

Fires, Management, and Land Mosaic Interactions: A Generic Spatial Model and Toolkit from Stand to Landscape Scales

-- Final report to the Joint Fire Science Program --

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Project Location: Wisconsin, Michigan, California, Arizona, South Carolina, Missouri, and Oregon

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Summary of Project: We developed a spatially explicit, PC Windows-based generic model accompanied by computer visualizations of forest stands and landscapes that allow land managers to examine the interaction of fire and management practices on current and future conditions in real landscapes. The computer model can be used to: (1) assess the fuel loading and fire risk, (2) visualize the stand dynamics, fuel accumulation, and fire spread, and (3) develop strategies for reducing the risk of fire under a variety of climates, fire disturbances, and management scenarios. The model will be applied and demonstrated in seven landscapes (see list of project locations) with varied climates, landforms, and vegetation. Annual net primary productivity and fuel loading is estimated using the PnET model. Outputs from PnET provide potential inputs for modeling fire spread/behavior using FARSITE (a two-dimensional model of fire growth including both surface and crown fire spread) as a function of spatial distribution of fuel types, climate (affecting soil moisture and fuel moisture), and topography. For each landscape, topographic features are generated from digital elevations models, and land cover, vegetation/fuel types are developed from satellite data or existing GIS layers. Outputs from the FARSITE model are in the form of images. A prototype has been developed and tested first on the Chequamegon National Forest in northern Wisconsin.

Achievements: The major achievements for the project up to date include: 1) archives of empirical, simulated, and analytical datasets for the 7 proposed study landscapes across the U.S. and continuing improvement of the project's web page; 2) applications of FARSITE model in a real landscape (e.g., Chequamegon National Forest, WI) combined with other models such as FRAGSTATS (a spatial pattern analysis program designed to quantify landscape structure at various scales), HARVEST (a timber harvest simulator designed to evaluate alternative strategies of forest management), and LandNEP (NPP and fuel loading estimates) to examine the relationships between fire spread and behavior and landscape characteristics and timber management scenarios; 3) the window interface of PnET model related to fuel loading study; 4) new publications, manuscripts, and presentations on professional journals and at national meetings; 5) enhancement of applications of animations and 3-D visualization in assisting managers to achieve better fire management strategies; and 6) organization of workshops and CD distributions to promote close collaborations, information exchanges, and feedback between researchers and managers. This project has also produced international influences as the Korean Forest Service, Fudan University,

Chinese Academy of Science, and IUFRO Congress (Australia) invited the PIs of this project for seminars. In addition to the following products produced by this project, this project has provided educational experience for many students and junior scientists. These include two postdoctoral research associates, three graduate students, and five undergraduate students (Justin Yoon, Inmo Kim, Dong Mei, Amber Hewitt & Rachel Henderson).

Publications (7)

Bresee, M., J. Le Moine, S. Mather, K. Brosofske, J. Chen, T.R. Crow, and J. Radmacher. 2004. Disturbance and landscape dynamics in the Chequamegon National Forest Wisconsin, USA, from 1972 to 2001. *Landscape Ecology* 19: 291-309.

Chen, J., K.D. Brosofske, A. Noormets, T.R. Crow, M.K. Bresee, J.M. Le Moine, E.S. Euskirchen, S.V. Mather, and D. Zheng, 2004. A Working Framework for Quantifying Carbon Sequestration in Disturbed Land Mosaics. *Environmental Management* 33: S210-221.

Cleland, D.T., T.R. Crow, S.C. Saunders and others. 2004. Characterizing historical and modern fire regimes in Michigan (USA): A landscape ecosystem approach. *Landscape Ecology* 19: 311-325.

Crow, T.R. and A.H. Perera. 2004. Emulating natural landscape disturbance in forest management – an introduction. *Landscape Ecology* 19: 231-233.

Ryu, S., J. Chen, T.R. Crow, and S.C. Saunders. 2004. Available Fuel Dynamics in Nine Contrasting Forest Ecosystems in North America. *Environmental Management* 33: S87-107.

Zheng, D., J. Chen, A. Noormets, J. Le Moine, and E. Euskirchen. 2004. Effects of climate and land use on landscape soil respiration in northern Wisconsin, USA: 1972 to 2001. *Climate Research* (provisionally accepted).

Zheng, D., J. Radmacher, J. Chen, T. Crow, M. Bresee, J. Le Moine, and S-R Ryu. 2004. Estimating aboveground biomass using Landsat 7 ETM+ data across a managed landscape in northern Wisconsin, USA. *Remote Sensing of Environment* (in press).

Manuscripts submitted and in revision (4)

Saunders, S.C., M.R. Mislivets, D.T. Cleland, J. Chen, K.D. Brosofske. Predicting fires across ecological climatic units of the northern Great Lakes Regions, U.S.A. *Environmental Management*

Wang, X., B. Song, J. Chen, D. Zheng, and T.R. Crow, 2004. Visualizing forest landscapes using public data sources. *Landscape & Urban Planning*.

Song, B., Mladenoff, D.J., He, H.S., Radeloff, V.C., Zastrow, D.E., and Watkins, T.J. Forest visualization at multiple scales for management and planning. *Environmental Modelling & Software*.

Zheng, D., J. Chen, J. LeMoine, and E. Euskirchen. 2004. Effects of landscape composition, fragmentation and edges on soil respiration in a managed land mosaic. *Landscape Ecology*.

Manuscripts in process (6)

Concilio, A. S. Ma, Q. Li, J. LeMoine, J. Chen, M. North, D. Moorhead, and R. Jenson. Soil respiration response to experimental disturbance in mixed conifer and hardwood forests. *Canadian Journal of Forest Research* (submitted).

LaCroix, J.J., S. Ryu, D. Zheng and J. Chen. 2004. Effects of landscape management and climate on fire spread. *International Journal of Wild land Fire*. (manuscript completed)

Ryu, S., J.Chen, J.A. Rademacher, D. Zheng, and T.R. Crow. 2004. Estimating fuel loading under various disturbance regimes and ecosystem types in Northern Wisconsin forest landscape. *Ecological Modelling* (manuscript completed)

Wang, X., B. Song, J. Chen, D. Zheng, and T. R. Crow. 2004. Challenges of visualizing forests and landscapes. *Journal of Forestry*

Wang, X., J. LaCroix, B. Song, J. Chen, and T. R. Crow. 2004. 3D-visualization of fire dynamics in Chequamegon National Forest, USA.

Zheng, D., J. LaCroix, S-R. Ryu, J. Chen, and T.R. Crow. 2004. Complex effects of landscape mosaics, management, and fuel type on fire spread in northern Wisconsin, USA. *Canadian J. of Forest Research*. (manuscript completed)

Presentations (23)

Chen, J. 2005. Alternative landscape management: can optimal outcomes be achieved? An invited seminar to the 2005 IUFRO Congress, Brisbane, Australia. August 2005.

Chen, J. 2004. Linking fires to landscape hierarchies. Invited Speaker. The IUFRO International Workshop, Tsukuba, Ibaraki, Japan. October

Chen, J., B. Song, T.R. Crow, D. Zheng, X. Wang, J. LaCroix, S-R. Ryu. 2004. Fires, management, and land mosaic interactions: A generic spatial model and toolkit from stand to landscape scales. JFSP annual workshop, April 11-14, Arizona, USA.

Chen, J. 2004. Fires, ecology, modeling and visualization. Fudan University, P.R. China (7/30/04)

Chen, J. 2004. Ecology and management of forested landscapes. Ohio University, Athens, OH. (3/4/04).

LaCroix, J. J., S. Ryu, D. Zheng and J. Chen. 2004. Model Applications: management and climate affect fire spread. Workshop of the Joint Fire Science Program, August 23rd, Rhinelander, WI. with links to web presentations:

http://research.eeescience.utoledo.edu/lees/research/jfsp/spotlight/CNFFARSITE_files/frame.htm

<http://research.eeescience.utoledo.edu/lees/research/jfsp/spotlight/FARSITE&HARVEST.ppt>

Ryu. S., J. Chen, and A. Noormets. 2004. Comparisons of modeled (PnET-Day) & Measured GEE in Managed Forest Ecosystems in Northern Wisconsin. The 7th annual meeting of the Chequamegon Ecosystem-Atmosphere Study. Jun 23-25, St. Paul, Minnesota.

Ryu, S., A. Concilio, J. Chen, D. Neher, S. Ma, and M. North. 2004. Effects of experimental burning and thinning on soil respiration and belowground characteristics. The Ecological Society of America 89th Annual Meeting, Aug. 1-6, Portland, Oregon, p. 444 (abstract).

Ryu, S-S, D. Zheng, J.J. LaCroix, J. Chen, and T.R. Crow. 2004. Possibility of model application to the forest fire management: using LandNEP and PnET models. Workshop of the Joint Fire Science Program, August 23rd, Rhinelander, WI.

Zheng, D., J. LaCroix, S-R Ryu, J. Chen, and T.R. Crow. 2004. Examining effects of landscape mosaics, fuel type, and management on fire spread and behavior in northern Wisconsin, USA using modeling approach. USDA, JFSP Workshop, August 23, Rhinelander, WI, USA.

Song, B., X. Wang, J. Cheng, T.R. Crow, D. Zheng, and E. Gustafson. 2004. 3-D visualization of forest landscape with fire and other disturbances. Workshop of the Joint Fire Science Program, August 23rd, Rhinelander, WI.

Chen, J. Fires, management, and ecosystem processes. Korean Forest Service, Seoul, S. Korea, Sept. 2, 2003.

Ryu, S., A. Noormets, J. Chen, T.R. Crow, 2003. Comparisons of modeled (PnET-Day) and measured carbon exchange in managed forest ecosystems in Northern Wisconsin. Annual Ameriflux Meeting, October 14-16, Boulder, Colorado, USA.

Song, B. 2003. Presentation to Forest service supervisors, managers, foresters of Francis Marion and Sumter National Forest, introducing the fire effects on forest landscape. Columbia, South Carolina.

Song, B., Xianli Wang, Eric Gustafson, P. Zollner. 2003. 3-D Visualization of Landscape Dynamics with Different Management Alternatives. 30th International symposium on remote sensing of environment, November 10-14.

Wang, X., and B. Song. 2003. Forest dynamics visualization using models. The 88th ESA Annual Meeting, Savannah, SC. P348.

Zheng, D., J. Chen, J.M. LeMoine, and E.S. Euskirchen. 2003. Fragmentation and edge effects on landscape-level soil respiration in a managed land mosaic in N. Wisconsin. The 4th North American Forest Ecosystem Workshop, June 16-20, Corvallis, OR, USA.

Ryu, S., J. Chen, T.R. Crow, and S.C. Saunders. 2002. Effects of Tree Mortality, Fire and Harvesting on Available Fuel in US Forests. USDA Symposium on Natural Resource Management to Offset Greenhouse Gas Emissions. Raleigh, NC, Nov.18-22, 2002.

Ryu, S., J. Chen, T.R. Crow, B. Song, S.C. Saunders, and D.T. Cleland. 2002. Simulating fuel loading of different forest ecosystems. The IUFRO Landscape Ecology Working Party, Ontario, Canada.

Ryu, S., J. Chen, T.R. Crow, S.C. Saunders, B. Song, D.T. Cleland, and M.F. Jurgensen. 2002. The interaction of climate, productivity, and decay rate on fuel loading in USA forests. The 87th ESA Annual Meeting, Tucson, AZ, P419.

Web pages: Project WebPage was developed on the server of Landscape Ecology and Ecosystem Science (LEES) Lab at http://research.eescience.utoledo.edu/lees/research/jfsp/index_files/slide0001.htm, which include latest results and animations from the FARSITE model simulations over a 27-day period in Chequamegon National Forest, WI., more complete datasets for the 7 sites across the country, and new animations based on FARSITE simulations to assist land managers to evaluate fire effects across the landscapes through 3-dimensional visualization.

A web-based, interactive PnET model was developed and posted

(http://research.eeescience.utoledo.edu/lees/research/jfsp/model/pnet/pnet_step1.asp). This interactive toolkit was designed to allow user to use flexible data inputs and remotely run via Internet. One can run PnET simulations on the web without installing the program in local computer to estimate NPP and NEP of an ecosystem. In the future, we are in a process of posting our fuel-loading model (Ryu et al.). By establishing this web page, we anticipate a close communication between researchers and land managers (i.e., technology transfer). The web site is currently available for internal login (i.e., need a password) but will soon be open to any stakeholders prior to our Workshop between Nov. 17 and 19, 2004.

Workshops for technology transfer:

- Project coordination and group discussion. May 6, 2003, Escanaba, MI.
- Modeling and Visualization on fire managements: case study in Chequamegon-Nicolet National Forest. August 23, 2004, Rhinelander, WI

Animations on CDs and Web:

- Using satellite image sequences to animate the landscape transformations in the Chequamegon-Nicolet National Forest from 1972 to 2001;
- 3-D visualization of Francis Marion national forest with VNS2 (Visual Nature Studio 2);
- Visualizing partial Chequamegon National Forests with VNS2;
- Visualizations of forest growth using FIA data and FVS model;
- Visualizations of forest fire and its dynamics;
- Create tree images libraries, including burned tree images.

Deliverable CDs

- Presentations in the JFSP workshop on August 23, 2004, Rhinelander, WI regarding applications of modeling (from the University of Toledo group) and visualizations (from the Clemson University group) on fire disturbances and a readme file;
- 3-D Visualization of Forest Landscape with Fire and Other Disturbances;
- Five publications in PDF format.

Other Products to be completed

- Simulations of fire spread/behavior in Southeastern Missouri Ozarks and Coastal South Carolina using FARSITE. The land-cover map of 2003 for Ozarks has been developed using Landsat 7 ETM+ image). A classified land cover map for the SC landscape was received from Francis National Forest. We are developing the fuel loading maps through collaborations with Dr. Carl Trettin of USDA Forest Service. Dr. Trettin is one the collaborators of this study.
- Three manuscripts, LaCroix et al., Ryu et al., and Zheng et al. will be submitted in October 2004.
- Two workshops have been scheduled to demonstrate the uses of our products to land managers and general public. They are:
 - 1) Bridge fire sciences and management, November 17-19, 2004, Charleston, SC;
 - 2) Tools for managing and understanding fires in forest landscapes, February 2005, Davis, CA.

Issues and future research direction: Although substantial progress has been made in collecting and organizing data, customerizations of PnET, LandNEP, and FARSITE models, significant amount of additional research is needed. Aids from other models seem necessary but such linkages and integrations

take extra time. We found out that running FARSITE is very time consuming because some parameters for the current version requires manual input to define the specific conditions for each run, suggesting a high demanding for staff time. For example, we pursued 540 runs of FARSITE for the Wisconsin landscape for different combinations of weather conditions and management alternatives, it took to high speed PCs to run about 4 weeks to complete these simulations. Furthermore, computer visualization based on the simulated results can offer exciting new and more efficient tool for managers to consider more-close-to-reality alternative management strategies, but it can only be done with simulated results of other ecosystem models.

Future research needs:

- 1) Sensitivity analysis for fuel type assignment because it can affect FARSITE model results significantly for any landscapes;
- 2) Detecting seasonal variability in fire spread/behavior across the landscapes in different fire regimes;
- 3) Applications of the model on landscapes with differences in vegetation type and structure, topographic contrast, and land use history, such as Missouri Ozark Forests and Francis Marion National Forest in SC to improve our current understanding of fire cause-effect relationship across landscapes. Inter-comparison of model simulation results among different fire regimes will enhance our knowledge on ecological consequences of fires and provide scientific basis for making better fire management strategies at regional level.
- 4) Develop simulation scenarios and modifications of our toolkit jointly with managers. This can be accomplished by including managers to our research team and by conducting additional user workshops.
- 5) Continue to streamline the PC Windows-based generic model to make it a practical yet robust tool for resource managers and planners.
- 6) The linkages between the database and visualizations need to be more emphasized in the future.
- 7) For easier to use of the 3-D visualization tool, the further simplification of the visualization procedure will be another focus of our research.