An Herbaceous Vegetation Study

New Mexico Adventures in:
Super Computing Challenge
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Executive Summary

There are 19 pueblos in New Mexico, all of which spread out across the state. One specific pueblo is the pueblo of Santo Domingo. Santo Domingo has about 80, 000 acres of land. On the Indian reservation is the Galisteo River channel that spreads along the reservation up to 20 miles in length and ½ mile across (width).

The Galisteo River channel contains to 98% in population of two particular invasive specie trees, Russian Olives (Elaeagnus angustifolia) and the Salt Cedars (Tamarix ramosissima). With a 98% invasive population, only 2% native plant species are among those in the Galisteo channel. Water is the primary source that attracts the vegetation.

Two experimental quads and 2 control quads were made in the Galisteo River channel. I determined the population of the native and invasive trees that are living in the river channel. Observations concluded that invasive species are tightly bunched up everywhere; the roots go deep into the ground and spread out pushing the native plants away where the roots do not get enough water. A perennial spring flows within the channel, and one of the key observations that is, if 95% of the non-native, invasive species are removed, there will be enough water and room for native plants to be reintroduced. With less water taken by the invasive species, the underground water flow may increase, causing the perennial spring to increase its surface water quantity.

The project, An Herbaceous Vegetation Study, is a simulation of how the removal of invasive species in an area can increase the quantity of native plant species on land with enough water provided for the native plants, and in addition can increase the

quantity of underground water that is provided by aquifers. The simulation uses Star Logo to model the amount of Invasive trees in the Galisteo River channel and gives a visual aid of how invasive species use up all the water taking it away from the native plants species to a point where the native plants do not have any water left for them to survive. Actions taking place, such as bulldozers coming in to the river channel and removing the invasive species, the Star Logo model demonstrates how the removal of the invasive species will positively affect the native plants, and provide for water to being used among the plants.

Introduction

The Herbaceous Vegetation Study is a Star Logo simulation of an environment with water quantity and the population of native and invasive plant species being predicted. Using Star Logo the Galisteo River channel environment was created, along with the agents of native plant species (plants other than invasive), the invasive plant species (Russian Olives and Salt Cedars), and the bulldozers, which may be removing the invasive plant species (these agents are referred to as turtles in the Star Logo program). The invasive species live among the native plant species in the environment where they both compete for water to survive; however, the invasive species are much too strong and large for the native species giving them control over water and land space, killing off the native species through water deprivation. The bulldozer agents may come in to remove the invasive species and fix provide enough water for the native plants to increase in population. In the environment a model is an example of water diffusion, which is spread across the river channel toward the two sets of plants. The significance of these elements are to help and to provide a better understanding and visual aid of how the removal of invasive species among native species can provide more water for the native species to grow, increasing their population and causing the water quantity (in this case) the perennial spring to increase its water flow.

Agent specifications

To create the environment, there are four types of agents to code. These agents are the (invasive species) Russian Olives and Salt Cedars, the native species, and the bulldozers that are removing the invasive species.

Invasive Species:

Russian Olives: (life span 50 years, water usage 97%)

```
to russian-olives-go
   set age age + 1
   if age > 50 [ die ]
   ask-patch-at 0 0 [set water-at 0 0 ((water-at 0 0) - water-usage)]

;; do this for all the other positions
   ask-patch-at 0 1 [set water-at 0 1 ((water-at 0 1) - (water-usage * (water-from-
neighbors / 100)))]

   ask-patch-at 1 1 [set water-at 1 1 ((water-at 1 1) - water-usage)] * (water-from-
neigbors / 100)))]
   ask-patch-at 1 0 [set water-at 1 0 ((water-at 1 0) - water-usage)] * (water-from-
neighbors / 100)))]
   ask-patch-at 1 -1 [set water-at 1 -1 ((water-at 1 -1) - water-usage)] * (water-from-
neighbors / 100))]
   ask-patch-at 0 -1 [set water-at 0 -1 ((water-at 0 -1) - water-usage)] * (water-from-
neighbors / 100))]
   ask-patch-at -1 -1 [set water-at -1 -1 ((water-at -1 -1) - water-usage)] * (water-from-
neighbors / 100))]
   ask-patch-at -1 0 [set water-at -1 0 ((water-at -1 0) - water-usage)] * (water-from-
neighbors / 100)))]
   ask-patch-at -1 1 [set water-at -1 1 ((water-at -1 1) - water-usage)] * (water-from-
neihgbors / 100)))]
```

Salt Cedars: (life span 30 years, water usage 93%)

```
to salt-cedars-go
set age age + 1
   if age > 30 [ die ]
   ask-patch-at 0 0 [set water-at 0 0 ((water-at 0 0) - water-usage)]

;; do this for all the other positions
   ask-patch-at 0 1 [set water-at 0 1 ((water-at 0 1) - (water-usage * (water-from-
neighbors / 100)))]

   ask-patch-at 1 1 [set water-at 1 1 ((water-at 1 1) - water-usage)] * (water-from-
neigbors / 100)))]
   ask-patch-at 1 0 [set water-at 1 0 ((water-at 1 0) - water-usage)] * (water-from-
neighbors / 100)))]
   ask-patch-at 1 -1 [set water-at 1 -1 ((water-at 1 -1) - water-usage)] * (water-from-
neighbors / 100))]
   ask-patch-at 0 -1 [set water-at 0 -1 ((water-at 0 -1) - water-usage)] * (water-from-
neighbors / 100))]
   ask-patch-at -1 -1 [set water-at -1 -1 ((water-at -1 -1) - water-usage)] * (water-from-
neighbors / 100))]
   ask-patch-at -1 0 [set water-at -1 0 ((water-at -1 0) - water-usage)] * (water-from-
neighbors / 100)))]
   ask-patch-at -1 1 [set water-at -1 1 ((water-at -1 1) - water-usage)] * (water-from-
neihgbors / 100)))]
```

Native Species: (life span 1 year, water usage 5%)

```
to native-species-go
set age age + 1
   if age > 1 [ die ]
   ask-patch-at 0 0 [set water-at 0 0 ((water-at 0 0) - water-usage)]

;; do this for all the other positions
   ask-patch-at 0 1 [set water-at 0 1 ((water-at 0 1) - (water-usage * (water-from-
neighbors / 100)))]

   ask-patch-at 1 1 [set water-at 1 1 ((water-at 1 1) - water-usage)] * (water-from-
neigbors / 100)))]
```

```
   ask-patch-at 1 0 [set water-at 1 0 ((water-at 1 0) - water-usage)] * (water-from-
neighbors / 100)))]
   ask-patch-at 1 -1 [set water-at 1 -1 ((water-at 1 -1) - water-usage)] * (water-from-
neighbors / 100))]
   ask-patch-at 0 -1 [set water-at 0 -1 ((water-at 0 -1) - water-usage)] * (water-from-
neighbors / 100))]
   ask-patch-at -1 -1 [set water-at -1 -1 ((water-at -1 -1) - water-usage)] * (water-from-
neighbors / 100))]
   ask-patch-at -1 0 [set water-at -1 0 ((water-at -1 0) - water-usage)] * (water-from-
neighbors / 100)))]
   ask-patch-at -1 1 [set water-at -1 1 ((water-at -1 1) - water-usage)] * (water-from-
neihgbors / 100))))]
```

The agent that represents the Russian olive is a tree shape that is olive green. The Russian olive agent has variables that represent and specify age, growth rate, life span, and water usage. The age represents how old the Russian olive is setting the age at a random number of 0 being a seedling and 1, 30, or 50 years depending on the type of plant species (invasive-Russian Olive or Salt Cedar) or the native species. The growth rate is a random number of how fast the trees grow per year, 1 being one new tree every month and (1, 30 or 50) being the highest of (1, 30, or 50) new trees a year. The life span intertwines with the age, where 0 is a seedling and (1, 30, or 50) are the trees are at their final age. After (1, 30, or 50) years of age, the tree dies, and the final correspondent variable is the water usage of 97% of its total that it takes from the native species.

The tree population is a randomly set number, from 1 through a hundred of the two types of plant species. There is also a random setting of bulldozers that are placed within the environment that will remove the invasive species in the Galisteo River channel. Each tree is randomly assigned to the environment, and each is represented by a separate color: olive green representing the Russian Olives; red representing the Salt

Cedars; purple representing the native species; and yellow; representing the yellow bulldozers.

Plant actions:

The native and invasive plant species are placed on the environment on an x and y axis, with a water value under each tree. The Russian Olives are set on a patch and the water value is 97% where they take up water that is all around them. The Salt Cedars are the same, with the same action of a water patch value, where the Salt Cedars take up 93% of the water that is all around them, according to the x and y axis.

The native plant species are quite similar, only the water usage is low in quantity; they only use up 3 to 5% of water depending on the population of the plants that surrounds them.

Bulldozer actions:

The bulldozers are placed at a random number and setting in the environment, taking one move at a time around the trees. From any starting point or patch, the tree is given a water value of how much water is underneath the tree. When the bulldozer moves about the patches or the environment, it removes a tree; then, the water value of the patch increases about half the value the patch began and a native plant species is then reintroduced.

The Environment

The simulation environment is set up in patches arranged on a grid which also consists of an x and y grid.

The Star Logo environment is a large quad of the Galisteo River channel that consists of water patches in the environment which represent the underground aquifer. Trees both native and invasive are set randomly on top of the environment with a water value. In the environment water diffusion is shown on the top right hand side of the grid, which represents the water dispersion that is flowing along the environment.

The dark, navy-blue represents the water quantity at its highest and deepest; the bright blue represents water that is somewhat deep; and the light blue represents water that spreads shallowly across the grid equally among the plants in the river channel, but the lighter blue also makes a point that there is not plentiful water within the light blue areas of the environment.

The User Interface

Before beginning the model/program, the different types of variables can be set by the user.

- The **Number of Russian Olives:** Slider controls the number of Russian Olives to be created in the environment. This variable might help, to view the percentage of Russian Olives and once removed how long it will take for native species to be re-introduced.
- The **Number of Salt Cedars:** Slide controls the number of Salt Cedars that will be created in the environment. This variable could also help to determine the invasive relationship between the Russian Olives and Salt Cedars in the environment.

- The **Number of Native Plants:** The slider controls the number of native species that will be introduce or placed within the environment. This will help to determine their action status within the environment, water, and the invasive species.

-The sum of the Russian Olives/Salt Cedars (Invasive Species) and the Native Plant species cannot equal greater than a 100% within the environment.

- The **Number of Bulldozers:** The bulldozer slider controls the number of bulldozers that are in the environment when they are traveling in the environment to remove the invasive species.
- Once all the variables are set, the user clicks and uses the water diffusion button, which sets the environment to the amount of water that should be within the environment (water flow) and how much water is provided among the plant species.
- Finally, once the water diffusion and variable are all set, the user then uses and clicks on the set-up and go button (which can also represent a forever or once rotation), which will then start up the computer model/program.

Running the Simulation

During the set up phase/step, the water is already at the time diffused to show how much water is present when the trees will be set up. The variables for the trees are already set (random must be equal to 100) where the trees are then set up randomly on the grid, each containing a water variable, each tree depending on what species is taking up the water all around and using it. If native species are around the invasive species, there is no match, not enough water so the native plant dies. The bulldozers that are set up then come at random in any specific spot; they travel around the environment removing the invasive species. Once the invasive species are removed, the native species will get a chance at the water, and will then be able re-introduce a few of the native plants in the soil, and also increase the water quantity of the underground water that the invasive species was taking up.

Once the set up phase is completed (when the setup button is clicked), a random setting of trees and machinery takes place invasive Russian Olives, Salt Cedars, and native species and bulldozers are scattered all over the light to dark blue patches on the grid, representing a water value. The bulldozers then travel randomly in every direction and remove the invasive species. Trees that are set randomly age as time passes. During the simulation, each tree that reaches its life span age dies out, and each tree removed by the bulldozers will increase in half the quantity of water that will be provided to the native species and will increase the water flow of the perennial spring. Each tree on a water patch removes up to 5 – 97% of the water value in each patch. Each patch of blue will eventually turn to a darker blue, which represents a higher water quantity within the environmental patch. Native species are re-growing as the invasive species are removed, no more purple turtles will bloom modeling the growing rate of native species. Every once in a while a green or red turtle (tree) will pop up on the blue water patches representing the slight re-growth of invasive species.

Assumptions

- Assumption 1- The random tree settings of invasive species will not completely be removed from the environment. Therefore they will always come back, but not in as large a quantity as before.
- Assumption 2 - Native plant species cannot survive with more than two invasive species around their land habitat, which will cause them to die out due to lack of water.
- Assumption 3 - Invasive species take up 93-97% of the water value from the native species.
- Assumption 4 - Invasive species are too large for the native species to compete against.
- Assumption 5- Native species only use up to 5% of the water value within their surroundings.
- Assumption 6- All plants die at the end of their life span. Russian Olives die at the age of 50, Salt Cedars die at the age of 30, and the native plant species die each year (yearly).
- Assumption 7- The water value increases in each patch when an invasive tree is removed or dies.
- Assumption 8 - Bulldozers are constantly removing invasive species.
- Assumption 9 - Native species are reintroduced when competition with invasive species is removed and there is enough water for the native plants.

- Assumption 10- Once invasive species are removed, perennial water flow increases, and the native plant population increases.

Results

Table 1: Water usage X Percent % taken from each neighbor:

15 % Russian Olives	138 Russian Olives	Ending Population 100 years
3% Salt Cedars	869 Salt Cedars	
1 % Native Species	3, 541 Native Species	
0 Bulldozers		

Table 2: Table 1: Water usage X Percent % taken from each neighbor:

40% Russian Olives	260 Russian Olives	Ending Population 100 years
55% Salt Cedars	668 Salt Cedars	
5% Native Species	1,970 Native Species	
25 Bulldozers		

Conclusion

Through experimental observations of changing variables, the more bulldozers arranged within the environment, the better quality and chance the native species have to reproduce and obtain enough water to survive. The bulldozers travel in the environment removing the invasive species and, which then increases the population of native species within the environment, and increasing the water flow of the perennial spring.

References

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Websites:

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"Russian Olives/ Salt Cedars," Invasive Species.com 28 Nov. 2005 <http://www. invasivespecies.edu>.

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Appendix A

The Star Logo code:

```
;; Observer procedures
;; Each patch has a water value
patches-own [
        saved-color
        saved-water
        saved-water-increase
        water
        water-increase
        ]

;; There are three kinds of turtles representing plant species
breeds [
        salt_cedars
        russian_olives
        native_species
        bulldozers
        ]

turtles-own [
        age
        lifespan
        water-usage
        water-from-neighbors
        ]

;; Herbacious vegetation project
```

```
;; About the project:  In this project there is a spring that is perennial and has a run off.
;; There is some ground water beneath after the water is absorbed.
;; The trees are randomly distributed

to setup_water
        ask-patches [
                set water (500 - pc)
                set water-increase (water / 10)
        ]
        ;restore_background
end

to save_background
        ask-patches [
                set saved-color pc
                set saved-water water
                set saved-water-increase water-increase
        ]
end


to restore_background
        ask-patches [
                setpc saved-color
                set water saved-water
                set water-increase saved-water-increase
        ]
end


;; Use this procedure by clicking the diffuse-water button only when you want to create a
new landscape
to diffuse-water   ; this is what we used to create the spring and water run off
        ask-patches [ if pc = blue [ set water ((random 50) + 25)] ]
        repeat 10 [diffuse water .9 ]
        ask-patches [scale-pc blue (int (water + 1)) 10 0]
end



to create_trees    ; this is what we used to create the trees

  clearturtles
  ifelse (percent_salt_cedar + percent_russian_olive + percent_native_species) > 100
  [
    print "error: must be less than or equal to 100"
```

```
      stop
   ]
   [
      let [:numpatches (screen-height * screen-width)]   ; gives us the total number of
patches

      let [:num_salt_cedars (:numpatches * (percent_salt_cedar / 100))]  ; how many salt
cedars to put in the envir.
      create-salt_cedars-and-do  :num_salt_cedars
                  [
                   place_uniquely
                   setshape tree_shape
                   setcolor 14
                   set age (random 30)
                   set lifespan 30
                   set water-usage 10
                   set water-from-neighbors 93]

      let [:num_russian_olives (:numpatches * (percent_russian_olive / 100))]  ; how many
russian olives to put in the envir.
      create-russian_olives-and-do :num_russian_olives
                  [
                  place_uniquely
                  setshape tree_shape
            setcolor 52
                  set age (random 50)
                  set lifespan 50
                  set water-usage 20
                  set water-from-neighbors 97]

      let [:num_native_species (:numpatches * (percent_native_species / 100))]  ; how
many native species to put in the envir.
      create-native_species-and-do :num_native_species
                  [
                  place_uniquely
                  setshape tree_shape
            setcolor 115
                  set age 0
                  set lifespan 1
                  set water-usage 5
                  set water-from-neighbors 0]
   ]

end
```

```
to create_bulldozers
          create-bulldozers-and-do num_bulldozers
                    [setxy random screen-width random screen-height
                    setshape bulldozer-shape
          setcolor 44]
end


to go
  ask-russian_olives [ russian-olives-go]
  ask-salt_cedars [ salt-cedars-go ]
  ask-native_species [ native-species-go ]
  ask-bulldozers [bulldozers-go ]

  ask-patches [set water water + water-increase]

end

;;Turtle Procedures

to place_uniquely
                           setxy random screen-width random screen-height
                                if count-turtles-here > 1 [place_uniquely]
end

to russian-olives-go
   set age age + 1
   if age > 50 [ die ]

   ;; current patch
   ask-patch-at 0 0 [set water-at 0 0 ((water-at 0 0) - 20)]

   ;; this is for all the neighboring positions
   ask-patch-at 0 1 [set water-at 0 1 ((water-at 0 1) - 19.4)]
   ask-patch-at 1 1 [set water-at 0 0 ((water-at 0 0) - 19.4)]
   ask-patch-at 1 0 [set water-at 0 0 ((water-at 0 0) - 19.4)]
   ask-patch-at 1 -1 [set water-at 0 0 ((water-at 0 0) - 19.4)]
   ask-patch-at 0 -1 [set water-at 0 0 ((water-at 0 0) - 19.4)]
   ask-patch-at -1 -1 [set water-at 0 0 ((water-at 0 0) - 19.4)]
   ask-patch-at -1 0 [set water-at 0 0 ((water-at 0 0) - 19.4)]
   ask-patch-at -1 1 [set water-at 0 0 ((water-at 0 0) - 19.4)]

   ;; if there is enough water here reproduce
   if (water-at 0 0) > 300 [
                                              hatch [
```

```
                                  set age 0
      jump 1
                        ;; add the rules for when a new tree dies

          if count-native_species-here > 0 [ kill one-of-native_species-here ]
     ]
   ]
   if (water-at 0 0) < 10 [die]

end


to salt-cedars-go
   set age age + 1
   if age > 30 [ die ]

   ;; current patch
   ask-patch-at 0 0 [set water-at 0 0 ((water-at 0 0) - 10)]

   ;; this is for all the neighboring positions
   ask-patch-at 0 1 [set water-at 0 1 ((water-at 0 1) - 9.3)]
   ask-patch-at 1 1 [set water-at 0 0 ((water-at 0 0) - 9.3)]
   ask-patch-at 1 0 [set water-at 0 0 ((water-at 0 0) - 9.3)]
   ask-patch-at 1 -1 [set water-at 0 0 ((water-at 0 0) - 9.3)]
   ask-patch-at 0 -1 [set water-at 0 0 ((water-at 0 0) - 9.3)]
   ask-patch-at -1 -1 [set water-at 0 0 ((water-at 0 0) - 9.3)]
   ask-patch-at -1 0 [set water-at 0 0 ((water-at 0 0) - 9.3)]
   ask-patch-at -1 1 [set water-at 0 0 ((water-at 0 0) - 9.3)]

   if (water-at 0 0) > 300 [
                                  hatch [
                                   set age 0
                              set heading random 360
      jump 2
          if count-native_species-here > 0 [ kill one-of-native_species-here ]
     ]
   ]
   if (water-at 0 0) < 10 [die]

end



to native-species-go
   set age age + 1
   if age > 1 [ die ]
```

```
    ;; current patch
    ask-patch-at 0 0 [set water-at 0 0 ((water-at 0 0) - 5)]

    if (water-at 0 0) > 100 [
       repeat 2 [
                                      hatch [
                                      set age 0
                     set heading random 360
                       jump random 3
              if count-russian_olives-here > 0 [ die ]
                if count-salt_cedars-here > 0 [ die ]

                             ]
                             ]
   ]
    if (water-at 0 0) < 10 [die]
end


to bulldozers-go
   rt random 90
   lt random 90
   fd 1
   kill-all-russian_olives
   kill-all-salt_cedars
end


to kill-all-russian_olives
   if count-russian_olives-here > 0 [
                    kill one-of-russian_olives-here
                       kill-all-russian_olives
   ]
end


to kill-all-salt_cedars
   if count-salt_cedars-here > 0 [
                     kill one-of-salt_cedars-here
                        kill-all-salt_cedars
   ]
end
```

Appendix B

Charts and Graphs

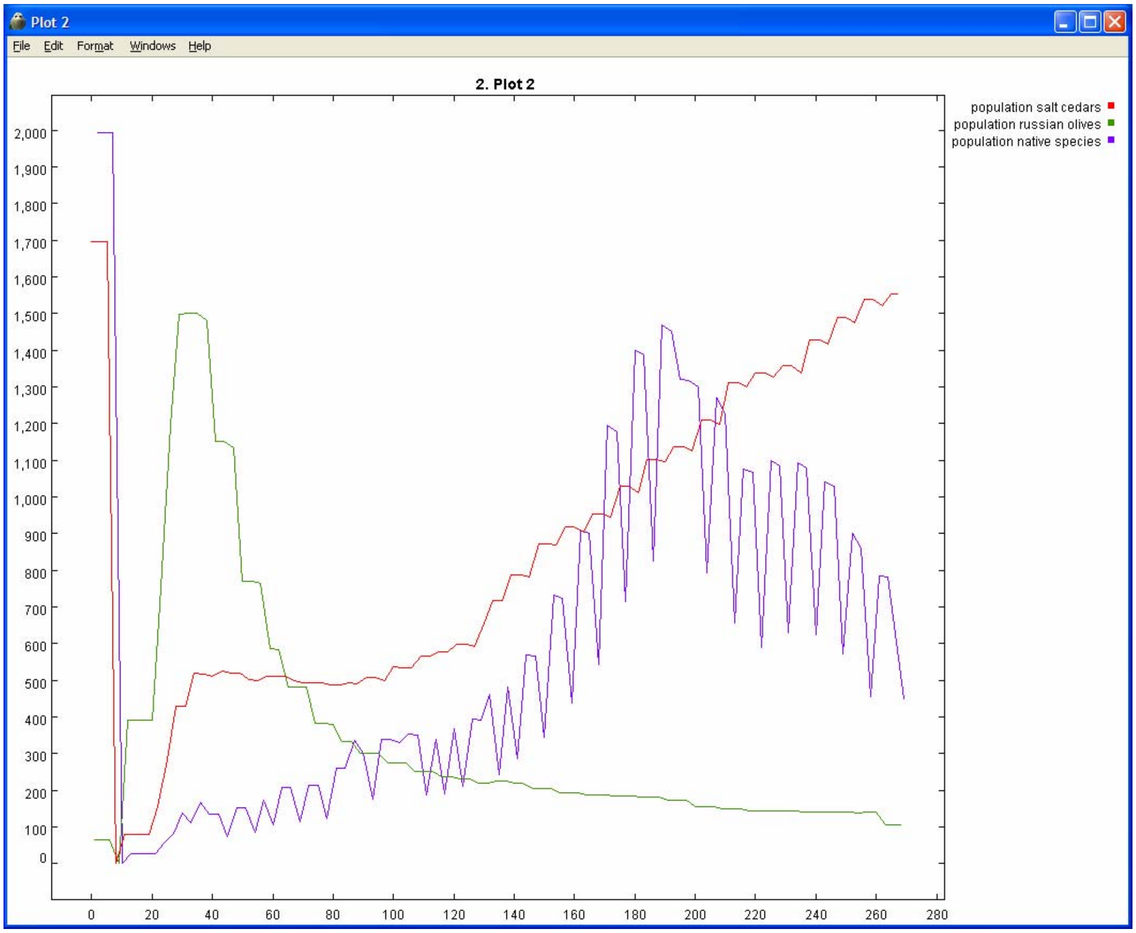

Chart : Water usage X Percent % taken from each neighbor

40% Russian Olives

55% Salt Cedars

5% Native Species

0 Bulldozers

240 Russian Olives

648 Salt Cedars

690 Native Species

Ending Population
100 years