Forest Fire Analytics

EECS 4414 - Information Networks (Fall 2020)

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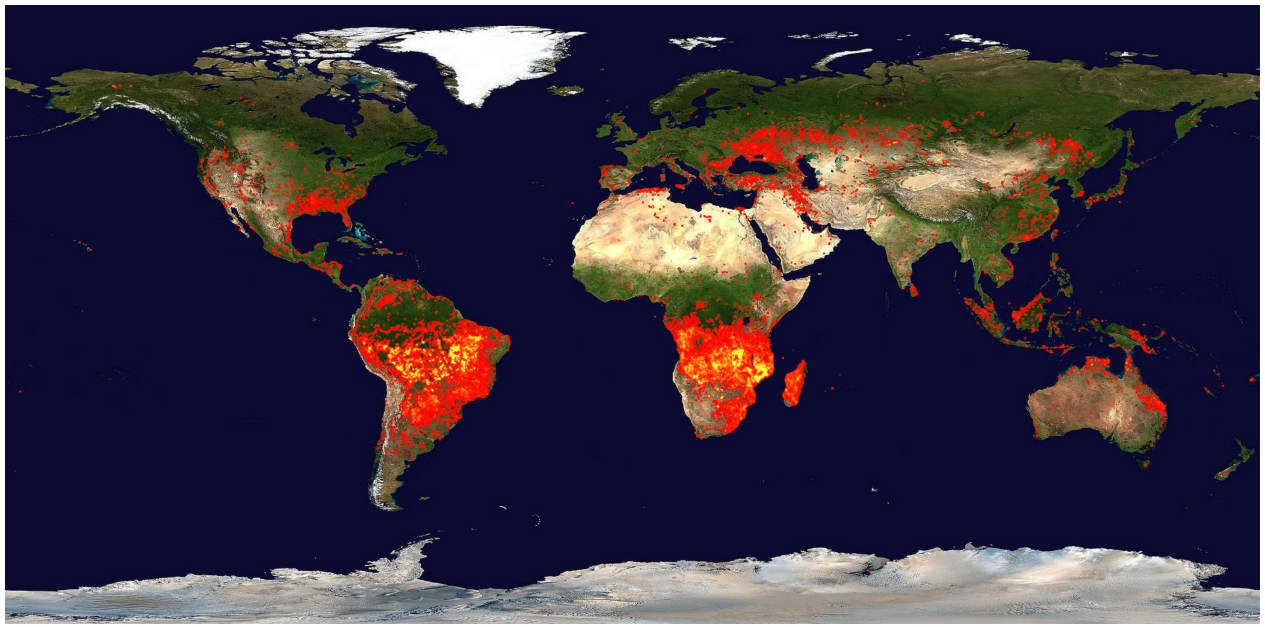
Outline

Introduction

- Forest fire - A growing problem world widely



- Irreversible environmental and socio-economic damages
- Need for more accurate fire simulation & efficient fire control

Introduction

Research focus:

- Fire propagation modelling based on topographical and weather conditions
- Forest fire simulation
- Forest fire control strategies

Problem Definition

Problem 1

Given an area, construct the lattice network G and integrate elevation, slope, aspect and wind conditions into the network through linear threshold model.

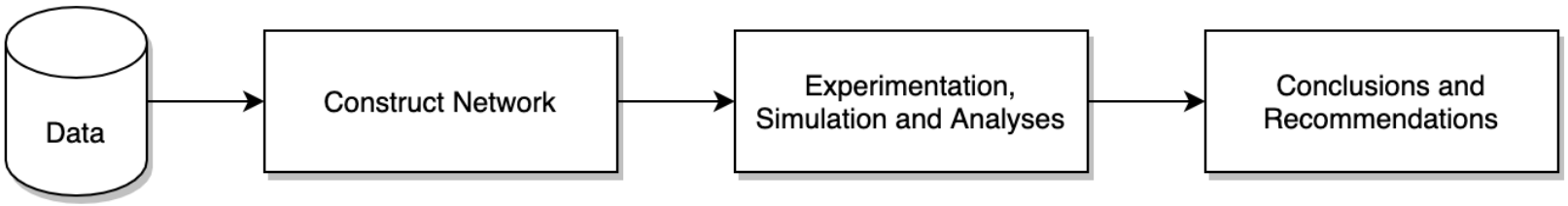
Problem 2

Given a lattice network, simulate wildfire propagation in the network.

Problem 3

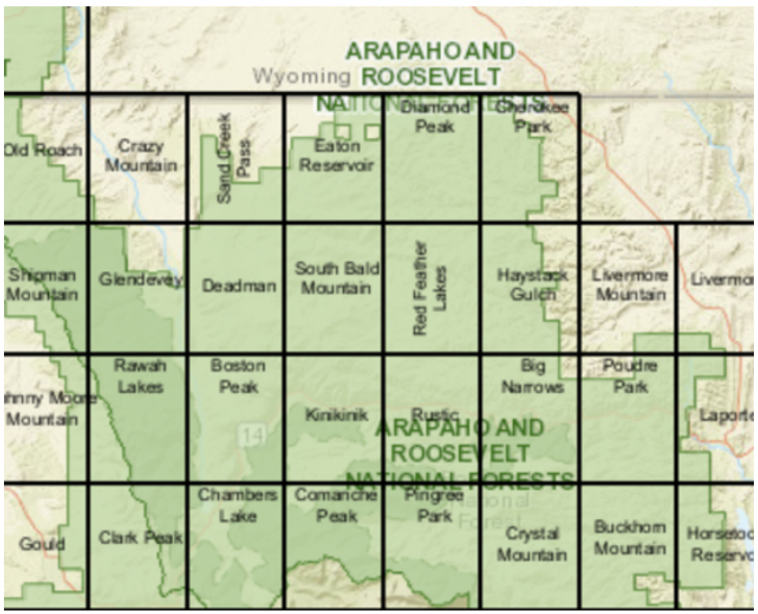
Propose fire prevention strategies to decrease the total damage caused by fire.

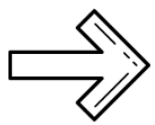
Framework

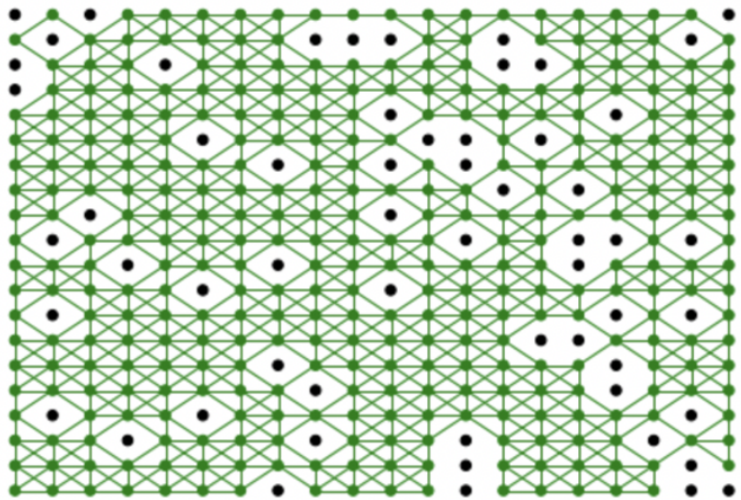

Data
Construct Network
Experimentation, Simulation and Analyses
Conclusions and Recommendations

Dataset

- The Roosevelt National Forest in Colorado
- Lattice network: 30m×30m grid forest
- Each grid includes: elevation, slope and aspect.







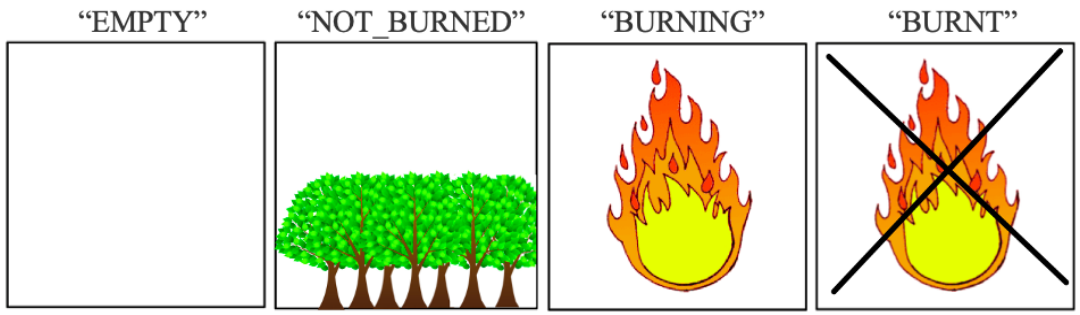
Methodology

Network Construction: a lattice network $G(N, E)$

N: set of nodes – terrain patches

E: set of edges between nodes – neighboring forests

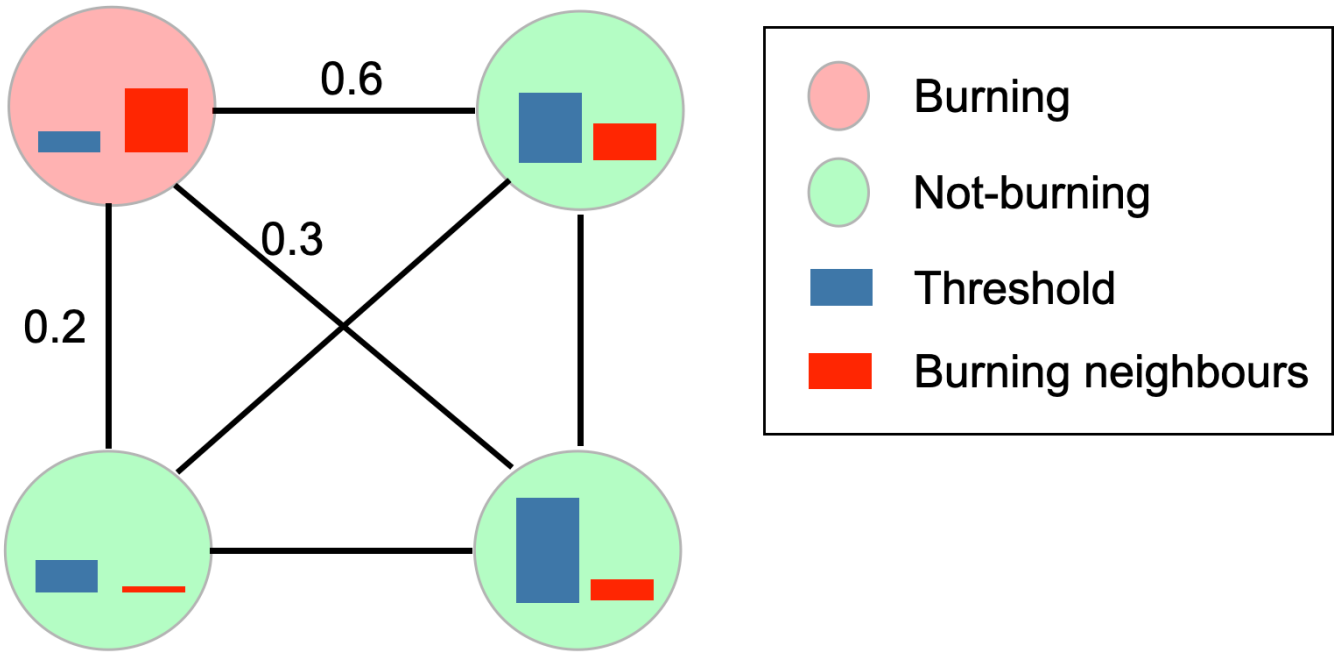
- (Forest) Node's states:



- ρ: the forest density of the network

Methodology

Network Construction - Linear Threshold Model:



Thresholds θ: determined by elevation, slope and aspect
Weights β: determined by wind and distance

Methodology

Topographic Influences on Forest Fire Behavior - Slope:

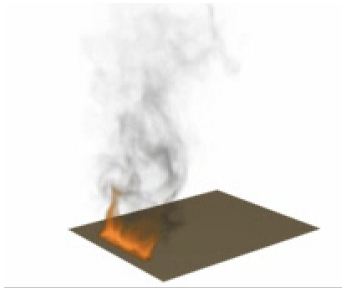


Fig1. zero slope

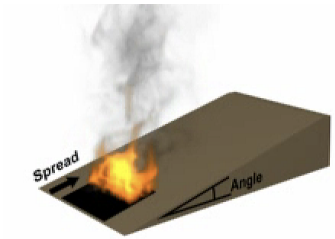


Fig2. low slope

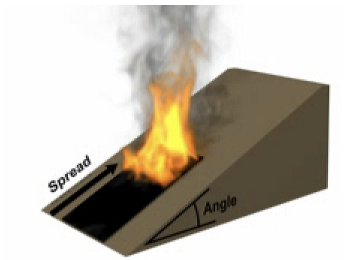


Fig3. medium slope

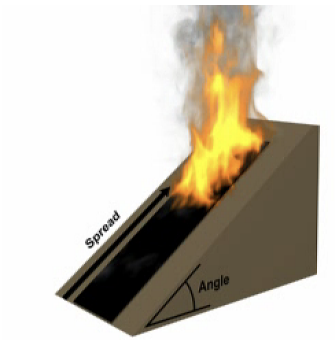
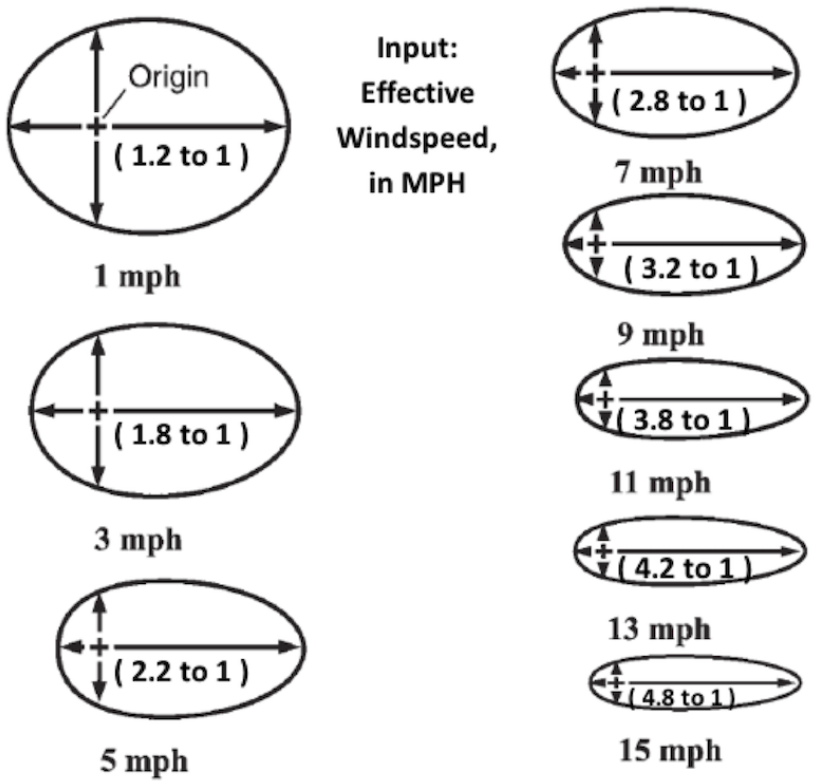


Fig4. high slope

Methodology

Weather Influences on Forest Fire Behavior - Wind:



Methodology

(Mathematical) model of features in node threshold & edge weight:

Symbol	Nomenclature	Formula
ϕ_s	slope coefficient	$5.275(\tan\phi)^2$
ξ	elevation coefficient	$\frac{1}{1+\ln(\max\{he^{-6},1\})}$
α	aspect coefficient	(See **Table 2**)
ϕ_w	wind speed	$\gamma\cos\tau$
δ	node Euclidean distance	$\sqrt{\Delta^2 x+\Delta^2 y}$

Methodology

Fire Prevention (removal of edges strategies):

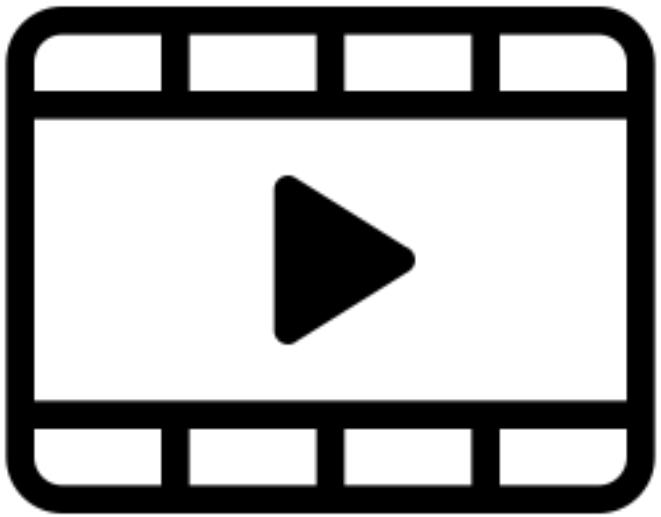
- Strategy 1: Using the Girvan-Newman (GN) algorithm:
  - removing edges with the highest betweenness scores
  - isolating communities of forests
  - limitation: location
- Strategy 2: Using the GN with extension (**FIGHTER**):
  - neighborhood-based Edge-Removal approach
  - takes into consideration the location of where edges are being pruned previously

Algorithms

- **INCINERATE**: Fire Simulation Algorithm
  - **INPUT**: The Graph $G(N, E)$
  - **OUTPUT**: The resultant forest graph after fire propagation simulation according to the LT model
- **FIGHTER**: Fire Prevention Algorithm
  - **INPUT**: Graph $G(N, E)$, K number of edges to remove, and threshold λ
  - **OUTPUT**: E', the edges removed based on betweenness centrality and local neighborhood

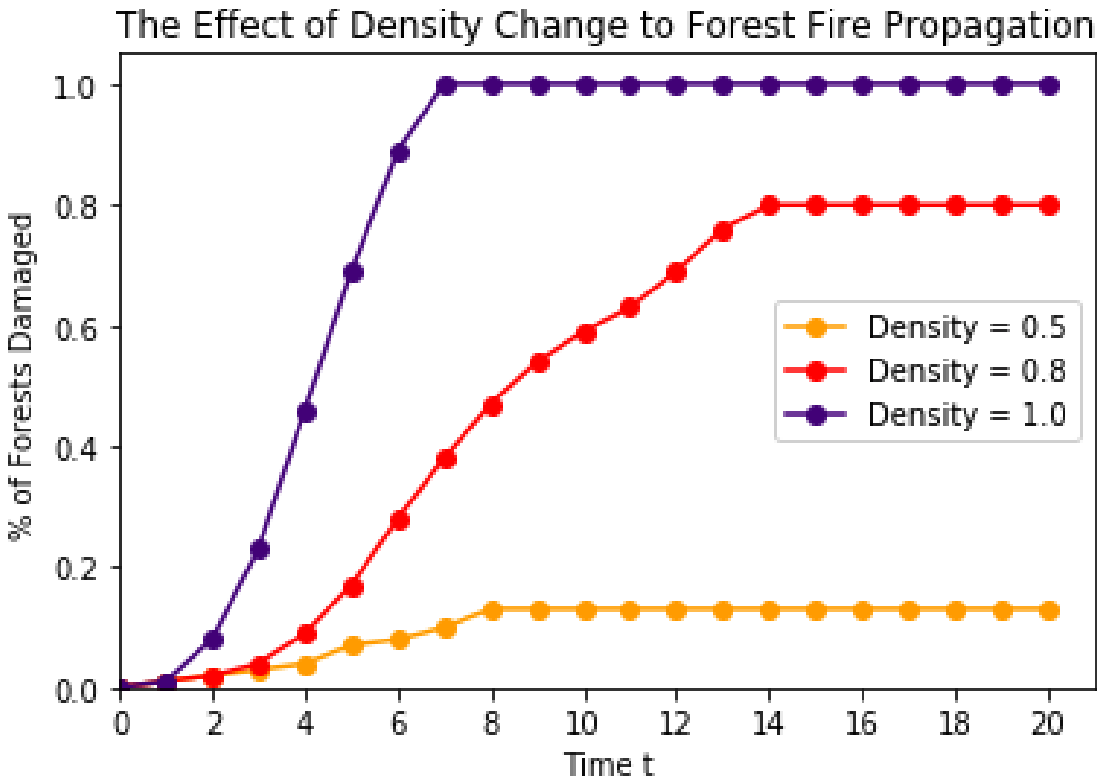
Experiments and Results

- Fire Propagation Simulator (**INCINERATE**)



Experiments and Results

Different values of the forest density ρ:



Experiments and Results

Effect of slope, elevation and wind on forest fire damages:

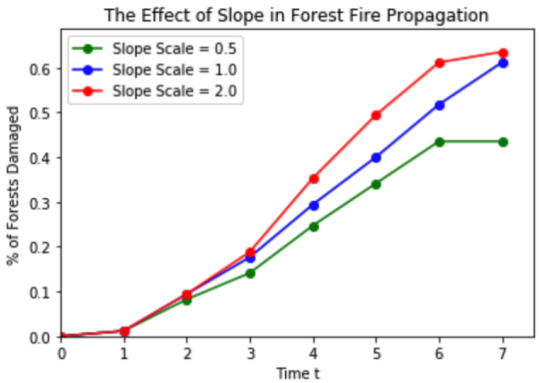


Figure: Slope

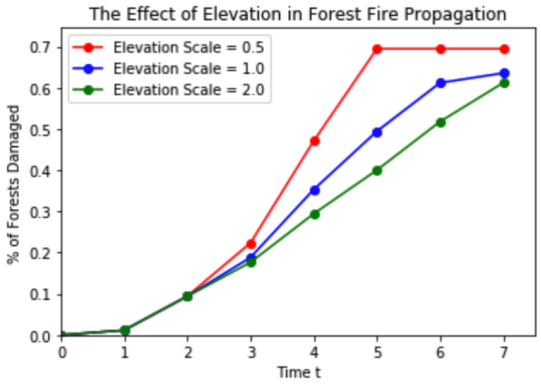


Figure: Elevation

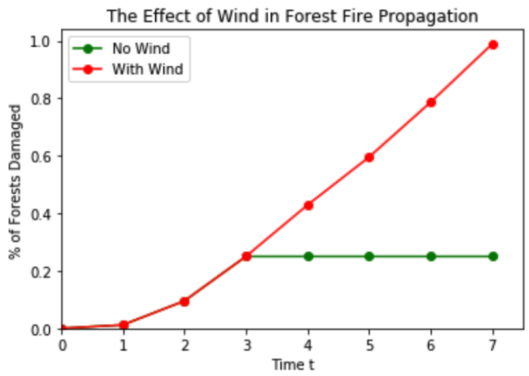
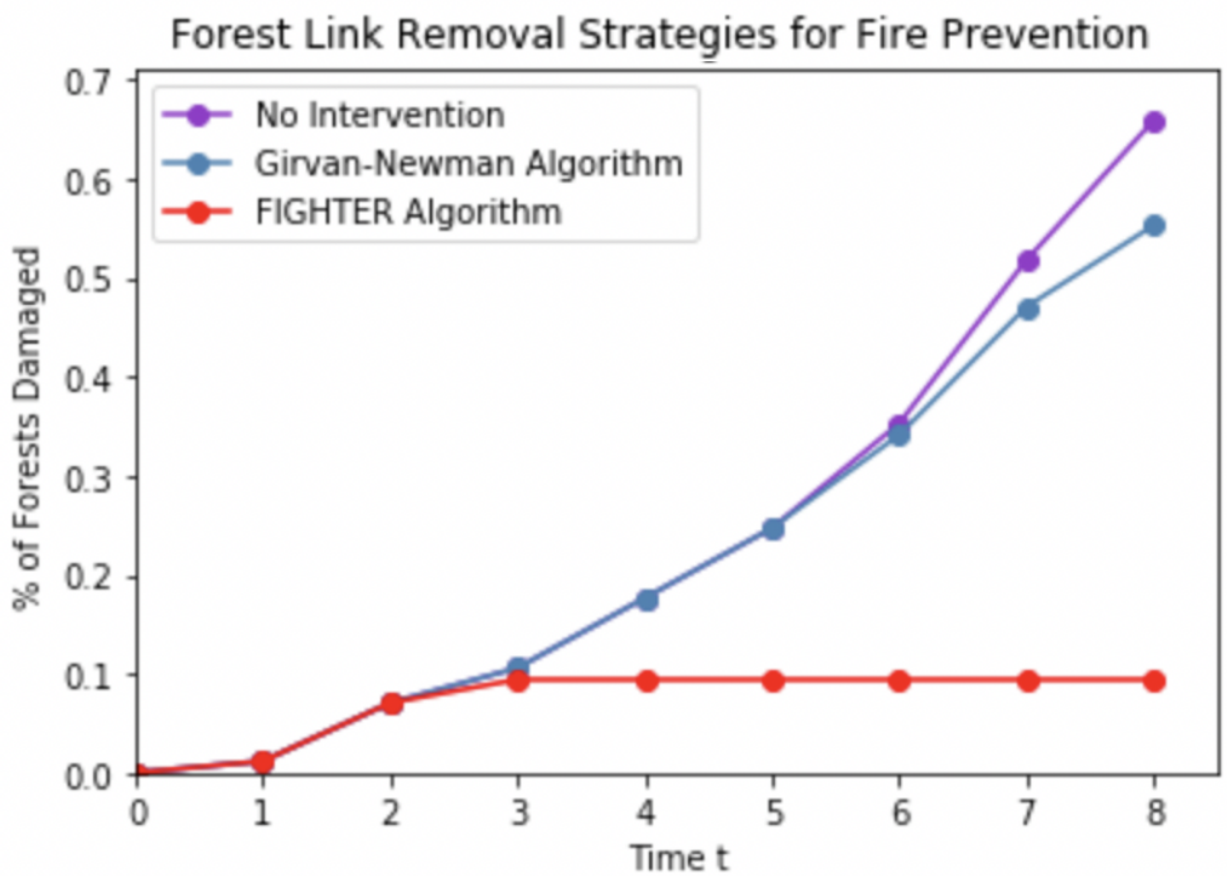


Figure: Wind

Experiments and Results

Result of different prevention strategies:



Conclusion

- We constructed the network by modelling features such as elevation, slope and aspect through linear threshold model.
- We simulated fire propagation in networks.
- We designed and implemented the prevention strategy and the strategy outperformed than Girvan-Newman.
- Possible future work could be including other factors that affect fire propagate and other prevention strategies.

Image Sources:

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- https://www.nasa.gov/topics/earth/features/wildfires.html
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Thank You!

Questions?