Simulating the Effects of Fire on Forests in the Russian Far East: Integrating a Fire Danger Model and the FAREAST Forest Growth Model Across a Complex Endangered Wildlife Habitat

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Introduction

The remaining natural habitat of the critically endangered Amur tiger (Panthera tigris altaica) and Amur leopard (Panthera pardus orientalis) is a vast, biologically and topographically diverse area in the Russian Far East (RFE). Although wildland fire is a natural component of ecosystem functioning in the RFE, severe or repeated fires frequently reset the process of forest succession, which may take centuries to return the affected forests to pre-fire states and significantly reduce habitat quality and long-term availability. The frequency of severe fire events has increased over the last 25 years, leading to irreversible modifications of some parts of the species’ habitats. Moreover, fire regimes are expected to continue to change toward more frequent and severe events under the influence of climate change. Here we present an approach to developing capabilities for a comprehensive assessment of potential Amur tiger and leopard habitat availability throughout the 21st century by integrating regionally parameterized fire danger and forest growth models. This work presents the first attempt to merge the FAREAST model with a fire disturbance model, to validate its outputs across a large region, and to compare it to remotely-sensed data products as well as in situ assessments of forest structure.

We ran the FAREAST model at 1,000 randomly selected points within forested areas in the RFE (Fig. 5). At each point, the model was calibrated for temperature, precipitation, elevation and soil characteristics. The model simulates 200 plots or 0.05 ha, starting with bare ground, representing a gap in the forest canopy created when a tree falls. The model was run a second time with a fire probability of 0.006 (6 fires every 1,000 years). The output of the model includes biomass estimates for 44 tree species that occur in the RFE, grouped by genus. We compared the biomass estimates from FAREAST and found that further analysis will be needed to distinguish differences in biomass according to parameters such as elevation, age of the forest, slope and aspect.

The FAREAST model was run at 1,000 points in Primorsky Krai with no fire risk component and subsequently with a fire occurrence rate of 0.006 (6 fires every 1,000 years). Large areas of Primorsky Krai contain undisturbed mixed deciduous/Korean pine/conifer forests. The study focused on the maximum biomass levels expected after about 150-250 years of succession (Yan and Shugart 2005).

We also compared biomass results from FAREAST at 987 points across the entire region with LIDAR-based estimates of biomass (PI – 2 yr-1) versus observed at 593 Forest Survey Stations in China. We also compared biomass results from FAREAST at 987 points across the entire region with LIDAR-based estimates of biomass (PI – 2 yr-1) versus observed at 593 Forest Survey Stations in China.

Impact on Fire of Wildlife Habitat

Approximately 330-390 mature Amur tigers (Miguel et al. 2006) and about 30 Amur leopards (WCS 2006) exist in the wild. Principle threats are inadequate prey, poaching, and loss of habitat from logging and development. Amur leopards are particularly vulnerable to loss of habitat from repeated human-caused fires, which convert forests to open grasslands (Figs. 7&8). Non-recurring, low intensity fires can improve habitat by clearing underbrush and nourishing soil, but severe or repeated fires can reset the process of forest succession. In the case of extremely severe or repeated fires, the original forest may take centuries to re-grow.

Land use types in the study area were divided into four forest categories derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) (Friedl et al. 2002) and the Map of Russia’s Forests (Burtunov et al. 2004): deciduous, coniferous, Mixed, and Shrub. The presence of fire disturbance in the landscape is a significant threat to wildlife. Fire may have a positive impact on wildlife such as Amur tigers, Amur leopards, and Siberian tigers. However, the long-term effects of fire disturbance on wildlife populations can be negative. The reintroduction of tigers and leopards in the RFE depends on the success of fire management strategies to maintain high levels of biodiversity.

Fire Danger Model

The Fire Danger Model is an individual-, gap-based model that simulates forest growth in a single location and demonstrates temporarily explicit forest succession leading to mature forests. The model incorporates the characteristics and requirements related to growth, mortality and regeneration, as well as the site characteristics, seasonality, soil moisture, and climate. It simulates the forest succession process in terms of biomass and vegetation changes (Yan and Shugart 2005).

We also compared biomass results from FAREAST at 987 points across the entire region with LIDAR-based estimates of biomass (PI – 2 yr-1). Biomass was derived using allometric equations and then predicted from GLAS waveform indices using neural network. GLAS was designed to measure the thickness of ice sheets and also provides land topography. The GLAS instrument is carried on the Ice, Snow, and Cloud, Earth System STUDY (ISCCS) satellite launched January 2003. By analyzing the sequence of laser data over time, changes in topography can be determined. The initial biomass comparison indicated that further analysis is needed by climate conditions, stage of succession, elevation, slope and aspect.

We also compared FAREAST-produced LAI with LAI estimates derived from MODIS data for the 987 GLAS points and found that the difference in LAI was less than one at 307 (31%) points, less than 0.5 at 125 (12.5%) points, and less than 0.2 at 51 (5.1%) points.

Next Steps

The next steps will be: 1) to further analyze results of the FAREAST simulations and calibrate the model with respect to slope and aspect; 2) to modify temperature and precipitation according to climate change scenarios projected in the Intergovernmental Panel on Climate Change 2007 report; 3) to develop a methodology to map disturbance across the study area using remotely sensed data; 4) to analyze discrepancies in biomass between GLAS estimates and FAREAST results in terms of disturbance and fire behavior of fire disturbance succession.

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Fig. 1. Land cover of study area (MODIS land cover product: IGBP classification, Loboda & Csiszar, 2007)

Fig. 2. Amur tiger present and potential habitat. Graphic: Wildlife Conservation Society

Fig. 3. Amur tiger & Amur leopard in Primorsky Krai, Russia, photographed by infrared motion-detecting camera. Photos: Wildlife Conservation Society (WCS)

Fig. 4. FAREAST model results for 1,000 random points: Comparison of biomass with MODIS data

Fig. 5. Biomass and LAI were compared at 1,000 random points representing forested areas in Amur tiger habitat in the RFE.

Fig. 6. FAREAST with fire represents a completely undisturbed forest. Adding fire disturbance creates slight displacement of biomass ($y = 3.6937x^{0.7409}$, $R^2 = 0.7715$).

Fig. 7. Points represent 97 GLAS Ikonos Laser Altimeter System (GLAS) data locations for which LAI and biomass estimates (TChs) were derived using two different approaches (described below) were compared.

Fig. 8. Burned area extent in the RFE during 2001 – 2005.

Fig. 9. Monthly mean fire occurrence probability surfaces were created using the decision tree method based on the analysis of fire data and landscape characteristics.

References


Amur tigers & Amur leopard in Primorsky Krai, Russia, photographed by infrared motion-detecting camera. Photos: Wildlife Conservation Society (WCS)