Evaluation of the effect of accessibility on forest stand structure with airborne laser scanning data and GIS-based models

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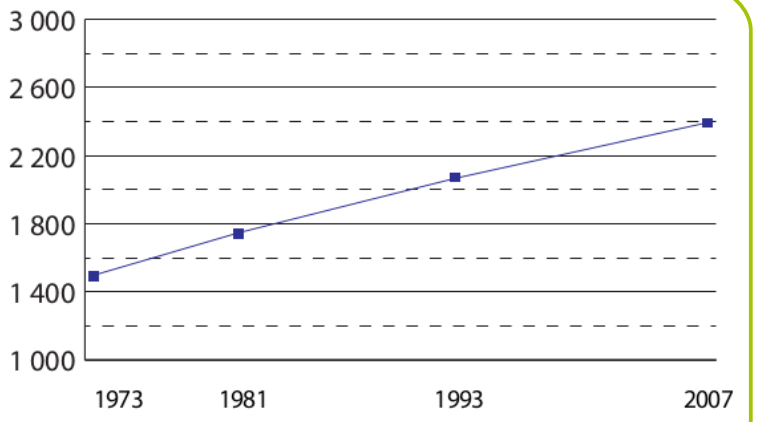
French context



Standing volume (x1000 m3) in France (source : l'IF #27)

National objectives for better wood mobilization

- National level statistics show that standing volume is increasing...
- ...but no operational-level mapping of forest resources.
- Harvesting in mountainous areas is not always technically or economically possible, particularly because of accessibility constraints.

→ Increased objectives might result in increased pressure on same areas ?

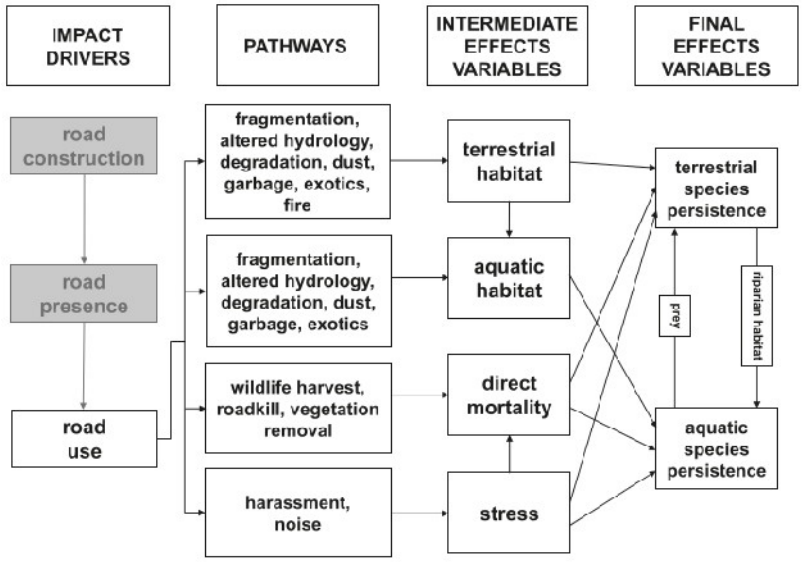
Hypothesis: harvesting intensity is driven by accessibility

Scientific context

Forest accessibility and forest

- Ecological effects of road network

(Spellerberg 1998, Trombulak & Frissel 2000, Coffin 2007, Robinson *et al.* 2010).

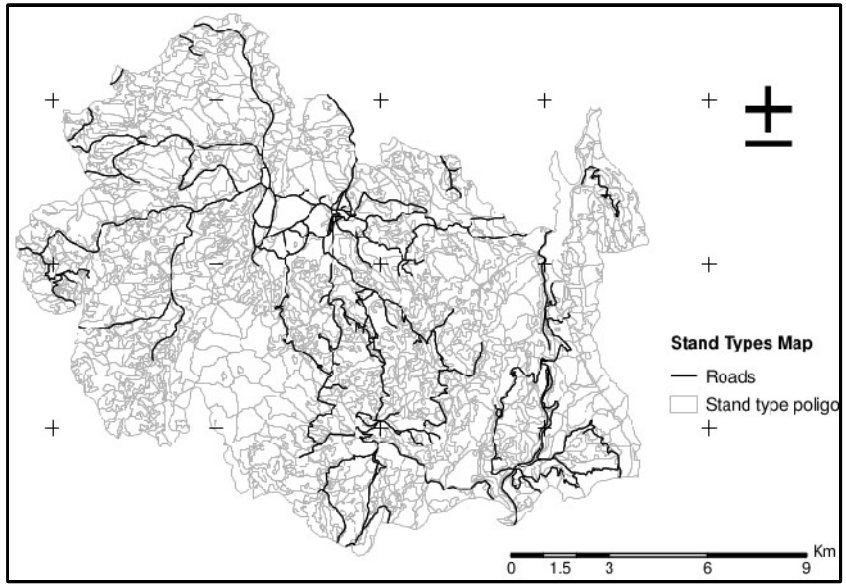


Robinson *et al.*, 2010. *A conceptual framework for understanding, assessing, and mitigating ecological effects of forest roads.*

Scientific context

Forest accessibility and forest

- Ecological effects of road network (Spellerberg 1998, Trombulak & Frissel 2000, Coffin 2007, Robinson *et al.* 2010).
- Fragmentation of forest by road network and harvesting (D'Eon & Glenn 2005, Eker & Coban 2010).

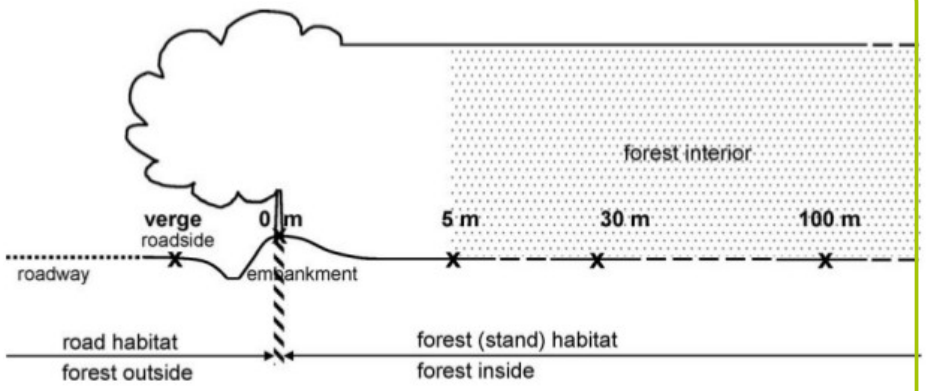


Eker & Coban, 2010. *Impact of road network on the structure of a multifunctional forest landscape unit in southern Turkey*

Scientific context

Forest accessibility and forest

- Ecological effects of road network (Spellerberg 1998, Trombulak & Frissel 2000, Coffin 2007, Robinson *et al.* 2010).
- Fragmentation of forest by road network and harvesting (D'Eon & Glenn 2005, Eker & Coban 2010).
- Effect of roads and interfaces on the forest stands (Watkins et al. 2003, Avon et al. 2010), trees (Delgado et al. 2007, Bate et al. 2007) or vegetation (Marcantonio et al. 2013).



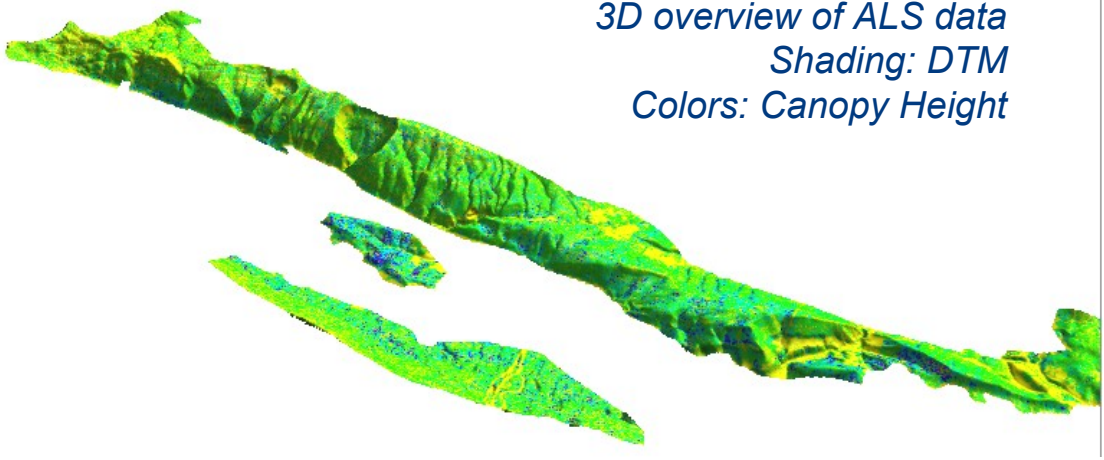
Avon *et al.*, 2010. *Does the effect of forest roads extend a few meters or more into the adjacent forest? A study on understory plant diversity in managed oak stands*

Objective of this study

Quantify the link between accessibility and forest structure

- Seen from the forest manager
  - Accessibility modelled from technical criteria
  - Basal area → parameter of interest
- Airborne Laser Scanning used to obtain a high resolution map of topography and basal area.

Skidder



3D overview of ALS data
Shading: DTM
Colors: Canopy Height

Study area

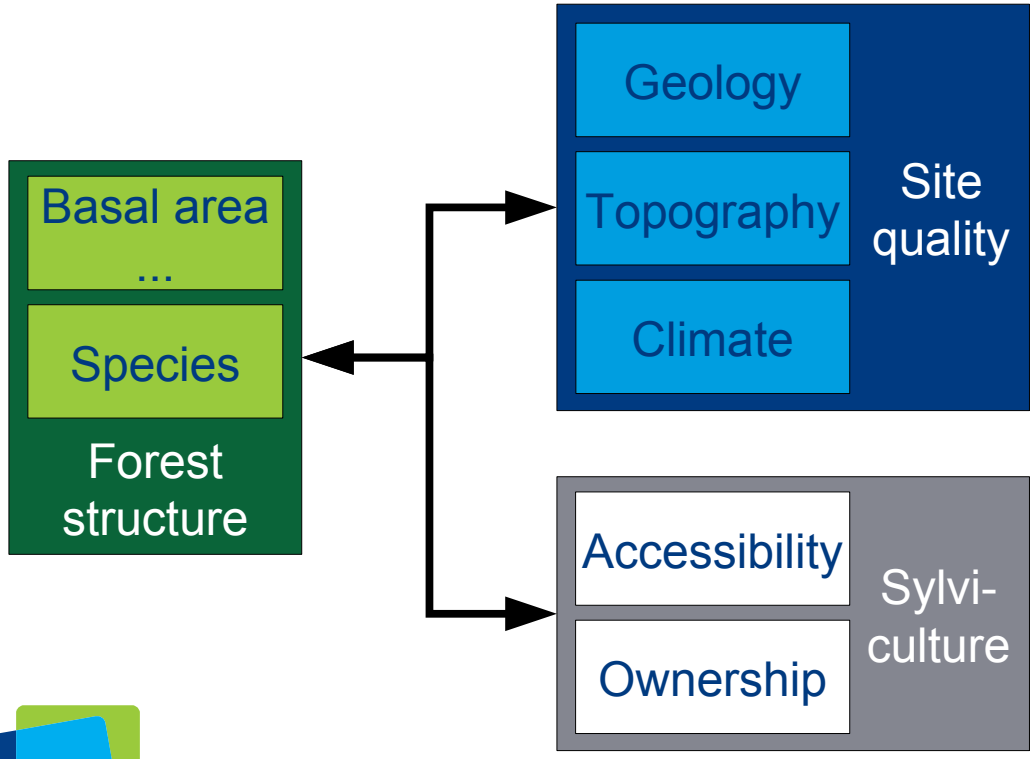
Quatre Montagnes forest

- ~ 5000 ha
- 2/3 public forests, 1/3 private
- Only skidder, no cable yarding
- Various tree species and stand structures

Study area location

Methods

Many factors affect forest structure

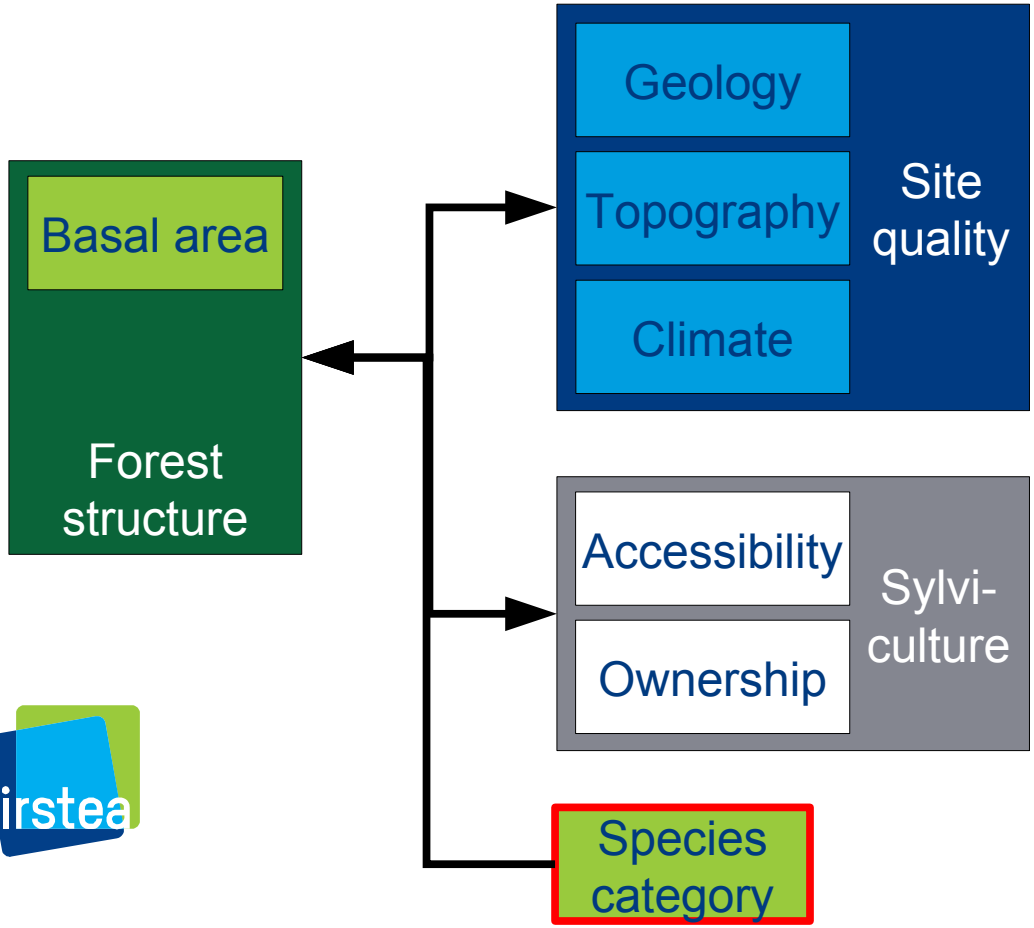


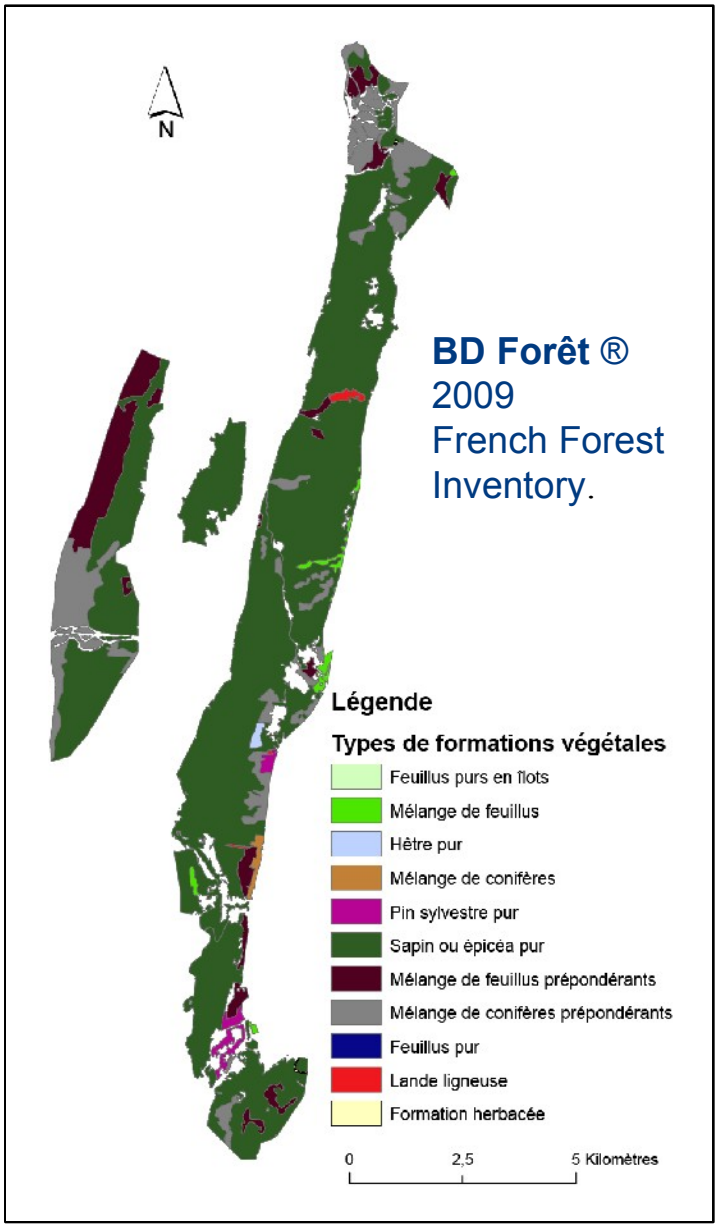
→ Separate the contributions of the different factors

irstea

Methods

Data: species

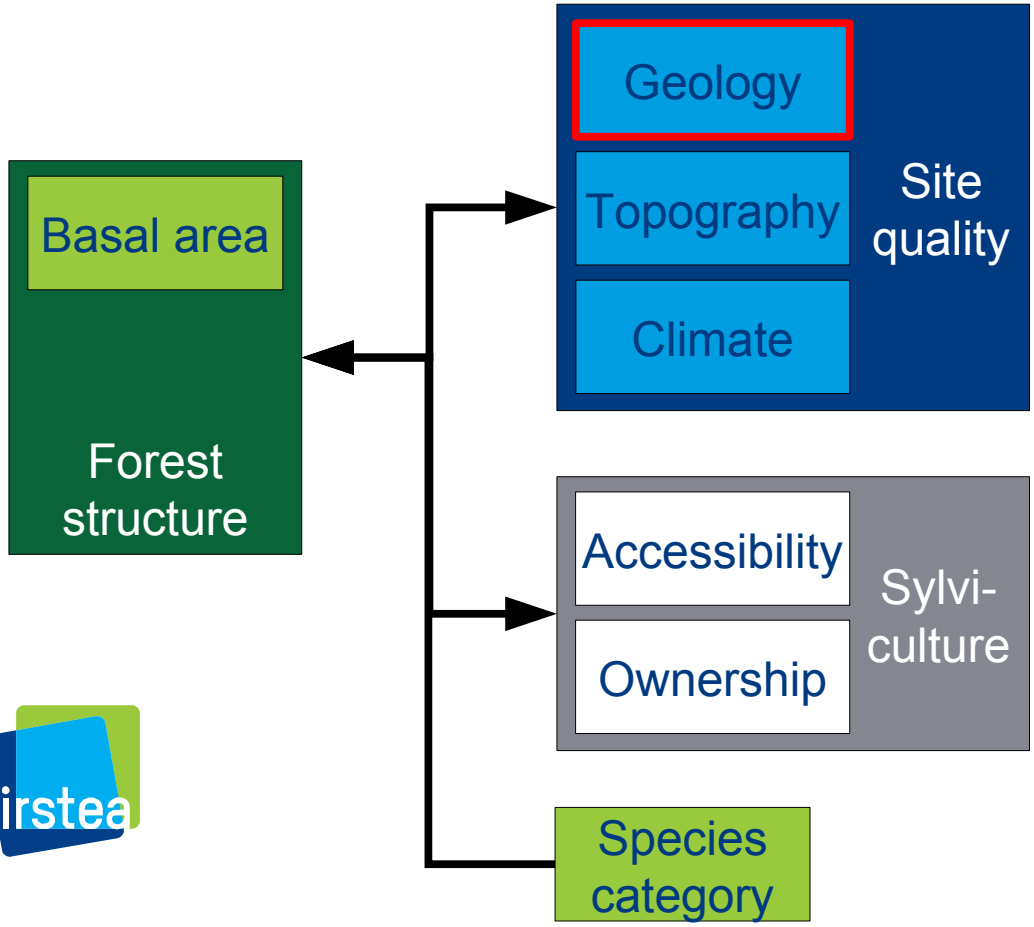


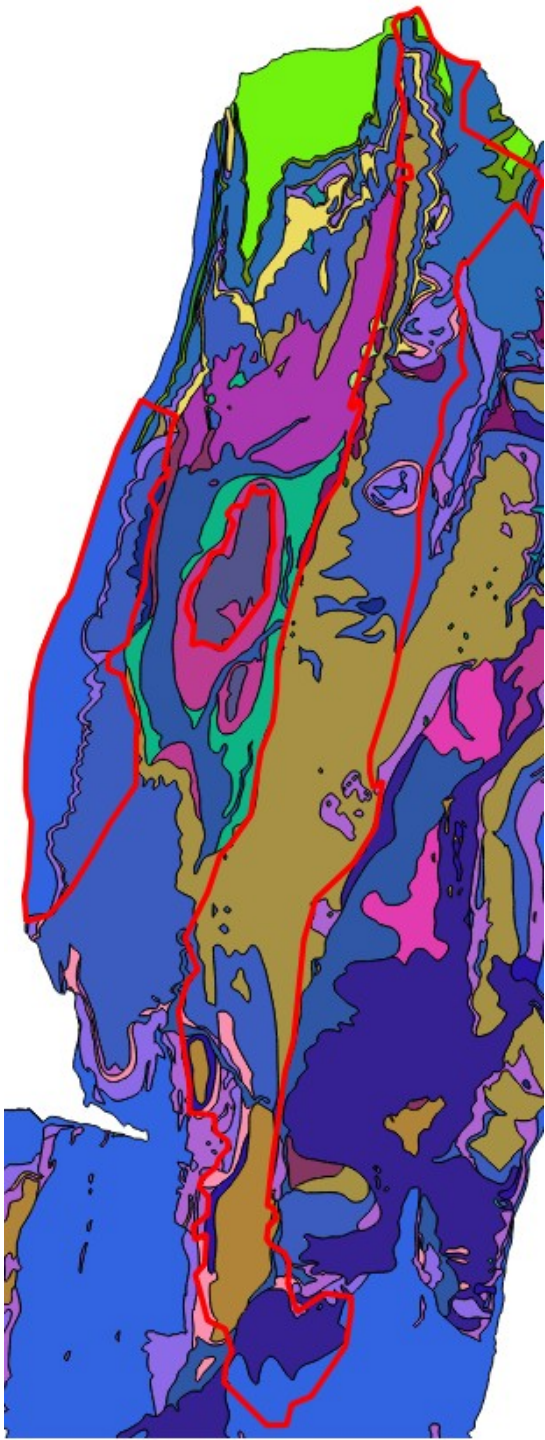


Réalisation : J.Bellier, 2014.

Methods

Data: Geology

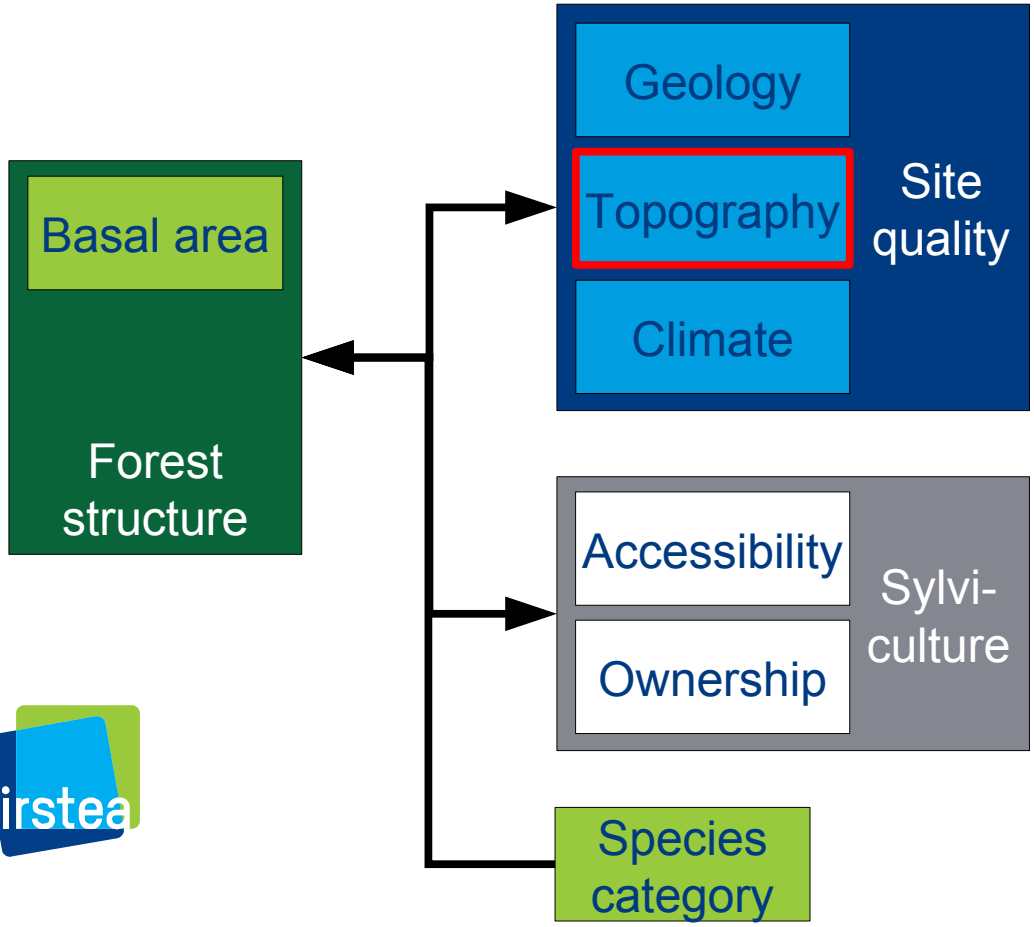


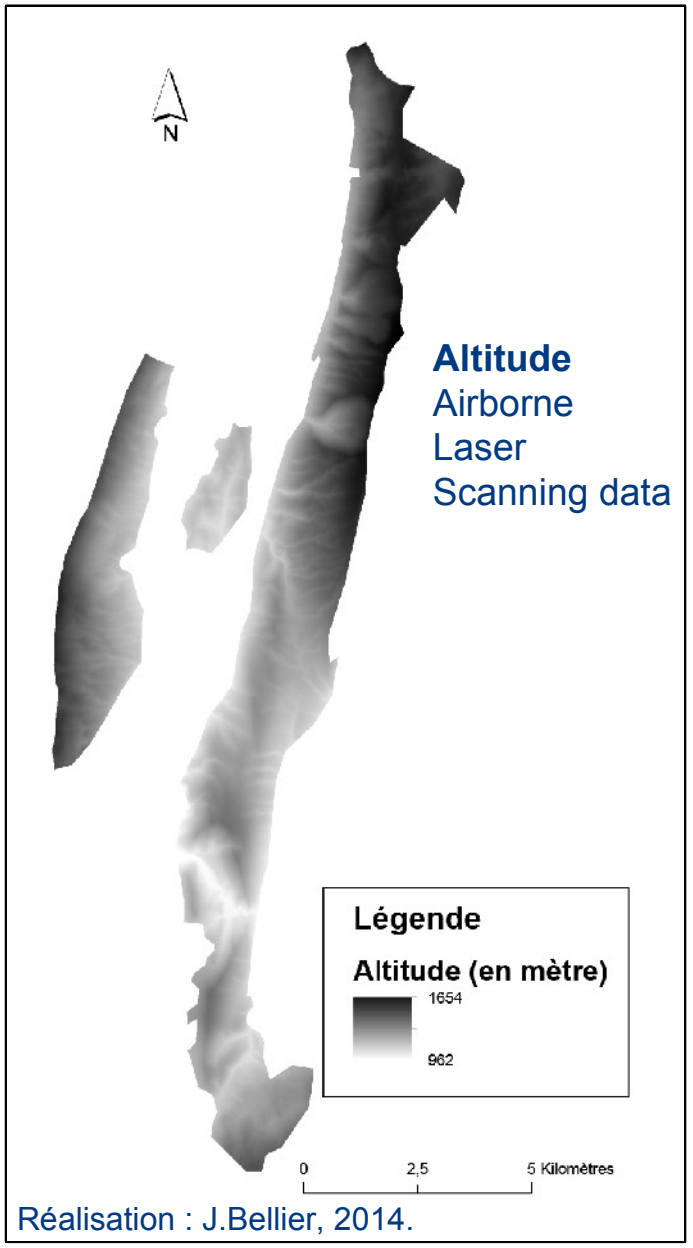


Geological map
Bureau de Recherches Géologiques et Minières

Methods

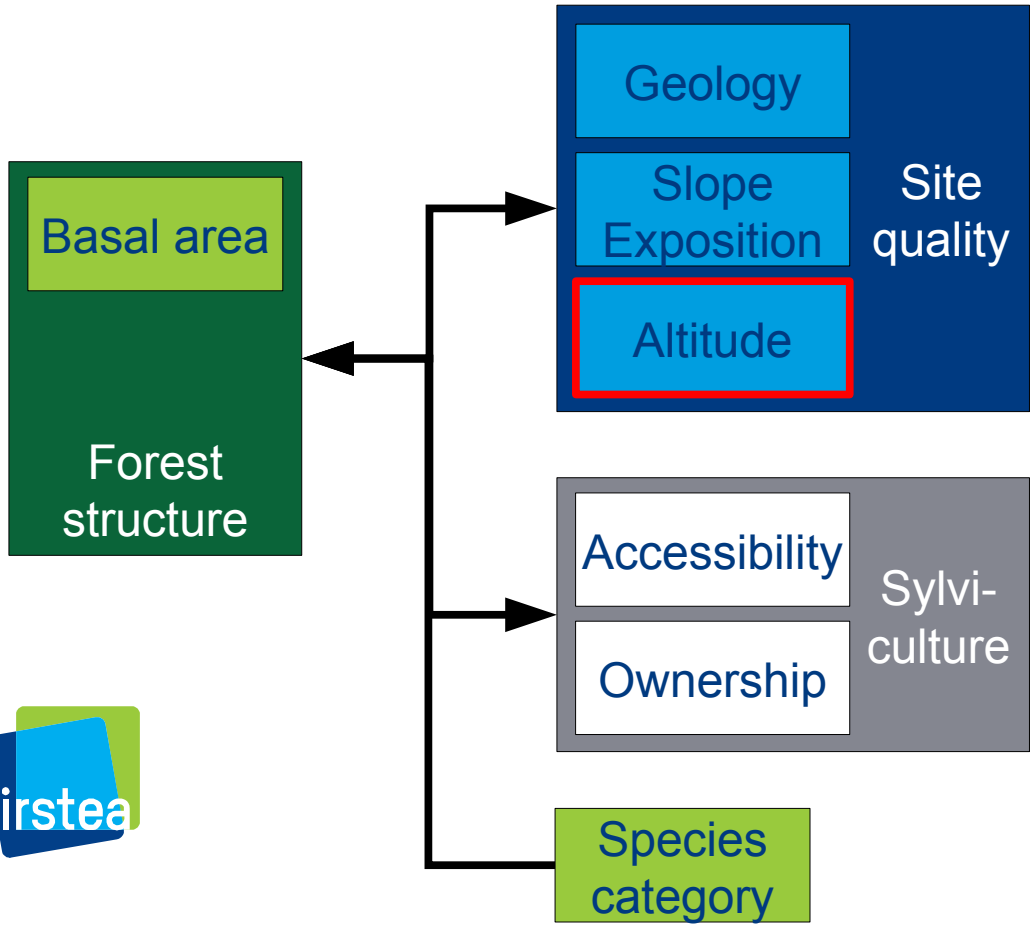
Data: Topography





Methods

Data: Geology

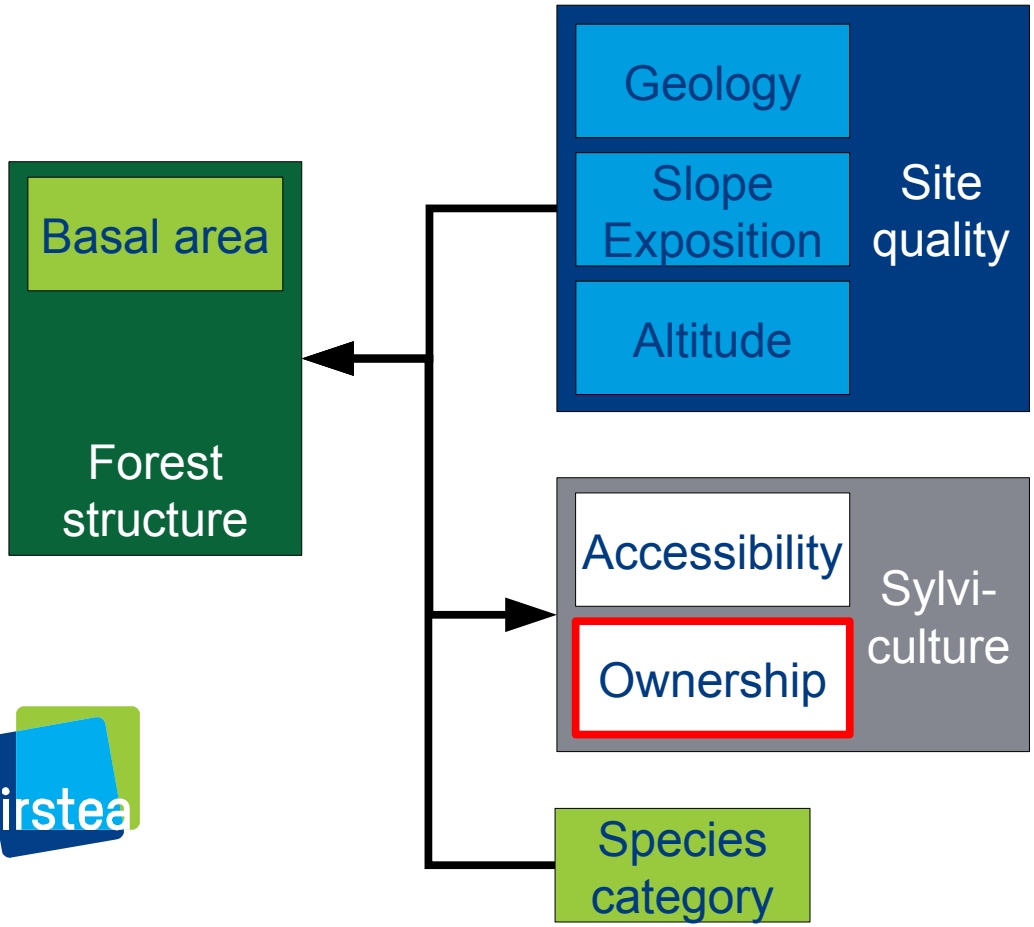


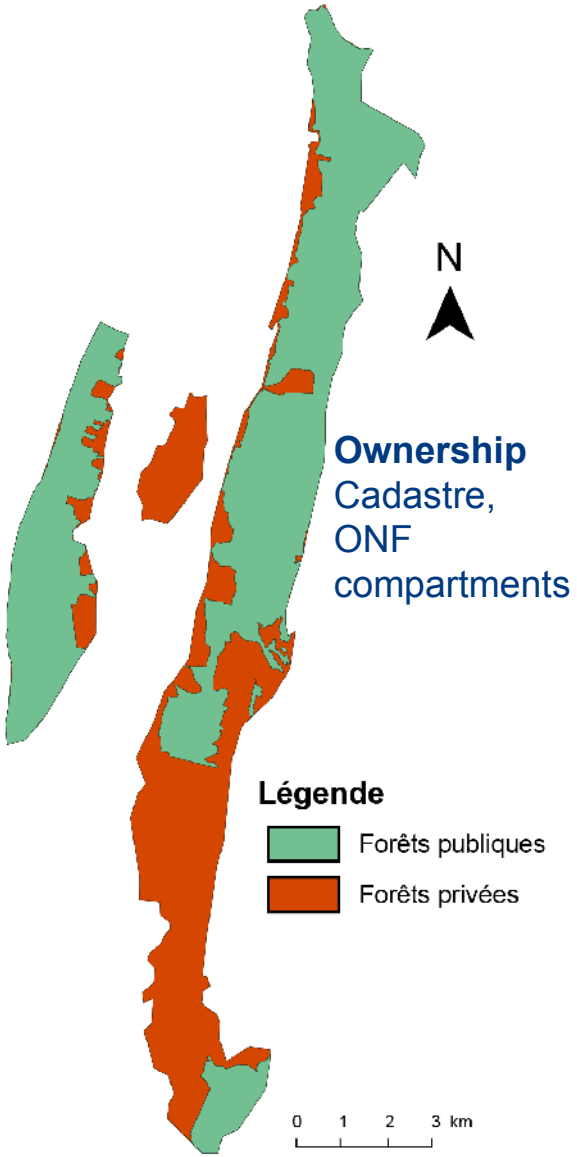
Computed from the digital terrain model:
- **Slope**
- **Exposition**

Altitude used as proxy for Climate

Methods

Data: Ownership



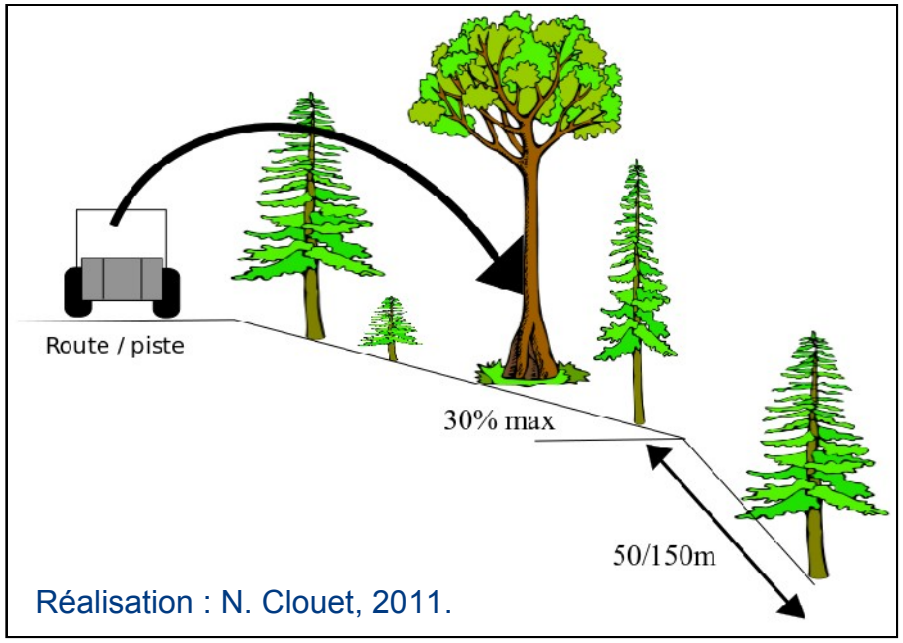


Réalisation : J.Bellier, 2014.

Methods

Data: Accessibility (Sylvaccess GIS model)

- If slope < 30 %, skidder can enter the forest area and winch from there

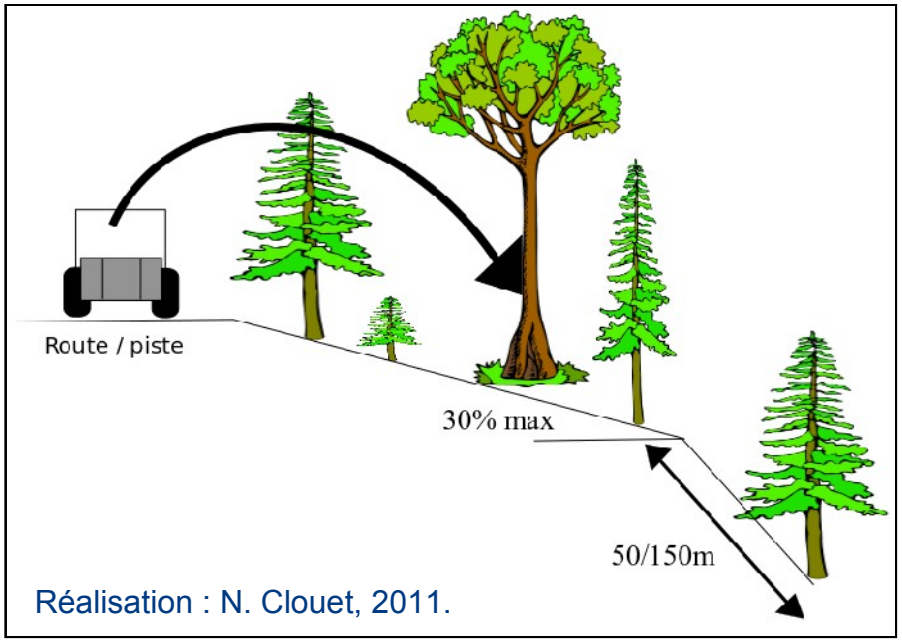


Réalisation : N. Clouet, 2011.

Methods

Data: Accessibility (Sylvaccess model)

- If slope < 30 %, skidder can enter the forest area and winch from there
- If slope > 30 %, skidder winches from the road or forest track
- Winch distances : 50 m upslope / 150 m downslope



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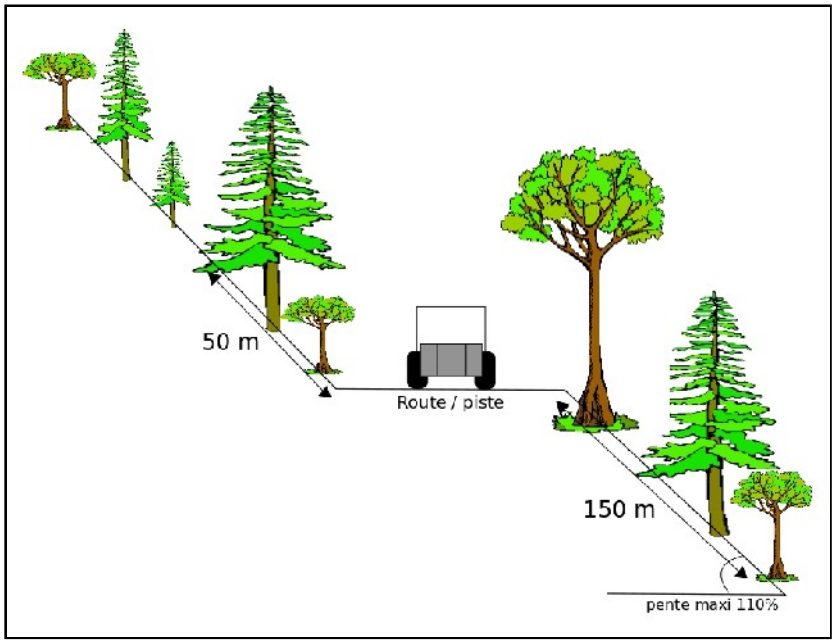

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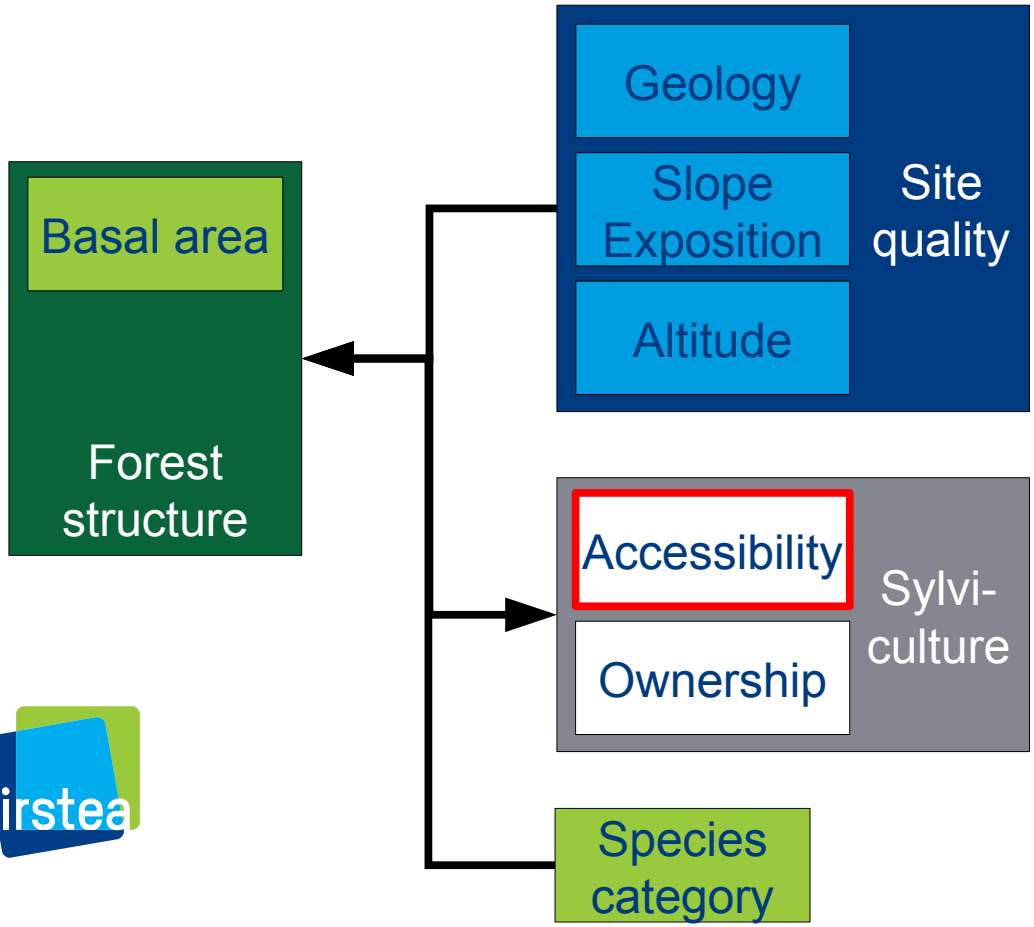
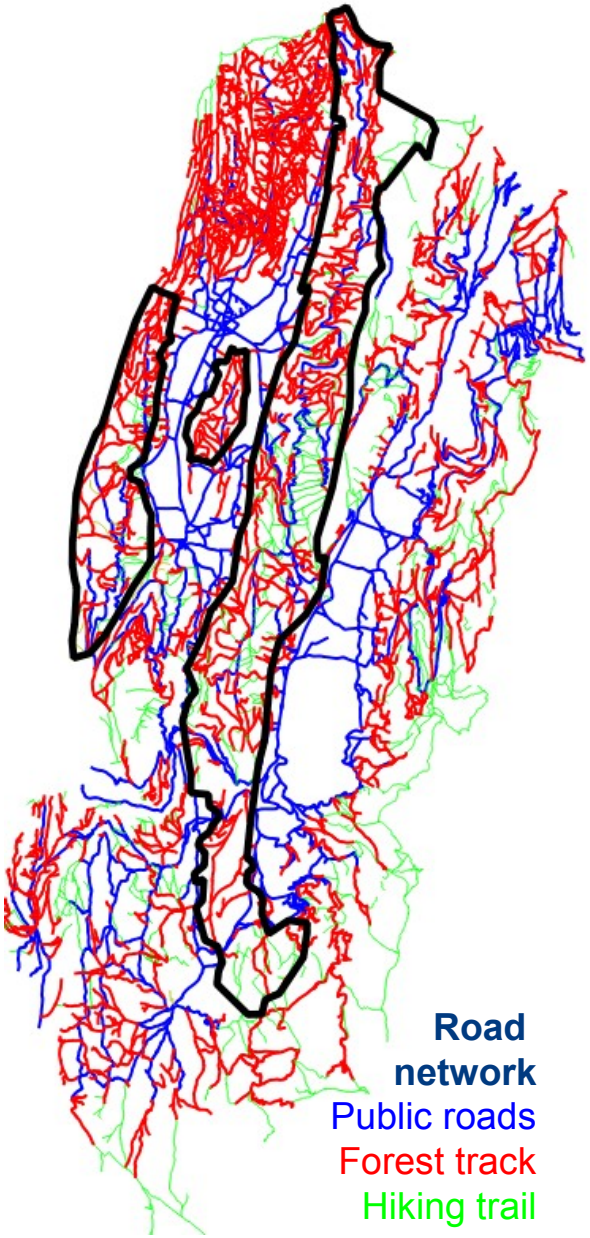
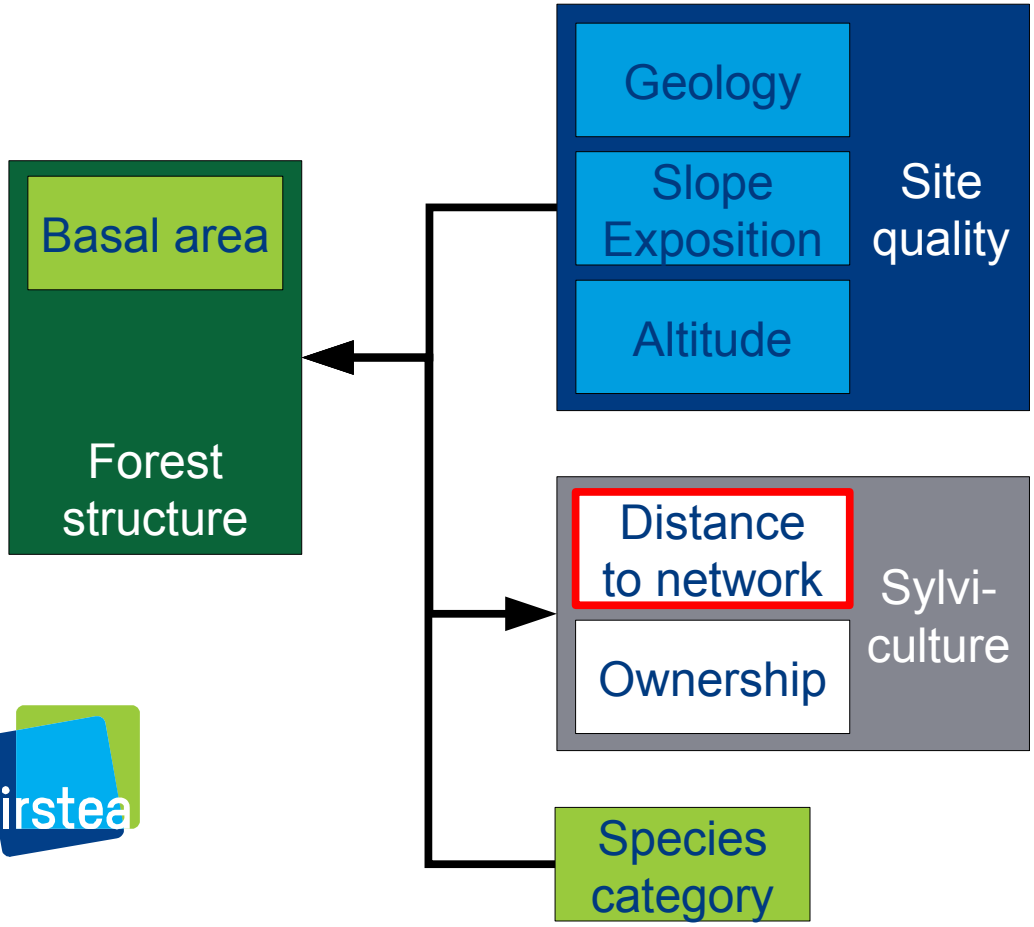


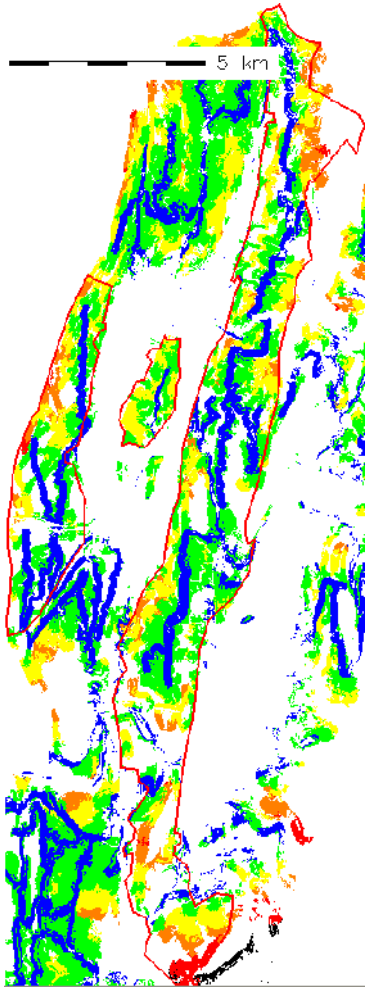


Source: ONF - ALS

Methods

Data: Accessibility (Sylvaccess model)





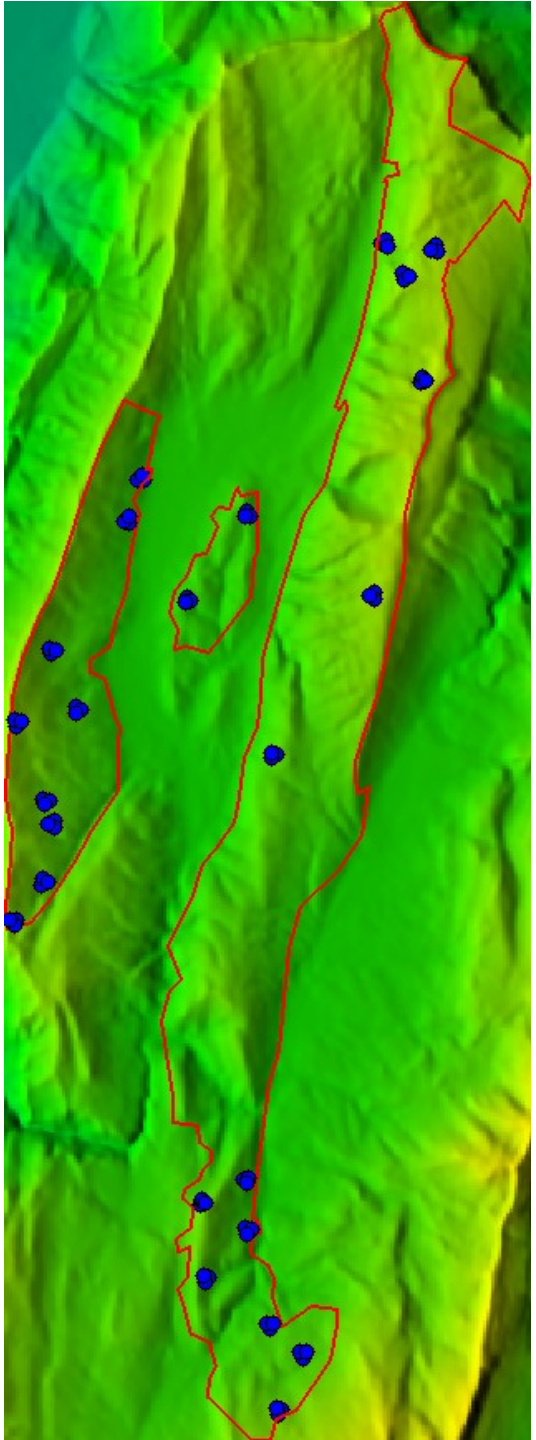
Total accessibility distance (winching + skidding)

Source: Dupire, 2012

Methods

Data: Basal area

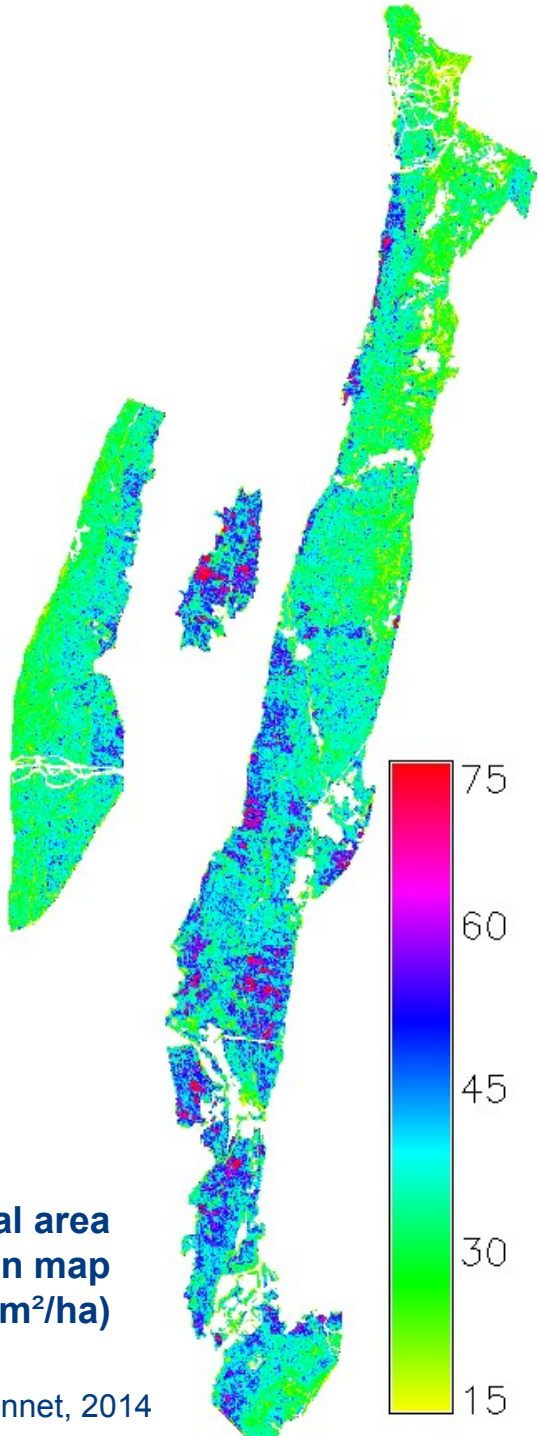
- Area-based prediction method from Airborne Laser Scanning data (*Næsset 2004*)
- Calibration : 24 groups of 4 plots (15 m radius, trees with DBH > 7.5 cm)



Methods

Data: Basal area

- Area-based prediction method from Airborne Laser Scanning data (*Næsset 2004*)
- Calibration : 24 groups of 4 plots (15 m radius, trees with DBH > 7.5 cm)
- Model RMSE = 6.6 m²/ha (18 %)
- Wall to wall mapping 25m resolution



Basal area prediction map (m²/ha)

Source: Monnet, 2014

Methods

Variables (quantitative - *categorical*)

Basal area ~

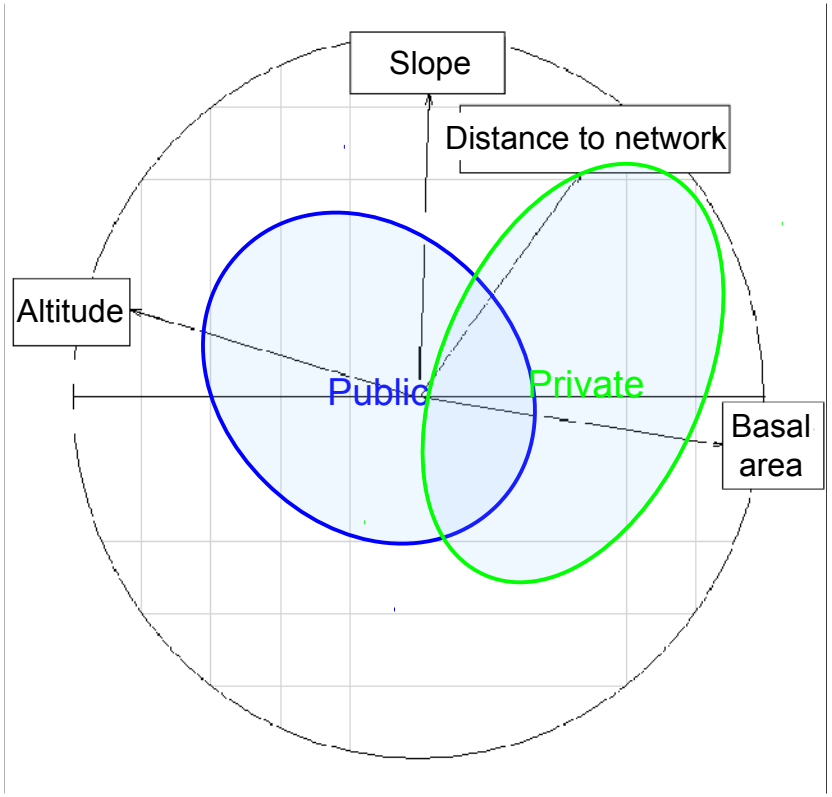
- *Geology*
- Slope
- *Exposition*
- Altitude
- Total distance
- *Ownership (public / private)*
- *Species*

Analysis of Covariance (ANCOVA)

- For the public and private forests separately
- Observations = pixels at 100 m resolution

Results

Principal Component Analysis for the four quantitative variables



PCA axes 1 (42.7%) and 2 (29.2%)

- Public forests : higher altitude and lower basal area
- Private forests : slightly larger distance
- Altitude negatively correlated with basal area (-0.61)

Results

ANCOVA model for **public** forests (R^2 = 0.43)

- *Coefficients of factor categories not shown*
- Basal area decreases with altitude and slope
- Basal area increases with distance to network (average of 1m^2/ha per every additional km)

Variables	Coefficient	Pr > |t|	Confidence interval (95%)	
Distance (m)	0.001	< 0.0001	0.0005	0.0014
Altitude (m)	-0.016	< 0.0001	-0.0179	-0.0147
Slope (%)	-0.079	< 0.0001	-0.1034	-0.0545

Results

ANCOVA model for **private** forests (R^2 = 0.2)

- *Coefficients of factor categories not shown*
- Basal area **increases** with slope
- Influence of altitude not significant
- Similar effect of distance to network (average of 1m^2/ha per every additional km)

Variables	Coefficient	Pr > |t|	Confidence interval (95%)	
Distance (m)	0.001	0.003	0.0004	0.0022
Altitude (m)	0.004	0.107	-0.0010	0.0098
Slope (%)	0.118	0.000	0.0552	0.1802

Discussion

Effect of skidding distance on basal area

- **Weak** (1m^2/ha per km) but **significant** both in public and private forests

Discussion

Effect of skidding distance on basal area

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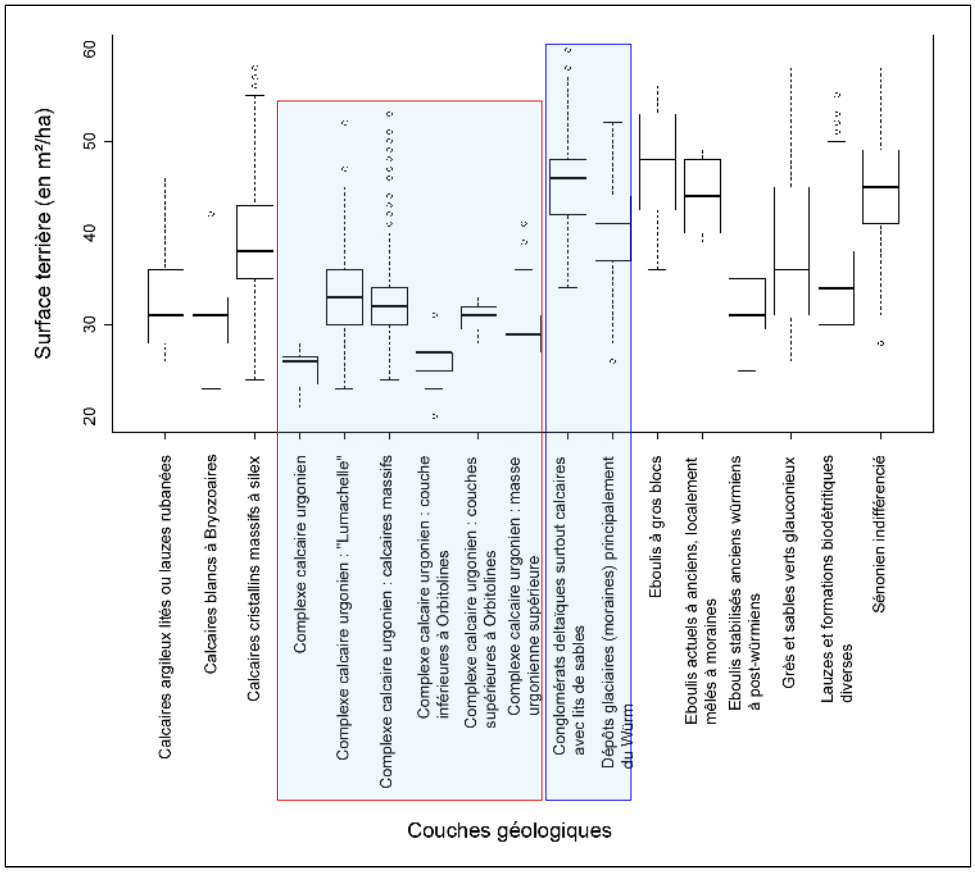


Difference in private / public forests

- Management is more **homogeneous in public forests** (road planning, uneven-aged management) than in private forests (small properties, many owners, low organization).
- Different geological classes, species...

Discussion

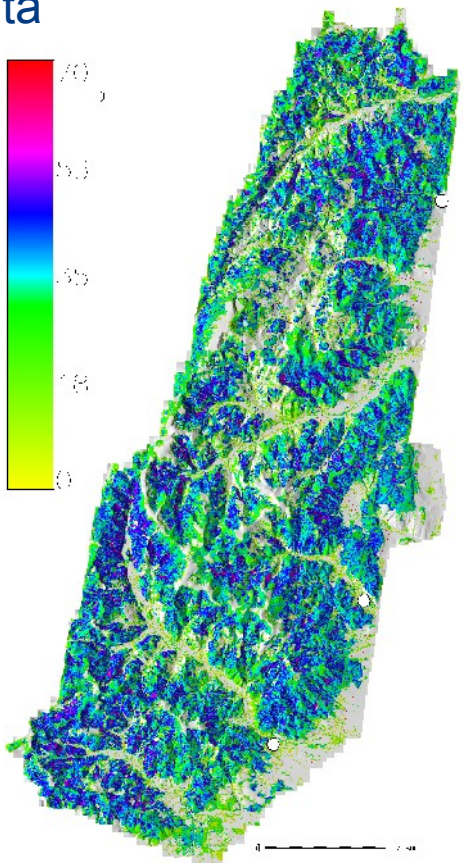
Interest of a Remote Sensing and GIS modelling based analysis

- High number of observations useful, despite model errors (ALS predictions, accessibility modelling, data resampling)

Limits

- Small study area → the approach should be tested on a larger study area (Vosges 1500 km^2)

Basal area (m2/ha)
ALS estimation



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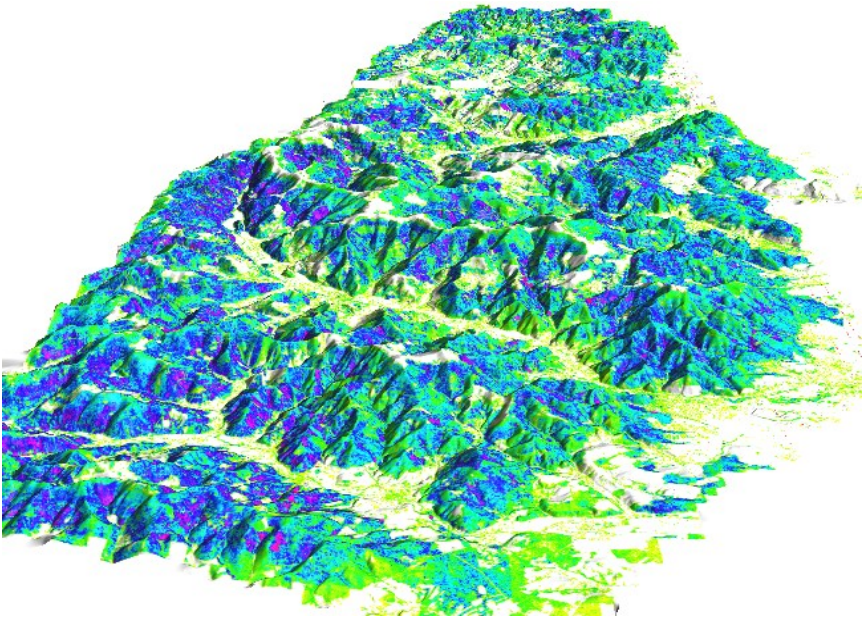

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