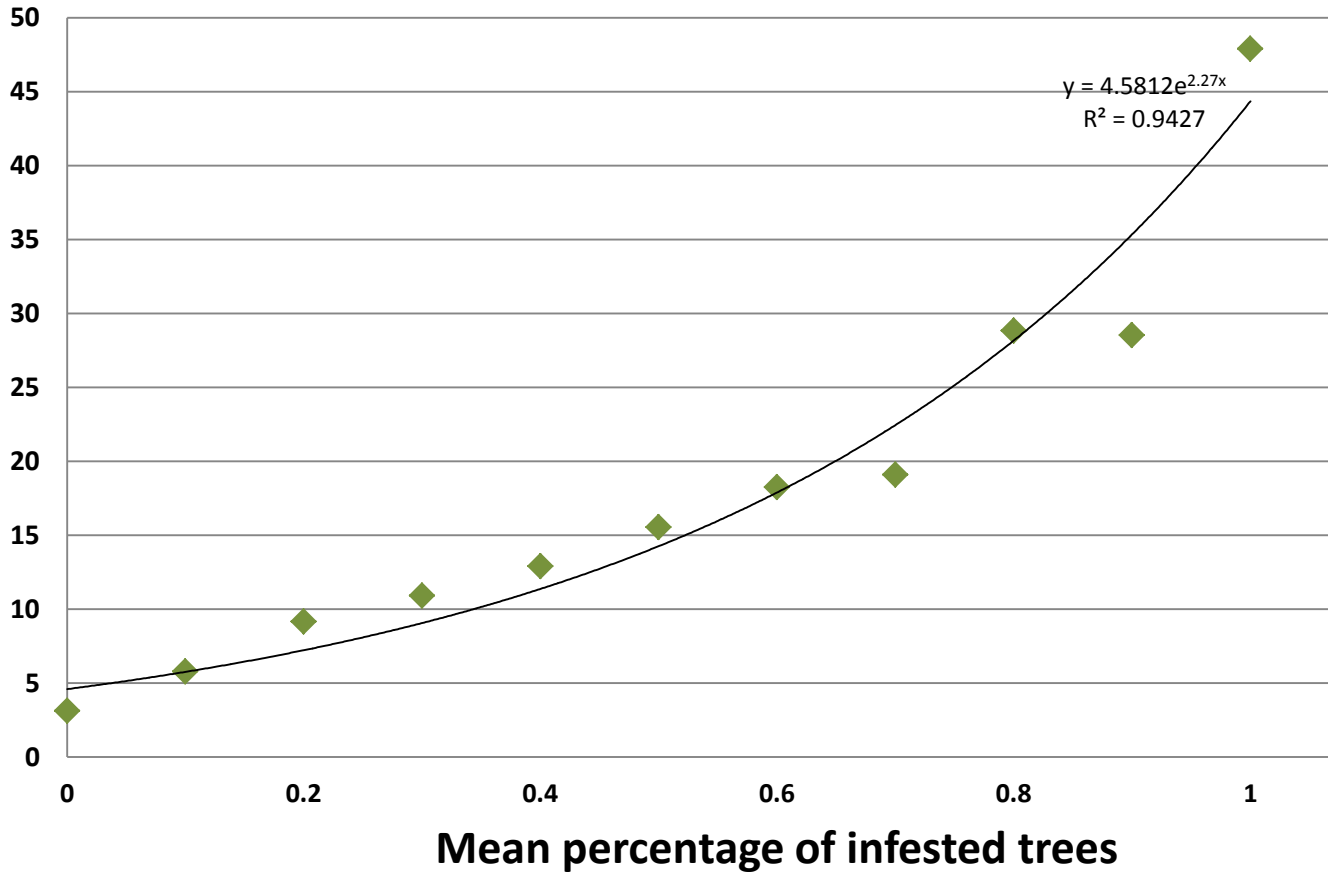
Effects of stand edge aspect on PP moth infestation



Stands facing West and South-West are significantly more infested

→ Relationship between **infestation** and **defoliation**

Relationship between % defoliation and mean percentage of infested trees



Hazard X Vulnerability X **Impact**



Based on past outbreaks records



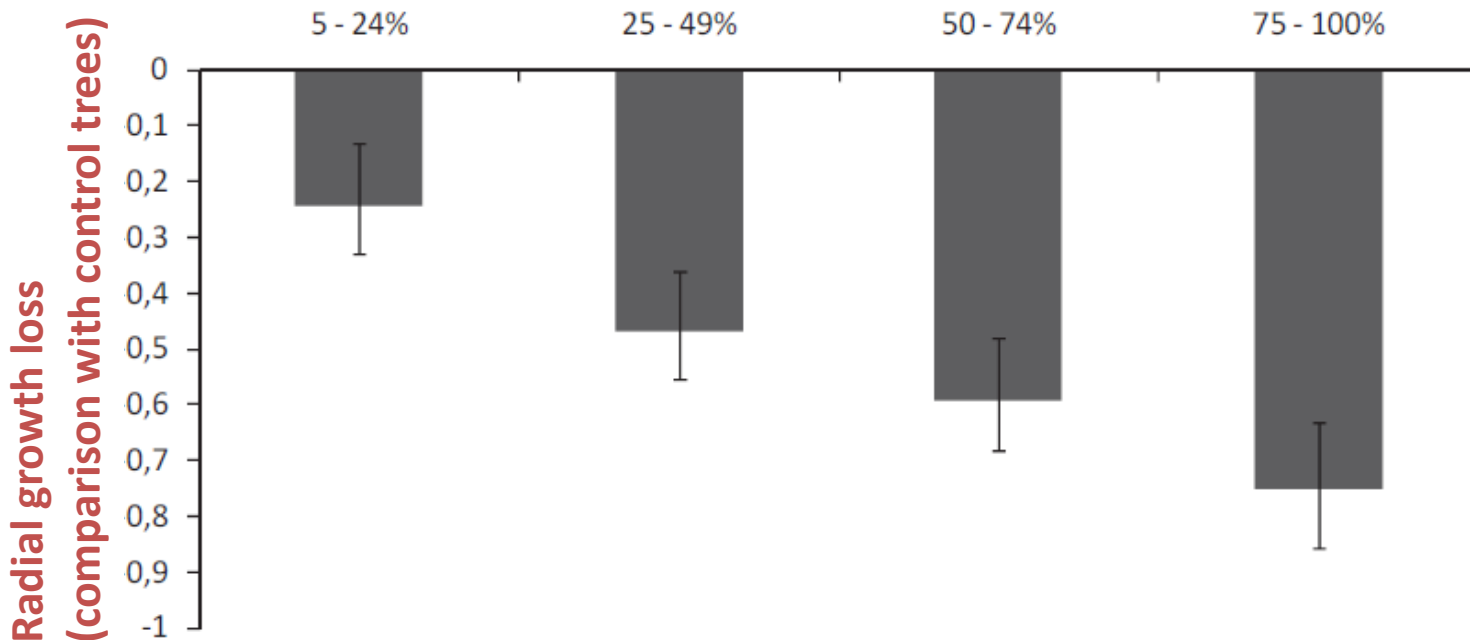
Patterns of individual tree and stand level PPM infestation



Relationship between PPM defoliation and tree growth loss

Impact resulting from PPM defoliation

Defoliation intensity



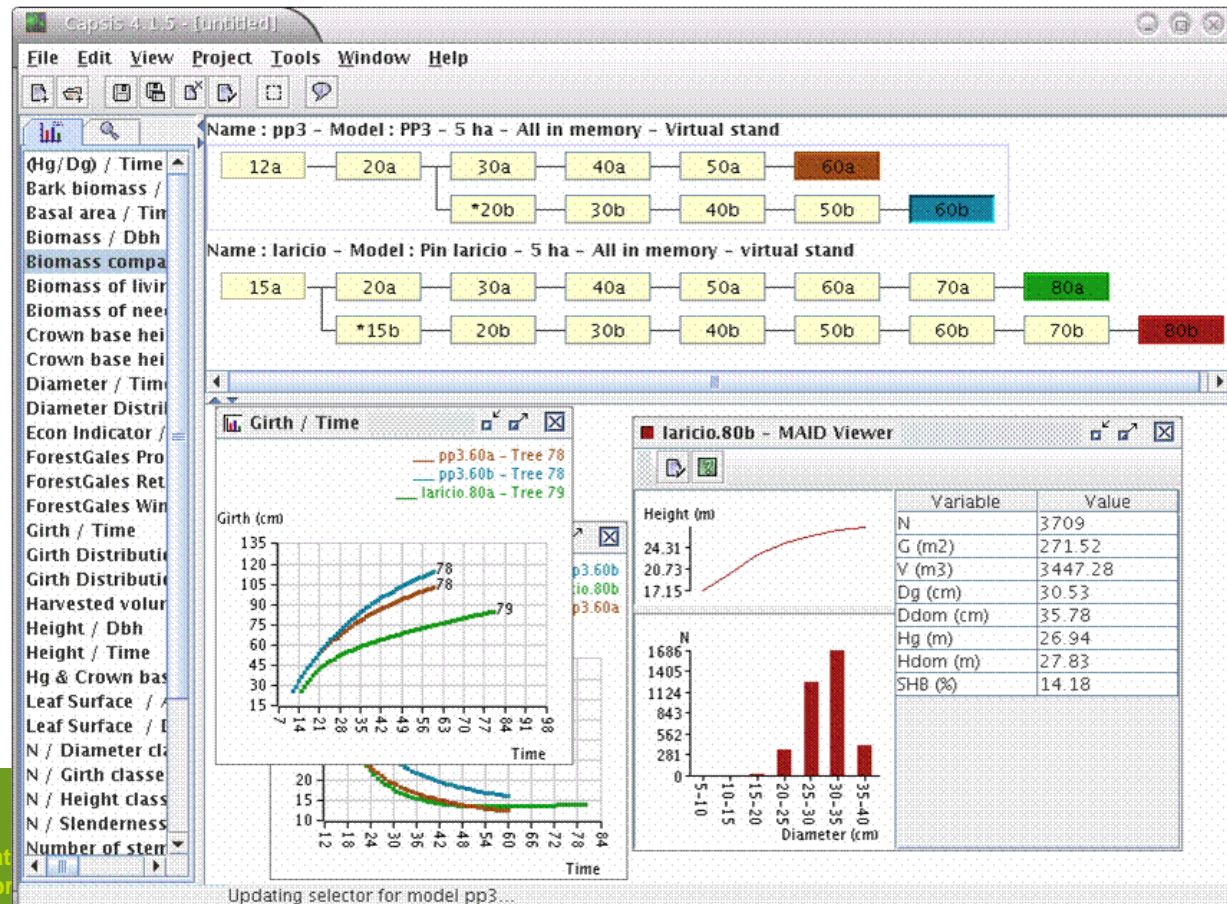
PPM impact :
Tree growth loss increases linearly with increasing defoliation intensity

Meta-analysis of defoliation intensity resulting from *Thaumetopoea pityocampa* on maritime pine growth loss (Figure by J.-S. Jacquet, 2012)

→ To summarize, the probability of a tree to be more or less defoliated depends on : **tree age, tree size, location in the stand and stand aspect.**

→ We need to integrate this information in an **individual-centered tree growth model.**

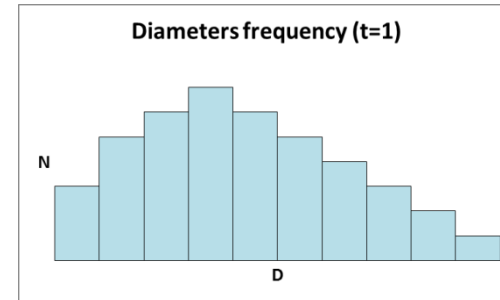
→ **PP3 is an empirical individual-centered tree growth model** available for monospecific and even-aged stands of maritime pine of South-West France



t=1

Theoretical (or real) initial stand

Initial stand: Age ≥ 7 years, density, G, Hdom



PP3 \rightarrow Empirical tree growth model for Maritime pine calibrated on undamaged, healthy stand and trees

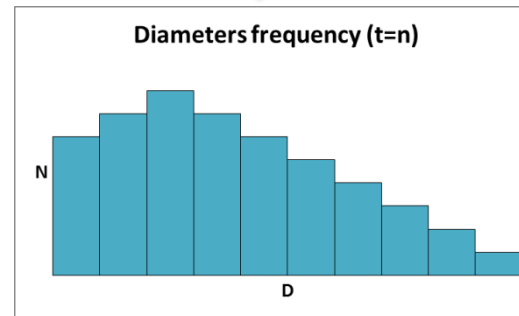
Silvicultural practices : thinnings

$$D_{\text{year}2} = D_{\text{year}1} + \Delta D t$$

t=n

Final stand: density, G, Hdom

Theoretical final stand



t=1

Theoretical (or real) initial stand

Initial stand: Age \geq 7 years, density, G, Hdom

Edge: yes-no \rightarrow Edge depth
Aspect : N, S, E, W...

7-year cycles of PPM infestations : % of infested tree, defoliation for each year

Initial edge part

Initial interior part

Higher level of infestation

Bigger trees infested in priority

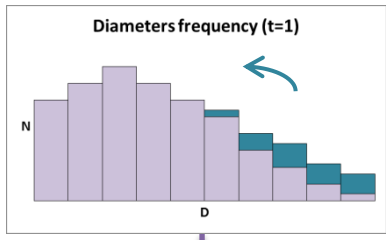
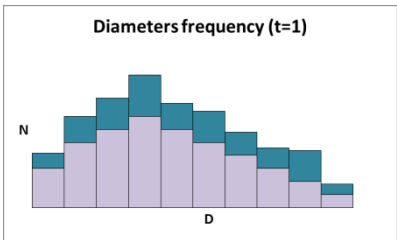
Silvicultural practices : thinnings

Final edge

Final interior

Final stand: density, G, Hdom

Final stand : exposed to PPM defoliation

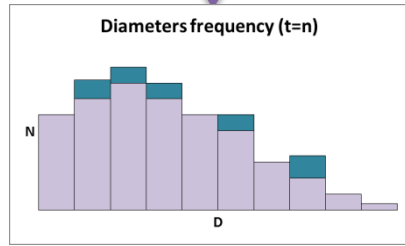
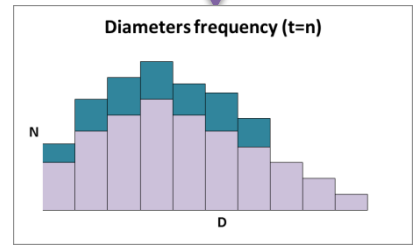


$$D_{year2} = D_{year1} + \Delta Dt$$

$$D_{year2} = D_{year1} + \Delta Dt$$

$$D_{year2} = D_{year1} + \Delta Dt - \text{growth loss}$$

$$D_{year2} = D_{year1} + \Delta Dt - \text{growth loss}$$



t=n

Conclusion

Full risk analysis



Tree growth model



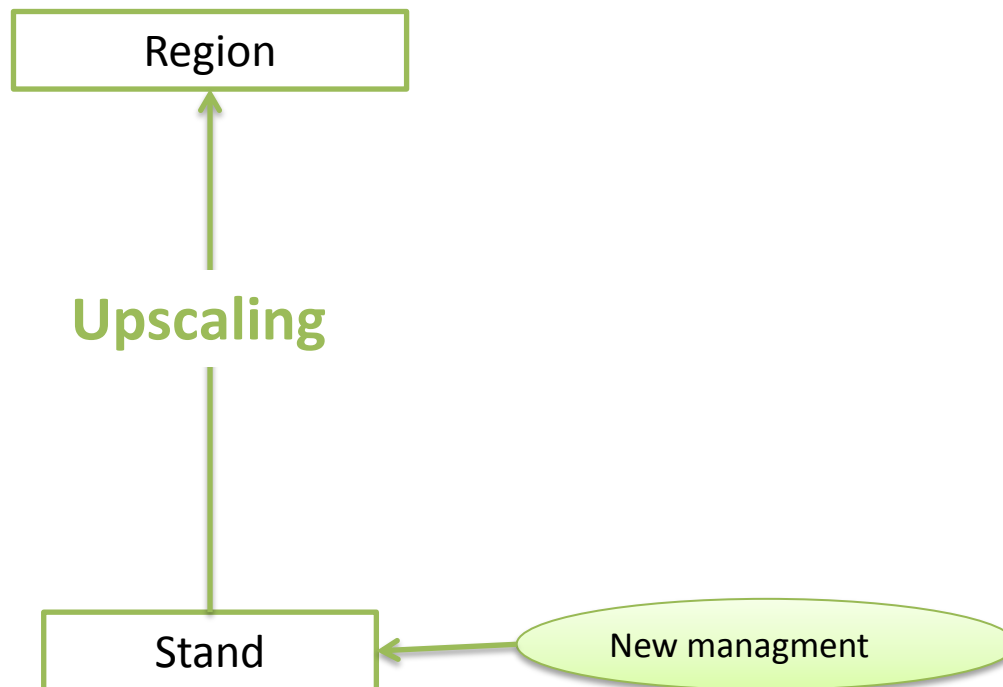
Pest population dynamics

Stand susceptibility to pest

Tree response to pest damage

Use the modeling tool to perform risk analyses for two important issues:

- The effect of new planted forest management strategies
- Assessment of risk at the regional level



Thank you !



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