Production-Biodiversity Tradeoff :

An integrated modeling approach based on uneven-aged mountain forests.

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Ecosystem services in forests

- **Forests provide numerous services**

  - Production, carbon storage, recreation…

  - Protection against natural hazards

  - Biodiversity conservation

- **Timber production – biodiversity trade-off**

  - Forest management affects biodiversity (Paillet et al.2010)

  - Due to negative impacts on natural attributes

    (Lassauce et al. 2011; Müller et al. 2008; Vuidot et al. 2011 …)

  - Getting worst / increasing management intensity ?

Improving biodiversity conservation

- **Protected areas**

- **Retention of natural attributes favorable to biodiversity**

  - Deadwood (Bauhus et al. 2009; Lassauce et al. 2011; Müller et Butler 2010)

    => 25% of forest species (Stockland et al. (2004)

  - Very large and old trees => micro-habitats

    (Bauhus et al. 2009; Fan et al. 2003; Larrieu et Cabanettes 2012; Vuidot et al. 2011)

- **Promote stand heterogeneity**

  (Bauhus et al. 2009; Boncina 2011; Gamborg et Larsen 2003; O'Hara et Gersonde 2004)

  - Species diversity

  - Structure diversity

  - ➢ **Mixed & uneven-aged forests**

  - ➢ **Group selection practices**

    (Cordonnier et al. 2008)

Objectives

- **Assess the response of <u>timber production</u> and <u>biodiversity conservation</u>**

    - To uneven-aged management drivers

    - In mixed spruce-fir forests of the western Alps (France)

- **Especially, assess the impact of :**

    - Harvesting / thinning intensity

    - Retention of natural attributes

    - Group selection practices

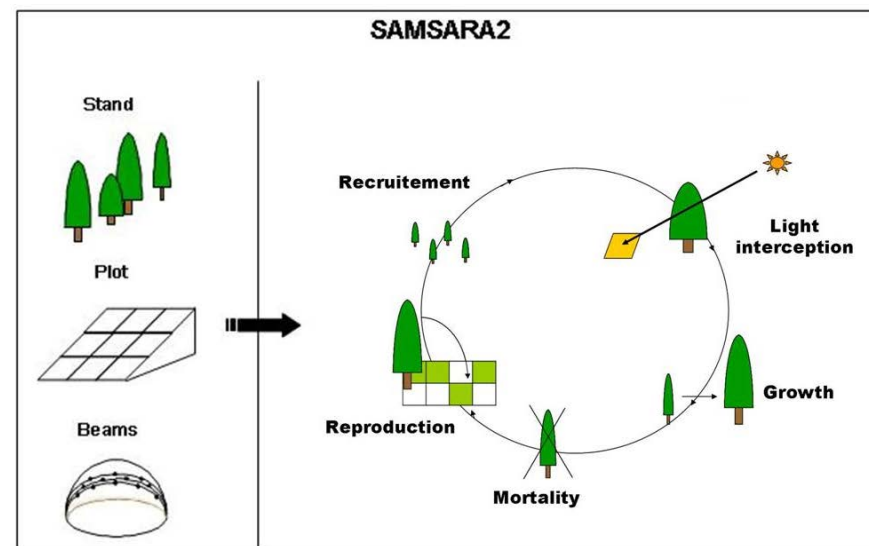- **Using a simulation approach**

Repetition of the cycle

Date t = 0   t + 10 years

Initial state   **Natural dynamics (Samsara2)**   **Silviculture algorithm**
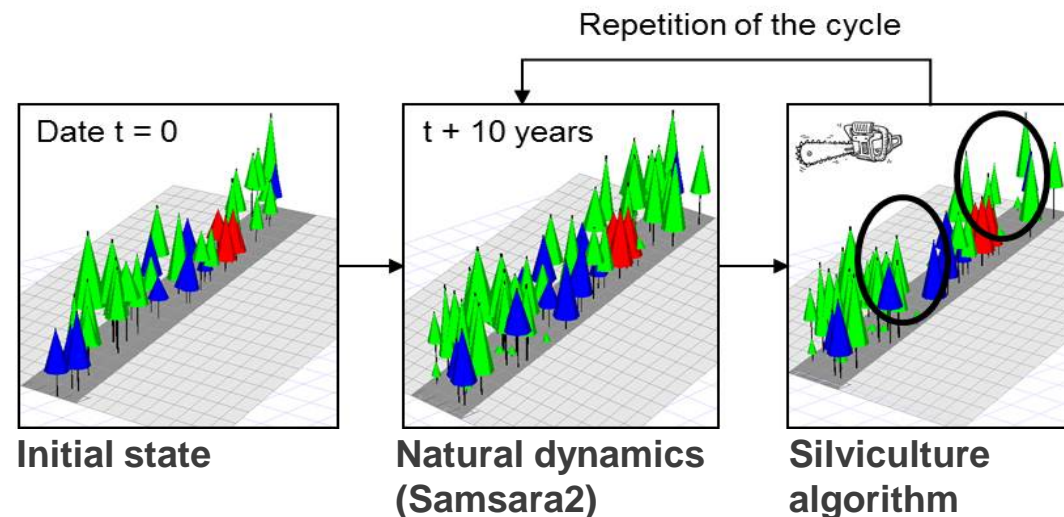
Simulation framework

Model : Samsara2
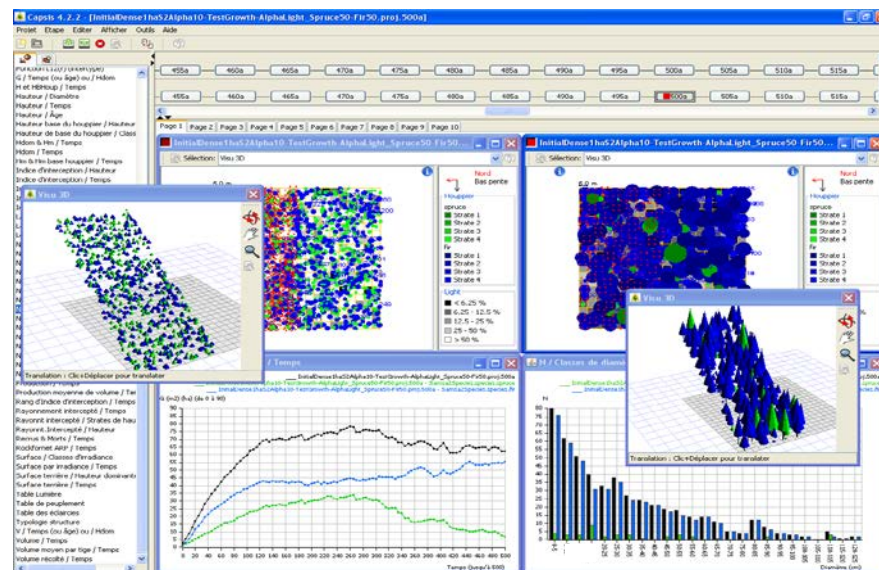
- Individual-based

- Spatially explicit

- Competition for light

  Courbaud et al. (2003) Agri For Meteo 116:1-18

- Spruce-fir (-beech)

➤ Courbaud et al. (2001) For Ecol Manage 145:15-28

Platform : Capsis4 (de Coligny 2005, 2007)

Capsis4

Capsis
Computer-aided projection of strategies in silviculture

➤ Dufour-Kowalski et al. (2012) Ann.For.Sci 69:221-233

Methodological framework

Lafond et al. (2014) Ann For Sci 71:173-186

Input parameters
- Silvicultural parameters
- Initial state
- Demographic parameters

Silviculture algorithm

Dynamics model (Samsara2)

Biodiversity models

Zilliox & Gosselin 2013

Holeksa et al. 2008

Output variables
- Timber production : volume, size & quality
- Structure & composition
- Biodiversity : dead wood & floristic diversity

Basal Area (m²/ha)

Time (years)

Sensitivity analysis : effects of variations of input parameters on response variables ?

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Methodological framework

Experiment design
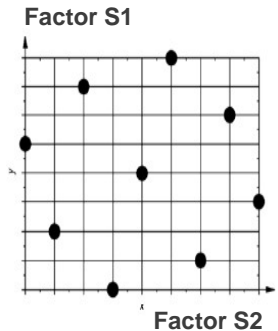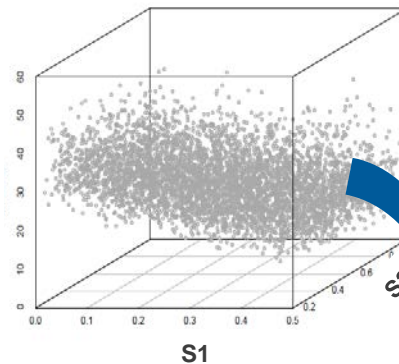
Factor S1

Factor S2

**OA-LHS plan
(5,000 unique combinations)**

**MODEL
SIMULATIONS**

Model output
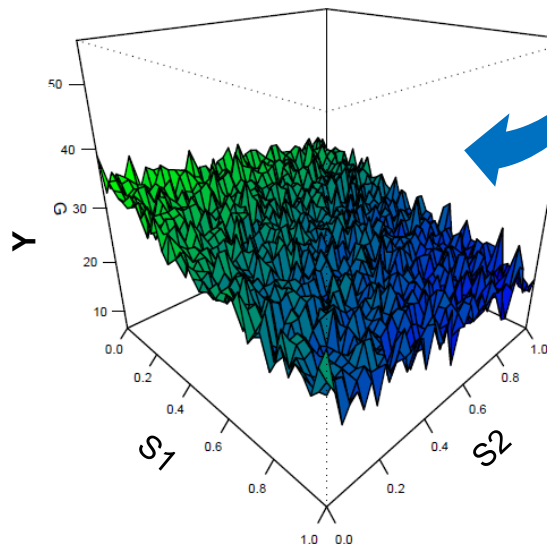
BUILDING METAMODEL

Multiple linear regression on the input factors

$Y = f (S1, S2, S3…Sn, D1, D2, IS1, IS2, IS3)$

Silviculture **Demography** **Initial State**

Metamodel

Effect of demography ?

Growth -

**Fixing
all other factors
(mean value)**
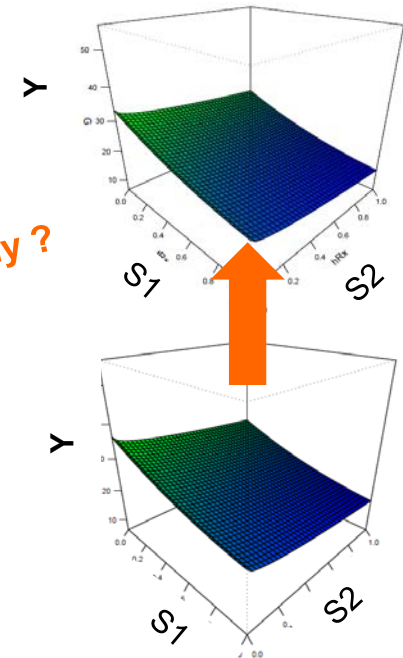
Sensitivity analysis

- **Sensitivity analysis indices**
    - Identification of key parameters
    - SRC = Standardized Regression Coefficients

METAMODEL

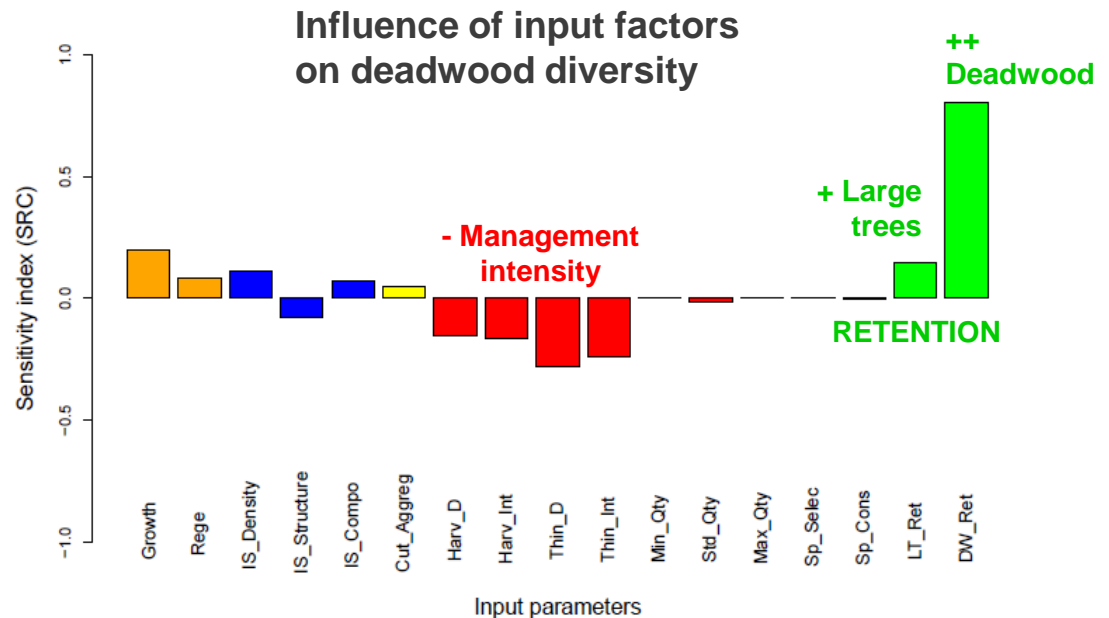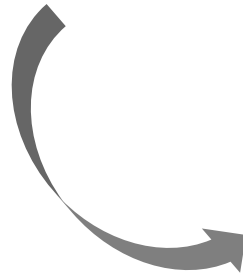$$Y = f (S1, S2, S3…Sn, D1, D2, IS1, IS2, IS3)$$

Influence of input factors on deadwood diversity

- Demography
- Initial State
- Spatial aggregation
- Intensity
- Biodiversity

➤ Lafond et al. *subm*. Environ Manag

Results

- **Sensitivity analysis results**

Management Drivers ↓	Biodiversity => diversity of:				Production	
	Dead wood	Tree size	Tree sp.	Understory sp.	Timber Vol.	Timber quality
Intensity	-	-	-	-	(-/+)	+
Gap size	(+)	++	-	-	(-)	
Large trees	+	++	(+)	(+)	(-)	-
Dead wood	++				-	++
Minor sp.			++	+		

- Increasing harvesting intensity

+ Retention measures

- **Indicators with opposed response**

  =>Trade-off ?

- **Factors with opposed effects**

  => Compensation ?

➢ Lafond et al. *subm*. Environ Manag

Results

- **Looking for compensation between management factors**

Management Drivers ↓	Biodiversity => diversity of:				Production	
	Dead wood	Tree size	Tree sp.	Understory sp.	Timber Vol.	Timber quality
Intensity	-	-	-	-	(-/+)	+
Gap size	(+)	++				
Large trees	+	++	(+)	(+)	(-)	-
Dead wood	++				-	++
Minor sp.			++	+		

Tree size diversity

> Lafond et al. *subm*. Environ Manag

Results

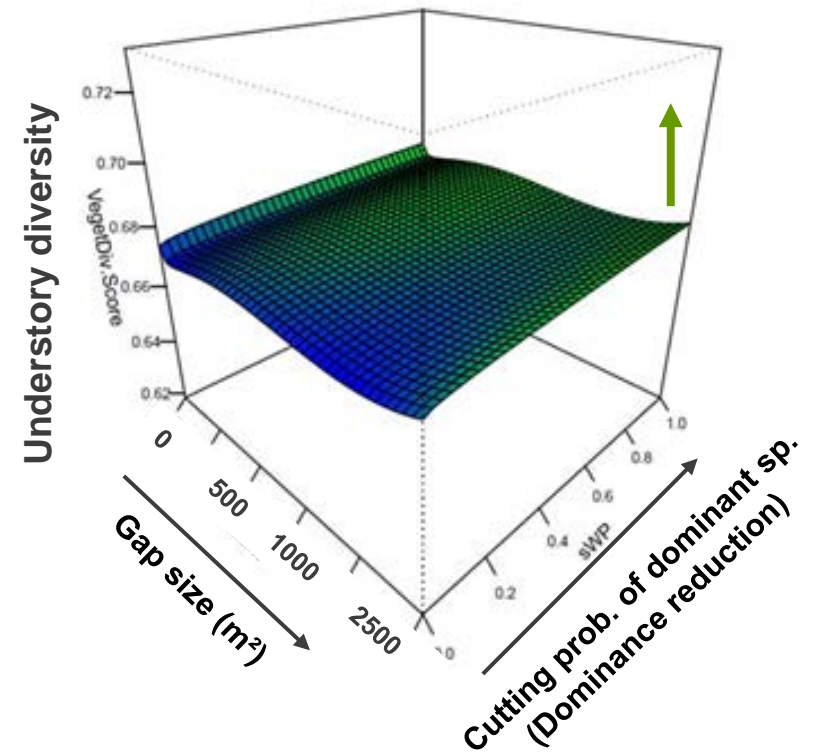- **Impact of gap creation & sensitivity to demographic factors**

High regeneration level
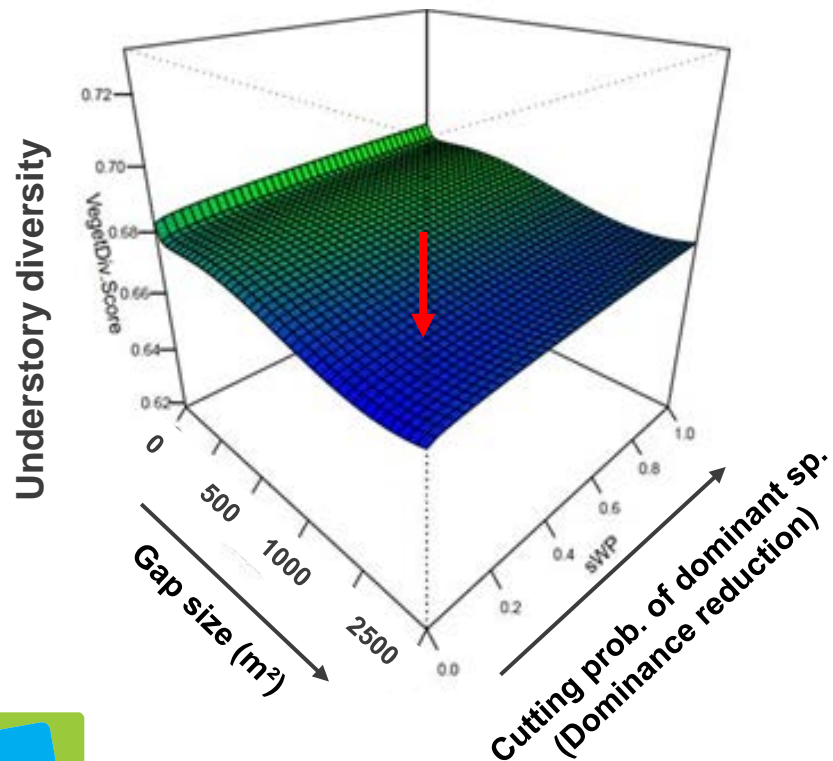
Low regeneration level

Conclusion

- **Impact of uneven-aged management factors ?**

  - ↑ Management intensity ↓ biodiversity

  - Compensated by retention measures (LT, DW)

  - Contrasted effects of gap creation

    ↑ Stand structure & deadwood diversity

    ↓ Tree and understory diversity

    & Sensitive to demographic factors (regeneration) !

- **Trade-offs between Ecosystem Services ?**

  - Production *vs* Biodiversity

    - e.g. Timber Volume *vs* Deadwood Diversity

  - Within a same ES ?

    - e.g. Structure *vs* Species Diversity (gap creation)

Thank you for your attention !