Models for adaptive forest management – editorial

Christopher P.O. Reyer[1], Harald Bugmann[2], Gert-Jan Nabuurs[3], Marc Hanewinkel[4, 5]

1 Potsdam Institute for Climate Impact Research, Telegrafenberg, P.O. Box 601203
14412 Potsdam, Germany

*corresponding author: reyer@pik-potsdam.de

2 Forest Ecology, Department of Environmental Systems Science, ETH Zürich, CH-8092 Zürich, Switzerland. harald.bugmann@env.ethz.ch

3. Alterra, Wageningen University and Research. Po Box 47, Nl 6700 AA Wageningen, The Netherlands. Gert-jan.nabuurs@wur.nl

4 Albert-Ludwigs-Universität Freiburg, Tennenbacher Str. 4, D-79106 Freiburg. marc.hanewinkel@ife.uni-freiburg.de

5 Eidg. Forschungsanstalt WSL, Zürcherstrasse 111, CH-8903 Birmensdorf.

1. Introduction

Anthropogenic climate change has been shown to impact forests around the globe (IPCC 2014). Given the expected future climate change as summarized in the 5th Assessment Report of the IPCC (IPCC 2013), the associated impacts are likely to strongly affect forest resilience as well as the products and services that forests provide to human societies (Reyer et al. 2015). In Europe, the extreme drought in the year 2003 (Ciais et al. 2005), a series of devastating storms (Central Europe 1990, France & Switzerland 1999, Slovakia 2004, Sweden 2005, Central Europe 2007) and severe fire seasons (Portugal 2003, Greece 2007) are clear signals. Not only trees are affected, but shifts in the altitudinal zones affected by bark beetle damages are observed as well (Krehan and Steyrer 2004). Also, latitudinal range shifts of biotic disturbance agents (Battisti et al. 2005) are early warning signals of future changes that may be considerably more severe (Lindner et al. 2010, Nabuurs et al. 2013, Reyer et al. 2014). Since European forests are intensively managed, adaptations of current management practices may hold promise in a changing climate.

However, this is a key challenge for sustainable resource management in Europe and also worldwide, as forest managers must deal with novel phenomena and multiple trade-offs. Not only climate is changing, but also societal demands for goods and services from forests. For example, the recent renewable energy strategy of the European Union is expected to result in a much greater demand for biomass for bio-energy generation. This intensifies competition for resources between forest industry, the energy sector and nature conservation/other protective functions and services (including biodiversity, protection from natural hazards, landscape aesthetics, recreation and tourism). Thus, management decisions are increasing in complexity to reflect not only the changing societal needs, but also the changing environmental conditions.

The project MOdels for AdapTIVE forest Management (MOTIVE) has evaluated the consequences of this intensified competition for forest resources given climate and land use change. The project focused on a wide range of European forest types under different intensities of forest management. MOTIVE aimed at developing and evaluating strategies that can adapt forest management practices to balance multiple objectives under changing environmental conditions. A special focus was put on forest models that can be used as tools to reflect different forest management strategies under changing climatic conditions.

European forests and the strategies to manage them are diverse, with each region featuring different tree species, ecological conditions, management goals, risks, and societal demands for goods and services. Therefore, the vulnerability of forestry to climate change under current management must be assessed at the regional scale, and it is pivotal that adaptive management strategies are developed in different ways for the different regions in Europe. Therefore, MOTIVE engaged in a series of case study regions that represent a wide variety of European forest conditions. This Special Feature presents some of the case study results, and the upscaling of the results to the European level.

There are seven papers dealing with adaptive forest management under climate change in seven distinct regions of Europe, namely Sweden (Andersson et al. 2015), Wales (Ray et al. 2015), The Netherlands (Hengeveld et al. 2015), Germany (Zell & Hanewinkel 2015), Austria (Maroschek et al. 2015), Romania (Bouriaud et al. 2015a) and Portugal (Palma et al. 2015). One additional paper synthesizes adaptive forest management strategies at the European level (Schelhaas et al. 2015), while the final paper presents an overview of institutional factors influencing the adaptation of forest management in Europe (Bouriaud et al. 2015b).

2. Adaptive management to avoid climate risks to ecosystem services

The evidence presented in the case studies shows that adaptive management strategies clearly contribute to securing forest ecosystem services under climate change. However, the effect of different management strategies is not always easy to be projected in the future because typically the state of the forest depends partly on the management but is also influenced by past land-use, changing disturbance regimes and uncertainty arising from the breadth of possible future climate conditions.

Maroschek et al. (2015) show that in the Montafon, a part of the Austrian Alps, adaptive management can strongly reduce the risk of landslides and snow avalanches. They present an assessment framework to analyse and communicate the effects of management and climate change on the provision of these services in mountain forests. A key factor that they identified for these services in the case study area was the interaction of bark beetle disturbances, legacies of past land-use practices, and forest management. In addition, it became evident that the quantitative assessment was supported strongly by the stakeholder process.

Similarly, Ray et al. (2015) found that adaptive management is needed for two types of plantation forests in Wales in order to maintain a broad portfolio of forest ecosystem services. They used a dynamic coupling of five UK forestry models, linked to six socio-economic futures, and assessed nine ecosystem service indicators. From the resulting broad portfolio of simulation results they concluded that there is a 20-50% chance of failing to deliver the ecosystem services that are requested by society. And important aspect was the strong exposure of these forests to wind disturbance, which necessitated the development of adaptive forest management to increase the resistance of forest stands to an increasing frequency and severity of high-wind evens.

3. Adaptive management by any means? The trade-offs of adapting forest management

Adaptive management, just as traditional management schemes, values some ecosystem services provided by forest more than others. Switching from conventional forest management to a particular adaptive management scheme can therefore induce new trade-offs between different ecosystem services. These trade-offs are reflected in several of the MOTIVE case-studies presented here and highlight that there are no 'one-fits-all' solutions, but rather a careful assessment of the needs and options is required to handle conflicting perspective and demands.

Zell & Hanewinkel (2015), for example, showed that in the Black Forest in Germany, storm-adapted management, basically mimicking storm damage, reduces traditionally highly relevant forest functions such as net present value of the stands, timber harvest and timber stock. They conclude that extreme adaptive strategies may be just as bad as the disturbances themselves, in terms of these traditional values of forestry.

Andersson et al. (2015) present a complex chain of coupled models to assess the impacts of adapting forest management to reduce storm risk on life-style services in southern Sweden. They used a process-based forest growth model driven by climate change scenarios to adjust forest productivity in a forest management model. At the same time they evaluated risk of storm damage using a probabilistic wind damage model. Altogether, their results showed that adaptive forest management successfully increases forest yield but at the same time alters the state of the forest, which in turn can severely impact other ecosystem services such as forest attractiveness for recreation. Thus, depending on the perspectives of forest owners and users, adaptive measures can have positive or negative impact on forest services.

Similar trade-offs between different forest owners were studied by Hengeveld et al (2015) in the Veluwe in the Netherlands. They show that both climate change itself but also the adaptation of individual forest owners to climate change affect ecosystem services. At the landscape level, precautionary forest management strategies balance changes in ecosystem services from climate change while also avoiding shifts between ecosystem services which are benefitting private forest owners versus and public benefits. When management strategies strive to maximize private benefits, the provision of ecosystem services for the general public are reduced.

4. Opportunities for adaptation

Because implementing adaptation is usually not straightforward and hindered by all kind of barriers, turning adaptation challenges into adaption opportunities is particularly relevant. The contribution of Bouriaud et al. (2015a) highlights that even though the existing forest composition is a challenge for forest management in the Frasin forest district in Romania, this can be turned into an opportunity for adapting forest management. The large proportion of old stands in these forests is increasingly under pressure from climate change. However, at the same time having forests in commercially harvestable age actually allows to schedule careful timber removal and adjustment of management practices in the near future.

Palma et al. (2015) showed how adaptive forest management in the Chamusca region in Portugal may help to fulfil the management objectives of different forest owners acting at different spatial scales in the region. They show that adaptation of forest management by optimizing cork extraction schedule, reducing debarking and increasing tree density increases cork productivity while business as usual management decreases cork production and carbon stocks under future climate change. However, the increase in tree density which increases productivity of the landscape is only possible, because current tree density is low thus providing a window of opportunity for adapting forest management. This may however lead to trade-offs with similarly increasing importance of agroforestry in the region.

5. Adapting Europe's forests to climate change

Besides focusing on regional case studies in order to assess adaptive management strategies at a spatial scale that is relevant for actual forest management, upscaling from the case study level is crucial to understand the wider implications of management changes and to support the generalization of case-specific scientific results. The contribution by Schelhaas et al. (2015) is placed in this context. They provided a novel approach of integrating adaptive management strategies in a European-scale forest simulation model, EFISCEN. Moreover, they presented a first approach to actually integrate the findings of species distribution models based on Hanewinkel et al. (2012), forest productivity changes from Reyer et al. (2014) and the MOTIVE case study results, from which they derived simplified adaptive management measures and incorporated those in EFISCEN throughout Europe. The results from the species distribution models and those of the MOTIVE case studies can, however, provide conflicting results. While acknowledging the differences in model type and approach that explain these differences, Schelhaas et al. (2015) tried to make use of the best that the different model types can provide. In this way, they were able to assess the effects of European-scale adaptation options on timber production, and showed that management changes often cannot keep up with the speed of desired species changes.

This biophysical perspective was complemented by Bouriaud et al. (2015b) for another crucial factor that determines the success of forest adaptation. They assessed how different institutional factors affect adaptive forest management across Europe. Based on ten European regions, they concluded that three factors determine Institutional opportunities for adaptation: (1) the openness of the forest management planning process; (2) the degree to which business-as-usual management is projected to be non-satisfactory in the future; and (3) the amount of synergies between ecosystem services.

6. Conclusions

The papers in this Special Feature summarize key elements of the work that has been carried out in the MOdels for adaTIVE forest management (MOTIVE) project. During the project, substantial model development has happened. For example, the inclusion of disturbances and of different management strategies in complex forest models is an important step towards higher local to regional model accuracy. This model development was combined with stakeholder participation at the case study level so as to foster the transfer of the scientific findings into actual forest management, and to tighten the link between forest practice needs and scientific model development. We stress that the results of these case studies should be interpreted within the context of model uncertainties and stakeholder demands for 'actionable' knowledge (Lindner et al. 2014).

Lastly, MOTIVE has contributed strongly to internalise a focus on ecosystem services into conventional forest management models. The joint assessment of climate change impacts and adaptive management strategies has fostered our understanding of and our capability to quantify trade-offs between different management strategies under changing environmental conditions, taking into account the different perspectives that the users of forests and their services may have.

7. Acknowledgements

The MOTIVE Project was funded by the 7th Framework Program of the EC (grant agreement No. 226544). We acknowledge all MOTIVE project partners for the successful completion of the project and are grateful to the Editor-in-Chief of Regional Environmental Change, Wolfgang Cramer, and the Managing Editor, Gabriele Götz, for making this Special Feature possible.

8. References

Andersson M, Kellomäki S, Gardiner B, Blennow K (2015) Life-style services and yield from south-Swedish forests adaptively managed against the risk of wind damage: a simulation study. Reg Environ Chang. doi: 10.1007/s10113-014-0687-8

Battisti A, Stastny M, Netherer S, Robinet C, Schopf A, Roques A, Larsson S (2005) Expansion of geographic range in the pine processionary moth caused by increased winter temperatures ecological applications. Ecol Appl 15(6):2084–2096

Bouriaud L, Bouriaud O, Elkin C, Temperli C, Reyer C, Duduman G, Barnoaiea I, Nichiforel L, Zimmermann N, Bugmann H (2015a) Age-class disequilibrium as an opportunity for adaptive forest management in the Carpathian Mountains, Romania. Reg Environ Chang. doi: 10.1007/s10113-014-0717-6

Bouriaud L, Marzano M, Lexer MJ, Nichiforel L, Reyer C, Temperli C, Peltola H, Elkin C, Blennow K, Duduman G, Taylor P, Bathgate S, Borges JG, Bouriaud O, Clerkx S, Garcia-Gonzalo J, Gracia C, Hanewinkel M, Hengeveld G, Kellomäki S, Kostov G, Maroschek M, Muys B, Nabuurs GJ, Nicoll B, Palahi M, Rammer W, Ray D, Tomé M, Zell J (2015b). Adapting European forest management to climate change: Institutional barriers and opportunities. Reg Environ Chang.

Ciais P, Reichstein M, Viovy N, Granier A, Ogee J, Allard V, Aubinet M, Buchmann N, Bernhofer C, Carrara A, Chevallier F, De Noblet N, Friend AD, Friedlingstein P, Grunwald T, Heinesch B, Keronen P, Knohl A, Krinner G, Loustau D, Manca G, Matteucci G, Miglietta F, Ourcival JM, Papale D, Pilegaard K, Rambal S, Seufert G, Soussana JF, Sanz MJ, Schulze ED, Vesala T, Valentini R (2005) Europe-wide reduction in primary productivity caused by the heat and drought in 2003. Nat 437:529-533.

Hanewinkel M, Cullmann DA, Schelhaas MJ, Nabuurs GJ, Zimmermann NE (2012) Climate change may cause severe loss in economic value of European forestland. Nat Clim Chang 3: 203-207. doi: 10.1038/NCLIMATE1687

Hengeveld GM, Didion M, Clerkx S, Elkin C, Nabuurs G-J, Schelhaas M-J (2015) The landscape-level effect of individual-owner adaptation to climate change in Dutch forests. Reg Environ Chang. doi: 10.1007/s10113-014-0718-5

IPCC (2013) Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY.

IPCC (2014). Summary for Policymakers. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY. pp 1-32

Krehan H, Steyrer G (2005) Borkenkäfer-Monitoring und Borkenkäfer-Kalamität. Forstschutz Aktuell 33:12-14

Lindner M, Maroschek M, Netherer S, Kremer A, Barbati A, Garcia-Gonzalo J, Seidl R, Delzon S, Corona P, Kolström M, Lexer MJ, Marchetti M (2010) Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. Forest Ecol Manag 259:698-709

Lindner M, Fitzgerald JB, Zimmermann NE, Reyer C, Delzon S, van der Maaten E, Schelhaas MJ, Lasch-Born P, Eggers J, van der Maaten-Theunissen M, Suckow F, Psomas A, Poulter B, Hanewinkel M (2014)

Climate Change and European Forests: What do we know, what are the uncertainties, and what are the implications for forest management? J Environ Manage 146:69-83. doi: 10.1016/j.jenvman.2014.07.030

Maroschek M, Rammer W, Lexer MJ (2015) Using a novel assessment framework to evaluate protective functions and timber production in Austrian mountain forests under climate change. Reg Environ Chang. doi: 10.1007/s10113-014-0691-z

Nabuurs GJ, Lindner M, Verkerk PJ, Gunia K, Grassi G, Michalak R,Deda P (2013) First signs of carbon sink saturation in European forest biomass. Nat Clim Chang. doi: 10.1038/NCLIMATE1853

Palma JHN, Paulo JA, Faias SP, Garcia-Gonzalo J, Borges JG, Tomé M (2015) Adaptive management and debarking schedule optimization of Quercus suber L. stands under climate change. Case study in Chamusca, Portugal. Reg Environ Chang.

Ray D, Bathgate S, Moseley D, Taylor P, Nicoll B, Pizzirani S, Gardiner B (2015) Comparing the provision of ecosystem services in plantation forests under alternative climate change adaptation management options in Wales. Reg Environ Chang. doi: 10.1007/s10113-014-0644-6

Reyer C, Lasch-Born P, Suckow F, Gutsch M, Murawski A, Pilz T (2014) Projections of regional changes in forest net primary productivity for different tree species in Europe driven by climate change and carbon dioxide. Ann For Sci 71:211-225

Reyer C, Brouwers N, Rammig A, Brook B, Epila J, Grant R, Holmgren M, Langerwisch F, Leuzinger S, Lucht W, Medlyn B, Pfeifer M, Steinkamp J, Vanderwel M, Verbeeck H, Villela D (2015) Forest resilience and tipping points at different spatio-temporal scales: approaches and challenges. J Ecol. doi: 10.1111/1365-2745.12337

Schelhaas M-J, Nabuurs G-J, Hengeveld G, Reyer C, Hanewinkel M, Zimmermann NE, Cullmann D (2015) Alternative forest management strategies to account for climate change-induced productivity and species suitability changes in Europe. Reg Environ Chang. doi: 10.1007/s10113-015-0788-z

Zell J, Hanewinkel M (2015) How treatment, storm events and changed climate affect productivity of temperate forests in SW Germany. Reg Environ Chang. doi: 10.1007/s10113-015-0777-2

Table 1. Summary of the regional case studies presented in this special feature

Region	**Country**	**Forest type**	**Disturbance considered**	**Ecosystem functions and services**	**Models**	**Reference**
Kronoberg	Sweden	Boreal forest	Wind damage	Stocking, Growth, Yield, Moose habitat suitability (hunting), Recreation index, Net present value, Net return	FinnFor, Forest Time Machine, WINDA-GALES	Andersson et al. 2015
Clocaenog, Gwydyr	Wales	Atlantic forests	Wind damage	Total biomass, Sawlog volume, Small diameter volume, Carbon, Recreation, Biodiversity, Operations/Employment	ESC, ForestGALES, ForestYield, ASORT, BSORT	Ray et al. 2015
Veluwe	The Netherlands	Atlantic forests	n.a.	Timber production, Landscape amenity, Carbon storage, Fire safety, Biodiversity	LandClim	Hengeveld et al. 2015
Black Forest	Germany	Temperate forests	Wind damage	Removed and standing volumes, Net present value	BWinPro, Empirical site index model, empirical storm risk model	Zell & Hanewinkel 2015
Montafon	Austria	Alpine forest	Bark beetles	Timber production, Landslide and avalanche protection	PICUS coupled to Landscape Assessment Tool	Maroschek et al. 2015
Frasin forest district	Romania	Temperate mountain forest	n.a.	Biomass, species composition, harvest	LandClim	Bouriaud et al. 2015a
Chamusca	Portugal	Mediterranean cork forests	Fire	Cork production, Carbon stock	SUBER	Palma et al. 2015