Spatial Simulation of Chaparral Plants with Frequent Wildfire

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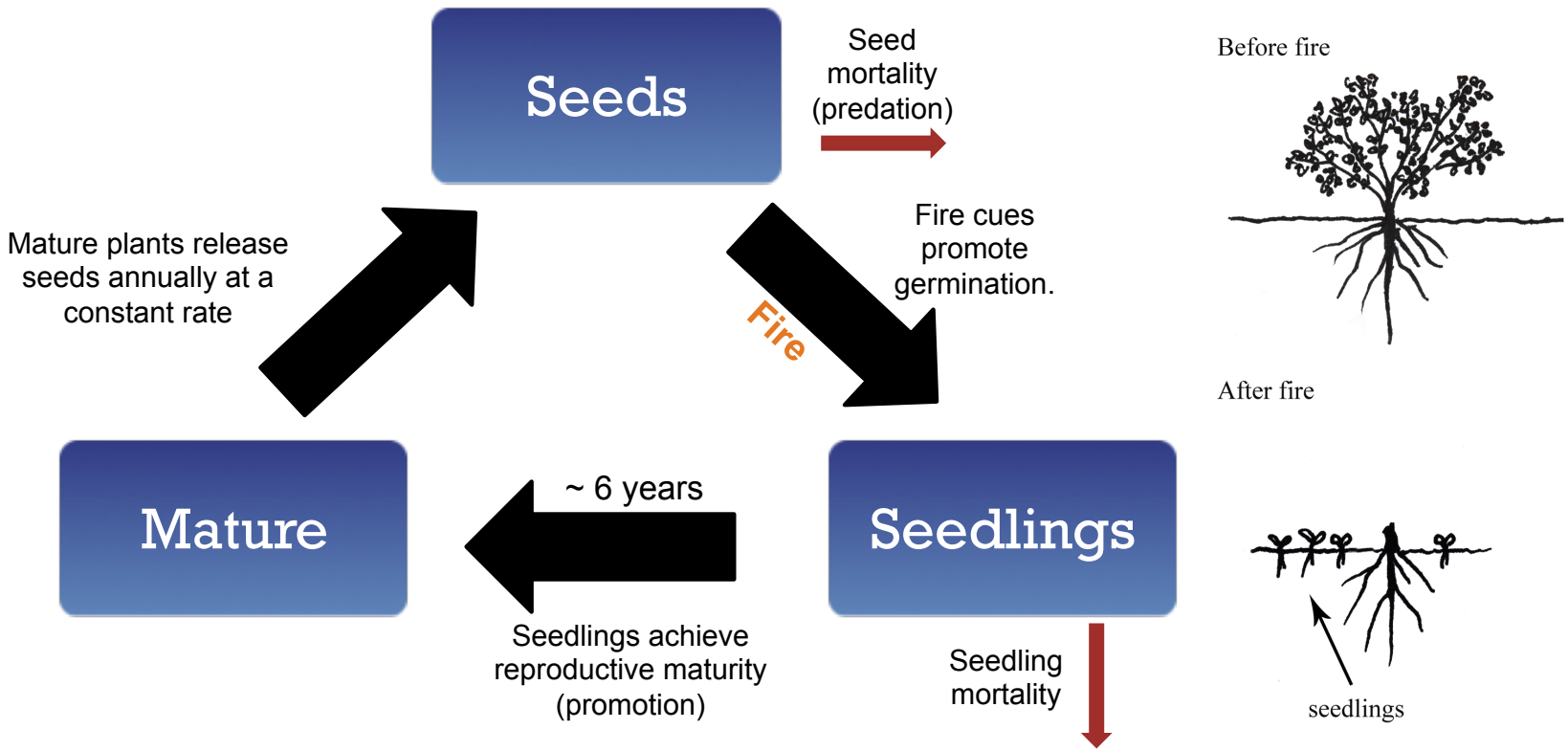
Chaparral Vegetation and Fire Frequency in the SMM

- Chaparral shrubs represent the dominant vegetation type in the Santa Monica Mountains (SMM).
- The deep roots of chaparral shrubs are responsible for keeping the hillside in tact.
- Recent increase in fire frequency in the SMM
  - Santa Monica Mountains, 1925-2001:
    Average time between fire was 32 years
  - Malibu Study Site, 1985-2011:
    Average Time Between Fire was just over 6 years
- Frequent wildfires have altered plant community structure.
  - Localized extinction of particular chaparral species.
  - Invasion of exotic grasses that increase flammability.
- Reduction in vegetation cover leads to decrease in slope stability, e.g erosion, mudslides.

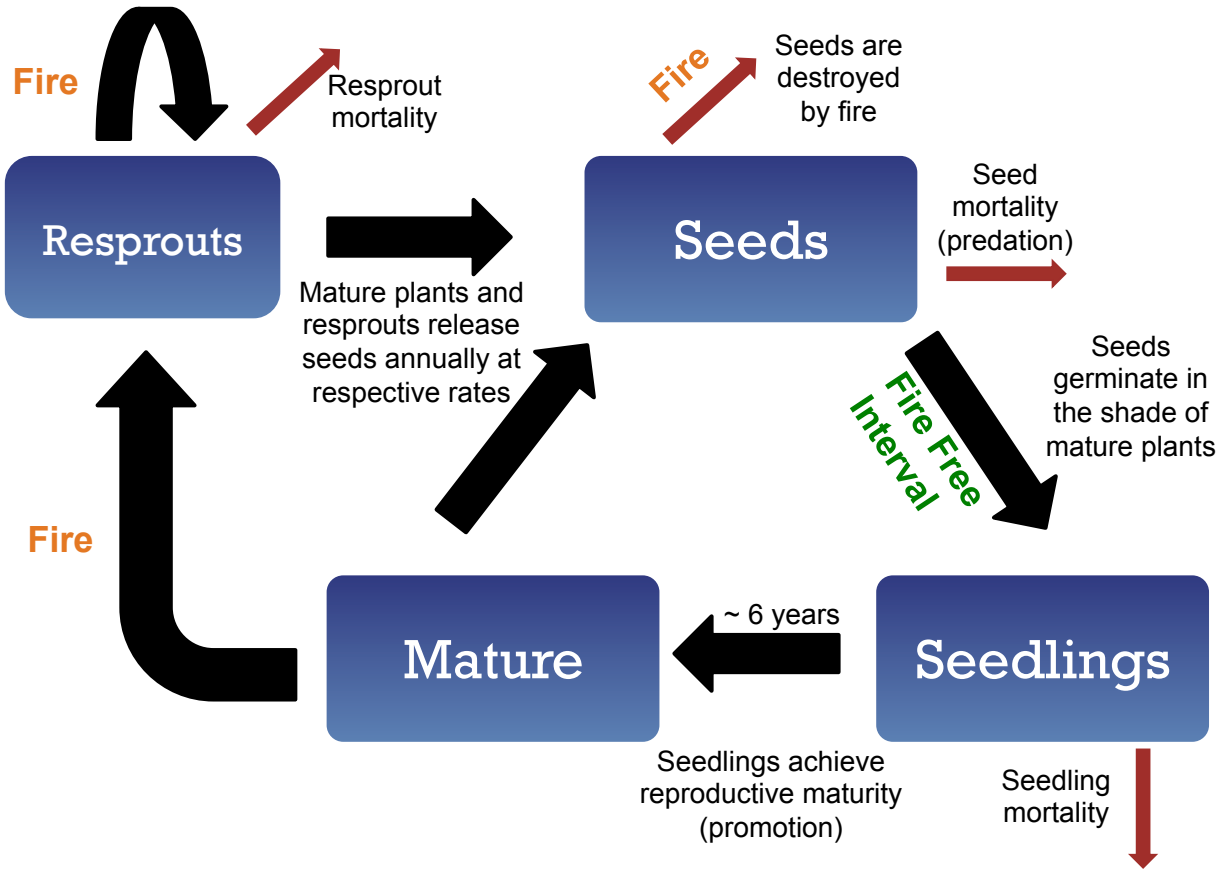
Nonsprouters (NS)

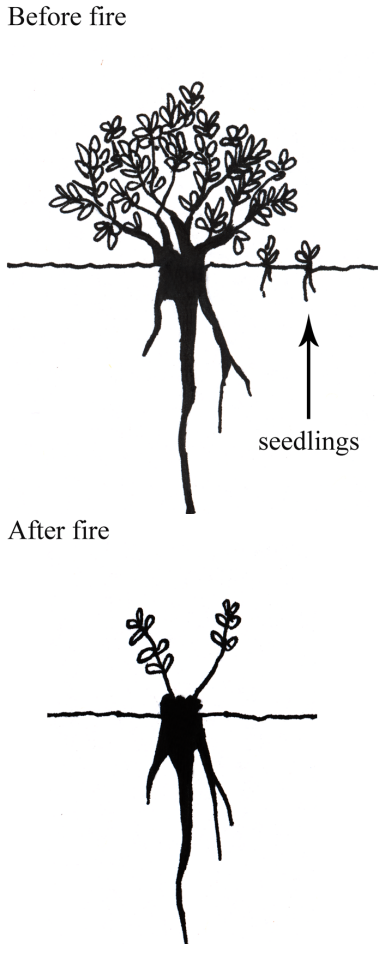
Nonsprouters are completely killed by fire and reproduce by seeds that germinate in response to fire cues.



Obligate Sprouters (OS)

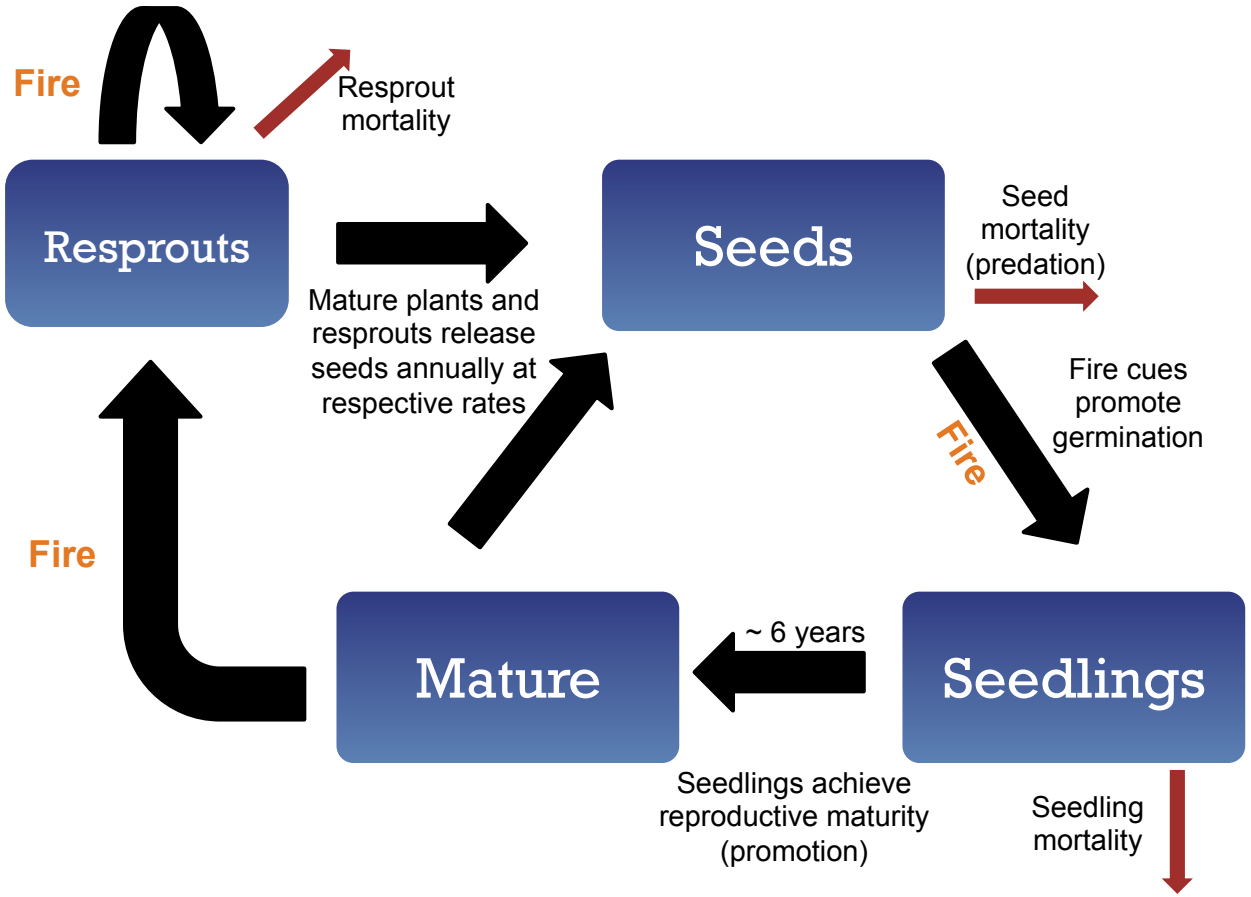
Obligate sprouters are not completely destroyed by fire but resprout from the root crown. OS recruit seedlings in the shade between wildfires because seeds are destroyed by fires.



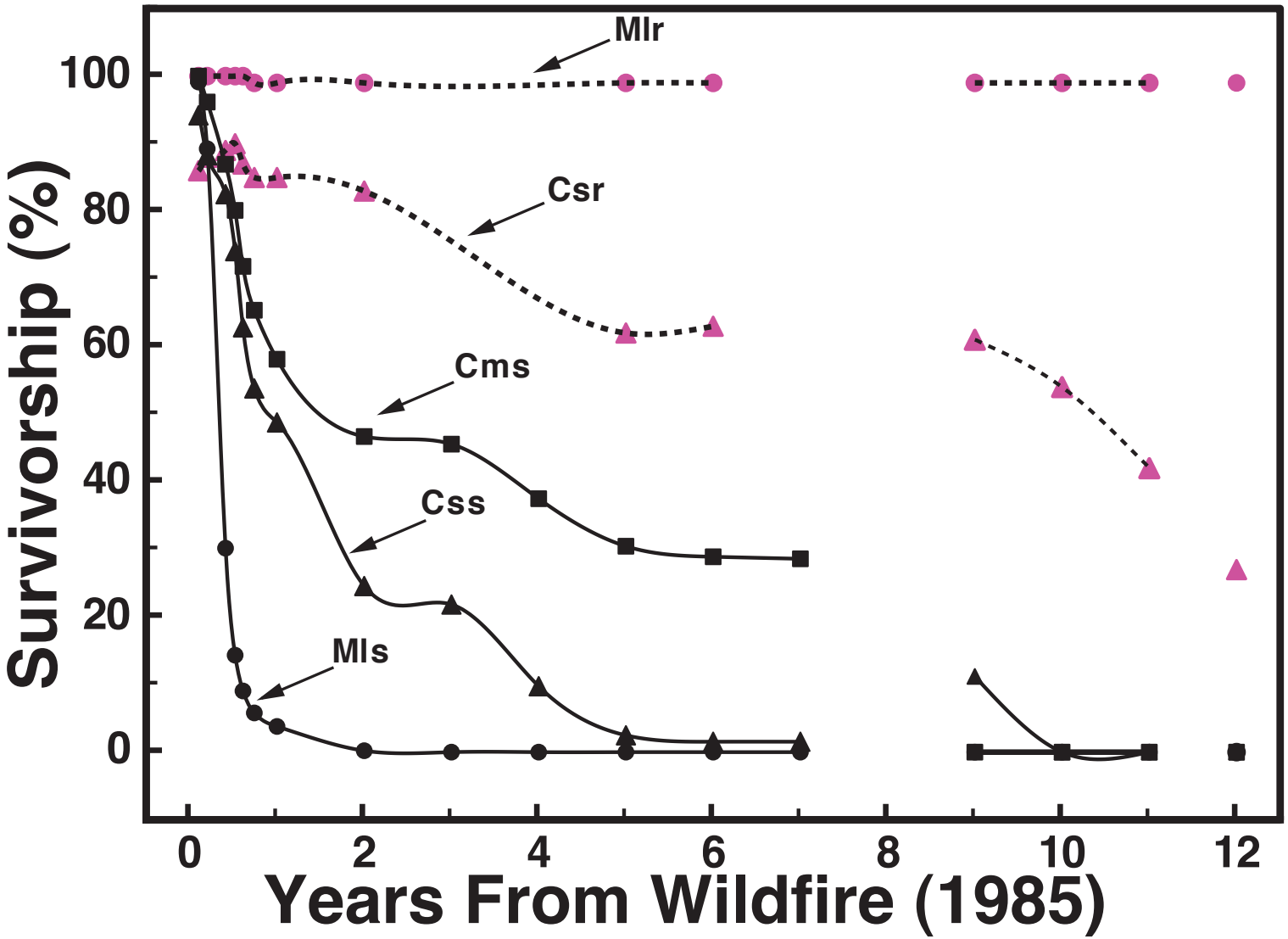


Facultative Sprouters (FS)

Facultative sprouters both resprout and reproduce by seeds that germinate in response to fire cues.



Species Survivorship Data



Changing Landscape

Comparison of frequently and non-frequently burned sites.

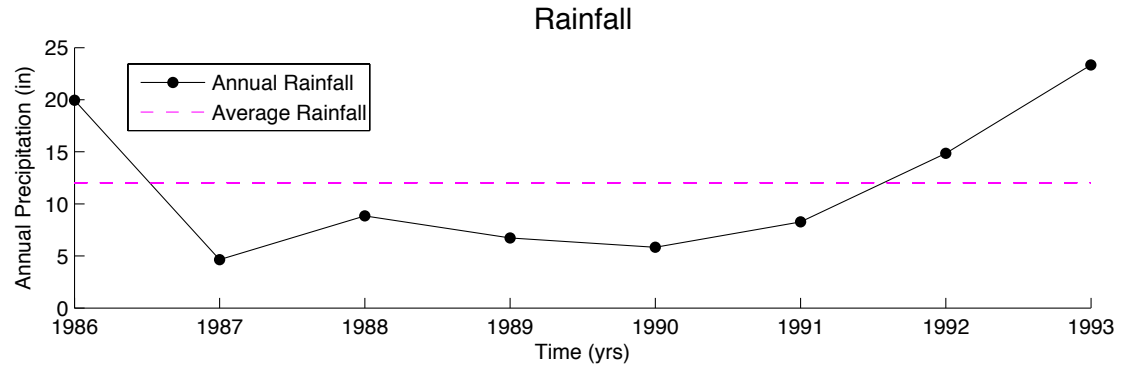
Program Goals

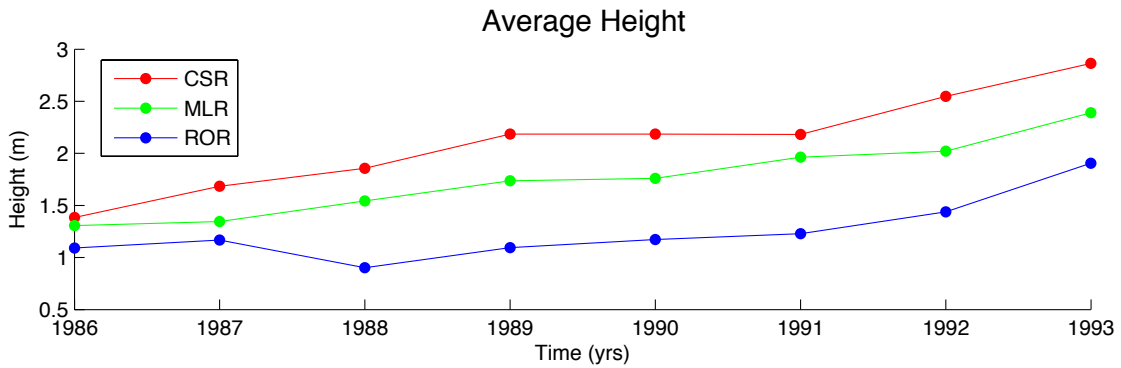
Use data about the plants to model our study site over time under different rainfall patterns and fire return intervals.

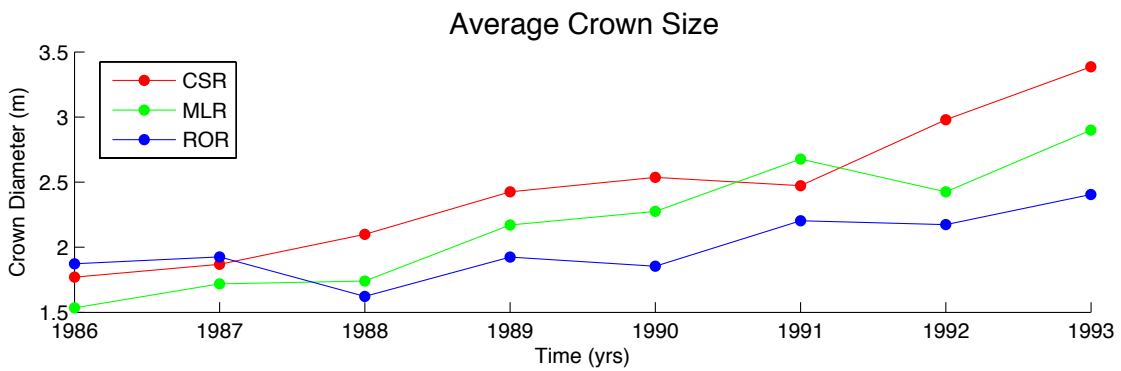
- Simulate individual plants at our study site
  - Plant Growth (Crown and Height)
  - Resprouting behavior
  - Seedling and resprout survival
  - Seed dispersal and germination
  - Spatial organization (interactions between plants)
- External factors:
  - Precipitation
  - Fire Return Intervals

Field Work

Yearly Growth Averages and Rainfall (1985-1993)

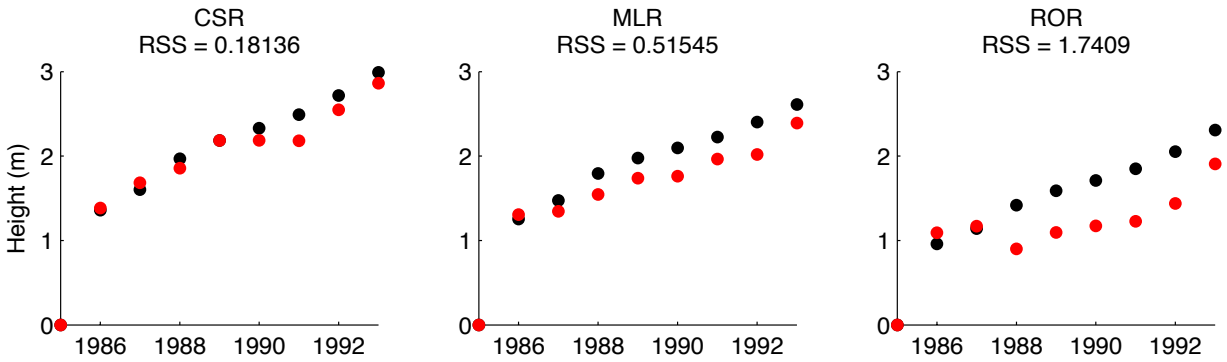




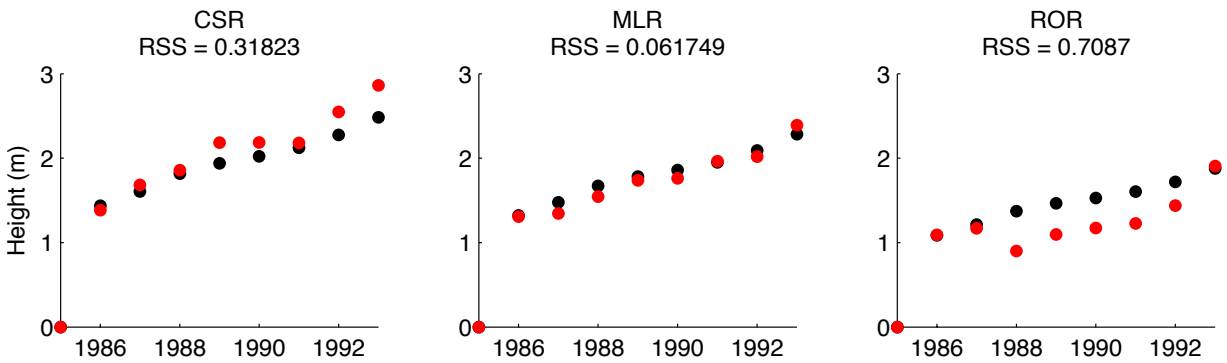


Estimating Change in Height (1985-1993)

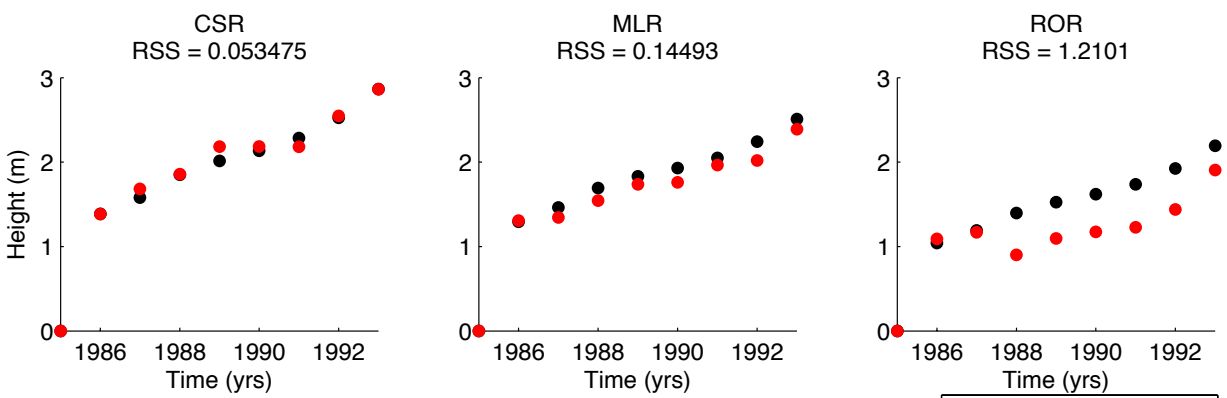
$$\Delta h(w,t) = awe^{-bt}$$



$$\Delta h(w,t) = \frac{aw}{t}$$

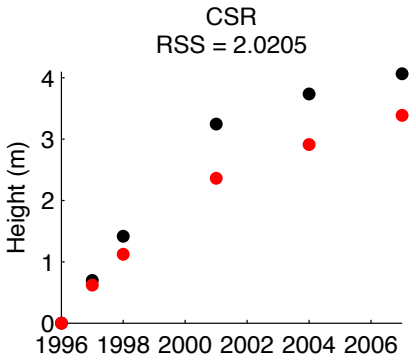


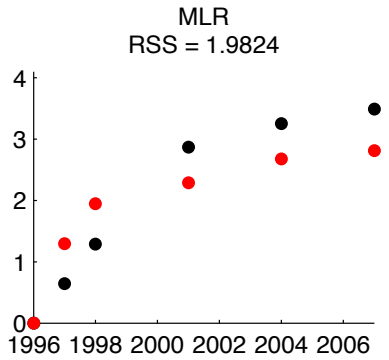
$$\Delta h(w,t) = \frac{aw}{t^b}$$

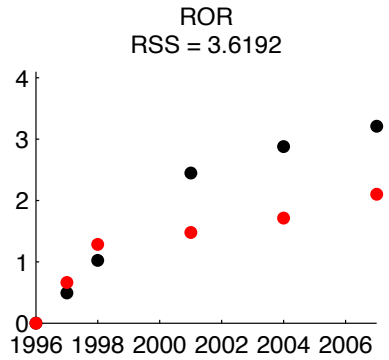


Projecting Change in Height (1996-2007)

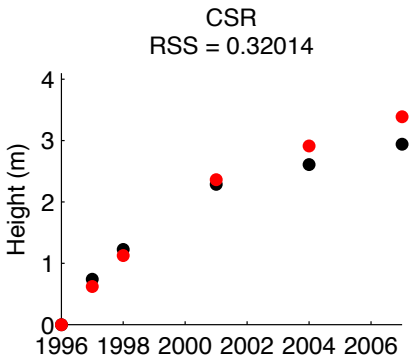
$$\Delta h(w,t) = awe^{-bt}$$

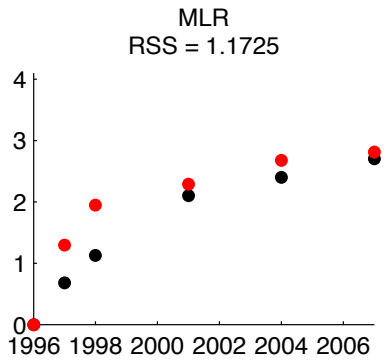


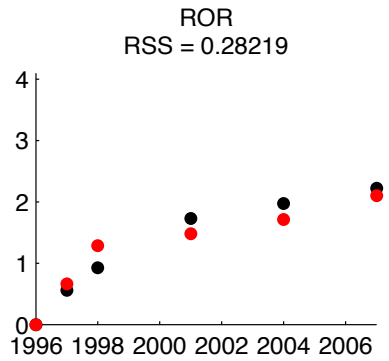




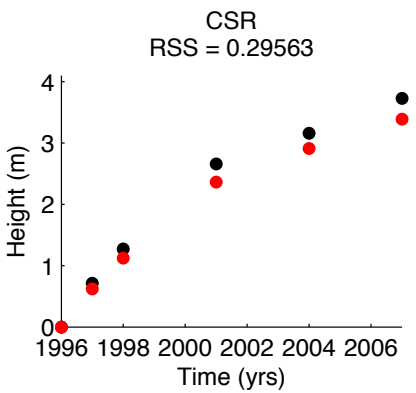
$$\Delta h(w,t) = \frac{aw}{t}$$

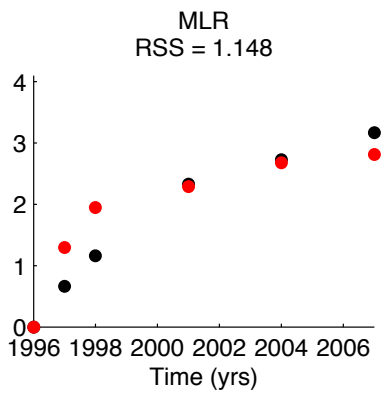


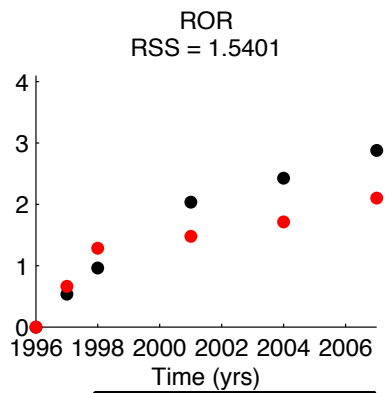


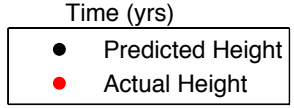


$$\Delta h(w,t) = \frac{aw}{t^b}$$



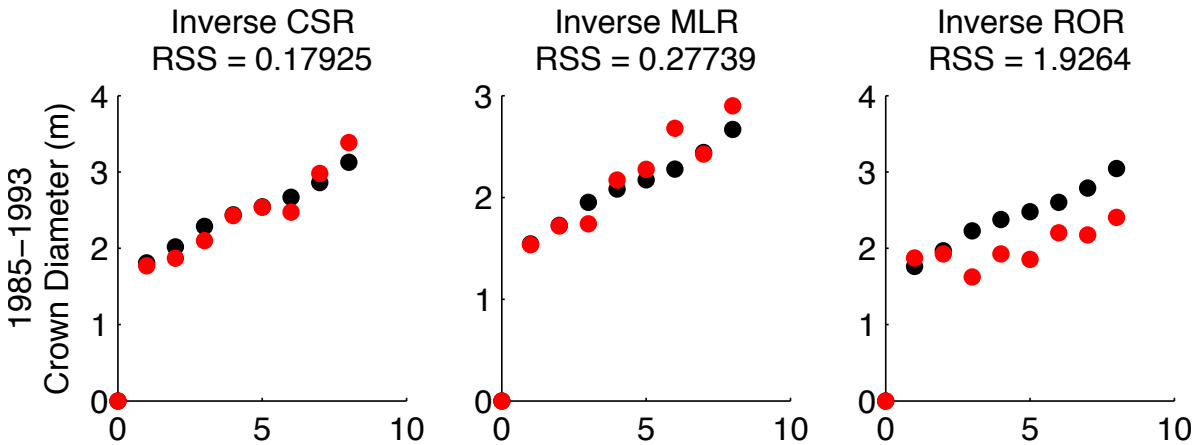




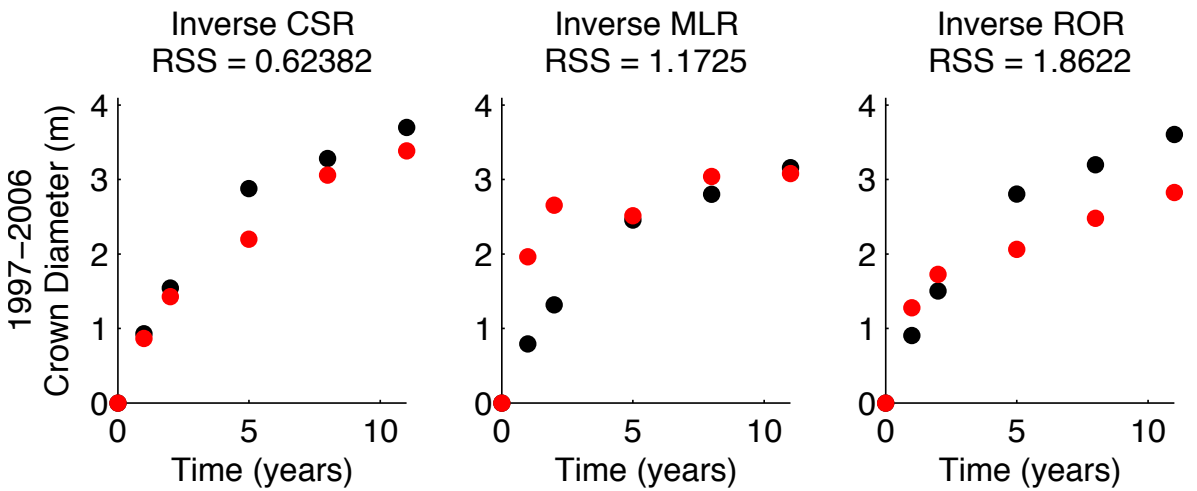


Modeling Crown Growth

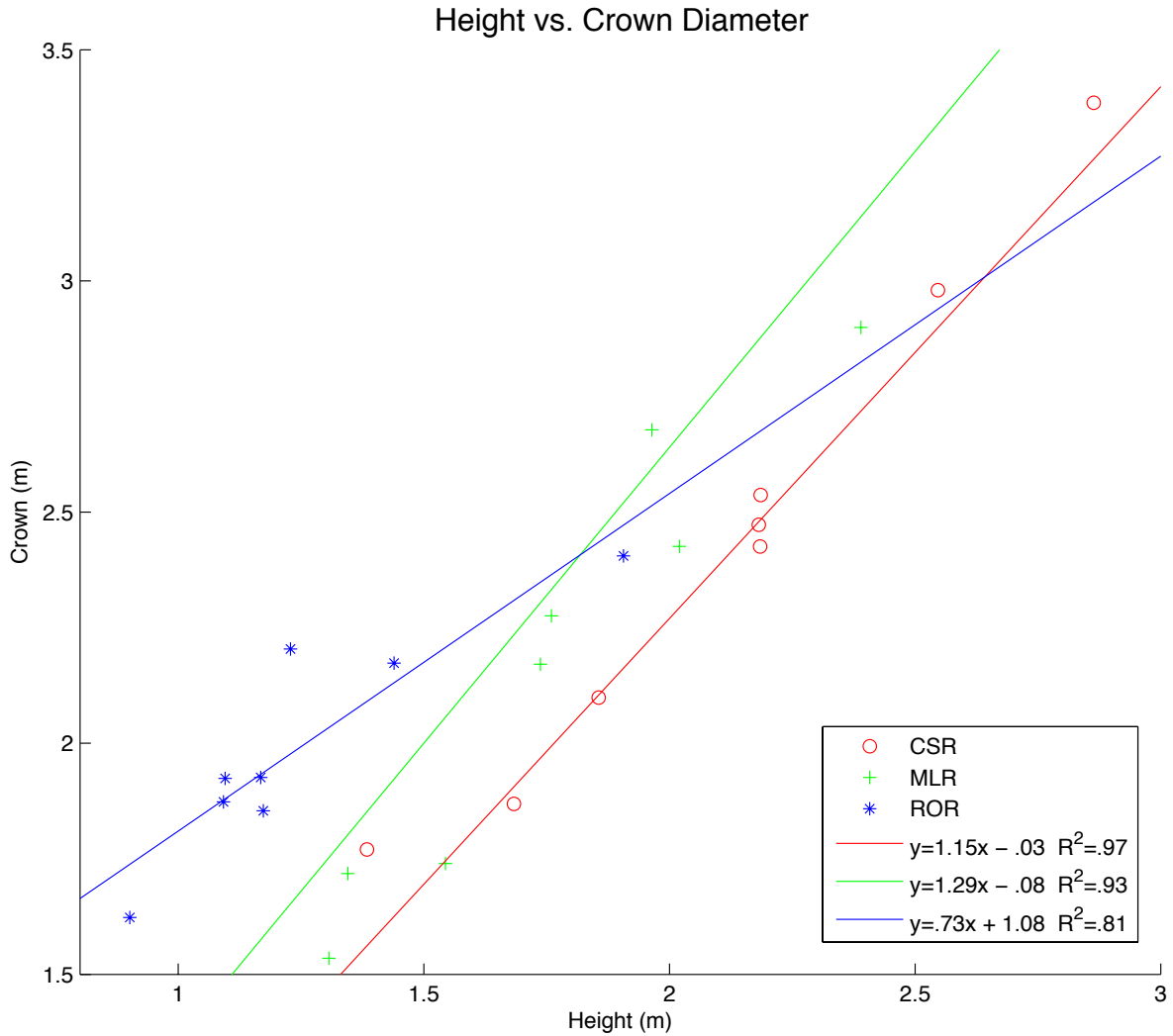
Estimating change in crown diameter (1985-1993)



Projecting change in crown diameter (1997-2006)

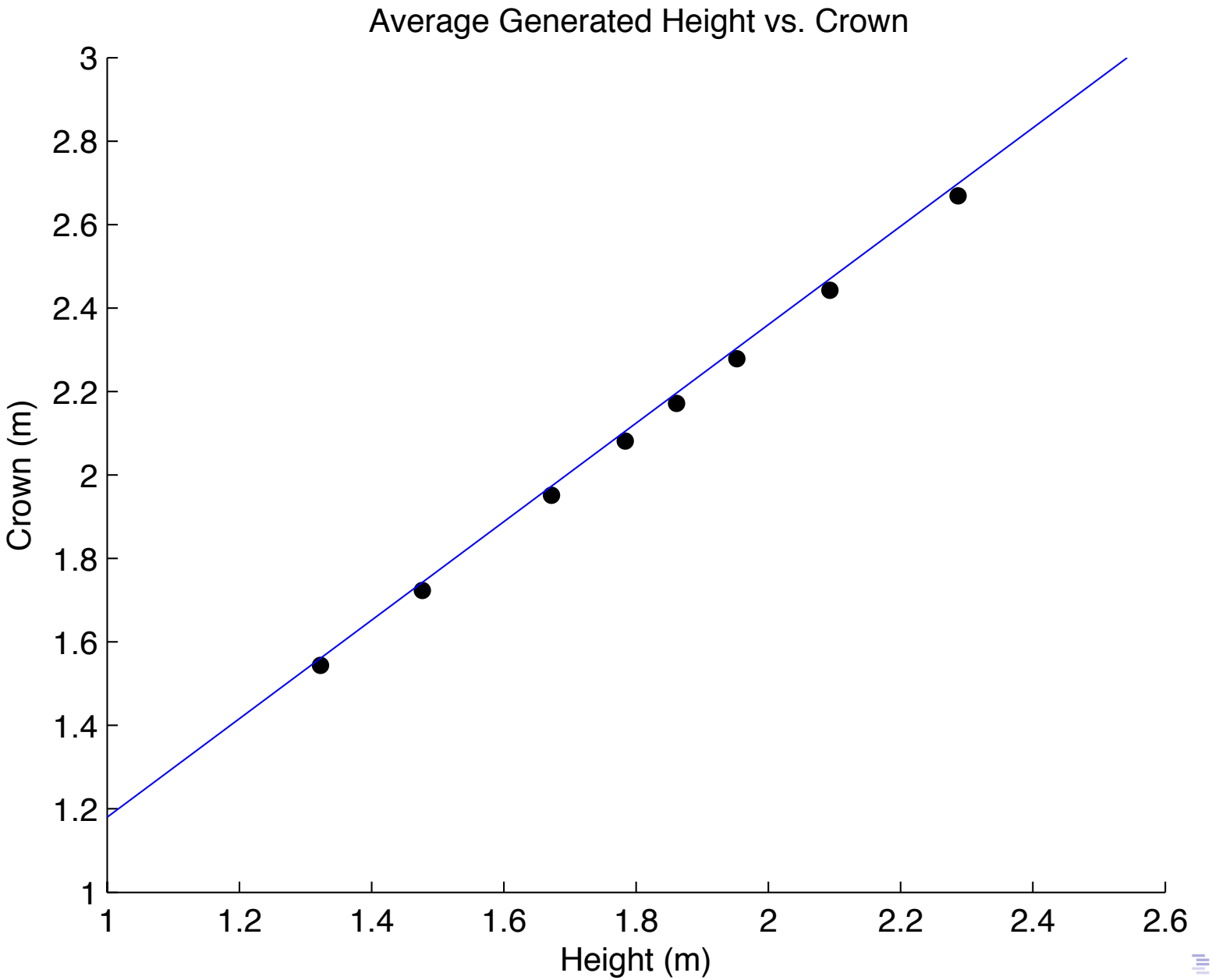


Correlation Between Height and Crown Size

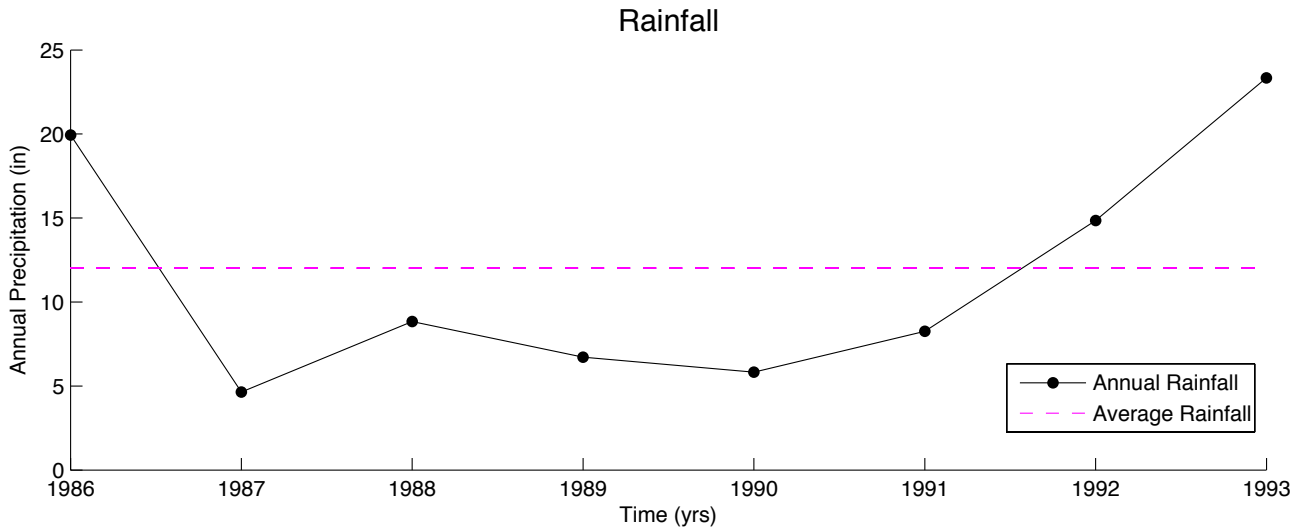


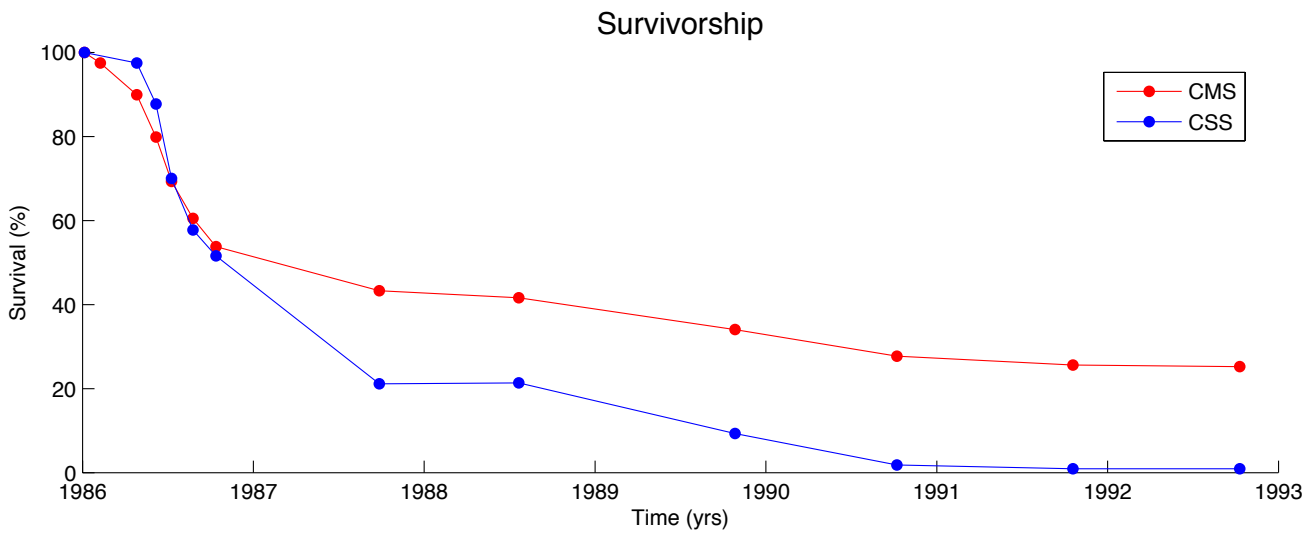
Based on average values from years 1986-1993

Natural Correlation of Height and Crown Parameters

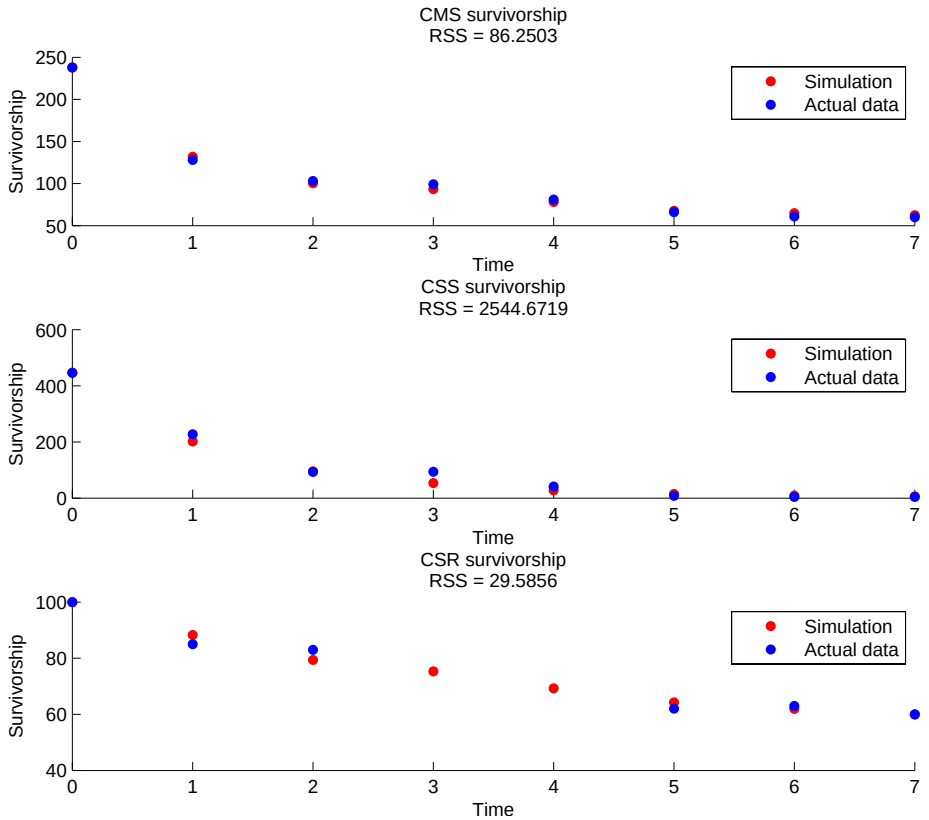


Correlating Survivorship with Rainfall





Survivorship Model: $P_i = P_{i-1} + aP_{i-1}\left(1 - \frac{P_{i-1}}{K+b}\right)$



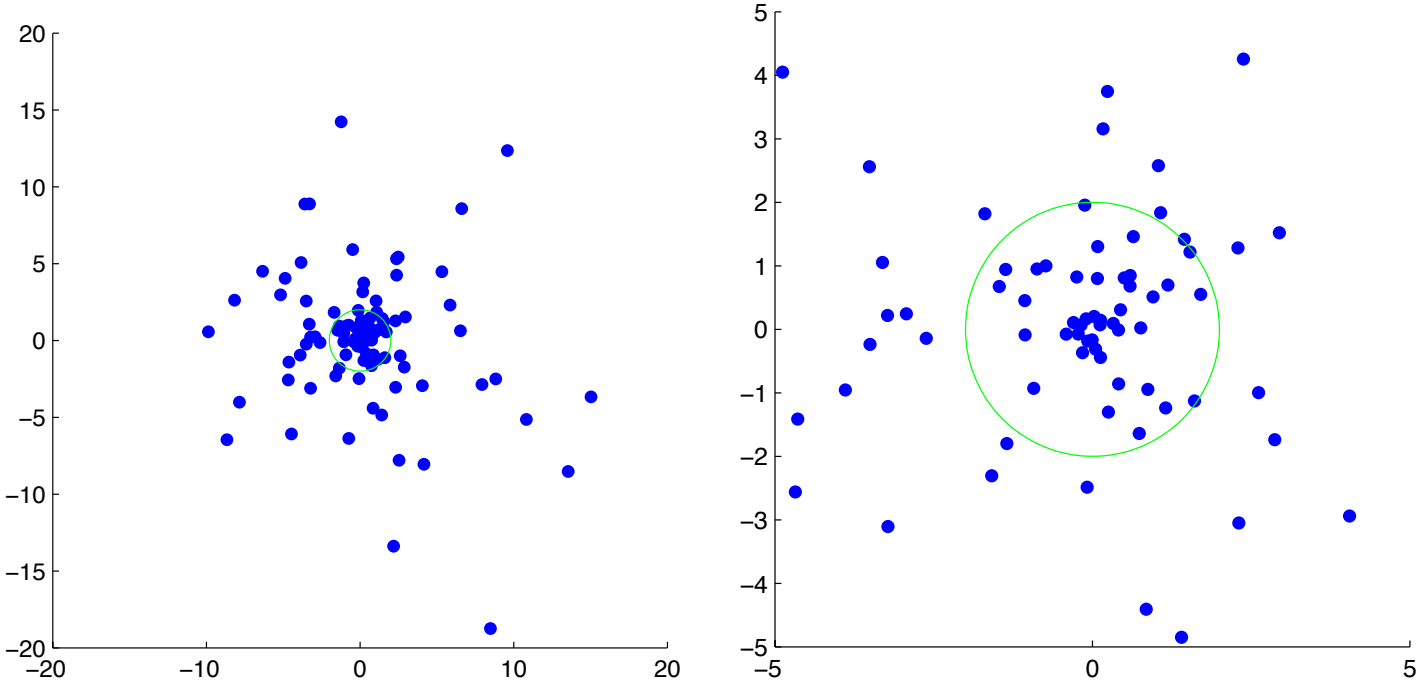
- P is seedling or resprout population
- a is rate of decay
- K is carrying capacity
- b adjusts the carrying capacity based on rainfall w

$b < 0: \quad w < 8$
$b = 0: \quad 8 \leq w \leq 16$
$b > 0: \quad w > 16$

Seed Dispersal

Radial distance is distributed exponentially with $\lambda = -\frac{\ln(0.65)}{r_{crown}}$.

Direction angle is distributed uniformly on $[0, 2\pi]$.



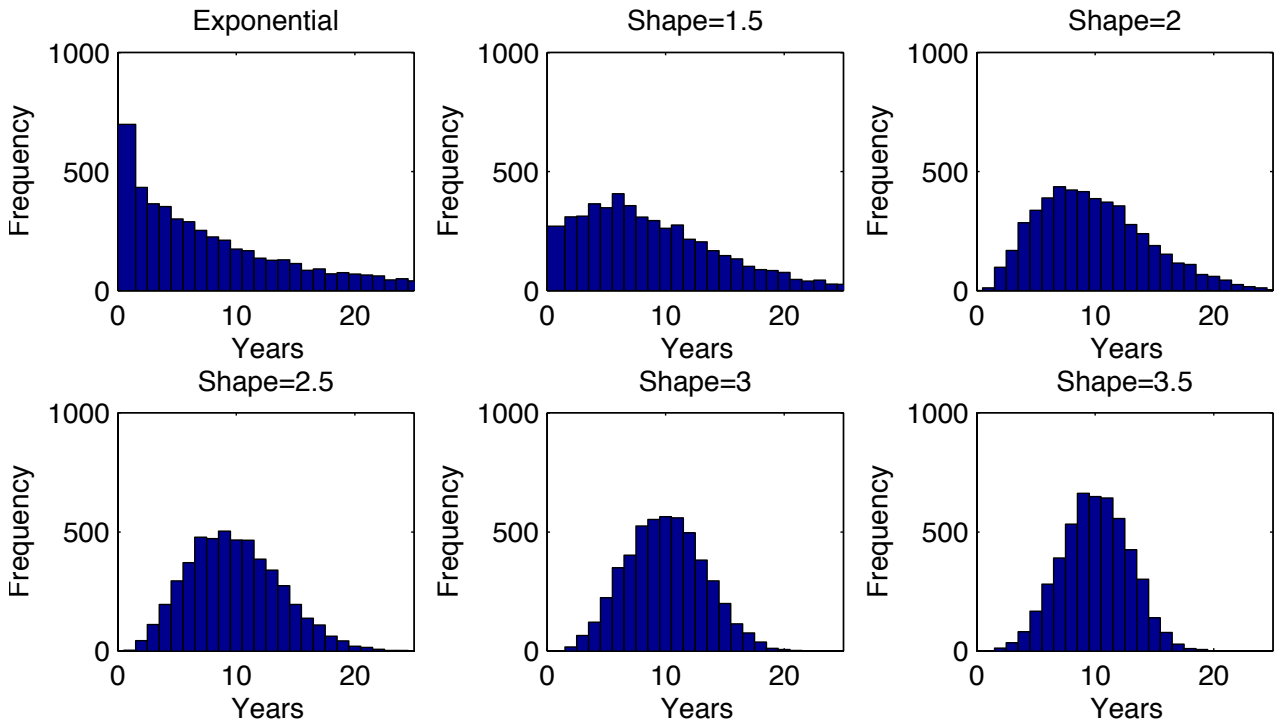
Simulating Fire Return Intervals

Weibull Distribution

$$f(x;\beta,\eta) = \frac{\beta}{\eta}\left(\frac{x}{\eta}\right)^{\beta-1} e^{(-x/\eta)^{\beta}}$$

Why?

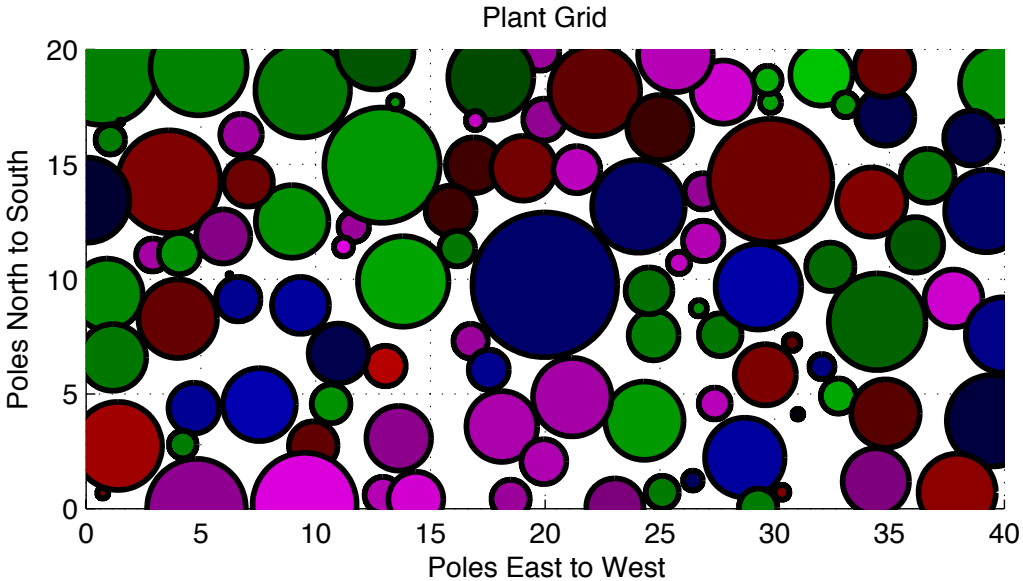
- Aging Effect/Build up
- Flexible



Plant Class

Plant Attributes:

- Age
- Species
- Height
- Crown



Member Functions

- Grow
- Collision
- Resprout/Burn

Graphics

- Color = Species
- Shade = Height
- Outline = Seedling

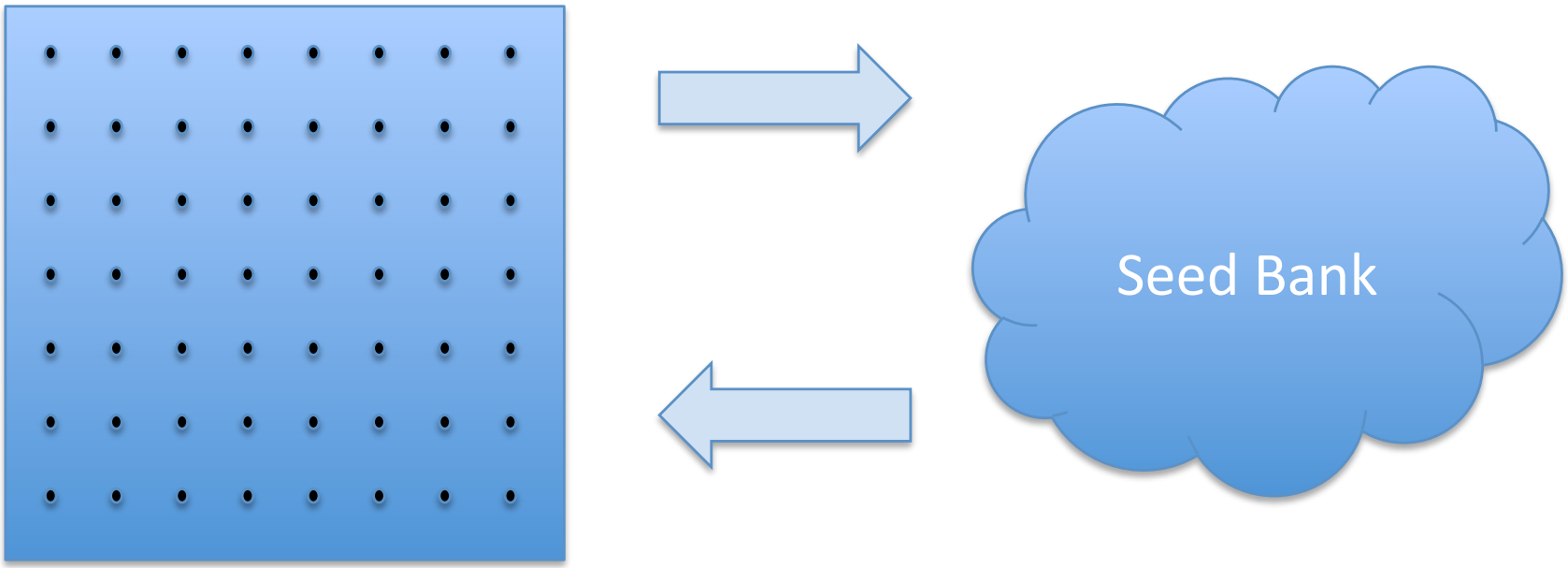
Plant Grid and Seed Bank

Plant Grid:

- Stores plants by nearest pole location
- Calculates collisions between plants

Seedbank:

- Stores released seeds from plants on the plant grid
- Germinates seeds and adds seedlings to plant grid



Plant Collisions

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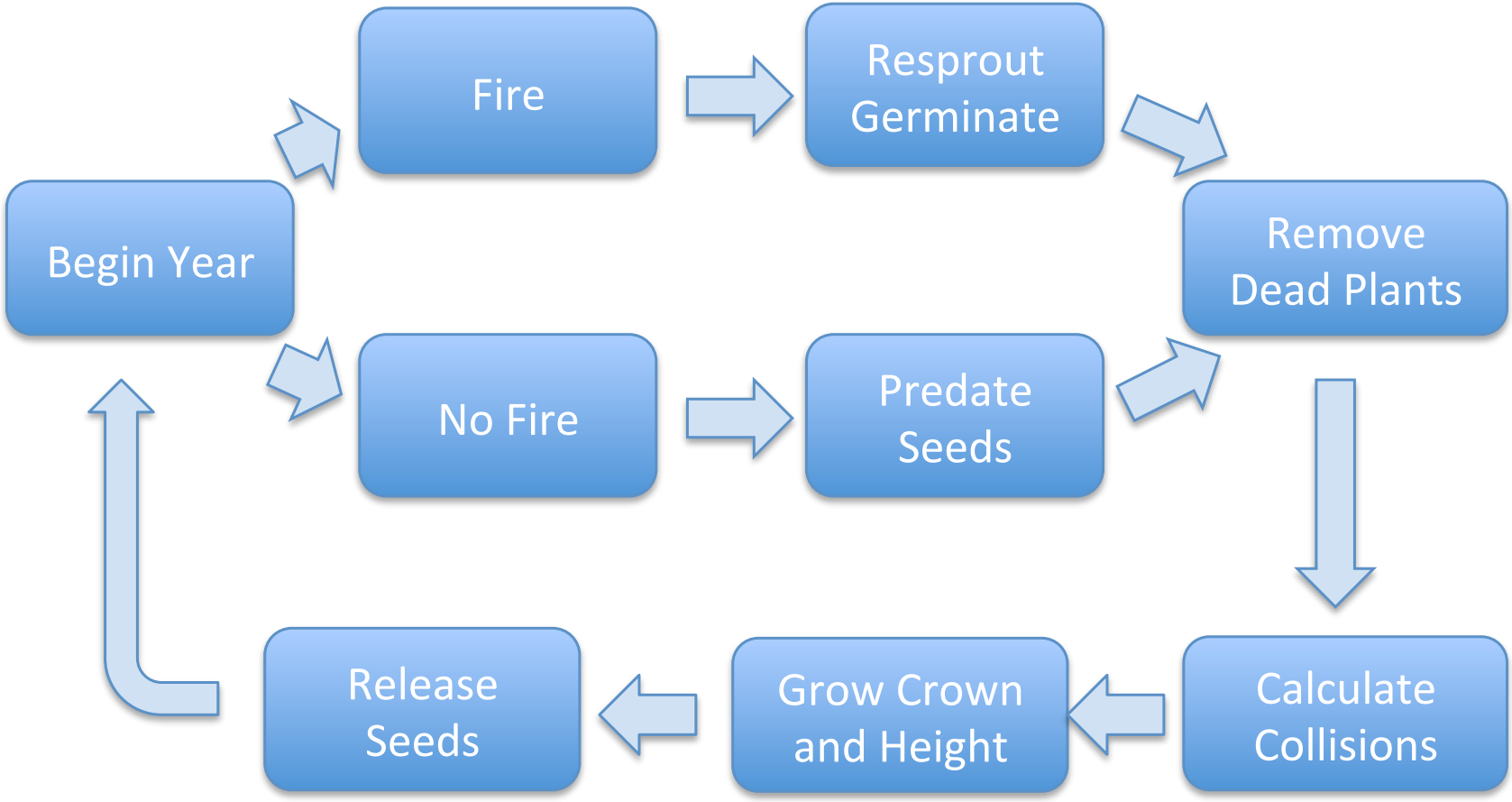
Life Cycle


Begin Year
Fire
Resprout
Germinate
Remove
Dead Plants
No Fire
Predate
Seeds
Calculate
Collisions
Grow Crown
and Height
Release
Seeds

Stochastic Fire Schedule with 6 Year Mean

Malosma laurina

(Loading movie...)

Ceanothus megacarpus

(Loading movie...)

Stochastic Fire Schedule with 20 Year Mean

Malosma laurina

(Loading movie...)

Ceanothus megacarpus

(Loading movie...)

Stochastic Fire Schedule All Species

6 Year Mean

(Loading movie...)

C. megacarpus
C. spinosus
M. laurina
R. ovata

20 Year Mean

(Loading movie...)

Stochastic Fire Schedule All Species with Varying Rain

Light Rain

(Loading movie...)

C. megacarpus
C. spinosus
M. laurina
R. ovata

Heavy Rain

(Loading movie...)

Simulation 1985-2012

(Loading movie...)

	Density	1985	Density	2012
Species	real	simulation	real	simulation
Cm	.179	.170	0	0
Cs	.260	.240	.11	.150
Ml	.374	.380	.624	.550
Ro	.187	.210	.266	.310

What will happen if fire continues to come frequently?

(Loading movie...)

Percent area covered at beginning: 75.4%

Percent area covered at end: 8.74%

Future Goals

- Simulate appropriate rain schedule
- Incorporate basal diameter
  - How base grows and how it is correlated to height and crown growth
  - Incorporate dead burnt stumps of mature plants
- Incorporate obligate sprouters
- Incorporate species specific seed dispersal strategies based on height and size of plant
- Verify assumptions about collisions and crowding

Resources

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Recovery patterns of three chaparral shrub species after wildfire.
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Acknowledgements

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- Dr. Timothy Lucas, our mentor.