Agent-based Modeling of Future Wildfire Risk

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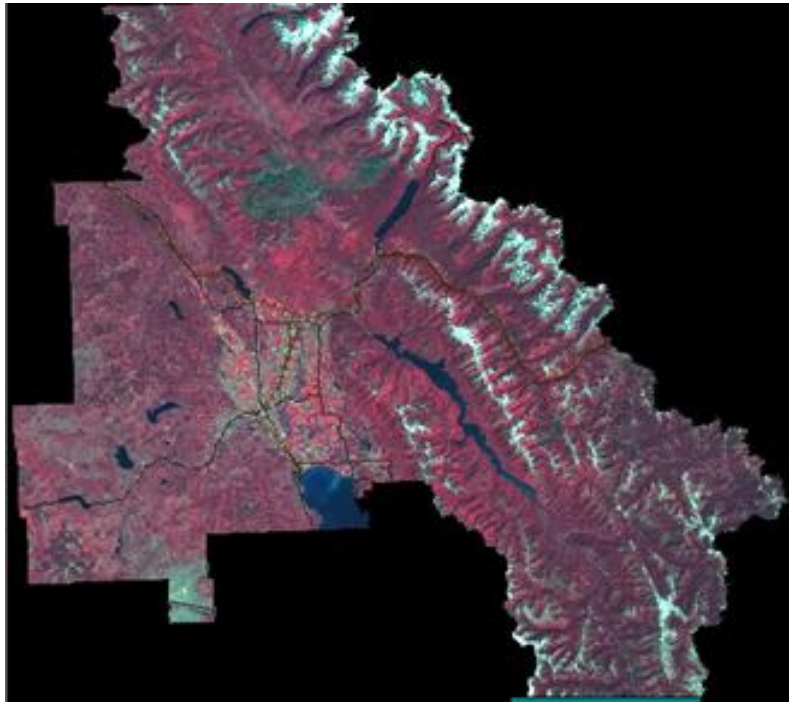
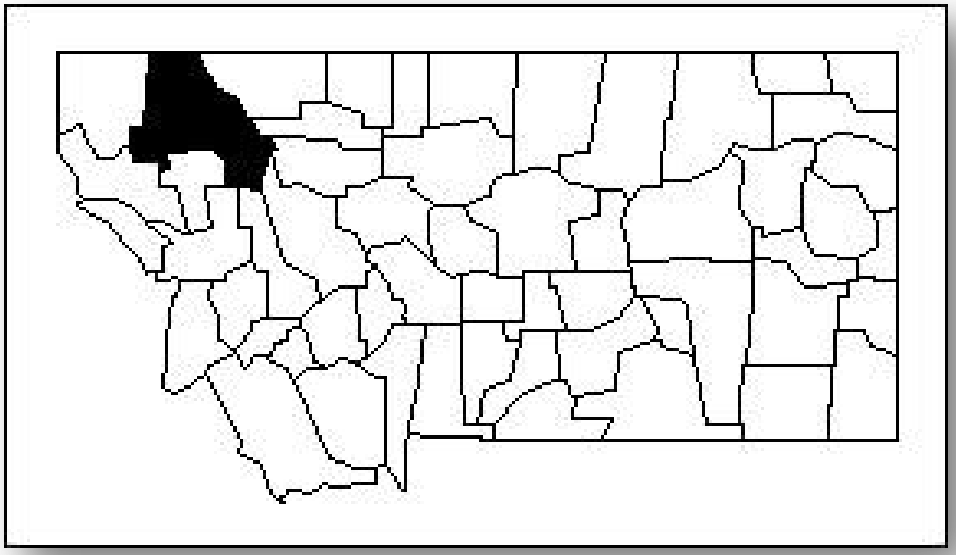
Objective of Presentation

- To describe an agent-based model (ABM) for evaluating the potential impacts of future residential development and climate change on wildfire risk in Flathead County, Montana.

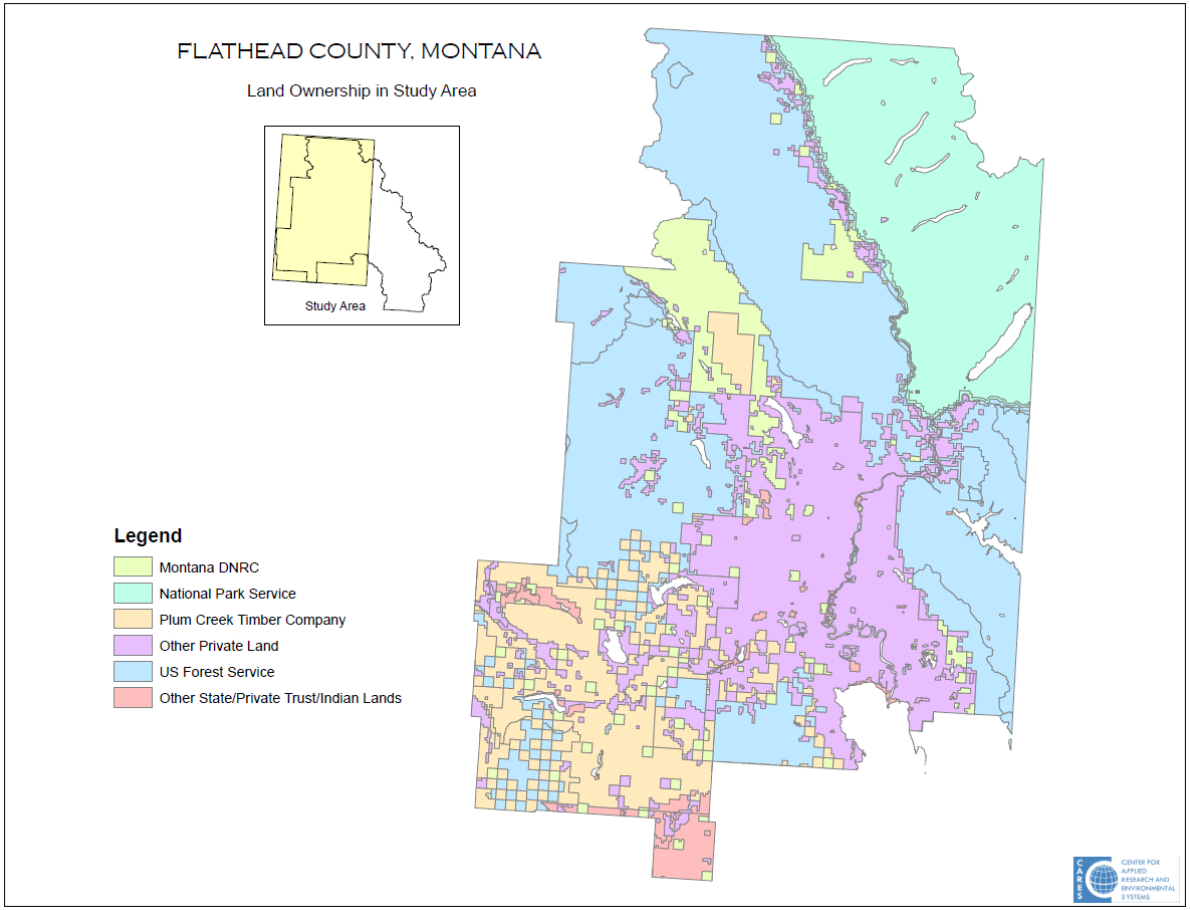
- Wildfire risk is defined as expected residential losses from wildfire in the wildland-urban interface (WUI).

Flathead County, Montana





Study Area

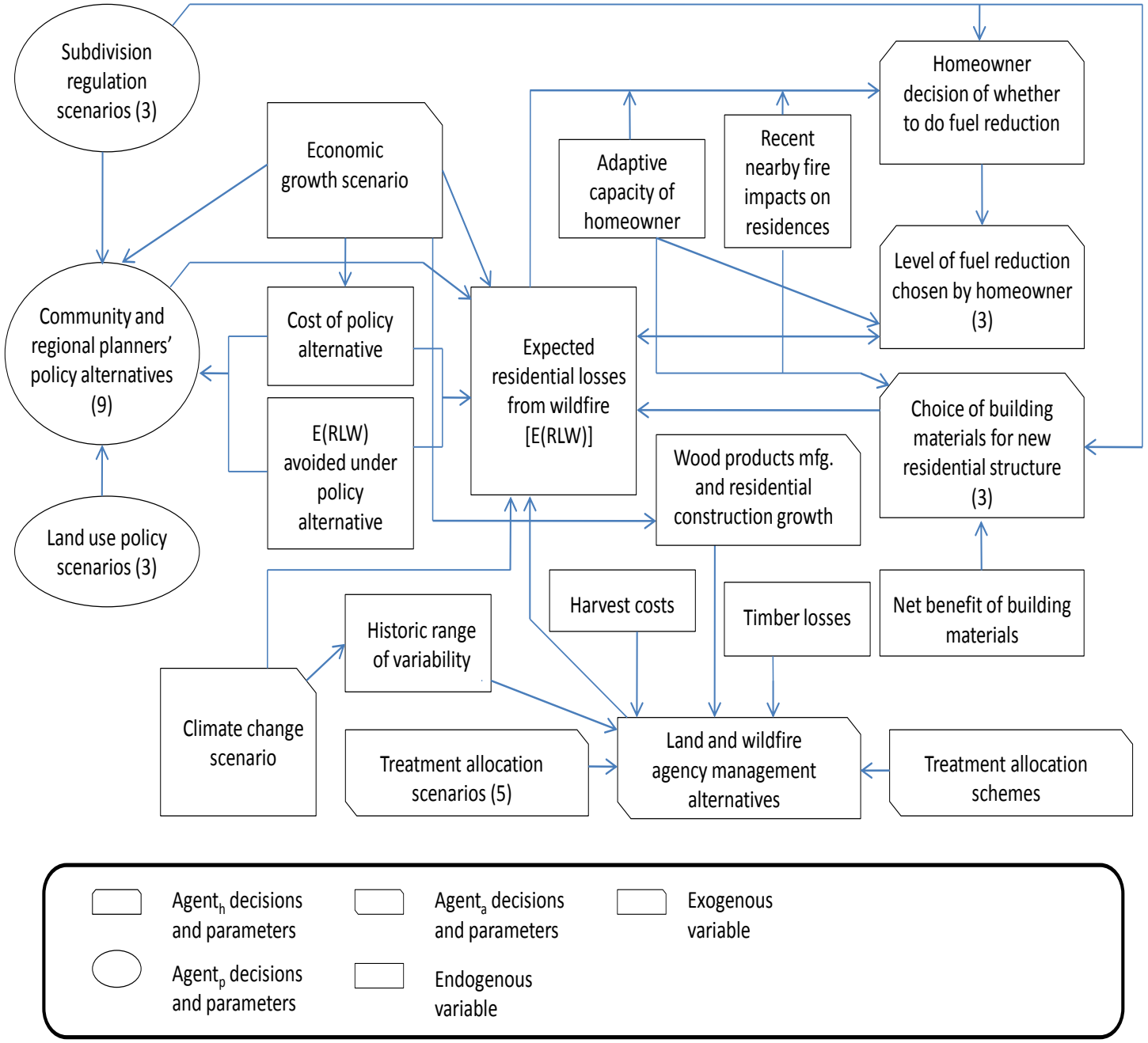


1.5 million acres

FIRECLIM ABM

- The ABM described here is part of the wildfire climate (FIRECLIM) model that is being used to:
  - simulate future wildfire risk in Flathead County under different assumptions about future residential development and climate change; and
  - demonstrate how communities in the study area can adaptively manage future wildfire risk.

- The FIRECLIM ABM has three agents:
  - Homeowners
  - Community and regional planners, and
  - Land and wildfire management agencies


Subdivision regulation scenarios (3)
Economic growth scenario
Adaptive capacity of homeowner
Recent nearby fire impacts on residences
Homeowner decision of whether to do fuel reduction
Level of fuel reduction chosen by homeowner (3)
Community and regional planners' policy alternatives (9)
Cost of policy alternative
E(RLW) avoided under policy alternative
Expected residential losses from wildfire [E(RLW)]
Choice of building materials for new residential structure (3)
Land use policy scenarios (3)
Wood products mfg. and residential construction growth
Harvest costs
Timber losses
Net benefit of building materials
Historic range of variability
Climate change scenario
Treatment allocation scenarios (5)
Land and wildfire agency management alternatives
Treatment allocation schemes
Agent$_h$ decisions and parameters
Agent$_a$ decisions and parameters
Exogenous variable
Agent$_p$ decisions and parameters
Endogenous variable

Description of FIRECLIM ABM

- This presentation gives a detailed description of the decision rules for homeowners and brief descriptions of the decision rules for community/regional planners and land and wildfire management agencies.

Homeowners' Decisions ($Agent_h$)

- Members of $Agent_h$ are individual homeowners that make three decisions:
  - whether to perform fuel reduction around residential structure(s) on their property;
  - the level of fuel reduction selected for their property given fuel reduction is performed; and
  - the roofing and exterior wall materials selected for new residential structures.

- These three decisions influence two conditional probabilities that in turn influence wildfire risk:
  - probability of structure losses from wildfire given a property burns; and
  - probability of wildfire-related loss in the aesthetic value of a property given the property burns.

First Decision

- A homeowner's decision of whether or not to perform fuel reduction on property i is determined based on the probability a homeowner performs fuel reduction on that property (i.e., p_i).

- Four variables influence p_i:
  - expected property losses from wildfire without fuel reduction;
  - homeowner's adaptive capacity to perform fuel reduction;
  - restrictiveness of WUI regulations chosen by community/regional planners; and
  - recent wildfire losses on nearby residential properties.

Rule for first decision:

- If $p_i \leq 0.5$, the homeowner does not perform fuel reduction on property i; or
- If $p_i > 0.5$, the homeowner performs fuel reduction on property i.

Second Decision

- The decision rule for the level of fuel reduction (i.e., full, heavy, light, or none) for a residential property utilizes a fuzzy Technique for Order Preference by Similarity of Ideal Solution (TOPSIS) method.

- TOPSIS is a variation of the ideal point method that ranks decision alternatives based on their closeness coefficients.

- A closeness coefficient measures how close the attributes of a fuel reduction treatment for a property are to the attributes of the fuzzy positive-ideal solution and how far away they are from the attributes of the fuzzy negative-ideal solution.

- The fuzzy positive-ideal solution has the most favorable and the fuzzy negative-ideal solution has the least favorable attributes.

Fuel reduction treatments are characterized using three attributes:

- expected residential losses from wildfire for the property;
- costs of treatments; and
- a contagion effect, which measures the extent to which higher levels of fuel reduction on one property increase fuel reduction on nearby properties.

Rule for second decision:

- The best fuel reduction treatment for a residential property is the one with the highest closeness coefficient.

Third Decision

- A homeowner's decision about building materials for residential structures is modeled in terms of the probability the homeowner for property i selects building materials in structure ignition class k, designated p_{ik}, where k = very high (vh), high (h), or low (l).

- The third decision is relevant only at the time residential structures are built.

- p_{ik} is influenced by five variables:
  - normalized expected marginal benefit of building materials for the high or very high structure ignition class relative to building materials for the low structure ignition class for property i;
  - normalized expected marginal cost of building materials for the high or very high structure ignition class relative to building materials for the low structure ignition class for property i;

- normalized adaptive capacity of the homeowner for property i to select building materials corresponding to structure ignition class k;
- normalized restrictiveness of WUI regulations pertaining to building materials for structures in ignition class k; and
- wildfire losses on nearby properties.

Rule for third decision:

- If $p_{ik} \leq 0.5$ for k = high or very high, the homeowner for property i selects building materials in the low structure ignition class;
- If $p_{ik} \leq 0.5$ and $p_{ik'} > 0.5$ for $k \neq k'$, the homeowner for property i selects building materials in structure ignition class k';
- If $p_{ik} > 0.5$, the homeowner for property i selects building materials in the high structure ignition class if $p_{ih} > p_{ivh}$ or the very high structure ignition class if $p_{ivh} > p_{ih}$.

Community-regional planners' decisions ($Agent_p$)

- Members of $Agent_p$ include local planning and zoning departments that have the authority to regulate residential and commercial development in the county.

- Members of $Agent_p$ make three kinds of policy decisions:
  - land use policies that influence the spatial characteristics of residential development (e.g., housing densities and setbacks of houses from water bodies);
  - minimum levels of fuel reduction around residential structures located in subdivisions; and
  - building materials used in residential structures located in subdivisions.

- Policy decisions influence the vulnerability of residential properties to wildfire losses.

Land and wildfire management agencies ($Agent_a$)

Members of $Agent_a$

- Flathead National Forest;
- Plum Creek Timber Company;
- Glacier National Park;
- Montana Department of Natural Resources and Conservation;
- Confederated Salish and Kootenai Tribes and other entities (i.e., county parks, Nature Conservancy); and
- Lands receiving state or regional funds for fuel reduction, lands managed by other logging companies, or residential properties managed by third party contractors.

- Each member of $Agent_a$ selects the best forest management alternative for the lands they own or manage.

- A forest management alternative specifies the number of acres in different forest treatments and the location of treated acres.

- A forest management alternative influences wildfire risk by modifying fuel loads, intensities of wildfires, and severity of wildfire losses on private land or timber losses from wildfires on public land.

Additional Information

- FIRECLIM ABM: Paveglio, T.B., and T. Prato. In press. Integrating dynamic social systems into assessments of future wildfire losses: An experiential agent-based modeling approach. In Dupont, H.C. (ed.), *Environmental Management: Systems, Sustainability and Current Issues*. Nova Science Publishers, Inc., Hauppauge, NY.

- FIRECLIM project: http://projects.cares.missouri.edu/fireclim-montana/