Economic evaluation of alternative wildfire management strategies

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Background

- Pressing need to consider potential short and long-term economic effects of alternative wildfire managment strategies
  - Fuel treatment benefits of wilderness wildfires
    - Parks et al. (2013); Haire et al. (2013); Teske et al (2012)
  - Tradeoffs in risk over space and time
    - Resources
    - Management costs (Houtman et al., 2013)
- Quantifying potential future outcomes challenging
  - Uncertainty in fire occurrence, behavior, fire effects
  - Costs and benefits of alternative strategies are not realized

Risk analysis

- Framework guiding fire and fuels management

$$E(NVC_j) = \sum_i p(f_i)RF_j(f_i)$$

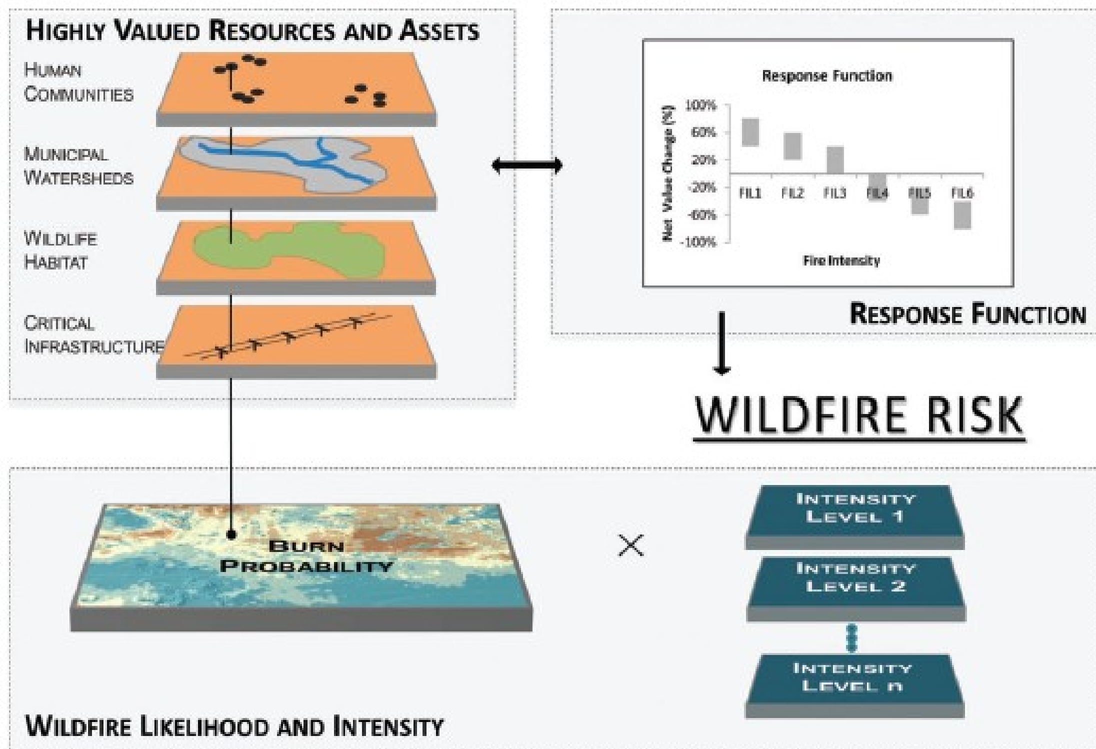
j = resource at risk

i = fire intensity level

RF = response function

p(f) = probability of fire

- Fuel treatments
  - Effectiveness
  - Prioritization
    - Mitigate/minimize risk
- Socio-economic analysis?



Scott et al. (2013) GTR-315

Integrate risk framework into cost-benefit analysis

- Cost plus net value change (C + NVC)
  - Cost: Initial suppression costs, future suppression costs
  - Net value change: Likelihood, response of resource values
    - Initial value change, future value change

$$Strategy_i = C_i + E(NVC)_i$$
$$Strategy_j = C_j + E(NVC)_j$$

- Estimate parameters in C + E(NVC)

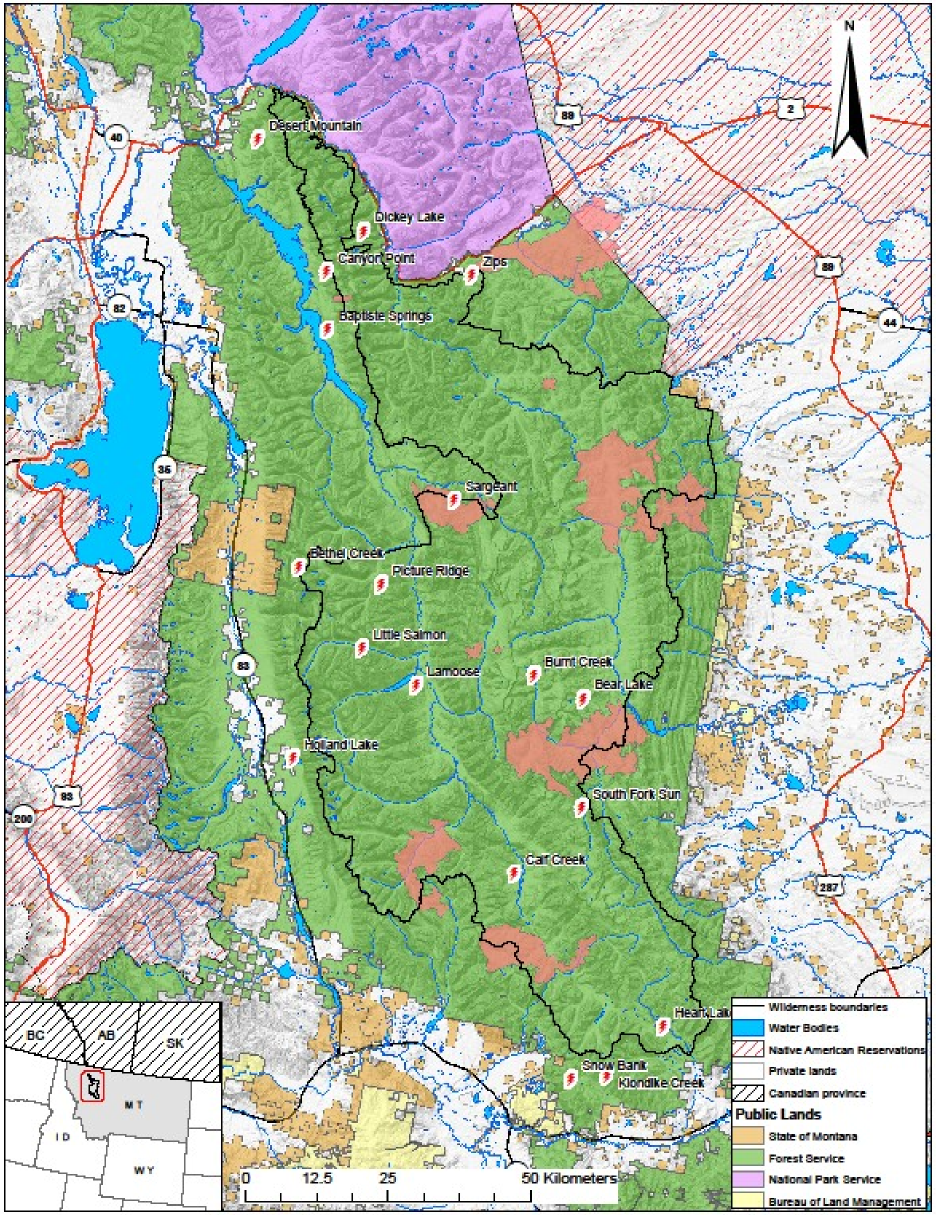
Objectives

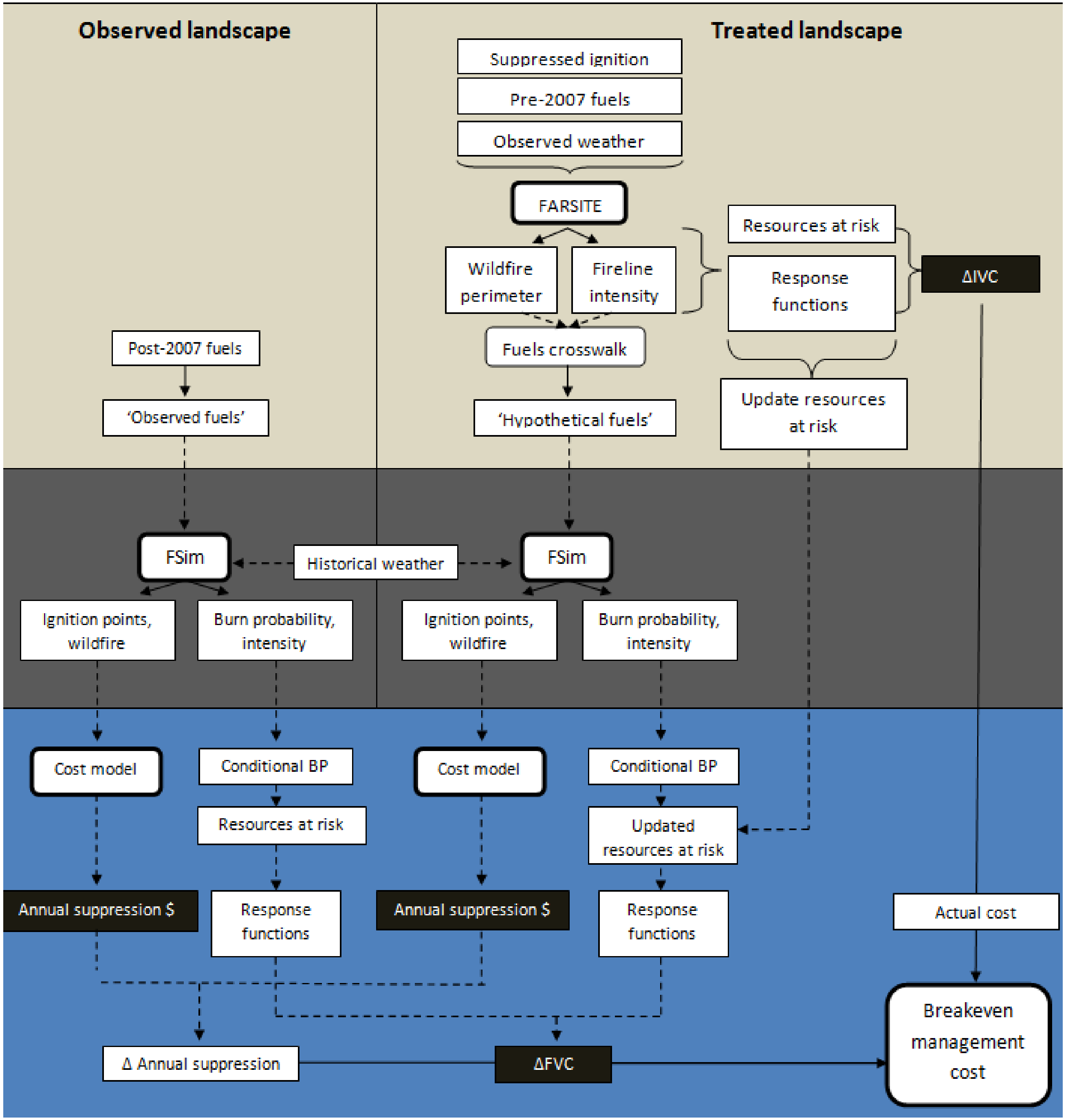
- Design a framework to quantify the C + E(NVC) between alternative wildfire management strategies using selected resources at risk
  - Suppression expenditures
  - Private structures
  - Commercial timber
  - Lynx habitat
- Apply framework to evaluate 'go/no-go' wildfire management strategies in Bob Marshall Wilderness Complex during 2007
  - Break-even management costs of alternative management strategies

Case study

- Bob Marshall Wilderness Complex
  - 625,000 hectares
  - Rich history of fire use

- Fire season of 2007
  - Active across northern Rockies
  - Aggressive implementation of Appropriate Management Response (AMR)
    - Full spectrum of response strategies
  - Numerous suppressed ignitions in BMWC




Observed landscape
Treated landscape
Suppressed ignition
Pre-2007 fuels
Observed weather
FARSITE
Resources at risk
Wildfire perimeter
Fireline intensity
Response functions
ΔIVC
Fuels crosswalk
Post-2007 fuels
'Observed fuels'
'Hypothetical fuels'
Update resources at risk
FSim
Historical weather
FSim
Ignition points, wildfire
Burn probability, intensity
Ignition points, wildfire
Burn probability, intensity
Cost model
Conditional BP
Cost model
Conditional BP
Resources at risk
Updated resources at risk
Annual suppression $
Response functions
Annual suppression $
Response functions
Actual cost
Breakeven management cost
Δ Annual suppression
ΔFVC

Developing landscape scenarios

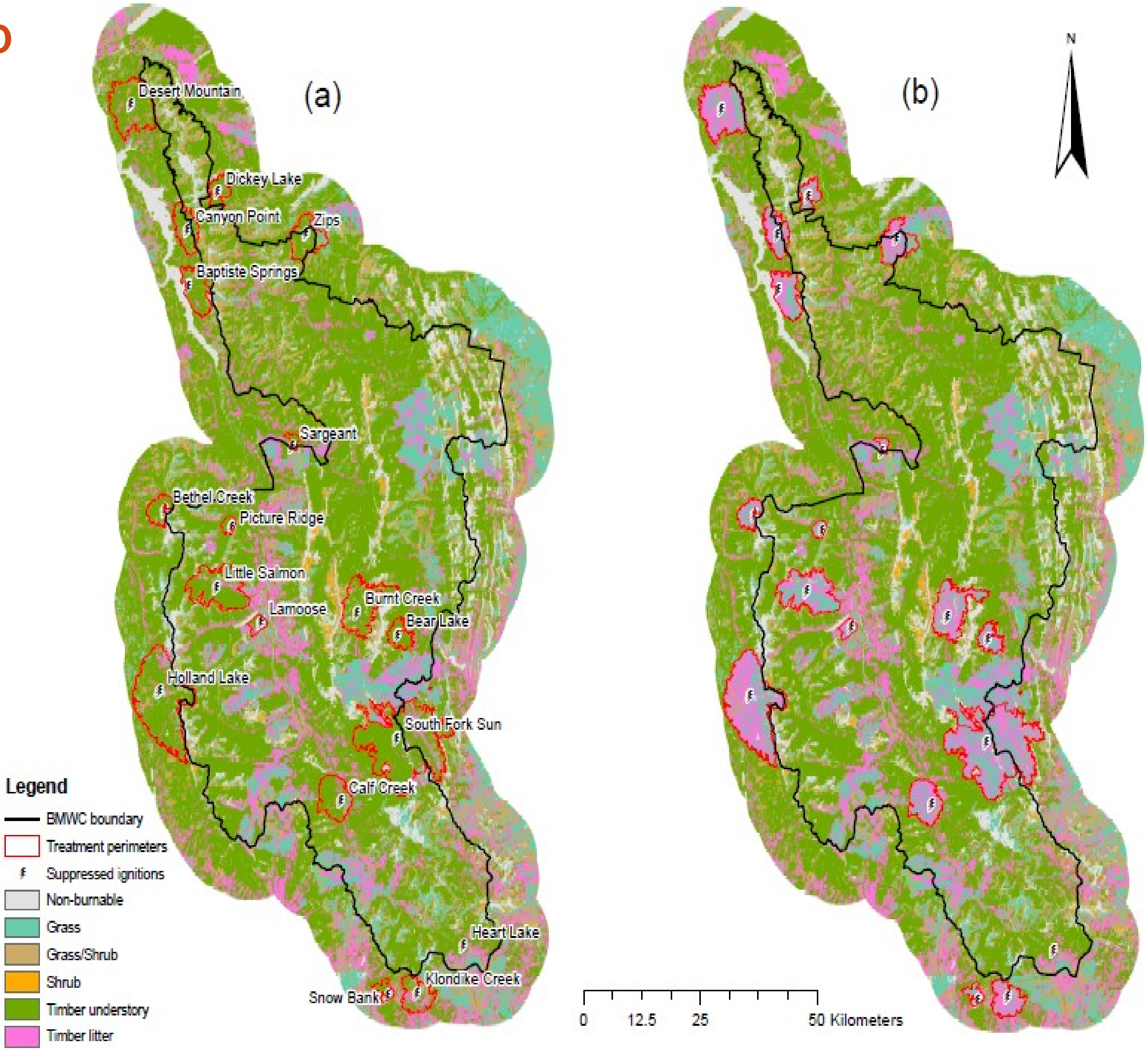
Observed landscape scenario

- Post-2007 fuels
  - LANDFIRE Refresh

Treated landscape scenarios

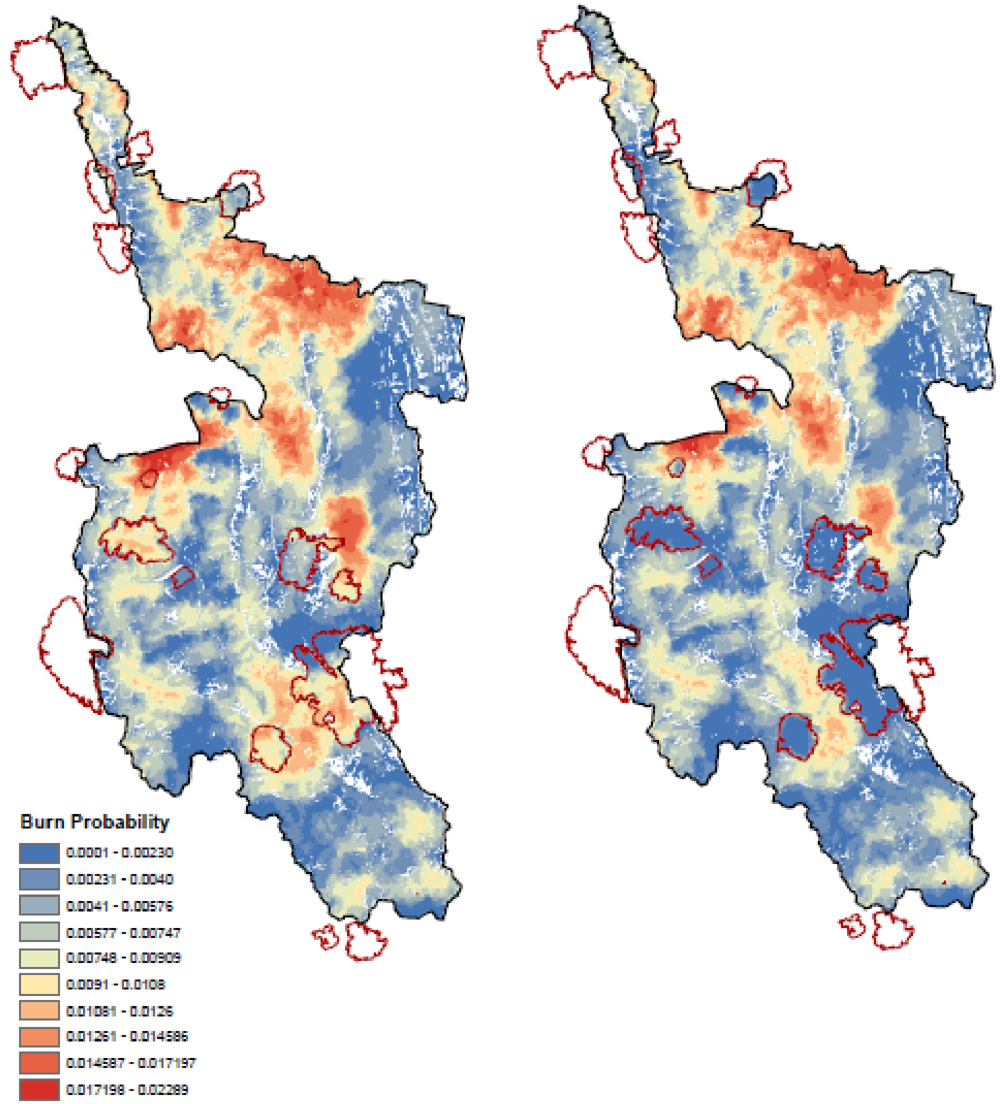
- Retrospective simulations
  - FARSITE (Finney, 1998)
  - Modified LANDFIRE Refresh
  - Observed weather
- Update fuels layers
  - Crosswalk fireline intensity

  into burn severity classes



Modeling burn probability and intensity

- Large Fire Simulator (FSim, Finney et al., 2011)
- Simulates fire occurrence, growth, and behavior
  - 25,000 artificial fire seasons
    - Historic weather observations
  - Spatially-explicit burn probability, intensity
  - Ignition points, simulated fire perimeters
- Constant weather and ignition locations between scenarios



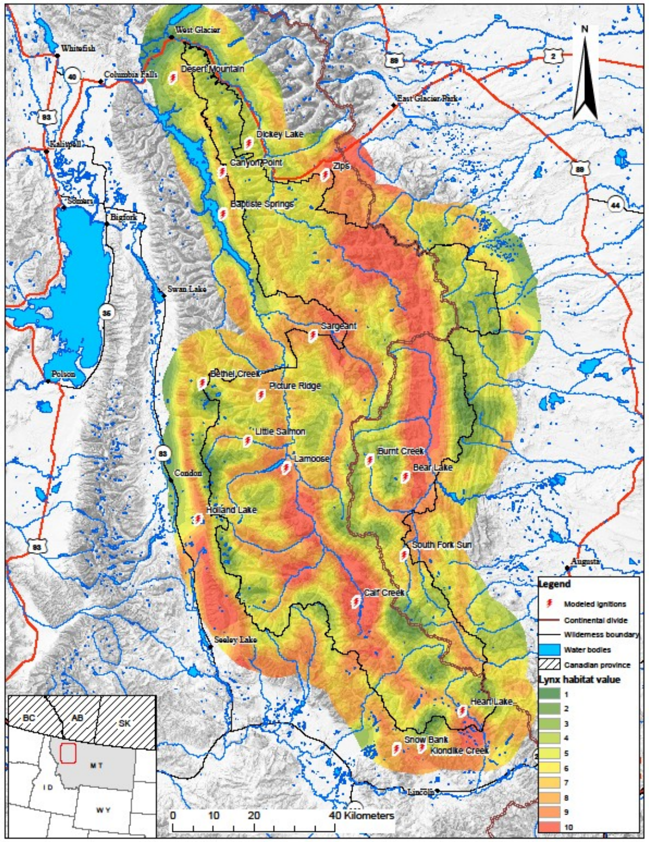
Estimating annual suppression expenditures

Fire name	Delta mean annual suppression costs ($)	% Reduction
Baptiste Springs	131,874	1.26
Bear Lake	8,026	0.077
Bethel Creek	117,197	1.12
Burnt Creek	29,448	0.28
Calf Creek	27,363	0.26
Canyon Point	158,186	1.52
Desert Mountain	427,808	4.10
Dickey Lake	98,962	0.95
Holland Lake	567,816	5.44
Little Salmon	36,358	0.34
Picture Ridge	26,394	0.25
Sergeant	41,899	0.40
Southfork Sun	19,299	0.18
Zips	44,554	0.42

- Pair regression cost model (Gebert et al., 2007) with FSim perimeters
  - Estimate suppression costs for each individual simulated fire
    - Observed, treated
  - Annualize results
  - Thompson et al. (2013)
- Intersect simulated perimeters with treatment fire perimeter
  - Cost unchanged for perimeters not intersecting treatment

Spatial distribution of resources at risk

- Structures
  - Cadastral dataset maintained by RMRS (points)
- Canada lynx habitat
  - Resource selection function (Squires et al., 2013)
  - Relative likelihood of lynx occupancy
- Commercial timber
  - FIA summary plot data from Region 1
  - Region 1 VMap
  - Predict volume/acre,age with regression tree



Valuing resources at risk

- Structures
  - State-wide median tax accessed value ($183,000)
- Lynx
  - Limited options for benefit transfer
  - $25/acre
- Commercial timber
  - Estimate harvest and haul costs (BBER)
    - Harvesting method, haul distance
  - Estimate revenue using 10 year median delivered log prices
  - Calculate stumpage value ($/acre)

Identify response functions

Resource	Response functions (range)					
	Very low	Low	Moderate	Mod – high	High	Very high
Lynx	1o [-10,30]	-10 [-30,50]	-20 [-40,0]	-40 [-60,-20]	-60 [-40,-80]	-80 [-60,-100]
Private structures	-80 [-60,-100]	-80 [-60,-100]	-80 [-60,-100]	-80 [-60,-100]	-80 [-60,-100]	-80 [-60,-100]
Stumpage – PSME, PIPO	40 [20,60]	10 [-10,30]	-20 [-40,-60]	-80 [-60,-100]	-100 [-80,-100]	-100 [-80,-100]
Stumpage – Other	-10 [10,-30]	-30 [-10,-50]	-70 [-50,-90]	-90 [-70, -100]	-100 [-80,-100]	-100 [-80, -100]

Calculate value change

- Initial value change in current time period
- Assume 20 year lifespan of fire treatment
  - Account for declining change in fire likelihood over 20 years
    - Decay in treatment effectiveness
    - Discount expected annual losses/benefits to present value
- Mature timber (> 100 years):

$$IVC_1 = \sum_{i=1}^{4} \theta_i * S(A)$$

$$IVC_2 = \sum_{i=5}^{6} \theta_i * S(A) + .40(S(A))$$

$$FVC_1 = 1/20 \sum_{i=1}^{4} \sum_{j=1}^{20} \left(\frac{(20-j)}{20} \right) * \Delta BP_i * \theta_i * \frac{S(A)}{(1+r)^{100}}$$

$$FVC_2 = 1/20 \sum_{i=5}^{6} \sum_{j=1}^{20} \left(\frac{(20-j)}{20} \right) * \Delta BP_i * \left[\frac{S(A)}{(1+r)^{100}} - \frac{\frac{S(A)}{(1+r)^{100)}}}{(1+r)^{j}} \right]$$

Calculate value change

- Immature timber:

$$IVC_1 = \sum_{i=1}^{4} \theta_i * \frac{S(A)'}{(1+r)^{100-age}}$$

$$IVC_2 = \sum_{i=5}^{6} \theta_i * \frac{S(A)'}{(1+r)^{100-age}} + .40(S(A)')$$

$$FVC_1 = 1/20 \sum_{i=1}^{4} \sum_{j=1}^{20} \left(\frac{(20-j)}{20}\right) * \Delta BP_i * \theta_i * \frac{S(A)'}{(1+r)^{100+(100-age)}}$$

$$FVC_2 = 1/20 \sum_{i=5}^{6} \sum_{j=1}^{20} \left(\frac{(20-j)}{20}\right) * \Delta BP_i * \left[\frac{S(A)'}{(1+r)^{100+(100-age)}} - \frac{\frac{S(A)'}{(1+r)^{100+(100-age)}}}{(1+r)^{j}}\right]$$

Calculate value change

- Lynx:

$$IVC = \sum_{i=1}^{6} \theta_i * HL$$

$$FVC = 1/20 \sum_{i=1}^{7} \sum_{j=1}^{20} \left(\frac{(20-j)}{20}\right) * \Delta BP_i * \left[\frac{HL * (1+r)^j - 1}{r(1+r)^j} + \frac{\frac{HL * \theta_i * (1+r)^{20-j} - 1}{r(1+r)^j}}{(1+r)^j}\right]$$

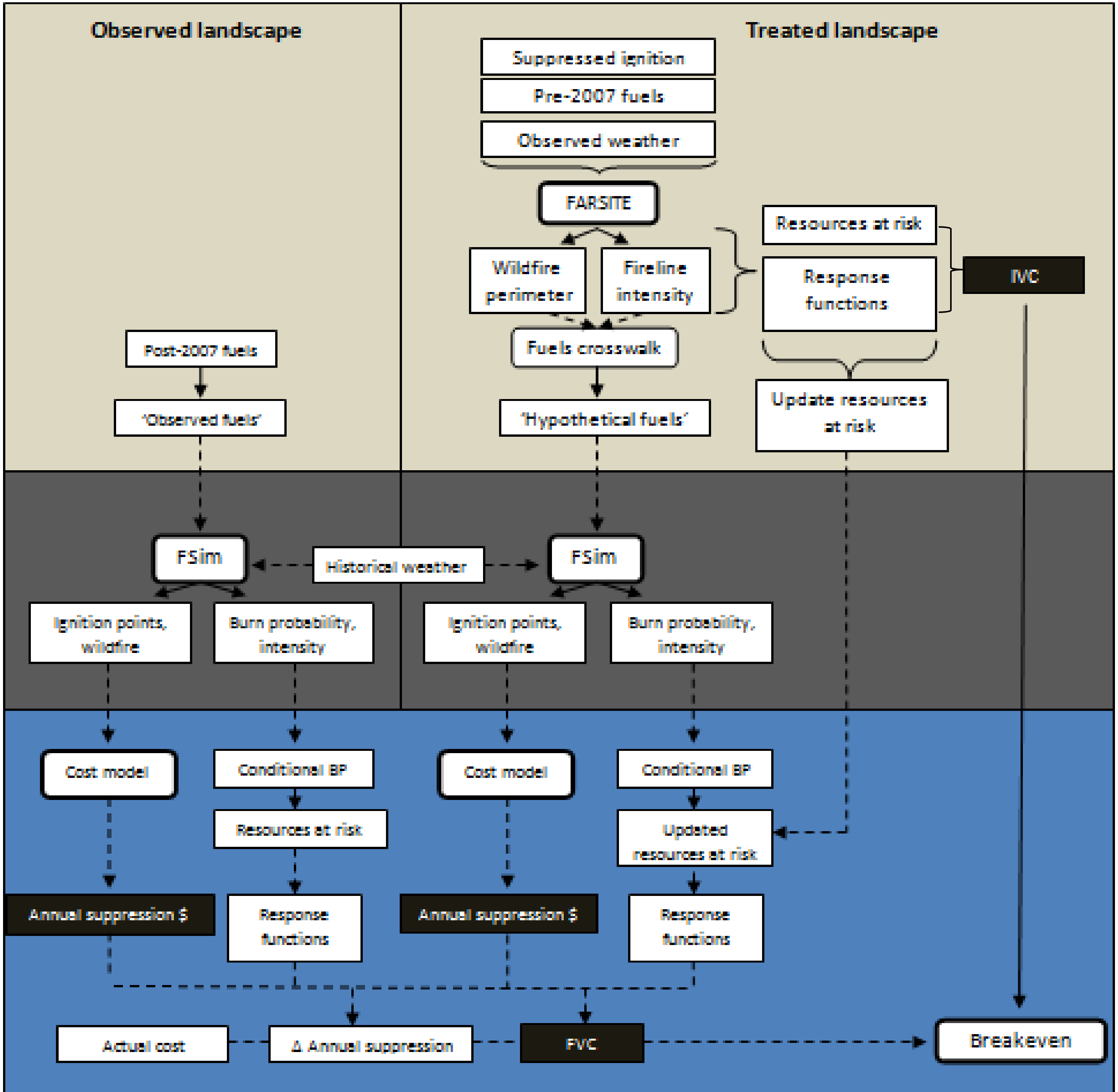
- Structures:

$$IVC = \sum_{i=1}^{6} \theta_i * SV$$

$$FVC = \sum_{i=1}^{6} \sum_{j=1}^{20} \left(\frac{(20-j)}{20}\right) * \Delta BP_i * \theta_i \frac{SV}{(1+r)^j}$$

- Suppression cost savings:

$$FVC = \sum_{j=1}^{20} \left(\frac{(20-j)}{20}\right) * \frac{Savings}{(1+r)^j}$$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FVC
Breakeven

Discussion

- Opportunities and challenges
  - Estimate range of maximum monitoring costs
    - Likelihood of being efficient?
  - Probabilistic wildfire simulation modeling
  - Mapping resources at risk, pairing with value estimate
  - Characterizing fire effects outside the pixel-level
- Linking changes to resource level with changes in value
  - What is the marginal unit?
- Myriad assumptions, propagation of errors
- Explore sensitivity of estimated break-even management cost:
  - Response functions
  - Shadow prices

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JOINT FIRE SCIENCE PROGRAM

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