Economically Optimal Forest Management in the Presence of Fire Risk and the Implications of Different Fuel Accumulation Patterns

(Formerly known as: Occurrence vs. Severity: Optimal Forest Management and Rotation Length in the Presence of Fire Risk in Florida)

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Forests and Fires in Florida

In 2010, Florida timber production spanned almost 16 million acres and contributed $14.7 billion to the state economy (FFS, 2010).

This production is threatened by wildfires, many of which are caused by lightning. Florida has the highest per acre rate of lightning strikes in the nation (NOAA, 2013).

Landowners can reduce the severity of fires by thinning stands and/or using prescribed burns to reduce the amount of fuel present for the wildfire.

Previous Work

Previous work in the economics literature has focused on determining the optimal rotation length in the presence of fire risk or other natural hazards (Alvarez and Koskela, 2006; Clark and Reed, 1989; Sims 2011).

Limited literature considers preventative action within a rotation. Amacher et al. (2005) determine the optimal level of within rotation treatment, but assume that such treatment only occurs once during the rotation, and they do not model fuel accumulation. Daigneault et al. (2010) allow for treatment in multiple years during a rotation, but assume that all accumulated fuel is removed during treatment.

Research Questions

- If the landowner can undertake preventative action to reduce the severity of fires, what level of action should be undertaken each year?
- How should prevention change over time within a rotation?
- How do assumptions about fuel accumulation affect the optimal prevention trajectory?

Model Components

- Considering management within one rotation
- Rotation length, *T*, is determined by the average time between fires which results in *V(T)* boardfeet of timber in the absence of fire
- Timber is sold for $p/boardfoot
- Fuel biomass accumulation (shrubs, saplings, pine needles, etc.), F_t, is explicitly modeled using three possible functions (logistic growth, concave growth, and exponential growth).
- If fire strikes, some portion of the timber, $K(F_T)$, will be salvageable. This portion is inversely proportional to the amount of fuel present to fuel the severity of the fire.
- The landowner can undertake any level of fuel removal, b_t, in every period for a cost of $c(b_t)$
- The discount rate is given by *r*.

Optimization Problem

$$\max_{b_t} \int_0^{E[T]} -c(b_t)dt + e^{-rE[T]}K(F_T)pV(T)$$

$$\text{subject to: } \dot{F}_t = f(F_t) - b_t$$

Results

Exponential fuel accumulation

- Optimal level of prevention increases throughout the rotation
- Accumulated fuel biomass increases throughout the rotation
- A longer expected rotation length puts the landowner on a lower trajectory with lower fuel removal and higher fuel biomass accumulation.

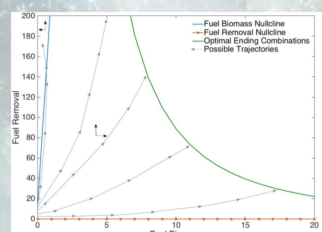

Figure 1. Fuel removal and fuel biomass phase diagram with exponential fuel accumulation

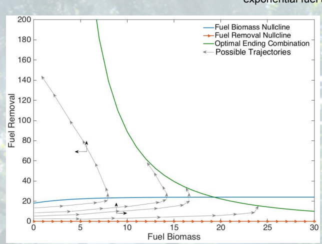

Figure 2. Fuel removal and fuel biomass phase diagram with concave fuel accumulation

Concave fuel accumulation

- Initially fuel biomass accumulates under low levels of fuel removal.
- Under low fire risk, fuel biomass increases throughout the entire rotation.
- Under higher fire risk and shorter expected rotation length, the landowner eventually increases fuel removal enough to begin decreasing fuel biomass.

Logistic fuel accumulation

- Fuel prevention begins at very low levels (Figure 3b) and biomass increases.
- For all levels of fire risk, fuel removal increases such that fuel begins to decrease later in the rotation. (Figure 3a)

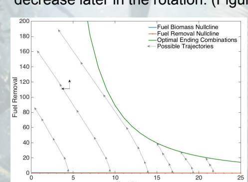

Figure 3a. Fuel removal and fuel biomass phase diagram with logistic fuel accumulation

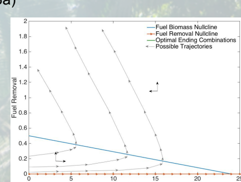

Figure 3b. Magnified view of the lower portion of Figure 3a.

Discussion

Previous economic studies of forest management under fire risk have largely ignored fuel accumulation dynamics. As the results and figures demonstrate, the pattern of accumulation has substantial effects on the pattern of optimal fuel prevention and biomass accumulation during the rotation.

For all cases:

- the landowner should begin the rotation with low levels of prevention, allowing the fuel biomass to accumulate.
- fuel removal increases throughout the rotation as the value of timber on the land increases and the potential economic loss in the event of a fire increases.
- higher fire risk entails higher levels of fuel removal and lower levels of fuel biomass accumulation (higher trajectories in the figures).

When natural limits to fuel accumulation exist:

- under higher fire risk, the landowner should increase fuel removal such that fuel biomass begins to decline later in the rotation.

When natural limits to fuel accumulation do not exist:

- the cost of drawing down fuel biomass later in the rotation exceed the benefits of doing so.
- Higher timber losses will occur in the event of a fire relative to concave and logistic accumulation

Future Work

- Allow for intermittent prevention instead of every year
- Determine the optimal rotation length given optimal fire prevention

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