CONTENTS

BOREAL FORESTS IN A CHANGING WORLD: CHALLENGES AND NEEDS FOR ACTIONS

KEYNOTE SPEECHES

Shvidenko A.Z. Changing World, Boreal Forests and IBFRA.............................. 8
Conrad Susan. Reflections on 18 years of collaborative fire research in Siberia........ 13

ORAL AND POSTER REPORTS

BOREAL FOREST RESOURCES AND THEIR MULTIPLE USES

Aleceano A.U. Condition and vital problem of employment of uneven-aged forests in the Russian far east.......................... 16
Chernenkova T.V., Kozlov D.N., Tikhonova E.V., Levitskaya N.N. Criteria and indicators of forest resources and their multiple uses in Moscow region........................................... 17
Danilin I.M. The dynamics of mountain forest ecosystems in Siberia.................. 21
Golovatskaya E.A., Volozhina M.V., Porokhova E.V. Storages of biomass and net primary production at oligotrophic bog ............................................. 26
Jonsson R. A challenging future for the Swedish forest sector – an analysis of major drivers of change in the use of wood resources................................................................. 30
Krausner F., Leduc S., Aoki K., Fass S., Obersteiner M., Schepaschenko D., Shvidenko A. Forest-based bioenergy in the Eurasian context........................................... 34
Kuznet R.S., Sokolov V.A. Dynamics of cedar stands in forestry enterprises of Krai region territory.................................................. 39
Murzaev R.T., Murzaeva R.K. Human impact of forest stability and development in Kyrgyzstan........................................... 41
Ovchinnikova N.F. Long-term forest vegetation inventories in the Sayan Mountains................................................................. 42
Poporov S.A., Makarov V.I. Study of chemical composition of the coalescing combustion products of pine tree (Pinus sylvestris), Siberian larch (Larix sibirica), marsh tea (Ledum palustre), lichen (Cladonia sp.) and celluloic substances............................................. 51
Quan Xiankai, Wang Chuanhua Fire root turnover of fine temperate forests in northeastern China................................................... 49
Shtyklin A.S. Forest resources of Siberia: conditions, dynamics, monitoring ............ 51
Sitko A.F., Pizman T.I. Analysis of the reflectance dynamics of coniferous and deciduous forest stands at Krasnoyarsk region territory based on ground measurements........................................... 55
Sobachkin D.E., Brendova A.V., Sobachkin R.S. The influence of density parameters in young pine forests of the natural origin on distribution of biometric...... 57
Sokolov V.A., Semenchkin I.V., Vyntra O.P., Kazim N.S., Sokolova N.V. Dynamics of Siberian cedar forest........................................................................... 60
Sun Yang. Gyan Healing Assessment on recreation site towards forest multiple use..... 62
Tretyakova I.N., Voroshilova E.V., Shvyrev D.N., Park M.E. Micropopulation by somatic embryogenesis of coniferous species in Siberia.......................... 65

GLOBAL ENVIRONMENTAL SIGNIFICANCE OF BOREAL FORESTS

Bartuev S., Shchennel A., Tchernetsky M., Ivanova Y. Assessment of boreal forests contribution to global seasonal dynamic of carbon dioxide in the atmosphere................................. 74
Kozhevnikova N.K., Dykharev V.N. Hydrological and protective functions of forest cover from water formation zone........................................... 76
Kozhevnikova N.K., Gurtman B.I., Gabarova T.S., Shaman V.F. Water balance of coniferous – deciduous forest ecosystems of Southern Sikhote-Alin in the period of restoration succession ........................................... 79
Krausn A.O., Yatskov M. Disturbance history, age structure, carbon balance and timber supply in forest landscapes of Russia........................................... 80
Lundmark T. The role of the Swedish forest in climate change mitigation................ 82
Makhortova I., Schepaschenko D., Shvidenko A., McCallum I. A system for heterogeneous soil respiration assessment of Russian land........................................... 86
Sabitov R.N. The state of boreal forests of Sakhalin island .................................. 86
Shaman V.F., Gabarova T.S., Kozhevnikova N.K., Boldeskul A.G., Garman B.I. A theoretical background of experimental research for rainforest runoff structure at a small forested catchment................................................... 90
ecosystems in Central Siberia (from eddy covariance measurements) ................................................................. 95

NATURAL AND HUMAN-INDUCED DISTURBANCES IN BOREAL FORESTS

Antamoshkina O.A. Estimating fire-caused boreal forest disturbances using remote sensing data ................................................................. 101
Baruchchik Yu.N. Siberian moth - a relentless modifier of taiga forest ecosystems in Northern Asia ................................................................. 105
Bustyakova E.N. The disturbances of pine-forest stands in Southern Altai, Sibrica and Pimus Sibrica Green pool conservation in culture in vitro ................................................................. 109
Bochkarev Y., Chernenkov K., Friedrich M., Boettger T. Impact of natural and man-made environmental factors on growth intensity of Scots pine and Siberian spruce in the central part of Murmansk region ................................................................. 113
Bogoslovskaya A.P. Soil microbial complexes of boreal forests of Central Siberia after the controlled fires of various intensities ................................................................. 117
Bryakhvostov A.I., Osvaldyk P.A., Gulëvna E.F. Forest fuel smoke producing capability ................................................................. 121
Butovits G.N., Gladkova G.A., Sibrina I.A. New areas of Picea jezoensis and Abies nephrolepis decline in the middle Sikhote-Alin ................................................................. 125
Dubrovskaya O., Sukhinin A., Malkhikh V., Silchenko Y. Modeling of smoke aerosol interaction with cloudiness over catastrophic wildfires in Siberia ................................................................. 129
Fleming R.A., Candau J.N. Interaction between forest insect defoliators and fire in the boreal zone - the state of the science ................................................................. 133
Gurov A.V., Battasii A., Roques A. Invertebrate response to the fragmentation of boreal forests: edge effects ................................................................. 137
Howitt R.E., Taylor D.L., Hoogwijk T.W.N., Chapin III F.S. Resprouting tundra shrubs may act as ecotonecomrial refugia during wildfire facilitating boreal tree seedling establishment ................................................................. 141
Kirichenko N.I., Baruchchik V.N. Trophic adaptation of the Siberian moth in its native range and beyond the distribution boundary ................................................................. 145
Kosolova M.D., Drozdovskaya O.V. Post-fire dynamics of sub-tidal mixed forest in the Emissay part of East Sayan ................................................................. 149
Korobianschikov O.P., Shmakov A.G., Chernov A.A., Silversberg V.M., Kosinov K.P., Maslov V.I. Applicability of thermal technology and non-volatile effectiveness in modeling the boreal forest fires ................................................................. 153
Kovaleva N., Ivanova G. Early stages of plant succession following experimental burning in Central Siberian Scots pine forests ................................................................. 157
Kopteva V.A., Kopteva T.A. Species of vegetation regeneration in anthropogenically disturbed mesotrophic dwarf shrub - sphagnum larch bogs of Primurje ................................................................. 165
Korchevar I.A., Belyaeva A., Krynien A., Umrowski H. The fire history and the age of some fennoscandinian taiga: the experience of modeling and the power of recognizing the consequences ................................................................. 169
Koulev R., Ponomarev E.I. Wildfires in the Republic Tyva ................................................................. 173
McRae D.J., Conard S.G., Ivanova G.A., Jm J.Z., Blake T.W., Ivanov A.V., Samosonova T.N., Sukhinin A.I., Kolesnikov V.A. The climate change factor on vegetation ................................................................. 177
Nechayeva E.N., Senkovskyy V.G. Spatial and temporal coherency of forest insects-philalgophes' population dynamics ................................................................. 181
Polivova E.V. Composition and dynamics of the coniferous and boreal forest fauna in western Siberia ................................................................. 185
Samosonova Yu., Ivanov V.A., McRae D.J., Baker S.P., Conard S.G. Chemical composition and dispersal properties of particulate smoke emissions from fires in boreal forests of Siberia ................................................................. 189
Samokova N.S., Bolshakov V.N., Samokova N.N. Geography of post-fire natural regeneration of pine forests in northern Eurasia ................................................................. 193
Sedov V.K. Positive influence of technogenic disturbance on the boreal forest development ................................................................. 197
Slepow J.G., Sukhinin A.I. Satellite monitoring of wildfire energy release in pine forests of eastern Siberia ................................................................. 201
Skripalshikova LN., Stavova V.Y., Tatrunitz A.I., Zhebureva O.N., Grechikova N.V. The geomicroflora of forests in anthropogenic landscapes of Krasnoyarsk - forest-steppe ................................................................. 205
Soja A.J., Ivanova G.A., Kukarskaya E.A., Predashkin A.S., Ivanov A.V., Kolesnikov V.A. Climate change impact on local ecological conditions for Gmelin's larch growth within the upper treeline - ecotone in Taimyr ................................................................. 209
Shishov V.V., Ivanovskaya A.B., Tyshkov V. Optimal tree-ring growing parameters for Siberian boreal forests ................................................................. 213
Shumakova L.A., Dats A.K., Shugarty H.K., Ivanov A.V. Climate sensitivity analysis of Russian boreal forests near the polar Urals ................................................................. 217
Sidorenko M.L., Bazouleva L.S. Preservation and reproduction of Listeria and Yersinia in soils of boreal

Sukhinin A.I. Space monitoring of catastrophic fires in Russian forests ................................................................. 221

Tatarova O.V., Sochovskyy V.G. The models of forest insects' invasion and estimation of outbreaks' risks ................................................................. 225
Ul'kova N.G., Logofet D.O., Belova I.N. Reformation after clear-cutting of taiga spruce forests as model of interaction between the key species ................................................................. 229
Ustynova V.A., Vorobievich E.I., Borisenko A.V., Zhmukovskaya V.S. Biological productivity of forests near the Ural copper smelters ................................................................. 233
Volchkina A.V., Korets M.A., Sofronova T.M. Management of active forest fires on the basis of their behavior prediction ................................................................. 237

RESILIENCE AND PRODUCTIVITY OF BOREAL FOREST UNDER CLIMATE CHANGE

Baginsky V.F. Prospective change in formation structure of Belarus forests in context of global warming ................................................................. 241
Bryakhvostov A.V., Yagovay E.A., Wirth C., Schulze E.D. 8°C variability within tree rings of the main boreal species in relation to climate ................................................................. 249
Bubkova V.V., Ponomarev A.G., Tatarnunova T.D., Per A.E., Fyastina I.V. Decrease of yuhita woody plants in the period of preparation to winter ................................................................. 253
Burkov I.A., Conard S.G., Sukhinin A.I., Kalenskaya O.P., Ponomarev E.I. Evaluation of postfire dynamics of ground cover depending on wildfires of varying severity in the lower Angara region ................................................................. 257
Christopher D.B. Hawkins, Amalech Dhar Mixtures of broombees and fennel are ecologically and economically desired in an uncertain future changing climate ................................................................. 261
Gordov E.P., Genina E.Yu., Shulgina T.M. Climate induced dynamics of bioclimatic indices for Siberia territory ................................................................. 265
Khoruk V.L., Shmatko M.L. Tree vegetation climate-driven changes within ecosystems in Siberia ................................................................. 269
Krivoshikov I.V., Yagovay E.V., Ivankov O.A. Patterns of floristic formation changes in subarctic bioclimatic region of East Sayan ................................................................. 277
Latt D.A., Suman J.K., Shukur H.H., Ershov O.V., Isakis A.S. Resilience of Russian boreal forests to increased wildfire frequency: findings from modelling studies ................................................................. 281
Matsuu H., Osawa A., Kajimoto T., Naguchi K., Joumera M., Danmouro M., Morishita T. Active layer depth regulates forest biomass regime in permafrost region ................................................................. 285
Masjapy V.S., Shmatkov S.V. Climate-driven changes of the stand age structure in the Polar Urals Mountains ................................................................. 289
Narimova D.I., Drozhdovich O.V., Ismailov D.M., Ponomarev E.I. Bioclimatic classification of forest ecosystems as a basis of their state and stability estimation in Altai-Sayan ecoregion ................................................................. 293
Orlova M.A., Lukin N.V., Kamaev I.O., Smirnov V.F., Krashchekov Y., Tukhatalova O.V., Ivanov L.G., Hoffmann A.M. Domesticated-industrie adapted forest advance on carbon in non-forest ecosystems ................................................................. 297
Oskorinta M.V., Savorova G.G. Structural and functional stability mechanisms of photosynthetic apparatus of coniferous in middle Siberia ................................................................. 301
Otsarvik T.M., Sukinasovskyy V.G. The modeling of succession processes in forest censuses ................................................................. 305
Uzhnovich R. Climate change and forest sustainability in Lithuania: a research review ................................................................. 309
Panyskina I., Leavit S.W. Ancient boreal forest in climatic disequilibrium: lessons from division and dendrochronology of subfossil wood in the U.S.A. Great Lakes area 10,000 to 14,000 °C yr ................................................................. 313
Popova E.V., Savorova G.G., Petrishina Y.V. Territorial dynamics of the photosynthetic oxygen producing organisms of Khatanga region ................................................................. 321
Rat L., Moon J. Does resilience offer a new model for sustainable forest management? ................................................................. 325
Skalin V.N., Komarov A.S., Bykhovets S.S. Simulation modelling of the effect of forest management regimes and climate change on nutrients balance in forest ecosystems ................................................................. 329
Shishov V.V., Ivanovskaya A.B., Tyshkov V. Optimal tree-ring growing parameters for Siberian boreal forests ................................................................. 333
Shumakova L.A., Dats A.K., Shugarty H.K., Ivanov A.V. Climate sensitivity analysis of Russian boreal forests near the polar Urals ................................................................. 337
Sidorenko M.L., Bazouleva L.S. Preservation and reproduction of Listeria and Yersinia in soils of boreal
15. Forest forest processes up-to-date tendency assessment // Forest forest theory. Krassimir B. Stoyanov: KSC SB AS USSR, 1991: 164-166. [In Russian].

***

BOREAL FORESTS AS A CARBON SINK: A REAL OPTIONS PERSPECTIVE

S. Fuss1, M. Gusti1,2, F. Kraxner2, K. Aoki3, I. Szolgayova1,3

1International Institute for Applied Systems Analysis, Ecosystems Services and Management Program, Laxenburg, Austria
2Tyrolean Polytechnic University, Innsbruck, Austria
3Comenius University, Bratislava, Slovakia

BOREAL FORESTS MAINTAIN TWO FUNCTIONS. ON THE ONE HAND, THEY ARE THE SOURCE OF INCOME FOR CONIFEROUS INDUSTRIAL WOOD SUPPLIERS; ON THE OTHER HAND, THEY PLAY AN INTEGRAL ROLE IN THE REGULATION OF THE EARTH’s CLIMATIC SYSTEM [1]. PEOPLE HAVE ACTIVELY THROUGH THE EXHAUST OF WOOD FOR COMMERICAL PURPOSES, AND INDIRECTLY THROUGH THE DEGRADATION OF CLIMATIC CHANGE, INTERVENED IN THIS SYSTEM. AT THE SAME TIME, POLICYMAKERS HAVE REPEATEDLY EXPRESSED THEIR INTEREST IN USING THE FOREST AS A SINK FOR CLIMATIC CHANGE MITIGATION. IN PRINCIPLE, MORE CARBON COULD BE STORED IN THE FOREST IF LARGER AREAS WERE ACCESSIBLE TO DUAL EFFECTS IN FOREST MANAGEMENT. HOWEVER, IN THE FACE OF UNCERTAINTY ABOUT THE REALIZATION OF POLICY, THE RISK ON INVESTMENT IN EXPANDED INFRASTRUCTURE AND ENHANCED MANAGEMENT ARE CONSIDERED AS HIGH. WE EMPLOY A SIMPLE REAL OPTIONS FRAMEWORK TO BROADEN THE POLICYMAKER’S PERSPECTIVE ON THIS SUBJECT.

BOREAL FORESTS HAVE BEEN ESTABLISHED TO HOLD A MAJORITY OF THE EARTH’S TERRESTRIAL CARBON [2]. AS A RESULT, THE POLICY DEBATE HAS BECOME A WIDER MITIGATION PORTFOLIO. HOWEVER, IT IS NOT POSSIBLE TO LOOK AT THIS AS A BENEFIT OF BOREAL FORESTS WITHOUT UNDERSTANDING THEIR ROLE IN THE LARGER SYSTEM. [1] GIVE AN EXTENSIVE ACCOUNT OF BOREAL FORESTS. Figure 1 TRIES TO SIMPLIFY THE MAIN IDEAS HIGHLIGHTED BY THE AUTHORS.

Fig. 1: A Systems View of Boreal Forests.

From Figure 1, it becomes clear that boreal forests are not only an integral part of the Earth system regulating climate and environmental conditions, but they also are a major source of income for the extraction of wood for commercial purposes. In addition, the extraction of other natural resources such as natural gas and minerals also occurs at the expense of boreal forests’ environment and living conditions.

Many previous studies have provided estimates of the extent to which the carbon sink potential of Canadian and Russian boreal forests. For example, Canadian forests were found to be a net sink before 2000, but due to the steep increases in frequency and intensity of wildfires and insect outbreaks, they are a net source nowadays, which is supposed to continue for at least two more decades [3]. [4] Estimated Russian boreal forests to be a net sink of 160 Mt C in 1993 and claimed that this number might increase, while more recent studies find huge variations in these numbers [5].

Even though the need to provide incentives for storing more carbon in forests has been part of the international discussion on climate change mitigation, no decisive action has been taken except for some isolated CDM projects related to avoiding deforestation and afforestation activities. On the other hand, it is also possible to use forests as a carbon sink as a result of improved management [6]. This is particularly relevant in the Russian boreal forest, where expansion to unused areas opens the possibility to improve forest management, such as thinning or the increase of rotations on the more productive areas to store higher amounts of carbon. However, such an expansion requires the building of new infrastructure to make a larger area accessible and this represents a major investment to decision-makers. Furthermore, there is no commitment to a clear carbon policy as of yet, so decision-makers face high uncertainty about the returns to their investment: if they cannot be sure when or how much they will be rewarded for storing carbon, this might represent a major obstacle to investments into infrastructure and enhanced management.

In this paper, we demonstrate that a systems perspective as drawn by [1] and others is important, but that the uncertainty created by the policy dimension adds a substantial option value to committing resources to new infrastructure and better management, even if the results of the exercise would be a desirable increase in the carbon sink. We use a real options model to illustrate the tradeoffs at work in the face of uncertain policy dynamics.

Real Options Theory rests on the idea that a real decision has features similar to a financial option and that keeping such an option open consequently has an economic value. For example, if an investment involving large costs to be sunk in the face of uncertainty about the future profit streams can be postponed, it may pay off to do so and make a better decision based on more complete information later on. This example illustrates the three characteristics of a decision problem that make real options a suitable approach: (a) the decision can be timed flexibly, (b) exercising the option (e.g., investing) is irreversible (e.g., since it involves large sunk costs), and (c) there is uncertainty about future costs and/or benefits associated with the decision [7].

Obviously, considering boreal forests as a carbon sink warrants similar considerations, as the decision to invest into sink-increasing options has uncertain returns if policymakers do not creditably commit to a carbon payment for each ton of stored carbon. As we intend to offer a perspective to policymakers rather than offering numerically precise predictions on investment dynamics, we abstract from many things such as the potential value of ancillary benefits and also the impacts of climate change, which will have further implications for the development of the carbon sink (cf. Figure 1). Instead, our thought experiment assumes that the decision maker’s profit πc are composed of the proceeds of selling the harvested wood Pw - Q - c the cost of extracting the wood from the forest V(C(x)) - Q.

In addition, he receives a carbon payment Ppc per ton of stored carbon in per year. Note that the amount of carbon stored is dependent on the state x: if x = 2 upon investment into new infrastructure cost c enabling improvements in forest management and hence increasing the carbon stored, i.e., C(2) > C(0). It will be possible, furthermore, to extract the same amount of wood in state x, as the wood extracted through thinning can also be sold, but the cost of extraction will be higher, i.e., V(C(2)) > V(C(1)). As the price for wood and the carbon quantity extracted are constant across both states, we can drop them from the calculations and only focus on PC and C.

The source of uncertainty in this thought experiment emanates from carbon policy, which is mimicked by Ppc, the carbon credit paid out for the amount of carbon stored in the forest. We assume that the development follows a Geometric Brownian Motion similar to experiences with current carbon markets to begin with.

\[
dP = \mu P dt + \sigma P dz_i
\]

(1)

where \( \mu \) is the trend, \( \sigma \) the volatility parameter and \( dz_i \) the increment of a standard Wiener process. Let us further define the gain from investing and improving management as \( G \), which is composed of the additional carbon stored, \( \Delta C \) multiplied by the price received per ton of carbon. The value of the investment at time 0 is thus

\[
V(G) = \mathbb{E}_{\mathbb{Q}} \left[ e^{-rT} (G - Q - \Delta VC) \right]
\]

(2)

where \( T \) is the end of the planning horizon, \( r \) the discount rate and the income from selling wood is assumed to be constant for both states. Assuming \( T = \infty \) for the moment, integration gives equation (3).

\[
V(G) = \frac{G}{r - \mu} - \frac{Q - \Delta VC}{r}
\]

(3)

2 This might be paid out of a dedicated REDD (Reduced Emissions from Deforestation and Degradation) fund as part of a project in a type of CDM setting or through linkage with an existing carbon market. The details of the implementation of such funding are beyond the scope of this exercise.
The decision-maker will only invest into infrastructure and better forest management if this value exceeds the value of the option to invest, \( F(\Pi) \). In other words, there is an economic value to waiting for better information on the development of the carbon policy and acting optimally on that at a later point in time. The critical value, \( G^* \), which will trigger investment, can be found by equation (5) as the derivative of the expected value with the value of exercising the option evolving according to the changes in \( F(\Pi) \) over time, as described in detail in [7]. Following this procedure, we find the difference equation (4), which holds for \( G \in [0, G^*] \):

\[
rF(G) = \mu GF(G) + \frac{1}{2} \sigma^2 G^2 F''(G)
\]

where time subscripts are omitted for clarity of exposition.

The boundary conditions are given by equations (5) to (7)

\[
\lim_{G \to -\infty} G = 0
\]

\[
F(G^*) = V(G^*) - I
\]

\[
F'(G^*) = \frac{1}{r - \mu}
\]

The problem being completely analogous to the one described in [7], we follow the same procedure arriving at the following solution form for \( F(\Pi) \):

\[
F(G) = A_1 G^\beta_1 + A_2 G^\beta_2
\]

where we are only interested in \( \beta_2 < 0 \) and

\[
A_1 = (G^*)^{-\beta_1} / \beta_1 (r - \mu), \quad A_2 = (G^*)^{-\beta_2} / \beta_2 (r - \mu)
\]

and we can solve for the threshold of the gain, at which investment occurs:

\[
G^* = \frac{\beta_1}{\beta_1 - 1} (r - \mu) \left( \frac{Q}{\Delta C} - 1 \right)
\]

which implies that the threshold level of the necessary carbon credit needs to be higher the lower the amount of additionally stored carbon \( \Delta C \).

Employing some rough estimates for the parameters, we can plot the value less the investment cost, \( NV - I \) and the option value, \( F \), in Figure 2. Where the two lines cross, we have the threshold value of the carbon gain, \( G^* \).

Note that the data are rough estimates abstracting for the time being from some important dynamics, so more research is needed to account for the full cost of expansion and the dynamics underlying the carbon budget. However, we can already on the basis of this simple exercise say that in order to reach 80% with an expectation of further rises to trigger investment into the required infrastructure for improved forest management and additional carbon storage. The following table demonstrates that relaxing the assumption of an infinite lifetime further raises this threshold and higher than anticipated investment costs do not make sense.

So, while the absolute numbers should not be taken at face value before a more complete dataset can be tested, the sensitivity analysis gives us important information about the impact of different parameters and how they change the underlying tradeoffs. In particular, a lower than expected carbon price will raise the carbon price needed to entice investment, which is also true for higher than anticipated operational (and maintenance costs). Most importantly for policymakers, is the message conveyed by the sensitivity of the trigger price with respect to carbon price volatility even if policymakers can make a credible commitment to raising carbon payments for additionally stored carbon in the forest, fluctuations in the same represent a disincentive for committing resources to the building of the necessary infrastructure.

Fig. 2. Option value (solid line) versus present value (dashed line).

<table>
<thead>
<tr>
<th>Table 1: Sensitivity analysis</th>
<th>G* (mill EUR)</th>
<th>F* (EUR/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>baseline</td>
<td>723</td>
<td>7.96</td>
</tr>
<tr>
<td>carbon gain halved, AC</td>
<td>723</td>
<td>15.72</td>
</tr>
<tr>
<td>Increased carbon price volatility, ( \sigma )</td>
<td>836</td>
<td>9.08</td>
</tr>
<tr>
<td>double investment cost, I</td>
<td>1,363</td>
<td>14.81</td>
</tr>
<tr>
<td>double operational cost</td>
<td>806</td>
<td>8.76</td>
</tr>
<tr>
<td>Shorter planning horizon, T=50</td>
<td>1,196</td>
<td>13.00</td>
</tr>
</tbody>
</table>

Future research should therefore not only concentrate on the composition of a more complete dataset, but also tackle different forms of uncertainty. The current analysis assumes that there will be carbon payment scheme evolving in a similar way as current carbon markets, but this is not guaranteed. On the contrary, there is also substantial uncertainty about the timing when such carbon payments could be introduced and there is also the question whether it will be introduced at all and if so whether it will be kept, which could be mimicked by introducing a Markov process.

In this paper, a simplistic yet important thought experiment has been carried out to provide a new perspective to the maintenance and sustainable use of boreal forests in Russia. In particular, we have employed a small real options application to model decision-making in the face of uncertain carbon policy, thereby illustrating the importance of clear commitments and unambiguous signals on the part of policymakers in order to achieve improved forest management and enable the storage of larger amounts of carbon in the forest as part of a larger mitigation portfolio.

Acknowledgements
The work presented in this paper has been supported by EU-funding in the frame of the following projects: GHG-EUROPE, POST-2012, NitroEurope and CC-TAP.

REFERENCES
The decision-maker will only invest into infrastructure and better forest management if this value exceeds the value of the option to invest, \( F(G) \). In other words, there is an economic value waiting to be better information on the development of the carbon policy and raising optimally on this at a later point in time. The critical value \( G^* \), which will trigger investment, can be found by equating the marginal value of waiting with the value of exercising the option evolving according to the changes in \( F(G) \) over time, as described in detail by [7]. Following this procedure, we find differential equation (4), which holds for \( G \in \{0, G^*\} \):

\[
rF(G) = \mu G F(G) + \frac{\sigma^2}{2} G^2 F'(G)
\]

where time subscripts are omitted for clarity of exposition.

The boundary conditions are given by equations (5) to (7):

\[
\lim_{G \to \infty} F(G) = 0
\]

\[
F(G^*) - V(G^*) - I
\]

\[
F'(G^*) = \frac{1}{r - \mu}
\]

The problem being completely analogous to the one described in [7], we follow the same procedures arriving at the following solution form for \( F(G) \):

\[
F(G) = A_1 G^\beta_1 + A_2 G^\beta_2
\]

where we are only interested in \( \beta_2 \) as \( \beta_1 < 0 \), \( \beta_2 = \frac{\sigma^2}{2} \mu - \frac{\mu^2}{2} + \frac{\sigma^2}{2} \left[ \left( \mu - \left( \frac{\sigma^2}{2} \right)^2 \right) + 2 \sigma^2 \right] / \sigma^2 \) and

\[
A_1 = (G^*)^{-\beta_2} / \beta_2 \left( r - \mu \right), \quad A_2 = (G^*)^{-\beta_1} / \beta_1 \left( r - \mu \right)
\]

which implies that the threshold level of the necessary carbon credit needs to be higher the lower the amount of additionally stored carbon \( AC \) is.

Employing some rough estimates for the parameters, we can plot the value less the investment cost, \( F(G) \), and the option value, \( F \), in Figure 2. Where the two lines cross, we have the threshold value of the carbon gain, \( G^* \).

Note that the data are rough estimates abstracting for the time being from some important dynamics, so more research is needed to account for the full cost of expansion and the dynamics underlying the carbon budget. However, we can already on the basis of this simple exercise say that a rising CO2 price would at least need to reach €80/ton with an expectation of further rises to trigger investment into the required infrastructure for improved forest management and thus additional carbon storage. The following table demonstrates that relaxing the assumption of an infinite lifetime further raises this threshold and higher than anticipated investment costs do the same.

So, while the absolute numbers should not be taken at face value before a more complete dataset can be tested, the sensitivity analysis gives us important information about the impact of different parameters and how they change the underlying tradeoffs. In particular, a lower than expected carbon price will raise the carbon price.

---

1 See [7], pages 108 and 109 for an economic explanation and derivation of the boundary conditions.

2 We assume for O that the 2010-2050 average projected harvest of 173.99 mm m² applies per year for the Russian boreal forest and that the area necessary expansion is 29.575 million ha, where 10 lm a 106 are needed to make 1 additional ha accessible for forestry. Operational costs will be higher by 0.44€ per m², as under improved forest management some wood is extracted through thinning, which is more expensive to de extracting it through simple clear-cut. 92 Tg CO₂ are additionally stored due to improved forest management each year, where the GUM WSC scenario data have been readjusted according to the 2003-2008 average net ecosystem balance by [8] adjusted furthermore by the accumulation in living biomass, which is about 35% (personal communication A. Shvidenko). The discount rate is about 20% according to [9].

---

Table 1: Sensitivity analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>( G^* ) (mill EUR)</th>
<th>( P^* ) (EUR/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>baseline</td>
<td>723</td>
<td>7.86</td>
</tr>
<tr>
<td>carbon gain halved, AC</td>
<td>723</td>
<td>15.72</td>
</tr>
<tr>
<td>increased carbon price volatility, σ</td>
<td>836</td>
<td>9.08</td>
</tr>
<tr>
<td>double investment cost, I</td>
<td>1,363</td>
<td>14.81</td>
</tr>
<tr>
<td>double operational cost</td>
<td>806</td>
<td>8.76</td>
</tr>
<tr>
<td>shorter planning horizon, T=50</td>
<td>1,196</td>
<td>13.00</td>
</tr>
</tbody>
</table>

Future research should therefore not only concentrate on the composition of a more complete dataset, but also tackle different forms of uncertainty. The current analysis assumes that there will be carbon payment scheme evolving in a similar way as current carbon markets, but this is not guaranteed. On the contrary, there is also substantial uncertainty about the timing when such carbon payments could be introduced and there is also the question whether it will be introduced at all and if so whether it will be kept, which could be mimicked by introducing a Markov process.

In this paper, a simplistic yet important thought experiment has been carried out to provide a new perspective to the maintenance and sustainable use of boreal forests in Russia. In particular, we have employed a small real options application to model decision-making in the face of uncertain carbon policy, thereby illustrating the importance of clear commitments and unambiguous signals on the part of policymakers in order to achieve improved forest management and enable the storage of larger amounts of carbon in the forest as part of a larger mitigation portfolio.

Acknowledgements

The work presented in this paper has been supported by EU-funding in the framework of the following projects: GHG-EUROPE, POST-2012, NitroEurope and CC-TAME.

References


SOCIO-ECONOMIC LOSS FROM IRRATIONAL FOREST USE IN KRASNOYARSK REGION

A.A. LALETIN1,2, V.A. SOKOLOV1, A.P. LALETIN2

1Sukachev Institute of Forest SB RAS, Krasnoyarsk, Russia
2NGO “Friends of the Siberian Forests”, Krasnoyarsk, Russia

This article shortly characterizes the forest reserves of one of the largest forest regions of Russia – Krasnoyarsk region. It can be seen in dynamics that for the last 50 years the quality of the forest reserves has degenerated significantly. This degeneration is caused by the irrational and unsustainable forest management. Authors propose some basic principles for sustainable forest management and provide some socio-economic mechanisms of solving the problem of illegal logging.

Forest resources of Krasnoyarsk region. Timber resources of the forests

In connection with the union of three subjects of the Russian Federation on 1 January 2007 - Krasnoyarsk Territory, Tuimyr (Dolgan-Nenets) and Evenki autonomous districts into one entity - Krasnoyarsk Region, the Krasnoyarsk Region land balance has changed. The total land area of the united region as 01.01.2008 amounts to 236,679.7 ha. Area of the region increased by 164,312.6 hectares. Area of forest land of Krasnoyarsk region amounts to 155,565.0 hectares. Area of lands under forest have increased by 97,578.5 ha in the united region. In the structure of land of Krasnoyarsk region forest fund lands constitute 65.7%. [4]

More than half of the forests in the region are represented by larch, about 17% by spruce and fir, 12% by pine and more than 9% by cedar. 88% of forests in the region are coniferous.

More than 10% of Russian timber reserves are concentrated in Krasnoyarsk region.

Forest dynamics of Krasnoyarsk region

The analysis of forest dynamics is based on the forest resource assessments, since 1961, - the year of the first simultaneous assessment of Siberian forests, when they were assessed with the inventory methods of varying accuracy: the method of III-IV categories of forest management regulation and the method of remote sensing by airplane (more than half of the area). [3]

During the 45-year period (1961 – 2007) in Krasnoyarsk Territory (Krasnoyarsk region, Republic of Khakassia), the area covered by forests decreased by 5108.2 thousand ha (5%), and the area of mature and over-mature coniferous and larch stands declined by 17210.4 thousand ha (25%) and 1670.5 thousand ha (17%), respectively. The total reserves of timber decreased by 3174.99 million m³ (12%); the accessible reserves of timber in coniferous stands decreased by 3725.06 million m³ (35%), but accessible reserves in deciduous stands increased by 10.14 million m³ (1%).

Consequently, the quality forest reserves of Krasnoyarsk region have already been degenerating for almost 50 years. The process of degradation has slowed down during the last years due to the sharp decline in logging volumes.

Development of the bases for forest management

According to the Russian Federation Forest Code (FC) the forest estate lands should be federally owned (article 8). Before the FC was released, however, parcels of forest land and forestry enterprises were transferred to the Subjects of the Russian Federation’s management under federal law #199 dated 31.12.2005. Forest enterprises have been converted into forest districts - local forest and field services management authorities