2009 BFRL Project Description

Project Title: Measuring the Fire Resilience of Wildland-Urban Interface Economies at the Community-Scale

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BFRL Program: Reduced Risk of Fire Spread in Wildland-Urban Interface Communities

Objective: To develop a decision support tool to evaluate the economics of homeowner fire mitigation on community disaster resilience.

Problem:

What is the problem? Advancements in measurement science are needed to assist wildland-urban interface (WUI) communities in (1) evaluating wildfire risks and vulnerabilities, (2) determining cost-effective strategies to mitigate economic losses, and (3) understanding incentives to encourage community-optimal levels of mitigation investments. WUI communities are increasing in numbers of new residents from more urbanized, low wildfire risk areas.[1] It is not surprising, then, that many new residents are unaware of the elevated risk[2,3] from living within forested landscapes,[4,5] and how their actions influence it. Because the actions taken by homeowners can affect the fire risk of those around them,[6] barriers (imperfect information and externalities) exist that expose homeowners to inefficiently high levels of risk. Increasingly, programs, such as Firewise,[7] are providing information to homeowners on fire dangers and ways to reduce them. While these programs provide an important first step in ensuring community

[1] Stewart, S. et al. 2005. Mapping the Wildland Urban Interface and Projecting Its Growth to 2030. Available at www.silvis.forest.wisc.edu/Library/Stats/uswuistats.pdf. Last accessed 05/12/2008.
[2] For instance, see Brenkert-Smith, H., P.A. Champ, and N. Flores. 2006. Insights Into Wildfire Mitigation Decisions Among Wildland-Urban Interface Residents. Society and Natural Resources 19:759-768.
[3] White House. 2003. Healthy Forests An Initiative for Wildfire Prevention and Stronger Communities. Available online at http://www.whitehouse.gov/infocus/healthyforests/Healthy_Forests_v2.pdf. Last accessed 05/12/2008.
[4] Bradshaw, W.G. 1987. The Urban/Wildland Interface Fire Problem. Can Social Science Play a Role? In: Gole, R.D., Cortner, J.J. (Eds.), People and Fire at the Wildland/Urban Interface (A Source Book). USDA Forest Service, Washington, D.C. as cited in Reams, M.A., et al. 2005. Goals, Obstacles and Effective Strategies of Wildfire Mitigation Programs in the Wildland-Urban Interface. Forest Policy and Management 7:818-826.
[5] Loeher, L.L. 1985. Fire Hazard: The Dimension of Resident's Attitude: 51-55. In: Radtke, K. (Ed.), Conference Proceedings Living in the Chaparral of Southern California as cited in Reams, M.A., et al. 2005. Goals, Obstacles and Effective Strategies of Wildfire Mitigation Programs in the Wildland-Urban Interface. Forest Policy and Management 7:818-826.
[6] Butry, D.T. and G.H. Donovan. 2008. "Protect Thy Neighbor: Investigating the Spatial Externalities of Community Wildfire Hazard Mitigation." *Forest Science* 54(4): 417-428.
[7] FIREWISE Community Program. 2008. www.firewise.org. Last accessed 05/12/2008.

resilience to wildland fire hazards, they place little emphasis, if any at all, on their cost-effectiveness. Economics suggests that self-sustaining levels of mitigation will occur if homeowners understand and financially incur the actual benefits and costs associated with their investment decisions.

Why is it hard to solve? The problem is hard to solve because the solution requires advancements in measurement science. Advancements are required to understand how homeowner risk affects the risk of neighbors, and how this interdependence influences community-centric mitigation investment decisions. Moving beyond a theoretical (economic) model of interdependent risk to produce an applied tool for community use, advancements in fire behavior modeling are also required.[8] Determining the economically optimal level of homeowner risk, from a community perspective, requires an understanding of wildland-to-structure and structure-to-structure fire transmissions during typical wildland fire weather events (i.e., hot, dry, and windy weather). Current wildland models of fire spread prove inadequate as they ignore the complexities of dense, heterogeneous fuels usually found in WUI developments.

How is it solved today, and by whom? It has not been solved. Significant progress has been achieved, however. In FY2007, in collaboration with the U.S. Forest Service, an economic model (theoretical) of community-based mitigation was developed (the first of its kind). This research demonstrated that interdependent fire risk significantly affects economic solutions.[6] In FY2008, this research was advanced by developing an incentive structure to induce community-optimal levels of mitigation by homeowners,[9] and to understand the factors that influence wildfire losses.[10] Also in FY2007 and FY2008, a GIS data library was assembled. The GIS library includes components of the data required, as inputs, to run fire spread models (e.g., LANDFIRE fuel models). Substantial effort still remains to transform the theoretical economic models into an applied tool, integrated with WUI-based fire spread models.

Why NIST? NIST is leading the Nation in the advancement of measurement science to evaluate the disaster resilience of the built environment and the cost-effectiveness of community-scale mitigation. This research is aligned with BFRL's *Fire protection and fire spread within buildings and communities* core competency, and with the *Measurement Science for Innovative Fire Protection* strategic priority, as this research will develop a decision support tool to assess homeowner fire risk, and the economics of mitigation, for WUI communities. By informing homeowners of their wildland fire risk, and of their risk interdependency across communities, greater investment into mitigation will occur, thus reducing the risk of fire spread and limiting fire-related economic damages.

Approach:

What is the new technical idea? The new technical idea is to integrate economic models of interdependent fire risk with the emerging models of WUI-fire risk and spread (e.g., the

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[8] Advancements in measurement science related to fire behavior are not the focus of this proposed study. However, they are the focus of other projects in the BFRL program *Reduced Risk of Fire Spread in Wildland-Urban Interface Communities*. Integrating research across these areas is key in ensuring meaningful community-based tools.
[9] Butry, D.T. and G.H. Donovan. 2008. "Identifying Optimal Incentive Strategies to Encourage Wildfire-Risk Mitigation in the WUI." *White Paper*.
[10] Thomas, D.S., D.T. Butry, and J.P. Prestemon. 2008. "Do Broken Windows Invite Arson?" *White Paper*.

Wildland-Urban Interface Fire Dynamic Simulator [WFDS] or similar). Integration will be accomplished within a geographic information system (GIS) environment—specifically as a ArcGIS add-on tool. Because a large number of GIS users exist within the fire protection and research community, building new tools within a GIS environment will facilitate their adoption and use. Conceptually, a GIS will be developed to work as an interface to pass geographic (spatial) information (e.g., LANDFIRE fuel maps, housing maps) to WFDS (or similar fire model) in which to produce predictions of fire spread within a community. This information will be used by an economic solver module that will determine the cost-effective levels of mitigation intensity, and associated spatial pattern, for houses within the WUI. Finally, a GIS spatial data layer will be produced, mapping the cost-effective locations of mitigation. This will provide communities with the ability to cost-effectively target mitigation. It can also be used to determine the effect that exogenous changes in fire risk (e.g., due to a change in forest management in a nearby wildland) has on expected community losses given fire.

Why can we succeed now? Previous research[6,9] has already demonstrated the proof of concept. Integration requires GIS software and vast computing power, which has only recently become commercially available for use in tool design and development. The relatively new GIS technologies have received broad acceptance and have been used to address fire issues. BFRL is unique in that it contains the required personnel to develop such a decision support tool. Besides staff working in the areas of WUI fire spread and WUI economics, BFRL has personnel capable of producing GIS-based software. It is this unique combination of talents that will ensure the seamless integration of economics and fire behavior research into a user-friendly, decision support tool for communities.

What is the research plan? The research plan is to develop a community-based decision support tool to evaluate the impact homeowner fire mitigation has on community disaster resilience. The research plan is multi-phased (multi-year) and modular. The culmination of the research plan is to integrate an economic module with emerging fire behavior work (being developed separately) into a single decision support tool, operated within a GIS, for WUI community use in planning for and preparing against wildland fire threats. The research plan is composed of six major tasks: (1) to operationalize the theoretical model of community-based mitigation investment; (2) to design and develop a GIS graphical user interface (GUI); (3) to develop a simulation procedure to generate estimates of homeowner ignition probabilities and fire exposure (attack) probabilities from the model of fire spread; (4) to integrate the model of fire spread with the economic model into a decision support tool; (5) to extensively test the draft and final versions of the tool; and (6) to publish a User's Manual and deploy the decision support tool. Tasks 1-4 will be completed annually in a sequential order.

The theoretical model of optimal community mitigation investment will be operationalized into an economic module to receive inputs from the fire spread model and the GIS interface, and to determine, given a user-defined community budget constraint, the optimal level of mitigation for each house within the WUI. The economic module will require information on the probability of ignition (house ignitibility), probability of fire exposure (attack), values at risk, and available mitigation technologies and their costs. The probability of ignition and probability of fire exposure will be generated from the fire spread model, while the other inputs will be derived from GIS data layers. Fire spread probabilities will be generated over a range of weather and

possible ignition locations using simulation methods. This will provide estimates of expected fire behavior, which is appropriate for community planning and preparation purposes. The GIS GUI will be designed using input from key stakeholders, and will be built within ArcGIS. Extensive testing will be conducted on each version (draft and final) of the software to ensure the results are accurate and consistent. Testing will also be conducted to ensure the GIS software is user-friendly and easily accessible. On the date of final release and deployment of the application, a User's Manual will also be released as a NIST publication and integrated into a Help function. The User's Manual will include a case-study illustration. The decision support tool and User's Manual will be WERB reviewed.

Recent Results: Recent results include four archival papers,[6,11,12,13] two white papers to be submitted to peer-reviewed journal outlets,[9,10] and four conference presentations.[14,15,16,17] A GIS library has been assembled, housing well over 160 GB of spatial data.

Outcome: Developed an economic model (theoretical) of community-based mitigation accounting for the spatial spillover of individual homeowner mitigation efforts.

Outcome: Built a GIS data library to facilitate WUI community wildland fire risk analysis.

Standards and Codes: An expected impact of this research is for standards organization, such as the NFPA committee on Forest and Rural Fire Protection, to implement the use of the economic decision support tool as a standard method facilitating community risk assessment and disaster planning.

Impact: For standards organization, such as the NFPA committee on Forest and Rural Fire Protection, to implement the use of the economic decision support tool as a standard method facilitating community risk assessment and disaster planning.

Impact: WUI communities adoption of cost-effective wildland fire mitigation strategies.

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[11] Butry, D.T. 2008. "Fighting Fire with Fire: Empirical Efficacy of Suppression and Fuels Management on Wildfire Behavior." *Environmental and Ecological Statistics*.

[12] Butry, D.T., M.L. Gumpertz, and M.G. Genton. 2008. "The Production of Large and Small Wildfires." In Holmes, T.P., J.P. Prestemon, and K.L. Abt (eds.), *Economics of Forest Disturbances: Wildfires, Storms, and Invasive Species*. Springer: Dordrecht, The Netherlands.

[13] Prestemon, J.P., and D.T. Butry. (In press). "Wildland Arson Management." In Holmes, T.P., J.P. Prestemon, and K.L. Abt (eds.), *Economics of Forest Disturbances: Wildfires, Storms, and Invasive Species*. Springer: Dordrecht, The Netherlands.

[14] Butry, D.T. and G.H. Donovan. "Identifying Optimal Incentive Strategies to Encourage Wildfire-Risk Mitigation in the WUI." Presented at the III International Symposium on Fire Economics, Planning, and Policy: Common Problems and Approaches, Carolina, Puerto Rico, April 2008.

[15] Butry, D.T. and G.H. Donovan. "Protect Thy Neighbor: Investigating the Spatial Externalities of Community Wildfire Hazard Mitigation." Presented at the International Association of Wildland Fire's Human Dimensions of Wildland Fire, Ft. Collins, CO, October 2007.

[16] Thomas, D.S., D.T. Butry, and J.P. Prestemon. "Do Broken Windows Invite Arson?" Presented at the III International Symposium on Fire Economics, Planning, and Policy: Common Problems and Approaches, Carolina, Puerto Rico, April 2008.

[17] Butry, D.T., S.K. Pattanayak, E.O. Sills, and D.E. Mercer. "Applying Program Evaluation Methods to Natural Resource Policy: Are Current Wildfire Mitigation Programs Effective?" Presented at the 2008 Environmental Evaluators Networking Forum, Washington, D.C., June 2008.