Fire in the Pines: A Landscape Perspective of Human-induced Ecological Change in the Pinelands of New Jersey

November 17th, 2011

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Department of Ecology and Evolution
Rutgers University
Ecology: Fire and succession

Fire in the Pine Barrens: Keeping the Oak at Bay

By IVER PETERSON
Published: May 29, 1992
Ecology: Fire effects

Jamie Cromartie
Unique Ecology

Endemic species, unique habitat
Fire adaptations
Nutrient poor, sandy soils

Endangered Swamp Pink

Threatened Pine Barrens Tree Frog

Dwarf Pine plains region

Endangered Northern Pine Snake

Michael Hogan photography
USFS
NJ Pine Barrens and Down Jersey

Rare Curly-grass fern
Human: Development

New Jersey Land Cover Change Animation

>1972
>1984
>1995
>2001
>2010

- Developed Land
- Cultivated/Grassland
- Upland Forest
- Bare Land
- Wetland
- Water

RUTGERS CRSSA
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Grant F. Walton Center for Remote Sensing and Spatial Analysis (CRSSA)
http://crssa.rutgers.edu
Human: Pinelands National Reserve

Created in 1978 as first National Reserve and now designated a US and International Biosphere Reserve

Administered by Pinelands Commission via CMP

~1,000,000 acres / 550,000 ha
Established in 1906 to protect life, property and forest resources, early Rx fire 1950s

“The goal is to limit the number of wildfires to under 2,000 annually and the acreage burned to less than one half of one percent (.5%) of the 3.15 million acres protected (all of NJ), or 15,750 acres.”
Coupled Human-Environment System

How does the Pinelands ecosystem affect us?
- Fire danger dictates development patterns
- Carbon sequestration

How do we affect the Pinelands ecosystem?
• Disturbance
  – Wildfire (accidental or arson)
  – Altered land
  – Climate change
• Management
  – Prescribed fire/ suppression
  – Protected areas
Paper map dataset
Focus on Barnegat and Mullica 1927-2002

2167 fires total
963 wildfires
1204 prescribed

‘Large fires’ >100 acres
Rx fire all sizes
3 interns, 2 years

Other info:
Cause of fire
Acres reported
Acres calculated
Fire start date
Fire end date
Fire regime

Landuse/Landcover change

Size, Location, Frequency

Ch 1

Defining the ecological wildland urban interface

Ch 2

Fire and Water

Ch 3

Fire and LULC Scenarios with LANDIS-II

Forest composition (Oak vs. Pine – who wins?)

Ch 4

Climate Scenarios with LANDIS-II

Forest composition and biomass
Chapter 2: Effects of wildfire on water quality

### Table

<table>
<thead>
<tr>
<th>Variable</th>
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<td><strong>pH</strong></td>
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<tr>
<td>Percent basin burned</td>
<td>0.248</td>
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<td>Days before fire</td>
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<td>Days after fire</td>
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<td>Hectares burned</td>
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<td>Overall model</td>
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<td>Days after fire</td>
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<td>Hectares burned</td>
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<td>Overall model</td>
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Fire regime

Landuse/Landcover change

Size, Location, Frequency

Fire and Water

Ch 1

Defining the ecological wildland urban interface

Ch 2

Historic landscape level relationships

Ch 3

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Forest composition and biomass
Chapter I – the WUI challenge
By marking, we project ourselves onto the environment (Huyghe 1962).

• How does our presence alter adjacent ecological processes?

“How altered landscapes will themselves influence disturbance regimes is not known (Turner 2005)”.

• Ecological Wildland-Urban Interface (EWUI) or the spatial extent to which altered land, through indirect changes in disturbance regimes, influences the adjacent ecology of natural areas
Area of Ecological Influence

Indirect Disturbance Influence - EWUI

Direct Disturbance Influence = Edge effect

Natural Area

Home

Yard
How to estimate the EWUI:

1. Spatial/temporal measure of human influence (altered land)

2. Record of spatial/temporal disturbance regime (fire)

3. Spatial measure of an ecological pathway (forest succession)

4. Method of evaluating the spatial extent and intensity of the human influence (buffer areas of altered land) on the disturbance regime and ecological pathway
1. Human Influence

Altered land 1986

Altered land 2002
2. Record of disturbance
3. Ecological Pathway

1986 to 2002

Transition Categories

Value
- Dec to Dec
- Con to Dec
- Con to Con
- Mix to Con

0 5 10 20 Kilometers

Change in Upland Forest Composition: Barnegat

Change in Upland Forest Composition: Mullica
4. Method for extent of influence

Buffers 1986

Buffers 2002
Altered land
Interior forest
Non forested
Forest area transitioning closer to altered land
Succession vs. Proximity to altered land

**a) Percent Total of Fire Frequencies for Forest Composition Change Categories:**
- Barnegat

<table>
<thead>
<tr>
<th>Category</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<td>UPCON to UPDEC</td>
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<td>UPMIX to UPCON</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>

**b) Percent Total of Fire Frequencies for Buffer Transition Categories:**
- Barnegat

<table>
<thead>
<tr>
<th>Category</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<td>Adjacent to altered</td>
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<tr>
<td>Transitioning toward altered</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior natural area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fire frequency per forest composition change category
Fire frequency per buffer transition category
Succession vs. Proximity to altered land

a) Percent Total of Fire Frequencies for Forest Composition Change Categories: Mullica

Percent burned

0 1 2 3 4 5
UPDEToUPDEC UPCONtoUPDEC UPCONtoUPCON UPMIXtoUPCON

Fire frequency per forest composition change category

b) Percent Total of Fire Frequencies for Buffer Transition Categories: Mullica

Percent burned

0 1 2 3 4 5
Adjacent to altered Transitioning toward altered Middle Interior natural area

Fire frequency per buffer transition category
a) Ignitions within Buffer Transition Categories: Barnegat

b) Ignitions within Buffer Transition Categories: Mullica
Conclusions:

- The EWUI extends 240-480m from altered land into interior natural areas of the Pinelands of New Jersey
- Areas with different disturbance and altered land histories will vary in EWUI extent and magnitude of ecological influence

“How altered landscapes will themselves influence disturbance regimes is not known (Turner 2005)”.

- Altered land can have a large indirect affect on disturbance regimes and thus ecological processes in adjacent natural areas
- Elucidating EWUI factors will assist in predicting future ecological change under different management plans
Clustering altered land may reduce EWUI effects and magnitude
Fire regime

Landuse/Landcover change

Size, Location, Frequency

Defining the ecological wildland urban interface

Ch 1

Fire and LULC Scenarios with LANDIS-II

Forest composition (Oak vs. Pine – who wins?)

Ch 3

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Forest composition and biomass

Ch 4

Fire and Water

Historic landscape level relationships
Chapter 3: The future’s so bright…

“I have sometimes been accused of being a ‘modeler’. I wish to state that I am not now nor have I ever been a modeler’. I was (and am) an ecologist who needed a model.”

Mladenoff (2005)
LANDIS-II architecture

- Ecoregions
- Initial Communities
- Disturbance
- Seed Dispersal
- Maximum Age
- Maximum Biomass
- Species Establishment Probability
- Aboveground Net Primary Productivity
Core LANDIS-II

Ecoregions

- Split into upland/lowland using LULC
- Classed into L/M/H WHC from SSURGO data
- Added Pine Plains ecoregion for 7 ecoregions total

<table>
<thead>
<tr>
<th>Description</th>
<th>Ecoregion</th>
<th>WHC (cm)</th>
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<tr>
<td>UpLow</td>
<td>2</td>
<td>6.965</td>
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<tr>
<td>UpMed</td>
<td>3</td>
<td>7.361</td>
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<td>UpHigh</td>
<td>4</td>
<td>7.680</td>
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<tr>
<td>WetLow</td>
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<tr>
<td>WetMed</td>
<td>6</td>
<td>7.933</td>
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<tr>
<td>WetHigh</td>
<td>7</td>
<td>8.437</td>
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<tr>
<td>Plains</td>
<td>8</td>
<td>7.236</td>
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</tbody>
</table>

Scheller RM, Van Tuyl S, Clark KL, Hom J, La Puma I (2011)
Core LANDIS-II

Initial Communities

• Developed from 2005-2009 FIA data with 14 species

• Cohorts based on dbh to age relationships for all species within the FIA dataset

• FIA forest type determined by dominant species and assigned randomly to forest type polygon

Scheller RM, Van Tuyl S, Clark KL, Hom J, La Puma I (2011)
### Species parameters

<table>
<thead>
<tr>
<th>Species</th>
<th>Longevity (yrs)</th>
<th>Age at maturity (yrs)</th>
<th>Shade tolerance</th>
<th>Fire tolerance</th>
<th>Effective seeding distance (m)</th>
<th>Max seeding distance (m)</th>
<th>Probability of resprout</th>
<th>Min resprout age (yrs)</th>
<th>Max resprout age (yrs)</th>
<th>Post-fire regeneration</th>
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<td>Acer rubrum</td>
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<td>10</td>
<td>4</td>
<td>1</td>
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<td>1000</td>
<td>0.5</td>
<td>10</td>
<td>140</td>
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<td>Chamaecyparis thyoides</td>
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<td>12</td>
<td>3</td>
<td>3</td>
<td>183</td>
<td>1000</td>
<td>0.5</td>
<td>5</td>
<td>100</td>
<td>100 respout</td>
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<td>Nyssa sylvatica</td>
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<td>15</td>
<td>4</td>
<td>2</td>
<td>30</td>
<td>1000</td>
<td>0.75</td>
<td>0</td>
<td>100</td>
<td>none</td>
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<tr>
<td>Pinus echinata</td>
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<td>20</td>
<td>1</td>
<td>3</td>
<td>60</td>
<td>500</td>
<td>0.75</td>
<td>5</td>
<td>25 respout</td>
<td></td>
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<tr>
<td>Pinus rigida</td>
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<td>5</td>
<td>1</td>
<td>3</td>
<td>60</td>
<td>250</td>
<td>0.75</td>
<td>5</td>
<td>60 respout</td>
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<tr>
<td>Quercus alba</td>
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<td>40</td>
<td>3</td>
<td>3</td>
<td>30</td>
<td>3000</td>
<td>0.5</td>
<td>5</td>
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<td>1</td>
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<td>0.5</td>
<td>5</td>
<td>75 respout</td>
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<tr>
<td>Quercus falcata</td>
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<td>5</td>
<td>25 respout</td>
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<tr>
<td>Quercus prinus</td>
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<td>3</td>
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<td>5</td>
<td>60 respout</td>
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<tr>
<td>Quercus velutina</td>
<td>250</td>
<td>20</td>
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<td>2</td>
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<td>3000</td>
<td>0.4</td>
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<td>Liquidambar styraciflua</td>
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<td>25</td>
<td>2</td>
<td>2</td>
<td>60</td>
<td>180</td>
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<td>10</td>
<td>2</td>
<td>2</td>
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<td>3000</td>
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<td>1</td>
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<td>0.75</td>
<td>5</td>
<td>150 respout</td>
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</table>

Shade and fire tolerance are on a scale from 1 (least shade tolerant/least fire tolerant) to 5 (most tolerant). Data derived from Scheller et al (2008, 2011).
Scenarios LANDIS-II

Current altered land

Future possible altered land

Conway and Lathrop 2005, Lathrop and Haag 2007

33,209 hectares = 82,061 acres
Scenarios LANDIS-II
Stochastic Fire Calibration LANDIS-II

<table>
<thead>
<tr>
<th>Modern fire regime</th>
<th>Final Calibration</th>
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<tr>
<td>stddev (ha)</td>
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<tr>
<td>mu</td>
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<tr>
<td>sigma</td>
<td>0.880</td>
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<tr>
<td>mean igtn/ yr</td>
<td>6.800</td>
</tr>
</tbody>
</table>

20 year modeled output

Percent difference

- Mean:
  - Modern: 1065.170
  - Final: 1226.414
  - Difference: 161.244

- Stddev:
  - Modern: 1958.719
  - Final: 1797.160
  - Difference: 161.559

- Mean Igt/yr:
  - Modern: 1.500
  - Final: 1.450
  - Difference: 0.050

- Sigma:
  - Modern: 0.880
  - Final: 8.603
  - Difference: -7.723

- Mean Igt/yr:
  - Modern: 6.800
  - Final: -3.390
  - Difference: 10.190
Results Forest Cover

Time = 0

Time = 100
<table>
<thead>
<tr>
<th>Model scenario</th>
<th>mu</th>
<th>sigma</th>
<th>mean igtn / yr</th>
<th>mean (ha)</th>
<th>stddev (ha)</th>
<th>mean igtn / yr</th>
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<td>Altered land</td>
<td>9.000</td>
<td>0.880</td>
<td>6.800</td>
<td>1061.509</td>
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<td>Altered with EWUI</td>
<td>9.000</td>
<td>0.880</td>
<td>6.800</td>
<td>523.506</td>
<td>1021.078</td>
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<tr>
<td>Buildout with EWUI</td>
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<td>6.800</td>
<td>268.766</td>
<td>510.661</td>
<td>1.580</td>
</tr>
</tbody>
</table>
Results Percent Total Biomass

(a) Altered Land Biomass

(b) Altered EWUI Biomass

(c) Buildout Biomass

(d) Buildout EWUI Biomass

Legend:
- ATWHCED
- PINE
- PINE PLAINS
- LOWDEC
- UPDEC
What did we learn?

“If fires are kept out … the usual forest growth that develops … follows this pattern: first, a pine stand develops; then hardwoods, chiefly oaks, seed under the pines. Later, as the pines mature and die, hardwoods dominate the stand.”

--Silas Little 1978
Conclusions

• Based on modern fire regime, model forecasts show quick decline in pine cover

• EWUI exacerbates the loss of fire

• Buildout scenarios and increased fragmentation also exacerbate the loss of fire

• Spatial results show areas of heterogeneity and where to focus efforts

• If prescribed fire outside of current Rx areas is not incorporated pine cover may be limited
**Ch 1**

*Defining the ecological wildland urban interface*

**Ch 2**

*Historic landscape level relationships*

**Ch 3**

*Fire and LULC Scenarios with LANDIS-II*

*Forest composition (Oak vs. Pine – who wins?)*

**Ch 4**

*Climate Scenarios with LANDIS-II*

*Forest composition and biomass*
“The resilience of many ecosystems is likely to be exceeded this century by an unprecedented combination of climate change, associated disturbances (e.g., wildfire), and other global change drivers (e.g., land-use change).”

IPCC Climate Change 2007: Working Group II: Impacts, Adaptation and Vulnerability
Climate Change Scenario

- A2 = Status quo
- Little cooperation
- Increasing population
- Downscaled to our region
Climate change as a disturbance

WHC for each Ecoregion

Functional group physiology: pine, southern hardwood, northern hardwood
Growing degree days: affect of temperature on photosynthesis and species establishment
CO₂ fertilization effect of stomatal conductance and water use efficiency (yes/no)
<table>
<thead>
<tr>
<th>Model scenario</th>
<th>mu</th>
<th>sigma</th>
<th>mean igtn / yr</th>
<th>mean (ha)</th>
<th>stddev (ha)</th>
<th>mean igtn / yr</th>
<th>Total area burned (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altered with EWUI</td>
<td>9.000</td>
<td>0.880</td>
<td>6.800</td>
<td>523.506</td>
<td>1.740</td>
<td>91090</td>
<td></td>
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<tr>
<td>Altered with EWUI and A2</td>
<td>9.000</td>
<td>0.880</td>
<td>6.800</td>
<td>496.804</td>
<td>1.630</td>
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<tr>
<td>Buildout with EWUI</td>
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<td>0.880</td>
<td>6.800</td>
<td>268.766</td>
<td>1.580</td>
<td>42465</td>
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</tr>
<tr>
<td>Buildout with EWUI and A2</td>
<td>9.000</td>
<td>0.880</td>
<td>6.800</td>
<td>259.972</td>
<td>1.450</td>
<td>37696</td>
<td></td>
</tr>
</tbody>
</table>

Final Calibration:

100 year output

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**Diagram Description:**

- **Axes:**
  - **Y-axis:** Hectares
  - **X-axis:** Ecoregion

- **Legend:**
  - PINE PLAINS
  - PINE

- **Bars:**
  - UPLow, UPMed, UPHigh, WETLow, WETMed, WETHigh, PLAINS

- **Ecoregions:**
  - UPLow: Low Altitude Upland
  - UPMed: Medium Altitude Upland
  - UPHigh: High Altitude Upland
  - WETLow: Low Altitude Wetland
  - WETMed: Medium Altitude Wetland
  - WETHigh: High Altitude Wetland
  - PLAINS: Plains

- **Legend Colors:**
  - Inactive
  - ATW-ICEF
  - PINE
  - PINE PLAINS
  - DECID

---

**Figure Details:**

- **a)**
- **b)**

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**Notes:**

- The table above summarizes the modeled results for different scenarios, including mean values and variances for the area burned over the year.
- The diagram illustrates the distribution of hectares across various ecoregions, highlighting the impact on different landscapes.
- The legend provides a color-coded reference for the types of vegetation or environmental conditions represented in the diagram.
Results: Total Biomass

- Altered EWUI
  - Total Biomass (g C m\(^{-2}\) y\(^{-1}\)) vs. Timestep
- Buildout EWUI
  - Total Biomass (g C m\(^{-2}\) y\(^{-1}\)) vs. Timestep
- Altered EWUI A2
  - Total Biomass (g C m\(^{-2}\) y\(^{-1}\)) vs. Timestep
- Buildout EWUI A2
  - Total Biomass (g C m\(^{-2}\) y\(^{-1}\)) vs. Timestep
Model limitations

- Insect defoliation (gypsy moth, southern pine beetle)
- Extremes in climate (drought)
- Epicormic sprouting abilities (effect depends on amount of fire)
Conclusions

• Climate change does not change fire regime

• Raising CO2 and temperature accelerates loss of pine cover

• Incorporating prescribed fire may be even more important for pine persistence under a changing climate
Which is better, pine or oak?

- Unique habitat
- Water quality
- Pre-colonial levels – more oak?
- 99% human caused ‘wildfire’
- Fire safety (access)
- Carbon sequestration
- Viability under climate change, insect infestations
Management Recommendations

For Pinelands Commission:

Limit further fragmentation to stop expansion of EWUI

Consider climate change in management plans

For New Jersey Forest Fire Service:

Include severity in fire records
Improve prescribed fire recording
Consistent large fire records

Goals include the idea that: “the continued integrity of the Pinelands vegetation is essential to the preservation and maintenance of the essential character (and ecological values) of the Pinelands”
Management Recommendations

For Land holders: DEP, Conservation groups, Private landholders

Accidental fire won’t maintain integrity of pinelands ecosystem

Expand scope to include maintenance of pine cover via ecologically based prescribed fire
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Questions?