A two-option approach to solving the decision problem of regeneration

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Option theory in forestry has been used for

• Adaptive harvest
• Old-growth and conversion
• Choice of tree species for afforestation (one and two-option)
• Spatial-intertemporal decisions (e.g. pollution contra ground-water extraction)
Case: Natural regeneration of Norway spruce on poor soils in Denmark contra oak.

- Natural regeneration is uncertain
- Existing stand might be windthrown if thinned
- Nat. reg. is cheaper
- Value of oak is higher (when established)

Two problems

1. If we have natural regeneration of N.spr. – should we convert to oak?
2. If we have an existing stand – when should we harvest it and with what should we regenerate it?

=> A problem with loops
**Inner loop**

\[ dA = \begin{cases} \alpha_A A dt + \sigma_A A dz & \text{with probability } 1 - \gamma dt \\ - A & \text{with probability } \gamma dt \end{cases} \]

\[ dB = \alpha_B B dt + \sigma_B B dw \]

\[ V = \max\{B - C_B, (1 + \delta dt)^{-1} E[V(B + dB, A + dA)]\} \]

Solved numerically

**Outer loop**

\[ R(A(0), T) = A(0) a_1 T^2 + A(0) a_2 T + A(0) a_3 \]

Windthrow

\[ W = \max\{V(A, B) + R_T, (1 + \delta dt)^{-1} E[W(V + dV, R_T + dR)]\} \]

Solved numerically with result from inner loop as input factor
Conclusions, inner loop

- Fixed costs: reservation value must be higher than actual difference
- Risk of regeneration failure reduces option value
Outer loop results - constant

Stochastic
The principle

Basic intersection

One intersection

Stochastic

Stochastic, stopping deterministic

continue  stop

Conclusions, outer loop

• Two planes intersect in A-B state-space
• Option values increase the value of waiting
  ⇒ Waiting intersects stopping from above when stochastic environment
• Stochastic elements in the existing stand is most important
Conclusions of the method

Sequential options can be treated by numerical DP.

=> Makes more real problems solvable – possible to analyse

Future use

Sequential options in other problems in forestry?
- Thinning
- Uneven-aged management
- Recreational values
Little difference between present and future stochastic values