Economics of Species Change under Risk of Climate Change and Increasing Information: A (Quasi-)Option Value Analysis

Marielle Brunette (LEF, Nancy)
Sandrine Costa (MOISA, Montpellier)
and Franck Lecocq (CIRED, Paris)

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Context

- Impact of climate change on :

Forest Ecosystems

- Increase temperature from 1.5˚C to 5˚C
- More intense precipitations during winter and longer droughts during summer
- Impact on phenology and reproduction of trees, on growth, on prevalence of risks

Forest Species

- Scots Pine (Kint et al., 2009)
- Norway Spruce (Briceno-Elizondo et al., 2006)
- Oak (Becker et al., 1994)
- European Beech (Nigh, 2006)

- Characteristics of forest sector : long-term and irreversible decisions.
- One solution to adapt forest to CC : shifts to climatically more robust species

  $\rightarrow$ Studied from a biophysical point of view but economic assessment are scarce : Hanewinkel et al. (2010), Yousefpour et al. (2010).

  $\rightarrow$ No consideration of : 1/ uncertainty about impact of CC on forest ecosystem ; 2/ increasing information

Objective

- Objective : to study the question of species choice in the context of climate change taking into account uncertainty about impact of CC on forest ecosystem and increasing information
- Methodology : Cost-Benefit Analysis + Quasi-option value (Arrow and Fisher (1974), Henry (1974))
  - Benefit to get information earlier, with implications both for private decision-making and public policies
  - Mitigation decisions on climate change
  - Forestry : management decisions under timber price volatility
- Framework : conversion of Norway spruce stands to Douglas-fir.
- Results : conditions under which species shifts make sense, optimal timing of species shifts, value of additional information.

The Case study

- Norway spruce (NS) : commonplace in Europe, resistant to cold, not very sensitive to last frosts, sensitive to water stress and droughts.
- Adaptation strategies :
  - uneven-aged system
  - conversion towards tree species more adaptated to future climatic condition : European beech in German Black Forest, Scots Pine in Northern Finland, Douglas-fir in French Black Mountain.

  $\Rightarrow$ We explore the economics of replacing NS with Douglas-fir in the context of the French Black Mountain
- Assumptions : monospecific, even-aged NS stand that has just been clear-cut, and in which natural regeneration is present.
  - Continuation of past practices would call for a new cycle of NS based on regeneration
  - An alternative sylvicultural trajectory would be to clear the stand and plant Douglas-fir.
- Two scenarios regarding the impact of CC on NS : either there is a high mortality of NS (with probability p) over the next spruce rotation (70 years) or there is not (with $(1 - p)$)
- Increasing information : uncertainty on the CC effects on NS will be resolved in n years ($n = 5$ or $n = 10$)
  $\hookrightarrow$ we assume that in one century, NS will not be adaptated to the stand anymore (it will be necessary to shift to Douglas-fir for the secodn rotation).

Immediate choice

Strategy 1 : regenerating NS now with view to shifting to Douglas-fir after end of rotation
Strategy 2 : planting Douglas-fir now with natural regeneration of Douglas-fir in subsequent rotation

A. Analysis of strategy 2

	Benefit (€/ha)	
Operations (years)	Plantation	Natural regeneration
Initial cost	Plantation(0) : -2132	Clearing(3) : -1212
Thinning (14) “dépressage”	-920	-1170
Thinning (24)	885	885
Thinning (37)	1305	1305
Thinning (51)	2989	2989
Thinning (68)	10584	10584
Thinning (71)	5170	5170
Harvest (74)	18315	18315
Net Present Value	NPV(DF,plant) = 452	NPV(DF,rege) = 1362

- Douglas-fir is assumed suited both to current and future climate, so that the yields and financial payoffs of strategy 2 are independent of the NS mortality scenario.
- Discount rate : 4%
- $LEV(DF) = NPV(DF, plant) + \frac{NPV(DF, rege)}{(1+r)^{74}} \times \frac{(1+r)^{74}}{(1+r)^{74}-1}$ = 531€/ha

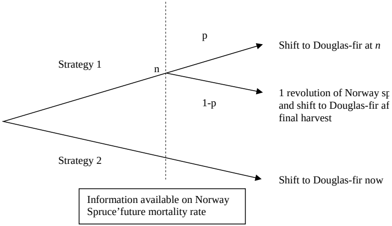
Strategy 1 with and without CC

B. Analysis of strategy 1 without CC

Operations (years)	Benefit (€/ha)
Clearing (0)	-597
Thinning (20) "dépressage"	-1023
Thinning (40)	1242
Thinning (50)	1518
Thinning (60)	2139
Harvest (70)	19417
Net Present Value	NPV(NS) = 859

- $LEV(NS) = NPV(NS) + \frac{LEV(DF)}{(1+r)^{70}} = 888$€/ha
- $LEV(NS) > LEV(DF) \rightarrow$ without CC, the best strategy would be to keep NS for one more rotation and then after to change to DF.

C. Analysis of strategy 1 with CC



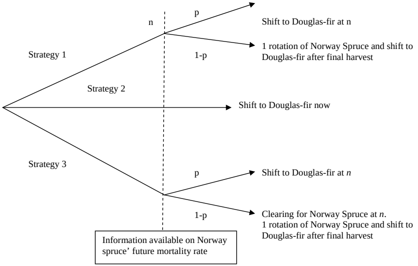
- $LEV(Strat1) = p(-597 + \frac{LEV(DF)-100}{(1+r)^n}) + (1-p)(NPV(NS) + \frac{LEV(DF)}{(1+r)^{70}})$
- For $n = 5$, if $p < 31.9\%$ then it is better to regenerate NS
- For $n = 10$, if $p < 30.2\%$, then it is better to regenerate NS

Sequential decision making

Strategy 3 : choice between regenerating NS and planting DF is delayed until the information about p is provided.

- Assumptions concerning this waiting period : no investment, thicker vegetation establishes
  - Clearing cost of NS regeneration = 800€/ha for n = 5 and 900€/ha for n = 10
    ↪ NPV(NS, delay = 5) = 702€/ha ; NPV(NS, delay = 10) = 655€/ha
  - Clearing cost before DF plantation increases of 100€/ha.

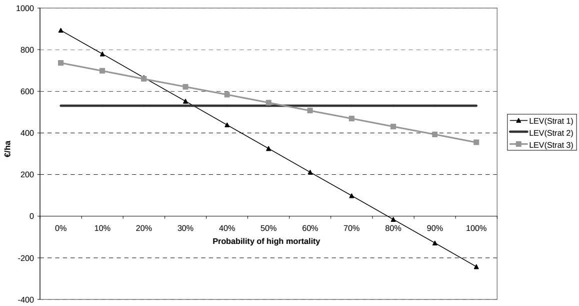
- Strategy tree becomes :



$$LEV(Strat3) = p\left(\frac{LEV(DF)-100}{(1+r)^n}\right) + (1-p)\left(NPV(NS, delay = n) + \frac{LEV(DF)}{(1+r)^{70}}\right)$$

Comparison of the 3 strategies for n=5

Figure 3. Value of the "Delay" scenario (for n = 5) relative to the best scenario among spruce regeneration and planting Douglas-fir.



- for n = 5 : $p < 20.8\%$ = strategy 1 ; for n = 10 : $p < 25.4\%$ = strategy 1
- for n = 5 : $20.8\% < p < 53.8\%$ = strategy 3 ; for n = 10 : $p < 39.9\%$ = strategy 3
- for n = 5 : $p > 53.8\%$ = strategy 2 ; for n = 10 : $p > 39.9\%$ = strategy 2

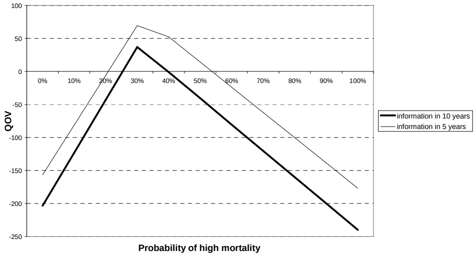
Quasi-option value

QOV is a way to measure the benefit of flexibility in an uncertain context :

$QOV = LEV(Strat3) - Max(LEV(Strat1), LEV(Strat2))$.

$\hookrightarrow$ positive QOV means that it is profitable to delay the decision

Figure 4. Quasi Option Value.

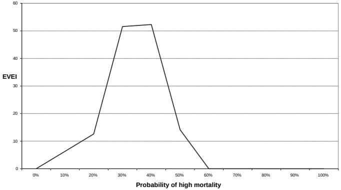


QOV gets smaller when the information comes later.

Expected Value of Earlier Information (EVEI)

$EVEI = Max(LEV_5(Strat1), LEV_5(Strat2), LEV_5(Strat3)) - Max(LEV_{10}(Strat1), LEV_{10}(Strat2), LEV_{10}(Strat3))$

Figure 6. Expected Value of Earlier Information.



- $p \leq 0.2$ (low probabilities) : lower value of earlier information ($<$ 12€/ha).
- $p \geq 0.6$ (high probabilities) : lower value of earlier information ($<$ 12€/ha).
- $0.2 < p < 0.6$ (in-between probabilities) : higher value of earlier information comes from strategy 3 which is the best strategy for these intermediate probabilities (12€/ha $<$ EVEI $<$ 52€/ha).

$\Rightarrow$ EVEI is low for low or high probabilities ; in-between, EVEI is between around 10 and 50€/ha, it increases the LEV by 2 to 9%.

Conclusion

- QOV approach may be very useful to analyse decision making in species choice
- Summary of the results :
  - without CC Strategy 1 dominates
  - with CC, the dominating strategy depends on p, the probability of high mortality of NS
    ↪ if the probability is low or high, it is more profitable to choose now
    ↪ for intermediate value of the probability, it is more profitable to delay
- Value of information belongs to the interval [6-52]€/ha in our case study
- Some limits : DF is not perfectly adaptated to CC, delay of 5 or 10 years seem to be optimistic