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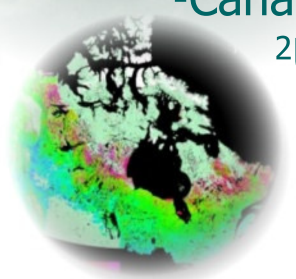

MODELLING LAND USE CHANGE IN CANADA WITH AN OPTION VALUE FRAMEWORK: AN AGRICULTURE-FORESTRY EXAMPLE FROM ALBERTA

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A bit of history

- **NRCan FAACs and Forest-2020 Federal Initiatives**:
  - A national effort examining afforestation as a climate change mitigation measure
  - Linked carbon sequestration and cost-benefit models in a spatial framework
- Several case studies explored afforestation and reforestation potential of various tree species (hybrid poplar, conifers, walnut, willows)
- **Recent work**:
  Two generic bioeconomic models have been developed to address various questions about the carbon economics of plantations and managed forests, wood for bioenergy, and more recently alien species impact and risk assessments:

  CFS-AFM:
  - Spatially explicit, simple carbon sequestration algorithm, Faustmann-type land value calculus

  CFS-FBM:
  - Spatially explicit and generic
  - Finite time horizon, annual accounting of costs, yields and carbon
  - Annual economic outputs (cash flows, NPV and break-even unit prices)
  - Carbon budget model based on CFS-CBM2 principles
  - Project-level accounting (including tonne-year carbon)
  - Heuristic harvest allocation and invasive species models

The option pricing in a land use change context

- Landowners usually face many options of uncertain value
- The time required to establish and grow trees versus crops introduces a real option value for remaining in agriculture (or forestry)
- Choosing one option means the other options may be lost.

- Land owner's choice

  = ***max*** [Convert to agriculture; Convert to forestry; Postpone decision]

We represent the opportunity to do a land use conversion as a European call option and use the modified Black-Scholes European spread option:

For the current land use S_1 and the alternative land use S_2:

$OV = max[S_2 - S_1 - C; 0]$ where $S_2 - S_1 - C = [S_1 e^{[b_1 - r]T^*} + Ce^{-rT^*}][S \cdot N[d_2] - N[d_1]]$

and $d_1 = d_2 - \sigma\sqrt{T^*}$ $\quad d_2 = \dfrac{\ln S + \left(\dfrac{\sigma^2}{2}\right)T^*}{\sigma\sqrt{T^*}}$ $\quad S = \dfrac{S_2 e^{[b_2 - r]T^*}}{S_1 e^{[b_1 - r]T^*} + Ce^{-rT^*}}$ $\quad F = \dfrac{S_1 e^{[b_1 - r]T^*}}{S_1 e^{[b_1 - r]T^*} + Ce^{-rT^*}}$

and $\sigma \approx \sqrt{\sigma_2{}^2 + (\sigma_1 F)^2 - 2\rho\sigma_2\sigma_1 F}$ and S_1 and S_2 follow a random walk process

Model and data assumptions

Land use bioeconomic model (agriculture-forestry interface):

- Spatially explicit, annual accounting of NPV, yields and carbon values
- 18-pool carbon budget model, permanent/temporary carbon offset options
- Links the optimal forest rotation with the option value calculus (numerically)

Data:

- **Biophysical data** – site suitability maps, regional yield tables, carbon model constants, decay rates and related climate variables
- **Agricultural land base** – Alberta SRD Land inventory data
- **Silvicultural costs and plantation yields** – Anderson et al. (2007)
- **Harvest / hauling costs** – FERIC transportation model
- **Price path for ag. and forest commodities** – Univ. of Alberta econometric model
- **Price path scenarios :**

  μ_{for}/μ_{ag} (Drift $_{\text{(wood price)}}$ / Drift $_{\text{(agric. price)}}$) = **0.5 (baseline), 1.5** and **3**

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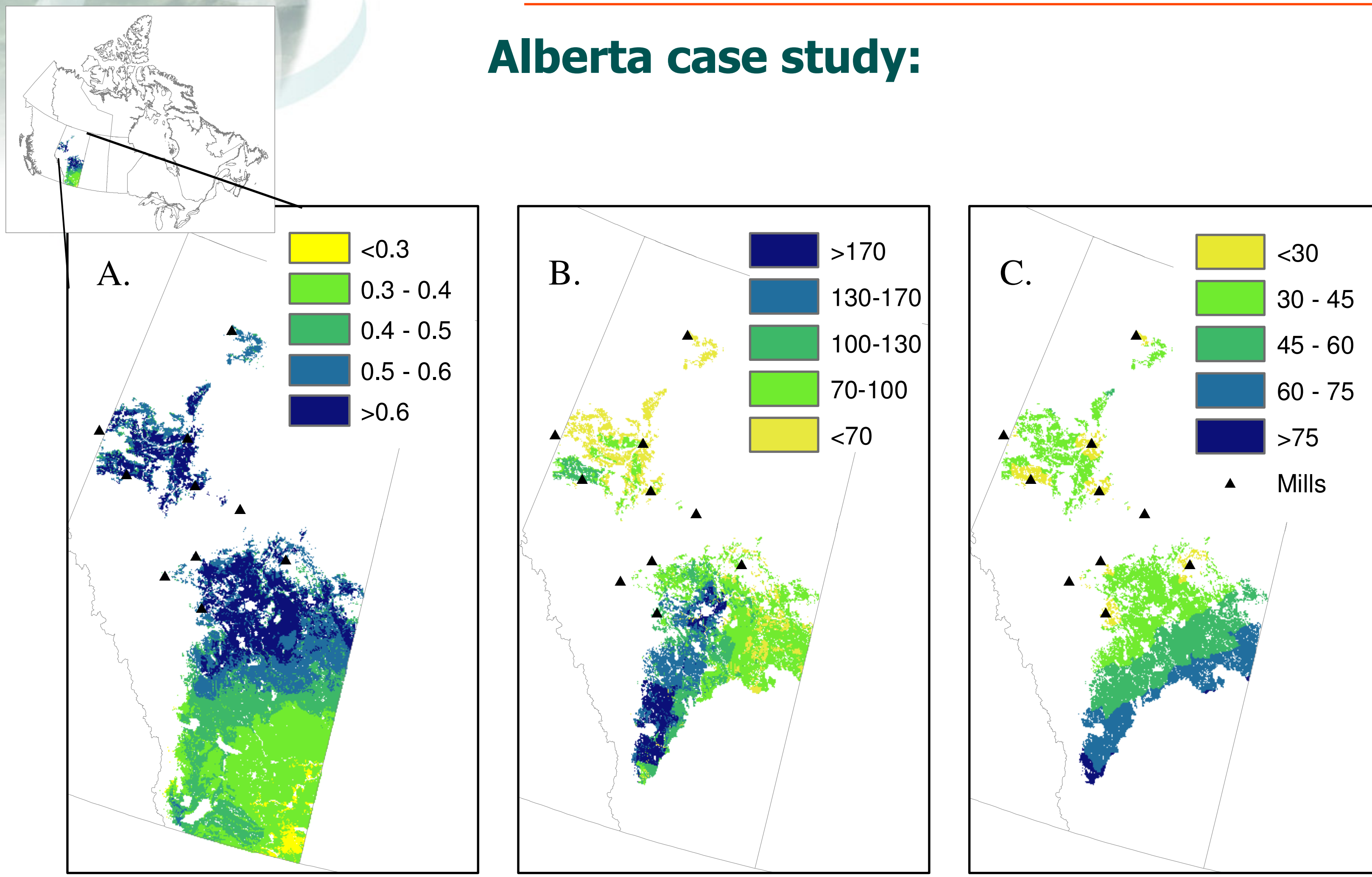
Key spatial inputs

Alberta case study:



Forest site productivity [0;1]

Net agricultural revenues $/ha/year

Fibre transportation costs, $/m^3

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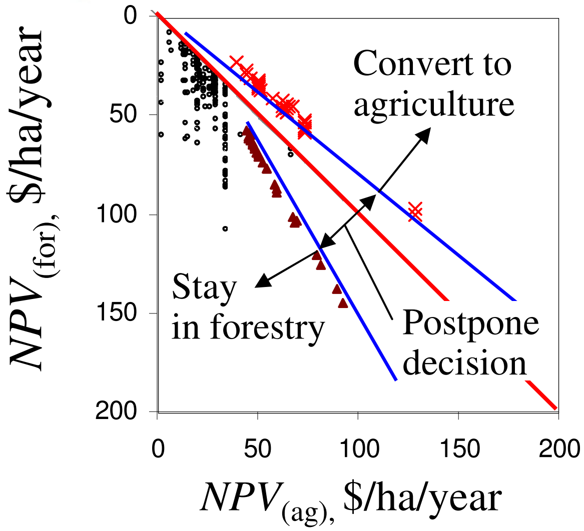
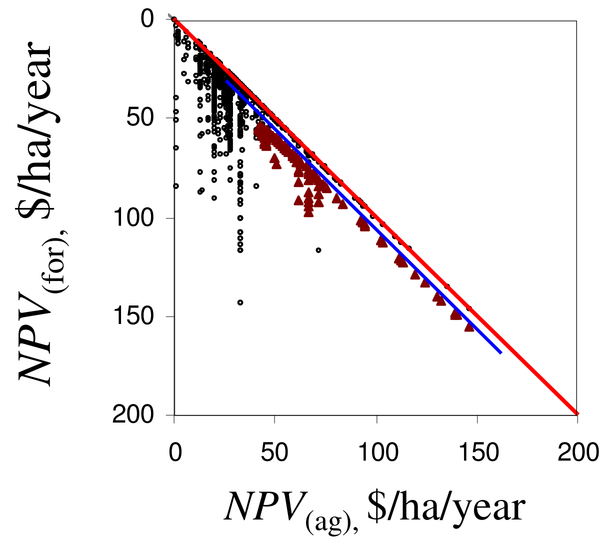
Option value and the land conversion decision

Successful (attractive) land use conversions

$\mu_{for}/\mu_{ag} = 0.5$ (baseline)



$\mu_{for}/\mu_{ag} = 1.5$

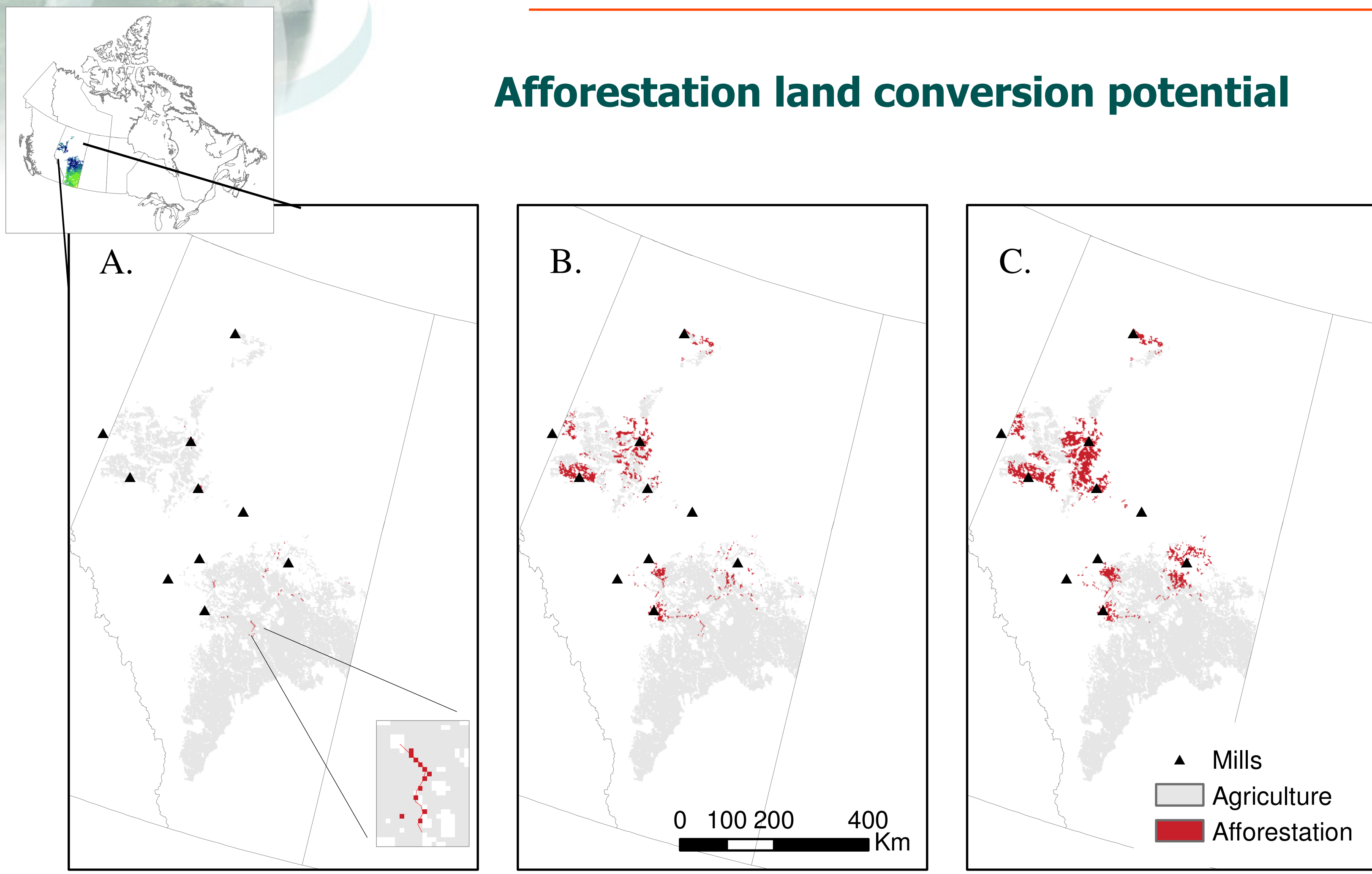


Conversions from agriculture to forestry: · NPV-only scenario, ▲ NPV+OV scenario

Conversions from forestry to agriculture: × NPV+OV scenario

Afforestation potential

Afforestation land conversion potential



NPV+OV	NPV+OV	NPV only
μ_{for}/μ_{ag} = 0.5 (baseline)	μ_{for}/μ_{ag} = 3	μ_{for}/μ_{ag} = 3

Land use change projections

Land use dynamics over time, million ha

μ_{for}/μ_{ag} scenario:	0.5 (baseline)				1.5		3	
Conversion[1]:	Ag.->For.		For.->Ag.		Ag.->For.		Ag.->For.	
Option value use[2]:	Yes	No	Yes	No	Yes	No	Yes	No
Period, years								
Right now	0.022	0.083	-	-	0.032	0.248	0.070	0.674
2 - 10	0.0004	-	-	-	0.001	0.014	0.070	0.154
11 - 20	0.002	-	-	-	0.010	0.017	0.104	0.156
Total over 20 years	0.024	0.083			0.043	0.28	0.24	0.98
Total over 55 years	0.035	0.083	0.0004	0.017	0.103	0.33	0.8	1.39

[1] "Ag.->For." – Conversion of agricultural land to forest plantations;
"For.->Ag." – Conversion of forest plantations to agricultural land after harvest.

[2] "Yes" – Land conversion metric includes the option value premium;
"No" – Land conversion metric is a static *NPV* value.

Concluding comments

- The results paint a more conservative perspective for plantation forestry and confirm the current situation in the Canadian Prairies
- Currently, afforestation activities are likely to remain linked to specific ecologically suitable sites for growing trees
- Marginal lands could be equally bad for both agriculture and forestry, and thus tend to experience more frequent land use conversions
- The approach works ... more policy questions can be addressed:
  - Carbon prices required to induce afforestation
  - Impacts of biotechnology and new emerging markets (bioenergy)
  - Climate change scenarios (shifts of climate zones and future uncertainties)
  - Landowners' behavior, responses to price signals and risk aversion
  - Deforestation scenarios

  Some issues:
  - Geographical variation of costs and agricultural production values
  - Temporary carbon prices and timing of carbon offsets
  - Endogenous price dynamics and market volatilities