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

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Journée Caqsis, 29-30/03, Bordeaux, France
Forest management

- Environment protection
- Economic interests
- Social demands
- Mixed forests

Complex decision making

Martell et al., 1998
Hernandez et al., 2014
Forest management Planning

- environment protection
- economic interests
- social demands
- mixed forests

Complex decision making

Strategic-level decisions

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

Martell et al., 1998
Hernandez et al., 2014
Forest management Planning

environment protection

economic interests

social demands

mixed forests

Complex decision making

Strategic-level decisions

Harvest
Harvest decision

✓ Harvest algorithms
✓ Harvest Models
Harvest decision

✓ Harvest Algorithms  difficult task

based on user-defined rules
objective function

✓ Harvest Models

Thurnher et al., 2011
Harvest decision

✓ 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
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
Explanatory variables

- Basal area (m²ha⁻¹); Stem density (stem ha⁻¹)
- Interval length (years); Spatial Correlation
- Slope classes; Ecological type – B, M, C
Dataset

Explanatory variables

- Basal area (m²ha⁻¹); Stem density (stem ha⁻¹)
- 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

\[ h_{ijk}(t) = h_0(t, g_{ijk}, \gamma) e^{x_{ijk}\beta} \]

- Probability of harvest
- Baseline: time-spatial, AAC
- Proportional: stand covariates
Model evaluation

\[ h_{ijk}(t) = h_0(t, g_{ijk} \gamma) e^{x_{ijk} \beta} \]

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

\[ \Pr(y_{ijk} = 1) = 1 - e^{-e^{\beta_1 \ln(\text{BA}_{ijk}) + \beta_2 N_{ijk} + \beta_3,s + \beta_4,v \sum_{z=t_1}^{t_2} e^{\gamma_0 + \gamma_1 \text{AAC}_z + u_i}} \]

- Basal area
- Stem density
- Slope classes
- Ecological type: Broadleaved
- AAC
- Cruise line
RESULTS

Forecasts
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.
Potential of SA to provide annual predictions of harvest occurrence

- Changes: economic conditions, legislation, management practices and length of intervals (Antón-Fernández, 2012; Thurner et al., 2011).
- Deal with uneven intervals and time-varying regional variables.

Variables

- Low stem density = High probability of mature stands
  harvest (Antón-Fernández, 2012)
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

Merci de votre attention!

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