Alien River Cloggers

New Mexico
Supercomputing Challenge
Final Report

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Team 79
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Executive Summary

The Salt Cedar is an invasive species native to Europe and Asia that was brought to New Mexico in the early nineteen hundreds to stop soil erosion along rivers. The problem we were addressing is how to get rid of the salt cedar in our riparian ecosystems. In this work, we were able to research our problem, developed a plan and made a program that simulates the Rio Grande riparian ecosystem adding in some variables like thinning certain amounts of trees and adding disease. The results of our modeling showed that all salt cedars would need to be removed from the environment to fully reduce their impact.

The Alien River Cloggers

Team 79: Jacob Holesinger and Kevin Tao
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Introduction

Introductions of alien species into local environments can cause problems when the alien species become invasive by adapting to, reproducing, and growing faster than the native species. The unnatural consumption of resources by the invasive species can decimate the native populations of flora or fauna. The Salt Cedar is an invasive species native to Europe and Asia that was brought to New Mexico in the early nineteen hundreds to stop soil erosion along rivers. The native stream vegetation had declined due to overgrazing. They were the put in because they were fast growing and had very extensive root systems. In solving one problem they created a bigger problem.

Problem

In many of New Mexico's riparian ecosystems the Salt Cedars have been outcompeting the cottonwoods in many ways. They are phreatophytes like the cottonwoods but they are also facultative which means that their roots can branch off and look for water if their is none in the area. Salt Cedar trees can produce seeds in their first year and they secrete a salt-like substance, hence the name "Salt Cedar". This gives them yet another advantage over the cottonwoods and poisons the rivers. The problem to address is how to eradicate the salt cedars and restore the natural ecosystem of the cottonwood.

Approach

The approach to our problem is to simulate the Rio Grande riparian ecosystem and add in the salt cedar and things with the potential to stabilize its population like biological controls and other means such as disease that only affect the salt cedar.

The first step was to create program overview. Our outline is shown in Figures 1-4. We worked on a water equation to model the availability of water to the trees as function of distance from the river. The first step with the actual programming was to make a program with just the cottonwoods. Then we added in the Salt Cedar. Then our plan was to add in various variables and biological controls and simulate multiple combinations to see which one will make the environment balanced.

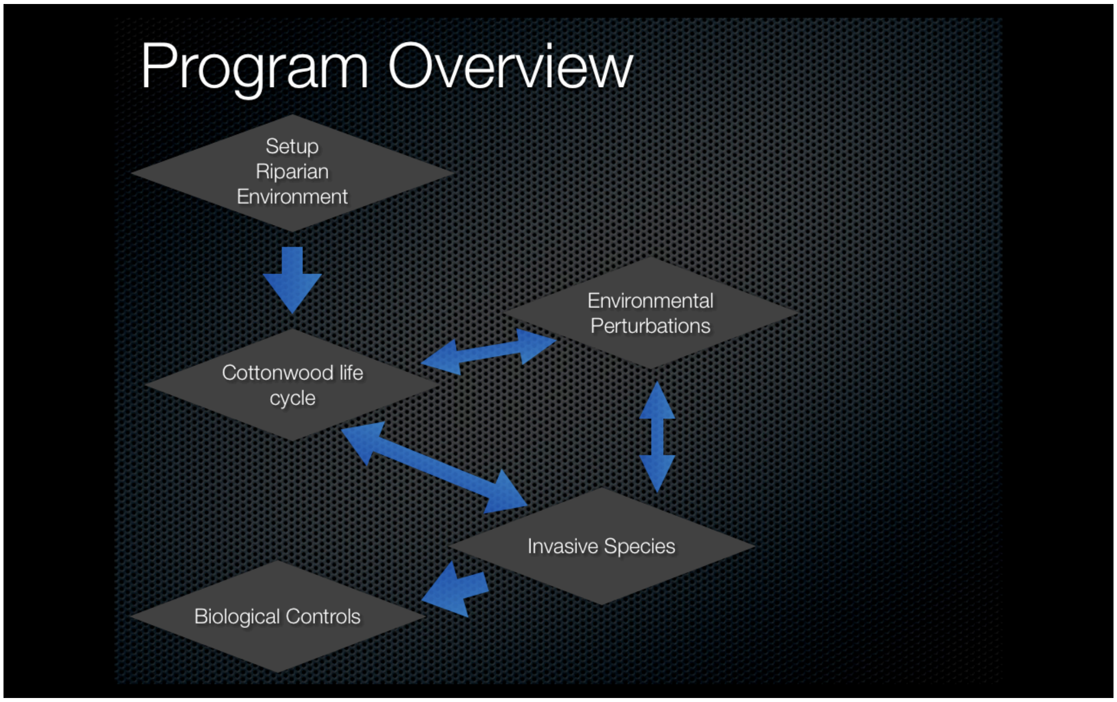


Figure 1: Outline of program development

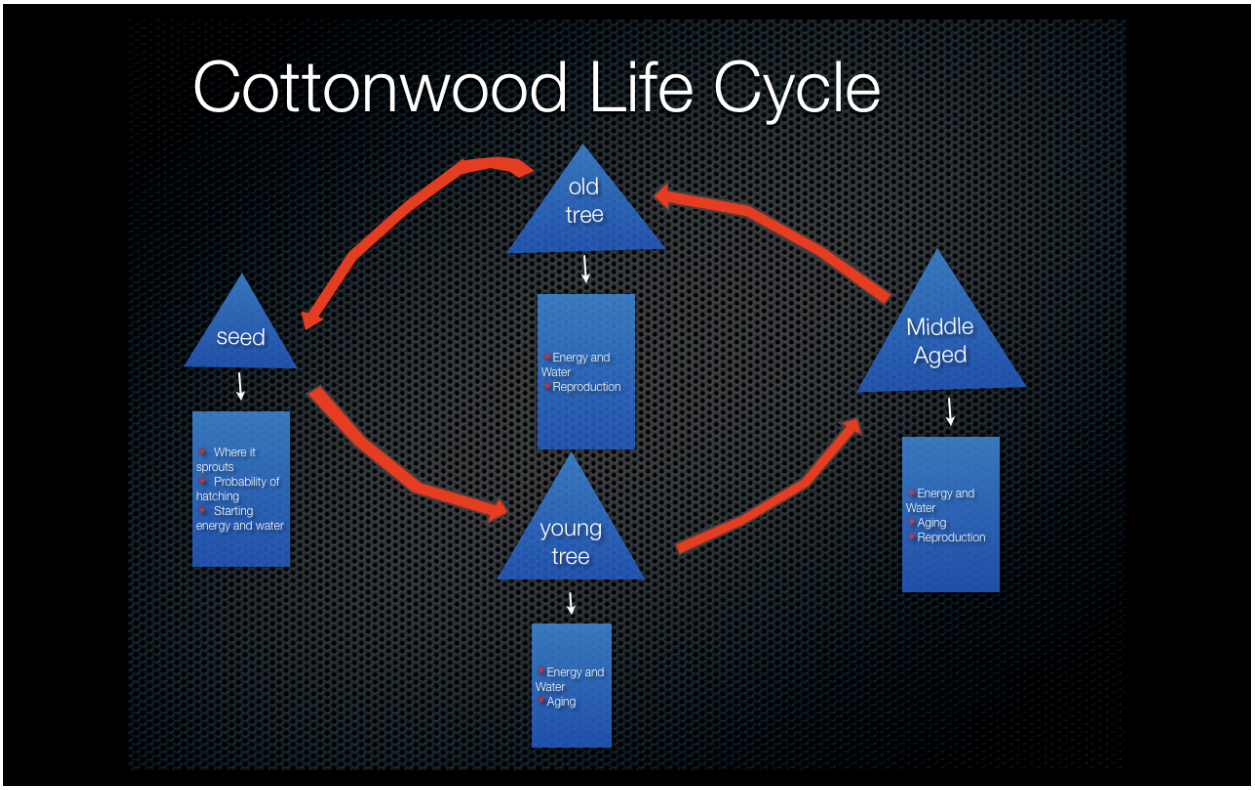


Figure 2: Cottonwood life cycle in the program

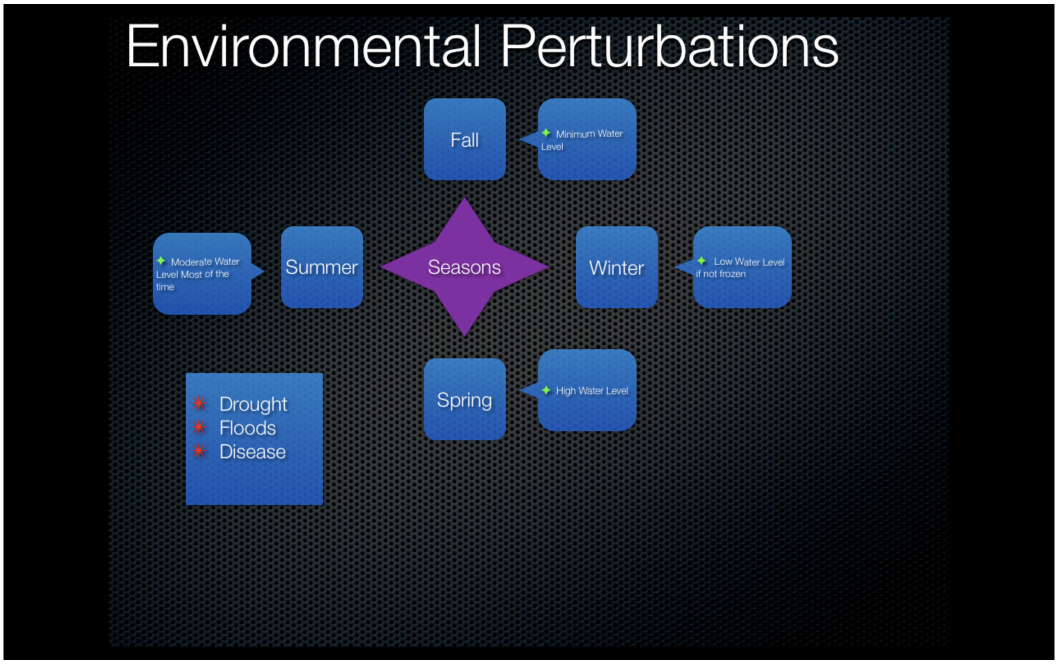


Figure 3: Seasons and environmental perturbations in program

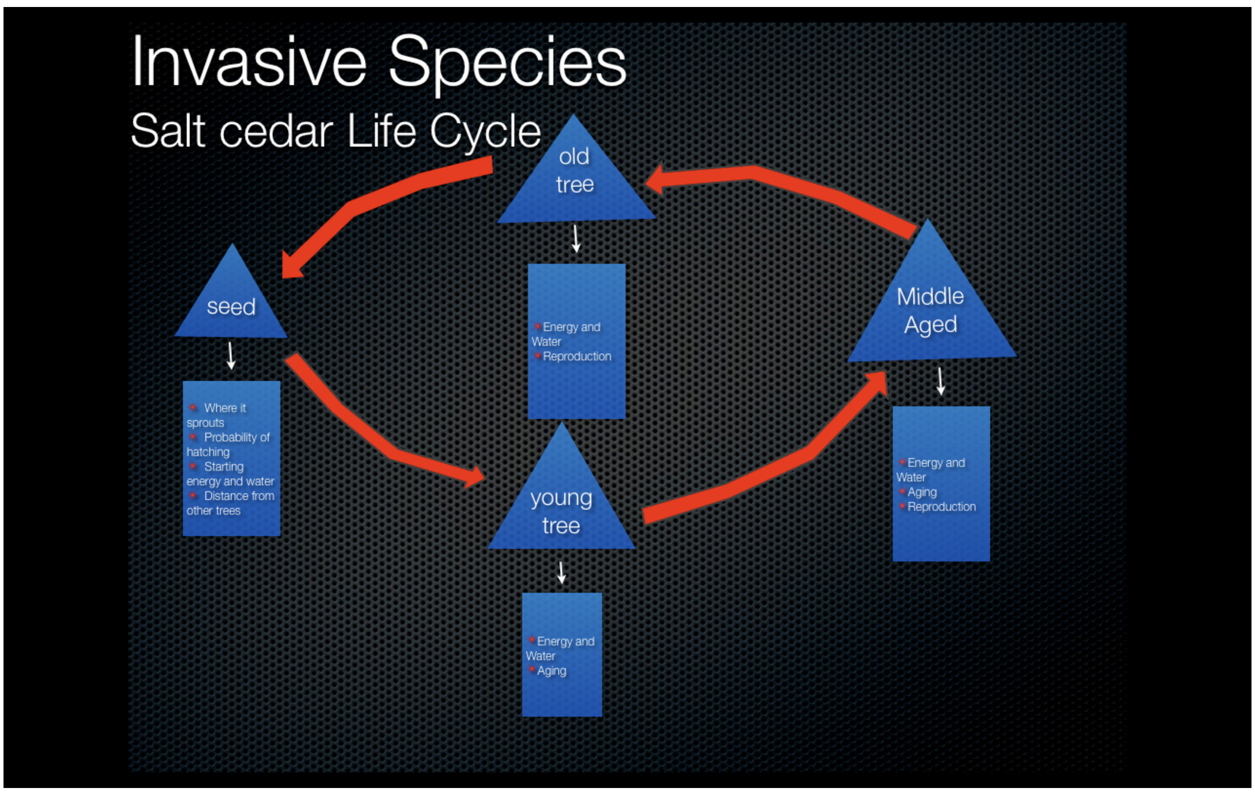


Figure 4: Salt cedars in program

Interface: In the interface we have a plot and monitor and some sliders controlling the number of cottonwoods to start with and their water to start with. In this we also have switches that if turned on label on the interface the energy and the number of trees near the trees. Also we have some buttons that create natural disasters and disease. In the grid in the center there are the cottonwoods along the river. The grids dimensions are 90 by 60.

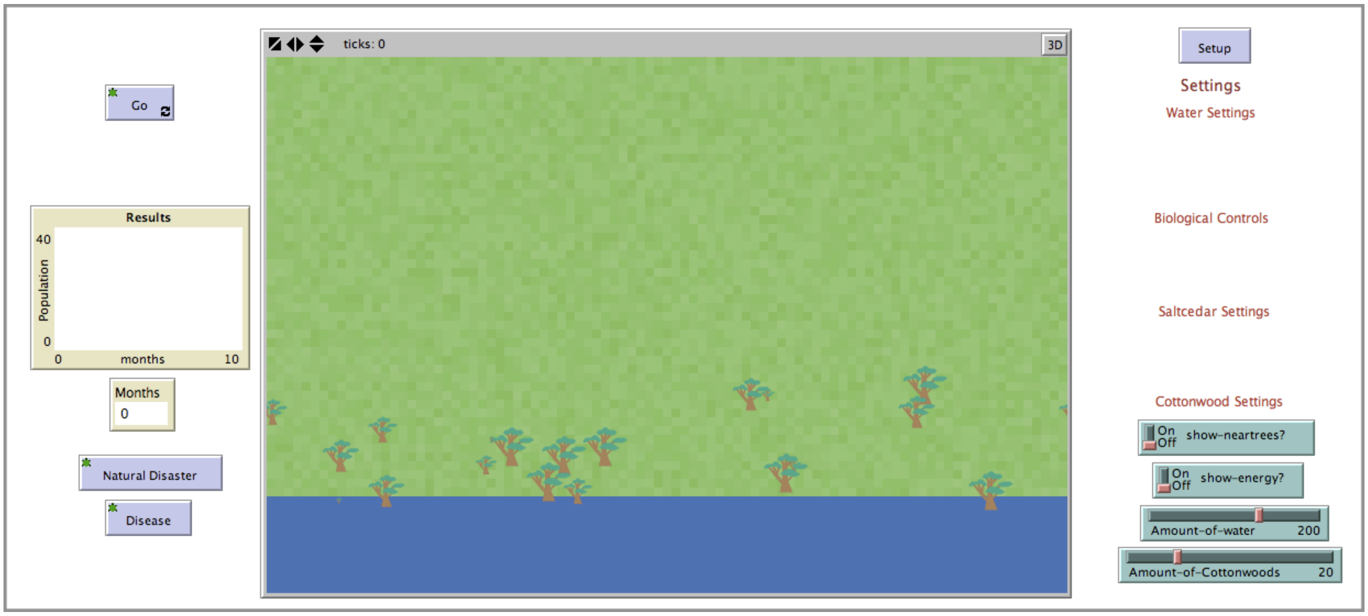


Figure 5: Layout of program interface.

Water equation development

The water equation has two parts or terms: groundwater and precipitation. The further away the trees are from the river, the more they have to rely on precipitation only. The equation for the water includes time in both terms to represent changes in the seasons. In the winter and early summer, the amount of water available is decreased while in spring and fall, the amount of water is more abundant to represent spring runoff and the late summer monsoon rains. Also there is a term in the precipitation term that gives some terrain so we have some “puddles”.

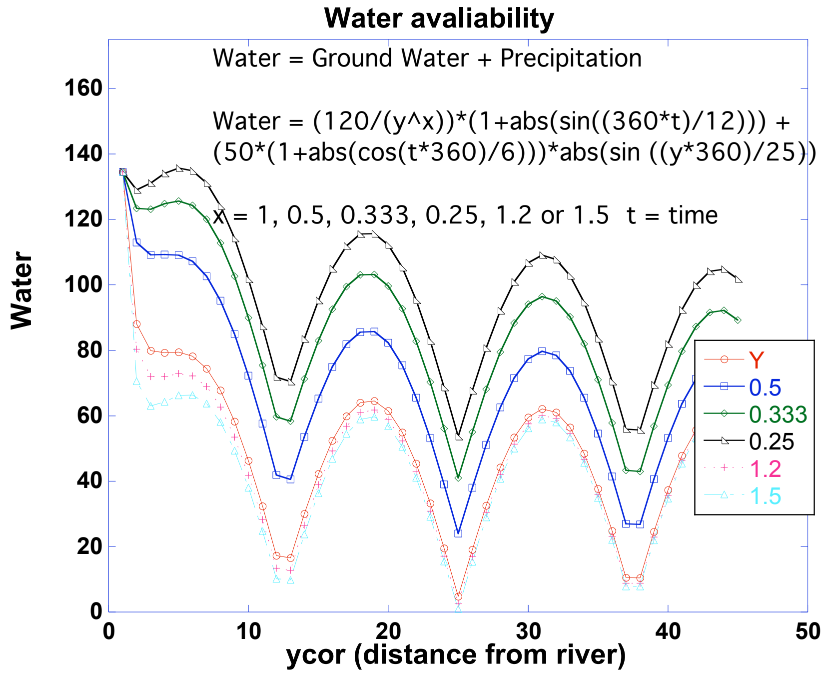


Figure 6: Graph of our results of our model where the water availability fall off as a power of the distance from the river.

To start our water equation development, we assumed that the water availability from the ground would fall off as 1/y where y is the distance from the river. Trees near the river were expected to have a much greater supply of water compared to trees further away. We assumed this because the cottonwoods and the salt cedars main source of water is the river. In our first attempt, we chose powers of distance from the river as shown in equation 1. The results from this model for the water availability using this equation is shown in Figure 6. The result from this model did not show the desired difference in water availability, with most of the water near the river.

Equation 1: (ground water)

water = (((60 / ([ycor] of myself)^power))) * (1 + abs (sin (months / 12 * 360)))) +

(precipitation)

(((25 - ([ycor] of myself)) * (1 * (abs(cos(months / 6 * 360))))*abs(sin ((y*360)/25)))

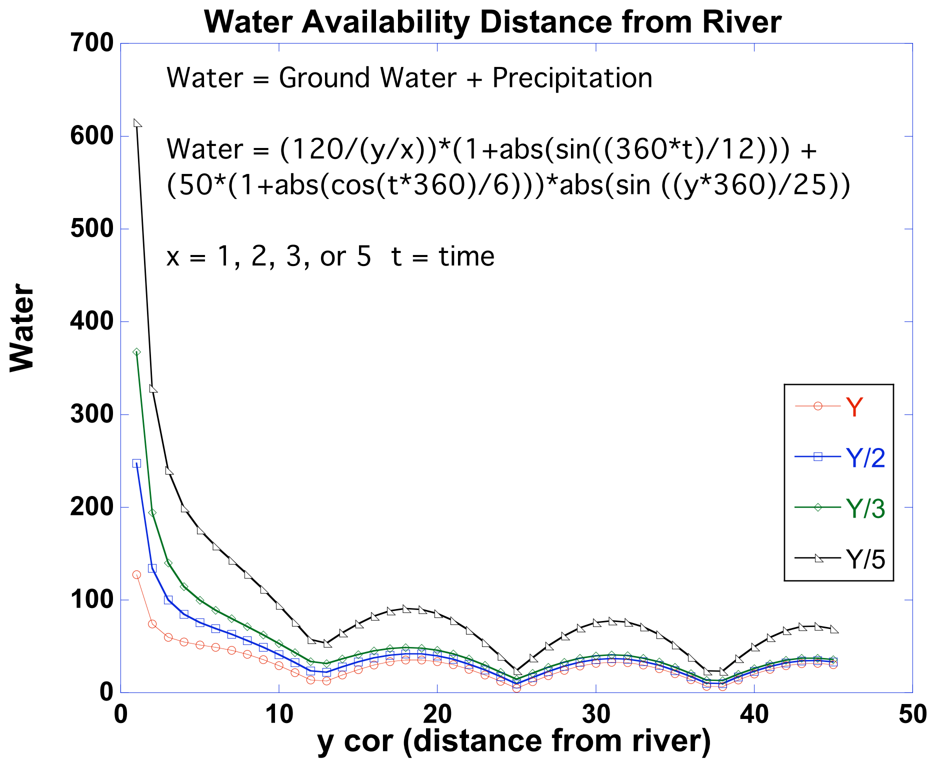


Figure 7: Results of the model with a y/x factor. We decided that using y/3 in the program would work well.

In our next model, we used a y over x in the equation. This model showed better results, having the trees rely mostly on the river. The end results are shown in figure 7.

Equation 2: (ground water)

water = (((120 / ([ycor] of myself)/x))) * (1 + abs (t / 12 * 360)))) +

(precipitation)

(((50 - ([ycor] of myself)) * (1 * (abs(cos(t / 6 * 360))))*abs(sin ((y*360)/25)))

t = 0 x = 1,2,3,5

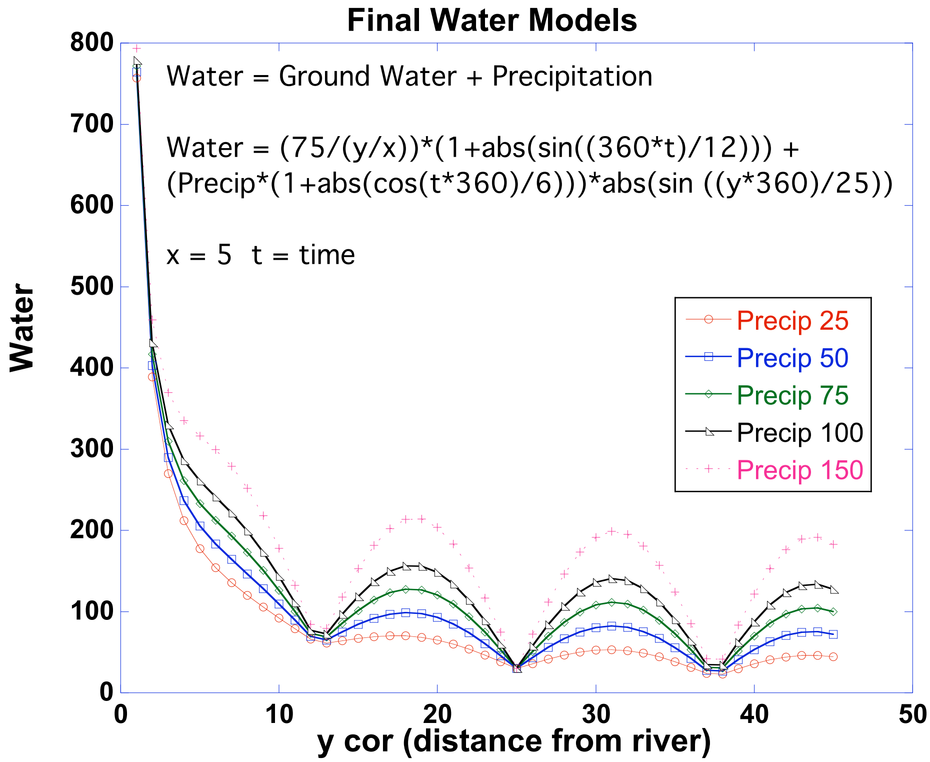


Figure 8: This is the results of the model where the precipitation was changed. We decided that using precipitation at 50 would work the best.

In the third model we changed the precipitation variable so that near the river their wasn't both the river and the precipitation water because the river would include the precipitation in it.

Equation 3: (ground water)

water = (((120 / ([ycor] of myself)/x))) * (1 + abs (t / 12 * 360))) +

(precipitation)

(((Precipitation - ([ycor] of myself)) * (1 * (abs(cos(t / 6 * 360))))*abs(sin ((y*360)/25)))

t = 0 x = 1,2,3,5 Precipitation = 25,50,75,100,150

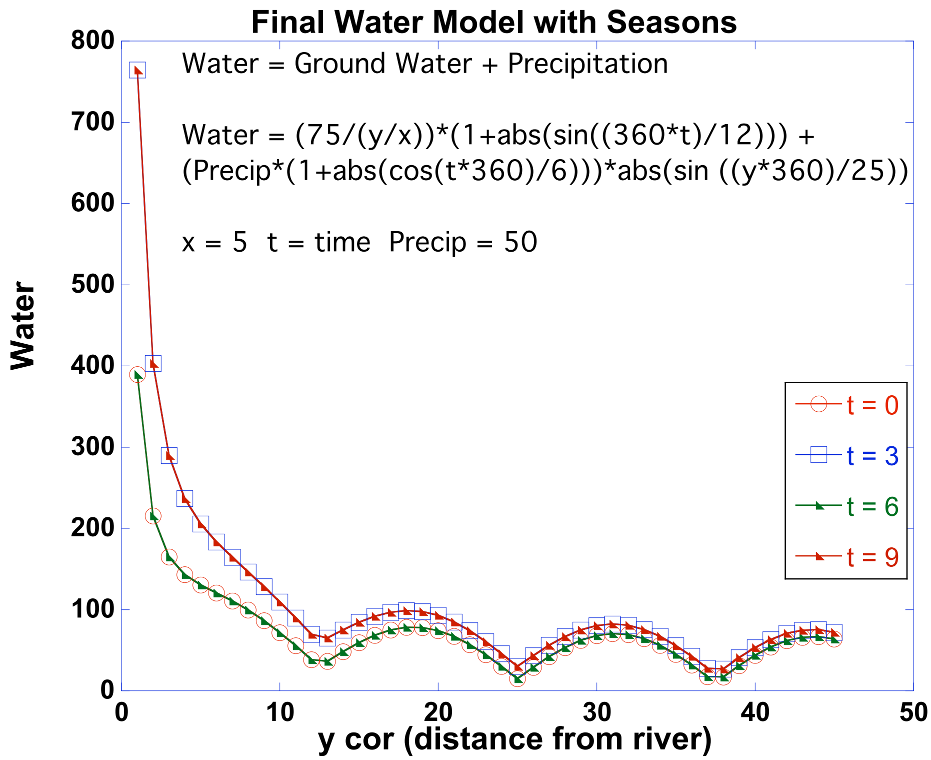


Figure 9: These are the results of the run with times. The seasons cycle through with t = 0 being spring t = 3 being summer t = 6 being fall and t = 9 being winter

In our fourth model we put in times at t = 0, t = 3, t = 6 and t = 9

Results

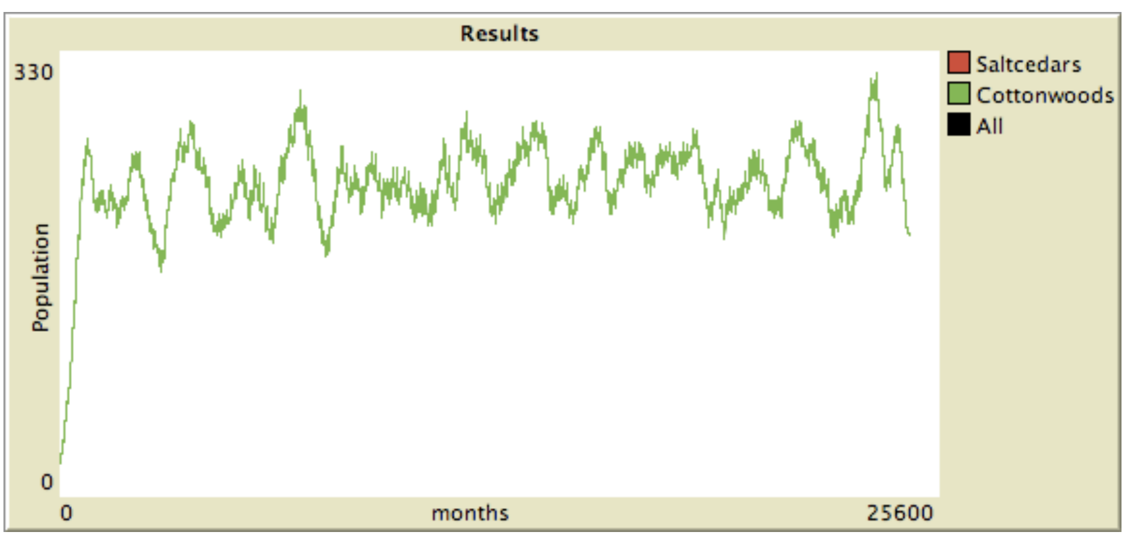
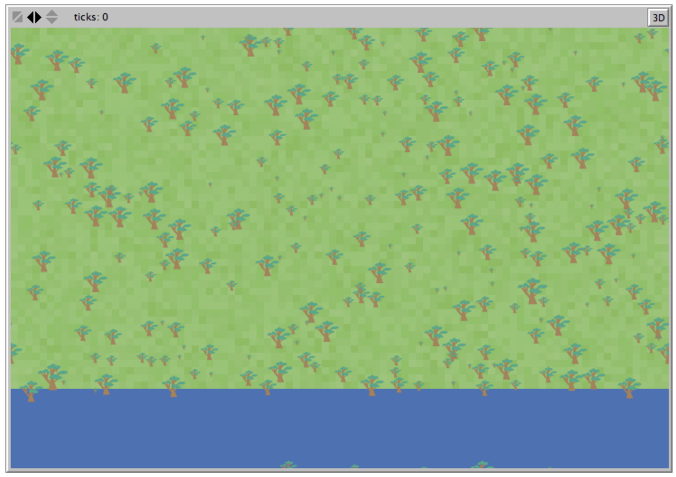
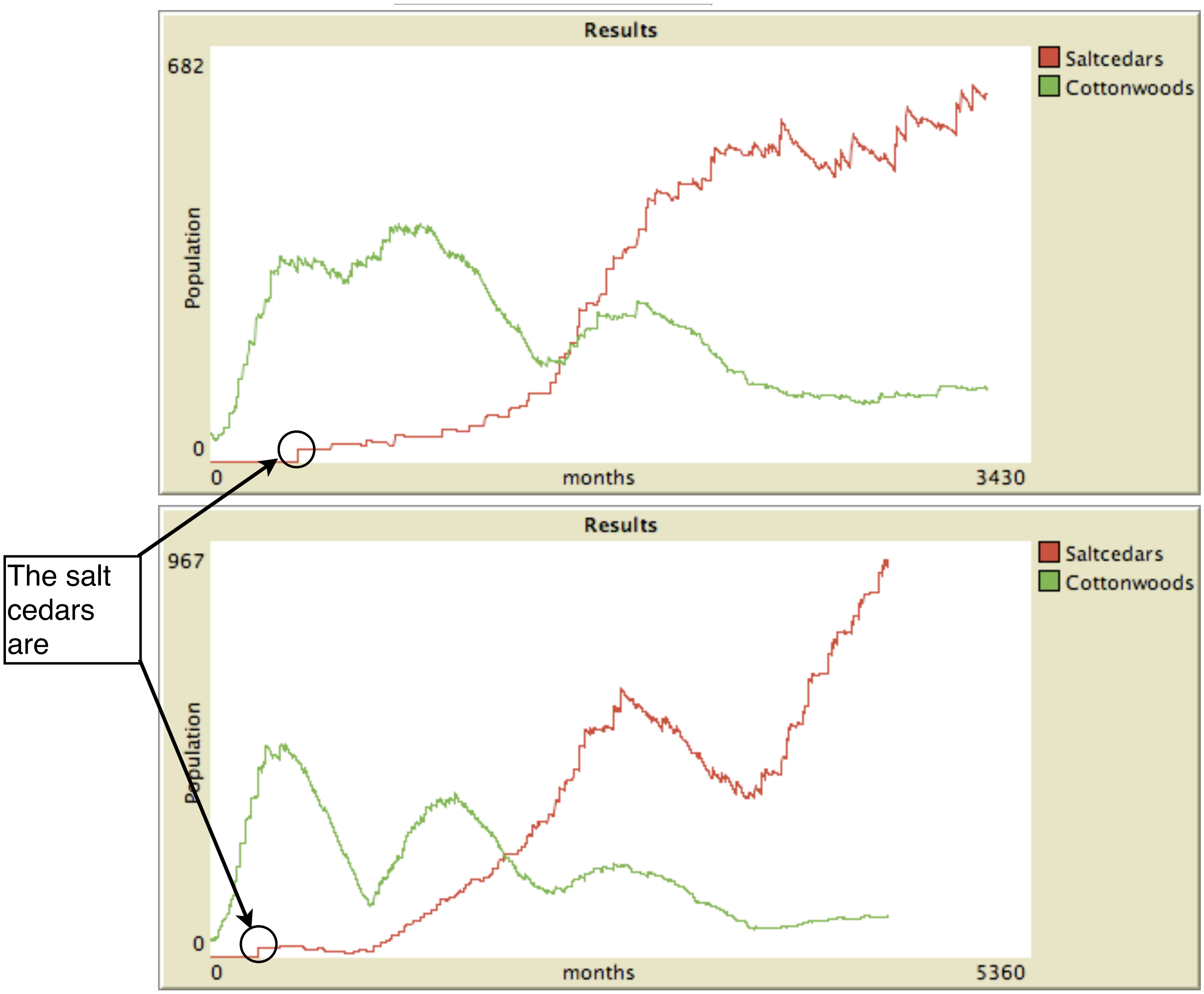


Figure 10: This graph shows just the cottonwoods. This pattern would be continuous.

Figure 11:
The trees did not cluster around the river like expected.





Figures 12: These graphs are the results when the salt cedars are added in after the cottonwoods have started. In these simulations the salt cedars took over fairly quickly and the cottonwood populations were severely depressed.

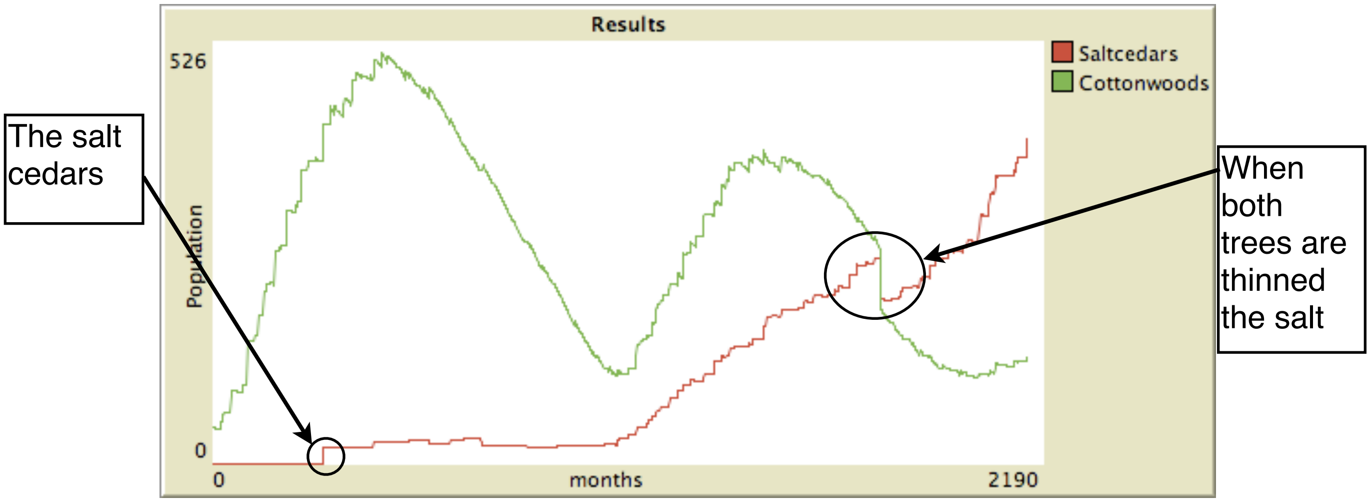


Figure 13: This graph shows the results of the simulation when the populations of both trees when equal where thinned by 25%. In this run the salt cedars came back first. This was the predicted outcome because the salt cedars are able to make seeds in their first year of existence.

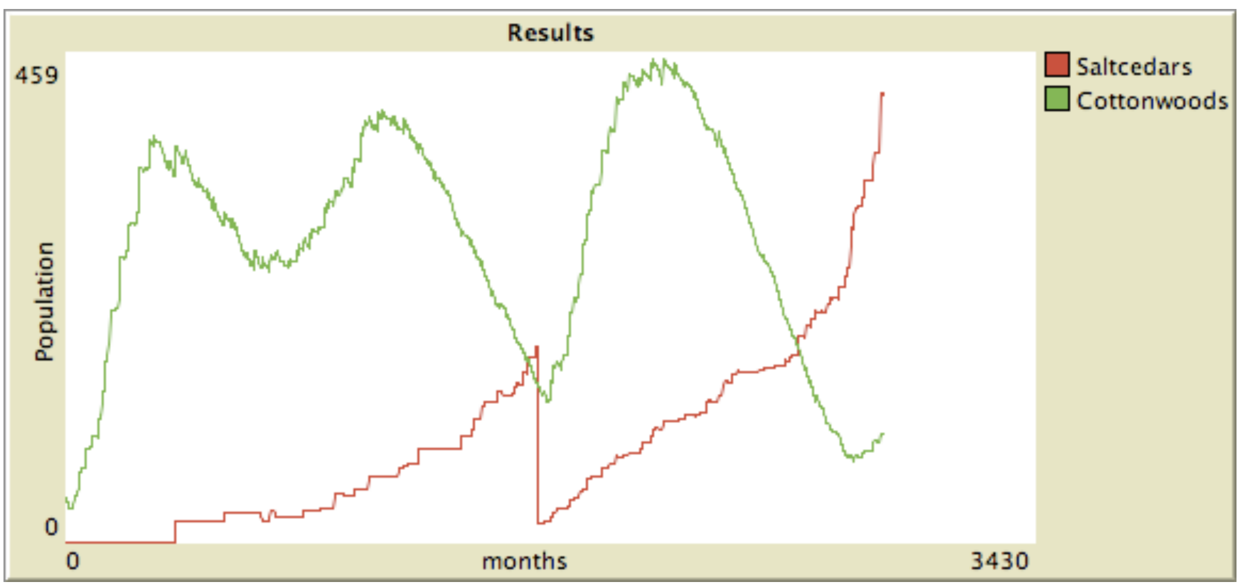


Figure 14: In this run of the model we took out 90 % of the salt cedars. The salt cedars were still able to take back control.

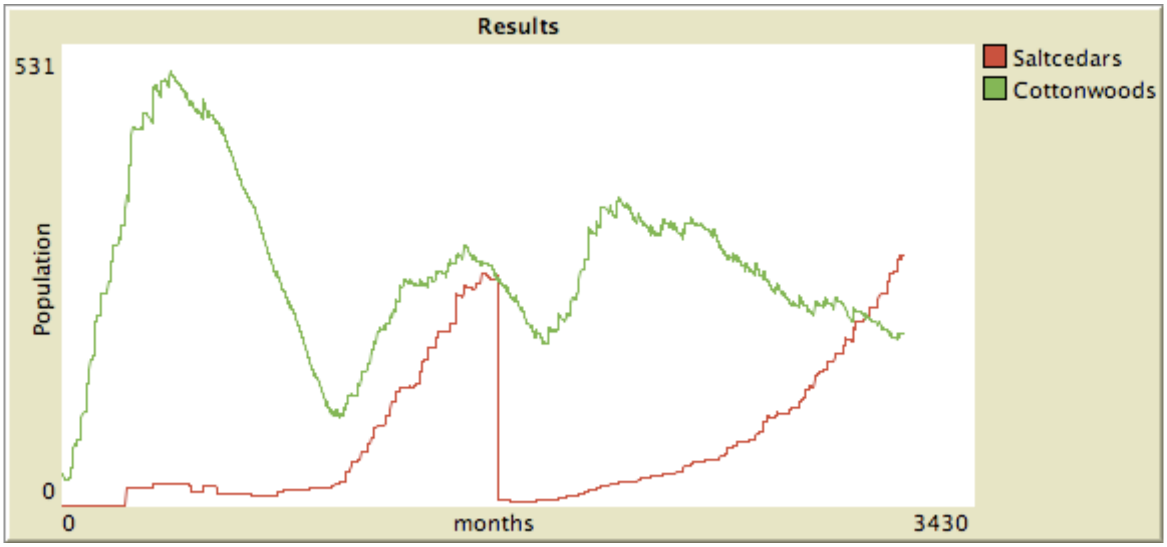


Figure 15: In this run we decreased the salt cedars population by 98%. The salt cedars still came back even from their low numbers of almost 1.

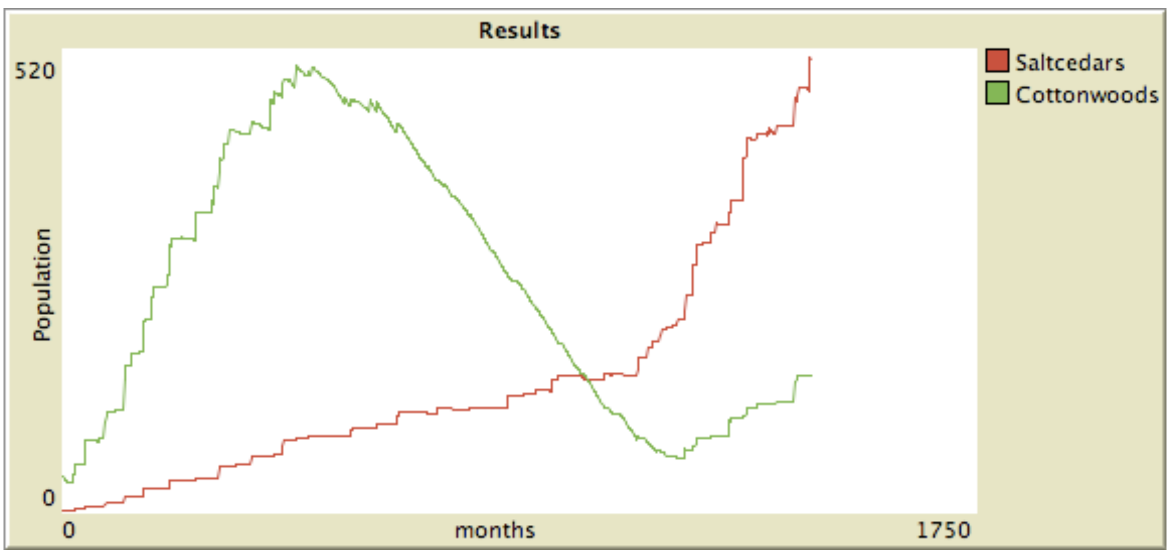


Figure 16: In this run of the program we tried starting off with one salt cedar and 20 cottonwoods. The salt cedar dominated making the cottonwoods die out

Discussion and Conclusion

It is interesting that the salt cedars were a solution to a problem of soil erosion along the rivers. However they turned out to be a bigger problem. When they were putting them in the ecosystem the computer had not been invented yet and they were not able to test the scenario first. In this work, we were able to research our problem, developed a plan and made a program that simulates the Rio Grande riparian ecosystem adding in some variables like thinning certain amounts of trees and adding disease. We did not have time to fully explore all the things we wanted to do. We also had one problem with our program, it was that the trees would not cluster by the river as shown in Figure 11. We expected most of the cottonwoods to be by the river based on our water equation. This may be a problem with balancing the amounts of water needed by the trees. The trees did seem to cluster due to the terrain we put into our water model. However, the results of just the cottonwoods showed that we could model a stable population of trees without invasive species.

When we added in the salt cedars, they overwhelmed the cottonwoods. With mechanical thinning of both trees the salt cedars came back first. When just the salt cedars were thinned they were able to regain control. In conclusion our program showed that the salt cedars can come back from little population therefore they have to be all exterminated if they are to be removed. Our program also showed that the salt cedar will come back first if there is an event which almost wipes out the trees. The salt cedars and cottonwoods without any variables in the program had a trend that would kill off the cottonwoods although we were not able to run it all the way through due to freezing problems.

Code

```
globals [
	months
	]
breed [ cottonwoods cottonwood ]
breed [ saltcedars saltcedar ]
turtles-own [
		agent-time
		agent-water
		water
		age
		neartrees
		]
to setup
ca  ;clear the map
ask turtles [ set agent-time 1 ]  ;set the months back to 1
set-default-shape cottonwoods "Cottonwood"  ;create ten cottonwoods on each side of the river
and set their age, length from the river and their water levels
create-cottonwoods Amount-of-Cottonwoods
```

```
  [
  set age 1 + random 1188
  setxy random-xcor 0 + random 15
  set water Amount-of-water
  ]
ask cottonwoods  ;set the cottonwoods size depending on their age and if their older than 90
decrease their water
  [
  if age < 120
    [ set size 1 ]
  if age >= 120 and age < 240
    [ set size 2 ]
  if age >= 240 and age < 480
    [ set size 3 ]
  if age >= 480 and age < 720
    [ set size 4 ]
  if age >= 720 and age < 960
    [ set size 5 ]
  if age >= 960
    [ set size 6 ]
  if age >= 1080
    [ set water ( water - 1 ) ]
  ]
create-terane
set-display
end

to graph  ;graph results
 set-current-plot "Results"
  set-current-plot-pen "cottonwoods"
  plot count cottonwoods
 set-current-plot "Results"
  set-current-plot-pen "saltcedars"
  plot count saltcedars
end

to set-display
ask turtles [ set label "" ]
if show-energy?
  [
  ask cottonwoods [ set label water ]
  ]
end

to create-terane
ask patches with [ pcolor = black ]
    [ set pcolor scale-color green ((random 500) + 5000) 0 9000 ]
ask patches with [ pycor <= 0 ]
  [
  set pcolor blue
  ]
end

to go
```

```
saltcedar-go
cottonwood-go
if show-energy?
  [
  ask turtles [ set label water ]
  ]
set months ( months + 1 )
set agent-time ( agent-time + 1 )
graph
-die-
end


to Add-saltcedars
set-default-shape saltcedars "saltcedar"
create-saltcedars 20
  [
  set age 1 + random 1188
  setxy random-xcor 0 + random 15
  set water Amount-of-water
  ]
end


to natural-disaster
ask cottonwoods
  [
  if random 100 > 75
    [ die ]
  ]
end


to disease
ask cottonwoods
  [
  if random 100 > 80
    [ die ]
  ]
end


to cottonwood-go
ask cottonwoods
  [
  set neartrees [size] of turtles in-radius ( [size] of myself )
  if show-neartrees?
    [
    ask cottonwoods [ set label neartrees ]
    ]
  set water  water + (( ((  [size] of myself + 1) ^ 2 ) / (mean neartrees * count cottonwoods in-
radius ([size] of myself)) )) * (((75 / (([ycor] of myself + 1) / 5))) * (1 + abs ( sin (months / 12 *
360))) + 25 * (1 * (abs(cos(months / 6 * 360))))* abs(sin ((( [ycor] of myself + [xcor] of myself)*
360)/ 25)))
```

```
  ]
;equation to determine water level
cottonwood-grow
end

to saltcedar-go
ask saltcedars
  [
  set neartrees [size] of turtles in-radius ( [size] of myself )
  if show-neartrees?
    [
    ask saltcedars [ set label neartrees ]
    ]
  set water  water + (( ((  [size] of myself + 1) ^ 2 ) / (mean neartrees * count turtles in-radius
([size] of myself)) )) * (((100 / (([ycor] of myself + 1) / 5))) * (1 + abs ( sin (months / 12 * 360))) +
25 * (10 * (abs(cos(months / 6 * 360))))* abs(sin ((( [ycor] of myself + [xcor] of myself)* 360)/
25)))
  if random 100 > 90
    [ secrete ]
  ]
saltcedar-grow
end


to secrete
ask saltcedars
  [
  ask turtles in-radius ( [size] of myself )
    [
    if ( random 1000 > 900 ) and ( breed = "cottonwood" )
      [ set water ( water - 2000 ) ]
    ]
  ]
end


to -die-
if water <= 0
  [ die ]
if ycor <= 0
  [ die ]
end

to cottonwood-reproduce
if age >= 60 and water >= 200
  [
  set water ( water - 150 )
  hatch random 3
    [
    setxy random-xcor random-ycor
    set age 1
    set size 1
    set water  ((((75 / ( ([ycor] of myself + 1) / 5)))) * (1 + abs ( sin (months / 12 * 360))) + 25 * (1 *
(abs(cos(months / 6 * 360))))* abs(sin (([ycor] of myself * 360)/ 25)))
```

```
    if ycor < 0
      [die]
    ]
  ]
end


to saltcedar-reproduce
if water >= 200
  [
  set water ( water - 150 )
  hatch random 2
    [
    setxy random-xcor random-ycor
    set age 1
    set size 1
    set water  ((((75 / ( ([ycor] of myself + 1) / 5)))) * (1 + abs ( sin (months / 12 * 360))) + 25 * (1 *
(abs(cos(months / 6 * 360))))* abs(sin (([ycor] of myself * 360)/ 25)))
    if ycor < 0
      [die]
    ]
  ]
end

to cottonwood-grow
ask cottonwoods
  [
  if age < 120 [ set water ( water - 150 ) ]
  if age >= 120 and age < 240 [ set water ( water - 200 ) ]
  if age >= 240 and age < 480 [ set water ( water - 250 ) ]
  if age >= 480 and age < 720 [ set water ( water - 300 ) ]
  if age >= 720 and age < 960 [ set water ( water - 350 ) ]
  if age >= 1080 [ set water ( water - 400 ) ]
  set age ( age + 1 )
  if age < 120
    [ set size 1 ]
  if age >= 120 and age < 240 and water >= 1
    [ set size 2 ]
  if age >= 240 and age < 480 and water >= 1
    [ set size 3 ]
  if age >= 480 and age < 720 and water >= 1
    [ set size 4 ]
  if age >= 720 and age < 960 and water >= 1
    [ set size 5 ]
  if age >= 960 and water >= 1
    [ set size 6 ]
  ]
cottonwood-reproduce
end


to saltcedar-grow
ask saltcedars
  [
```

```
  if age < 120 [ set water ( water - 150 ) ]
  if age >= 120 and age < 240 [ set water ( water - 200 ) ]
  if age >= 240 and age < 480 [ set water ( water - 250 ) ]
  if age >= 480 and age < 720 [ set water ( water - 300 ) ]
  if age >= 720 and age < 960 [ set water ( water - 350 ) ]
  if age >= 1080 [ set water ( water - 400 ) ]
  set age ( age + 1 )
  if age < 120
    [ set size 1 ]
  if age >= 120 and age < 240 and water >= 1
    [ set size 2 ]
  if age >= 240 and age < 480 and water >= 1
    [ set size 3 ]
  if age >= 480 and age < 720 and water >= 1
    [ set size 4 ]
  if age >= 720 and age < 960 and water >= 1
    [ set size 5 ]
  if age >= 960 and water >= 1
    [ set size 6 ]
  ]
saltcedar-reproduce
end
```