Forest Management Planning Under Uncertainty

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Overview

Impact of fire on timber supply

Explicit modelling of stochastic fire loss processes

Using simple models to manage complex ecosystems

Current research initiatives

Sources of Uncertainty

200+ year planning horizons

Fire

Insects

Disease

Changes in markets

Changes in manufacturing technology

Changes in social attitudes and government policy

Focus on Fire and Timber Supply

Fire a natural component of boreal forest ecosystems

Detrimental impacts on people, property and timber production

Beneficial impacts on natural ecosystem processes

Highly variable across both time and space

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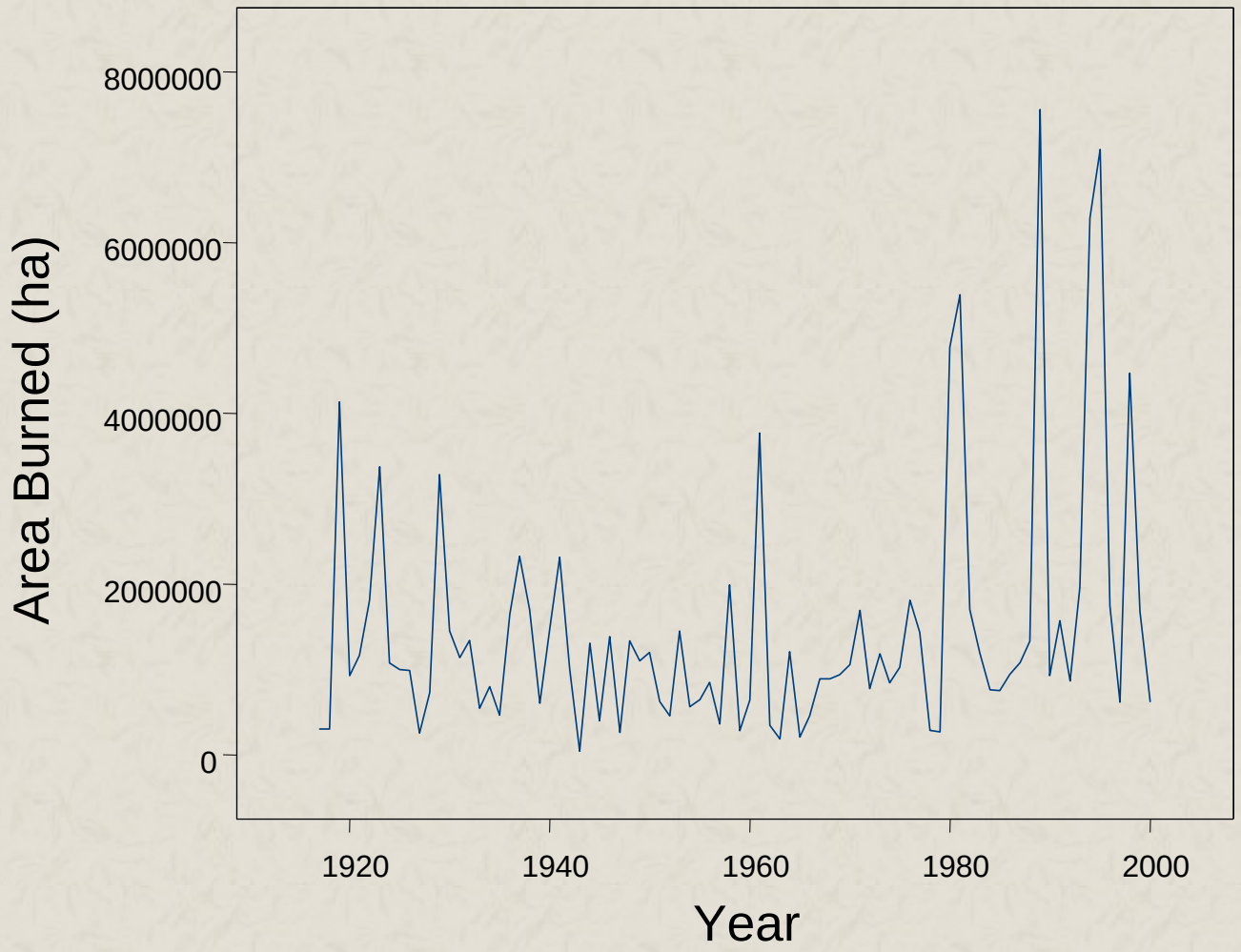
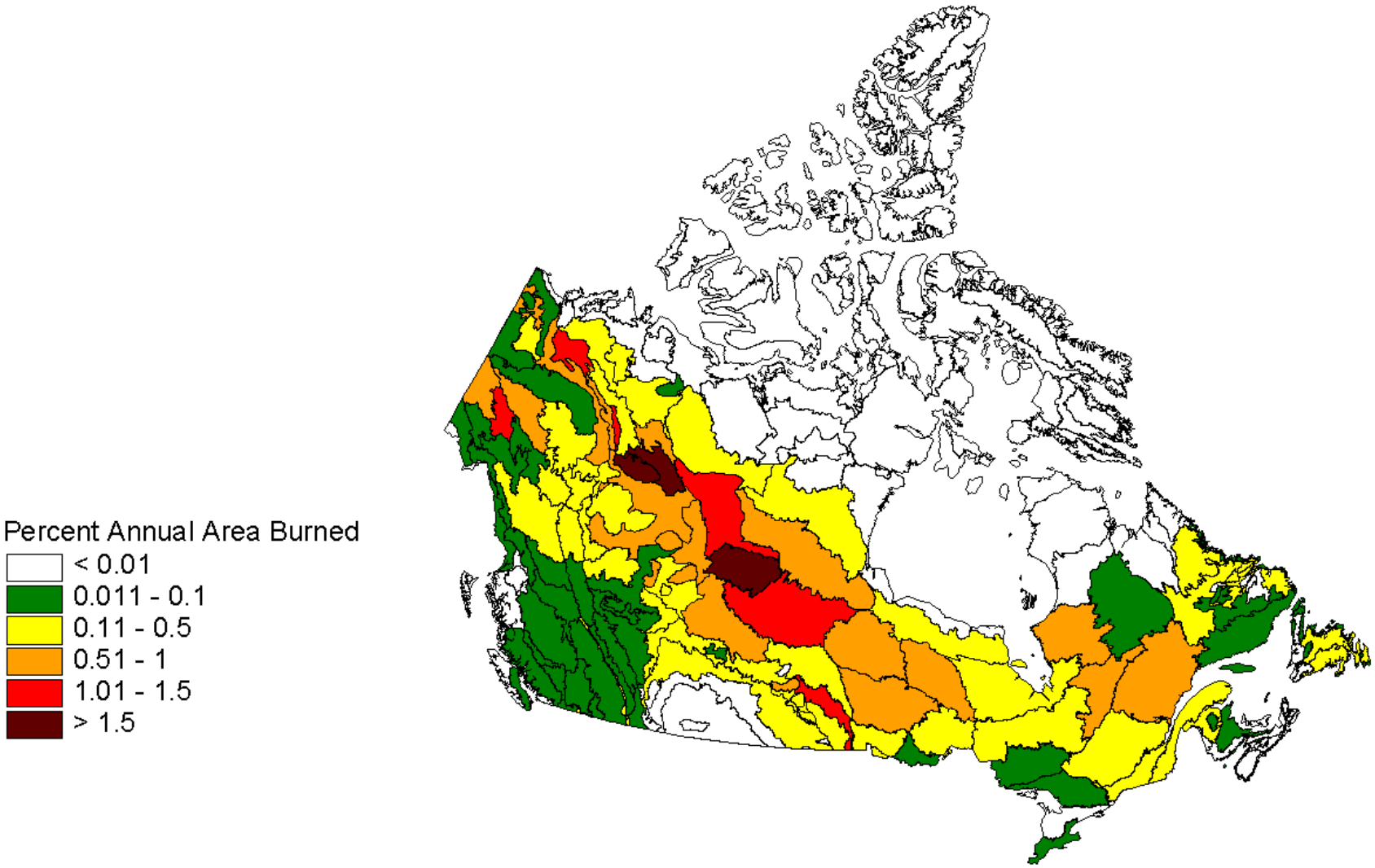
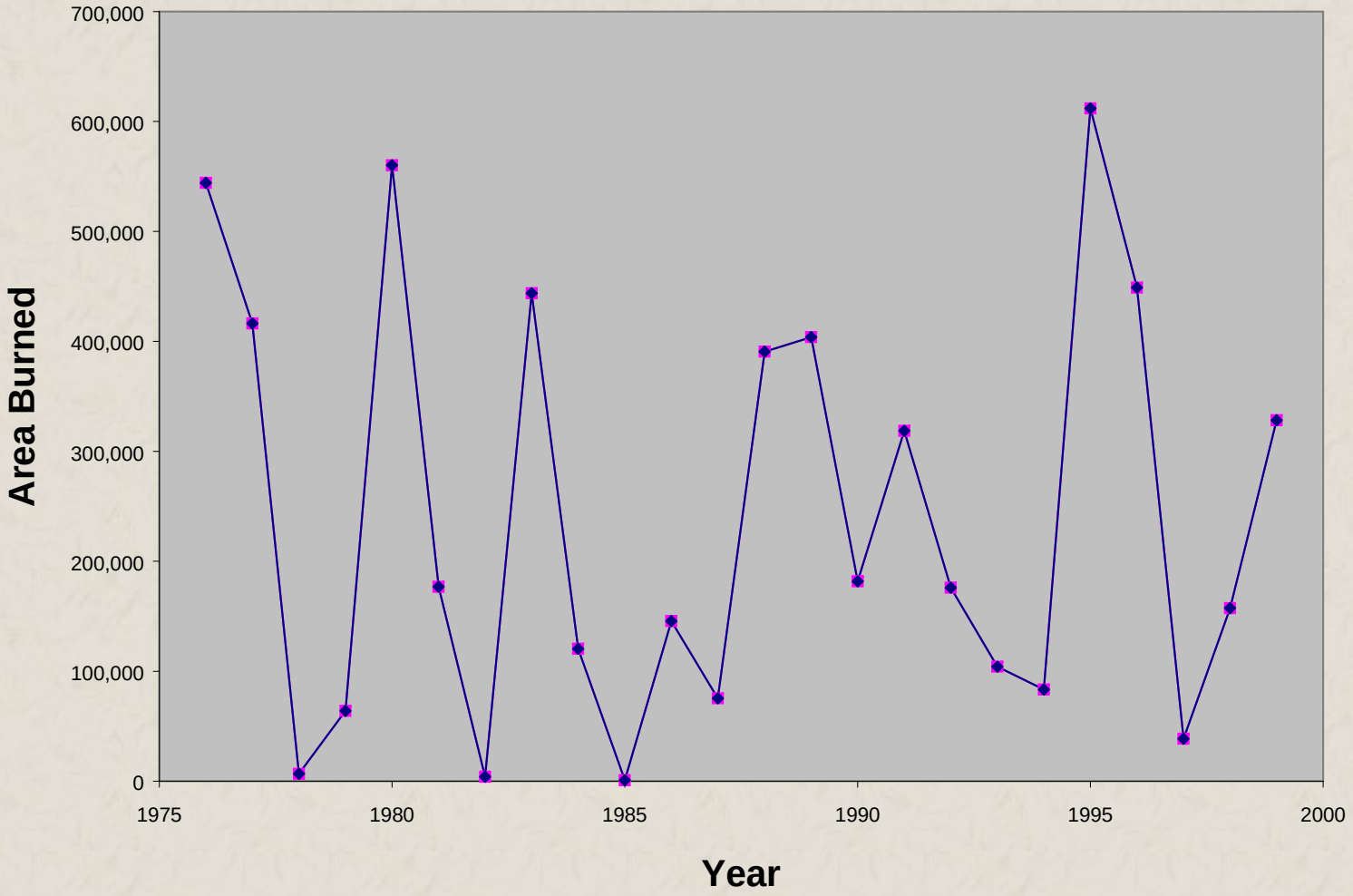
Annual Area Burned in Canada



Annual Burn Rate by Eco-region



Annual Area Burned in Ontario



What is the Impact of Fire on Timber Supply ?

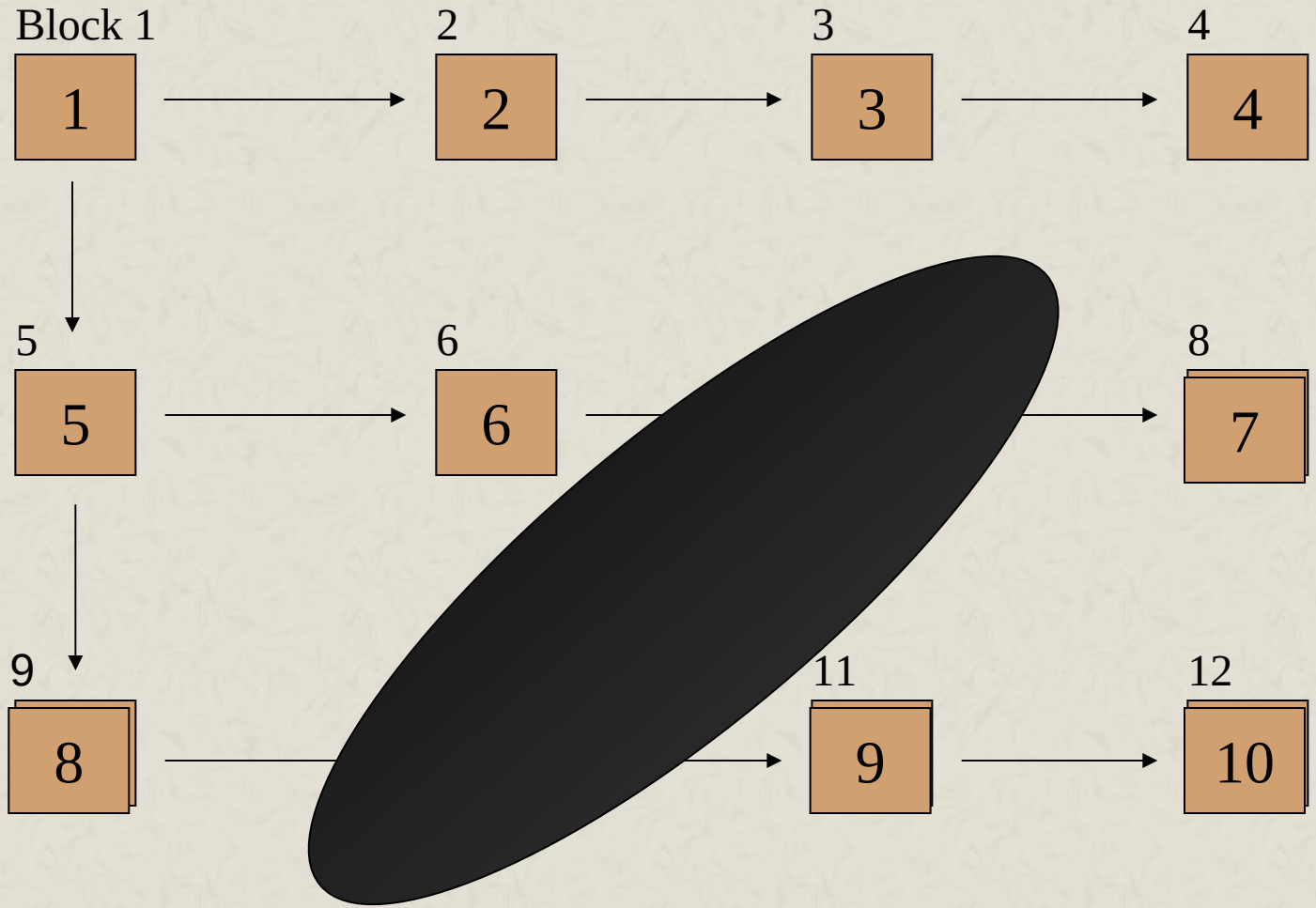
When a fire burns merchantable timber it :

1) Reduces the supply of merchantable timber currently available

2) Increases the supply of less valuable “salvageable” timber ?

3) Disrupts plans and increases costs

Impact of a Fire on Harvesting



Build roads to blocks 8,9,11, and 12 earlier than planned (more expensive)

Harvest blocks 8, 9, 11 and 12 earlier than planned (less volume/ha)

Where Do We Start ?

What is the value of a forest stand that is scheduled to be harvested in 5 years?

It depends on the probability that it will burn in years 1 through 4

What is the value of saving that stand from fire this year if it will burn next year anyway ?

Very little

What is the value saved this year if the stand might burn next year ?

Less than its discounted sale price next year

Continuing

The value saved (or lost) depends on the possibility the stand might burn in the future.

Losses influenced by the ability to replace burned stands with others

Loss depends on how you plan to harvest the forest before and after the burn

Need to evaluate forests given specified fire regimes and harvest plans before we can evaluate the impact of specific fires.

Four Perspectives

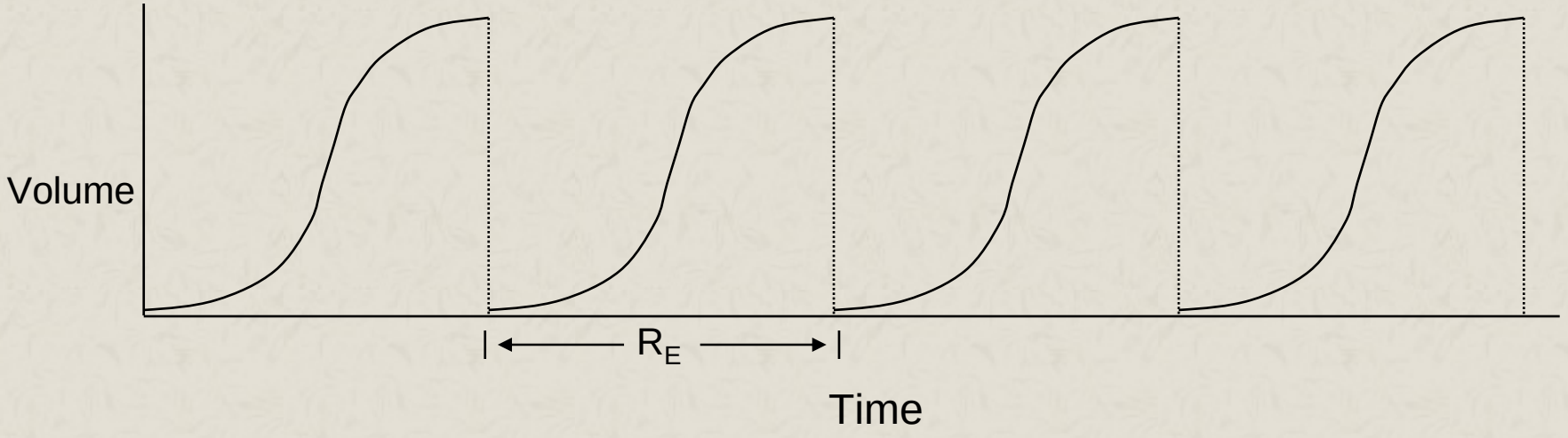
Stand level analysis

- impact of fire regimes
- impact of a specific fire

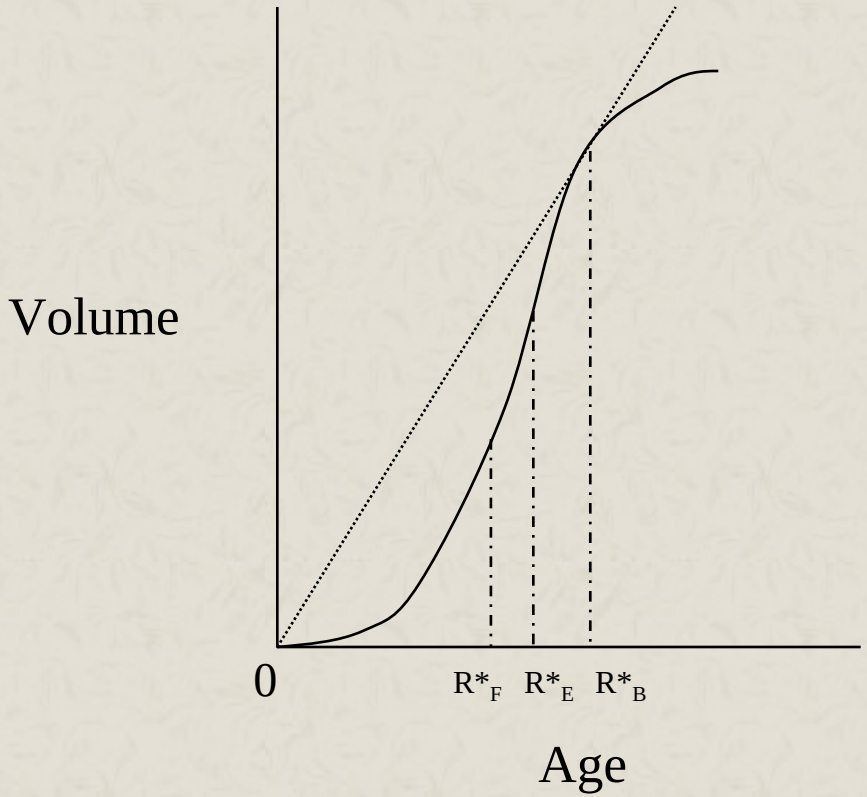
Forest or landscape level analysis

- impact of fire regimes
- impact of a specific fire

Impact of fire at the stand level



Stand Level Assessment of a Fire Regime



Soil expectation value (SEV) approach to optimum Faustmann rotation

Stand Level Assessment of a Fire Regime

Assess the productivity of a site (a hectare) in the absence of fire (SEV without fire threat)

Assess the productivity of a site (a hectare) in the absence of fire (SEV with fire threat)

Assess the impact of the fire regime in terms of the reduction in SEV of the stand that is threatened by fire

$\Rightarrow SEV_{\text{without fire}} - SEV_{\text{with fire}}$

Stand Level Impact of a Specific Fire

Assess immediate economic loss

$\Rightarrow$ multiply volume burned by stumpage rate

Assess reduction in expected SEV due to the fire, accounting for potential future fire losses

$\Rightarrow$ Expected [$SEV_{\text{before fire}}$] – Expected [$SEV_{\text{after fire}}$]

Impact of a Fire Regime

Jack Pine, Site class II, stumpage rate of $ 30 / m^3, discount rate of 3%

Annual burn probability of 0.02

Opt rotation and SEV with no fire	$1,372 / ha at 37 years
Opt rotation and SEV with fire	$ 875 / ha at 34 years
Economic impact of fire	Reduces SEV by 36%
Value of fire management?	Increases SEV by 53%

Forest Level Analysis

Small landowners manage forest stands but large forest licensees manipulate forest stands to manage forest landscapes

Construct roads, harvest stands and carry out silviculture activities to provide harvest flows that are compatible with mill demands

Forests are regulated at the forest level, not the stand level

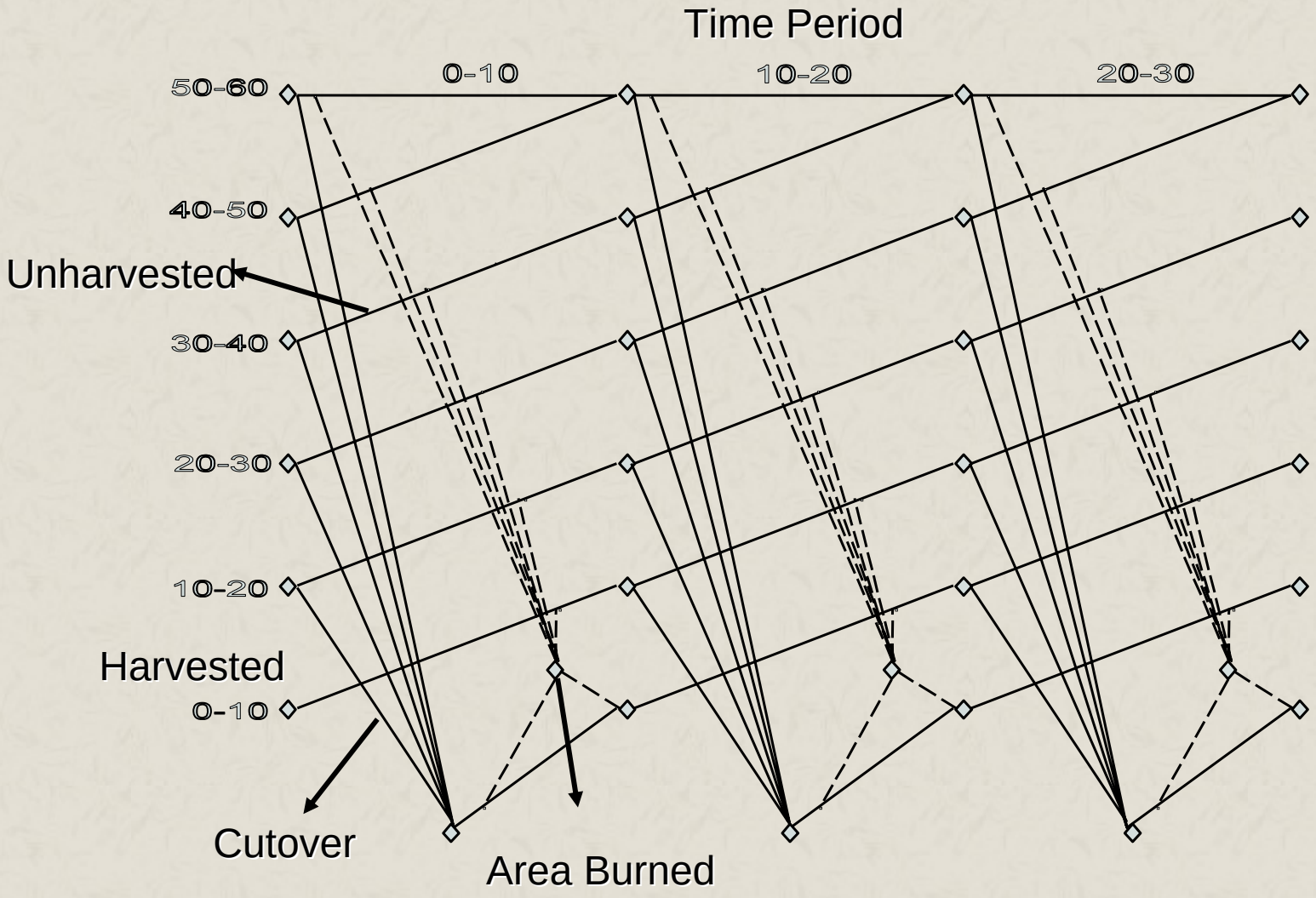
Impact of Fire on Timber Supply

Reed and Errico forest level timber harvest scheduling model (model III) with constant average annual burned area

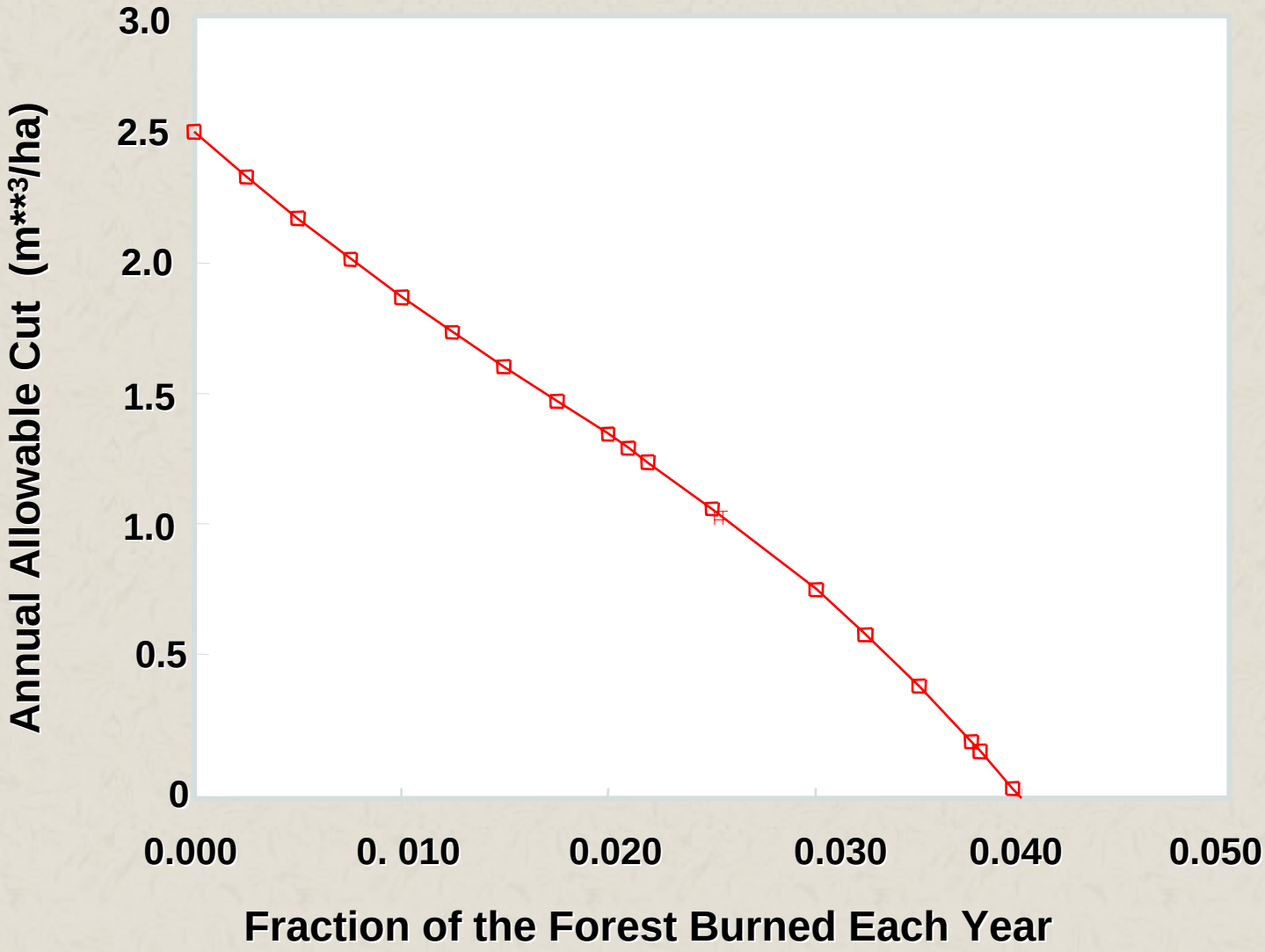
Maximize average annual harvest volume (or present net worth)

Subject to
- harvest flow constraints
- terminal conditions (e.g., age class structure)

Model III with Fire and Harvesting



Impact of Burn Fraction on Harvest



A Hypothetical Flammable Forest

100,000 ha of site class II Jack Pine

a) Forest I: all stands 75 years old
b) Forest II: balanced over 8 - 10 year age classes (a “fully regulated” forest)

Annual burn fraction = 0.10 %

Complete road access established

Cut and burned areas regenerate naturally at no cost

Timber Management in the Forest

300 year planning horizon partitioned into 10 year periods

Constant harvest flow

Terminal volume of 4.02 million cubic metres (40.2 m^3/ha)

Stumpage of \$30 / m^3

Interest rate 3.0%

Ignore salvage, harvest, regeneration, and transportation costs

Forest Level Assessment of a Fire Regime

What is the economic impact of a specific fire regime?

Economic Impact	=	Value of the forest with no fire loss	-	Value of the forest with a specific fire regime

Estimate Forest Value With/Without Fire

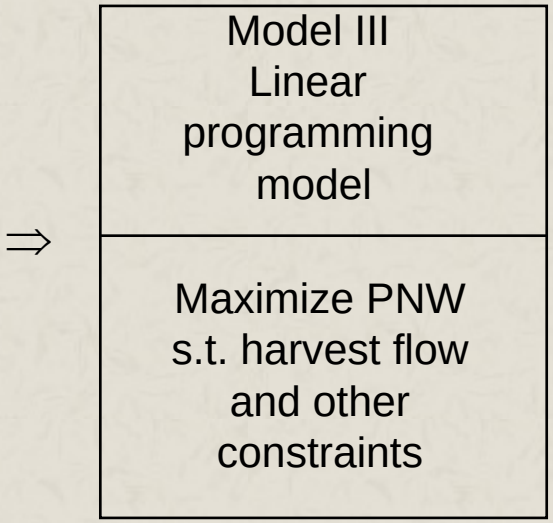
<u>Forest Description</u>

current age class structure (by working group)

growth and yield functions

harvest flow and other constraints

average annual burn fraction



<u>Harvest Schedule</u>

planned harvest (by working group, age class, and period)

Impact of a Fire Management Program in Forest II

Fire Mgmt. Program	Annual Burn Fraction	Present Net Worth ($)	Area Cut Period 1 (ha)	Volume Period 1 (m^3)
None	0.020	141,350,900	7,358	1,397,994
Fire Prot.	0.001	251,570,459	13,150	2,488,091
Value of fire management		110,219,559 (78.0%)		1,090,097 (78.0%)

Impact of a Specific Fire

Expected return given the best planned harvest schedule before the fire (run timber supply model with unburned forest)

Less

Expected return given the best revised harvest schedule after the fire (run the timber supply model with the same forest, a portion of which has been burned)

Fire Loss in Forest II

Fire Area: 30,000 ha
(30% of the area of the forest)

Fire Loss: $ 50,908,265 (not $171 million)
(20.2% of the PNW)

503,494 cubic metres/period
(20.2% of the cut)

An Explanation

Hypothetical forest has an abundant supply of wood available for harvest

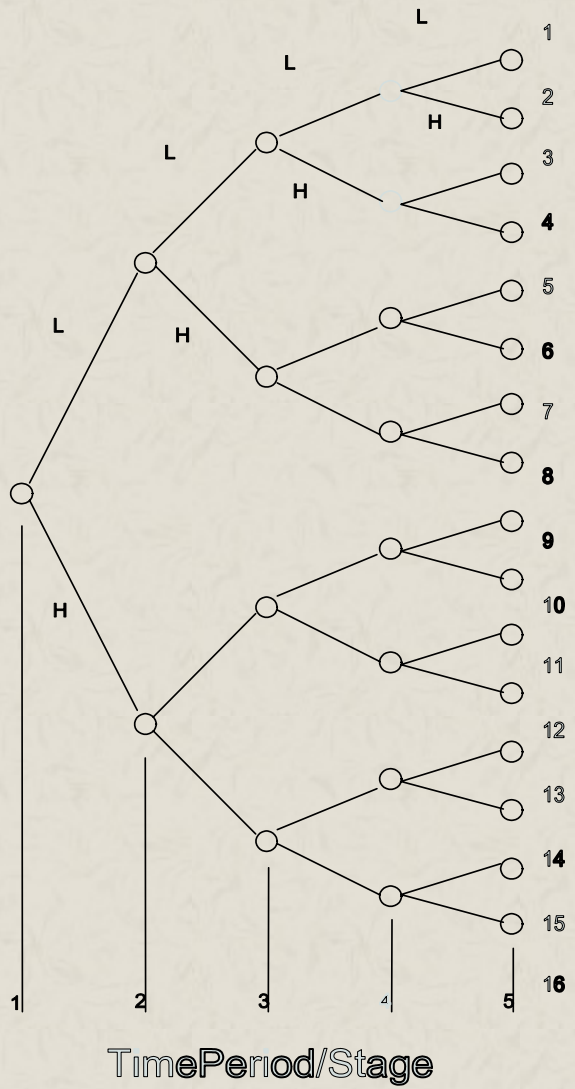
Harvest levels can be adjusted to spread the fire loss out over the entire 300 year planning horizon

“Postpone” harvest of the burned area until it regenerates and reduce the annual harvest level to compensate for the recent loss

Explicit Modelling of Stochastic Fire Loss

Develop discrete scenarios (e.g., sequences of high and low decadal burn rates) for the first four periods and estimate the likelihood that each of those scenarios will occur

Incorporate scenarios in a stochastic programming model

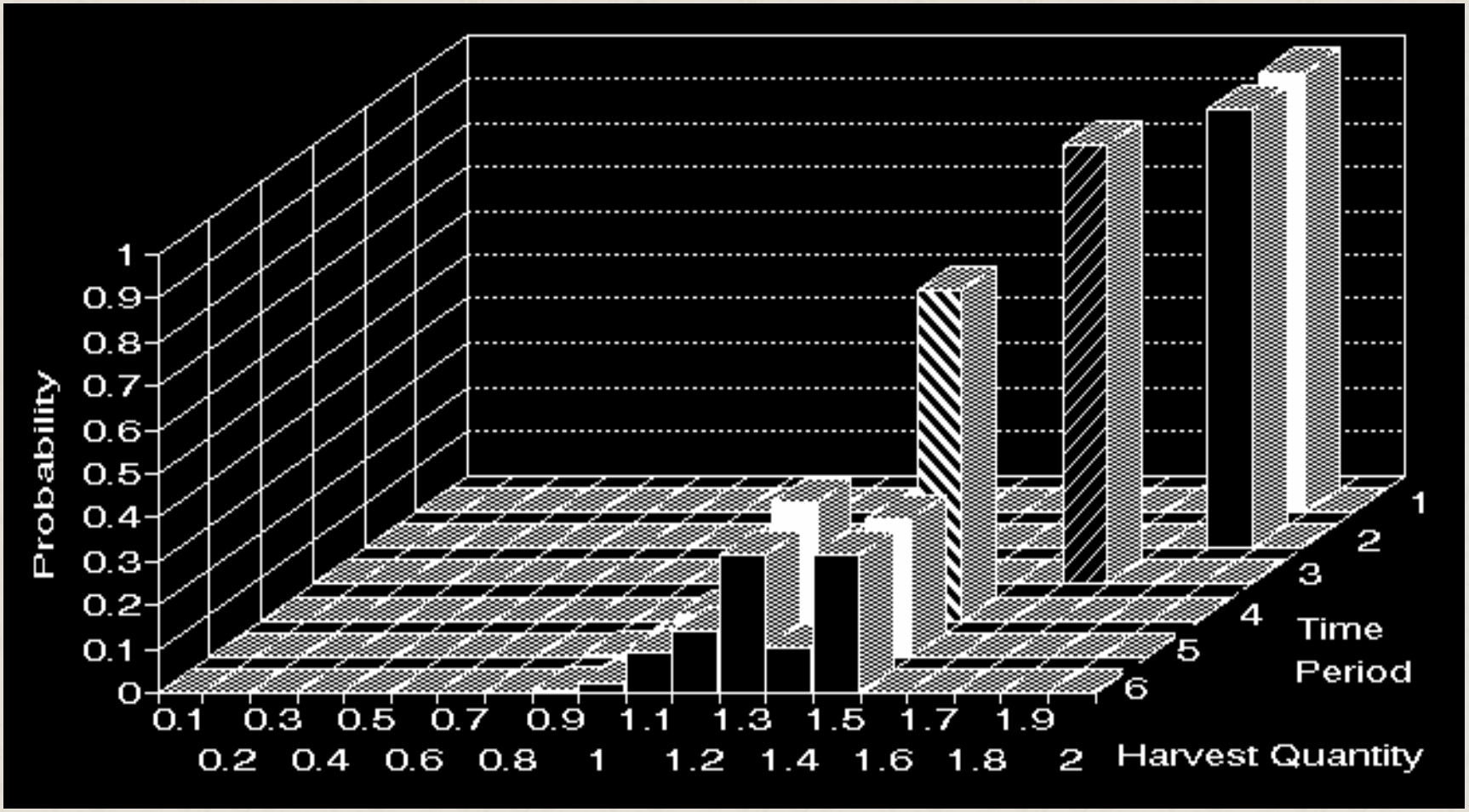


Stochastic Programming Model

Maximize present net worth of the harvest minus a penalty for harvest flow decreases

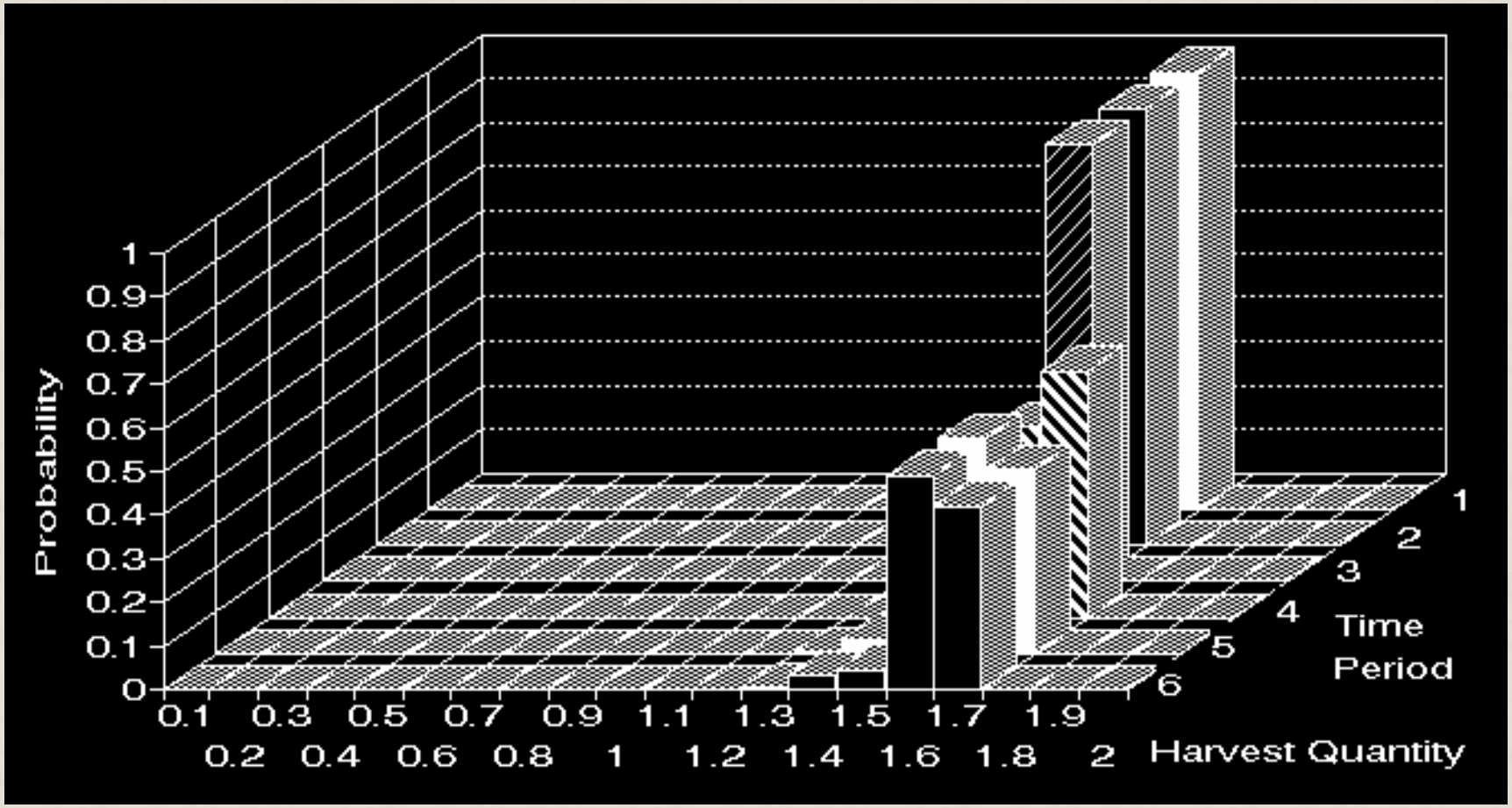
Higher penalties discourage decreases in harvest flows

Low Harvest Penalty



Harvest volume decreases and becomes more variable over time

High Harvest Penalty



Harvest flow increases and is reasonably stable in the future

Green Compromise

Increase the harvest flow reduction penalty

- Harvest level decreases initially
- Harvest level increases and total amount of wood harvested increases over the entire planning horizon
- Harvest flow is less variable
- Small decrease in present net worth

Climate Change

Climate change appears to be having an impact on fire regimes in the boreal forest region of Canada now

How might it shape future harvest levels?

Tembec Romeo-Malette test case in Northeastern Ontario

What We Did

1. Predicted fire occurrence now and with climate change
2. Predicted escaped fire rates now and with climate change
3. Predicted annual burn probability across the landscape now and with climate change
4. Assessed the impact of fire on representative natural and IFM stands now and with climate change

Predicting fire occurrence with climate change

Used Wotton fire occurrence prediction model to multiply current RMF fire occurrence rates

Now	23.8	people	14.2	lightning
2 x CO2	x1.1	people	x1.1	lightning
3 x CO2	x1.2	people	x1.4	lightning

Predicting Burn Probability

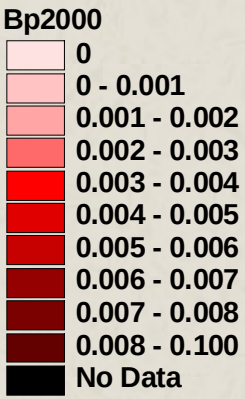
Simulate daily fire occurrence and escape given fuel and current (or future) weather at the fire

Simulate the growth of escaped fires across the landscape

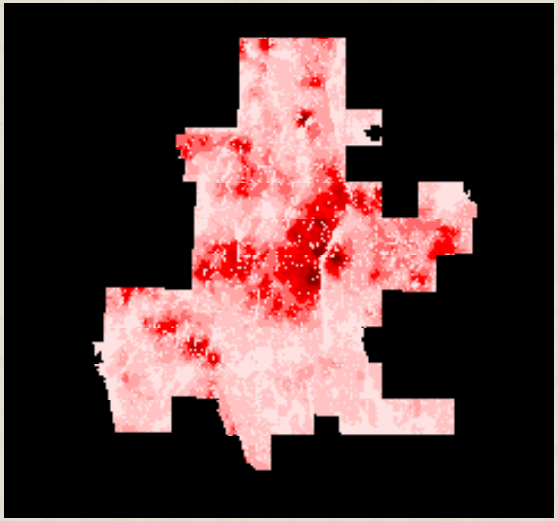
Repeat for 1000 simulated years and determine how often each cell burned

BP_i = number of times cell i burned / 1000

Tembec Burn Probability Maps



BP 2040



BP 2090