Linking KNN maps with the allowable cut optimization model: Case study of Valcartier Forest

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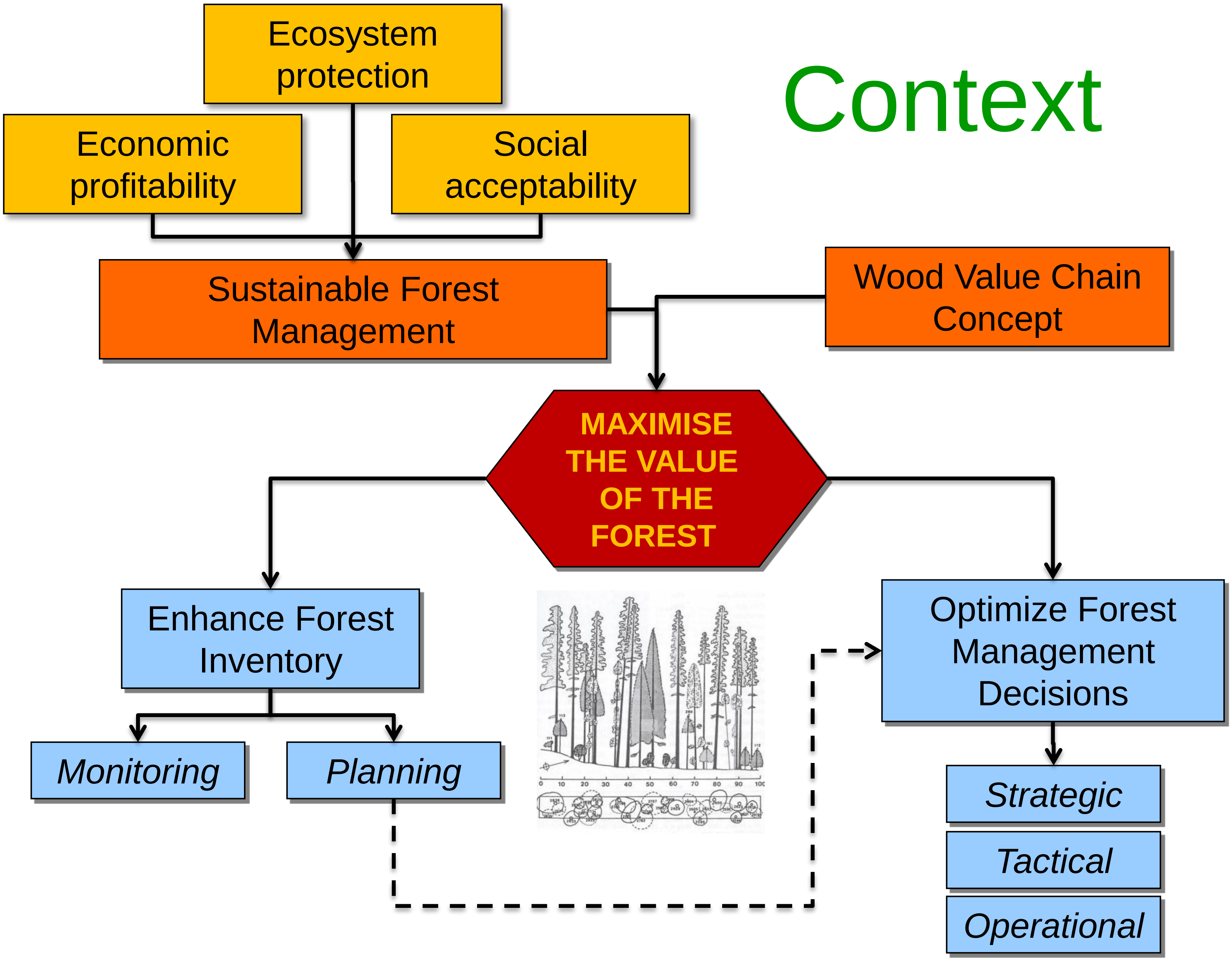
Context


Ecosystem protection
Economic profitability
Social acceptability
Sustainable Forest Management
Wood Value Chain Concept
MAXIMISE THE VALUE OF THE FOREST
Enhance Forest Inventory
Monitoring
Planning
Optimize Forest Management Decisions
Strategic
Tactical
Operational

Objective

To integrate forest inventory, forest growth forecast and optimization methods by:

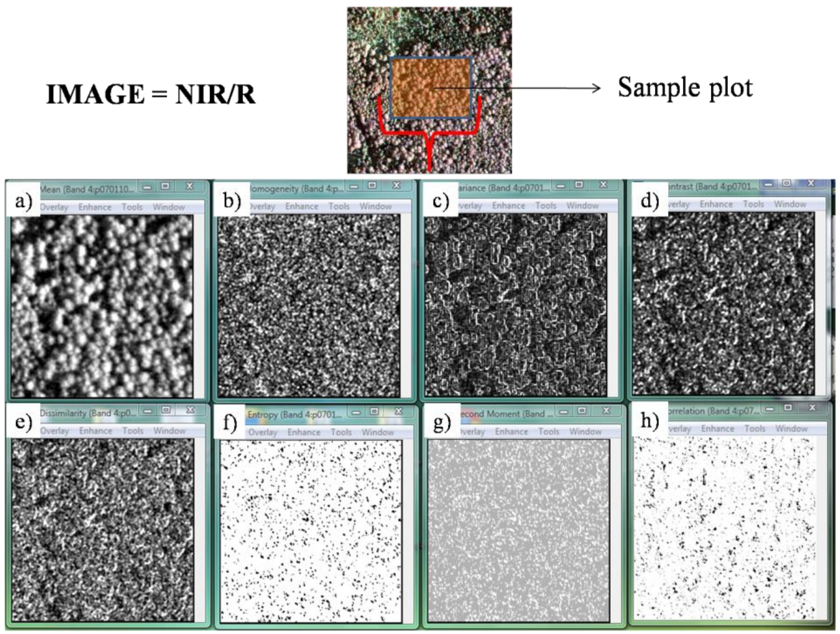
1. Using the KNN method to produce a stand table map.
2. Using operational research methods for optimizing strategic forest management decisions.

Using KNN method to produce the stand table map: MSN technique

- MSN (most similar neighbour) is a variant of k-NN,
- It utilises canonical correlation analysis to create a linear combination of the variables that maximises the correlation between the **X** and **Y** variables,
- The canonical variables created are then used to calculate the distance between the reference and the target sets

Reference: Moeur, M. and Stage, A. R. (1995). Most similar neighbor : An improved sampling inference procedure for natural resource planning. Forest Science, 41(2):337–359.

Using KNN method to produce the stand table map: Textural data of the aerial photo

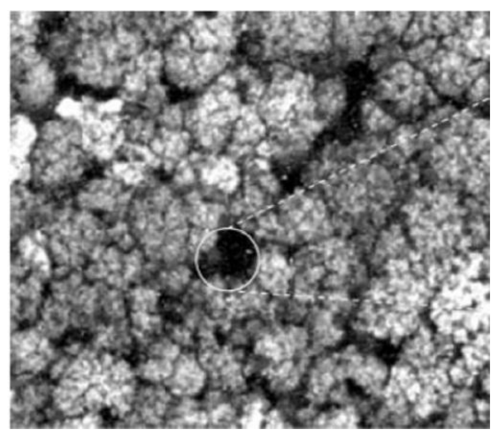


a) mean, b) variance, c) homogeneity, d) contrast, e) dissimilarity, f) entropy, g) second moment and h) correlation.

Principle: ground plot data are the Y variables while photo data are used as X variables

X variables: textural data of a pixel window.

Y variables: number of trees by dbh class and by species group



Tree canopy determining the texture in the image subset of 30m x 30m

Tree groups

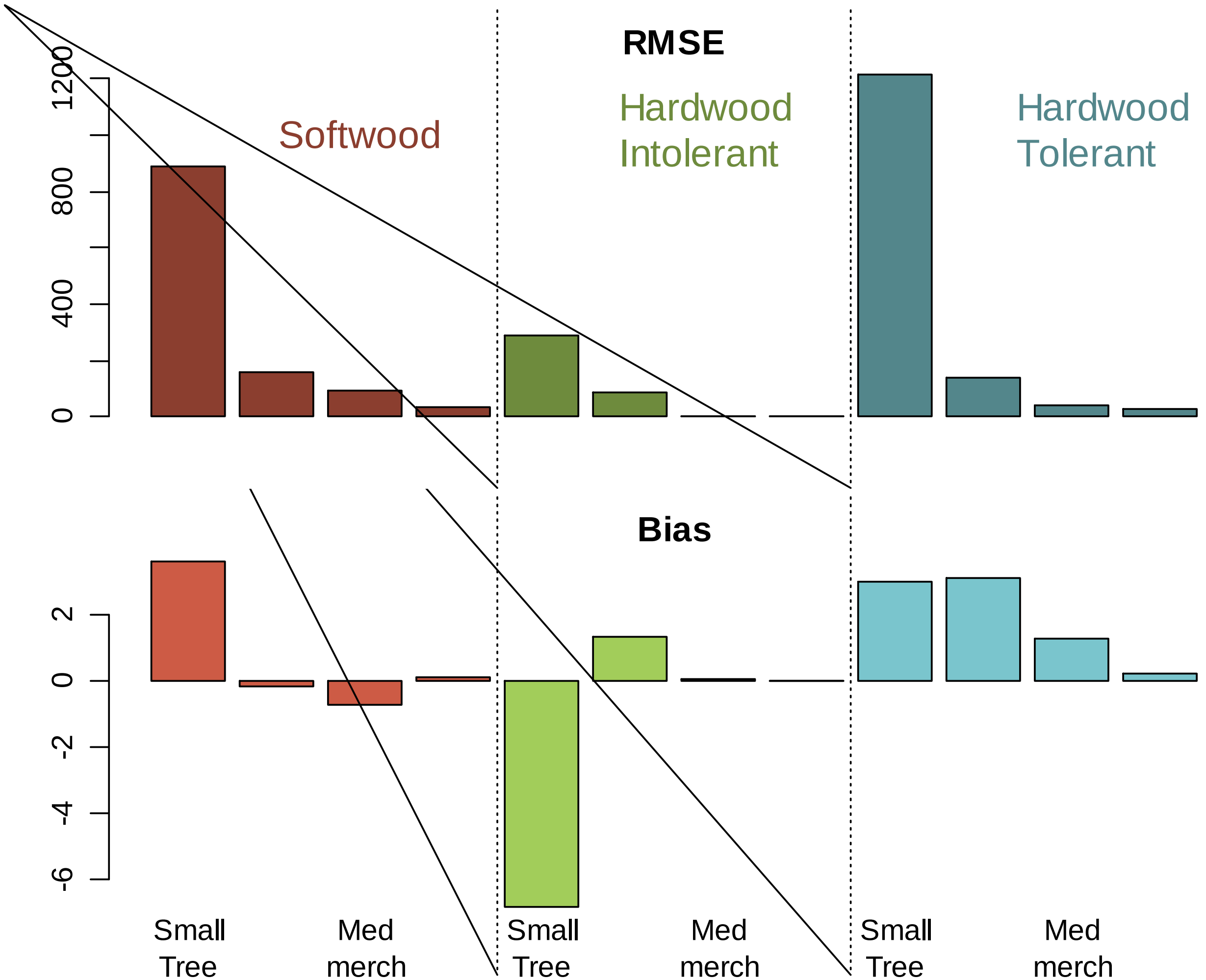
Trees are grouped by

1. Size class (DBH)
2. Species group
    - ***Option 1***: *Softwood, Hardwood*
    - ***Option 2***: *Softwood, Tolerant Hardwood, Intolerant Hardwood*

Size class	Softwoods	Hardwoods
Sapling	1-9cm	1-9cm
Poles	9-15cm	9-25cm
Small Timber	15-25cm	25-35cm
Large Timber	25cm+	35cm+

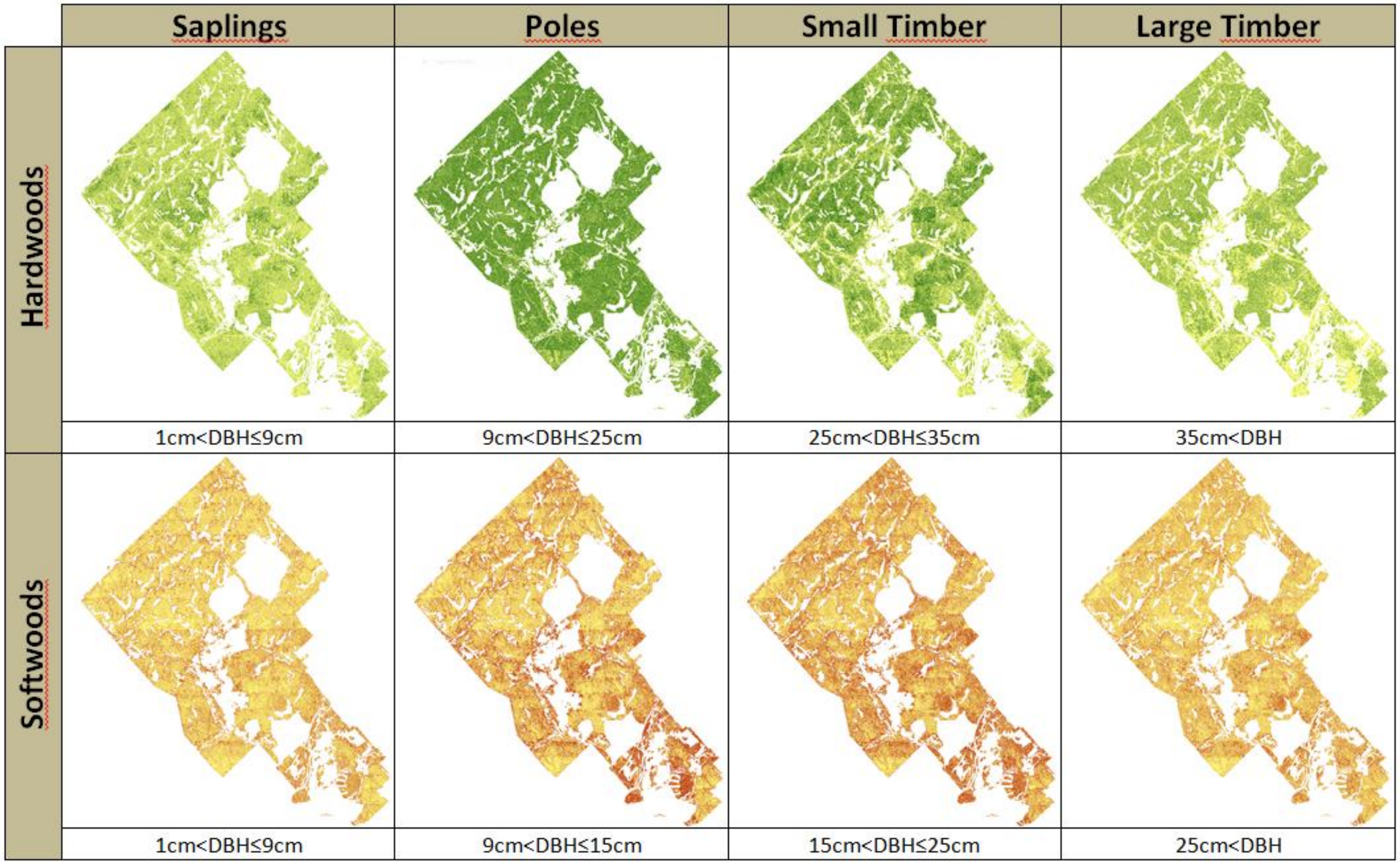
Using KNN method to produce the stand table map: Result option 1

Using KNN method to produce the stand table map: Result option 2



Stand Table Map: Result

Valcartier Forest: 200 km^2



Using Biolley Optimization Model for Strategic Forest Planning : Goals

Key decision of Strategic planning

1. Definition of forest management goals
   a. Products & Services
   b. Ecosystem protection
2. Definition of policies & guidelines for the tactical and operational planning

Purpose of Strategic modeling

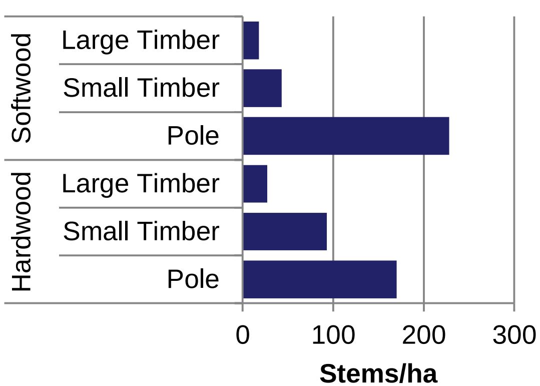
- To assess the possible impacts of policies & guidelines on forest management outcomes
- Coarse scale
- Non spatial

Using Biolley Optimization Model for Strategic Forest Planning: Forest Growth Model

$$y_{t+1} = G \times (y_t - h_t) + I_t$$

Variable	Description	Notes
y_t	Vector of the number of standing trees/ha per tree class at time t	*y_1 is an average given by the KNN inventory*
G	5-yr Transition matrix	*Calibrated with PSPs*
h_t	Vector of the number of harvested trees/ha per tree class at time t	*Decision variables*
I_t	Vector of the number of new trees/ha at time t (ingrowth)	*Predicted by a linear function of y_t* *Calibrated with PSPs*
t	5-years Time steps (from 1 to 30)	

KNN inventory



TRANSITION MATRIX			Initial stage					
			Hardwood			Softwood		
			Pole	Small Timber	Large Timber	Pole	Small Timber	Large Timber
Final stage	Hardwood	Pole	0,91	0,00	0,00	0,00	0,00	0,00
		Small Timber	0,06	0,96	0,00	0,00	0,00	0,00
		Large Timber	0,00	0,02	0,98	0,00	0,00	0,00
	Softwood	Pole	0,00	0,00	0,00	0,83	0,00	0,00
		Small Timber	0,00	0,00	0,00	0,04	0,88	0,00
		Large Timber	0,00	0,00	0,00	0,00	0,02	0,96

Using Biolley Optimization Model for Strategic Forest Planning : Goals

Strategic goals for the Valcartier forest

1. Maximize harvest revenues
2. Sustain non-declining revenues over 150 yrs
3. Protect the integrity of the forest ecosystem

Ecological issues

a. Species composition
b. Diversity of stand and landscape structure
c. Number of large trees (standing & dead)

3 policy alternatives	Strategic Goals
I. Free harvest	1
I. Non-declining revenues	1+2
I. Non-declining revenues + Production of >40% Large tree after 100 yrs	1+2+3 (issue C)

Using Biolley Optimization Model for Strategic Forest Planning: Objective and Constraints

$$max \sum_{t=1}^{30} h_t v c_t$$

	Contraints	Notes
1	$h_t \leq y_t$	*Cut less than stock*
2	$h_t \geq 0$	*Nonnegative harvest*
3	$h_{t+1} v \geq h_t v$	*Non-declining revenues*
4	$h_{29} = h_{30}$	*Steady-state of the last two periods*
5	$l_t \geq 0{,}40$ *for* $t \geq 20$	*Maintenance of 40% large trees after 100 yrs*

Variable	Description
y_t	*Vector of the number of standing trees/ha per tree class at time t*
h_t	*Vector of the number of harvested trees/ha per tree class at time t*
v	*Vector of stumpage value per tree category*
c_t	*Compound factor for time t*
l_t	*% of basal area of large trees*
t	*5-years Time steps (from 1 to 30)*

3 policy alternatives	Constraints
Free harvest	1+2
Non-declining yield	1+2+3+4
Non-declining yield + Production of >40% Large tree after 100 yrs	1+2+3+4+5

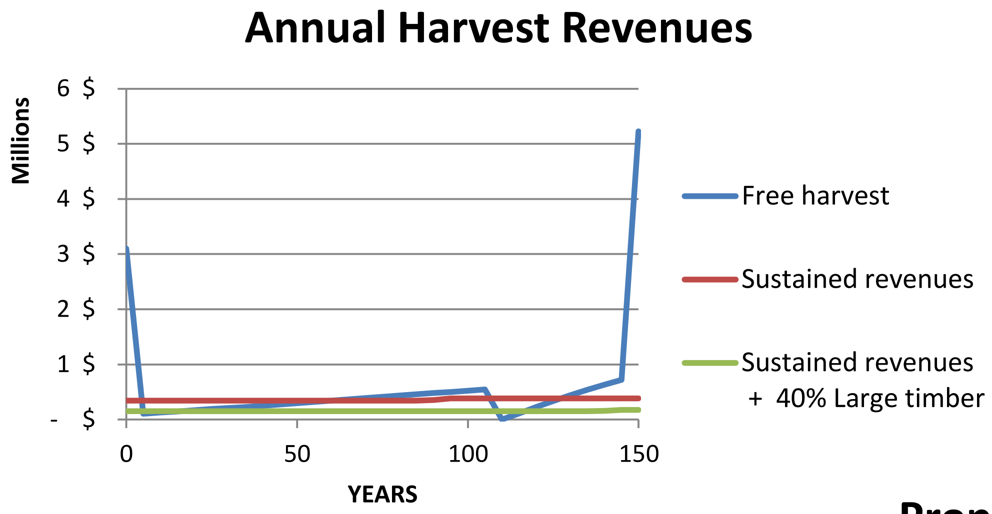
Using Biolley Optimization Model for Strategic Forest Planning: Results

Policy	Average Harvest		NPV	
	Volume	Revenues		
	m^3/yr	$/yr	$	Comparison
Free harvest	112 000	584 000	23 158 000	100%
Sustained revenues	33 000	359 000	11 922 000	51%
Sustained revenues + 40% Large timber	17 000	152 880	5 194 000	22%

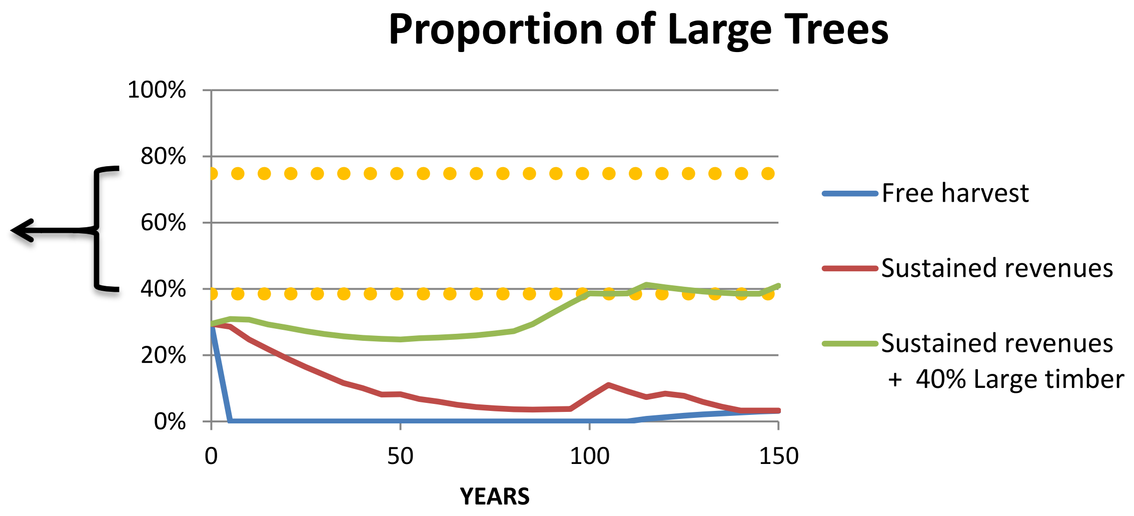
In comparison to free harvest…

- A non declining revenue policy reduces the NPV by 50%
- Adding a policy to maintain large trees decreases the NPV by 78%

Using Biolley Optimization Model for Strategic Forest Planning: Results



Expected range of variation for the unmanaged forest over the next 1 000 yrs



Conclusions

The produced KNN stand table map has made possible the application of ecosystem sustainability concept with indicators of tree size, species diversity for optimizing the allowable cut.

This application of the stand table map based on KNN method to optimize the timber harvesting is a first in Canada.

Next steps:
(1)mapping of gaps and regeneration
(better silviculture prescriptions, monitoring & ingrowth predictions)
(2)tactical decision model adapted to uneven-aged management of heterogeneous stands.

The ability to integrate the wood value chain concept requires a strong link between strategic/tactical/operational plannings. This is possible thanks to the flexibility of the KNN method :

- it considers several response variables and multiple ancillary variables at the same time,
- The results that can be easily compiled to different levels of resolution for different planning needs.