Using survival analysis to predict the harvesting of forest stands in Quebec, Canada

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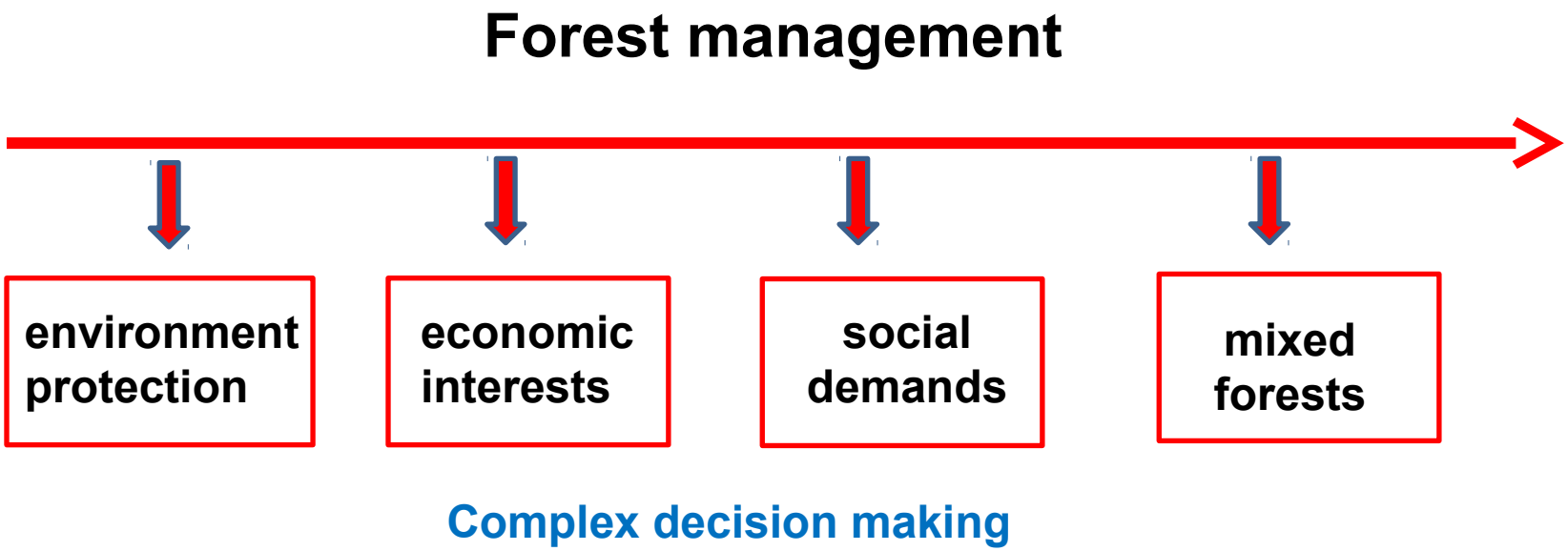
INRA Institut National de la Recherche Agronomique
UQAR Université du Québec à Rimouski
LERFoB
CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico

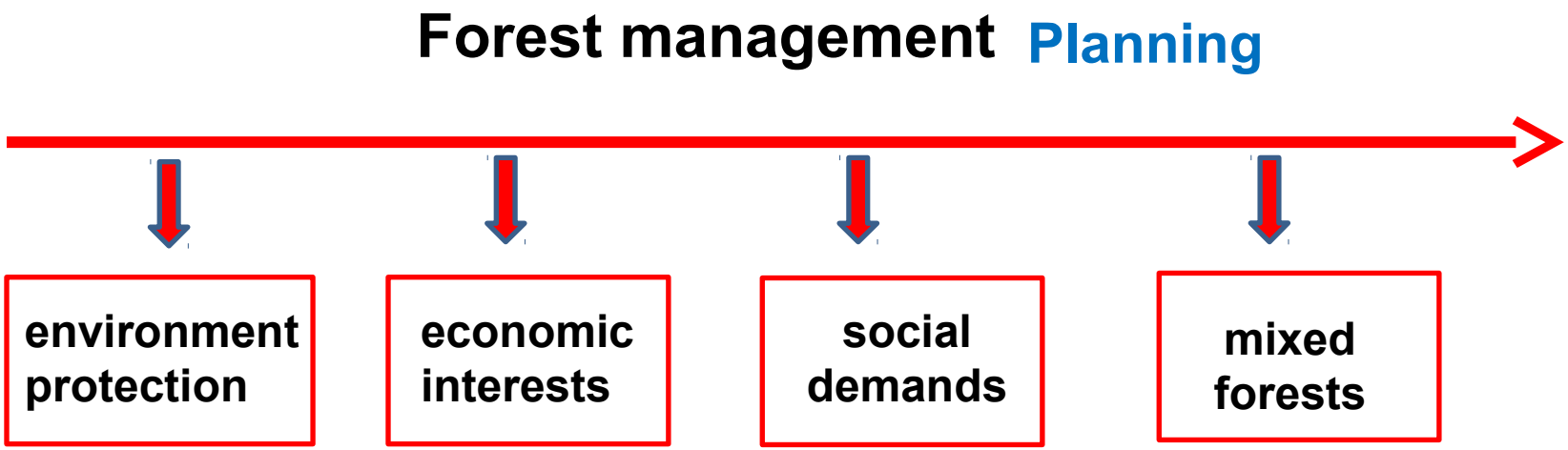
GENERAL CONTEXT



Martell et al., 1998

Hernandez et al., 2014

GENERAL CONTEXT

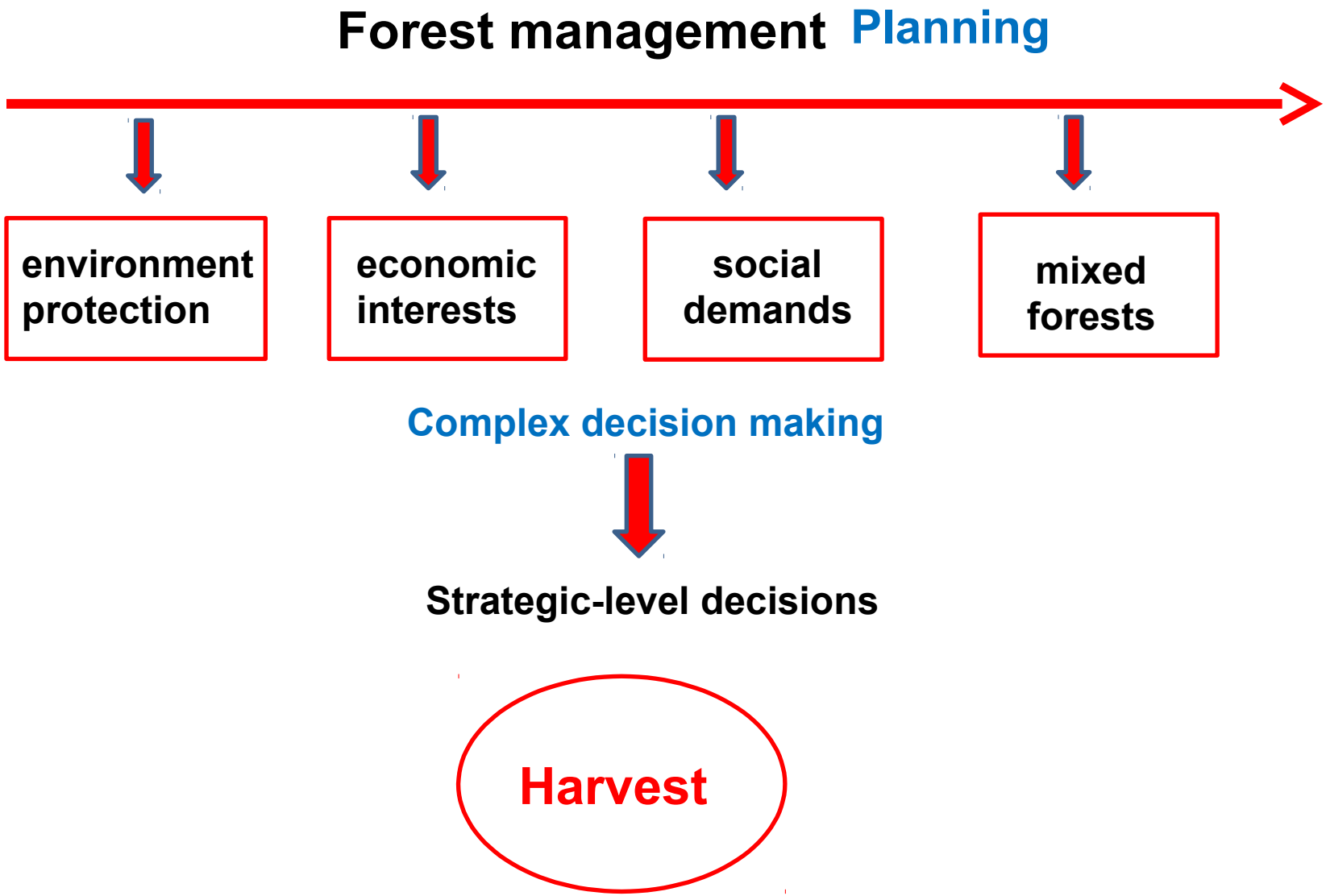


- large areas
- long-term time horizons
- silvicultural policies
- legislation issues

Martell et al., 1998

Hernandez et al., 2014

GENERAL CONTEXT



Harvest decision

x

- ✓ Harvest algorithms
- ✓ Harvest Models

Harvest decision

x

✓ **Harvest Algorithms** difficult task

based on user-defined rules

objective function

✓ **Harvest Models**

Thurnher et al., 2011

Harvest decision

x

✓ **Harvest Algorithms** difficult task

✓ **Harvest Models** LR : temporal information

- tree- or plot-level probability -> **logistic regression**
- limitations
  - Exact date of the harvest is unknown
  - Intervals overlap
  - Changes in sampling intensity
  - Uneven time intervals

Wang et al., 2013

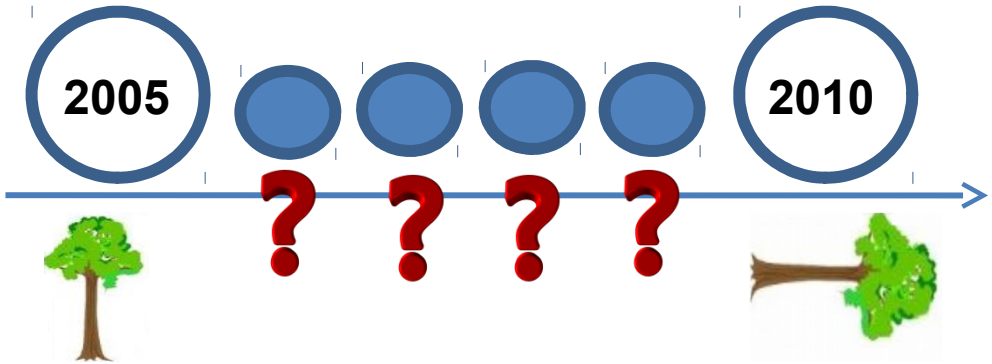
Thurnher et al., 2011

Harvest decision

- ✓ **Harvest Algorithms** difficult task
- ✓ **Harvest Models : Logistic Regression** does not effectively use temporal information

- ✓ **Harvest Models:** **Survival Analysis**

  deal with interval-censored data



Lawless, 2003

Harvest decision

- ✓ **Harvest algorithms** difficult task
- ✓ **Harvest Models : Logistic Regression** does not effectively use temporal information

- ✓ **Harvest Models:** **Survival Analysis**

  deal with interval-censored data

  time-varying explanatory variables

  - Basal Area: between intervals
  - AAC: within intervals

Harvest decision

- ✓ **Harvest algorithms** difficult task
- ✓ **Harvest Models : Logistic Regression** does not effectively use temporal information

- ✓ **Harvest Models:** **Survival Analysis**

  deal with interval-censored data

  time-varying explanatory variables

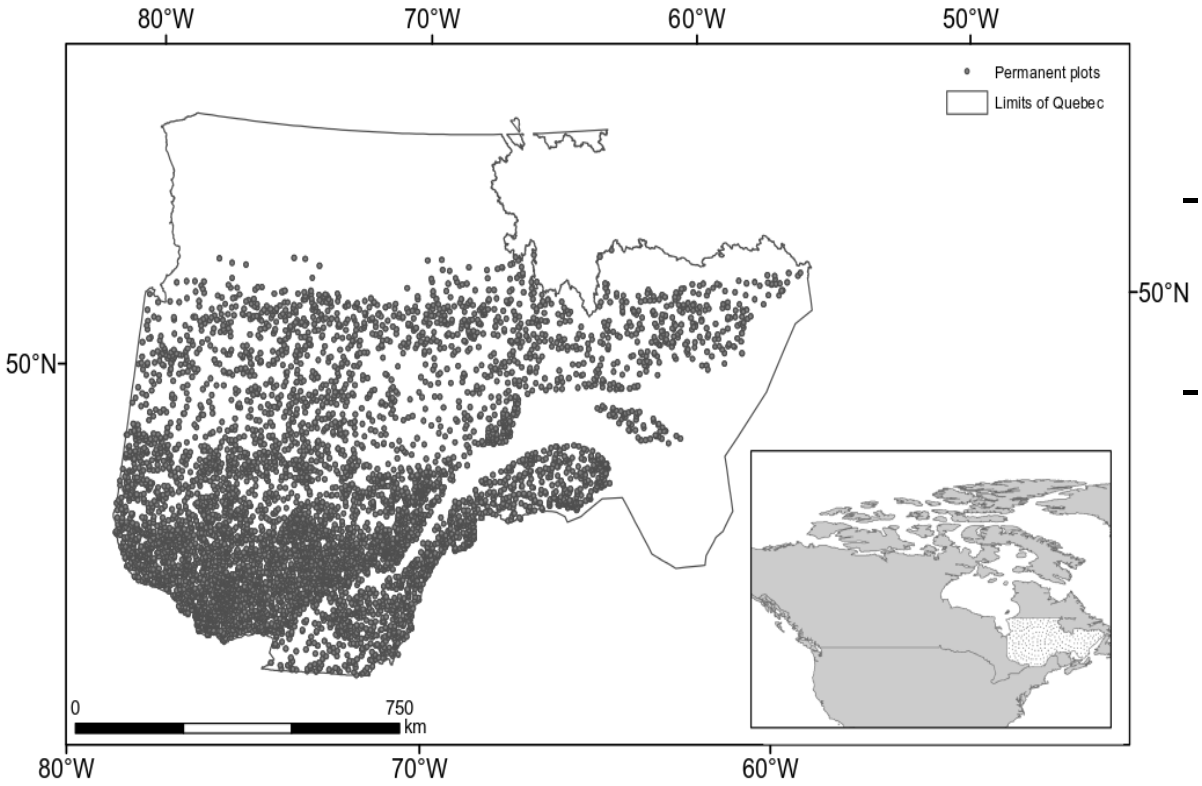
  multiple levels of explanatory variables

  - Exchange rate
  - Management strategy changes

OBJECTIVE

Develop a survival model to predict the plot-level harvest occurrence

Dataset

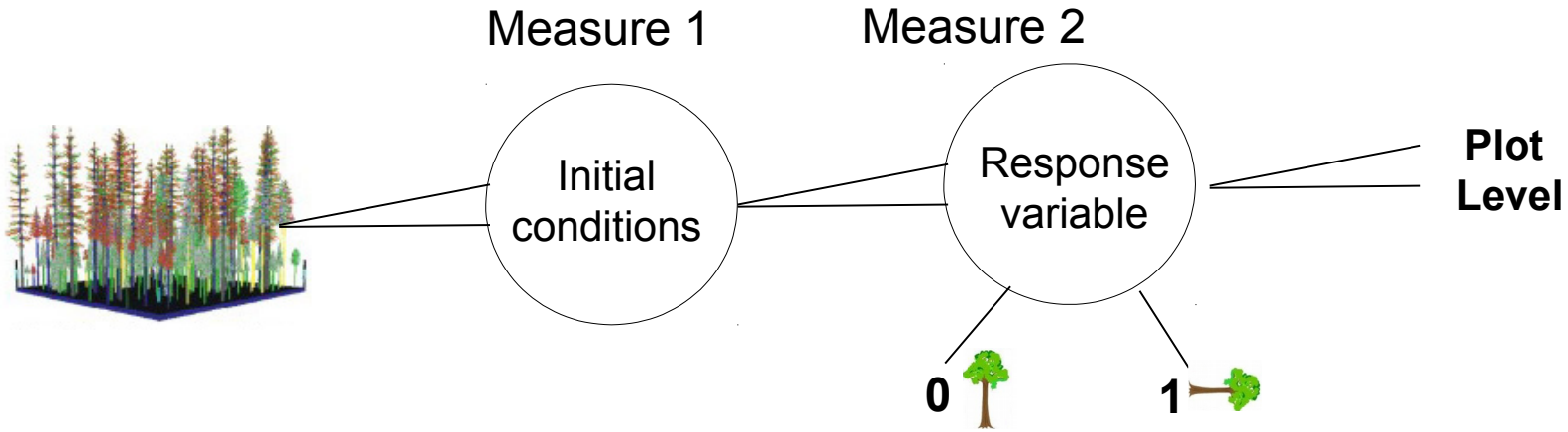


PFI Quebec:

- Nordic temperate zone: broadleaved and mixed stands
- Boreal zone: coniferous stands

- **12,596 measures – 1988:2014**
- **Uneven intervals: 2 to 6 measures/plot**
- **400 m²**
- **DBH min: 9.1 cm**

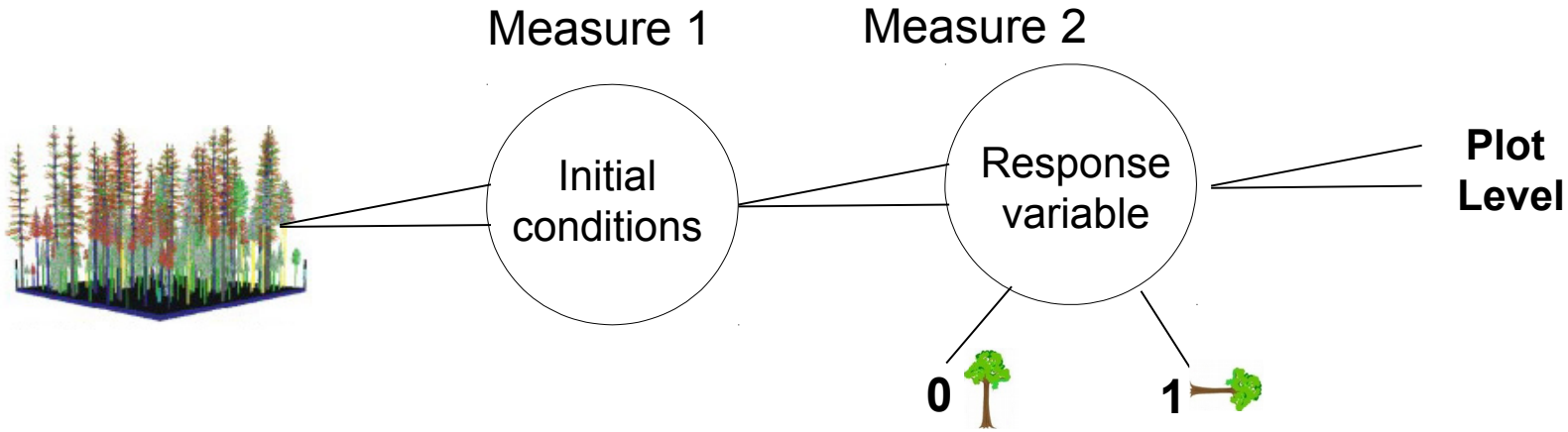
Dataset



Explanatory variables

- Basal area (m^2ha^{-1}); Stem density (stem ha^{-1})
- Interval length (years); Spatial Correlation
- Slope classes; Ecological type – B, M, C

Dataset



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- Interval length (years); Spatial Correlation
- Slope classes; Ecological type – B, M, C

- AAC – Regional annual allowable cut volumes
- Countervailing duty
- Exchange rate

Statistical development

Proportional hazard model

$$h_{ijk}(t) = h_0(t, \boldsymbol{g}_{ijk}\boldsymbol{\gamma}) e^{\boldsymbol{x}_{ijk}\boldsymbol{\beta}}$$

Probability of harvest

Baseline: time-spatial, AAC

Proportional: stand covariates

Model evaluation

$$h_{ijk}(t) = h_0(t, \boldsymbol{g}_{ijk}\boldsymbol{\gamma})e^{\boldsymbol{x}_{ijk}\boldsymbol{\beta}}$$

- AIC
- 10-fold cross-validation
- Hosmer-Lemeshow test
- ROC – AUC
- Short-term forecasts (10-year) of harvest probabilities

The final model

$$\Pr(y_{ijk}=1) = 1 - e^{-e^{\beta_1 \ln(\mathrm{BA}_{ijk}) + \beta_2 \mathrm{N}_{ijk} + \beta_{3,s} + \beta_{4,v}} \sum_{z=t_1}^{t_2} e^{\gamma_0 + \gamma_1 \mathrm{AAC}_z + u_i}}$$

Basal area +

Stem density −

Ecological type

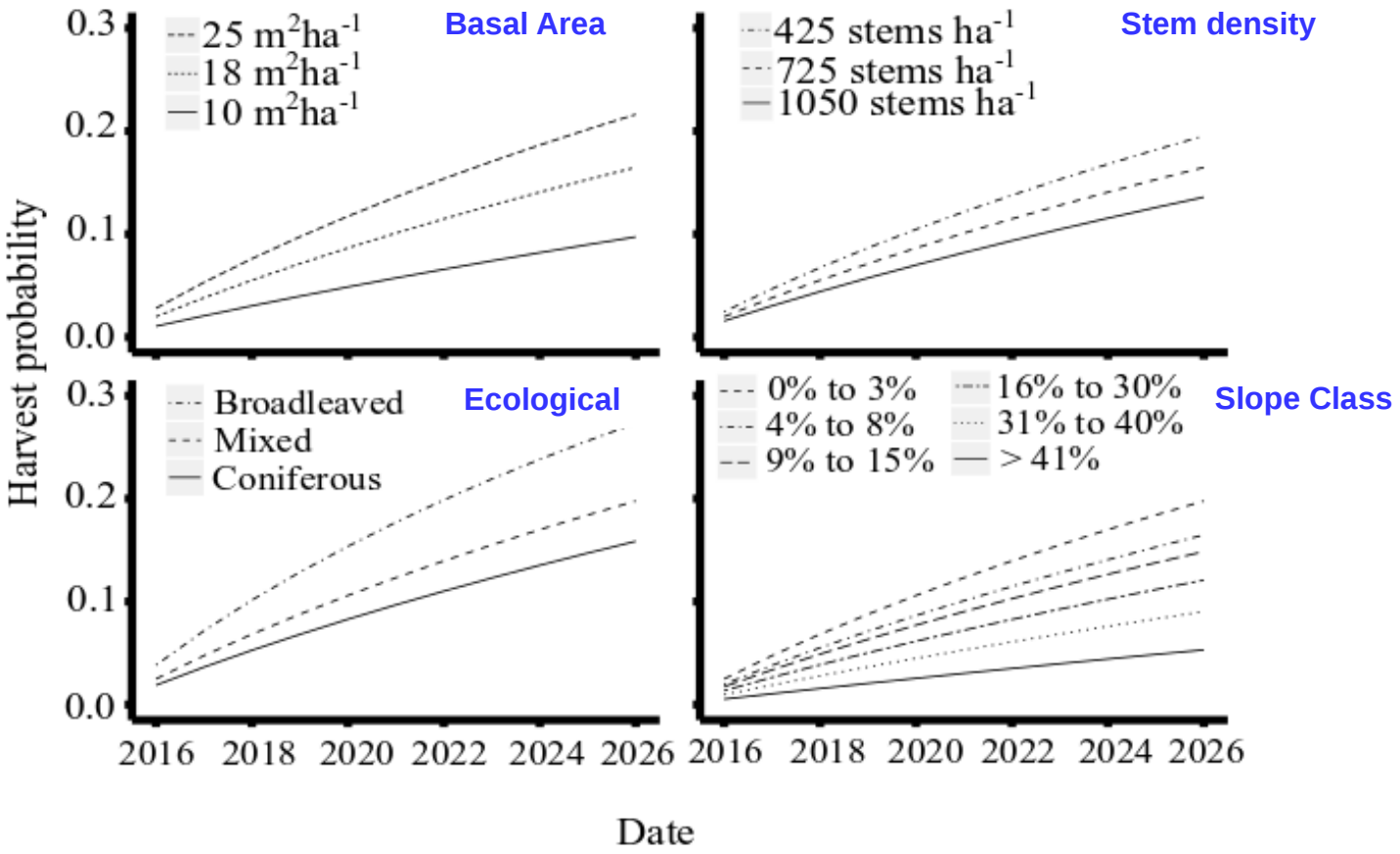
+ Broadleaved

Slope classes −

AAC +

Cruise line +

Forecasts


Basal Area
25 m²ha⁻¹
18 m²ha⁻¹
10 m²ha⁻¹
Stem density
425 stems ha⁻¹
725 stems ha⁻¹
1050 stems ha⁻¹
Ecological
Broadleaved
Mixed
Coniferous
Slope Class
0% to 3%
4% to 8%
9% to 15%
16% to 30%
31% to 40%
> 41%
Harvest probability
0.0
0.1
0.2
0.3
2016
2018
2020
2022
2024
2026
Date

DISCUSSION

- ✓ **Potential of SA to provide annual predictions of harvest occurrence**
  - Changes: economic conditions, legislation, management practices and length of intervals (Antón-Fernandez, 2012; Thurner et al., 2011).
  - Deal with uneven intervals and time-varying regional variables.

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- ✓ **Variables**
  - Low stem density = High probability of harvest (Antón-Fernandez, 2012) } mature stands

DISCUSSION

- ✓ Potential of SA to provide annual predictions of harvest occurrence
  - Changes: economic conditions, legislation, management practices and length of intervals (Antón-Fernandez, 2012; Thurner et al., 2011).
  - Deal with uneven intervals and time-varying regional variables.
- ✓ **Variables**
  - High stem density = low probability of harvest (Antón-Fernandez, 2012) } mature stands
  - Spatial correlation improved the model fit (BoWang and Gadow, 2006)

Limitations

- Random effects to account for spatial correlations
- Tactical planning
- Multiple random effects

Contributions

- The market / management strategy may change during the intervals
- Strategic level: harvesting probability on a long-term planning horizon
- Applicable to a wide range of forest types
- Coupled to a growth model: generate large-area growth predictions

Contributions

Melo, L.C.; Schneider, R.; Manso, R.; Saucier, J-P.; Fortin, M. Using Survival Analysis to predict the harvest occurrence in forest stands in Quebec, Canada. *Canadian Journal of Forest Research*, **accepted March/2017**.

Merci de votre attention!

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