

Modeling and Assessing Insect Disturbance on Boreal Forests in the Krasnoyarsk region of Russia by Employing the FAREAST Gap Model and Local Forest Inventory and Disturbance Data.



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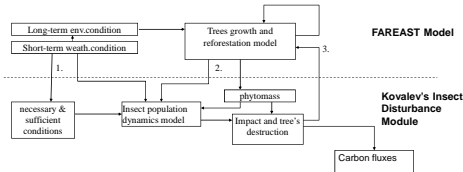


Introduction and Background

FAREAST: an individual-based forest dynamics model was initially developed to simulate the forested region around Changbai Mountain in northern China (Yan and Shugart 2005). In recent years the model has been expanded across Siberia to include 223 further sites (Razuvaev et al. 2008). Simulating the birth, growth and death of individuals over a twelfth of a hectare, the output provides a detailed picture of changing species composition and biomass over time. The data generated by the model was then validated for 46 of the sites by employing a linear regression between the simulated biomass (tCha⁻¹) and inventory data (Shuman 2008). With the proven ability of the model to accurately depict the composition of the forest for much of the boreal orbit, additional modules have been developed to account for disturbance as a result of factors acting outside the normal successional development of the forest.

Anton Kovalev developed a module to account for the recent growing populations of the needle defoliator, Siberian Silkworm (*Dendrolimus sibiricus*) and the disturbance impact they have on the Siberian forests. The module consumes short term (daily) climatic conditions and tree growth and regeneration data generated on the FAREAST end of the model. This is then processed to produce a probability of an individual trees' destruction, assuming insect outbreak, that is then fed back into the FAREAST growth and regeneration module.

Figure 1: Model Structure and Integration with FAREAST

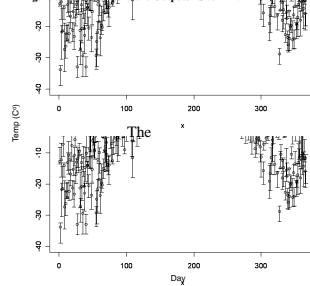


Inventory data for the region, prior to insect disturbance exists allowing outputs of the FAREAST model to be validated for the region under the new climatic parameters. Both the novel climate generation and outputs were compared against meteorological data and forest inventory data to provide the base operational structure for the insect disturbance module.

Data & Methods - Daily Climate

Insect outbreaks occur as a result of small scale climatic events operating over a short period of days. Tree growth and reforestation operates on monthly climate data. To integrate the insect module into the FAREAST model a new climatic model was created to generate daily mean temperatures, daily minimums and maximums and daily precipitation. To generate daily temperatures, inventory data from 2 weather stations (Razuvaev et al. 2008) near the Usolsky forest region were processed to generate a mean temperature and standard deviation for each day of the year. Dependent on the time of year and the temperature, an associated distribution for minimum and maximum was also generated. This data was then used to parameterize the climatic conditions (figure 3).

Figure 3: Daily Temperature Outputs - Site ID 29574



Precipitation was calculated by fitting a curve to the cumulative frequency of the log transformed daily volume of rain for each month. From this polynomial regression, 12 quartic equations were generated. The equation is of the form:

$$y = ax^4 + bx^3 + cx^2 + dx + e$$

Where y is the frequency of rain and x is the log volume of precipitation.

Numbers randomly drawn from the y axis of the regression simulated both number of dry days and if rain occurs, associated volumes.

Figure 4: Site 29574 (Krasnoyarsk) linear regression between simulated and processed meteorological data - Temperature

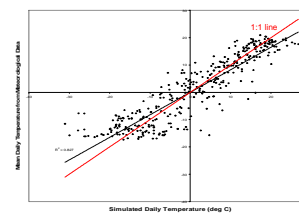
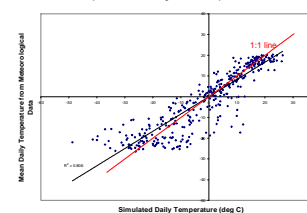


Figure 5: Site 29282 (Bogucany) linear regression between simulated and processed meteorological data - Temperature



There is as expected a strong correlation between the simulated data and the original meteorological data, with R² values

Figure 6: Simulated Mean Daily Temperature

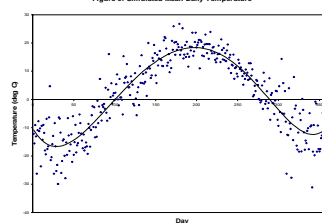
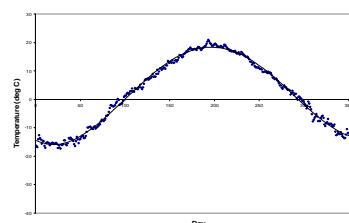


Figure 7: Mean Daily Temperature from Field Meteorological Data



Species Composition

The species compositions from the two sites create very different pictures across the age cohorts. Site 29282 (Bogucany) generates a diverse forest stand when mature. Site 29574 (Krasnoyarsk) develops into a more typically boreal homogenous stand with *Pinus* and *Picea* as the two dominant species (figure 8 & 9).

Figure 8: Site 29282 (Bogucany) Species Composition Over Time

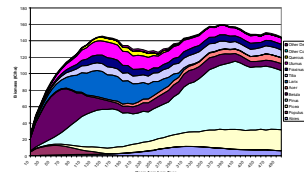
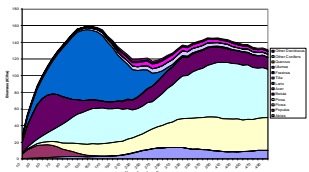


Figure 9: Site 29574 (Krasnoyarsk) Species Composition Over Time



Data Analysis – Simulated vs. Inventory

Comparisons of inventory to model simulated biomass (tCha⁻¹) garnered mixed results. A linear regression of biomass for each species across age cohorts showed strong relationships for *Betula* (Birch) with an R² value of 0.7533 for the Krasnoyarsk site and an R² value of 0.7855 for the Bogucany site (figure 10). Both *Pinus* (Pine) and *Picea* (Spruce), the two apparent dominants in the mature stands from the model simulation, showed weak correlations with R² coefficients < 0.08 and < 0.3 respectively for both simulation sites (figure 11).

Figure 10: Linear Regression of Birch Biomass for the 2013 Krasnoyarsk simulated data and Usolsky forest inventory data

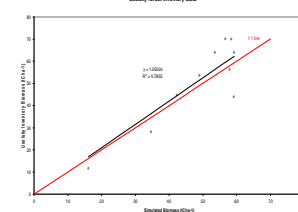
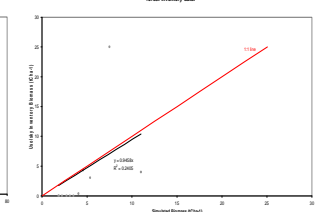


Figure 11: Linear Regression of Pine Biomass for the 2013 Krasnoyarsk simulated data and Usolsky forest inventory data



Discussion & Conclusions

The current structure of daily climate generation, while statistically similar to inventory meteorological data, has been shown to skew temperatures towards warmer climates. This creates an effective shift in the latitude that is being simulated by the site. This in turn impacts species composition, which in previous work has been shown to quite accurately generate biomass data for the central Siberian Krasnoyarsk region (Shuman 2008). Further work needs to be done to effectively and accurately generate daily climate data that generates accurate biomass results from FAREAST before the insect module is implemented further.

The Krasnoyarsk region and in particular the Usolsky GIS and database provide invaluable information to ground truth an insect model. As such further pursuit to integrate Kovalev's model into FAREAST is still of great value, especially given the increasing pressure of the Siberian Silkworm on the Siberian Boreal forest environment. Further research and novel approaches into small scale climate simulation remains the crucial first step to creating a powerful predictive disturbance model for the Boreal forests of Russia.

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Study Site & Model Integration

Integration and validation of the Insect Disturbance Module is dependent on the validation of simulated daily climatic data and the resultant biomass (tCha⁻¹) and species composition for a site without a disturbance event. After this step, the insect disturbance model can be fully integrated and resultant biomass and species composition examined post a disturbance event.

The validation of the new climate model and biomass outputs without disturbance was carried out for the Usolsky forest in the Krasnoyarsk region of central Siberia. The region has seen a number of outbreaks of Siberian Silkworm populations after 1992, with as much as 25% of the region affected by the moth as of 1996 (see figure 2) (Yershov 2006).

Figure 2

Insect Disturbance in the Usolsky forest - Krasnoyarsk

