Millar Western Forest Products Ltd.

Biodiversity Analysis of the Preferred Forest Management Scenario

Frédérik Doyon, PhD, RPF

In collaboration with Robin Duchesneau and Stephen Yamasaki

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EXECUTIVE SUMMARY

Biodiversity values have been assessed by applying a suite of indicator models to the Preferred Forest Management Scenarios (PFMS) derived from the Timber Supply Analysis Impact Assessment Group on FMU W13 and FMU W11 of Millar Western Forest Products FMA. Biodiversity indicator models used in this analysis encompasses several dimensions of biodiversity and can be directly linked to many VOITs (Values, Objectives, Indicators, and Targets) required by Alberta's planning standards. These indicator models cover a) stand internal habitat features, b) ecosystem diversity, c) landscape spatial configuration, and d) habitat supply models.

The same indicator models were also applied to a random selection of 40 steps selected from ten 500-year simulations of landscape dynamics under the natural disturbance regime (NDR) in order to define the Natural Range of Variation (NRV) for these indicators and, hence, being able to assign forest management targets. Simulations were obtained using the Athabasca Plains Landscape Model (APLM, Yamasaki et al. in preparation) that reproduces the fire disturbance regime for the area.

The risk of losing biodiversity values in applying the PFMS was addressed by assessing how many times an indicator was outside the NRV and by the temporal trend of the indicator over the simulation horizon. Based on these two principles, we developed a risk assessment scheme defining the risk level and the time horizon at which the risk will be fully expressed.

For W13 and W11, in regards of ecosystem diversity indicator, we found:

- None the indicators that are related to the forest age are indicating an important deviation from the NRV. In fact according to the NDR, more younger seral stage openings should be produced, particularly in Hw and HwMix cover type;

- There is a loss in ecosystem diversity under the PFMS for both FMUs. There are not enough young seral stages in "Hw" and HwMix" cover types and the proportion of old seral stages of the softwood-dominated mixedwood is too low in both FMUs. Moreover, the proportion of the hardwood in the landscape is reduced over time even though it is already low from the start. Low-density stands are reduced with time under the level that it is suspected to be non-natural, particularly in W13.

In regards of landscape fragmentation, we found:

- W13 under the PFMS is more contrasted than under the NDR while for W11 it is similar.
- Patch size distribution under the PFMS is in general similar to the one under the NDR although there are more large patches under the NDR.
- OLD GROWTH core area is not a problem in both FMUs as it exceeds the NRV
- OLD GROWTH patches are less connected under the PFMS than under the NDR for the "Hw", "HwMix" in both FMUs, and for the "SwMix" in W11 while "Sw" OLD GROWTH patches connectivity is comparable.

In regards of internal forest stand structure, we found:

- In W13, the special elements that are specifically of concern are the downed woody debris, the amount of Aw and Pb in the stand, and many understory vegetation covers (ground lichen, herbaceous cover and different shrub type covers).
- The special elements particularly of concern in W11 under the PFMS scenarios are the DWD volume, the ground lichen cover, and the herbaceous cover.

In regards of wildlife habitat suitability, we found the following species are a high priority concern as identified in the following table:

W13		W11	
Speceis	**Starting within NRV?**	**Speceis**	**Starting within NRV?**
American Marten	No	American Marten	Yes
Canada Lynx	No	Canada Lynx	No
Least Flycatcher	No	Least Flycatcher	No
Northern Flying Squirrel	No	Snowshoe Hare	Yes
Pileated Woodpecker	No	Southern Red-Backed Vole	Yes
Snowshoe Hare	No		
Southern Red-Backed Vole	No		
Three-toed Woodpecker	Yes		
Woodland Caribou	No		

In W13, all but one species is currently outside the NRV, while in W11 the situation is better with two of three species outside the NRV. Recommendations are made for attenuating the impact of the PFMS to these biodiversity values of high priority.

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1. Introduction

Biodiversity conservation in managed forests has been recognised by scientists as a cornerstone for ensuring forest sustainability (Burton et al. 1992, Gustafsson and Weslien 1999). Nowadays in forestry, maintaining biodiversity while using the forest for human uses, like timber, has become the major challenge of applying the paradigm of ecosystem management (Hunter 1990, Noss 1993, Grumbine 1994). As humans better understand ecosystem functioning and the numerous relationships among its elements, which interact at different scales, we, at the same time, just start to measure the challenge of managing such complexity. The tools traditionally used are now outdated by the complexity of the overall system. Forest managers are thus in needs for strategic planning analytical tools for assessing alternative management strategies in terms of biodiversity values (Daust and Sutherland 1997).

In order to help forest managers to include biodiversity in their forest management value assessment, we developed an analytical procedure and a strategic planning toolbox (Biodiversity Assessment Project Toolbox) (Doyon and Duinker 2003). In the BAP approach, potential responses of the forest to forecasted actions are simulated using projection tools and relevant indicator models are applied to the projections to track changes in abundance or quality of valuable forest conditions. The analysis of the indicator model outcomes leads to a reformulation and retesting of the management strategies until an acceptable management strategy is achieved (forecasting loop). Such a portrayal is consistent with well-established frameworks for adaptive management (Walters 1986).

The Biodiversity Assessment Project (BAP) has first been applied for the publicly owned forest managed by Millar Western Forest Products in Alberta (Doyon and Duinker 2003, Messier et al. 2003, Van Damme et al. 2003). In this document, the BAP toolbox have been improved to reflect the requirements of the new forest management strategy and has been applied to the finial selected forest management scenario.

The goal of this project was 1) to identify which biodiversity values could be possibly at risk if the new forest management strategy is applied by applying the BAP toolbox and comparing the results to a baseline scenario that would reflect the forest conditions under the natural disturbance regime, 2) to assess the risk, and 3) to propose recommendation for attenuating the risk.

2. Methodology

2.1 Simulations

2.1.1 PFMS

In this project, we compared two scenarios. The first scenario we used was coming from the Timber Supply Analysis Impact Assessment Group (TSA IAG) and was representing a forest management scenario that is presented in the Detailed Forest Management Plan (DFMP). This scenario is called the Preferred Forest Management Scenario (PFMS). It is generated under the Patchworks environment and is spatially explicit. The PFMS simulation covers a horizon starting at year 2006 and ending at year 2211. Simulation steps are generated every 5 years (hence creating 41 steps for the simulation horizon). Analyses in the BAP Toolbox of the PFMS are completed in a raster environment and the pixel size is 16th of a hectare. For the purpose of understanding the contribution of the unmanaged portion of the landscape to the biodiversity, certain indicators were reported separately for the managed and the unmanaged portion of each FMU.

2.1.2 NDR

The Natural Disturbance Regime scenario has been generated with the Athabasca Plain Landscape Model (APLM) with the empirical stochastic fire sub-model (Yamasaki et al, in preparation). This sub-model generated fires based on an observed distribution of fire size and recurrence. Following stand dynamics is depending on a regeneration model that takes into account the in situ and ex situ availability of propagules for each species and the establishment probability according to the microsite availability on a specific site. Depending on the regeneration obtained and the site, APLM select a stand development curve. The stand characteristics of each stand development curve have been simulated under the FORECAST model (see Duchesneau et al., in preparation for details). Analysis in the BAP Toolbox of the

NDR are completed in a raster environment and the pixel size is 16th of a hectare although simulation in the APLM is completed at a 1 ha resolution.

2.2 Applying the BAP toolbox

The Biodiversity Assessment Project (BAP) toolbox (Doyon and Duinker 2003, Messier et al. 2003, Van Damme et al. 2003) has been applied to the 41 steps of the PFMS scenario and the 40 steps of the NDR scenario, separately by FMU (W11, W13). Many of the indicators that are used in the BAP toolbox can be directly associated with the Value Objectives Indicators Targets (VOITs) of the planning standards (Table 1).

Table 1. List of biodiversity indicators modeled under the BAP toolbox .

Type	Name	Units
Special Habitat Elements	Arboreal lichen index	Dimensionless
Special Habitat Elements	Aw_Poplar %	%
Special Habitat Elements	Coniferous %	%
Special Habitat Elements	Deciduous %	%
Special Habitat Elements	DENS(Live trees, Aw, Pb, d>25&h>7)	ha-1
Special Habitat Elements	DENS(Live trees, Aw, Pb, Sw d>40)	ha-1
Special Habitat Elements	DENS(Live trees, d>25)	ha-1
Special Habitat Elements	DENS(Snags conifers d>=20)	ha-1
Special Habitat Elements	DENS(Snags, d>20)	ha-1
Special Habitat Elements	DENS(Snags, diseased or damaged trees, d>25)	ha-1
Special Habitat Elements	Downed woody debris cover %	%
Special Habitat Elements	Downed woody debris volume	m3 ha-1
Special Habitat Elements	Free-to-Manoeuver-Flying-space index	Dimensionless
Special Habitat Elements	Fruit-bearing shrub cover %	%
Special Habitat Elements	Ground lichen %	%
Special Habitat Elements	Height to live crown	m
Special Habitat Elements	Herbaceous %	%
Special Habitat Elements	Low shrub cover %	%
Special Habitat Elements	Low shrub forage %	%
Special Habitat Elements	Shrub cover>0.20m %	%
Special Habitat Elements	Shrub cover>1m %	%
Special Habitat Elements	Stand age	years
Special Habitat Elements	Stand height	m
Special Habitat Elements	Tall Shrub cover %	%
Special Habitat Elements	Willow %	%
Special Habitat Elements	Willow&rose %	%
Ecosystem	Area-weighted age (Mean, 25, 50, 75th %tiles)	years
Ecosystem	OldGrowthness	OG area equivalent
Ecosystem	Age class structure	% of landscape
Ecosystem	Seral stages (Overall)	% of landscape
Ecosystem	Seral stages (by cover type)	% of landscape
Ecosystem	Ecosystem diversity	Dimensionless
Ecosystem	Habitat distribution	% of landscape
Ecosystem	Stand density	% of landscape

Table 1. List of biodiversity indicators modelled under the BAP toolbox (continued).

Type	Name	Units
Landscape	Contrast-weighted edge length	km
Landscape	Mean edge contrast index	Dimensionless
Landscape	Patch size (Mean, 25, 50, 75th %tiles) (overall)	ha
Landscape	Patch size (Mean, 25, 50, 75th %tiles) (by cover type)	ha
Landscape	Patch size (Mean, 25, 50, 75th %tiles) (Old Growth/cover type)	ha
Landscape	Total amount of core area (overall, Old Growth)	ha
Landscape	Core area patch size (Mean, 25, 50, 75th %tiles) (overall)	ha
Landscape	Core area patch size (Mean, 25, 50, 75th %tiles) (by cover type)	ha
Landscape	Core area patch size (Mean, 25, 50, 75th %tiles) (OG/cover type)	ha
Landscape	Patch shape (Mean, 25, 50, 75th %tiles) (overall)	Dimensionless
Landscape	Patch shape (Mean, 25, 50, 75th %tiles) (by cover type)	Dimensionless
Landscape	Patch shape (Mean, 25, 50, 75th %tiles) (Old Gr. by cover type)	Dimensionless
Landscape	Patch connectivity (seral stage)	km
Landscape	Patch connectivity (Old Growth by cover type)	km
Habitat Supply Models	American Marten	Mean SI value (0-1)
Habitat Supply Models	Barred Owl	Mean SI value (0-1)
Habitat Supply Models	Brown Creeper	Mean SI value (0-1)
Habitat Supply Models	Canada Lynx	Mean SI value (0-1)
Habitat Supply Models	Elk	Mean SI value (0-1)
Habitat Supply Models	Least Flycatcher	Mean SI value (0-1)
Habitat Supply Models	Moose	Mean SI value (0-1)
Habitat Supply Models	Northern Flying Squirrel	Mean SI value (0-1)
Habitat Supply Models	Northern Goshawk	Mean SI value (0-1)
Habitat Supply Models	Pileated Woodpecker	Mean SI value (0-1)
Habitat Supply Models	Ruffed Grouse	Mean SI value (0-1)
Habitat Supply Models	Snowshoe Hare	Mean SI value (0-1)
Habitat Supply Models	Southern Red-Backed Vole	Mean SI value (0-1)
Habitat Supply Models	Spruce Grouse	Mean SI value (0-1)
Habitat Supply Models	Three-toed Woodpecker	Mean SI value (0-1)
Habitat Supply Models	Varied Thrush	Mean SI value (0-1)
Habitat Supply Models	Woodland Caribou	Mean SI value (0-1)

SHE indicator models are presented in Doyon 2006 (in preparation). Documentation of the BAP toolbox is available in Duinker et al (2000), Doyon and McLeod (2000a and 2000b), Higgelke et al. (2000) and Rudy (2000).

There are seventeen Habitat Supply Models in the BAP Toolbox (Table 1). Model development procedure is explained in Higgelke et al. (2000). Explanation for each model can be obtained online at (http://giant.lakeheadu.ca/carisweb/hsm/bap_reports/bap_reports_main.htm).

2.3 Analysis

2.3.1 Defining the Natural Range of Variation for biodiversity indicator models

The NDR model has been used for defining the natural range of variation (NRV) of the biodiversity indicator models. To define the NRV, 10 simulations were run over 800 years. As the first hundreds of years can highly be constrained by the initial footprint of the landscape, we sampled steps from the simulation only between year 300 and year 800 (500 years span). Forty simulation steps were randomly selected, 4 by simulation runs.

Biodiversity indicators were then applied to these 40 randomly selected steps. Outputs values were then ranked from lowest to the highest for each bioindicators. The 95% confidence interval (CI95%) was defined by the range between by the 2nd and the 39th values. We used such Monte Carlo approach to define the CI95% instead of any parametrical statistical method because it is not constraint by any assumption on the distribution of the values.

2.3.2 Comparing the values of the bioindicator between the PFMS and the NDR

Biodindicator values under the PFMS were compared to the CI95% obtained under the NDR in different ways. First, means were compared between PFMS and NDR using their corresponding CI95% (SPSS 1988, 2000). Second, we were also interested in observing if a temporal trend was detectable for a bioindicator over the simulation horizon. For example, no difference in mean could be observed but a significant and important declining trend could be showing a gradual, constant long term risk. To do so, linear regression was performed to test for a relationship between a bioindicator and time (SPSS 1988, 2000).

2.3.3 Availability of habitat by suitability classes

To be able to fulfill the VOITs requirements in regards of habitat management, suitability index values had to be translated into Low, Moderate and High suitability class. However, as suitability index (SI) values are not direct population response to habitat suitability but a relative rank of habitats, thresholds that would separate to different quality classes can not be objectively defined without field validation. Nevertheless, we defined a procedure that gives a relative proportion of SI quality classes. To do so, we take the minimum and maximum values observed in all simulation steps coming from the PFMS and the NDR to define the global range observable for a SI and split that range in three equidistant classes. Then, for each step, we computed the area in each of these three classes.

3. Results

3.1 Forest management unit W13

3.1.1 Ecosystem indicator

Forest age

Mean area-weighted average forest age in W13 for the entire horizon is 80 years. It is higher than the CI95% of the NDR scenario by 5 years (Mean+CI95%= 75.3, Table 1.) Area-weighted stand age starts to increase after the first 55 years (2061) and stay below the average in the first 100 years of the horizon (Figure 1). In the first 50 years, the 25th and the 50th percentiles vary drastically, occasioning important forest age structure changes. We see in first 10 years a huge increase in very young forests (as expressed by the lowering of the 25th percentile) that is also detected for the 50th percentile between years 2036-2041 and between years 2076-2086 for the 75th percentile. In the last 100 years of the simulation horizon, the 75th percentile increases to 130 years.

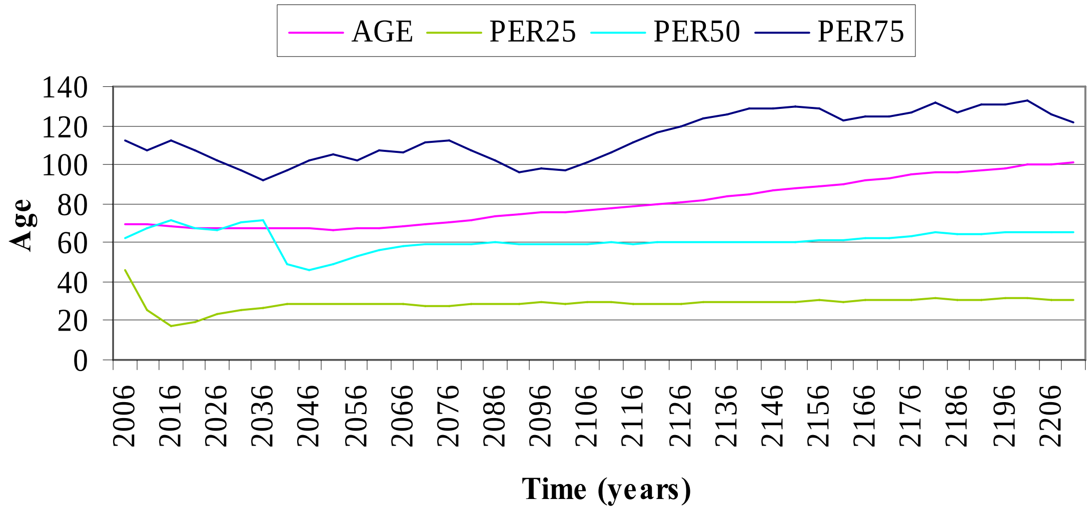

Figure 1. Area-weighted average forest age and 25th percentiles (25, 50 and 75) of area-weighted age of FMU W13 under the PFMS scenario during the next 200 years.

The forested landscape in W13 is aging only on the unmanaged portion of the landbase (Figure 2). Indeed, on the unmanaged portion of the forested landbase, mean area-weighted stand age steadily and linearly increases with time. On the managed portion of the forested landbase, age is reduced during the first 50 years and slowly gets back to the initial age during the next 150 years of the simulation horizon.

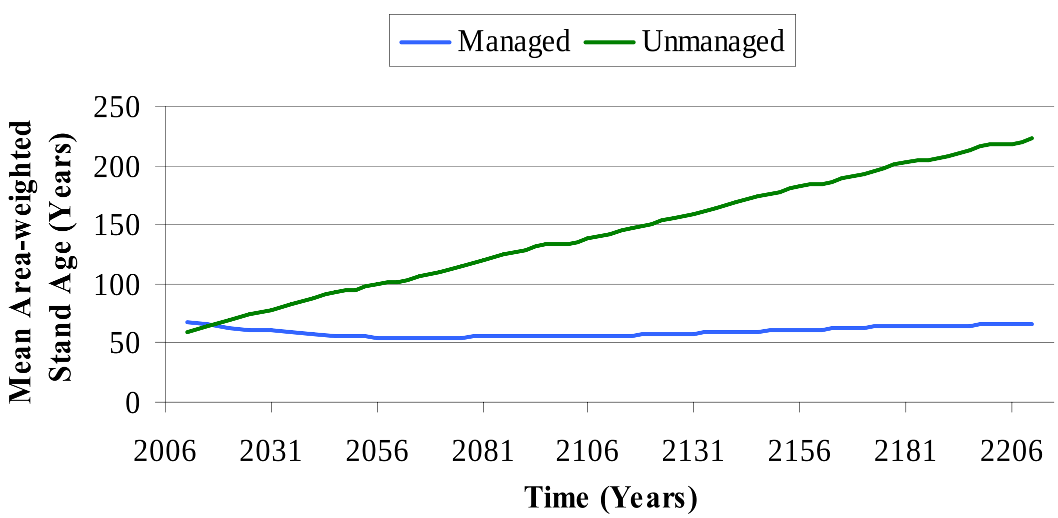

Figure 2. Mean area-weighted stand age on the managed and the unmanaged forested landbase of FMU W13 under the PFMS scenario during the next 200 years.

When compared to the NRV (Table 2), we observed that the 25th and the 50th percentile are close to the upper limit (32 and 62 years respectively). However, the 75th percentile is over the upper bound of the NRV (108 years) for the last half of the simulation horizon.

Table 2. Age structure indicators of FMU W13 under the NDR scenario.

Age structure parameter	Mean	CI 95%
Area-weighted mean	66.52	8.80
25th percentile	20.80	10.74
50th percentile	48.56	13.25
75th percentile	93.44	14.28

The average age class structure of W13 is characterized by a close to uniform distribution portion between 0 to 80 years, followed by a negative exponential distribution (Figure 3). In average, 14% of the landscape will be over 150 years old under that PFMS scenario. However, this average mostly expressing the last 100 years rather than the more bumpy age class structure generated by the surge cut of the beginning of the horizon (Figure 4).

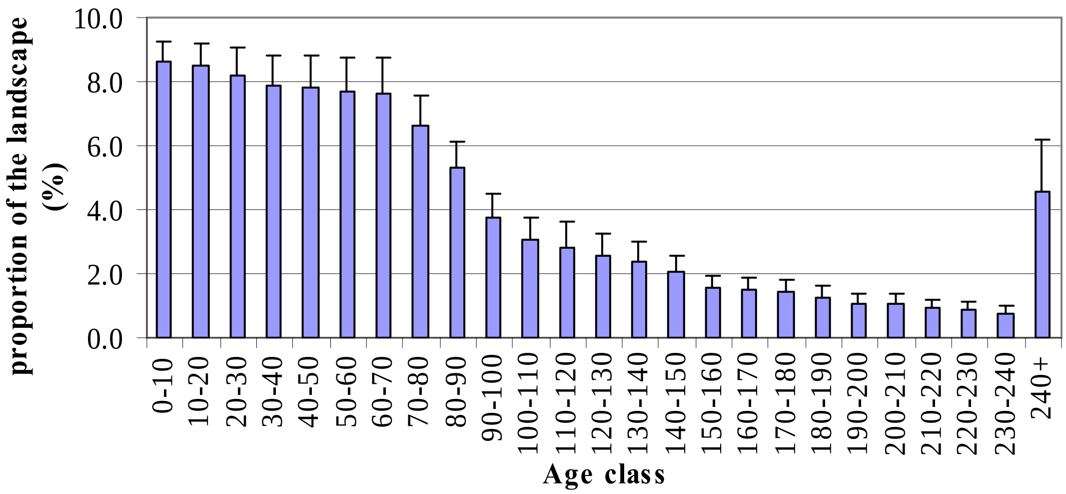

Figure 3. Average age class structure of FMU W13 under the PFMS scenario during the next 200 years. Bars show average proportion of the landscape in that age class and error bars express the +95% confidence interval.

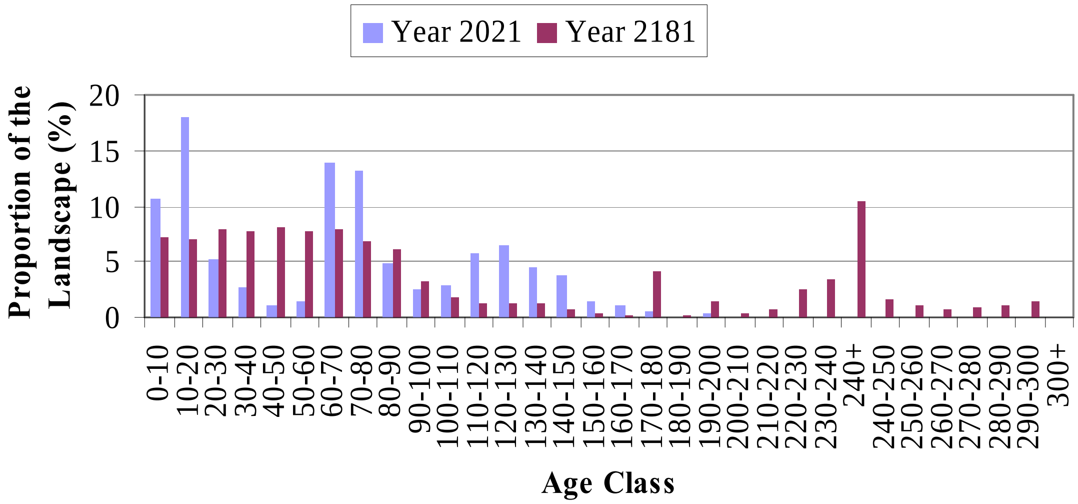

Figure 4. Age class structure of FMU W13 under the PFMS scenario at years 2021 and 2181.

Under the NDR, the mean age class distribution follows an negative exponential distribution with 9.7% of the forested landscape being over 150 years (Figure 5). When compared to the age class distribution under the PFMS, we observe an under-representation of the 0 to 20 age classes and an over-representation of the 50 to 80 years age classes. The proportion of stands of 240 years and more is about the same in the PFMS and the NDR (close to 4%).

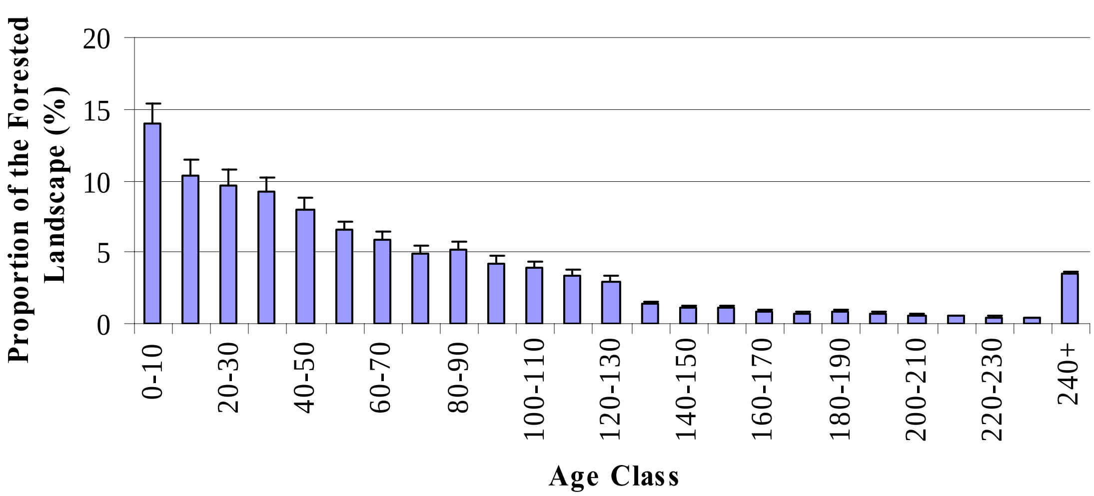

Figure 5. Age class structure of FMU W13 under the NDR scenario. Bars show average proportion of the landscape in that age class and error bars express the +95% confidence interval.

Seral stage

W13 is dominated by YOUNG, IMMATURE and MATURE forests most of the simulation horizon (Figure 6). The proportion of the younger seral stages (CLEARCUT, REGEN, YOUNG, and IMMATURE) is greater on the managed landbase the entire gross landbase. However, on average there is still 6.7% OLD GROWTH on the managed landbase.

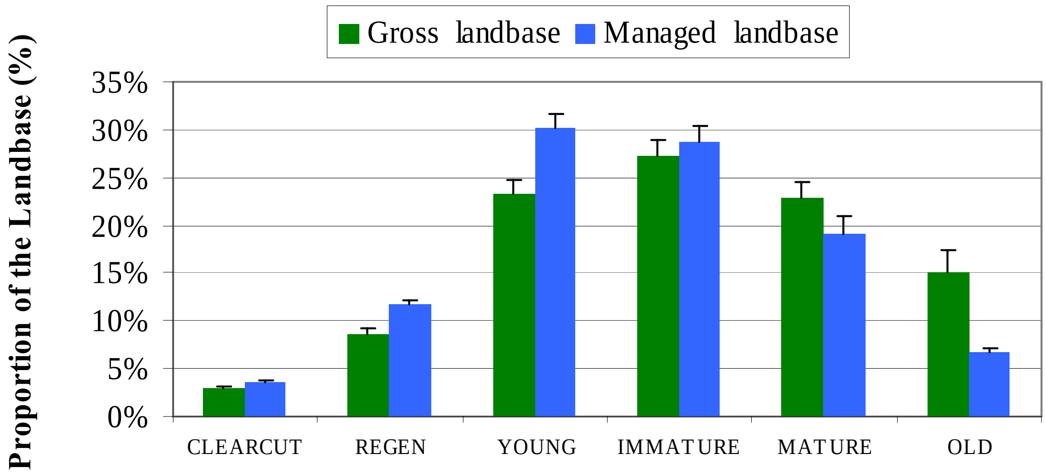

Figure 6. Mean proportion of the different seral stages of the gross and the managed landbase FMU W13 under the PFMS scenario during the next 200 years. Error bars gives the 95% confidence interval.

Under the NDR, proportion of YOUNG, IMMATURE, and MATURE seral stages is similar to the ones observed under the PFMS (Figure 7). We observe less OLD GROWTH and more recent openings (CLEARCUT and REGEN) under the NDR than under the PFMS and these three seral stages are outside the NRV bounds.

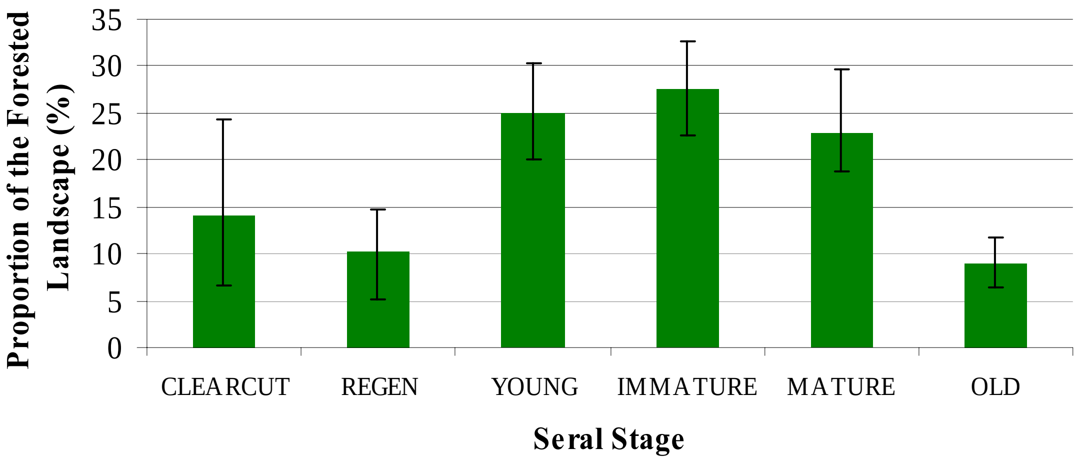

Figure 7. Mean proportion of the different seral stages of FMU W13 under the NDR scenario. Error bars gives the 95% confidence interval.

Looking at the seral stages temporally, we observed, in the beginning of the horizon, an increase in CLEARCUT, REGEN and YOUNG seral stages and followed by a stabilization after 50 years (Figure 8). Also, there is a transfer in area between MATURE and OLD GROWTH all along the simulation horizon.

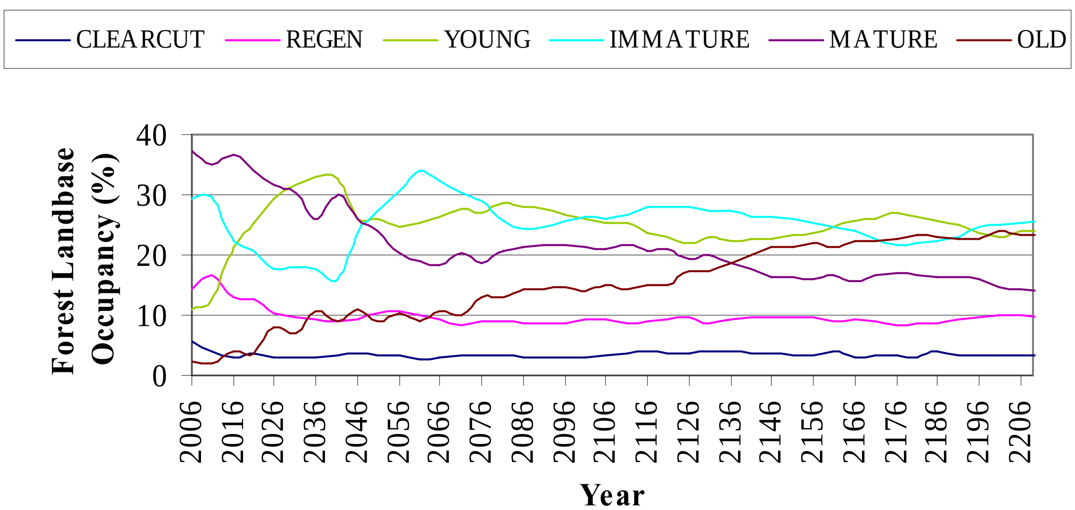

Figure 8. Proportion of the different seral stages of FMU W13 under the PFMS scenario during the next 200 years.

OldGrowthness index does not follow exactly the pattern of the OLD GROWTH seral stage (Figure 9). As, in the OldGrowthness index, late mature stands can partly contribute to the OldGrowthness index, we observe in the beginning a reduction of the OldGrowthness index with the reduction of MATURE and OLD GROWTH stands in the managed landscape. Indeed, on the managed landbase, there is a reduction of 23 000 ha of OLD GROWTH equivalent area during the first half of the simulation horizon. However, compensation of the OLD GROWTH seral stage on the unmanaged landbase allows to inverse the trend and OldGrowthness starts to increase at year 2046 on the gross landbase.

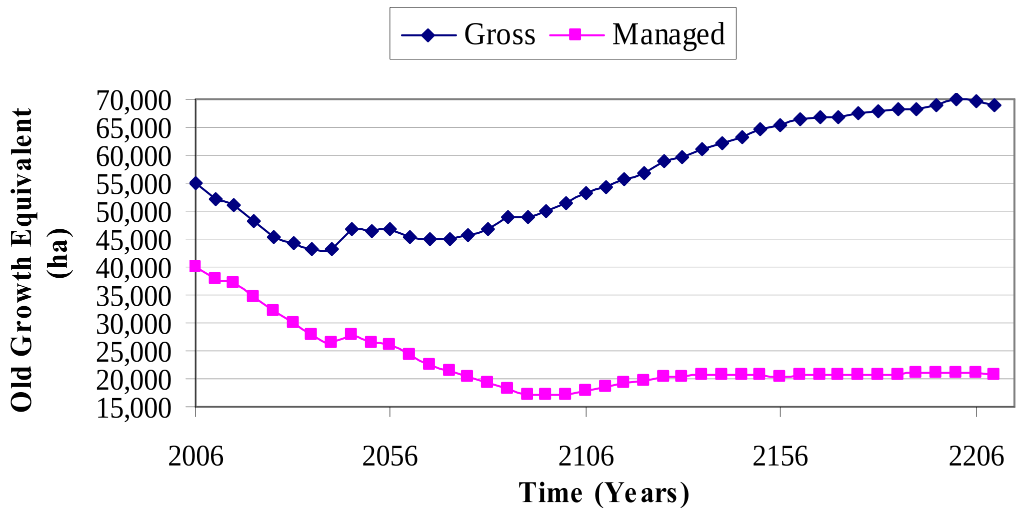

Figure 9. Old Growth area equivalent as computed by the OldGrowthness index on gross and managed landbase in FMU W13 under the PFMS scenario during the next 200 years.

Under the PFMS scenario, the distribution of the seral stages is not homogeneous among the cover types in W13 (Figure 10). Proportionally, OLD GROWTH seral stage is much more important for the "SwMix" and "Sw" cover types while the MATURE sera stage is much more important for the "Hw" and "HwMix" cover types. The "SW" cover type is mostly dominated by YOUNG and IMMATURE cover types.

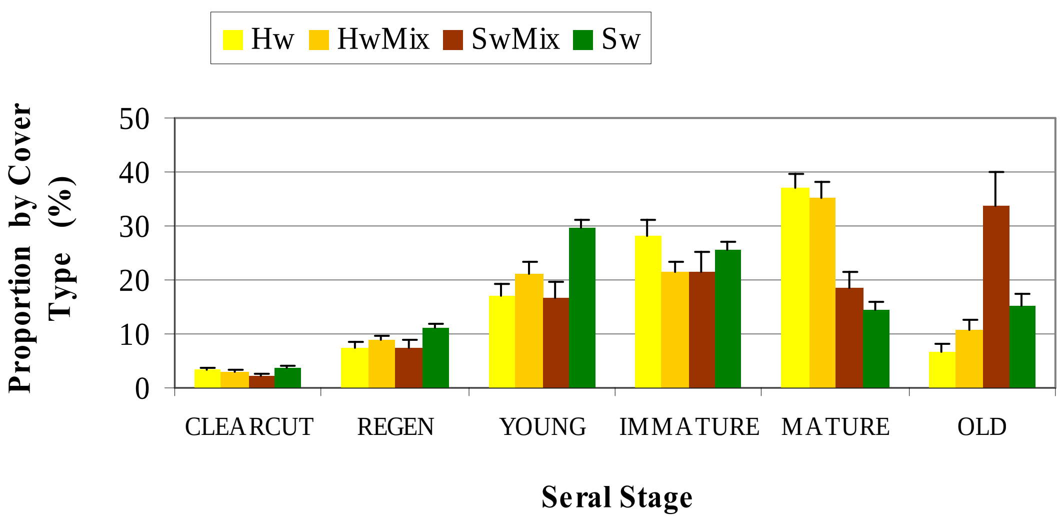

Figure 10. Mean proportion, by cover type, of the different seral stages of FMU W13 under the PFMS scenario during the next 200 years. Error bars gives the 95% confidence interval.

When compared seral stages by cover type with the NDR scenario, two observations can be made. First, CLEARCUT seral stage of “Hw” and “HwMix” under the PFMS scenario is lower than the lower bound of the NRV while the OLD GROWTH seral stage is much higher than the upper bound of the NRV (Figure 10 and Figure 11). Secondly, the seral stage distribution of the “SwMix” cover type under the PFMS is not enough skewed toward the younger seral stages. Consequently, there is more REGEN, YOUNG, and IMMATURE seral stages and less MATURE and OLD GROWTH than observed inside the bounds of the NRV for that cover type. In regards of the “SW” cover type, only the IMMATURE seral stage is outside the NRV.

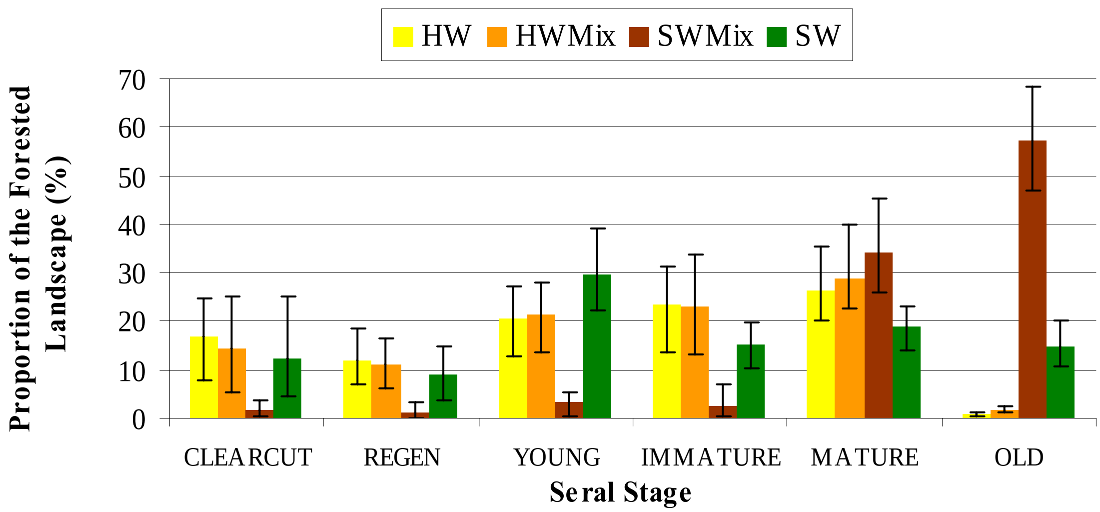

Figure 11. Mean proportion, by cover type, of the different seral stages of FMU W13 under the NDR scenario. Error bars gives the 95% confidence interval.

When looked specifically by cover type, seral stages are much more fluctuating with time, characterized by drastic shifts in seral stage proportion in less then 50 years (Figure 12). For the Hardwood and the Hardwood-dominated mixed cover types, we observe an increase of the YOUNG and IMMATURE seral stages at the expense of the MATURE seral stage. OLD GROWTH seral stage is very low for the HARDWOOD cover type all along the simulation horizon. In the HwMix, it increases, up to 25% of this cover type, and then slowly decreases to almost nothing by the end of the simulation.

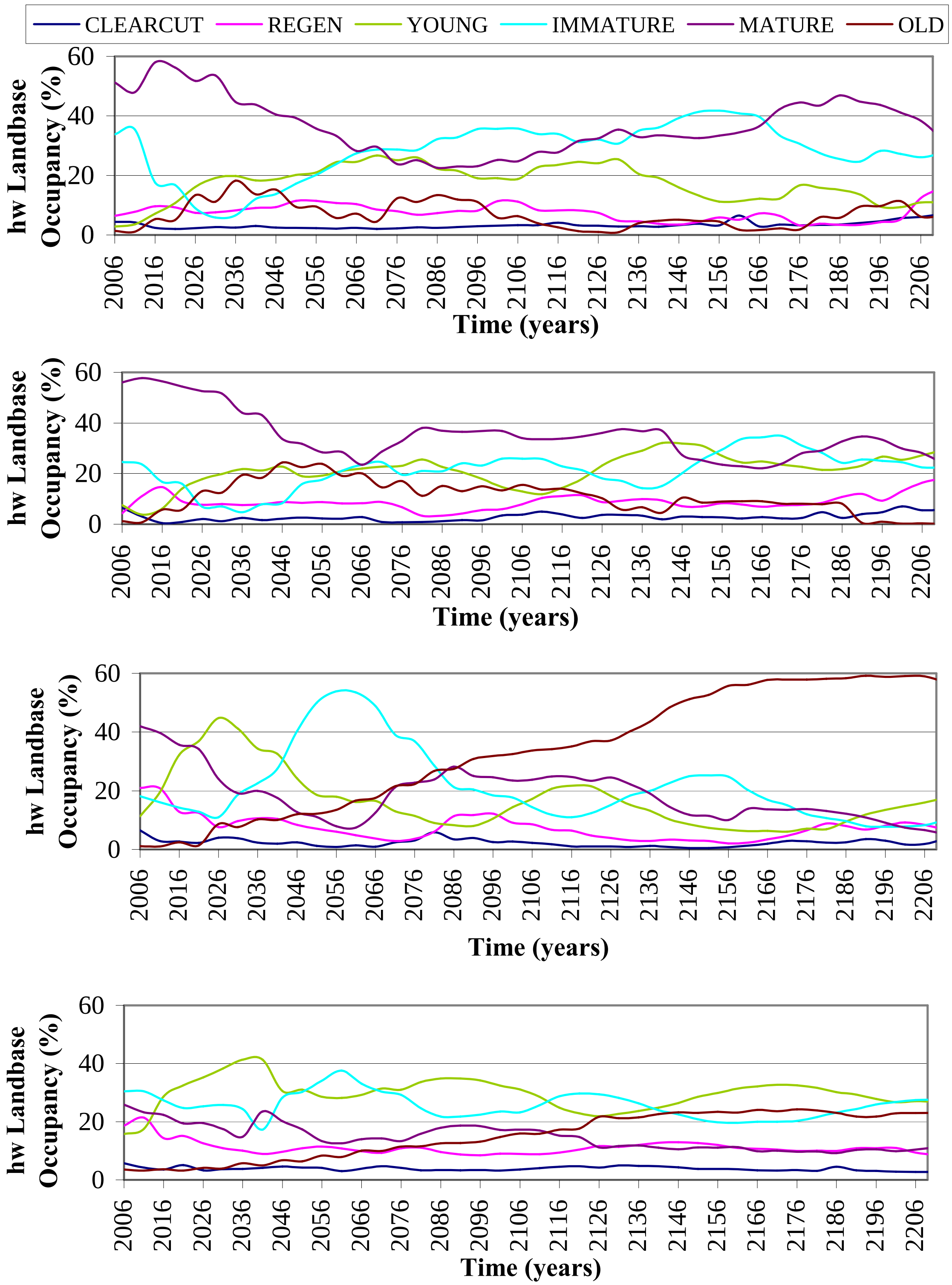

Figure 12. Proportion of the different seral stages of FMU W13 under the PFMS scenario for the four cover types during the next 200 years.

Ecosystem diversity

Ecosystem diversity significantly decreases with time (P<0.001, R2=0.040) in W13 under the PFMS scenario (Figure 13). It fluctuates for the first 150 years and then radically decreases in the last 60 years to a level that is under the lower NRV bound.

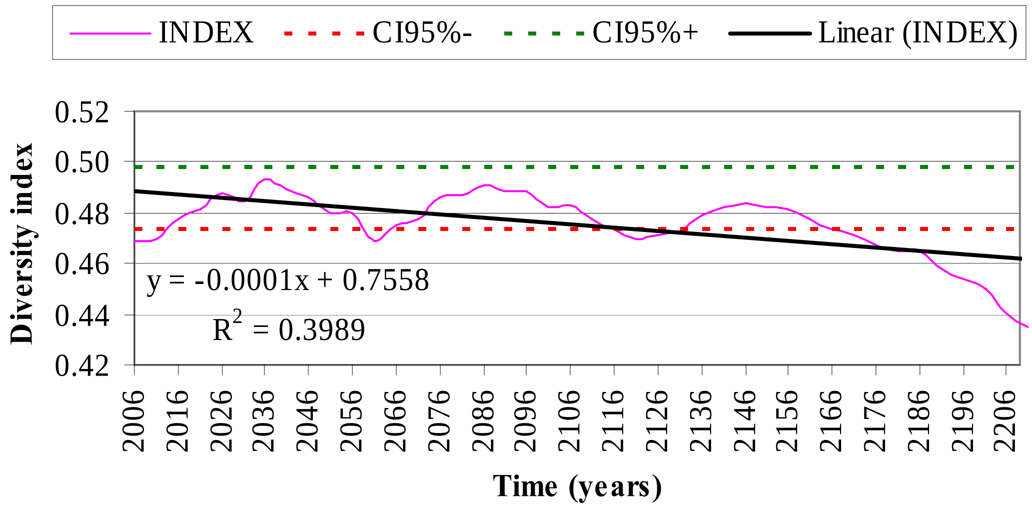

Figure 13. Changes in ecosystem diversity as measured by Shannon-Wiever diversity index of FMU W13 under the PFMS scenario during the next 200 years. Dotted lines represent bounds of the natural range of variation as determined from the NDR scenario.

Such reduction in ecosystem diversity is mainly due to a reduction of evenness in cover type (Figure 14) and because evenness in seral stage increases with time (Figure 8). Around 2146, at the same time as the diversity index is down-hilling (Figure 13), we observe a switch between “Hw” and “Sw” cover types in favor of “Sw” cover type generating a reduction in evenness (Figure 14).

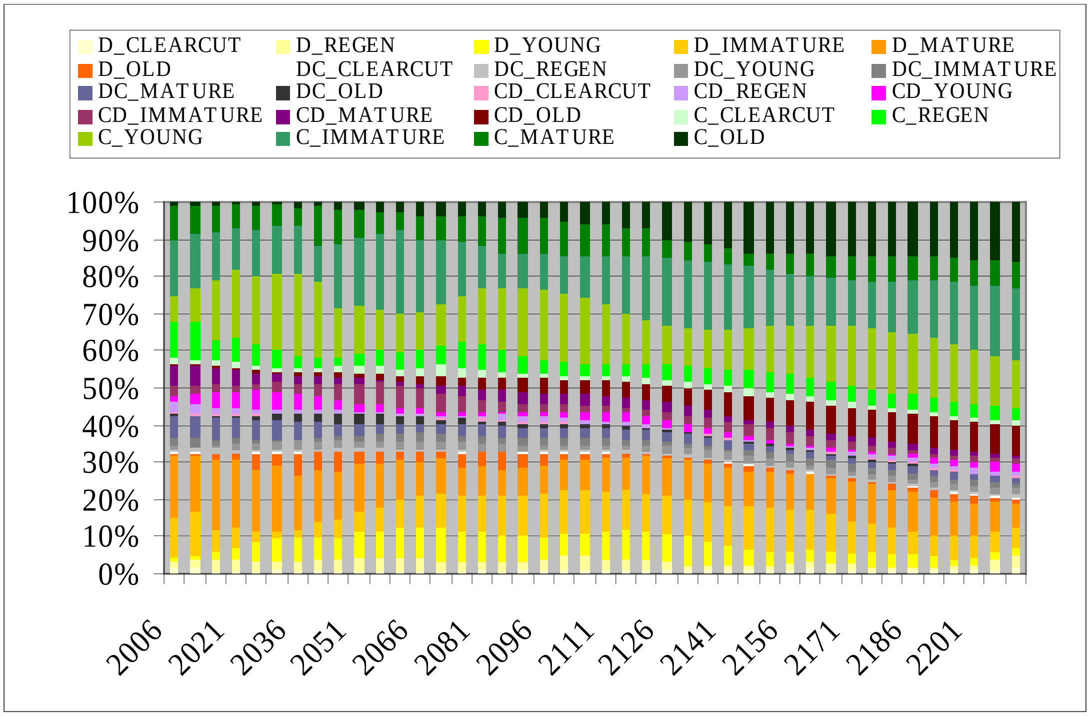

Figure 14. Changes in proportion of seral stages by cover type in FMU W13 under the PFMS scenario during the next 200 years.

The habitat composition observed under the NDR comprises much less mixedwood (Figure 15). In fact, under the NDR, there is only 8.5% of the landscape compared to 20% under the PFMS. This should generate less ecosystem diversity but as the proportion of the seral stages among each of the two dominant cover types ("Hw" and "Sw") is much more even under the NDR than under the PFMS, ecosystem diversity is comparable between the PFMS and the NDR.

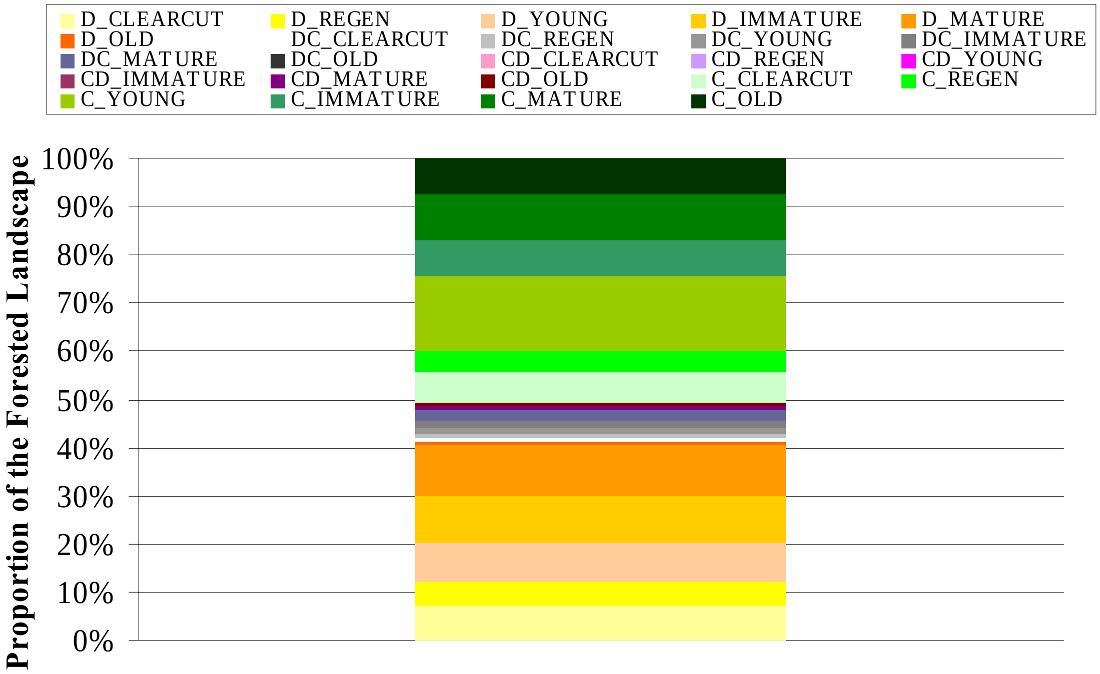

Figure 15. Proportion of seral stages by cover type in FMU W13 under the NDR.

Stand density

We also observed a reduction in the evenness of the stand density along the simulation horizon (Figure 16). A change of 8% of the forested habitat, switching from AB density type to SwMix density type, is occurring during the first 50 years. Even if this information is not included in the computation of the diversity index, it contributes to a reduction in overall ecosystem diversity in reality. This might be even more important as under the NDR scenario, AB density stands are representing between 27% and 36% of the forested area.

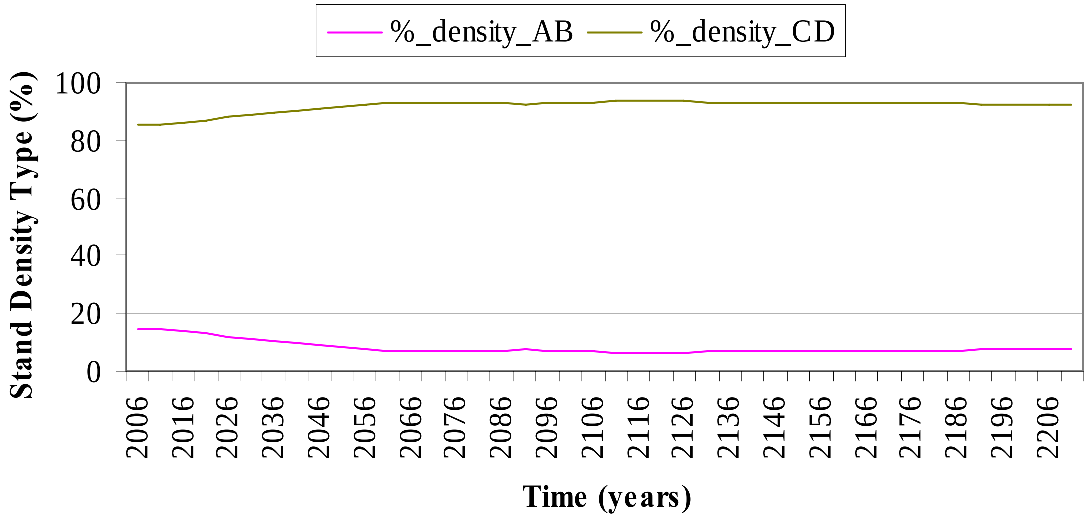

Figure 16. Changes in stand density class in FMU W13 under the PFMS scenario during the next 200 years.

3.1.2 Landscape configuration indicators

Edge

Under PFMS, the landscape contrast, as expressed by the mean edge contrast index and the contrast-weighted edge length, increases (Figure 17 and Figure 18). During the first 50 years of the simulation, CWEL drastically and significantly increases. Such response in not only due to a increase in the number of edge but also due to an increase on the mean edge contrast (Figure 18). However, there is a tendency starting at year 2146 to return to the initial MECI, contributing to the reduction in the CWEL at the end of the simulation horizon. The CWEL under the PFMS scenario is always greater the upper bound of the NDR scenario. However, the MECI is maintained inside the NRV for almost all the simulation horizon.

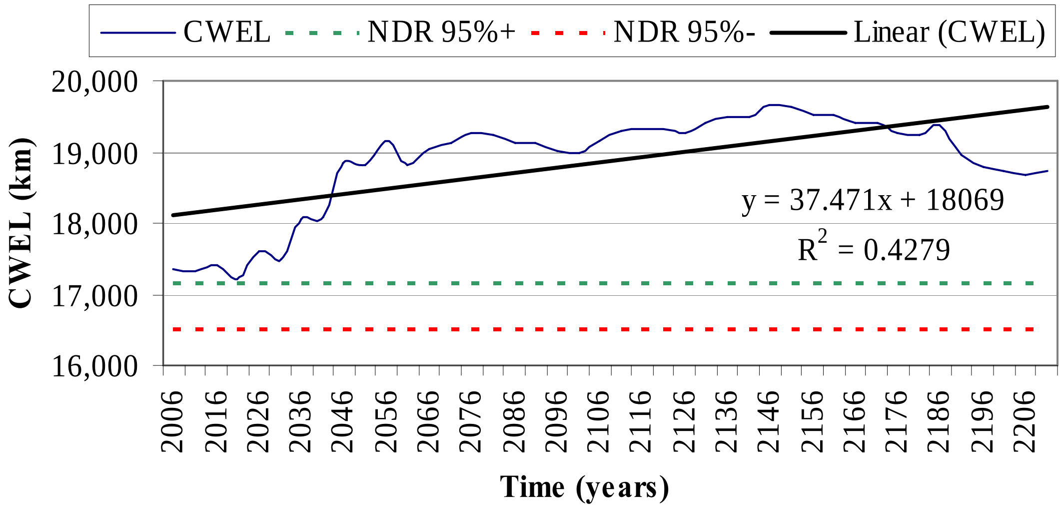

Figure 17. Changes in contrast-weighted edge length (CWEL) in FMU W13 under the PFMS scenario during the next 200 years. Dotted lines represent bounds of the natural range of variation as determined from the NDR scenario.

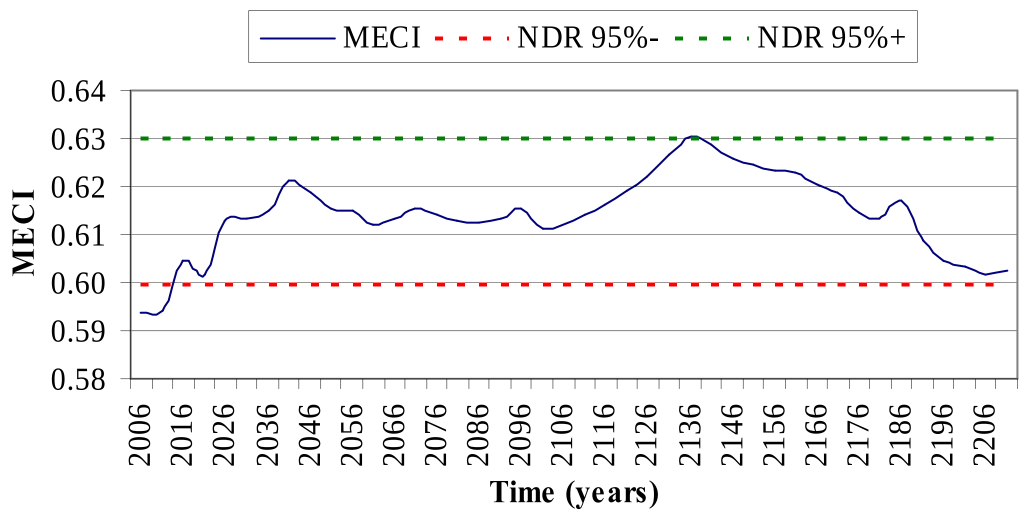

Figure 18. Changes in mean edge contrast index (MECI) in FMU W13 under the PFMS scenario during the next 200 years. Dotted lines represent bounds of the natural range of variation as determined from the NDR scenario.

Patch size

All habitat type considered together, mean patch size is rather small (12.4 ha±CI95%=0.18 ha, Table 3). Many natural (water bodies, streams, bogs and other wetlands, barrens, etc.) and artificial (roads, pipelines, well pads, etc.) landscape features contribute to dissect and to fragment this landscape.

Table 3. Patch size distribution parameter (mean and 25th percentiles (25, 50 and 75)) of patch size in FMU W13 under the PFMS scenario.

	Average	Patch size distribution parameter		
		25th percentile	50th percentile	75th percentile
95%+	12.57	11.58	32.04	101.55
Mean	12.39	11.38	30.96	93.26
95%-	12.20	11.18	29.88	84.97

Under the NDR, the average patch size is smaller (5.23 ha, Table 3 and Table 4). However, the distribution is much more spread. Indeed, we observe that under the NDR the 25th percentile is smaller than under the PFMS, the 50th percentile is equal, and the 75th percentile is greater (the double!) under the NDR.

Table 4. Patch size distribution parameter (mean and 25th percentiles (25, 50 and 75)) of patch size in FMU W13 under the NDR scenario.

	Average	Patch size distribution parameter		
		25th percentile	50th percentile	75th percentile
95%+	5.26	6.00	33.00	211.19
Mean	5.23	5.62	29.16	175.13
95%-	4.93	5.00	25.38	131.31

Mean patch size significantly decreases with time ($P<0.001$, $R^2=0.46$), mostly due to a reduction of the proportion of large patch in the landscape (Figure 19). Indeed, the 75th patch size percentile is lowered from 175 ha to 80 ha in the first 80 years and then slightly keeps going down. Such result is convergent with the CWEL results.

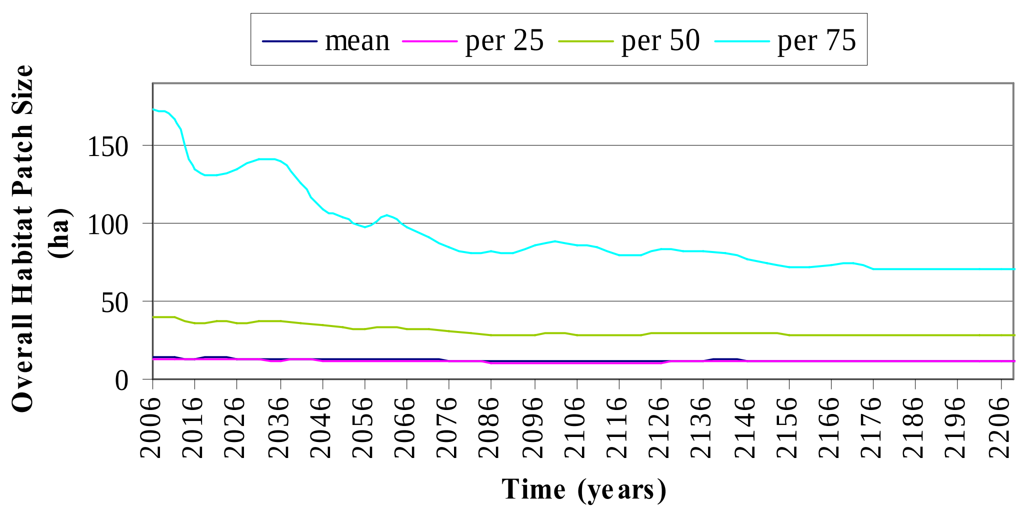

Figure 19. Mean and 25th percentiles (25, 50 and 75) of patch size in FMU W13 under the PFMS scenario during the next 200 years.

OLD GROWTH mean patch size of mixedwood stand (HwMix and SwMix) cover types is smaller than the overall habitat mean patch size (Table). OLD GROWTH mean patch size is the largest in the "Sw" cover type. This pattern is also observed under the NDR scenario (Table 5). However, the OLD GROWTH patch size is by three times smaller under the NDR for all the cover types than under the PFMS. Such difference is greater than between mean patch size (indistinctly of the habitat type).

Table 5. Mean patch size (ha) of OLD GROWTH habitat of the four different cover types in FMU W13 under the PFMS scenario during the next 200 years and under the NDR scenario.

	Hw	HwMix	SwMix	Sw
PFMS				
Mean	12.92	6.83	7.84	14.79
CI95%	1.17	0.32	0.39	0.86
NDR				
Mean	3.11	1.96	2.85	5.45
CI95%	2.15	0.52	0.59	1.17

The "Sw" cover type is only in this cover type that we see an increase of the OLD GROWTH patch size over the simulation horizon, particularly in the 75th percentile (Figure 20). In the other cover type, the OLD GROWTH mean patch size maintains itself with some fluctuation around the mean (not shown).

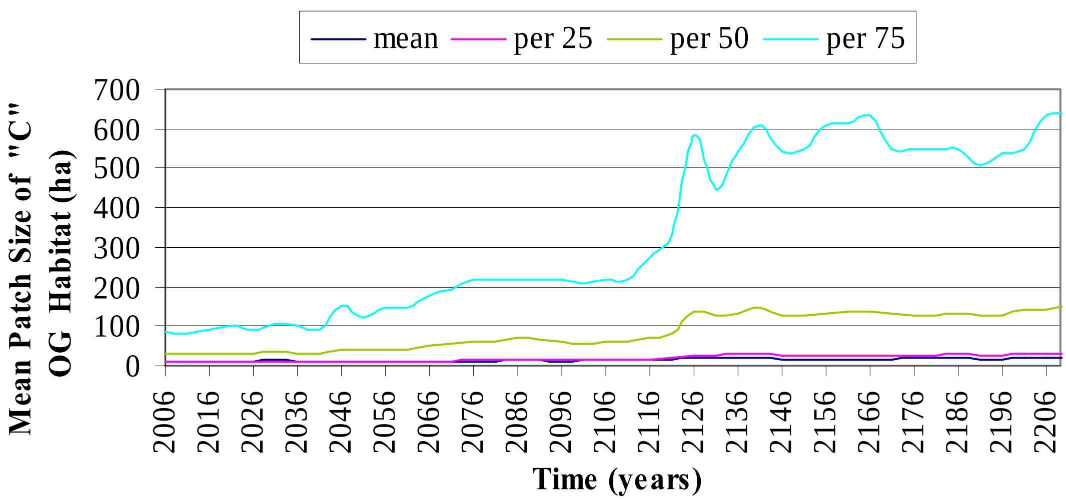

Figure 20. Mean and 25th percentiles (25, 50 and 75) of coniferous OLD GROWTH habitat patch size in FMU W13 under the PFMS scenario during the next 200 years.

Core area

Core area decreases under the PFMS and gets under the NRV after 50 years and stabilized around 46% of the forested area (Figure 21). Old growth core area starts under the lower bound of the NRV but steadily increases after 100 years beyond the upper limit of the NRV.

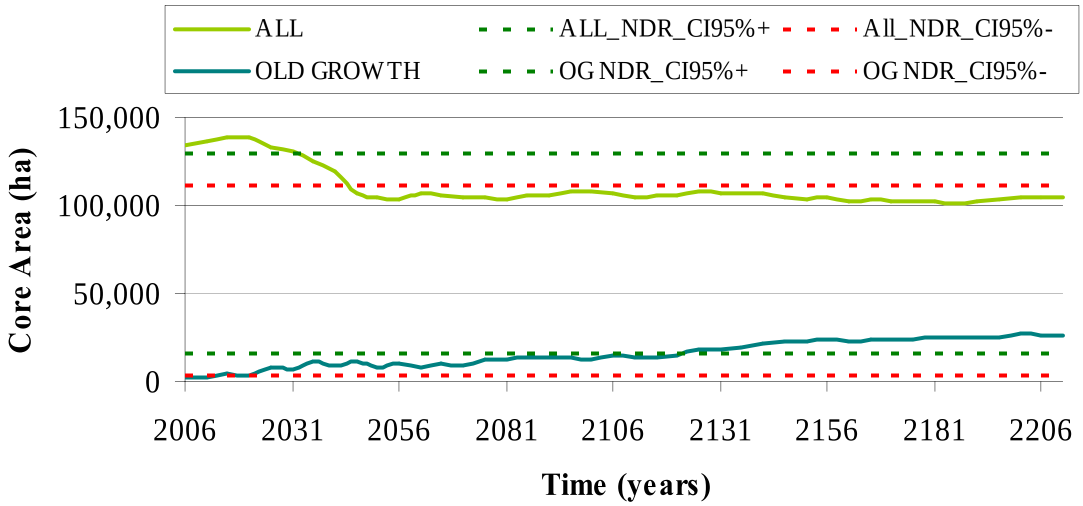

Figure 21. Overall and OLD GROWTH habitat core area in FMU W13 under the PFMS scenario during the next 200 years. Dotted lines represent bounds of the natural range of variation as determined from the NDR scenario.

Mean core habitat patch size is three time smaller (4.11 ha ±95%CI=1.18 ha) than habitat patch size, suggesting that the landscapes generated under PFMS is very edgy. Under the NDR the core area patch size distribution has a mean of 3.14 ha with the 25th, 50th, and 75th percentile being 4.67 ha, 19.48 ha, and 81.98 ha respectively. Overall core habitat patch size behave much more like the habitat patch size (Figure 22). Applying the PFMS scenario strongly reduces the largest core patches in the first 40-50 years. Consequently, after that first half century, the largest quarter of the total core habitat in the landscape is composed of core habitat patches starting at 50 ha, which is 32 ha lower than what is observed under the NDR.

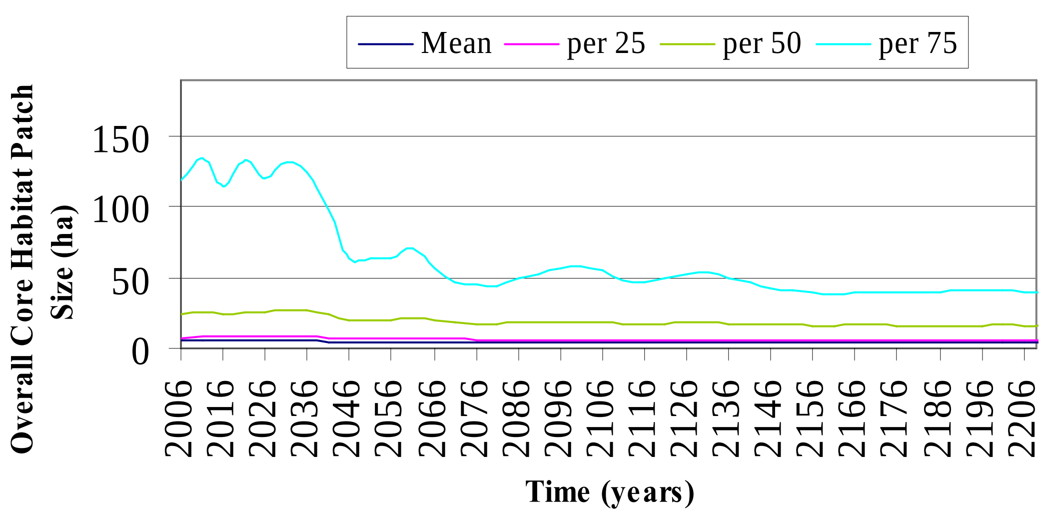

Figure 22. Mean and 25th percentiles (25, 50 and 75) of overall core habitat patch size in FMU W13 under the PFMS scenario during the next 200 years.

When looked by cover type, we observed that OLD GROWTH habitat core area patch size for the mixedwood cover types (HwMix, SwMix) is very small (around 2 ha per patch, Table 6). However, it is even smaller under the NDR. In fact, the OLD GROWTH habitat core area mean patch size is smaller under the NDR for all the cover types. We can observe an increase of the habitat core patch size for SwMix. In fact, the size of large (75th and 50th percentiles) core habitat patches of “SwMix” and “Sw” cover types increases considerably with time (Figure 23 and Figure 24).

Table 6. Core habitat mean patch size (ha) of OLD GROWTH habitat of the four different cover types in FMU W13 under the PFMS scenario during the next 200 years and under the NDR.

Cover type	PFMS		NDR	
	mean	95%CI	mean	95%CI
Hw	4.26	0.59	1.86	1.20
HwMix	1.78	0.13	0.93	0.35
SwMix	2.17	0.16	1.40	0.28
SwMix	4.72	0.29	3.21	0.59

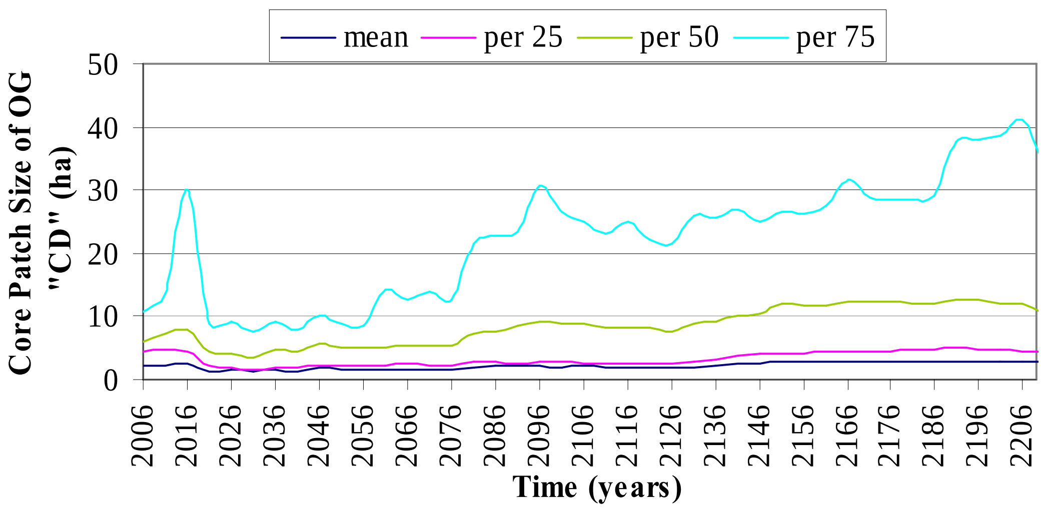

Figure 23. Mean and 25th percentiles (25, 50 and 75) of coniferous-dominated mixedwood OLD GROWTH core habitat patch size in FMU W13 under the PFMS scenario during the next 200 years.

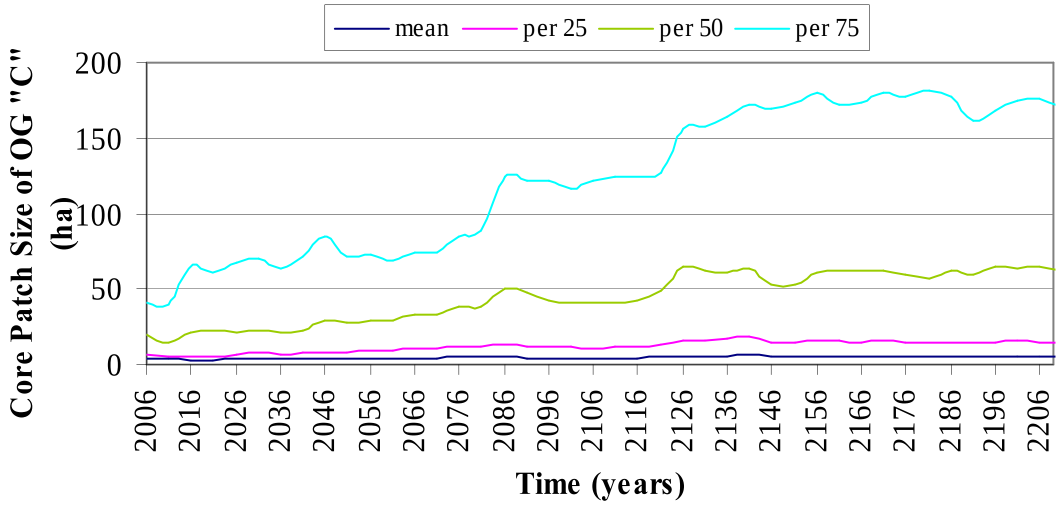

Figure 24. Mean and 25th percentiles (25, 50 and 75) of coniferous OLD GROWTH core habitat patch size in FMU W13 under the PFMS scenario during the next 200 years.

Patch shape

One of the effects of reducing the patch size in the landscape is the reduction of the patch shape complexity because having smaller patches make them more round and compact. That is what we are observing when we looked at the shape index (Figure 25). Shape index reduction is the greatest in the "Hw" and "HwMix" cover types but the fastest in the "SwMix" cover type.

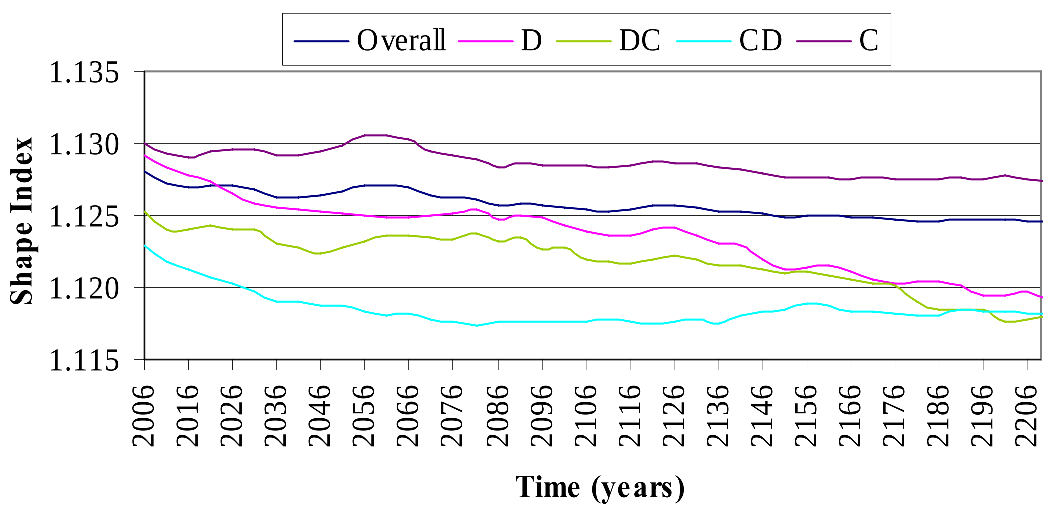

Figure 25. Shape index of the overall and by cover type habitat patches in FMU W13 under the PFMS scenario during the next 200 years.

Mean patch shape index under the NDR is much smaller for the overall habitat and by cover type than under the PFMS (Table 7). However, this difference is probably mainly due to the fact that the NDR model is a spatially explicit raster-based model generating many "islands" inside larger clusters of pixel. It is however interesting to compare the ranking among the cover type and to observe that under the NDR, the "Hw" cover type is the one with the more complex shape while under the PRMS, it is the "Sw" cover type.

Table 7. Shape index of the overall and by cover type habitat patches in FMU W13 under the NDR scenario.

	Mean	CI 95%
Overall	1.04052	0.00099
Hw	1.04743	0.00165
Hm	1.03803	0.00348
Sm	1.03138	0.00469
Sw	1.03810	0.00146

Patch connectivity

Mean nearest neighbor distance (MNND) between patches is the highest in W13 (5.6 km) for CLEARCUT habitat (Figure 26). Developing stands (REGENERATING + YOUNG) and forest stands (IMMATURE + MATURE) have low mean nearest distance between patches (close to 1 km). The MNND between OLD GROWTH patches rapidly lowered with time from 5 km to 2 km in the first 30 years and then slowly keep reduced to almost 1 km by three quarter of the simulation horizon.

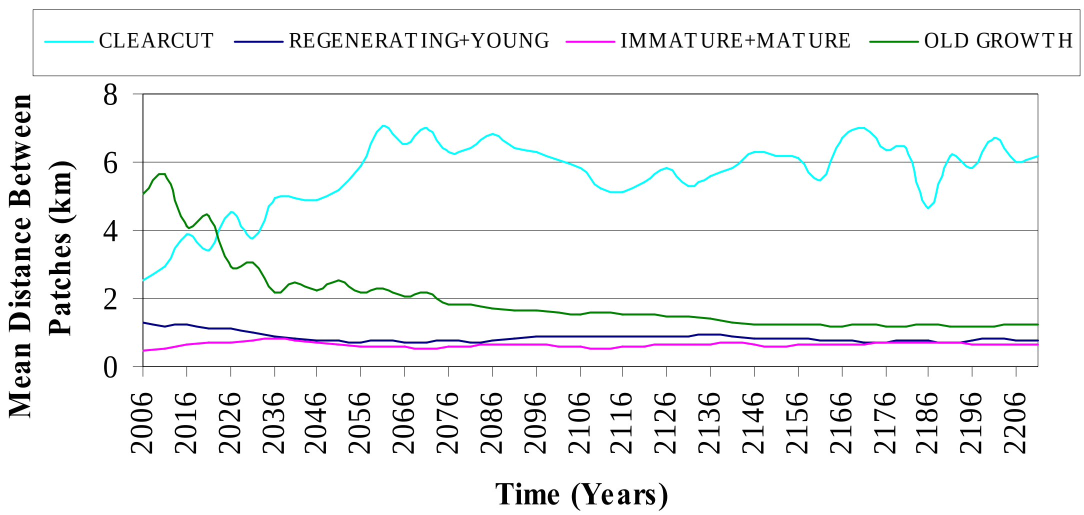

Figure 26. Mean nearest neighbor distance between patches of 4 seral stage classes in FMU W13 under the PFMS scenario during the next 200 years.

As we are particularly interested in understanding the OLD GROWTH patch spatial distribution, we also looked at the MND between OLD GROWTH patches of the same cover type. For the "Hw" cover type, MND between OLD GROWTH patches stays below the upper limit of the NRV for the first half of the simulation and then get to higher values (Figure 27). For the "HwMix" cover type, the MND is below the upper limit of the NRV for most of the time (Figure 27). However, at the last 25 years of the simulation MND explodes et gets up to 5000 m! For the "Sw" and "SwMix" cover types, it starts over the upper limit of the NRV but rapidly get inside the bounds of the NRV.

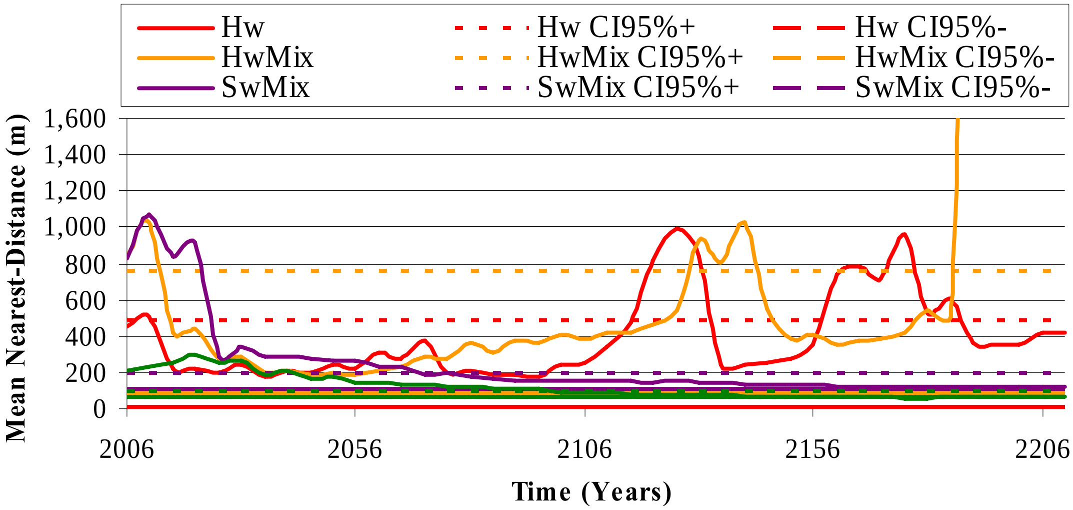

Figure 27. Mean nearest neighbor distance between OLD GROWTH patch of the same cover type in FMU W13 under the PFMS scenario during the next 200 years. Dotted lines represent bounds of the natural range of variation as determined from the NDR scenario.

3.1.3 Special habitat elements indicators

Many SHE indicators (19 over 28) are showing a significant reduction during the simulation horizon (Table 8). Among them, DENS(Aw d>25_h>7), DWD Volume and cover %, Aspen+Poplar %, Willow cover %, Deciduous %, Willow&rose cover %, Ground lichen %, Density of tree >25cm, Low shrub forage cover %, Herbaceous cover %, arboreal lichen index, Low shrub cover %, Tall shrub cover %, and Shrub cover>0.20m %, show a predicted reduction by the linear regression of more than 10% (Table 8, Value Delta/Mean). The most critical ones in W13 are the density of large aspen or poplar trees, the volume of downed woody debris and the willow and rose shrub cover%. On the other end, density of snags conifers and large trees (Aw, Pb, and Sw d>=40 cm) increases because of the aging of the forest.

Some SHE variables have a very different mean depending if it summarized for the managed or the unmanaged landbase (Table 8). The following SHE variables have a greater value on the managed landbase: Deciduous %, DENS(Live trees, Aw, Pb, d>25&h>7), Herbaceous %, Willow %, and Willow&rose %. However, most of the SHE have higher values on the unmanaged portion of the landbase like: Arboreal lichen index, Basal area (m2/ha), Canopy closure%, DENS(Live trees, Aw, Pb, Sw d>40), DENS(Live trees, d>25), DENS(Snags conifers d>=20), DENS(Snags, d>20), DENS(Snags, diseased or damaged trees, d>25), Downed woody debris cover %, Downed woody debris volume, Free-to-Manoeuver-Flying-space index, Ground lichen %, Height to live crown, Shrub cover>0.20m %, Shrub cover>1m %, Stand height, Tall Shrub cover %.

When the values under the PFMS are compared to the natural range of variation (NRV) of the SHE as expressed to the SHE mean and CI95% values obtained under the Natural Disturbance Regime simulations (NDR), we observe the biggest difference with the understory vegetation (lichen, herbaceous and shrub covers), the arboreal lichen, the abundance of DWD and the abundance of deciduous species in the landscape (Table 8).

Table 8. Statistics of the Special Habitat Element (SHE) model outputs for the gross, managed, and unmanaged portions of FMU W13 under the PFMS scenario during the next 200 years and the NDR.

	PFMS								NDR	
	Gross		Managed	Unmanaged						
Special Habitat Element	Mean	CI95%	Mean	Mean	Slope[1] 10^2	R2	*P* (F)*	Value Δ [2]	Mean	CI95%
Arboreal lichen index	140.48	2.39	120.25	183.56	-9.29	0.52	-	-19.04	170.01	18.37
Aw_Poplar %	14.87	0.68	15.10	14.39	-3.62	0.99	-	-7.43	16.77	0.72
Basal area (m^2/ha)	19.70	0.25	18.76	21.70	0.28	0.04	0.19	0.58	17.72	0.88
Canopy closure%	62.80	0.76	59.83	69.10	0.57	0.02	0.38	1.16	57.64	2.75
Coniferous %	74.40	1.05	73.29	76.76	5.53	0.95	-	11.33	65.23	1.02
Deciduous %	25.60	1.05	26.71	23.24	-5.53	0.95	-	-11.33	34.77	1.02
DENS(Live trees, Aw, Pb, d>25&h>7)	22.43	1.51	24.05	18.97	-7.97	0.96	-	-16.33	21.85	3.61
DENS(Live trees, Aw, Pb, Sw d>40)	16.52	0.63	11.39	31.62	3.03	0.78	-	6.21	12.32	1.60
DENS(Live trees, d>25)	79.99	2.13	20.10	45.17	-9.42	0.67	-	-19.30	61.72	8.10
DENS(Snags conifers d>=20)	17.86	1.24	32.76	73.62	4.92	0.54	-	10.09	15.52	1.69
DENS(Snags, d>20)	28.11	1.01	74.40	91.89	0.77	0.02	0.37	1.57	30.33	2.81
DENS(Snags, diseased or damaged trees, d>25)	67.23	1.07	12.10	25.95	5.61	0.95	-	11.50	49.44	4.59
Downed woody debris cover %	5.79	0.21	4.38	8.78	-0.77	0.45	-	-1.57	7.81	0.31
Downed woody debris volume	50.49	2.96	44.76	89.65	-12.88	0.65	-	-26.41	79.70	3.15
Free-to-Manoeuver-Flying-space index	6.12	0.05	5.95	6.47	-0.04	0.02	0.35	-0.08	6.85	0.26
Fruit-bearing shrub cover %	5.34	0.06	5.10	5.86	-0.20	0.35	-	-0.42	6.33	0.10
Ground lichen %	1.43	0.04	1.13	2.09	-0.20	0.78	-	-0.40	1.98	0.07
Height to live crown (m)	4.57	0.03	4.33	5.80	-0.08	0.26	0.00	-0.16	4.26	0.32
Herbaceous %	31.95	0.50	36.53	22.20	-2.52	0.87	-	-5.17	35.33	2.40
Low shrub cover %	9.55	0.14	9.22	10.24	-0.52	0.50	-	-1.07	14.00	1.17
Low shrub forage %	10.13	0.23	10.28	9.80	-1.15	0.87	-	-2.36	13.46	0.49
Shrub cover>0.20m %	18.12	0.22	15.83	23.00	-0.96	0.64	-	-1.97	23.86	0.28
Shrub cover>1m %	6.03	0.06	5.68	6.78	-0.22	0.40	-	-0.45	8.29	0.33
Stand age (years)	90.37	6.45	63.96	141.41	34.52	0.99	-	70.77	74.43	8.23
Stand height	11.45	0.16	10.44	13.59	0.80	0.90	-	1.64	10.29	0.84
Tall Shrub cover %	9.55	0.14	9.22	10.24	-0.52	0.50	-	-1.07	14.00	18.37
Willow %	3.03	0.75	3.28	2.50	-0.70	0.67	-	-1.43	6.47	0.72
Willow&rose %	4.49	0.85	4.86	3.70	-0.95	0.76	-	-1.96	8.40	0.88

[1] Significant temporal trend over the simulation horizon

[2] Value expressing the difference between the beginning and the end of the simulation of the linear regression predicted SHE values.

3.1.4 Habitat suitability indicators

Under the PFMS, we observed a significant reduction in 25 SIs and an increase in 21 SIs (Table 9). Species negatively affected by the application of the PFMS scenario are:

Barred Owl, Brown Creeper, Canada Lynx, Least Flycatcher, Northern Flying Squirrel, Northern Goshawk, Ruffed Grouse, Snowshoe Hare, and Woodland Caribou.

Species positively affected by the application of the PFMS scenario are:

Northern Red-Backed Vole, Spruce Grouse, Three-toed Woodpecker, and Varied Thrush.

Among the species negatively affected by the application of the PFMS, important reduction in habitat quality was detected for the Brown Creeper (R^2=0.62), Least Flycatcher (R2=0.90), Northern Flying Squirrel (R2=0.88), and the Snowshoe Hare (Food, R2=0.56), as express by the SI delta values of their respective HSMs (Table 9).

However, when compared to the NDR, mean value of the PFMS scenario is outside the NRV obtained under the NDR scenario for the following species (Table 9): American Marten, Brown Creeper (Hiding), Least Flycatcher, Moose (Food_Mild Winter), Moose (Hiding), Northern Flying Squirrel, Pileated Woodpecker, Snowshoe Hare, Southern Red-Backed Vole, Three-toed Woodpecker (Nesting), Woodland Caribou (Food_Winter).

For most of these species (or specific SI of the species), we observed less Medium and High quality habitat under the PFMS than under the NDR scenario (Table 10). In addition to the species for which, in average, the mean SI values are significantly different and lower under the PFMS than under the NDR scenario, if we concentrate on high quality habitat, we also observe that there is much less habitat area for the following species: Barred Owl, Canada Lynx (Denning), Northern Goshawk (Food), Ruffed Grouse.

During the first 15 years, the PFMS scenario is reducing by at least 25% of the High quality habitat for the Southern Red-Backed Vole and the Spruce Grouse while the PFMS reduces it by at least 50% for the American Marten (Table 10).

Table 9. Statistics of the different suitability index (SIs) of the wildlife species habitat suitability models in FMU W13 under the PFMS scenario during the next 200 years and under the NDR scenario.

	PFMS									NDR	
Species	SI	Mean[1]	StDev	CI95%	Slope[2] 10^4	R2	F	P(F)*	SI Δ[3]	Mean	CI95%
American Marten	ALL	0.58	0.02	0.01	-0.37	0.02	0.66	0.42	-0.01	0.72	0.05
American Marten	COVER	0.44	0.06	0.02	8.58	0.77	136.00	-	0.18	0.35	0.08
American Marten	HIDING	0.69	0.01	0.00	-1.05	0.25	13.43	0.00	-0.02	0.81	0.04
Barred Owl	ALL	0.25	0.01	0.00	-1.00	0.19	9.40	0.00	-0.02	0.19	0.05
Barred Owl	COVER	0.30	0.03	0.01	-4.29	0.81	169.14	-	-0.09	0.27	0.05
Barred Owl	FOOD	0.32	0.04	0.01	-6.09	0.88	282.95	-	-0.12	0.28	0.05
Barred Owl	NEST	0.18	0.01	0.00	1.45	0.41	27.74	-	0.03	0.13	0.05
Brown Creeper	ALL	0.10	0.02	0.01	-2.53	0.62	64.30	-	-0.05	0.07	0.03
Brown Creeper	FOOD	0.15	0.02	0.01	-1.78	0.37	23.65	-	-0.04	0.12	0.04
Brown Creeper	HIDING	0.05	0.01	0.00	-1.21	0.67	82.58	-	-0.02	0.03	0.01
Brown Creeper	NEST	0.19	0.03	0.01	-1.40	0.08	3.60	0.07	-0.03	0.23	0.06
Canada Lynx	COVER	0.35	0.02	0.01	-1.94	0.36	22.42	-	-0.04	0.29	0.07
Canada Lynx	DEN	0.04	0.00	0.00	-0.59	0.72	102.81	-	-0.01	0.06	0.00
Canada Lynx	FOOD	0.50	0.02	0.01	-0.63	0.03	1.32	0.26	-0.01	0.47	0.06
Elk	CO_S	0.67	0.03	0.01	3.65	0.76	127.33	-	0.07	0.54	0.10
Elk	CO_W	0.67	0.03	0.01	3.65	0.76	127.33	-	0.07	0.54	0.10
Elk	FO_S	0.78	0.01	0.00	-0.37	0.03	1.09	0.30	-0.01	0.76	0.03
Elk	FO_W	0.61	0.01	0.00	-1.07	0.44	31.87	-	-0.02	0.64	0.02
Elk	HI_S	0.52	0.02	0.01	-0.36	0.01	0.33	0.57	-0.01	0.48	0.05
Elk	HI_W	0.52	0.02	0.01	-0.34	0.01	0.31	0.58	-0.01	0.48	0.05
Least Flycatcher	FOOD	0.22	0.04	0.01	-6.93	0.90	347.32	-	-0.14	0.37	0.02
Moose	CO_S	0.78	0.02	0.01	2.05	0.38	24.32	-	0.04	0.68	0.09
Moose	CO_SW	0.63	0.02	0.01	2.03	0.44	31.34	-	0.04	0.46	0.08
Moose	FO_MW	0.61	0.04	0.01	-6.31	0.95	692.50	-	-0.13	0.74	0.05
Moose	FO_S	0.92	0.01	0.00	0.11	-	0.15	0.70	-	0.89	0.01
Moose	FO_SW	0.57	0.01	0.00	-0.11	-	0.19	0.66	-	0.55	0.05
Moose	HI	0.59	0.02	0.00	-0.14	-	0.12	0.73	-	0.68	0.06
Northern Flying Squirrel	ALL	0.48	0.03	0.01	-4.85	0.88	296.75	-	-0.10	0.55	0.02
Northern Flying Squirrel	COVER	0.32	0.07	0.02	-11.68	0.95	802.50	-	-0.24	0.35	0.06
Northern Flying Squirrel	FOOD	0.57	0.01	0.00	0.32	0.08	3.54	0.07	0.01	0.58	0.02
Northern Flying Squirrel	HIDING	0.61	0.02	0.01	-2.26	0.65	75.91	-	-0.05	0.75	0.04
Northern Goshawk	ALL	0.46	0.02	0.01	-0.50	0.03	1.09	0.30	-0.01	0.45	0.07
Northern Goshawk	FOOD	0.27	0.02	0.01	2.08	0.40	26.83	-	0.04	0.25	0.07

Table 9. Statistics of the different suitability index (SIs) of the wildlife species habitat suitability models in FMU W13 under the PFMS scenario during the next 200 years and under the NDR scenario (continued).

	PFMS									NDR	
Species	SI	Mean[1]	StDev	CI95%	Slope[2] 10^4	R2	F	P(F)*	SI Δ[3]	Mean	CI95%
Northern Goshawk	NEST	0.80	0.06	0.02	-8.72	0.80	161.11	-	-0.18	0.82	0.06
Northern Goshawk	NEST_S	0.16	0.05	0.01	-6.83	0.82	184.38	-	-0.14	0.22	0.07
Pileated Woodpecker	ALL	0.58	0.02	0.01	0.78	0.06	2.47	0.12	0.02	0.58	0.06
Pileated Woodpecker	COVER	0.61	0.02	0.00	1.15	0.22	11.06	0.00	0.02	0.51	0.07
Pileated Woodpecker	FOOD	0.43	0.04	0.01	-0.59	0.01	0.30	0.59	-0.01	0.52	0.06
Pileated Woodpecker	NEST	0.76	0.01	0.00	-0.33	0.03	1.18	0.29	-0.01	0.75	0.07
Ruffed Grouse	ALL	0.38	0.01	0.00	-1.18	0.54	47.11	-	-0.02	0.37	0.02
Ruffed Grouse	COVER	0.30	0.01	0.00	-1.50	0.57	52.56	-	-0.03	0.29	0.01
Ruffed Grouse	HIDING	0.51	0.01	0.00	-0.72	0.15	7.17	0.01	-0.01	0.49	0.05
Snowshoe Hare	COVER	0.62	0.01	0.00	-0.81	0.23	11.66	0.00	-0.02	0.72	0.05
Snowshoe Hare	FOOD	0.59	0.02	0.01	-2.05	0.56	51.02	-	-0.04	0.74	0.05
Southern Red-Backed Vole	ALL	0.47	0.01	0.00	1.83	0.65	73.97	-	0.04	0.53	0.02
Southern Red-Backed Vole	COVER	0.42	0.04	0.01	5.51	0.79	148.23	-	0.11	0.42	0.03
Southern Red-Backed Vole	HIDING	0.57	0.01	0.00	-1.24	0.37	23.33	-	-0.03	0.69	0.04
Spruce Grouse	ALL	0.56	0.02	0.01	3.26	0.82	177.46	-	0.07	0.47	0.04
Spruce Grouse	COVER	0.54	0.03	0.01	3.91	0.79	147.01	-	0.08	0.43	0.07
Spruce Grouse	FOOD	0.59	0.03	0.01	3.85	0.76	125.53	-	0.08	0.55	0.03
Spruce Grouse	NEST	0.63	0.01	0.00	1.17	0.27	14.62	-	0.02	0.55	0.02
Three-toed Woodpecker	ALL	0.43	0.08	0.02	10.33	0.64	71.99	-	0.21	0.47	0.07
Three-toed Woodpecker	FOOD	0.56	0.04	0.01	4.28	0.38	24.87	-	0.09	0.54	0.05
Three-toed Woodpecker	NEST	0.36	0.09	0.03	11.32	0.64	72.33	-	0.23	0.46	0.09
Varied Thrush	ALL	0.59	0.03	0.01	4.32	0.79	147.74	-	0.09	0.47	0.07
Varied Thrush	FOOD	0.59	0.03	0.01	4.47	0.81	166.92	-	0.09	0.54	0.05
Varied Thrush	NEST	0.60	0.02	0.01	3.42	0.71	97.36	-	0.07	0.46	0.09
Woodland Caribou	COV_R	0.08	-	-	-	1.00	NA	NA	-	0.08	N/A
Woodland Caribou	FOOD_R	0.16	-	-	-	0.66	79.31	-	-	0.16	-
Woodland Caribou	FOOD_S	0.76	0.01	0.00	0.87	0.86	238.69	-	0.02	0.76	0.00
Woodland Caribou	FOOD_W	0.33	0.04	0.01	-4.76	0.64	72.12	-	-0.10	0.46	0.04

[1] Significant lower difference of the value under the PFMS compared to the value under the NDR

[2] Significant temporal trend over the simulation horizon

[3] Value expressing the difference between the beginning and the end of the simulation of the linear regression predicted mean SI values

Table 10. Area (km2) of Low, Medium and High quality habitat in FMU W13 under the PFMS scenario (average) and under the NDR (average).

				PFMS (average) Habitat area (km^2)			NDR (average) Habitat area (km^2)		
		SI value threshold							
Species	SI	Low/Med	Med/High	Low	Med.	High	Low	Med.	High
American Marten	ALL	0.3	0.7	577.0	968.0	1,473.0	105.0	176.0	1,605.0
American Marten	COVER	0.3	0.7	512.0	2,121.0	385.0	998.0	1,094.0	219.0
American Marten	HIDING	0.3	0.7	114.0	1,271.0	1,633.0	105.0	645.0	2,193.0
Barred Owl	ALL	0.2	0.5	583.0	2,310.0	126.0	1,041.0	1,195.0	44.0
Barred Owl	COVER	0.2	0.5	221.0	2,517.0	280.0	693.0	1,699.0	135.0
Barred Owl	FOOD	0.2	0.5	133.0	2,526.0	360.0	627.0	1,794.0	153.0
Barred Owl	NEST	0.3	0.7	2,252.0	752.0	15.0	1,580.0	313.0	5.0
Brown Creeper	ALL	0.2	0.5	2,278.0	626.0	114.0	1,511.0	401.0	35.0
Brown Creeper	FOOD	0.3	0.7	2,269.0	695.0	54.0	1,527.0	407.0	3.0
Brown Creeper	HIDING	0.1	0.3	2,096.0	846.0	76.0	1,493.0	458.0	10.0
Brown Creeper	NEST	0.3	0.7	2,143.0	677.0	198.0	1,326.0	569.0	183.0
Canada Lynx	COVER	0.3	0.7	1,533.0	564.0	921.0	1,150.0	342.0	710.0
Canada Lynx	DEN	0.1	NA	2,091.0	927.0	0.0	524.0	2,122.0	0.0
Canada Lynx	FOOD	0.3	0.7	784.0	1,032.0	1,202.0	741.0	629.0	1,123.0
Elk	CO_S	0.3	0.7	678.0	290.0	2,051.0	689.0	450.0	1,391.0
Elk	CO_W	0.3	0.7	678.0	290.0	2,051.0	689.0	448.0	1,393.0
Elk	FO_S	0.3	0.7	99.0	578.0	2,340.0	167.0	716.0	2,018.0
Elk	FO_W	0.3	0.7	290.0	1,354.0	1,375.0	182.0	1,119.0	1,587.0
Elk	HI_S	0.3	0.7	731.0	1,188.0	1,100.0	387.0	1,265.0	1,092.0
Elk	HI_W	0.3	0.7	734.0	1,181.0	1,103.0	401.0	1,191.0	1,143.0
Least Flycatcher	FOOD	0.3	0.7	2,041.0	460.0	517.0	877.0	703.0	817.0
Moose	CO_S	0.3	0.7	451.0	162.0	2,405.0	544.0	118.0	1,971.0
Moose	CO_SW	0.3	0.7	657.0	493.0	1,868.0	635.0	779.0	1,154.0
Moose	FO_MW	0.3	0.7	721.0	891.0	1,406.0	361.0	464.0	1,937.0
Moose	FO_S	0.3	0.7	80.0	139.0	2,800.0	236.0	142.0	2,473.0
Moose	FO_SW	0.3	0.7	444.0	1,350.0	1,224.0	402.0	1,122.0	1,209.0
Moose	HI	0.3	0.7	465.0	1,208.0	1,346.0	301.0	749.0	1,756.0
Northern Flying Squirrel	ALL	0.3	0.7	221.0	2,261.0	537.0	142.0	2,264.0	511.0
Northern Flying Squirrel	COVER	0.3	0.7	1,647.0	847.0	524.0	973.0	935.0	421.0
Northern Flying Squirrel	FOOD	0.3	0.7	71.0	2,472.0	475.0	124.0	2,193.0	614.0
Northern Flying Squirrel	HIDING	0.3	0.7	112.0	1,710.0	1,197.0	90.0	968.0	1,896.0

Table 10. Area (km2) of Low, Medium and High quality habitat in FMU W13 under the PFMS scenario (average) and under the NDR (average) (continued).

		SI value threshold		PFMS (average) Habitat area (km^2)			NDR (average) Habitat area (km^2)		
Species	SI	Low/Med	Med/High	Low	Med.	High	Low	Med.	High
Northern Goshawk	ALL	0.3	0.6	99.0	2,430.0	489.0	213.0	2,263.0	391.0
Northern Goshawk	FOOD	0.2	0.5	243.0	2,715.0	60.0	546.0	2,030.0	56.0
Northern Goshawk	NEST	0.3	0.7	16.0	667.0	2,335.0	6.0	478.0	2,531.0
Northern Goshawk	NEST_S	0.3	0.7	2,249.0	621.0	148.0	1,219.0	761.0	173.0
Pileated Woodpecker	ALL	0.3	0.6	16.0	972.0	2,030.0	52.0	1,724.0	1,206.0
Pileated Woodpecker	COVER	0.3	0.6	16.0	657.0	2,346.0	159.0	1,914.0	832.0
Pileated Woodpecker	FOOD	0.3	0.7	128.0	2,777.0	114.0	150.0	2,627.0	135.0
Pileated Woodpecker	NEST	0.3	0.7	27.0	502.0	2,489.0	33.0	890.0	2,072.0
Ruffed Grouse	ALL	0.3	0.6	208.0	2,690.0	120.0	308.0	2,487.0	5.0
Ruffed Grouse	COVER	0.2	0.5	221.0	2,625.0	173.0	156.0	2,736.0	15.0
Ruffed Grouse	HIDING	0.3	0.7	117.0	2,459.0	442.0	162.0	2,345.0	396.0
Snowshoe Hare	COVER	0.3	0.7	459.0	1,141.0	1,418.0	295.0	719.0	1,796.0
Snowshoe Hare	FOOD	0.3	0.7	477.0	1,216.0	1,326.0	297.0	667.0	1,843.0
Southern Red-Backed Vole	ALL	0.3	0.7	235.0	2,403.0	381.0	261.0	2,436.0	136.0
Southern Red-Backed Vole	COVER	0.3	0.7	486.0	2,141.0	392.0	517.0	2,108.0	26.0
Southern Red-Backed Vole	HIDING	0.3	0.7	218.0	1,873.0	927.0	172.0	1,168.0	1,557.0
Spruce Grouse	ALL	0.3	0.6	102.0	1,184.0	1,732.0	249.0	2,148.0	445.0
Spruce Grouse	COVER	0.3	0.6	114.0	1,362.0	1,542.0	476.0	1,667.0	538.0
Spruce Grouse	FOOD	0.3	0.7	58.0	1,885.0	1,075.0	90.0	2,702.0	162.0
Spruce Grouse	NEST	0.3	0.7	140.0	1,337.0	1,541.0	160.0	2,399.0	347.0
Three-toed Woodpecker	ALL	0.3	0.7	1,089.0	1,062.0	867.0	577.0	1,543.0	489.0
Three-toed Woodpecker	FOOD	0.3	0.7	633.0	1,019.0	1,367.0	478.0	1,536.0	667.0
Three-toed Woodpecker	NEST	0.3	0.7	1,385.0	946.0	687.0	622.0	1,343.0	612.0
Varied Thrush	ALL	0.3	0.7	313.0	1,334.0	1,371.0	577.0	1,543.0	489.0
Varied Thrush	FOOD	0.3	0.7	363.0	1,271.0	1,384.0	478.0	1,536.0	667.0
Varied Thrush	NEST	0.3	0.7	315.0	1,223.0	1,480.0	622.0	1,343.0	612.0
Woodland Caribou	COV_R	0.3	0.7	2,743.0	13.0	263.0	1,266.0	4.0	851.0
Woodland Caribou	FOOD_R	0.3	0.7	2,480.0	34.0	504.0	963.0	6.0	1,367.0
Woodland Caribou	FOOD_S	0.4	0.7	18.0	115.0	2,886.0	0.0	512.0	2,506.0
Woodland Caribou	FOOD_W	0.2	0.5	65.0	2,669.0	284.0	0.0	1,820.0	1,199.0

3.2 Forest management unit W11

3.2.1 Ecosystem indicator

Forest age

Mean area-weighted average forest age in W11 for the entire horizon is 107 years, 25 years older than W13. It is also older than CI95% limit of the mean area-weighted age observed under the NDR by 28 years (Mean+CI95%=78.9 years, Table 11).

Table 11. Age structure indicators of FMU W11 under the NDR scenario.

Age structure parameter	Mean	CI95%
Area-weighted mean	69.99	8.87
25th percentile	19.89	10.76
50th percentile	50.71	17.93
75th percentile	98.14	16.57

Area-weighted average forest age increases with time, particularly after 50 years (Figure 28). Such increase is due to the aging of the old portion of the landscape. Indeed, the 25th and the 50th percentiles stay around the age of 41 and 88 years respectively all the simulation horizon while the 75th percentile is increasing from 100 years to 275 years.

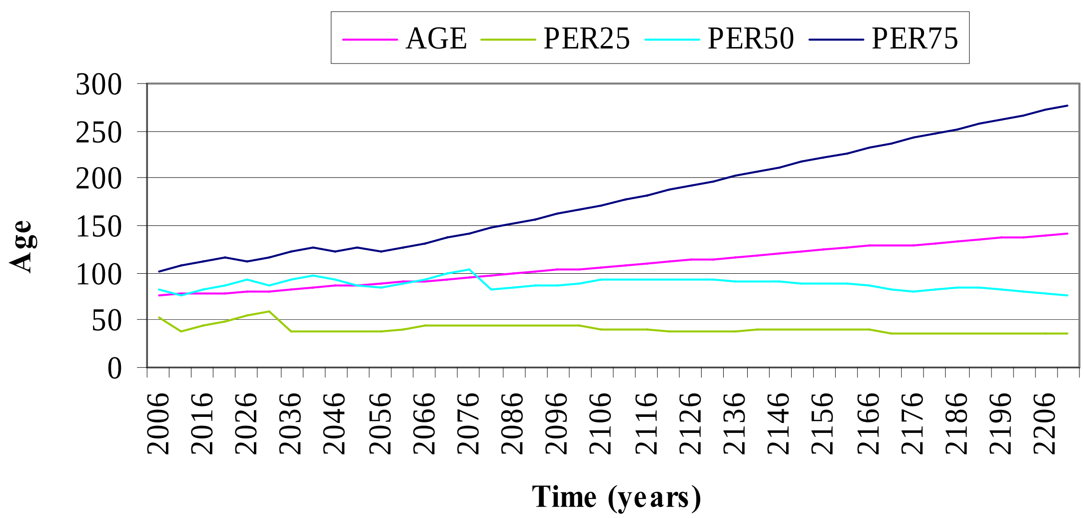

Figure 28. Area-weighted average forest age and 25th percentiles (25, 50 and 75) of area-weighted age of FMU W11 under the PFMS scenario during the next 200 years.

The forested landscape in W11 is aging only on the unmanaged portion of the landbase (Figure 29). Indeed, on the unmanaged portion of the forested landbase, mean area-weighted stand age steadily and linearly increases with time from 58 to 250 years. On the managed portion of the forested landbase, age is reduced during the first 50 years and stabilized around age 60 during the next 150 years of the simulation horizon.

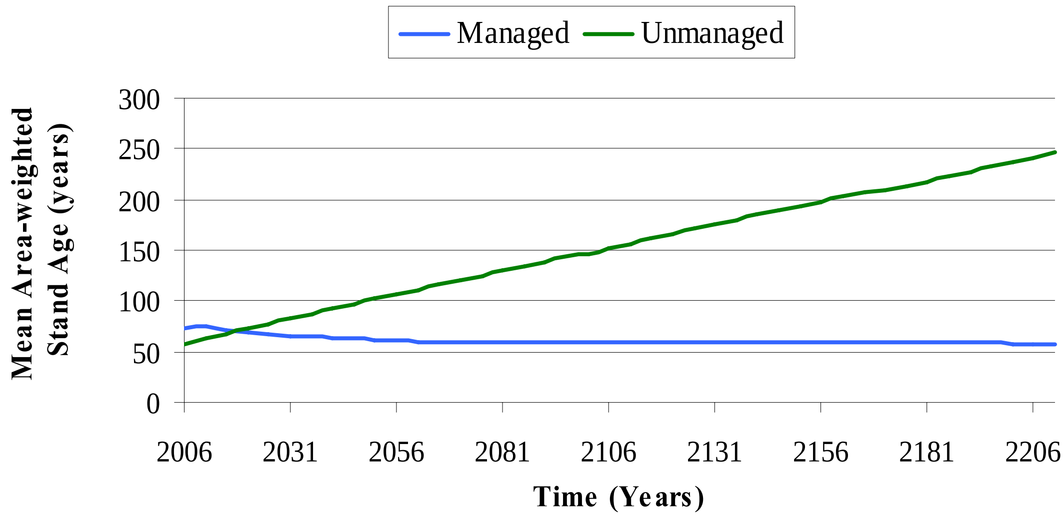

Figure 29. Mean area-weighted stand age on the managed and the unmanaged forested landbase of FMU W11 under the PFMS scenario during the next 200 years.

Under the NDR, the age structure is in average close to 40 years younger (Table 11). Under the PFMS, all percentile indicators are higher (almost the double!) than under NDR (particularly the 75th in the second half of the simulation horizon) and are over the limit of the upper bound of the NRV for most of the simulation horizon.

The average age class structure of W11 is characterized by a linearly declining distribution starting at age 30-40 years (Figure 30). In average, 27% of the landscape will be over 150 years old under that PFMS scenario.

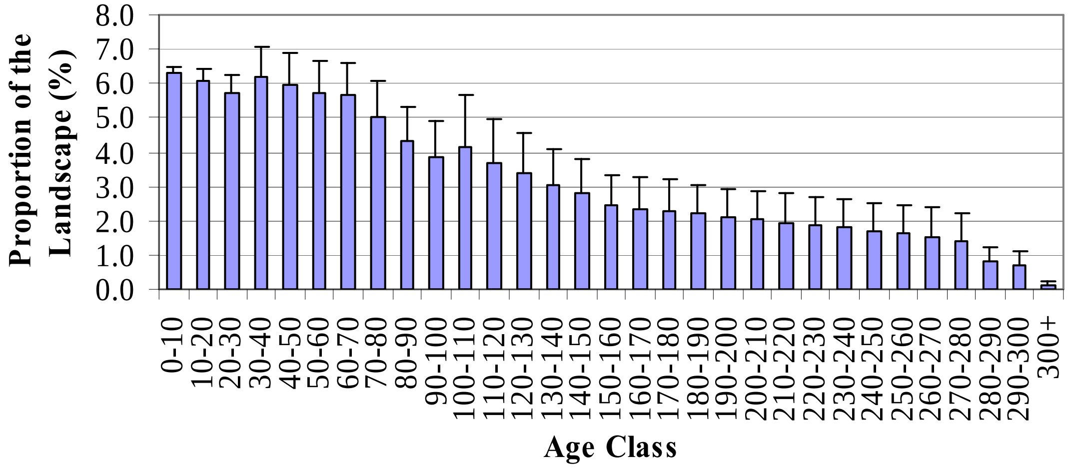

Figure 30. Average age class structure of FMU W11 under the PFMS scenario during the next 200 years. Bars show average proportion of the landscape in that age class and error bars express the +95% confidence interval.

However, the age class distribution is highly changing and do not look like the average at any point of the horizon simulation. Indeed, in the beginning of the simulation, the age structure is rather modal at year 2041 while it is strongly bimodal at year 2201 (Figure 31).

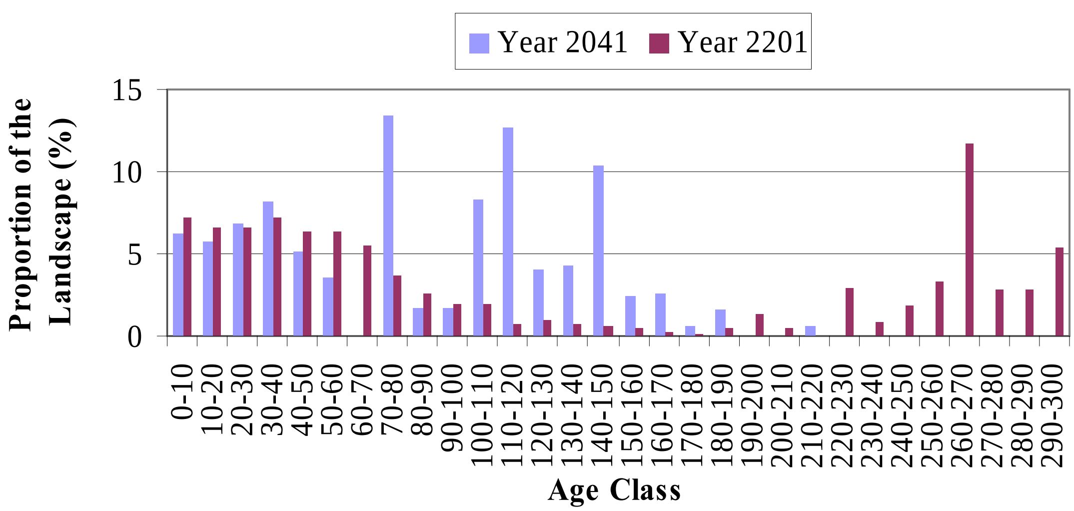

Figure 31. Age class structure of FMU W11 under the PFMS scenario at years 2041 and 2201.

Under the NDR, the mean age class distribution follows an negative exponential distribution with 11.4% of the forested landscape being over 150 years (Figure 32).

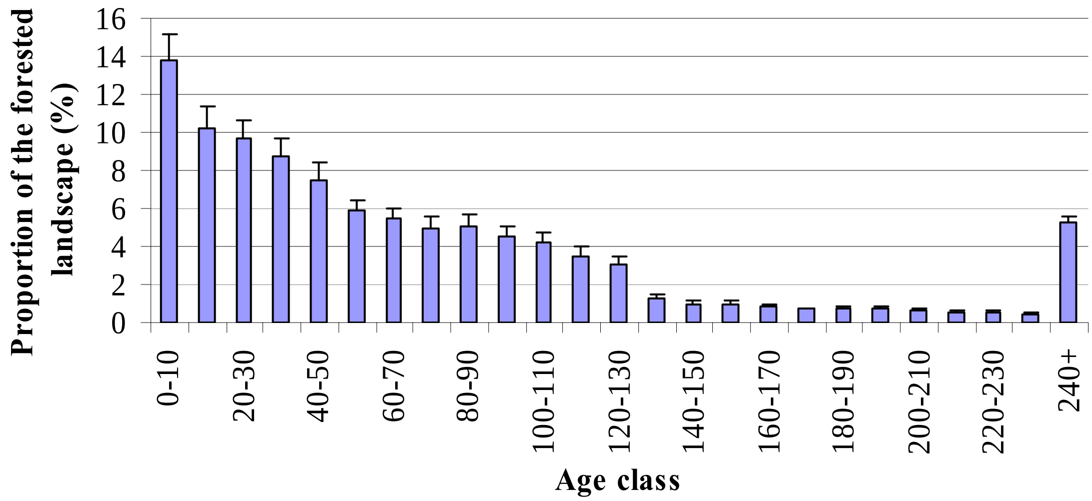

Figure 32. Age class structure of FMU W13 under the NDR scenario. Bars show average proportion of the landscape in that age class and error bars express the +95% confidence interval.

Seral stage

In W11 on the gross landbase, the importance of a seral stage increases as the age of the seral stage increases (Figure 33). Hence, on average, W11 is dominated by OLD GROWTH or MATURE forests. However, much of OLD GROWTH observed on the gross landsbase is coming from the unmanaged landbase. Indeed, on the managed portion of the landscape, the proportion of younger seral stages is more important.

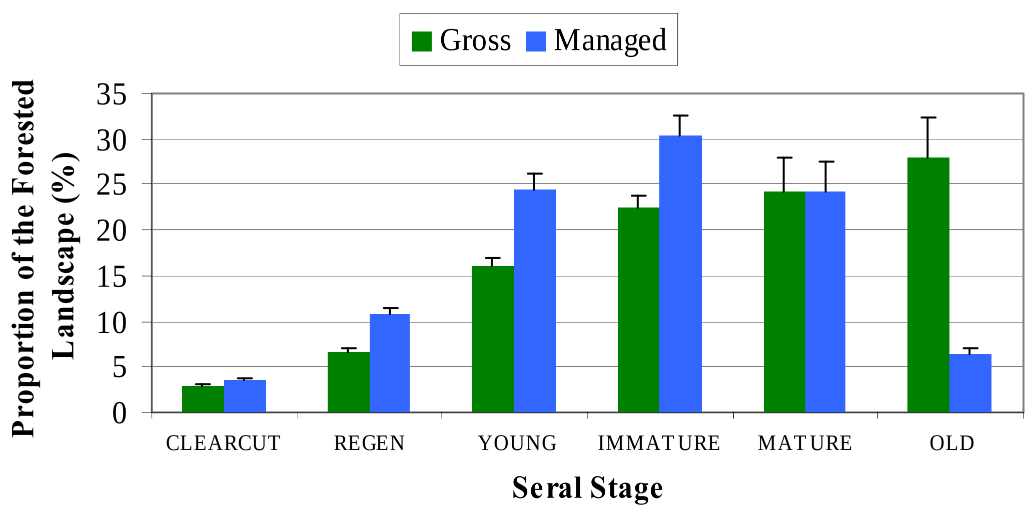

Figure 33. Mean proportion of the different seral stages of FMU W11 under the PFMS scenario during the next 200 years. Error bars gives the 95% confidence interval.

Under the NDR, we observed much less OLD GROWTH (less of the half) and more recent openings (CLEARCUT and REGEN) and YOUNG than under the PFMS (Figure 34). Of these three stages, CLEARCUT and OLD GROWTH are outside the NRV; there is too few CLEARCUT and too much OLD GROWTH under the PRMS when compared to the NRV. IMMATURE and MATURE seral stages are about the same in the two scenarios.

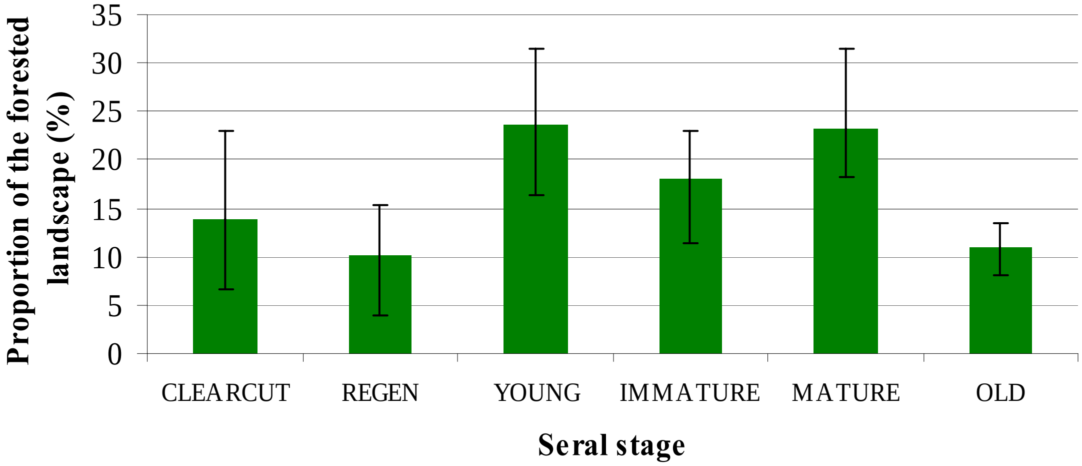

Figure 34. Mean proportion of the different seral stages of FMU W11 under the NDR. Error bars gives the 95% confidence interval.

After 100 years, 40% of the landscape is in OLD GROWTH seral stage (Figure 35). As in W13, we also observed a transfer in area between MATURE and OLD GROWTH all along the simulation horizon. The proportion in IMMATURE seral stage is decreasing with time while the proportion in CLEARCUT and REGEN seral stages slightly increase with time.

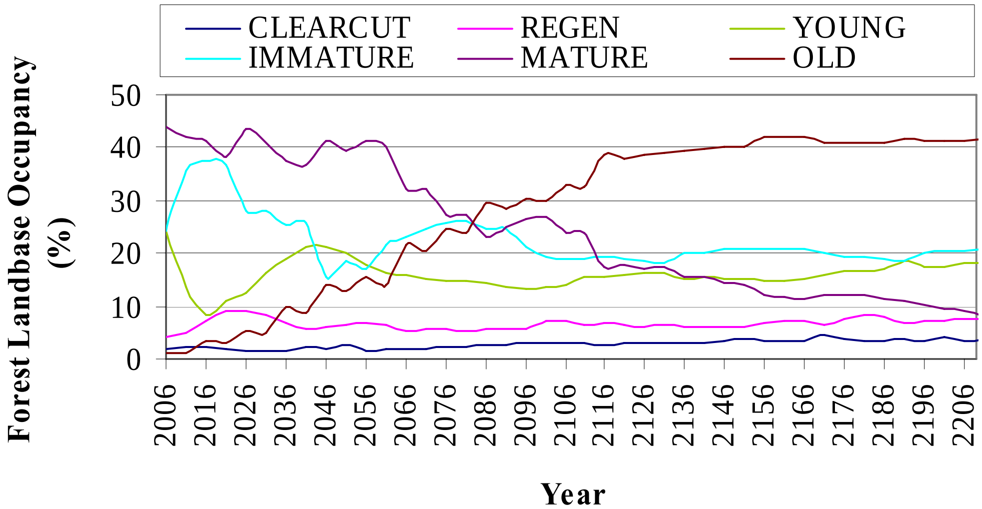

Figure 35. Proportion of the different seral stages of FMU W11 under the PFMS scenario during the next 200 years.

OldGrowthness index behaves like the pattern of the OLD GROWTH seral stage (Figure 36). Much of the OldGrowthness is coming from the unmanaged landbase. Indeed, on the managed portion of the landbase, there is a 8000 ha reduction in OLD GROWTH area equivalent happening during the first 60 years.

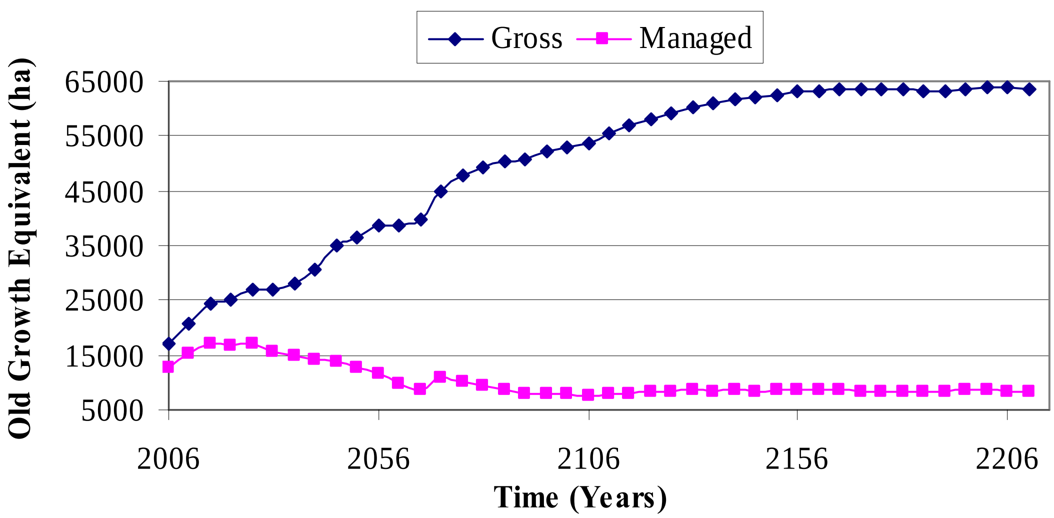

Figure 36. Old Growth area equivalent as computed by the OldGrowthness index in FMU W11 under the PFMS scenario for the four cover types during the next 200 years.

The distribution of the seral stage is not homogeneous among the cover types in W11 (Figure 37). In this FMU even more than in W13, the “Sw” cover type is contributing the most to the OLD GROWTH seral stage while the inverse is seen for the “Hw” cover type. The “Hw” cover type is mostly concentrated in the IMMATURE seral stage.

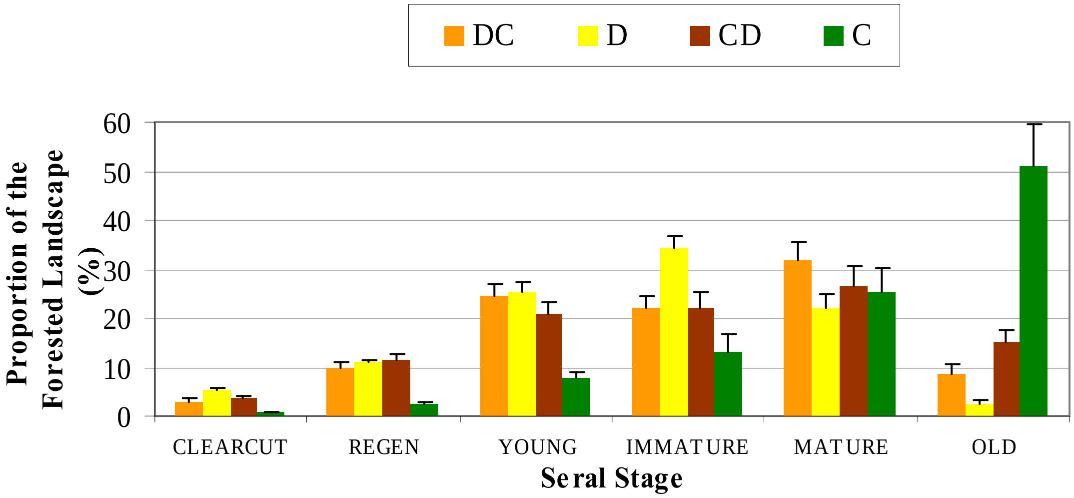

Figure 37. Mean proportion, by cover types, of the different seral stages of FMU W11 under the PFMS scenario during the next 200 years. Error bars gives the 95% confidence interval.

When compared to the NDR scenario, first we observe that, under PFMS, the seral stage distribution of the "Sw" cover type under the PFMS is too much skewed toward the younger seral stages (Figure 38). Consequently, there is less CLEARCUT, REGEN, and YOUNG seral stages and too high proportion of MATURE and OLD GROWTH than observed inside the bounds of the NRV for that cover type. The inverse is detected for the "SwMix" cover type: the PFMS generates more REGEN, YOUNG and IMMATURE, and less OLD GROWTH than observed inside the NRV. Concerning the "HW" and the "HwMix" cover types, CLEARCUT seral stage is under the lower bound of the NRV while OLD GROWTH is over the upper bound of the NRV.

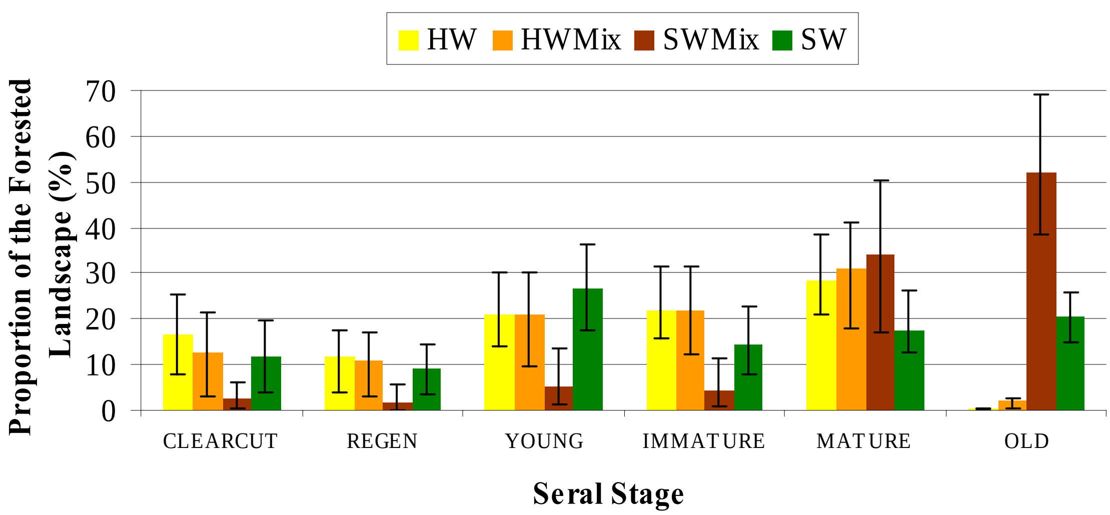

Figure 38. Mean proportion, by cover type, of the different seral stages of FMU W11 under the NDR scenario. Error bars gives the 95% confidence interval.

Indeed, if we looked at the seral stage proportion over time for each cover type, we observed that, by the end of the simulation horizon, 80% of the “Sw” cover type is represented by the OLD GROWTH seral stage (Figure 39) while it represents less than 5% for the “Hw” and “HwMix” cover types. After 40 years, the “Hw”, “HwMix” and “SwMix” cover types become dominated by the YOUNG and IMMATURE seral stages after a serious reduction of the MATURE seral stage.

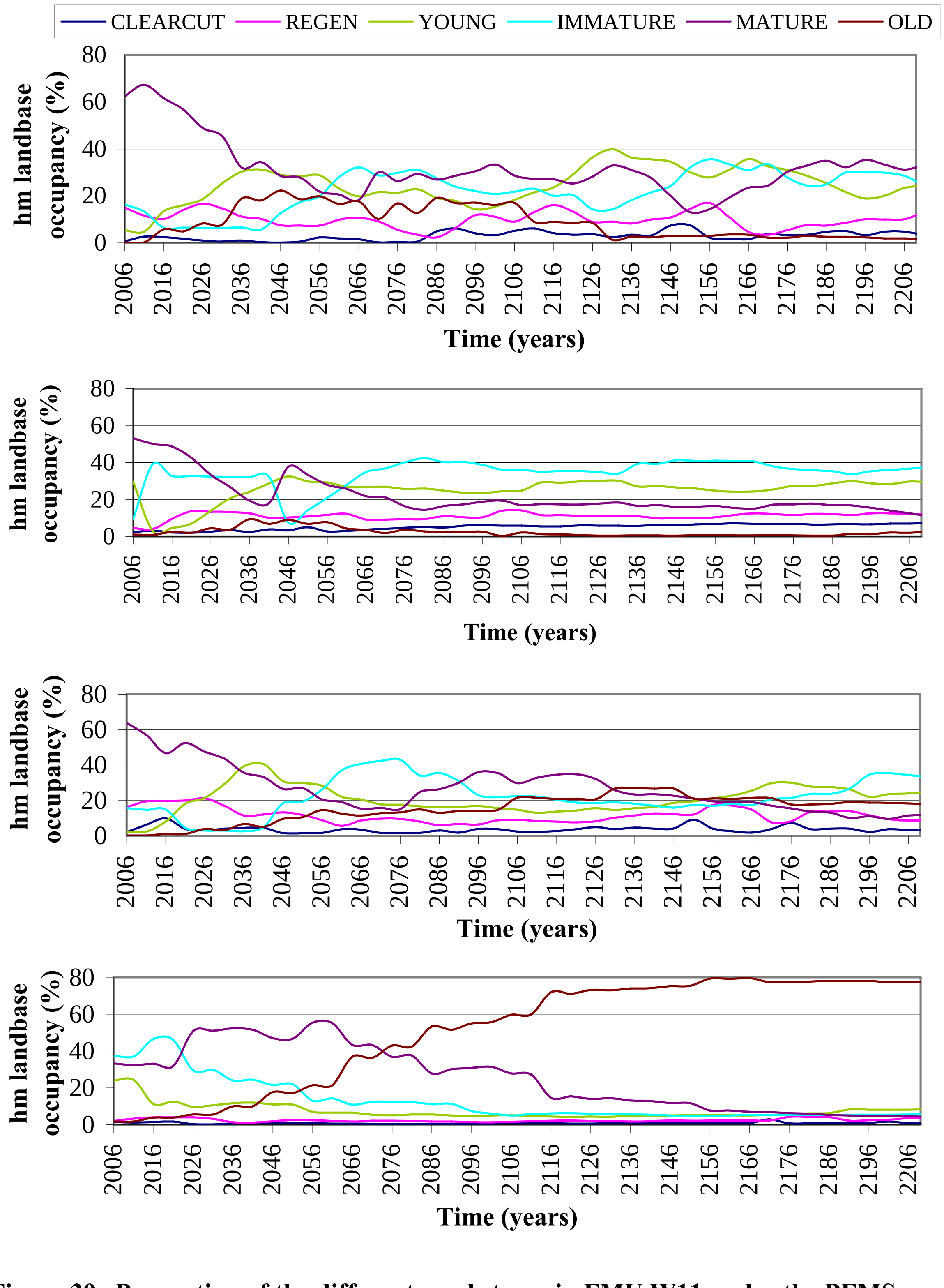

Figure 39. Proportion of the different seral stages in FMU W11 under the PFMS scenario for the four cover types during the next 200 years.

Ecosystem diversity

In average, W11 is less diversified in habitat than W13. In W11, ecosystem diversity decreases right at the beginning of the horizon and than stabilizes around 0.40 (Figure 40). However, the overall decrease trend over the simulation horizon is not statistically significant (P>0.05).

Compared to the NDR scenario, ecosystem diversity is less diversified under the PFMS scenario (Figure 40). In fact, ecosystem diversity is lower and outside the NRV for the entire simulation horizon.

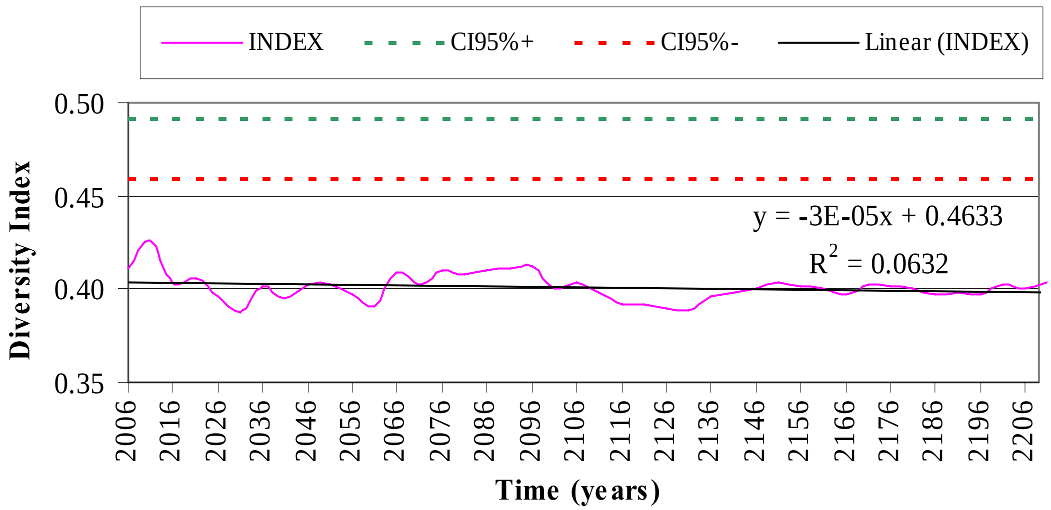

Figure 40. Changes in ecosystem diversity as measured by Shannon-Wiever diversity index in FMU W11 under the PFMS scenario during the next 200 years. Dotted lines represent bounds of the natural range of variation as determined from the NDR scenario.

Contrary to W13, in W11, each cover type (same color family) proportion remains the same all along the simulation horizon in the landscape (Figure 41). Evenness is about maintained all through the simulation as the dominance of "Hw" MATURE is slowly replaces by the dominance of "Sw" OLD GROWTH. Consequently, because of these two outcomes, ecosystem diversity does not change much.

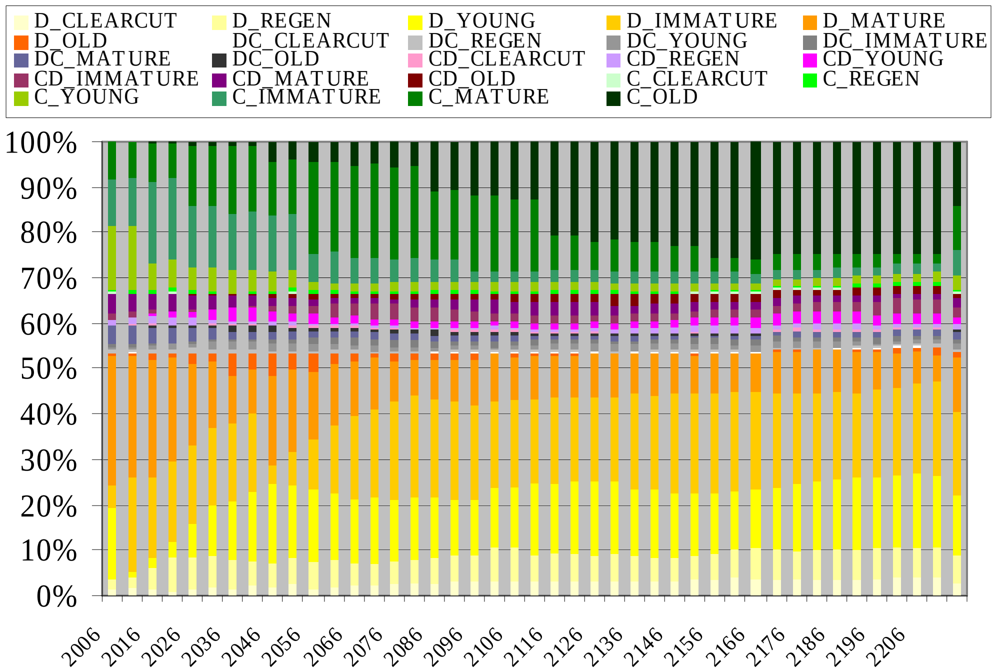

Figure 41. Changes in proportion of seral stages by cover type in FMU W11 under the PFMS scenario during the next 200 years.

In W11, the habitat composition observed under the NDR comprises very few mixedwood (4.9%) (Figure 42), let it be 8.2% less than under the PFMS (13.1%). As observed in W13, because the seral stages are more uniformly distributed under the NDR for the "Hw" and the "Sw" cover types, the ecosystem diversity is higher under the NDR than under the PFMS.

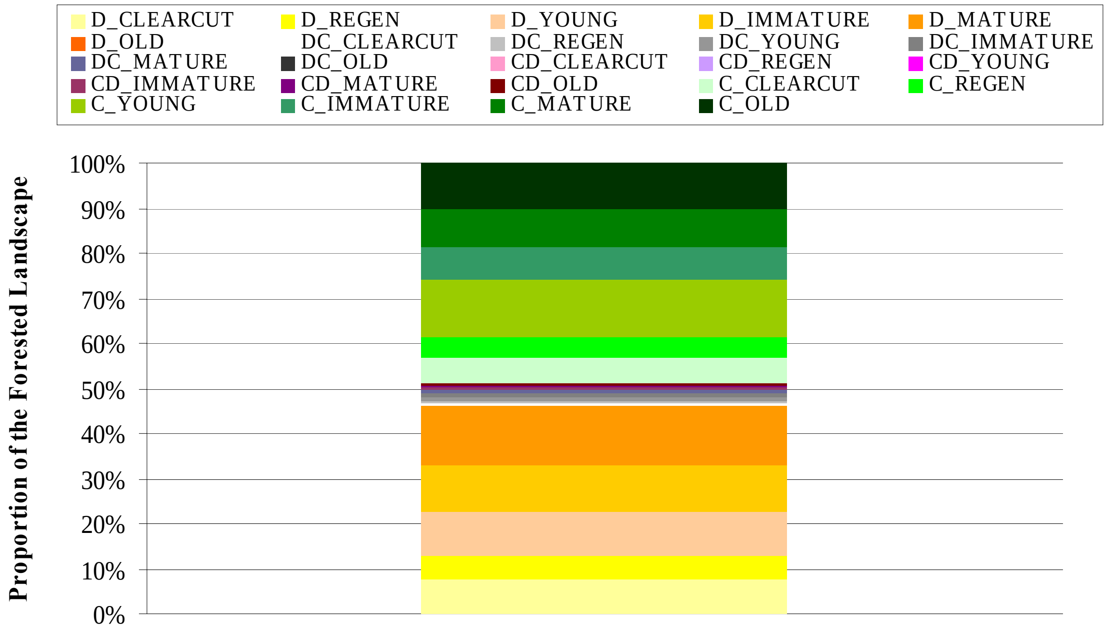

Figure 42. Proportion of seral stages by cover type in FMU W11 under the NDR.

Stand density

As observed in W13, there is a reduction of the proportion of the area in stands with low (AB) density along the simulation horizon (Figure 43). This is 13% reduction (24% to 11%) and it is mostly occurring during the first 70 years. Under the NDR scenario, AB density stands cover 37% of the landscape (37%, CI95%=32% to 43%).

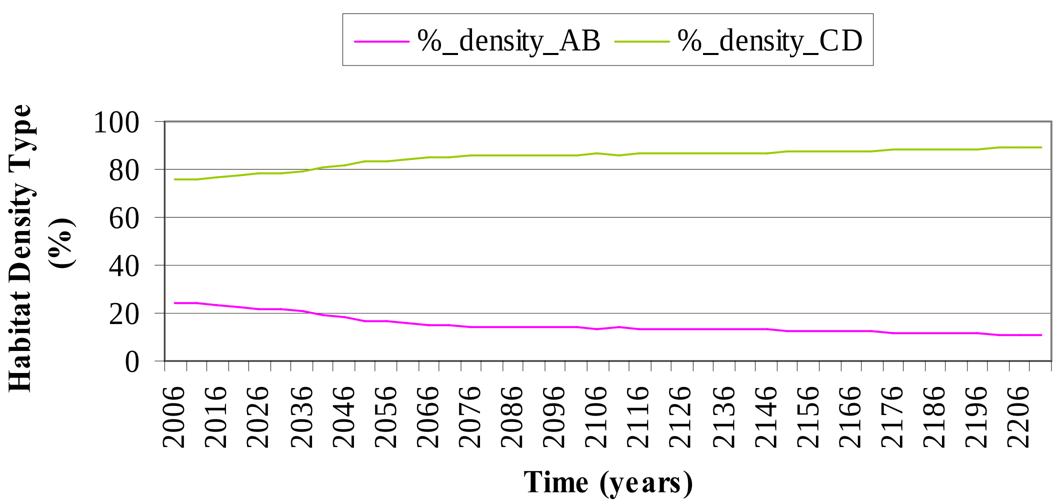

Figure 43. Changes in stand density type in FMU W11 under the PFMS scenario during the next 200 years.

3.2.2 Landscape configuration indicators

Edge

Applying the PFMS scenario to W11 increases the amount of edge by 13% in the first forty years and than stabilized around 9200 (km) (Figure 44). The variations of CWEL observed under the PFMS are all within the NRV.

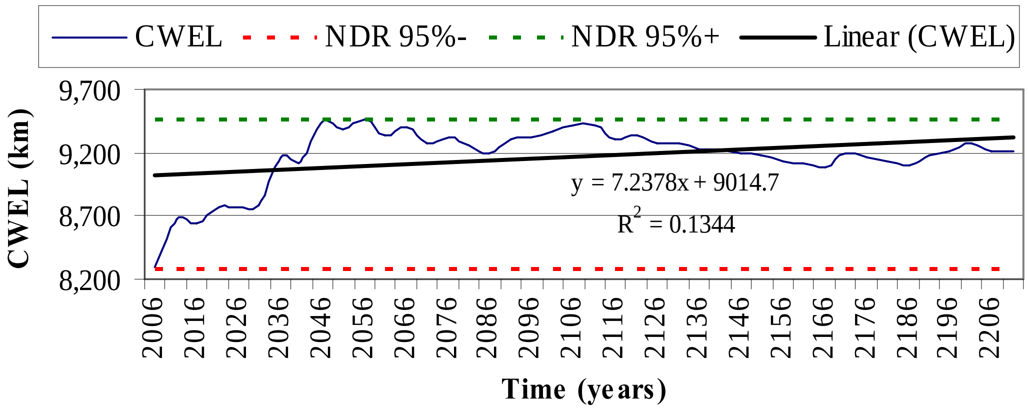

Figure 44. Changes in contrast-weighted edge length (CWEL) in FMU W11 under the PFMS scenario during the next 200 years. Dotted lines represent bounds of the natural range of variation as determined from the NDR scenario.

The change in CWEL is certainly due to the increase of the MECI that moves from 0.61 to 0.68 early in the simulation (Figure 45). MECI in W11 (0.65±95%CI=0.005) is more important than in W13 (0.615±95%CI=0.003). For most of the simulation horizon, MECI is over the upper bound of the NRV.

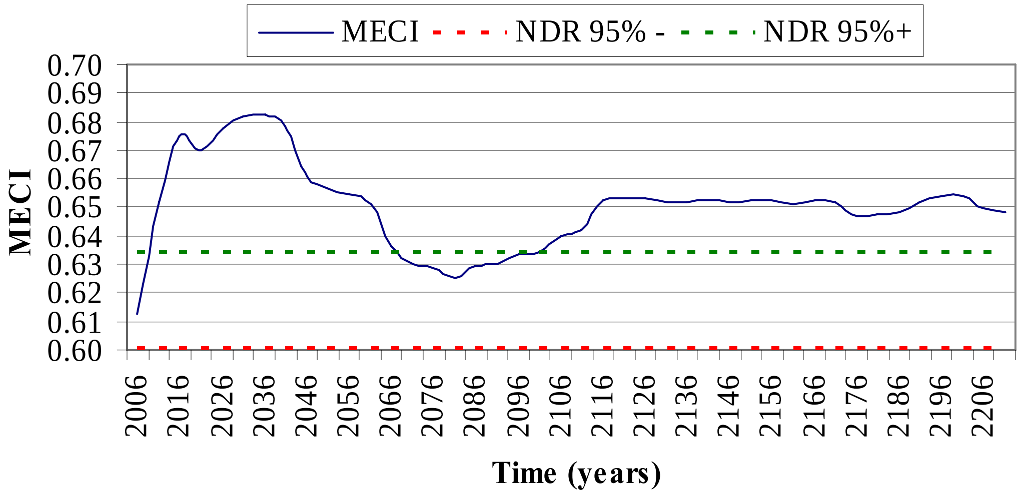

Figure 45. Changes in mean edge contrast index (MECI) in FMU W11 under the PFMS scenario during the next 200 years. Dotted lines represent bounds of the natural range of variation as determined from the NDR scenario.

Patch size

Mean patch size in W11 is 17.1 ha (±CI95%=0.14 ha, Table 12). It is greater than what it is in W13 by 5 ha; this may be explained by the fact that W11 is less dissected by roads and pipelines than W13.

Table 12. Patch size distribution parameter (mean and 25th percentiles (25, 50 and 75)) of patch size in FMU W11 under the PFMS scenario.

		Patch size distribution parameter		
	Average	25th percentile	50th percentile	75th percentile
95%+	17.25	16.00	46.29	163.48
Mean	17.11	15.82	45.73	156.50
95%-	16.97	15.65	45.16	149.51

Under the NDR, the average patch size is smaller (6.82 ha, Table 12 and Table 13). Although not as striking as in W13, the patch distribution of NDR is more spread. We observe that under the NDR the 25th and the 50th percentile are smaller than under the PFMS, but the 75th percentile is greater under the NDR.

Table 13. Patch size distribution parameter (mean and 25th percentiles (25, 50 and 75)) of patch size in FMU W11 under the NDR scenario.

		Patch size distribution parameter		
	Average	25th percentile	50th percentile	75th percentile
95%+	5.64	6.20	30.34	178.20
Mean	6.82	6.94	34.25	218.69
95%-	4.79	5.63	26.69	143.13

Mean patch size significantly decreases with time (P<0.001, R2=0.45), a reduction that occurs in the first 30 years (Figure 46); during these first years, the 75th patch size percentile is reduced from 250 ha to 150 ha and then stabilizes.

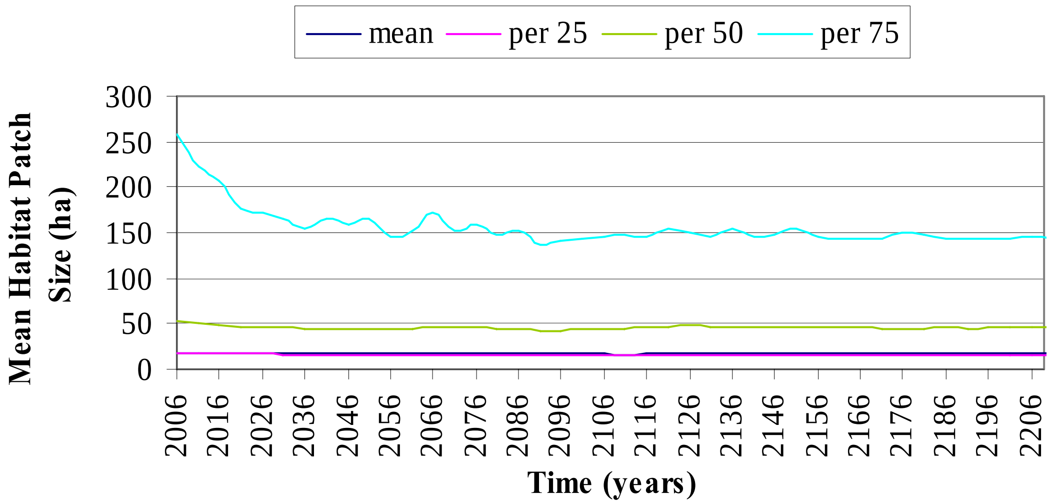

Figure 46. Mean and 25th percentiles (25, 50 and 75) of patch size in FMU W11 under the PFMS scenario during the next 200 years.

OLD GROWTH mean patch size in W11 is similar to what is observed W13 for the "Hw" (Table 5 and Table 14). However, for "HwMix", "SwMix" and particularly for "Sw" cover types OLD GROWTH patches are greater in W11 than in W13. OLD GROWTH patches under the NDR are smaller than under the PFMS (Table 14). Indeed, for the "Sw" cover type, OLD GROWTH mean patch size is almost four times greater under the PFMS than under the NDR scenario.

Table 14. Mean patch size (ha) of OLD GROWTH habitat of the four different cover types in FMU W11 under the PFMS scenario during the next 200 years and under the NDR scenario.

	Hw	HwMix	SwMix	Sw
PFMS				
Mean	12.64	8.83	9.79	37.18
CI95%	1.96	1.27	0.71	4.00
NDR				
Mean	3.66	2.19	3.00	7.02
CI95%	3.07	0.84	0.95	1.69

Increasing the amount of "Sw" OLD GROWTH the way it is in W11 with the PFMS scenario exponentially increases the patch size as express by the 25th, 50th and 75th patch size percentile between year 2061 to year 2146 (Figure 47). In fact, by the end of the simulation, the "Sw" OLD GROWTH patch size is 50 ha, 1819 ha, 2631 ha, and 9764 ha for the mean, the 25th, the 50th, and the 75th percentiles, respectively.

Inversely, the "Hw" OLD GROWTH mean patch size is significantly decreasing in W11 with time (P<0.01, R2=0.27). Although fluctuating a lot, it starts at 16 ha and decreases at 6 ha (Figure 47)!

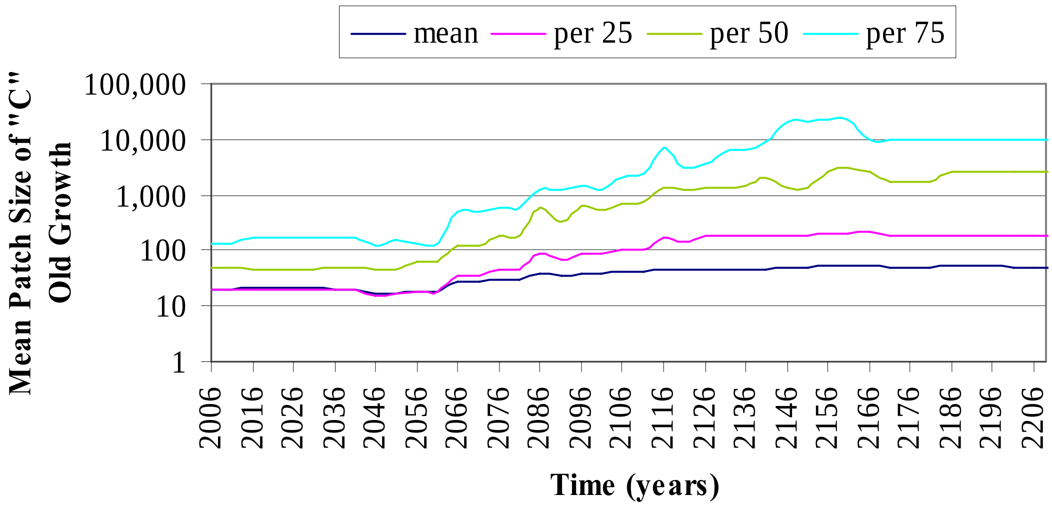

Figure 47. Mean and 25th percentiles (25, 50 and 75) of "Sw" OLD GROWTH habitat patch size in FMU W11 under the PFMS scenario during the next 200 years. Note that the y-axis is logarithmic.

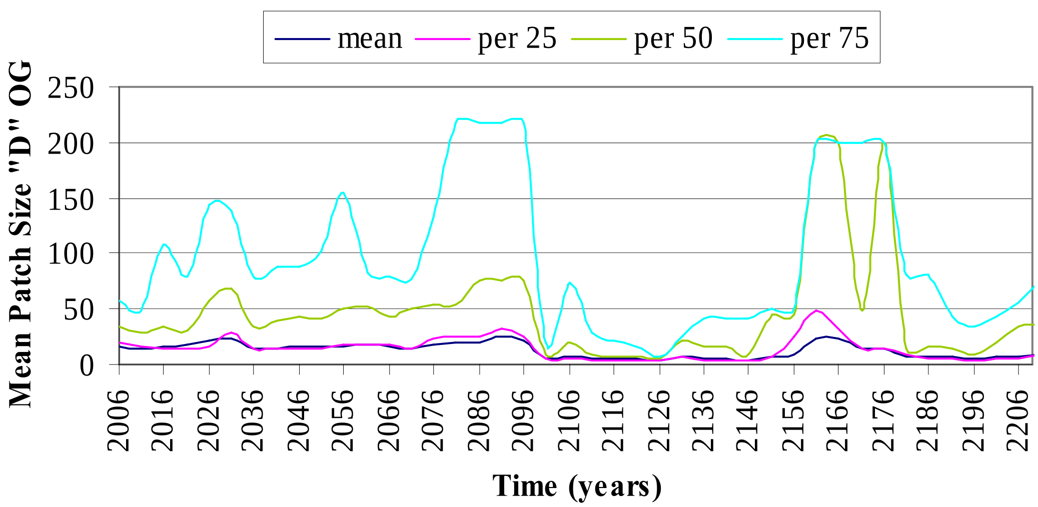

Figure 48. Mean and 25th percentiles (25, 50 and 75) of "Hw" OLD GROWTH habitat patch size in FMU W11 under the PFMS scenario during the next 200 years.

Core area

Core area decreases under the PFMS but stay close to or over the NRV upper bound (Figure 49). Core area represents around 46% of the entire forested area of the FMU. Old growth core area starts under the lower bound of the NRV and increases up to almost four times the upper limit of the NRV.

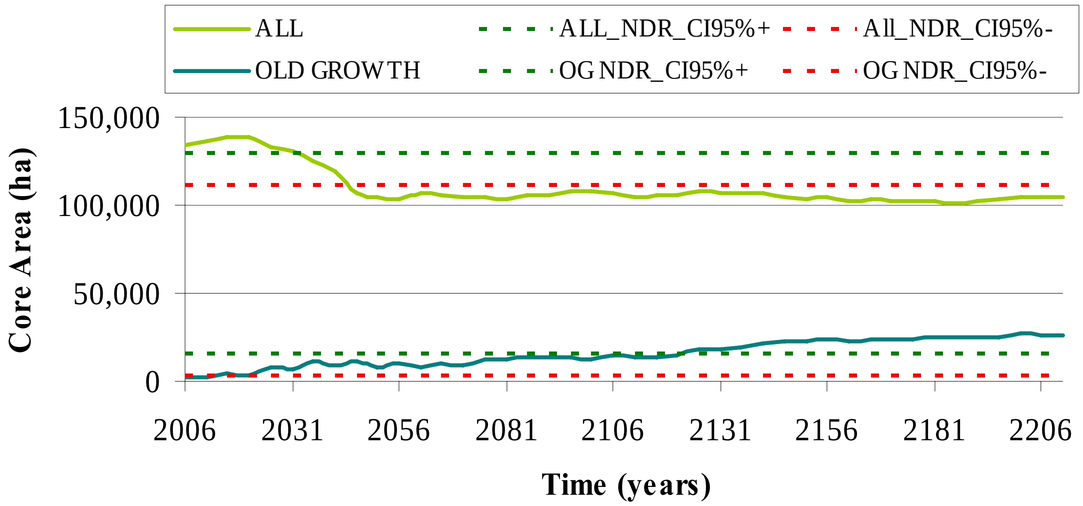

Figure 49. Overall and OLD GROWTH habitat core area in FMU W11 under the PFMS scenario during the next 200 years. Dotted lines represent bounds of the natural range of variation as determined from the NDR scenario.

Mean core habitat patch size is 5.44 ha (±95%CI=0.24 ha) in W11. It is rather small when compared to the mean patch size (17 ha), suggesting that the landscape is highly contrasted as expressed by the MECI. However, even under the NDR, the mean core overall habitat patch size is low (3.48 ha). The overall habitat core area patch size distribution under the NDR is similar to the one observed under the PFMS as expressed by the 25th, 50th, and 75th percentiles (5.29ha, 21.62 ha, and 88.03 ha , respectively). Overall core habitat patch size behave much more like the habitat patch size (Figure 50) although the 75th percentile do not stop reducing like the mean patch size.

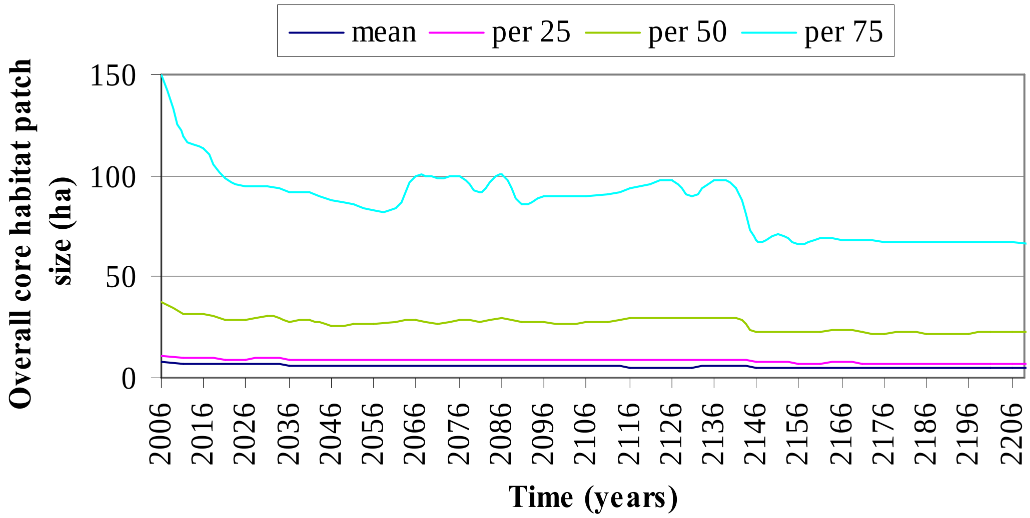

Figure 50. Mean and 25th percentiles (25, 50 and 75) of overall core habitat patch size in FMU W11 under the PFMS scenario during the next 200 years.

When looked by cover type, the OLD GROWTH core habitat mean patch size is greater in W11 than in W13 for the "HwMix", "SwMix", and "Sw" cover types (Table 15). OLD GROWTH core habitat mean patch size is smaller under the NDR than under the PFMS for all cover types. OLD GROWTH core habitat is again the largest for the coniferous cover type. However, if we do a ratio of OLD GROWTH core habitat mean patch size over the OLD GROWTH habitat mean patch size, it is for the coniferous cover type that the ratio is the smallest (0.25), compared to the three other cover types (around 0.40) meaning that it requires largest patches of "Sw" stand to generate a OLD GROWTH core habitat patch of equivalent size of any of the three other cover types in W11. This may be due to a more complex shape of this kind of patch or by the fact that this patch is surrounded by more contrasted habitats.

Table 15. Core habitat mean patch size (ha) of OLD GROWTH habitat of the four different cover types in FMU W11 under the PFMS scenario during the next 200 years and under the NDR.

	PFMS		NDR	
Cover type	**mean**	**95%CI**	**mean**	**95%CI**
Hw	4.96	0.63	1.57	0.98
HwMix	3.91	0.67	0.97	0.31
SwMix	4.19	0.52	1.35	0.34
SwMix	9.39	0.82	4.29	0.81

Dynamically, OLD GROWTH core habitat patch size behaves essentially like OLD GROWTH habitat patch size and consequently, time series are not presented.

Patch shape

Contrary to in W13, patch shape index is mostly stable for the overall habitat patch and by cover type (Figure 51). The two pure cover types have more complex patches, especially the coniferous cover type while the mixedwood cover type have more simple patches.

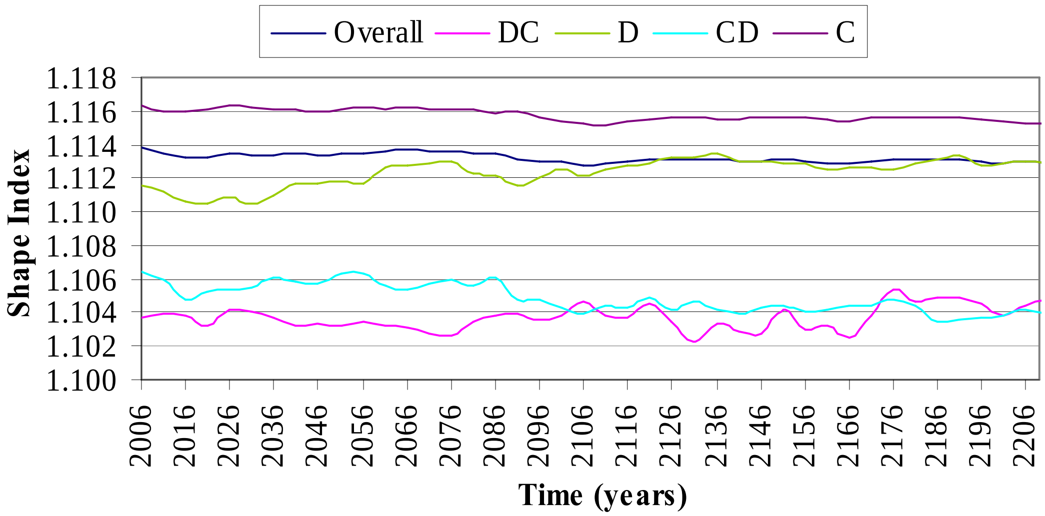

Figure 51. Shape index of the overall and by cover type habitat patches in FMU W11 under the PFMS scenario during the next 200 years.

Mean patch shape index under the NDR is much smaller for the overall habitat and by cover type than under the PFMS (Table 16).

Table 16. Shape index of the overall and by cover type habitat patches in FMU W11 under the NDR scenario.

	Mean	CI95%
Overall	1.04338	0.00123
Hw	1.03846	0.00452
Hm	1.04466	0.00332
Sm	1.03194	0.00897
Sw	1.04380	0.00311

If we look only at the OLD GROWTH patches, all cover types exhibit about the same patch shape complexity, although "Hw" and "HwMix" cover types might be more fluctuating and lower (Figure 52).

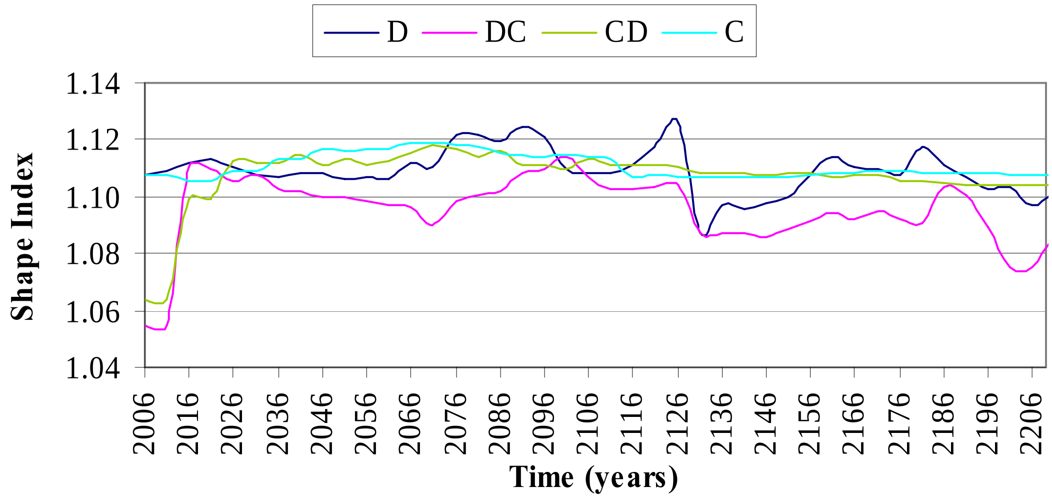

Figure 52. Shape index of the overall and by cover type OLD GROWTH habitat patches in FMU W11 under the PFMS scenario during the next 200 years.

Patch connectivity

Mean nearest neighbor distance (MNND) between clearcut patches is the greatest in W11 (8.6 km). All other seral stage classes have low mean nearest distance between patches (below 2 km) after year 2046 (Figure 53). Before, MNND between OLD GROWTH patches is reduced from 13 km to 2 km.

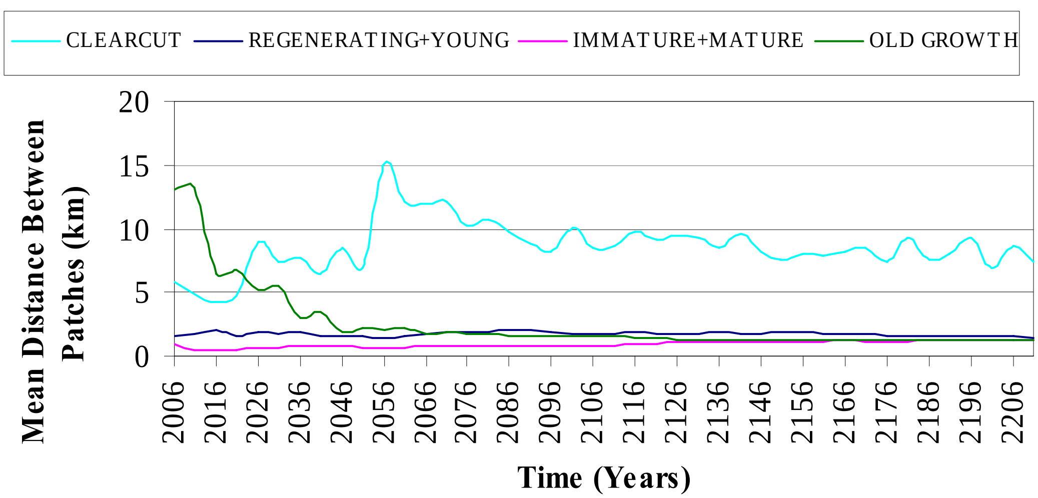

Figure 53. Mean nearest neighbor distance between patches of 4 seral stage classes in FMU W11 under the PFMS scenario during the next 200 years.

As we are particularly interested in understanding the OLD GROWTH patch spatial distribution, we also looked at the MNND between OLD GROWTH patches of the same cover type. For the “Hw” cover type, MNND between OLD GROWTH patches stays below the upper limit of the

NRV for the first half of the simulation and then get to higher values (Figure 54). For the "HwMix" cover type, the MND is below the upper limit of the NRV for most of the time (Figure 54). However, at the last 25 years of the simulation MND explodes et gets up to 5000 m! For the "Sw" and "SwMix" cover types, it starts over the upper limit of the NRV but rapidly get inside the bounds of the NRV.

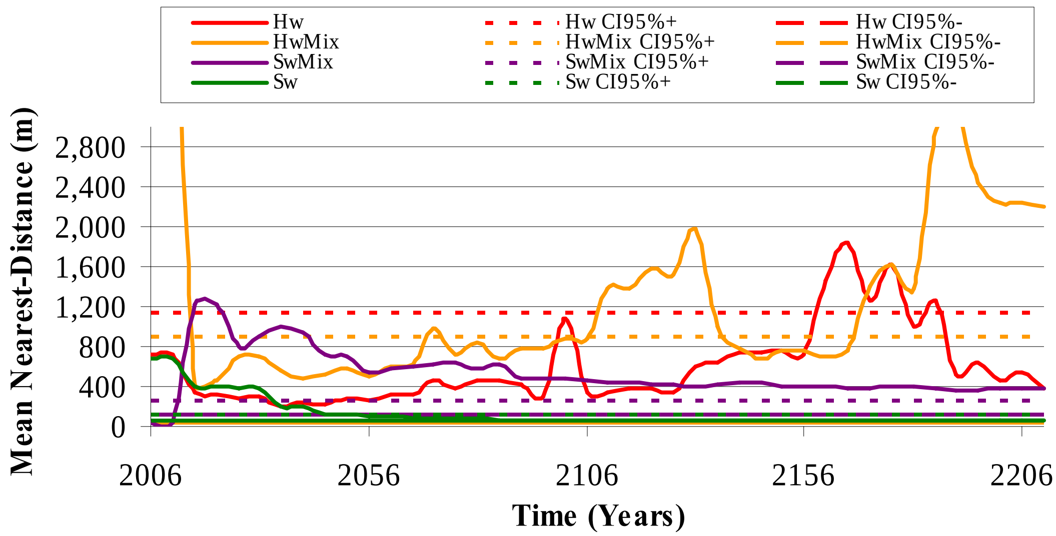

Figure 54. Mean nearest neighbor distance between OLD GROWTH patch of the same cover type in FMU W11 under the PFMS scenario during the next 200 years. Dotted lines represent bounds of the natural range of variation as determined from the NDR scenario.

3.2.3 Special habitat elements indicators

There are 14 SHE indicators showing a significant reduction during the simulation horizon (Table 17). Among them, basal area, density of tree with DBH>25cm, density of Aspen trees with dbh>25cm and height>7m, Aspen+Poplar %, canopy closure, arboreal lichen cover index, downed woody debris volume, and height-to-live crown show a predicted reduction by the linear regression of more than 10% (Table , Value Delta/Mean). The most critical one in W11 is the density of tree with DBH>25cm which shows a decrease of more than 50%. On the other end, density of snags conifers dbh>=20cm, low shrub cover %, tall shrub cover %, increases because of the aging of the forest.

Some SHE variables have a very different mean depending if it summarized for the managed or the unmanaged landbase (Table 17). Contrary to W13, most of the SHE variables have greater value in the managed portion than in the unmanaged portion: Arboreal lichen index, Aw_Poplar %, Basal area (m2/ha), Canopy closure%, Deciduous %, DENS(Live trees, Aw, Pb, d>25&h>7), DENS(Live trees, d>25), Fruit-bearing shrub cover %, Height to live crown (m), Herbaceous %, Low shrub cover %, Low shrub forage %, Shrub cover>1m %, Tall Shrub cover %Willow %, and Willow&rose %. However, some SHE variables have higher values on the unmanaged portion of the landbase. These are : Coniferous %, DENS(Live trees, Aw, Pb, Sw d>40), DENS(Snags conifers d>=20), Downed woody debris cover %, Downed woody debris volume, Ground lichen %, and Shrub cover>0.20m %.

When the values under the PFMS are compared to the natural range of variation (NRV) of the SHE as expressed to the SHE mean and CI95% values obtained under the Natural Disturbance Regime simulations (NDR), we observe the biggest difference with the basal area, ground lichen, some shrub covers, the abundance of DWD and the abundance of coniferous species in the landscape (Table 17).

Table 17. Statistics of the Special Habitat Element model outputs for the gross, managed, and unmanaged portions of FMU W11 under the PFMS scenario during the next 200 years and the NDR.

	PFMS								NDR	
			Manged	Unmaaged						
Special Habitat Element	Mean	CI95	Mean	Mean	Slope[1]10[2]	R2	*P* (F)*	Value Δ[2]	Mean	CI95%
Arboreal lichen index	179.56	3.04	192.46	164.09	-7.46	0.21	0.00	-15.30	158.78	18.89
Aw_Poplar %	14.35	0.34	18.82	8.99	-1.59	0.73	-	-3.26	12.61	0.87
Basal area (m^2/ha)	19.70	0.25	20.74	17.11	-1.79	0.86	-	-3.66	15.73	0.89
Canopy closure%	60.78	1.26	65.10	55.61	-6.33	0.87	-	-12.98	51.51	2.85
Coniferous %	67.76	0.15	54.01	84.25	0.67	0.72	-	1.37	71.50	1.17
Deciduous %	32.24	0.15	45.99	15.75	-0.67	0.72	-	-1.37	28.50	1.17
DENS(Live trees, Aw, Pb, d>25&h>7)	25.42	1.10	36.64	11.98	-4.96	0.70	-	-10.17	16.13	3.44
DENS(Live trees, Aw, Pb, Sw d>40)	19.38	0.64	16.53	22.79	2.40	0.48	-	4.91	11.82	1.56
DENS(Live trees, d>25)	74.93	3.92	88.41	58.77	-20.40	0.93	-	-41.82	47.06	7.90
DENS(Snags conifers d>=20)	19.50	1.00	16.34	23.28	5.16	0.91	-	10.58	12.64	1.38
DENS(Snags, d>20)	29.85	0.26	29.16	30.68	0.50	0.12	0.02	1.03	23.88	2.15
DENS(Snags, diseased or damaged trees, d>25)	70.90	0.45	47.54	50.01	2.28	0.87	-	4.66	38.92	3.50
Downed woody debris cover %	6.94	0.06	5.86	8.23	-0.13	0.20	0.00	-0.27	7.15	0.31
Downed woody debris volume	66.16	1.02	59.80	84.03	-4.21	0.59	-	-8.63	73.01	3.20
Free-to-Manoeuver-Flying-Space index	6.45	0.08	6.83	6.00	0.44	0.96	-	0.91	6.82	0.31
Fruit-bearing shrub cover %	5.28	0.02	6.53	3.77	0.06	0.41	-	0.12	4.84	0.13
Ground lichen %	1.71	0.01	1.09	2.44	-0.04	0.78	-	-0.09	2.11	0.08
Height to live crown (m)	4.84	0.05	5.36	4.77	-0.25	0.75	-	-0.50	3.87	0.26
Herbaceous %	27.18	0.13	38.09	14.09	-0.38	0.29	0.00	-0.78	30.74	2.63
Low shrub cover %	11.88	0.60	12.87	10.70	3.18	0.98	-	6.52	14.31	1.42
Low shrub forage %	11.32	0.06	15.61	6.16	-0.24	0.61	-	-0.50	10.83	0.51
Shrub cover>0.20m %	23.53	0.12	19.14	28.79	0.61	0.88	-	1.26	27.50	0.37
Shrub cover>1m %	7.26	0.09	8.44	5.85	0.48	0.94	-	0.98	7.68	0.34
Stand age (years)	113.31	9.29	73.77	166.18	50.08	1.00	-	102.67	82.38	8.96
Stand height	12.46	0.06	12.19	12.78	0.23	0.52	-	0.48	9.86	0.69
Tall Shrub cover %	11.88	0.60	12.87	10.70	3.18	0.98	-	6.52	14.31	0.21
Willow %	4.57	0.08	7.07	1.57	0.32	0.61	-	0.65	6.50	0.17
Willow&rose %	6.10	0.05	9.09	2.51	0.03	0.01	0.45	0.07	8.38	0.19

[1] Significant temporal trend over the simulation horizon

[2] Value expressing the difference between the beginning and the end of the simulation of the linear regression predicted SHE values.

3.2.4 Habitat suitability indicators

In W11, under the PFMS, we observed a significant reduction in 35 SIs and an increase in 17 SIs (Table 18). Species negatively affected by the application of the PFMS scenario are:

Barred Owl, Brown Creeper, Canada Lynx, Elk (cover), Northern Goshawk, Pileated Woodpecker, Spruce Grouse, and Varied Thrush.

Species positively affected by the application of the PFMS scenario are:

American Marten, Northern Red-Backed Vole, Ruffed Grouse, Three-toed Woodpecker, Snowshoe Hare, and Woodland Caribou.

Among the species negatively affected by the application of the PFMS, important reduction in habitat quality was detected for the Barred Owl (R2=0.38), Brown Creeper (R2=0.83), Canada Lynx (FOOD&COVER, R2>=0.70), Elk (COVER, R2=0.77), Northern Goshawk (R2=0.72) and Spruce Grouse (R2=0.76), and Varied Thrush (R2=0.90) as express by the delta values of SIs of their respective HSM (Table 18).

When compared to the mean habitat quality observed under the NDR, we detect a significant and lower difference for the American Marten(All and Hiding), the Canada Lynx (Denning), the Least Flycatcher, the Moose (Food_Mild Winter), Northern Flying Squirrel (Hiding), Ruffed Grouse (Cover), and Southern Red-Backed Vole (All, Cover and Hiding).

In addition to the species for which, in average, the mean SI values are significantly different and lower under the PFMS than under the NDR scenario, we observed less Medium and High quality habitat under the PFMS than under the NDR scenario (Table 19) for the following species: Barred Owl, Canada Lynx (Food), Northern Goshawk (All), Pileated Woodpecker (Nesting), Ruffed grouse (All), Snowshoe Hare (Cover and Food), Spruce Grouse (Cover), and Woodland Caribou (Food_Winter).

During the first 15 years, the PFMS scenario is reducing by at least 25% of the High quality habitat for the Southern Red-Backed Vole and the Three-toed Woodpecker while the PFMS reduces it by at least 50% for the American Marten and the Ruffed Grouse (Table 19).

Table 18. Statistics of the different suitability index (SIs) of the wildlife species habitat suitability models in FMU W11 under the PFMS scenario during the next 200 years and under the NDR scenario.

		PFMS								NDR	
Species	SI	Mean[1]	StDev	CI95%	Slope[2]10^4	R2	F	P(F)*	SI Δ[3]	Mean	CI95%
American Marten	ALL	0.71	0.03	0.01	4.57	0.83	193.72	0.42	0.09	0.78	0.05
American Marten	COVER	0.41	0.05	0.02	7.09	0.68	86.51	-	0.15	0.28	0.07
American Marten	HIDING	0.69	0.03	0.01	4.67	0.98	1,831.17	0.00	0.10	0.77	0.05
Barred Owl	ALL	0.22	0.02	0.01	-2.33	0.38	24.52	0.00	-0.05	0.15	0.04
Barred Owl	COVER	0.28	0.03	0.01	-3.80	0.86	242.54	-	-0.08	0.21	0.04
Barred Owl	FOOD	0.31	0.02	0.01	-2.80	0.86	246.14	-	-0.06	0.23	0.05
Barred Owl	NEST	0.15	0.03	0.01	-1.83	0.17	8.37	-	-0.04	0.10	0.04
Brown Creeper	ALL	0.08	0.02	0.01	-3.33	0.83	191.90	-	-0.07	0.06	0.03
Brown Creeper	FOOD	0.12	0.03	0.01	-4.53	0.91	392.79	-	-0.09	0.09	0.05
Brown Creeper	HIDING	0.04	0.01	-	-1.55	0.84	208.76	-	-0.03	0.02	0.01
Brown Creeper	NEST	0.17	0.02	0.01	-1.25	0.14	6.57	0.07	-0.03	0.17	0.06
Canada Lynx	COVER	0.29	0.04	0.01	-6.04	0.84	206.99	-	-0.12	0.25	0.05
Canada Lynx	DEN	0.05	-	-	-0.04	0.10	4.65	-	-	0.06	0.00
Canada Lynx	FOOD	0.41	0.03	0.01	-4.07	0.70	94.28	0.26	-0.08	0.40	0.06
Elk	CO_S	0.60	0.04	0.01	-5.79	0.77	133.10	-	-0.12	0.47	0.08
Elk	CO_W	0.60	0.04	0.01	-5.79	0.77	133.09	-	-0.12	0.47	0.08
Elk	FO_S	0.69	0.01	-	-0.89	0.58	56.30	0.30	-0.02	0.71	0.03
Elk	FO_W	0.66	0.01	-	2.18	0.84	217.63	-	0.04	0.60	0.03
Elk	HI_S	0.59	0.01	-	0.83	0.19	9.44	0.57	0.02	0.47	0.05
Elk	HI_W	0.60	0.01	-	0.89	0.21	10.68	0.58	0.02	0.47	0.05
Least Flycatcher	FOOD	0.27	0.01	-	-1.36	0.49	38.27	-	-0.03	0.35	0.02
Moose	CO_S	0.78	0.01	-	-1.33	0.54	46.56	-	-0.03	0.63	0.08
Moose	CO_SW	0.60	0.01	-	-1.70	0.66	76.22	-	-0.03	0.43	0.06
Moose	FO_MW	0.61	0.01	-	-0.91	0.25	13.50	-	-0.02	0.69	0.04
Moose	FO_S	0.83	0.01	-	-1.02	0.71	98.35	0.70	-0.02	0.81	0.01
Moose	FO_SW	0.59	-	-	-0.08	0.01	0.58	0.66	-	0.50	0.04
Moose	HI	0.60	0.04	0.01	5.75	0.97	1,453.80	0.73	0.12	0.65	0.05
Northern Flying Squirrel	ALL	0.49	0.01	-	-0.35	0.06	2.64	-	-0.01	0.50	0.02
Northern Flying Squirrel	COVER	0.35	0.04	0.01	-5.02	0.76	127.91	-	-0.10	0.31	0.05
Northern Flying Squirrel	FOOD	0.54	0.01	-	0.16	0.02	0.93	0.07	-	0.53	0.02
Northern Flying Squirrel	HIDING	0.63	0.02	0.01	3.84	0.96	989.19	-	0.08	0.69	0.04
Northern Goshawk	ALL	0.44	0.03	0.01	-3.81	0.72	102.17	0.30	-0.08	0.41	0.06

Table 18. Statistics of the different suitability index (SIs) of the wildlife species habitat suitability models in FMU W11 under the PFMS scenario during the next 200 years and under the NDR scenario (continued).

		PFMS								NDR	
Species	SI	Mean[1]	StDev	CI95%	Slope[2] 10^4	R2	F	P(F)*	SI Δ[3]	Mean	CI95%
Northern Goshawk	FOOD	0.24	0.03	0.01	-4.06	0.70	93.40	-	-0.08	0.22	0.05
Northern Goshawk	NEST	0.85	0.02	-	0.04	-	0.01	-	-	0.83	0.07
Northern Goshawk	NEST_S	0.17	0.02	-	-1.96	0.59	57.66	-	-0.04	0.19	0.05
Pileated Woodpecker	ALL	0.56	0.01	-	-1.17	0.29	16.19	-	0.01	0.51	0.07
Pileated Woodpecker	COVER	0.55	0.03	0.01	-5.42	0.95	695.12	-	-0.01	0.46	0.08
Pileated Woodpecker	FOOD	0.44	0.02	0.01	2.60	0.47	34.96	-	0.09	0.42	0.07
Pileated Woodpecker	NEST	0.74	0.02	0.01	-2.72	0.51	40.88	0.12	-0.02	0.71	0.09
Ruffed Grouse	ALL	0.36	0.01	-	1.54	0.91	392.76	0.00	-0.11	0.34	0.02
Ruffed Grouse	COVER	0.25	0.01	-	0.12	0.02	0.76	0.59	0.05	0.27	0.01
Ruffed Grouse	HIDING	0.55	0.03	0.01	4.42	0.96	1,055.46	0.29	-0.06	0.45	0.05
Snowshoe Hare	COVER	0.55	0.04	0.01	5.66	0.97	1,222.14	-	0.03	0.66	0.05
Snowshoe Hare	FOOD	0.53	0.01	-	0.16	0.03	1.07	-	-	0.67	0.05
Southern Red-Backed Vole	ALL	0.39	-	-	0.51	0.57	53.09	0.01	0.09	0.44	0.02
Southern Red-Backed Vole	COVER	0.29	-	-	-0.65	0.87	274.80	0.00	0.12	0.32	0.02
Southern Red-Backed Vole	HIDING	0.58	0.03	0.01	4.39	0.97	1,319.40	-	-	0.65	0.04
Spruce Grouse	ALL	0.47	0.02	0.01	-2.50	0.76	126.15	-	-0.05	0.40	0.04
Spruce Grouse	COVER	0.46	0.02	0.01	-2.35	0.72	103.53	-	-0.05	0.38	0.06
Spruce Grouse	FOOD	0.48	0.02	0.01	-3.04	0.80	156.93	-	-0.06	0.46	0.03
Spruce Grouse	NEST	0.58	0.02	0.01	-2.64	0.75	120.38	-	-0.05	0.49	0.02
Three-toed Woodpecker	ALL	0.39	0.06	0.02	7.95	0.73	106.33	-	0.16	0.39	0.06
Three-toed Woodpecker	FOOD	0.51	0.02	0.01	0.61	0.04	1.68	-	0.01	0.44	0.05
Three-toed Woodpecker	NEST	0.33	0.07	0.02	9.69	0.79	153.71	-	0.20	0.39	0.08
Varied Thrush	ALL	0.46	0.03	0.01	-5.13	0.90	354.00	-	-0.11	0.39	0.06
Varied Thrush	FOOD	0.44	0.02	0.01	-3.32	0.84	203.72	-	-0.07	0.44	0.05
Varied Thrush	NEST	0.50	0.05	0.02	-7.93	0.88	288.64	-	-0.16	0.39	0.08
Woodland Caribou	COV_R	0.27	-	-	-	1.00	NA	NA	-	0.27	N/A
Woodland Caribou	FOOD_R	0.44	-	-	-	0.81	168.19	-	-	0.44	-
Woodland Caribou	FOOD_S	0.73	0.01	-	2.14	0.95	784.84	-	0.04	0.71	0.00
Woodland Caribou	FOOD_W	0.44	0.02	0.01	0.72	0.06	2.76	-	0.01	0.43	0.04

[1] Significant lower difference of the value under the PFMS compared to the value under the NDR

[2] Significant temporal trend over the simulation horizon

[3] Value expressing the difference between the beginning and the end of the simulation of the linear regression predicted mean SI values

Table 19. Area (km2) of Low, Medium and High quality habitat in FMU W11 under the PFMS scenario (average) and under the NDR (average).

Species	SI	SI value threshold		PFMS (average) Habitat area (km^2)			NDR (average) Habitat area (km^2)		
		Low/Med	Med/High	Low	Med.	High	Low	Med.	High
American Marten	ALL	0.3	0.7	142.0	763.0	2,013.0	105.0	176.0	1,605.0
American Marten	COVER	0.3	0.7	473.0	1,689.0	521.0	998.0	1,094.0	219.0
American Marten	HIDING	0.3	0.7	123.0	963.0	1,845.0	105.0	645.0	2,193.0
Barred Owl	ALL	0.2	0.5	551.0	1,988.0	89.0	1,041.0	1,195.0	44.0
Barred Owl	COVER	0.2	0.5	348.0	2,104.0	319.0	693.0	1,699.0	135.0
Barred Owl	FOOD	0.2	0.5	223.0	2,213.0	424.0	627.0	1,794.0	153.0
Barred Owl	NEST	0.3	0.7	1,398.0	622.0	7.0	1,580.0	313.0	5.0
Brown Creeper	ALL	0.2	0.5	1,411.0	522.0	86.0	1,511.0	401.0	35.0
Brown Creeper	FOOD	0.3	0.7	1,445.0	514.0	35.0	1,527.0	407.0	3.0
Brown Creeper	HIDING	0.1	0.3	1,324.0	701.0	55.0	1,493.0	458.0	10.0
Brown Creeper	NEST	0.3	0.7	1,307.0	622.0	163.0	1,326.0	569.0	183.0
Canada Lynx	COVER	0.3	0.7	1,018.0	573.0	705.0	1,150.0	342.0	710.0
Canada Lynx	DEN	0.1	NA	955.0	1,387.0	0.0	524.0	2,122.0	0.0
Canada Lynx	FOOD	0.3	0.7	656.0	982.0	917.0	741.0	629.0	1,123.0
Elk	CO_S	0.3	0.7	466.0	396.0	1,825.0	689.0	450.0	1,391.0
Elk	CO_W	0.3	0.7	466.0	396.0	1,825.0	689.0	448.0	1,393.0
Elk	FO_S	0.3	0.7	142.0	957.0	1,818.0	167.0	716.0	2,018.0
Elk	FO_W	0.3	0.7	128.0	1,276.0	1,523.0	182.0	1,119.0	1,587.0
Elk	HI_S	0.3	0.7	318.0	1,262.0	1,212.0	387.0	1,265.0	1,092.0
Elk	HI_W	0.3	0.7	312.0	1,213.0	1,272.0	401.0	1,191.0	1,143.0
Least Flycatcher	FOOD	0.3	0.7	1,042.0	572.0	665.0	877.0	703.0	817.0
Moose	CO_S	0.3	0.7	301.0	110.0	2,394.0	544.0	118.0	1,971.0
Moose	CO_SW	0.3	0.7	373.0	723.0	1,658.0	635.0	779.0	1,154.0
Moose	FO_MW	0.3	0.7	531.0	573.0	1,538.0	361.0	464.0	1,937.0
Moose	FO_S	0.3	0.7	135.0	351.0	2,437.0	236.0	142.0	2,473.0
Moose	FO_SW	0.3	0.7	212.0	1,423.0	1,233.0	402.0	1,122.0	1,209.0
Moose	HI	0.3	0.7	345.0	981.0	1,448.0	301.0	749.0	1,756.0
Northern Flying Squirrel	ALL	0.3	0.7	168.0	2,127.0	604.0	142.0	2,264.0	511.0
Northern Flying Squirrel	COVER	0.3	0.7	911.0	895.0	566.0	973.0	935.0	421.0
Northern Flying Squirrel	FOOD	0.3	0.7	135.0	2,091.0	697.0	124.0	2,193.0	614.0
Northern Flying Squirrel	HIDING	0.3	0.7	118.0	1,265.0	1,552.0	90.0	968.0	1,896.0

Table 19. Area (km2) of Low, Medium and High quality habitat in FMU W11 under the PFMS scenario (average) and under the NDR (average) (continued).

Species	SI	SI value threshold		PFMS (average) Habitat area (km²)			NDR (average) Habitat area (km²)		
		Low/Med	Med/High	Low	Med.	High	Low	Med.	High
Northern Goshawk	ALL	0.3	0.6	88.0	2,410.0	457.0	213.0	2,263.0	391.0
Northern Goshawk	FOOD	0.2	0.5	323.0	2,422.0	45.0	546.0	2,030.0	56.0
Northern Goshawk	NEST	0.3	0.7	6.0	445.0	2,562.0	6.0	478.0	2,531.0
Northern Goshawk	NEST_S	0.3	0.7	1,288.0	622.0	196.0	1,219.0	761.0	173.0
Pileated Woodpecker	ALL	0.3	0.6	0.0	1,418.0	1,600.0	52.0	1,724.0	1,206.0
Pileated Woodpecker	COVER	0.3	0.6	4.0	1,555.0	1,457.0	159.0	1,914.0	832.0
Pileated Woodpecker	FOOD	0.3	0.7	102.0	2,735.0	108.0	150.0	2,627.0	135.0
Pileated Woodpecker	NEST	0.3	0.7	0.0	654.0	2,364.0	33.0	890.0	2,072.0
Ruffed Grouse	ALL	0.3	0.6	311.0	2,400.0	86.0	308.0	2,487.0	5.0
Ruffed Grouse	COVER	0.2	0.5	388.0	2,292.0	64.0	156.0	2,736.0	15.0
Ruffed Grouse	HIDING	0.3	0.7	87.0	2,164.0	707.0	162.0	2,345.0	396.0
Snowshoe Hare	COVER	0.3	0.7	396.0	1,024.0	1,317.0	295.0	719.0	1,796.0
Snowshoe Hare	FOOD	0.3	0.7	543.0	868.0	1,222.0	297.0	667.0	1,843.0
Southern Red-Backed Vole	ALL	0.3	0.7	394.0	2,204.0	141.0	261.0	2,436.0	136.0
Southern Red-Backed Vole	COVER	0.3	0.7	726.0	1,704.0	73.0	517.0	2,108.0	26.0
Southern Red-Backed Vole	HIDING	0.3	0.7	205.0	1,498.0	1,170.0	172.0	1,168.0	1,557.0
Spruce Grouse	ALL	0.3	0.6	139.0	1,775.0	1,006.0	249.0	2,148.0	445.0
Spruce Grouse	COVER	0.3	0.6	153.0	2,009.0	747.0	476.0	1,667.0	538.0
Spruce Grouse	FOOD	0.3	0.7	114.0	2,534.0	290.0	90.0	2,702.0	162.0
Spruce Grouse	NEST	0.3	0.7	150.0	1,467.0	1,294.0	160.0	2,399.0	347.0
Three-toed Woodpecker	ALL	0.3	0.7	712.0	1,040.0	763.0	577.0	1,543.0	489.0
Three-toed Woodpecker	FOOD	0.3	0.7	489.0	946.0	1,236.0	478.0	1,536.0	667.0
Three-toed Woodpecker	NEST	0.3	0.7	864.0	931.0	611.0	622.0	1,343.0	612.0
Varied Thrush	ALL	0.3	0.7	415.0	1,556.0	753.0	577.0	1,543.0	489.0
Varied Thrush	FOOD	0.3	0.7	514.0	1,419.0	722.0	478.0	1,536.0	667.0
Varied Thrush	NEST	0.3	0.7	347.0	1,419.0	1,006.0	622.0	1,343.0	612.0
Woodland Caribou	COV_R	0.3	0.7	1,268.0	4.0	847.0	1,266.0	4.0	851.0
Woodland Caribou	FOOD_R	0.3	0.7	967.0	6.0	1,359.0	963.0	6.0	1,367.0
Woodland Caribou	FOOD_S	0.4	0.7	0.0	519.0	2,499.0	0.0	512.0	2,506.0
Woodland Caribou	FOOD_W	0.2	0.5	0.0	1,876.0	1,143.0	0.0	1,820.0	1,199.0

4. Risk Assessment

4.1 Approach

Biodiversity assessment is a data intensive process generating large amounts of output. We developed a risk assessment process to distill the output down into succinct products to provide direction for resource managers. Risk assessment is designed to identify elements of biodiversity that are outside the NRV and are not improving with time. Biodiversity elements that are not identified as being at risk are not reported in this assessment. The intent is to identify only the potential areas of concern so that appropriate management action can be taken to address biodiversity before significant harm develops.

We assessed the risk of losing a biodiversity value according to the two following principles:

- A biodiversity value is not at risk if it remains inside the NRV;
- A biodiversity value is not at risk if its related indicators do not show a significant temporal trend expressing a reduction of the value.

Consequently to these principles, a risk assessment scheme has been developed (Table 20). With this scheme, the risk associated with a biodiversity value is either **low**, **moderate** or **high**, and is either at the **short** or **long term**. We applied this scheme to all the indicator models, verified if there was a significant temporal trend and how much the indicator output values where inside the NRV, and then assigned the defined a priority of concern as either high, medium or low priority.

Table 20. Risk assessment and concern priority scheme for the biodiversity indicator.

	Inside the NRV	Outside the NRV	
	Most of the time	**Half of the time**	**Most of the time**
No temporal trend	No concern	Moderate concern at short term	High concern at short term
Significant temporal trend	Low concern at long term	High concern at long term	High concern at short term

The term "concern" is used for risk categories in Table 20 to reflect the difference between plausible outcomes derived from modeling and actual future. Classifying a biodiversity element as a concern provides direction to managers to modify operations to retain biodiversity.

4.2 Ecosystem and landscape indicators

4.2.1 Forest Age

When the entire horizon is considered, forest age is older under the PFMS than under the NDR for both FMUs. Under the PFMS, forest age increases due to the aging of the unmanaged portion of the landscape, particularly the very old portion of the landscape. However, even if we consider only the managed portion of the forest, forest age is still within the NRV, although lower than the average age under the NDR. Consequently, if we consider all the indicators that are related to the forest age (Mean area-weighted stand age, age percentile break-ups, seral stages and oldgrowthness), none these indicators are indicating an important deviation from the NRV.

Risk Assessment:

Both FMUs: No concern on the gross landbase. Moderate concern at short term if we considered only the managed portion of the landbase.

Recommendation:

None

4.2.2 Forest Age Structure

Looking at the age structure shows that there is an under representation of young stands (0-20 years) and an over representation of the medium-aged stands (50-80 years) in both FMUs. Such effect is due to the normalization of the forest under management compared to the inverse "J" distribution inherent in the NRV. The differences observed are within the NRV for medium-aged stands. However, the CLEARCUT and OLD GROWTH seral stages are outside the NRV.

Risk Assessment:

Both FMUs: Low concern at long term

Recommendation:

Increase the amount of young seral stages in the landscape particularly in the "Hw" and the "HwMix" cover type by reducing the rotation for these two cover types.

4.2.3 Ecosystem diversity

For this assessment we consider the proportion of the different habitat types (seral stages by cover type), the ecosystem diversity index, and the density class proportion. The landscape generated under the PFMS is less diversified than under the NDR for both FMUs. In W13, the risk is at long term while in W11 the difference is important all along the simulation horizon. In both FMUs, we observed that the habitat proportion is less balanced under the PFMS than under the NDR: There is not enough young seral stages in "Hw" and HwMix" cover types and the proportion of old seral stages of the softwood-dominated mixedwood is to low in both FMUs. Moreover, the proportion of the "HW" in the landscape is reduced over time even if it is already low from the start. Low-density stands are reduced with time under a level that it is suspected to be non-natural, particularly in W13.

Risk Assessment

W13: Concern at long term

W11: Concern at short term

Recommendation:

Re-equilibrate of the seral stage proportion. Limit the proportion of the softwood to 50% of the landscape. Generate older "SwMix" stands by thinning from above the "HwMix" stands. Do not allow the representation of the low-density stands below 10%.

4.2.4 Landscape fragmentation

Looking at the edge indicator, we observed that W13 under the PFMS is more contrasted than under the NDR while for W11 it is similar (although the MECI is higher). Both landscapes have a truncated patch size distribution compared to the NRV: there is too few small patches (although this might be just an effect of the difference in resolution between Patchworks and SELES projections) and large patches. In W13, this makes the overall core area decreasing under the NRV. OLD GROWTH core area is not a problem in both FMUs as it's higher than the NRV. OLD GROWTH patches are less connected under the PFMS than under the NDR for the "Hw", "HwMix" in both FMUs, and for the "SwMix" in W11 while "Sw" OLD GROWTH patches connectivity is comparable.

Risk Assessment

W13: Moderate concern at long term

W11: Low concern at long term

Recommendation:

Most of the edges come from the road and the O&G infrastructures. To compensate such effect, careful attention should be paid to build back large forest tracts. Two ways can be used to achieve this:

- generate more large patches; and
- dissolve some boundaries by making different patches similar in composition and structure with time.

4.3 Special Habitat Elements

For the special habitat elements, we proceed more specifically by looking at each variable. Managing the forest for timber modifies the internal structure of the habitat. In W13, the special elements that are specifically of concern are the downed woody debris, the amount of Aw and Pb in the stand, and many understory vegetation covers (ground lichen, herbaceous cover and different shrub type covers) (Table 21).

Recommendation:

Special attention should be paid to the retention of certain habitat features when clearcutting and site-preparing. To increase the DWD volume, variable retention should be used. Site preparing should not destroy the DWD and the understory vegetation. Many understory vegetation cover are disappearing because of the high density of the stands and the Vegetation Management Strategies. A more global approach is required for maintaining these SHEs in the landscape at a level comparable to the NRV by allowing more low density stands that do not have VMS at their origin.

Table 21. Risk analysis of the Special Habitat Elements for FMU W13 under the PFMS.

Special Habitat Element	NRV[1]	Temporal trend (%)[2]	Priority of concern
Arboreal lichen index	-	-	High concern at short term
Aw_Poplar %	-	-	High concern at short term
Coniferous %	+	+	High concern at mid term
Deciduous %	-	-	High concern at mid term
DENS(Live trees, Aw, Pb, d>25&h>7)	=	-	Low concern at long term
DENS(Live trees, Aw, Pb, Sw d>40)	+	+	No concern
DENS(Live trees, d>25)	+	-	Low concern at long term
DENS(Snags conifers d>=20)	+	+	No concern
DENS(Snags, d>20)	=	=	No concern
DENS(Snags, diseased or damaged trees, d>25)	+	+	No concern
Downed woody debris cover %	-	-	High concern at short term
Downed woody debris volume	-	-	High concern at short term
Free-to-Manoeuver-Flying-space index	-	=	Moderate concern at short term
Fruit-bearing shrub cover %	-	=	Moderate concern at short term
Ground lichen %	-	-	High concern at short term
Height to live crown (m)	=	=	No concern
Herbaceous %	-	-	High concern at short term
Low shrub cover %	-	-	High concern at short term
Low shrub forage %	-	-	High concern at short term
Shrub cover>0.20m %	-	-	High concern at short term
Shrub cover>1m %	-	=	Moderate concern at short term
Stand age (years)	+	+	No concern
Stand height	+	+	No concern
Tall Shrub cover %	=	-	Low concern at long term
Willow %	-	-	High concern at short term
Willow&rose %	-	-	High concern at short term

[1] +: PFMS mean significantly greater than the NDR mean, -: PFMS mean significantly lower than the NDR mean

[2] +: > 10% change of the PFMS mean; -: < 10% change of the PFMS mean.

The W11 PFMS has maintained the SHEs much more inside the NRV than W13 PFMS. We observed much less SHE being of concern in W11 than in W13 (Table 22). This may be due to the large amount of the unmanaged portion of the W11 FMU or the presence of crop plans in W13. The SHEs particularly of concern in W11 under the PFMSs are DWD volume, ground lichen cover, and herbaceous cover. Many shrub covers start with values lower than the NDR but recover with time and get inside the NRV. These have been classified as “Low concern at short term .

Table 22. Risk analysis of the Special Habitat Elements for FMU W11 under the PFMS.

Special Habitat Element	NRV[1]	Temporal trend (%)[2]	Priority of concern
Arboreal lichen index	+	=	No concern
Aw_Poplar %	+	-	Low concern at long term
Coniferous %	-	=	Low concern at short term
Deciduous %	+	=	No concern
DENS(Live trees, Aw, Pb, d>25&h>7)	+	-	No concern
DENS(Live trees, Aw, Pb, Sw d>40)	+	+	No concern
DENS(Live trees, d>25)	+	-	Low concern at long term
DENS(Snags conifers d>=20)	+	+	No concern
DENS(Snags, d>20)	+	=	No concern
DENS(Snags, diseased or damaged trees, d>25)	+	=	No concern
Downed woody debris cover %	=	=	Moderate concern at long term
Downed woody debris volume	-	-	High concern at short term
Free-to-Manoeuver-Flying-space index	-	+	Low concern at short term
Fruit-bearing shrub cover %	+	=	No concern
Ground lichen %	-	=	High concern at short term
Height to live crown (m)	+	-	No concern
Herbaceous %	-	=	High concern at short term
Low shrub cover %	-	+	Low concern at short term
Low shrub forage %	=	=	No concern
Shrub cover>0.20m %	-	=	Low concern at short term
Shrub cover>1m %	-	+	Low concern at short term
Stand age (years)	+	+	No concern
Stand height	+	=	No concern
Tall Shrub cover %	-	+	Low concern at short term
Willow %	-	+	High concern at short term
Willow&rose %	-	=	High concern at short term

[1] +: PFMS mean significantly greater than the NDR mean, -: PFMS mean significantly lower than the NDR mean

[2] +: > 10% change of the PFMS mean; -: < 10% change of the PFMS mean.

Recommendation:

In W11, Standard Operating Procedures should included careful management of ground features while site-preparing. This should allow maintenance the DWD and the ground lichen patches. Variable retention, although much less required than in W13, should also used in W11 for DWD recruitment, particularly in areas where there is much less unmanaged forests close to it.

4.4 Habitat Suitability Models

For the HSMs, as for the special habitat elements, we proceed more specifically by looking at each SI model. To do the risk assessment for the wildlife habitats, we looked at the mean SI value, its temporal trend and also the distribution of Low, Medium and High quality habitat.

In W13, the American Marten, Canada Lynx, Least Flycatcher, Northern Flying Squirrel, Pileated Woodpecker, Snowshoe Hare, Southern Red-Backed Vole, Three-toed Woodpecker, and the Woodland Caribou are at concern at short term (Table 23). All wildlife of concern is related to one of the SHEs that are also of concern. For example, the quality of the habitat of many of wildlife species of concern is relying on DWD (American Marten, Canada Lynx, Southern Red-backed Vole), snags (Pileated Woodpecker, Three-toed Woodpecker), shrub cover (Snowshoe Hare, Moose), Aspen/Poplar abundance (Least Flycatcher), ground lichen (Woodland Caribou) and arboreal lichen (Woodland Caribou, Northern Flying Squirrel). Spatial configuration does not seems to be a problem other than for the Northern Goshawk (Nesting-Spatial SI).

Table 23. Risk analysis of the wildlife for FMU W13 under the PFMS.

Species	SI	Mean	Trend	Med+ High	High	Priority of concern
American Marten	ALL	-	-			High concern at short term
American Marten	COVER					
American Marten	HIDING	-	-		-	High concern at short term
Barred Owl	ALL					
Barred Owl	COVER					
Barred Owl	FOOD					
Barred Owl	NEST					
Brown Creeper	ALL					
Brown Creeper	FOOD					
Brown Creeper	HIDING					
Brown Creeper	NEST					
Canada Lynx	COVER					
Canada Lynx	DEN	-	-	-	-	High concern at short term
Canada Lynx	FOOD					
Elk	CO_S					
Elk	CO_W					
Elk	FO_S					
Elk	FO_W	-	-		-	Moderate concern at short term
Elk	HI_S					
Elk	HI_W					
Least Flycatcher	FOOD	-	-	-	-	High concern at short term
Moose	CO_S					
Moose	CO_SW					
Moose	FO_MW	-	-		-	High concern at short term
Moose	FO_S					
Moose	FO_SW					
Moose	HI	-	-		-	High concern at short term
Northern Flying Squirrel	ALL	-	-			High concern at short term
Northern Flying Squirrel	COVER		-			
Northern Flying Squirrel	FOOD				-	
Northern Flying Squirrel	HIDING	-	-		-	High concern at short term
Northern Goshawk	ALL					
Northern Goshawk	FOOD					
Northern Goshawk	NEST		-			
Northern Goshawk	NEST_S		-	-	-	Moderate concern at mid term
Pileated Woodpecker	ALL					
Pileated Woodpecker	COVER					
Pileated Woodpecker	FOOD	-	-		-	High concern at short term
Pileated Woodpecker	NEST					
Ruffed Grouse	ALL					
Ruffed Grouse	COVER					
Ruffed Grouse	HIDING					
Snowshoe Hare	COVER	-	-		-	High concern at short term
Snowshoe Hare	FOOD	-	-		-	High concern at short term

Table 23. Risk analysis of the wildlife for FMU W13 under the PFMS (continued).

Species	SI	Mean	Trend	Med+ High	High	Priority of concern
Southern Red-Backed Vole	ALL	-	-			High concern at short term
Southern Red-Backed Vole	COVER					
Southern Red-Backed Vole	HIDING	-	-		-	High concern at short term
Spruce Grouse	COVER					
Spruce Grouse	FOOD					
Spruce Grouse	NEST					
Three-toed Woodpecker	ALL					
Three-toed Woodpecker	FOOD					
Three-toed Woodpecker	NEST	-		-		High concern at short term
Varied Thrush	ALL					
Varied Thrush	FOOD					
Varied Thrush	NEST					
Woodland Caribou	COV_R	NA	NA	-	-	
Woodland Caribou	FOOD_R			-	-	
Woodland Caribou	FOOD_S					
Woodland Caribou	FOOD_W	-	-		-	High concern at short term

Recommendation:

If most of the recommendations on the SHEs are applied, most of the problems with the wildlife habitat will be fixed. Specific spatial arrangement of nesting Northern Goshawk should allow retrieving enough clusters of nesting habitats in the same area. To do so, special attention should be paid to retaining in the landscape large Aspen/Poplar and white spruce to favour the recruitment of such nesting habitat clusters.

In W11, wildlife species of concern are about the same as in W13, except for the Woodland Caribou and Northern Flying Squirrel habitat quality that is within the NRV when the PFMS is applied (Table 24). The first two HSMs are related to the arboreal lichen, while the two woodpecker HSMs are related to snags, SHEs that are not of concern in W11 under the PFMS.

Table 24. Risk analysis of the wildlife for FMU W11 under the PFMS.

Species	SI	Mean	Trend	Med+ High	High	Priority of concern
American Marten	ALL	-				High concern at short term
American Marten	COVER					
American Marten	HIDING	-			-	High concern at short term
Barred Owl	ALL					
Barred Owl	COVER					
Barred Owl	FOOD					
Barred Owl	NEST					
Brown Creeper	ALL					
Brown Creeper	FOOD					
Brown Creeper	HIDING					
Brown Creeper	NEST				-	Low concern at short term
Canada Lynx	COVER					
Canada Lynx	DEN	-	-	-		High concern at short term
Canada Lynx	FOOD				-	Low concern at short term
Elk	CO_S					
Elk	CO_W					
Elk	FO_S					
Elk	FO_W					
Elk	HI_S					
Elk	HI_W					
Least Flycatcher	FOOD	-	-	-	-	High concern at short term
Moose	CO_S					
Moose	CO_SW					
Moose	FO_MW	-	-	-	-	High concern at short term
Moose	FO_S					
Moose	FO_SW					
Moose	HI	-			-	High concern at short term
Northern Flying Squirrel	ALL					
Northern Flying Squirrel	COVER					
Northern Flying Squirrel	FOOD					
Northern Flying Squirrel	HIDING	-			-	High concern at short term
Northern Goshawk	ALL					
Northern Goshawk	FOOD				-	
Northern Goshawk	NEST					
Northern Goshawk	NEST_S			-		Low concern at short term
Pileated Woodpecker	ALL					
Pileated Woodpecker	COVER					
Pileated Woodpecker	FOOD				-	Low concern at mid term
Pileated Woodpecker	NEST					
Ruffed Grouse	ALL		-			Moderate concern at long term
Ruffed Grouse	COVER	-		-		Concern at short term
Ruffed Grouse	HIDING					
Snowshoe Hare	COVER	-	-		-	High concern at short term
Snowshoe Hare	FOOD	-	-	-	-	High concern at short term
Southern Red-Backed Vole	ALL	-				High concern at short term
Southern Red-Backed Vole	COVER	-		-		High concern at short term
Southern Red-Backed Vole	HIDING	-	-		-	High concern at short term

Table 24. Risk analysis of the wildlife for FMU W11 under the PFMS. (continued).

Species	SI	Mean	Trend	Med+ High	High	Priority of concern
Spruce Grouse	ALL					
Spruce Grouse	COVER					
Spruce Grouse	FOOD					
Spruce Grouse	NEST					
Three-toed Woodpecker	ALL			-		Low at concern at mid term
Three-toed Woodpecker	FOOD					
Three-toed Woodpecker	NEST			-		Low at concern at mid term
Varied Thrush	ALL					
Varied Thrush	FOOD					
Varied Thrush	NEST					
Woodland Caribou	COV_R					
Woodland Caribou	FOOD_R					
Woodland Caribou	FOOD_S					
Woodland Caribou	FOOD_W					

Recommendation:

The same recommendations developed for W13 applies to W11 but with fewer constraints. In W11, non-productive forests contribute much more to the abundance of SHEs on average in the landscape than in W13. However, pockets of low SHE availability should be identified in regards to spatial distribution of productive and non-productive forests. Moreover, monitoring of natural disturbance is important because natural disturbance in non-productive forest could radically change this portrait. Risk analysis under stochastic dynamics in regards of how the productive forest could still support good habitats if natural disturbance is added to the dynamics of the landscape would be an important analytical support to this exercise.

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Frédérik Doyon, PhD, RPF

Scientific director at Institut québécois d'aménagement de la forêt feuillue
Adjunct professor (Université du Québec en Outaouais)
58, rue Principale
Ripon, Qc
J0V 1V0, Canada
www.iqaff.qc.ca
tel. 819.983.2206
fax. 819.983.6588
email: fdoyon@iqaff.qc.ca

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