STRAIGHT FIRE TITLE

Mathematical Modeling Presentation

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Roadmap

- Motivation and Background
- Landscape Modeling
  - Plant Classes
  - The Algorithm
  - Seed Dispersal
  - Long-term Behavior
- Modeling Wildfires
  - Key Parameters
  - Monte Carlo Simulations
  - Wildfire Response Teams
  - The Grid
- Results and Conclusions

Fire Bad

Motivation and Background

- More than 9,000,000,000* USD in insurance claims (North CA, October 2017)
- 2,044,800** households at risk in California
- Wildfire response teams need a defense plan
- How does wildlife respond and recover from wildfires?
- Wildfires are rapidly eradicating more area each year

*California Department of Insurance
**Data based from 2010 Census data

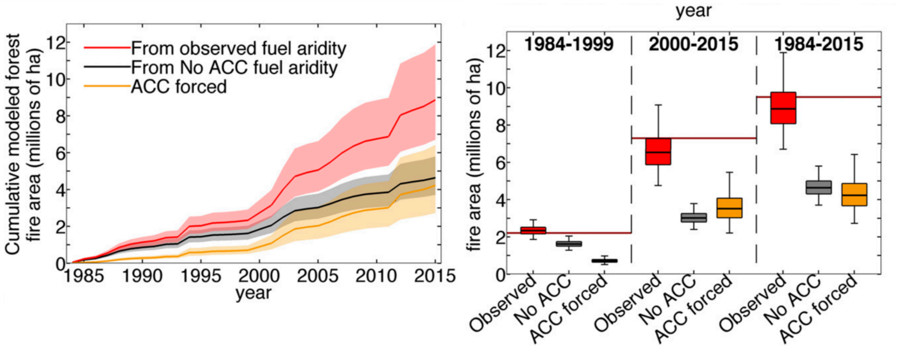


Figure: Abatzoglou, John T., and A. Park Williams. "Impact of anthropogenic climate change on wildfire across western US forests." Proceedings of the National Academy of Sciences 113, no. 42 (2016)

Landscape Fire Succession Models (LSFMs)

General Information

General Algorithm:

- Evolve landscape
- Ingite fire
- Spread fire
- Repeat

Grid:

- Size : 50 x 50
- 2500 Nodes
- 0.01 km^2 per Node
- Each node is dominated by a single plant class

Landscape Plant Classes

Transitions Between Species

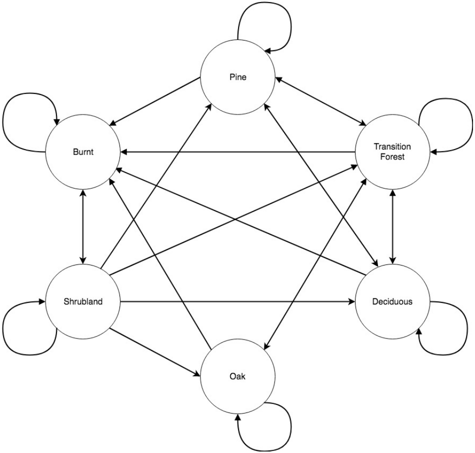


Figure: Plant classes in a Mediterranean climate.

Evolving the Landscape

Algorithm

- Randomly populate a grid point with some plant class. This class will be specified as $C_{current}$. Statement 1
- Determine the next plant class that the grid point will become. This class will be specified as C_{next}. Statement 2
- Find the amount of time it takes for this class transition. This time will be specifed as ΔT. Statement 3
- Iterate time until ΔT has passed. Set $C_{current} = C_{next}$. Statement 4
- Repeat Statements 2-5. Statement 5

Seed Dispersal Probability

Methods of Dispersal

Parameters to Consider:

- Seed size and aerodynamic type.
- Wind driven dispersal.
- Animal driven dispersal.
- Whether a tree is mature enough to disperse seeds.

Assumptions:

- Pine and deciduous tree seeds are mainly dispersed by the wind.
- Acorns are mainly dispersed by birds.
- If a seed is deposited into a node, it will grow into maturity and that is the next class for that node.
- All plants are instantly able to produce seeds.
- If fires completely remove a plant class from the landscape, there is a small chance that one of their seeds could still appear in a node.

Seed Dispersal Probability

Equations and Behavior

Wind-driven dispersal for Pine and Deciduous trees:

$$P(x) = e^{-\frac{b \cdot x}{MD}} \tag{1}$$

where $b = 5$ is a distance-decrease factor, $MD = 100$ is the maximum dispersal distance for pine and deciduous trees, and x is the distance to the nearest pine or deciduous tree.
Bird-driven dispersal for Oak trees:

$$P(x) = \frac{1}{x\sigma\sqrt{2\pi}} \exp\left[-\frac{(\ln(x) - \mu)^2}{2\sigma^2}\right] \tag{2}$$

where $\mu = 46.7$ m is the mean of the dispersal distribution and $\sigma = 2.34$ is the standard deviation of of the dispersal distribution (both of which are empirically gotten).

Landscape Evolution

Long-term Behavior

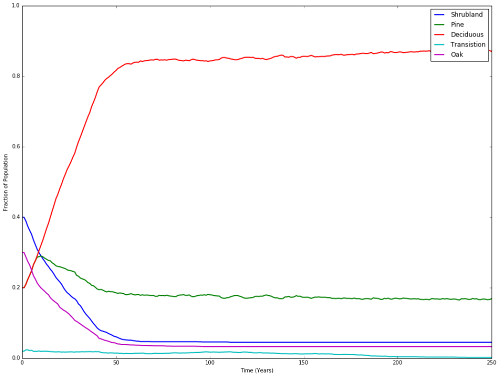


Figure: Landscape makeup over 250 years.

Modeling Wildfires

Key Parameters

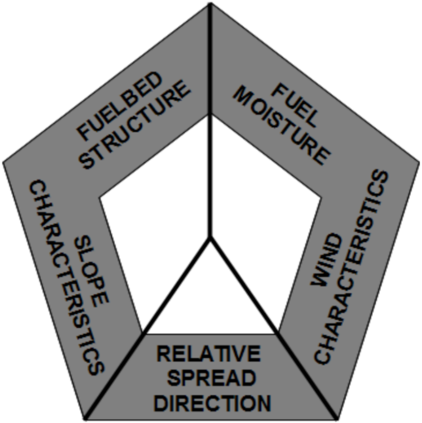


Figure: Scott, Joe H. "Introduction to Wildfire Behavior Modeling." National Interagency Fules, Fire, &Vegetation Technology Transfer., Wild Fire Managment RD&A (2012)

MED-Spread Model:

Coefficient of Spread (CoS)

$$CoS = W_f * fuel + W_m * moisture + W_w * wind + W_e * elevation$$

Intensity:

- Stochastic variable
- Random float [0,2]

Probability of Ignition (P_i)

$$P_i = (1 - e^{CoS})^{Intensity}$$

Fuel Models

Explained

- The MED-Spread model has fuel as a parameter in calculating the coefficient of spread of the fire.
- The fuel load is the amount of flammable material in some area $[\frac{\text{tons}}{\text{acre}}]$.
- The fuel load can be affected by the type of vegetation, the size of vegetation, density of vegetation, and moisture content.
- MED-Spread provides a model for calculating the fuel at each node within a landscape grid.
- However, this equation would require us to produce and store even more information about each cell node.

Fuel Models

Cont.

Fuel loads for different classes:

- Burnt = Non-burnable
- Shrubland = $3.2123751 \text{x} 10^{-3}$ tons/m^2
- Pine = $1.2355258 \text{x} 10^{-3}$ tons/m^2
- Deciduous/Oak = $8.648680706 \text{x} 10^{-4}$ tons/m^2
- Transition Forest = $9.884206521 \text{x} 10^{-4}$ tons/m^2

Fuel load vaules from "Aids to determining fuel models for estimating fire behavior." by Hal E. Anderson

Fighting the Fire

Wildfire Response Teams (WRT)

Response Locations R_L = The number of Nodes on fire

Number of Wildfire Response Teams (N_{WRT}):

$$N_{WRT} = \sum_{i=0} k_i * (R_L)^i$$

- i is related to the degree of response
- if the maximum response is reached the maximum N_{WRT} stay until the wildfire is over

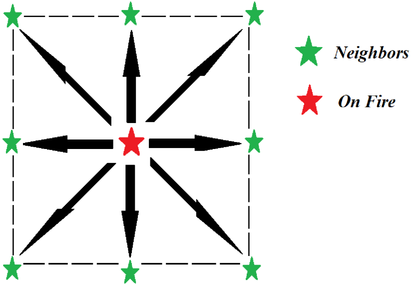
Probability of Extinguish (P_{Ex})

$$P_{ex} = 0.5$$

The GRID

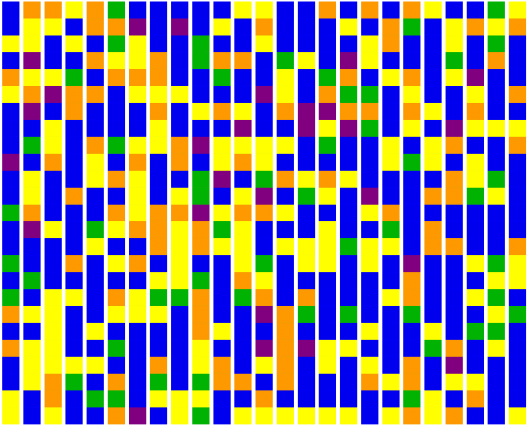
Discretizing the Forest

- Size : 50 x 50
    - 2500 Nodes
    - 0.01 km^2 per Node
    - Each node is a single species
- Ignition:
    - WRT => simulate Probability of Extinguished
    - Each WRT responds to a single Node
    - Simulate at each Neighbor
    - Continue until all fires have burned out or have been extinguished



Demonstration

It’s gif like the peanut butter



Conclusion

Closing Remarks

- Wildfires will be exacerbated by climate change in the coming years
- Massive loss of biomass if we cannot effectively control wildfire
- Wildlife will not recover unless drastic measures are taken

Future work:

- **Time Series Simulation $\approx$ 250 years**
- Change wind from a ignition probability parameter to parameter that determines Neighbors
- Rework WRT code and model
- Map the paths of wildfire spread for various distributions in hope of gaining some insight

Thanks for listening!

And remember

ONLY YOU CAN PREVENT FOREST FIRES!