

Chapter VIII: Climate change and practical forest management - when to worry and when not?

Jette Bredahl Jacobsen, Rasoul Yousefpour and Bo Jellesmark Thorsen

Across Europe climate change is expected to have quite different impacts on forest ecosystems varying with e.g. latitude, altitude, local ecological conditions and forest management practises. However, just how large and how severe the changes will be is subject to considerable uncertainty. Therefore a crucial question is when to adjust to such long-term expected changes. Should adjustment be made now in anticipation of change but with great uncertainty about changes and impacts, or made only when changes and their impacts are observed and understood better, or should they be made gradually as we see the impact on forests? To what extent is it relevant and possible to go for strategies that try to optimize expected outcomes and make the most of forthcoming changes? When might it be equally relevant to pursue strategies that focus on reducing, as far as possible, the potential losses, and hence maximize the outcome in the worst case?

This chapter discusses these issues using two stylised approaches to handling the uncertainty forest managers face. These approaches we call the reactive approach and the proactive approach. We discuss when the benefits and importance of encouraging a proactive decision making approach among forest owners is particularly large, and when a more reactive management approach might be favourable or at least justified.

The reactive management approach

The reactive manager can be described as a decision maker who awaits and observes the actual outcomes and impacts of climate change as it develops, and adjusts management gradually to observed effects only. This decision making approach does not include forecasting or forming expectations about the likelihood of different climate change developments, nor their potential future impacts on forest ecosystems. A decision maker using this approach does not adjust current decisions to the possible implications indicated by such forecasts or expectations.

The results of forest owner surveys undertaken in MOTIVE indicate that while many forest owners do consider climate change a factor in their decision making, others are less explicit about this. Decision making approaches like this may be quite widespread among forest managers. If uncertainty about direction and/or impact of climate change is very large, the decision maker has little basis for firm expectations, and it may be a relevant approach if not the most favourable one. It may also be a relevant approach to follow if the expected changes are small, or if they are of gradual form. This could be where changes

mainly affect growth or other ecosystem aspects in a way where management schemes like thinning or regeneration decisions can be adjusted smoothly and gradually fitted to the changed forest state.

Among the MOTIVE case studies, we do find specific cases, where such an approach is at least close to optimal. The Boreal case in North Karelia, eastern Finland, is an example of that. They analysed management schemes for mixed stands of Norway spruce, Scots pine and birch, and found that with respect to handling the uncertain growth development under climate change, reactive (anticipatory) approaches are not truly different from a proactive (adaptive) management approach. The reason is that in this specific case, climate change is not likely to drastically impact the health or stability of the ecosystem, but rather it gradually changes the absolute and relative performances of the species. Forest management, however, can capture and react adequately to most of this in a reactive manner. They also find, as is a standard result, that the proactive approach is much more important when it comes to handling price uncertainty.

There may be situations, also in the Boreal areas, where forest managers and society may benefit significantly more from talking a proactive approach. An example of this could be where the choice of tree species to favour regeneration would be better based on expectations than past observations. Or there may be cases, where climate change induced increases in hazard risks may call for early action to avoid losses.

The proactive management approach

The proactive management approach is in the literature also referred to as the fully adaptive management approach. As opposed to the former, the decision maker applying this approach does not only observe the development of the current climate and the state of the forest ecosystems; (s)he also assess likely developments and impacts of climate change using numerous sources of information and observations. The decision maker bases current decisions as much on observed status of the forest as on expectations of future climate change impacts and implications for forest management. If the proactive manager makes good forecasts and forms well-founded expectations, (s)he should perform at least as well as the reactive manager. However, searching for and assessing information is costly and expectations and forecasts may be imprecise, ill-founded or biased, and it is in some situations not obvious that much is gained from such an approach. In other cases, it is more obviously a clear advantage.

In MOTIVE a decision model for even-aged beech stand in Switzerland was developed, assessing the optimal management scheme for a number of site conditions for given future climate developments (Trasobares et al., 2013). However, there is uncertainty with respect to which scenario is the more realistic, so management was optimised (thinning and timing of clear-felling) for 4 different climate change scenarios at various locations. The financial results, in terms of Land Expectation Values (LEV), from a site with good current

Table 1. Land expectation values for beech in Switzerland on good soil conditions, depending on which climate scenario is realized and which climate scenario management is optimized for. For details of the model, see Trasobares et al. (2013).

LEV2 (CHF/ha) WP (m ³ /ha*y)	MANAGEMENT OPTIMIZED FOR:				
REALIZED CLIMATE	CURRENT	A1B_MPI	A1B_HADLEY	A1B_RCA- ECHAM5	RISK %
CURRENT	LEV2 = 3023.4	LEV2 = 2880.8	LEV2 = 2927.8	LEV2 = 2880.9	4.7 (142.2)
A1B_MPI	LEV2 = 4255.5	LEV2 = 4330.2	LEV2 = 4139.8	LEV2 = 4312.3	4.4 (190.4)
A1B_HADLEY	LEV2 = 1864.8	LEV2 = 1811.8	LEV2 = 1969.2	LEV2 = 1803.1	8.4 (166.1)
A1B_RCA_ECHAM	LEV2 = 3945.9	LEV2 = 3998.2	LEV2 = 3824.5	LEV2 = 4001.4	4.4 (176.9)
Average	3272.4	3255.1	3215.3	3249.4	ryerey

growth conditions are shown in Table 1. The diagonal shows the return from the optimal management for the four different climate scenarios. As is seen, two scenarios (A1B_MPI and A1B_RCA_ECHAM5) will result in an improved return whereas the opposite is true for the more extreme scenario predicted by the AqB_Hadley climate change model. Proactive managers may consider these different scenario optimal strategies and base their decision on their beliefs or expectations about the probability of different scenarios becoming true.

It may be relevant to consider what the consequences are on forest revenue in case we optimize for one climate development, but another is realised. These returns are given by the off diagonal results. As can be seen the losses are up to 8% in case we believe the A1B_MPI climate change scenario to be the one realized and optimize management for that, but it turns out that A1B_Hadley is realised instead. A minimax strategy would therefore suggest that we choose the management optimized for A1B_Hadley, as it has the largest minimum outcome. Optimising the expected return across climate change scenarios requires some beliefs or probabilities of each scenario. If we assume that they are equally likely, i.e. we believe 25% in each, then picking the management strategy optimised for the current climate gives the highest average result (bottom row), though it is only slightly higher than the best alternative. Other locations in Switzerland show other results; in general the poorer the soil, the more severe the consequences of choosing the wrong management strategy.

The results show that the proactive decision approach takes more information into account and the decision maker may gain from this. The specific analyses of Trasobares et al (2013) also demonstrate that while climate change may both bring gains and losses, and while both may be of significant sizes at least in relative terms, the potential losses are not necessarily catastrophic for the current tree generations, even if long term consequences may perhaps be more significant (Hanewinkel et al 2012).

Only a few cases in MOTIVE have considered the issue of tree species choice, which is one of the most far-reaching decisions in forestry where proactive assessment of the potential long term impacts may play the largest role. In one such MOTIVE application (Schou et

Table 2. Simulated land expectation values (LEV) [€/ha] for given climate change outcomes for a new forest stand. The expected LEV are estimated under equal subjective probabilities (beliefs) about which scenario is true. The “before” (“after”) values are maximized values before (after) uncertainty about climate development is resolved.

Species	Climate change outcome			Expected LEV	
	Worst	No-change	Best	Before	After
Norway spruce	-17882	807	7540	-3178	2993
Oak	632	632	632	632	

al., 2012), we analysed the case of a forest manager in Denmark who needs to decide when to harvest an existing, maturing Norway spruce stand and whether to reforest using Norway spruce or oak. Oak is projected to be fairly insensitive to climate change in this region and a likely future main species, whereas this is not so for Norway spruce (Hanewinkel, 2012). At current growth conditions Norway spruce economically outperforms oak on most sites, even with mediocre performance. With climate change, increased risks of windthrows, drought-related bark beetle pests and the like may reduce the profitability of Norway spruce, but economic sensitivity analyses reveal that quite a bit of negative impact is needed to reduce the expected economic performance below that of oak.

We investigated the effects on the forest owner’s decision when (s)he faces possible climate change, simplified into three scenarios among which oak is only truly superior to Norway spruce in one, and when (s)he may be uncertain as to which of these scenarios come true for still either 10, 20 or 30 years. Under a proactive decision approach, forthcoming information implies a value of waiting, as can be seen in Table 2 where the expected LEV of making the best decision *after* the climate change development is evident (€ 2,993) is higher than the expected value of making the best decision *before*. If we can wait establishing the new stand until we are fairly certain, we may rule out the worst alternative, thereby increasing the expected value. However, if the worst of the modeled climate scenarios does not come true, then it will still be favourable on this location to establish Norway spruce also in the next rotation.

However, waiting has a cost in terms of delaying the harvest of the existing stand. The decision maker needs to trade off this cost against the positive impact of waiting for information evident on the expected value of the new stand. The further into the future the decision maker thinks information will be available, the more costly is waiting, and the more likely (s)he will base her decision on her/his *ex ante* expectations. Table 3 illustrates the decisions made for different ages of the Norway spruce stand and time periods until the climate change uncertainty is resolved, when (s)he currently find all scenarios equally likely and is risk neutral. As can be seen, with more than 20 years of continued uncertainty, the decision maker will for all ages above 50 harvest now and reforest with oak. When uncertainty is resolved in 10 years the decision maker can postpone harvesting of the 60 year old stands, and wait for certainty.



Table 3. The optimal harvest decisions for the proactive decision maker, when (s)he finds all three scenarios equally likely *ex ante*, across the Norway spruce current stand age and for the three different periods before climate development is known.

	50 years	60 years	70 years	80 years
Certainty in 10 years	Delay harvest	Delay harvest	Harvest now	Harvest now
Certainty in 20 years	Delay harvest	Harvest now	Harvest now	Harvest now
Certainty in 30 years	Delay harvest	Harvest now	Harvest now	Harvest now

Again this case illustrates that proactive decision making and optimal delaying of decisions may outperform other decision approaches. However, the case also shows that if uncertainty is expected to prevail for longer periods, the decision maker may in any case resolve to making decisions based on *ex ante* lack of information.

The forest owner's decision and society's

In many of the cases analysed in MOTIVE, the forest owners may consider the economic consequences of climate change on the current forests health and production likely to be not too severe for the nearest decades. For that reason (s)he may be less likely to engage in dramatic adaptation measures in forest management, and is more likely to resort to reactive decision approaches. However, from a welfare economic perspective, that is society's point of view; the potential consequences of climate change may be more severe, the reason being that the long-term provision of many ecosystem services like biodiversity conservation, recreational uses, and erosion protection may be more sensitive to climate change. An obvious case is the increased risks of forest fires in Southern Europe, which calls for adaptive management measures that may not be preferable for the individual owners. This potential discrepancy between what adaptive forest management may be optimal for society and what may be optimal for the forest owner should be addressed. It may be wise for society to coordinate the collection of better information on likely impacts and to disseminate and advise forest owners on adaptive measures, or to design policy instruments and regulation measures that create incentives for forest managers to align decisions and management with society's objectives.

References

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