Global Earth Observation - Benefit Estimation: Now, Next and Emerging

GEOBENE

Assessing the economic, social and enviromental benefits of the GEO domains

Optimal Forest Management with Stochastic Prices & Endogenous Fire Risk

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Objective

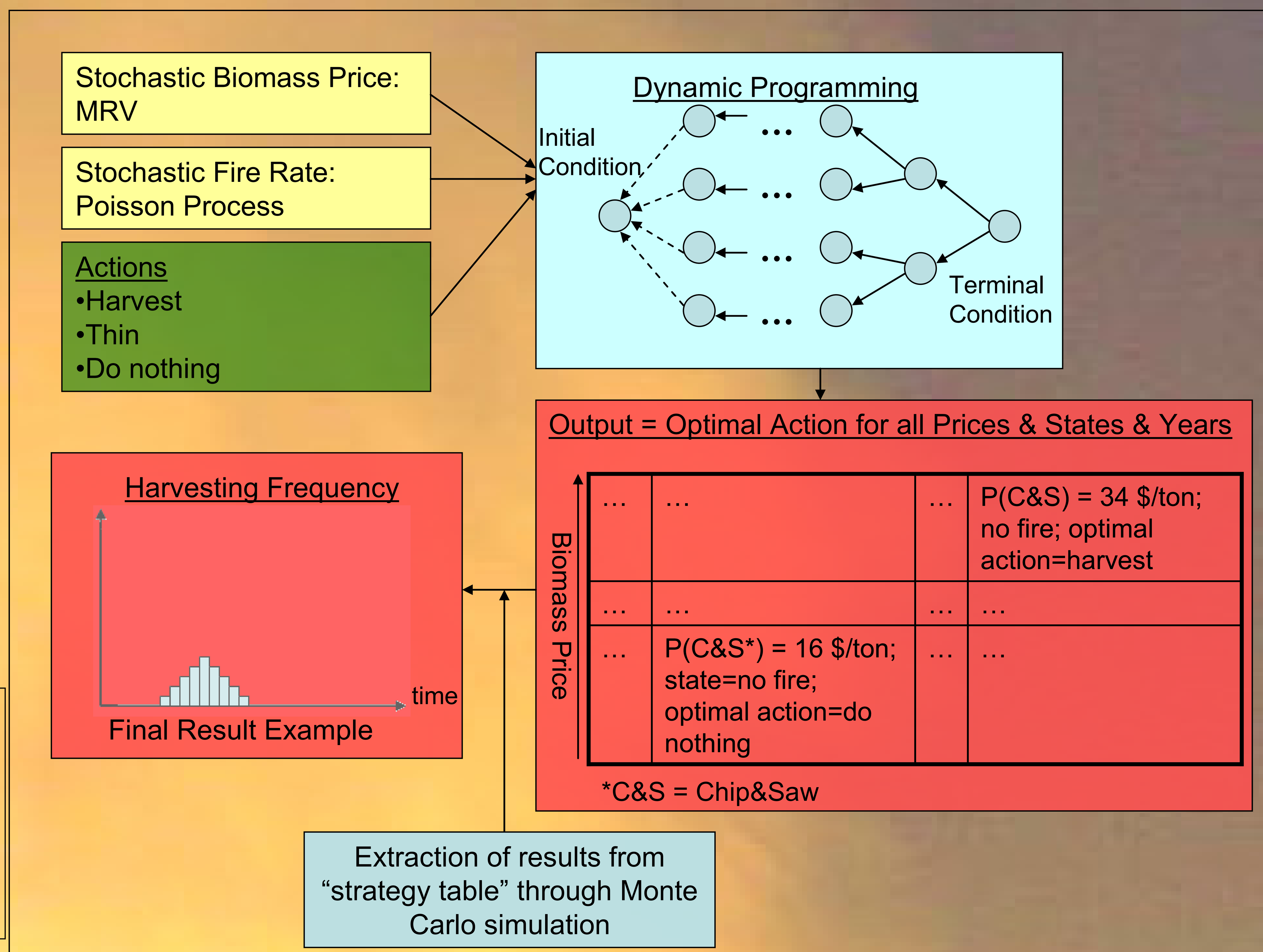
Earth observations are one way to reduce the risk to standing forests from damages caused by wild fires, since they enable early warning systems, preventive actions and faster extinguishing of fires, before they spread out. Another channel through which fire hazard can be reduced is the thinning of the forest, so the risk of a fire occurring becomes partially endogenous. In order to shed more light on optimal forest management under such endogenous fire risk, we develop a real options model, where the price of biomass is stochastic and the harvesting decision needs to be timed optimally in the face of these uncertainties. We find that there is a positive value of information. In other words, there is a positive willingness to pay for Earth observations by forest managers.

Approach

The major inputs are the sources of uncertainty: the arrival rate of the fire - which follows a Poisson process - and the price for wood on the market, which fluctuates around a constant mean. The problem can be formulated as an optimum control problem, where the managerial decisions of harvesting, thinning and doing nothing are the available options. We use backward dynamic programming to determine all optimal decisions in each possible price instance, for all possible states and in each year. This gives us the opportunity to use Monte Carlo simulation to extract the final results from this output. In the diagram we have chosen harvesting frequency as an example, but there are also decisions concerning thinning, of course. Furthermore, the output can also be used to compute the corresponding profit distributions and other outcomes.

Variables	unit	mean	std. dev.
Growing stock volume	cubic feet/acre	1333.5	1110.89
Stand age	Years	18	7.771
Stand density	100 trees/ acre	3.92	3.396
Site productivity class	-	3.8	0.992

Data for loblolly pine (FIA, 2006)



Major results

Reducing fire risk by obtaining better information through EO will therefore lead to longer rotations and thus also higher-quality wood output.

Expected profits fall, as the rate of fire increases. We can analyze the impact of Earth observation (through a decrease in the rate of fire) on risk in terms of expected profits, measured by the Conditional Value-at-Risk (CVaR): CVaR-risk (calculated as the average of the lowest 5% of profits) is rising with increasing fire risk and can even be negative.

The distribution of expected profits for low fire risk (yellow) is much narrower than the one for larger fire risk (upper panel). The average harvesting time increases substantially, as fire risk decreases.

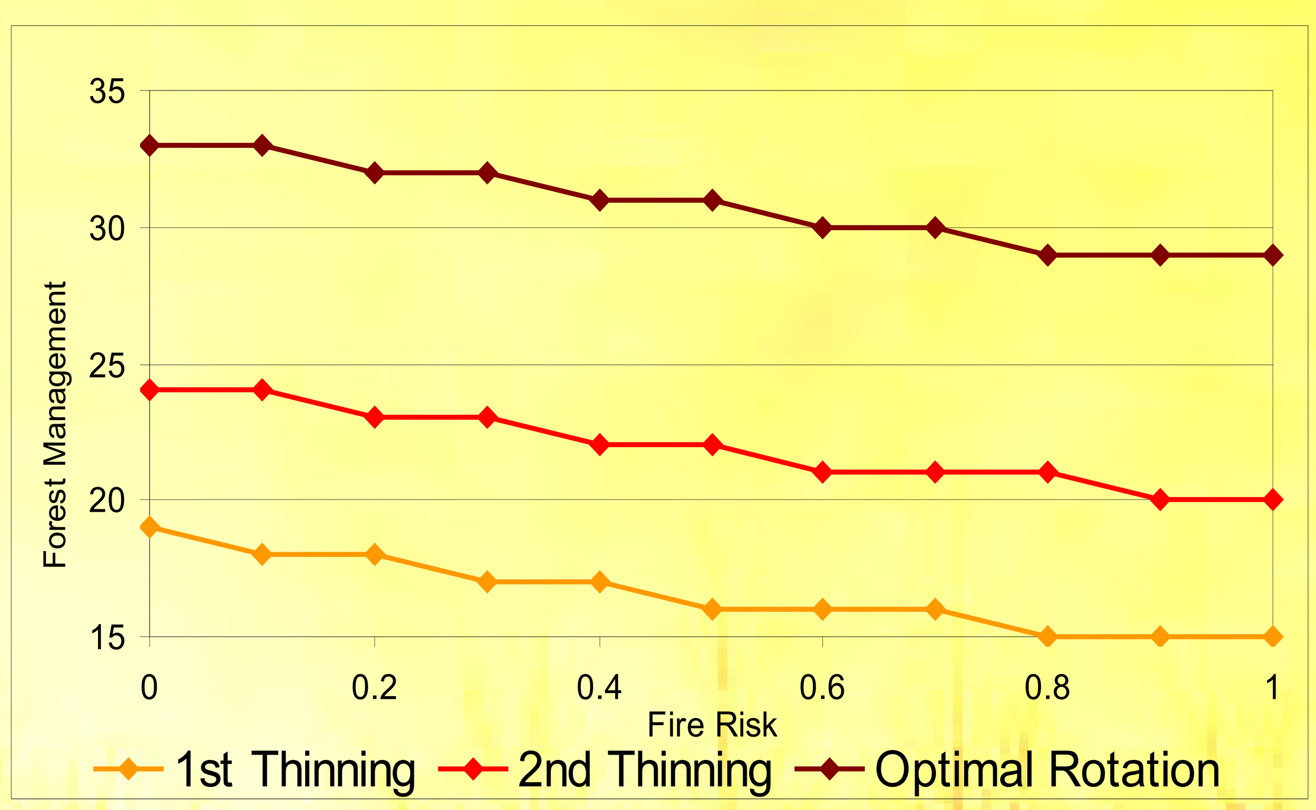
Data used

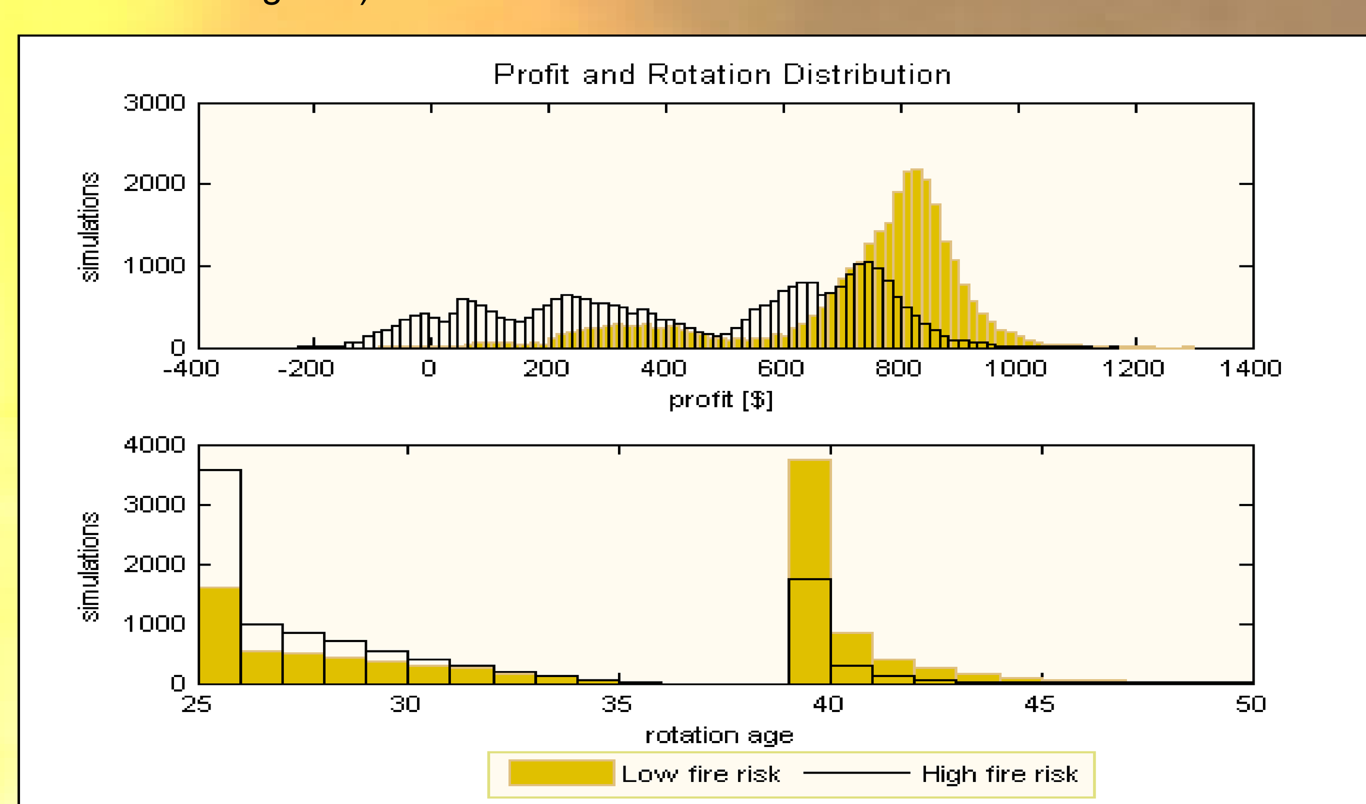
•Forest growth estimation: the average growing stock volume (GSV) per tree on plot i depends on the stand age on plot i, where a is the maximum value of GSV per tree, which is about 143 cubic feet in our case (b = shape, c = the maximum age).

•Extension of single-tree model to stand-model: employ the self-thinning line used in Huang (2007).

•Two thinnings of prescribed intensity during one rotation period: extend the volume function to describe the volume for each stand age and each thinning decision possible.

•Estimate the diameter as a function of GSV per tree (increasing relationship at a diminishing rate).



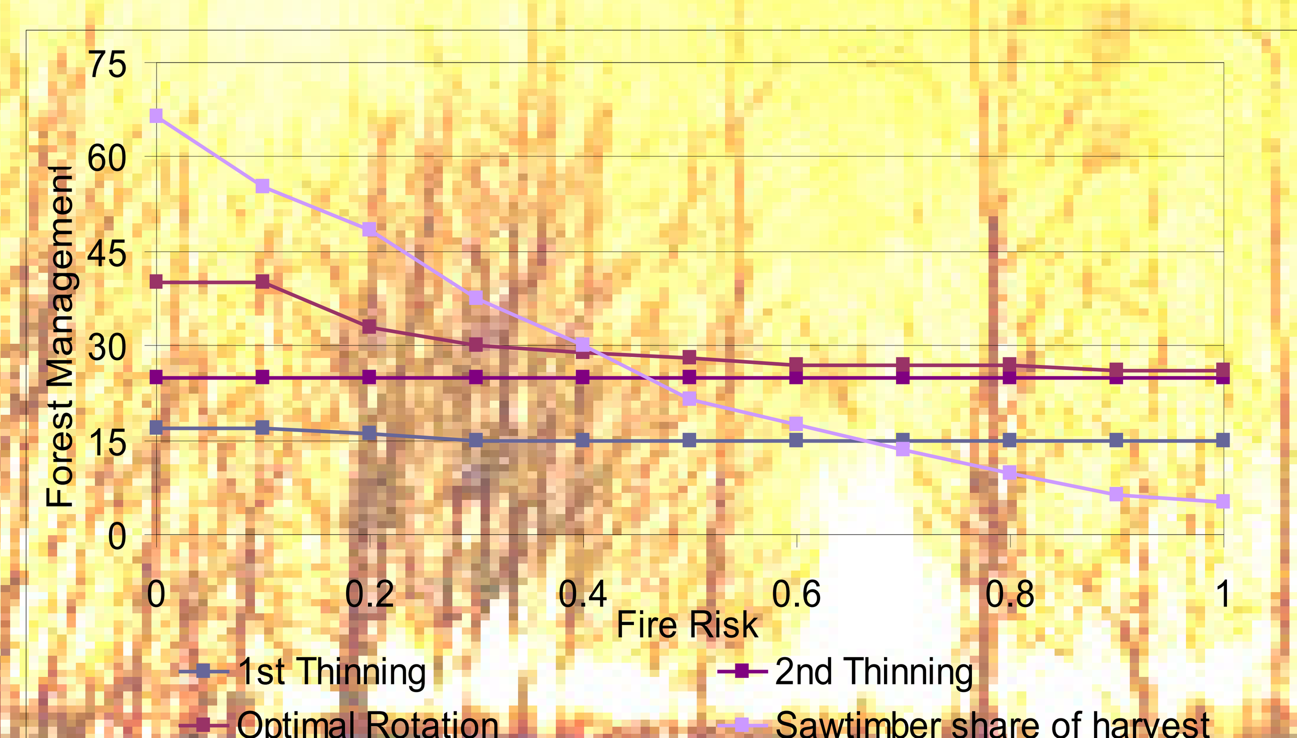


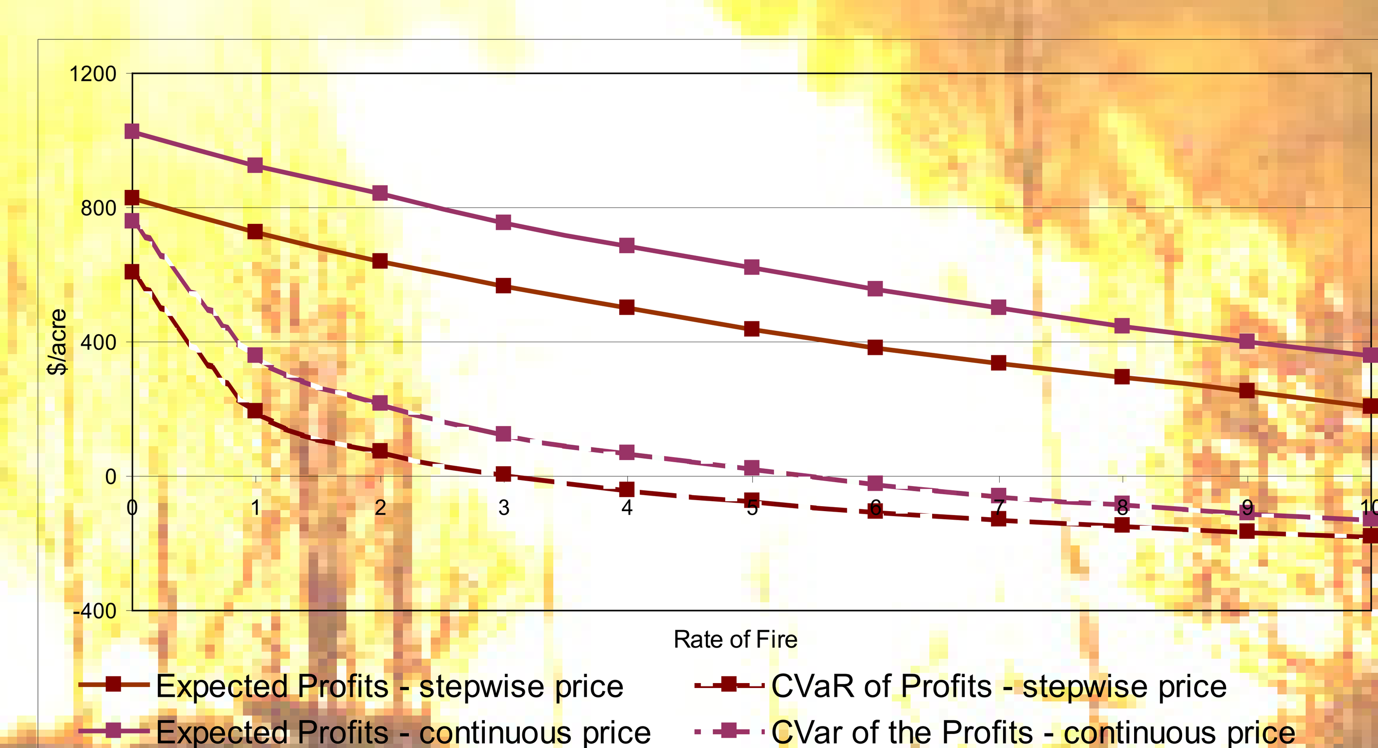
General conclusions

The fire risk being defined as loss of a forest stand in case of fire, the results have shown that Earth observation can lead to considerable gains in terms of expected profits and risk by reducing the fire risk. Rotations will be longer as a result of more security and the share of saw timber can be increased substantially.

Extension

While this model applies at the stand-level and thus optimizes the forest management decisions of a single decision-maker, it can be used to form decision-rules, which can then be fed into larger-scale models, revealing also the spatial dimensions of optimal forest management decisions in the face of fire risk. See our other poster "Improvement in Optimal Forest Management through Earth Observations: A Global Integrated Analysis Considering Fire Risk" for this specific extension.





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