

Conversion of Siberian Larch Forests in Response to Climate Change

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Introduction

In Siberia, increased temperatures have been documented which exceed predictions made by global climate models (Soja *et al* 2007). The Siberian boreal forest may also affect the Earth's climate through temperature driven changes in the regional forest composition and resultant changes in surface albedo. In particular, Siberia is dominated by Larch (*Larix spp.*) forest and a warmer climate may accelerate the natural succession from Larch, which is a deciduous conifer, to evergreen, or dark, conifer forest. The albedo change associated with a shift from light to dark conifer forest promotes additional climate warming that may be large enough to counter balance the carbon storage that results from growing the evergreen forest (Betts 2000). It is possible that a human-mediated introduction of European Larch (*Larix decidua*) would mitigate the effects of climate change in Siberia. More specifically, European Larch is adapted to warmer climate conditions and its introduction to Siberia could slow the rate of conversion from deciduous to evergreen conifer forests.

The dynamic vegetation model FAREAST (Yan and Shugart 2005) simulates the composition of the Russian boreal forest in response to current and changing climate conditions and is ideal for exploring the feedback between climate and forest composition at both the continental and regional scale. For this analysis, species range maps for the 52 species included in the model have been added, and species are included on a site specific basis. The model was used to simulate the impact of changes in temperature and precipitation on both total and genera specific biomass across Siberia and then in six different regions. Model runs with and without European Larch are compared in order to assess the potential for the introduction of this species to mitigate the effects of climate change, especially the positive feedback among temperature, forest type and surface albedo.

Methods

Climate sensitivity analysis was used to evaluate the response of total forest biomass and the biomass of *Larix spp.* and evergreen, or dark, conifers at 372 sites across Siberia to changes in temperature and precipitation and to the inclusion of *Larix decidua*. A total of 12 treatments involving different combinations of temperature and precipitation change and European Larch introduction were used (Table 1).

Table 1. Treatments used in climate sensitivity analysis	
Change in temperature	Base + 4 degrees
Change in precipitation	Base ± 10%
Introduction of <i>Larix decidua</i>	Base + <i>Larix decidua</i>

For the model runs with temperature or precipitation change, a linear increase in temperature or precipitation or both takes place from year zero to year 200 of the simulation. This is followed by an additional 150 years of simulation during which the climate stabilizes around the conditions attained in year 200. A non-parametric factorial ANOVA was used to assess differences in the biomass (tCha⁻¹) of *Larix spp.*, dark conifers and the total forest biomass among model runs that employed different climate treatments at ten year intervals. This analysis was completed at the continental scale (Figure 4), and for six regional subsets (Figure 3) including northwest Siberia, central border of east and west Siberia, two sets from southern Siberia, and two sets from the Russian Far East. These regions represent areas with a broad range of climatic conditions and offers a representative sample of different forest types within Russia.

Local Results

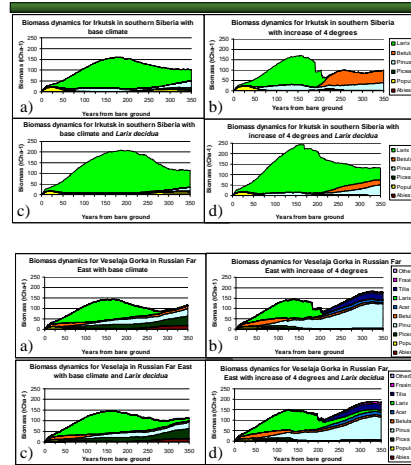
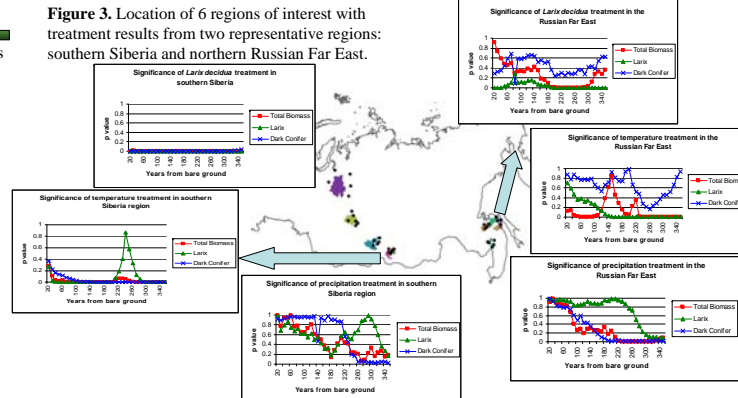


Figure 1. Simulated mixed species biomass dynamics (tCha⁻¹) for Irkutsk in southern Siberia. Effect of temperature increase of 4 degrees across 200 years causes transition from *Larix spp.* dominance to mixed species forest (b) when compared to base scenario (a). Addition of *Larix decidua* increases total biomass (c) and prevents replacement of *Larix spp.* in response to temperature increase (d).

Figure 2. Simulated mixed species biomass dynamics (tCha⁻¹) for Veselaja Gorka in the Russian Far East. Effect of temperature increase of 4 degrees across 200 years causes transition to mixed species forest dominated by *Pinus spp.* (b) when compared to base scenario (a). Addition of *Larix decidua* does not significantly effect total biomass (c) or prevent replacement of *Larix spp.* in response to temperature increase (d).

Regional Results

Figure 3. Location of 6 regions of interest with treatment results from two representative regions: southern Siberia and northern Russian Far East.



The regional scale analysis indicates that:

- Changes in temperature and the introduction of *Larix decidua* have a significant impact on total, *Larix spp.* and dark conifer biomass in low diversity areas such as southern Siberia but not in high diversity areas like the Russian Far East
- Changes in precipitation do not significantly impact biomass for any class at the regional level

Continental Results

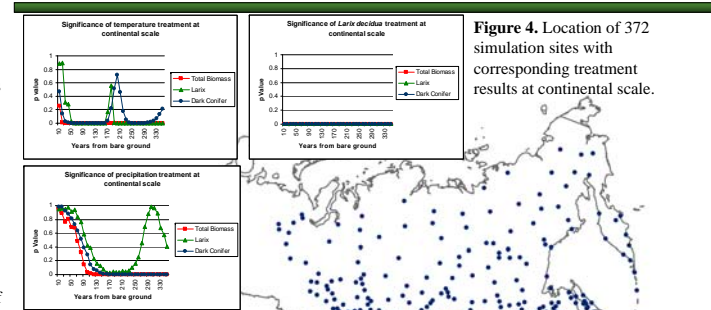


Figure 4. Location of 372 simulation sites with corresponding treatment results at continental scale.

The continental scale analysis indicates that:

- Addition of *Larix decidua* has a significant impact on all biomass classes
- Changes in temperature have a significant impact on all classes of biomass with non-significant peak coinciding with *Larix spp.* succession around year 200
- Changes in precipitation significantly impact the biomass of all classes at natural succession transition point from years 130 to 220 and continue to be significant for total and dark conifer biomass after this point

Conclusions

- At the local scale, introduction of *Larix decidua* within low diversity areas across Siberia increases overall biomass and prevents conversion of existing Larch forest to dark conifer forest in response to temperature increase. Within the higher diversity Russian Far East, *Larix decidua* does not significantly increase total biomass nor does it prevent conversion of forest from light to dark conifer in response to temperature change.
- At the regional scale, *Larix decidua* introduction and temperature change have a significant impact on all classes of biomass in low diversity areas across Siberia. Areas of higher diversity, such as the Russian Far East, were not significantly affected by *Larix decidua*, and showed variable response to temperature change. Changes in precipitation did not significantly impact any class of biomass for the regions analyzed. This further emphasizes that the low species diversity across Siberia makes it vulnerable to conversion of forest type in response to temperature change.
- At the continental scale, the introduction of *Larix decidua* has a significant impact on all classes of biomass at all time points. *Larix decidua* may therefore be useful in mitigating the impacts of increasing temperatures and delaying conversion from Larch to dark conifer forest. Changes in temperature and precipitation both have significant effects on all classes of biomass, but the temperature increase has the greatest effect on *Larix spp.* and dark conifer biomass before and after the successional transition point from years 130 to 220. Further analysis is required to explain the timing of significance of the precipitation effect and any connection to successional dynamics.

- Overall, these results indicate that the impact that a change in climate has on forest composition and total biomass varies dramatically with the spatial scale being considered. This has broad implications in terms of climate change studies and the generality of results produced by global climate models.

Acknowledgements

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