Assessing Fire Danger from Remotely Sensed Products within the Amur Tiger Habitat

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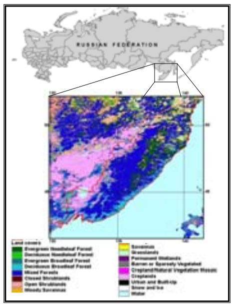
The Amur tiger habitat in the Russian Far East

Forests of the Russian Far East are the world's richest temperate forests and the main habitat of the critically endangered Amur Tiger (*Panthera tigris altaica*). The changes in the natural fire cycle prompted by decades of intensive economic development and the rising frequency of large fires are recognized as one of the gravest threats to this ecosystem. The Amur tiger's low population densities and reproductive potential even within high quality habitat make this species particularly vulnerable to fire induced habitat reduction, degradation and fragmentation. Complex terrain, low density of transportation network and unavailability of reliable in-situ data on fire occurrence over the entire tiger range make remote sensing the only viable source of data. This project presents an approach to Fire Danger assessment within a broader framework of Fire Threat Modeling. The remotely sensed data driven Fire Threat Model (FTM) has been developed to provide spatially explicit and temporally dynamic quantitative assessment of fire threat to the Amur tiger.



Background

The FTM is a new tool aimed at identifying fire susceptible areas of highest importance for a given resource.

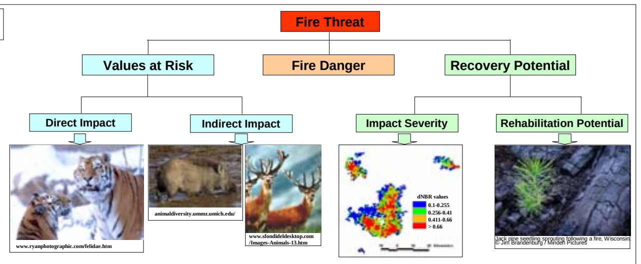
•outputs spatially explicit and temporally dynamic maps of fire threat

• designed for resource management.

• provides a framework for developing quantitative assessments of various parameters and their contribution to the overall potential impact of fire on a given resource

• designed to be used for operational resource monitoring

• provides the possibility for predictive assessment of fire threat and evaluation of potential resource management scenarios aimed at minimizing the fire threat



A reduced version of the FTM includes the major components: Fire Danger - the most generic (but regionally specific) component and Values at Risk and Recovery Potential - both highly region specific and resource specific.

Fire Danger Modeling from Remotely Sensed Data

Risk of Ignition Module (ROI)

• assessed from MODIS active fire product (Giglio et al, 2002) for 2001-2004 through Fire Spread Reconstruction approach (Loboda and Csiszar, in press)

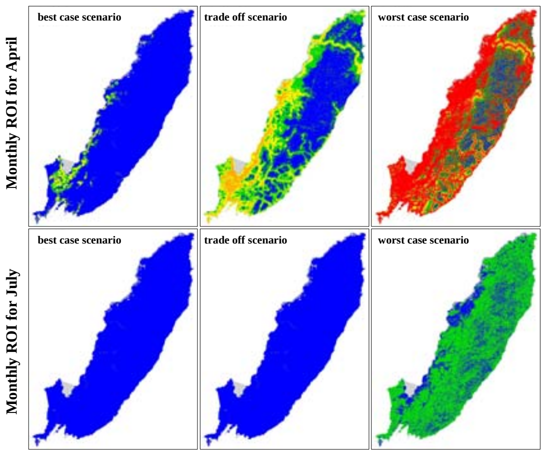
• modeled as a function of area's proximity to: 1) roads, 2) railroads, 3) settlements, 4)land use, and 5) as a function of slope gradient

• average ignition load (L) is calculated as $L_y = \left(\sum_{i=1}^{4} f_{zi} / \sum_{i=1}^{4} f_{ti}\right) / (A_z / A_t)$

f_{zi} is the number of ignitions within a given buffer zone in year i, f_{ti} is the total number of ignitions within the study area in year i, A_z is the area of the given buffer zone, and A_t is the total area of the study area

• L stretched between 0 and 1 to convert to fuzzy membership values

• ROI = (r_j, rr_j, s_j, t_j, lu_j), where r, rr, s, t, and lu represent roads, railroads, settlements, terrain and land cover/land use respectively for each j[th] point



• Datasets were aggregated using Ordered Weighted Averaging approach with fuzzification

• Aggregation produced:

- "best case" scenario (MIN) w=[1, 0, 0, 0, 0]
- "worst case" scenario (MAX) w=[0, 0, 0, 0, 1]
- "trade-off" scenario (MEAN) w=[0.2,0.2,0.2,0.2,0.2]

(Loboda and Csiszar, submitted)

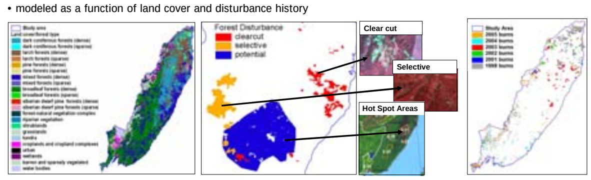
Risk of Ignition :

- very low
- low
- moderate
- high
- very high

Potential Fire behavior Module (PFB)

• assessed from MODIS regional burned area product (Loboda et al, submitted) for 2001-2005

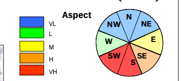
• modeled as a function of land cover and disturbance history



Land cover map was produced from MODIS Land Cover product (MOD12Q1), Land Cover Map of Russia and Russia's Forests

Forest Disturbance map was produced through merging manually outlined visible areas of logging in the Landsat scenes with Maps of Hotspot Areas of Forest Change

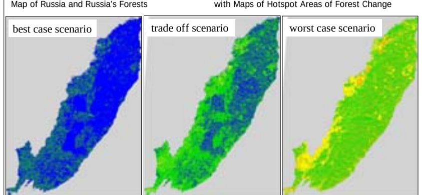
Yearly maps of fire disturbance were produced from merged AVHRR (1998) and MODIS (2001-2005) burned areas



Slope %	0-10	11-30	31-50	51-70	71-100
Danger	VL	L	M	H	VH

	VL	L	M	H	VH
VL	VL	VL	L	M	M
L	VL	L	L	M	H
M	L	L	M	H	H
H	M	M	H	VH	VH
VH	M	H	H	VH	VH

Fire behavior as a function of slope and aspect generated from SRTM DEM was included in the analysis



• Potential Fire Behavior was assessed based on the methodology described for the Risk of ignition with appropriate modifications

• PFB = (lc_j, ld_j, fd_j, $terr_j$) where lc, ld, fd, and terr are ladn cover, logging disturbance, fire disturbance, and terrain respectively for each j[th] pixel

• Potential Fire behavior was evaluated for 3 seasons

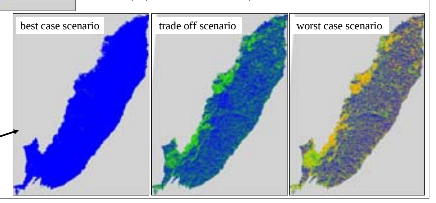
- early (January – May)
- mid (June - August)
- late (September – December)

Potential Fire Behavior

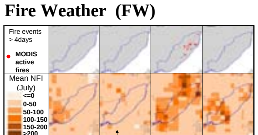
- very low spread
- low spread
- moderate spread
- high spread
- very high spread

Above: scenarios of potential fire behavior during early season

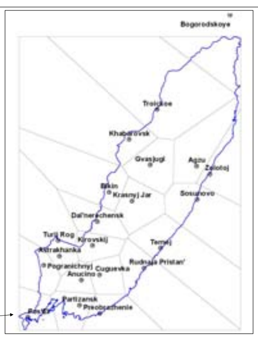
Right: scenarios of potential fire behavior during late season



Fire Weather (FW)



Maps of mean monthly NFI (Nesterov Fire Index) derived from Reanalysis 1 (T and RH) and GPCP (precipitation) data for July 2001-2004 show the correspondence between unusually high NFI values and an increase in large fire occurrence in the RFE.



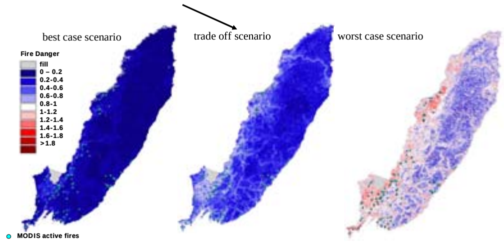
For operational assessment of fire danger in the RFE weather daily records of maximum temperature, dew point, and precipitation were obtained from 21 weather stations in the region (<wunderground.com>) The NFI values were calculated for each station and gridded through the proximity function. Fire Weather danger is low for NFI < 300, moderate for 300<=NFI<1000, high for 1000<= NFI<4000, and extreme for NFI >= 4000. NFI was stretched between 0 and 1 using (NFI * 0.7) for NFI < 1000, and (NFI * 0.07) for NFI >= 1000

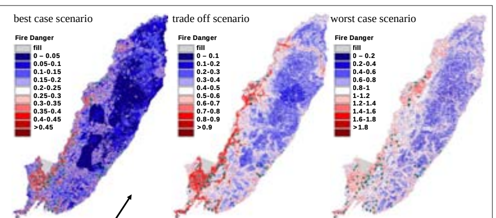
Daily Fire Danger Estimates for May 2006

• Fire danger (FD) levels were calculated for May 2006 using equation FD = SUM(ROI, PFB, FW), where ROI is the risk of ignition, PFB – potential fire behavior, and FW – fire weather in fuzzy membership values

• Projected fire danger levels were compared with daily MODIS fire detections for May 2006

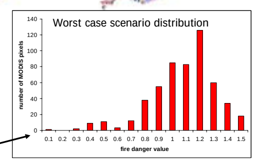
• 3 scenarios of fire danger levels for May 16[th] (day with the largest number (226) of fire detections in May) show considerable difference in fire danger levels (below)





• Notwithstanding the difference in the absolute levels of fire danger estimated by 3 scenarios MODIS fire detections are found within areas of comparatively higher fire danger levels for all scenarios (left and above)

• The analysis of frequency distribution of MODIS fire detections during May 16 – May 26 shows that the majority of fire detections are found within areas where fire danger is estimated to be greater than 0.8 (right)



Conclusions

• Elements of Fire Danger modeling can be evaluated from the remotely sensed data. Remotely sensed data sources provided an opportunity to develop a consistent approach to evaluating factors influencing fire danger in the Russian Far East at the regional level.

• Unavailability of high resolution daily weather data for the entire study area presents a major limitation to the operational application of the model. Additionally, the interpolation of weather station observations over the area of complex terrain introduces a considerable uncertainty in fire danger prediction.

• All three scenarios are found to output meaningful scenarios of fire danger. However, proper assignment of danger levels is necessary for each scenario.

• Fire occurrence in the Russian Far East recorded by the MODIS active fire product in May 2006 coincides with areas of higher fire danger levels estimated through the Fire Danger module of the FTM

• Longer-term analysis of fire occurrence and fire danger modeling is necessary to provide conclusive evaluation of the model's outputs.

Future Work

• Further comparison of MODIS fire detections with the projected fire danger levels for 2006 will provide a more solid basis for evaluation of model outputs and fine tuning model parameterization

• Multi- temporal analysis of fire danger levels from various scenarios will be used to select the most appropriate model aggregation approach.

• Other approaches based on varying weights of input parameters will be evaluated on 2006 fire data

• The fine-tuned model will be tested in its predictive capability to provide output parameters of fire danger for 2007 fire season.

• Field campaign aimed at the validation of burned area product and assessment of impact severity and rehabilitation potential in the Russian Far East will take place in September 2006.

• Historic assessment and operation forecasting of Fire Threat to the Amur tiger will be completed by 2007.

• Additionally, scenarios of potential future changes in Fire Threat to the Amur tiger driven by climate and land use change will be evaluated.

Acknowledgements and References

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