Optimal Forest Management of Douglas-fir in Western Oregon: Stochastic Prices, Carbon Sequestration, and Wildfire Risk

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Outline

Introduction

FC~48% of Oregon

65 % Douglas fir

~60,000 Jobs

$18 billion annually

Introduction

- Forest carbon programs promote extended rotations and sustainable practices.

    a. Oregon's Forest Carbon Offset Program

    b. California Cap-and-Trade Program

    c.Regional Greenhouse Gas Initiative (RGGI)

- At federal level

    Conservation Reserve Program (CRP)

    Environmental Quality Incentives Program (EQIP)

Provide Economic viability + Ecological benefits

Introduction (Contd)

- Wildfires threaten both economic and ecological forest values.
- Wildfire frequency and severity in Oregon have risen in recent decades (North et al., 2015).
- Fires cause economic losses and release large amounts of stored carbon (Hurteau et al., 2009).
- Classical models (e.g., Faustmann, Hartman) often overlook wildfire risk and market variability.
- There's a need for decision frameworks that incorporate both timber price uncertainty and wildfire risk in Douglas-fir forests.

Objective

- Evaluate how market dynamics and wildfire threats influence optimal harvest timing by considering timber revenue, carbon sequestration benefits, and wildfire risk in decision-making.

Model of the study

Use Reservation Price Approach: Represents a price that makes the landowner indifferent between harvesting or waiting one extra year

Assumptions:

(1) Timber prices are the only source of uncertainty;

(2) Timber prices at different time points are statistically uncorrelated;

(3) The landowner is risk-neutral.

Model of the study

Prevaling Timber Price

$$P(t) = E[P] + \varepsilon(t); \varepsilon(t); \varepsilon(t) \sim N(0, \sigma^2[P])$$

If the stand reached the maximum harvest age T ⟹ Harvest immediately

$$W(T) = [E(P(T) - C_h]V(T) + L - E(t)$$

Denotation:
C_h = Harvesting costs,
$V(t)$ = Timber volume at stand age t,
L = Land value,
$E(t)$ = Carbon emission tax.

Model of the study

If age t < T Two options:

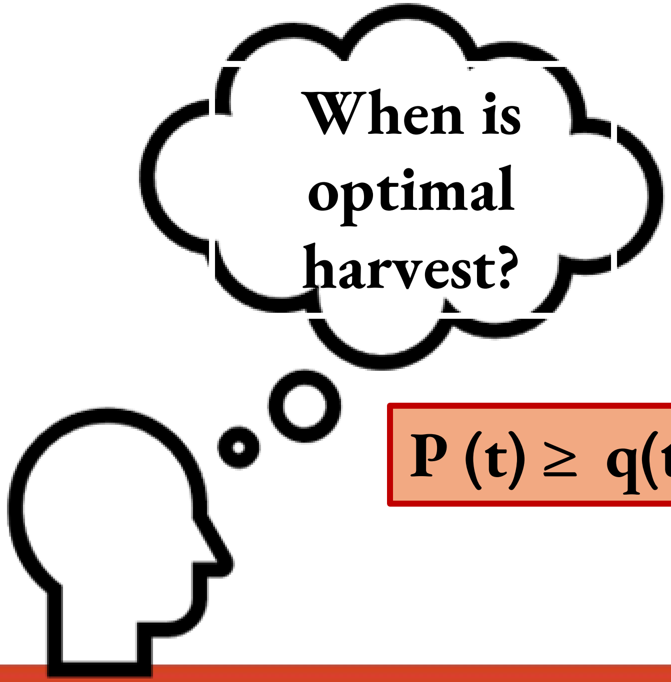
When $R_1 > R_2$, Harvest now is preferred option!

(1) Harvest now

$$R_1 = (P - C_h)V(t) + L - E(t)$$

(2) delay the harvest one extra year

$$R_2 = \big(1 - \lambda(t)\big)W(t+1)e^{-r} + \lambda(t)(S(t+1) + L) - L + D(t)$$



Optimal reservation price

$$q(t) = \frac{\big(1-\lambda(t)\big)W(t+1)e^{-r} + \lambda(t)(S(t+1)+L) - L + D(t) + E(t)}{V(t)} + C_h$$

P (t) ≥ q(t)

Model of the study

Once q(t) is determined, the expected value of stand at age t is calculated

$$W(t) = \int_{q(t)}^{+\infty}[(P - C_h)V(t) + L - E(t)]f_t(P)\,dP \;+\; \int_{-\infty}^{q(t)}[(1 - \lambda(t))W(t+1)e^{-r} + \lambda(t)(S(t+1) + L) - L + D(t)]\,f_t(P)\,dP$$

After that, land value of stand at age t is calculated

$$L = W(1)e^{-r} - C$$

Model Application: Cost and Price Information

Douglas-fir in Western Oregon

- Planting Density: 740 trees/ha
- Planting cost: 494 $/ha
- Harvesting cost: 169.5 $/ha
- Mean timber price: 312.6 $/cubic meter
- SD: 54.6 $/cubic meter
- Interest Rate: 4%
- Minimum harvest age: 19 years
- Maximum harvest age: 100 years

(ODF, 2022)

Model Simulation

Wildfire Risk Assumption:

Constant Risk

$$\lambda = \frac{t_d}{50}$$

Age Dependent Risk

$$\lambda = 2t\frac{(X - t_a)}{(t_b - t_a)(t_c - t_a)}\,(t_a = 0, t_b = t_c = 50)$$

Parameters:

- λ (wildfire risk): 0, 0.02, 0.04
- g (salvage): 0.3, 0.5, 0.7
- β (long-lived wood): 0.7, 0.8, 0.9
- Carbon prices: $15, $25, $35

→ 81 Scenarios

Results

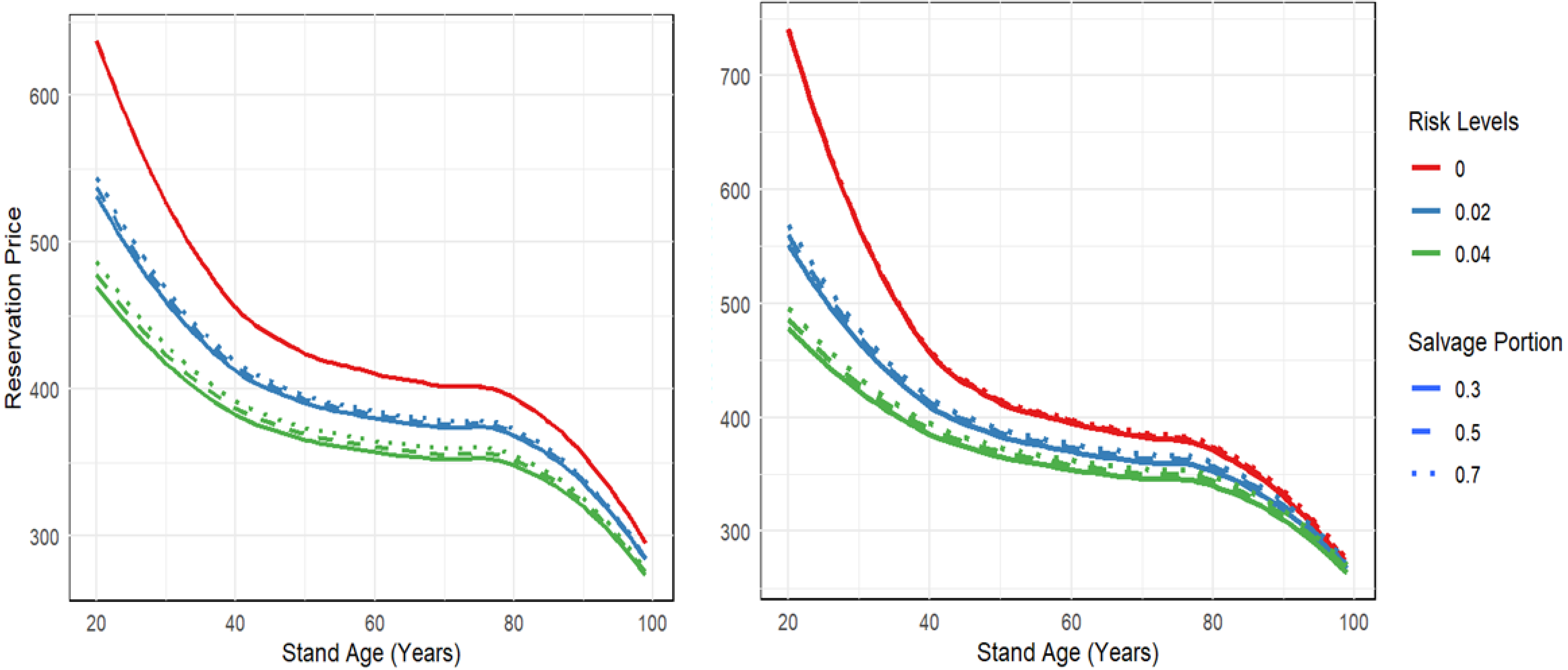


Fig 1: Optimal reservation prices under different risk levels (a) Constant risk (b) Age-dependent risk

Results

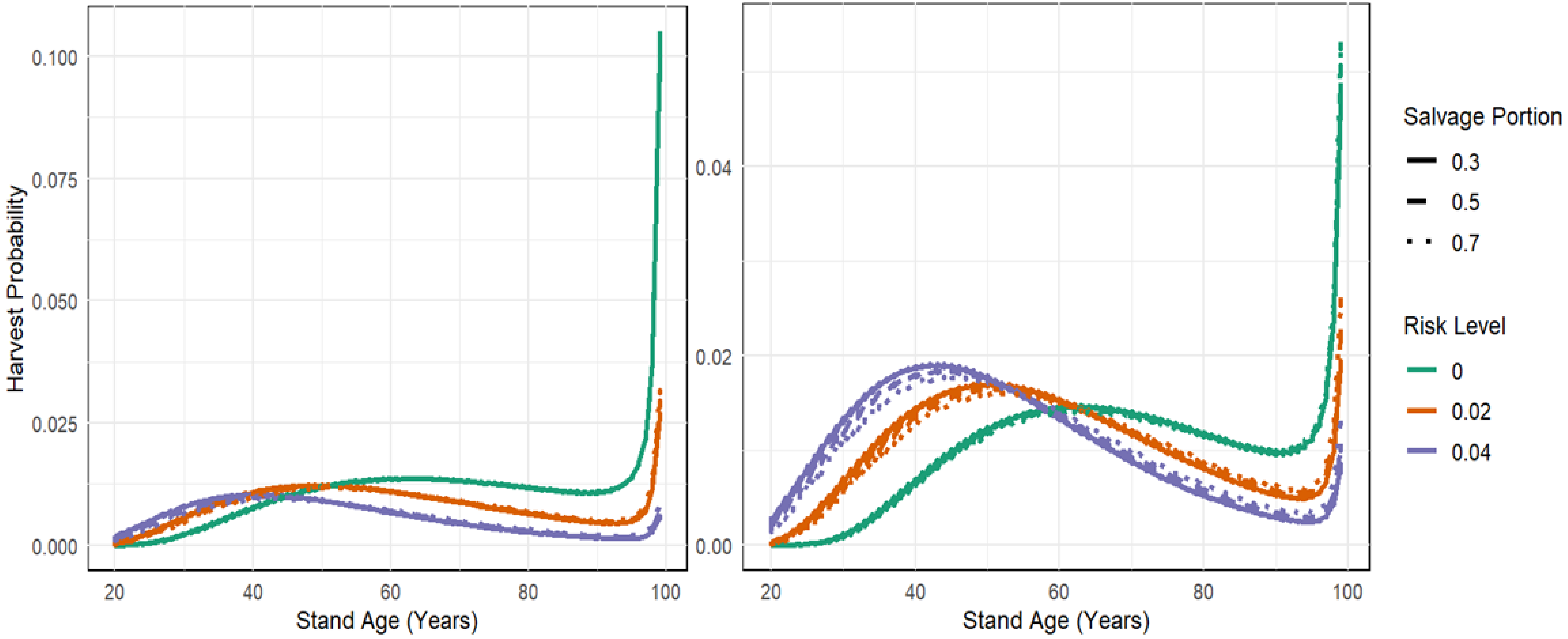


Fig 2: Harvest probability across stand ages under different risk levels(a) Constant risk (b) Age-dependent risk

Results

Table 2: Land value (L), mean harvest age with different wildfire risk levels and salvage portions related to reservation price strategy.

Constant Risk						
Risk level	Salvage Portion (0.3)		Salvage Portion (0.5)		Salvage Portion (0.7)	
	Land Value ($/ha)	Mean harvest age (yr)	Land Value ($/ha)	Mean harvest age (yr)	Land Value ($/ha)	Mean harvest age (yr)
0	14,104.3	65.2	14,104.3	65.2	14,104.3	65.2
0.02	8,990.2	39.8	9,194.8	40.2	9,404.5	40.6
0.04	5,878.8	23.4	6142.2	23.9	6414.1	24.5
Age Dependent Risk						
0	4,858.8	56.3	5,335.8	56.3	5,814.5	56.3
0.02	7,014.6	49.2	7,272.1	49.8	7,538.8	50.6
0.04	9,124.2	43.5	9,187.8	44.5	9,260.5	45.6

Results

Table 3: Mean harvest age under different carbon prices

Risk	Carbon Price ($/tCO2e)	Mean Harvest Age (year)
Constant Risk		
	15	64.9
	25	65.2
	35	65.4
Age-dependent risk		
	15	56
	25	56.3
	35	56.6

Discussion: Key Takeaways

🔥 **Wildfire Risk Accelerates Harvests**
Age-dependent risk especially cuts land value and shortens optimal harvest age.

🪵 **Salvage Logging Softens the Blow**
Higher salvage portions (up to 70%) help recover timber value post-fire.

💰 **Carbon Pricing Extends Rotations**
At $35/tCO_2e, carbon benefits encourage longer cycles — unless fire risk intervenes.

🧠 **Perception Shapes Behavior**
Landowners act on both actual and perceived wildfire risk.

🛠️ **Adaptive Management is Essential**
Flexibility is key to balancing profit, carbon goals, and resilience.

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Thank you!

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