INVASION SCIENCE RESEARCH SYMPOSIUM

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Improving Biocontrol in Invasive Species: Agent-Based Model Insights

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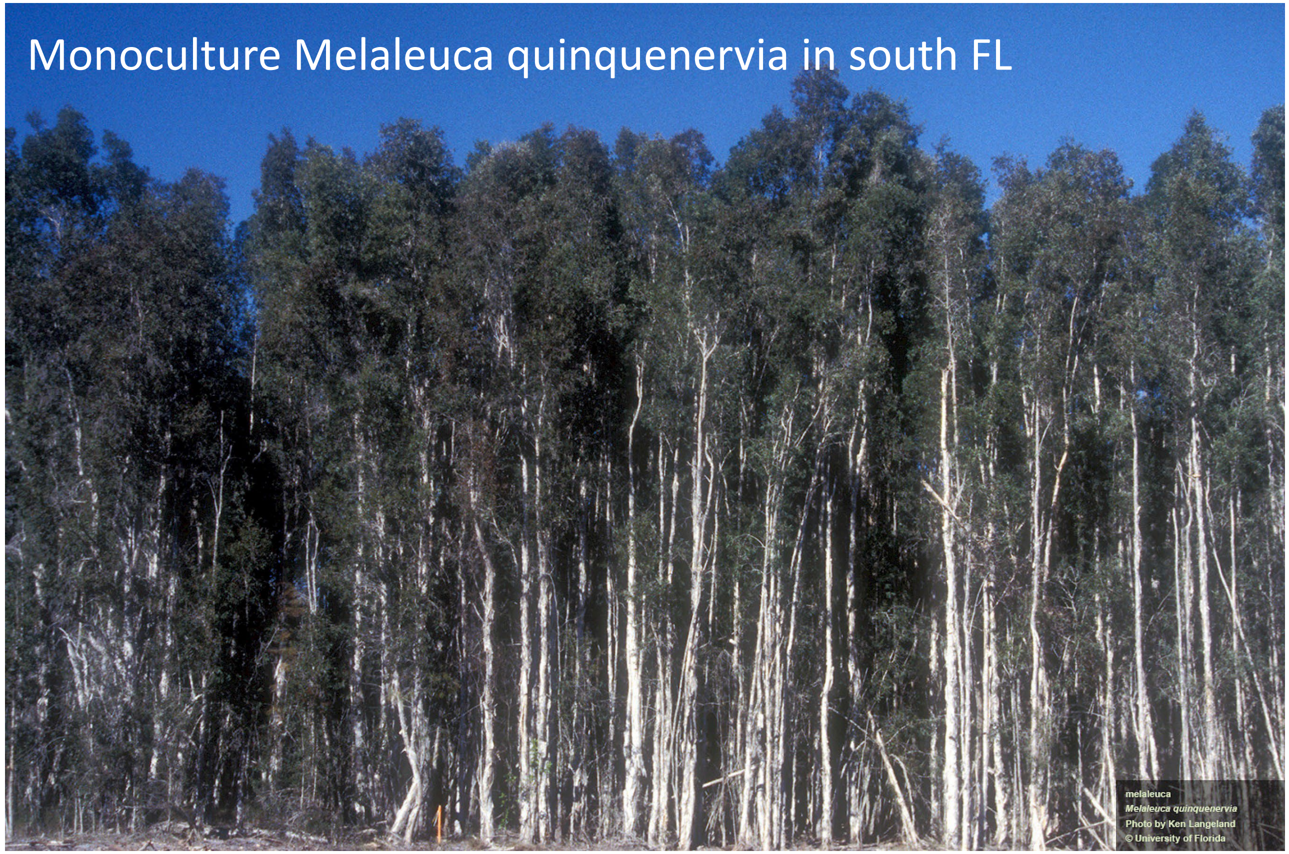
- Background: who, where and why
- Objectives: what we are interested in
- Methods: Agent-Based Model
- Results: why they're helpful
- Conclusion



Who, where and why

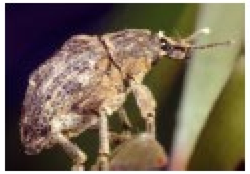
Background	Objectives	Methods	Results	Conclusion

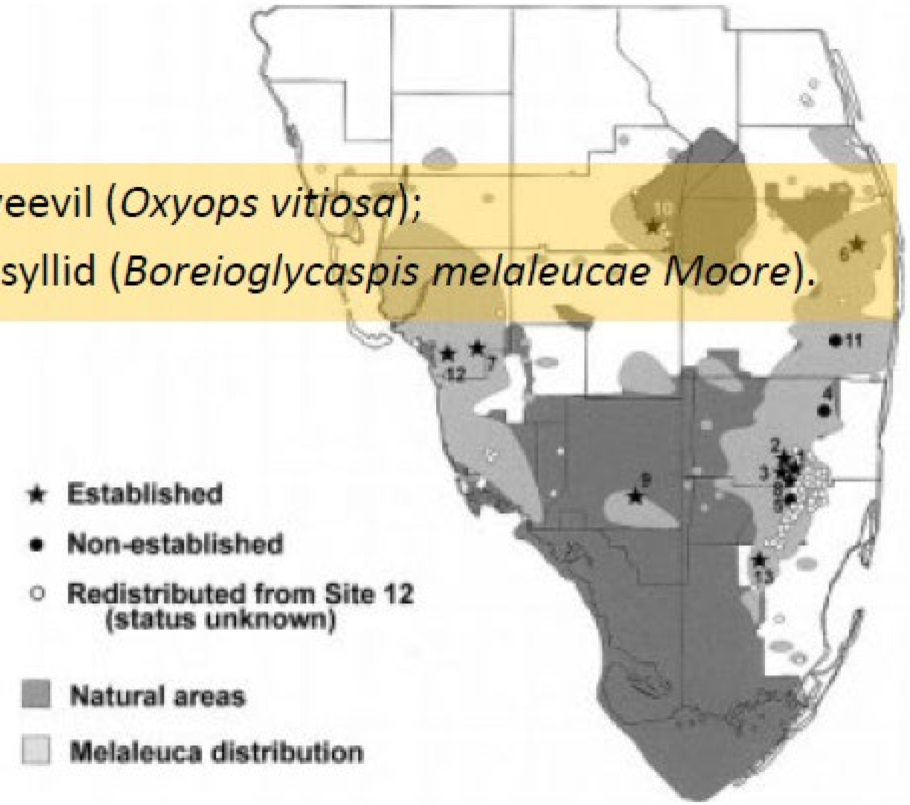
Who, where and why

Herbicides applied to melaleuca using the "frill-and-girdle" technique. Application areas are dyed blue.

Bio-control

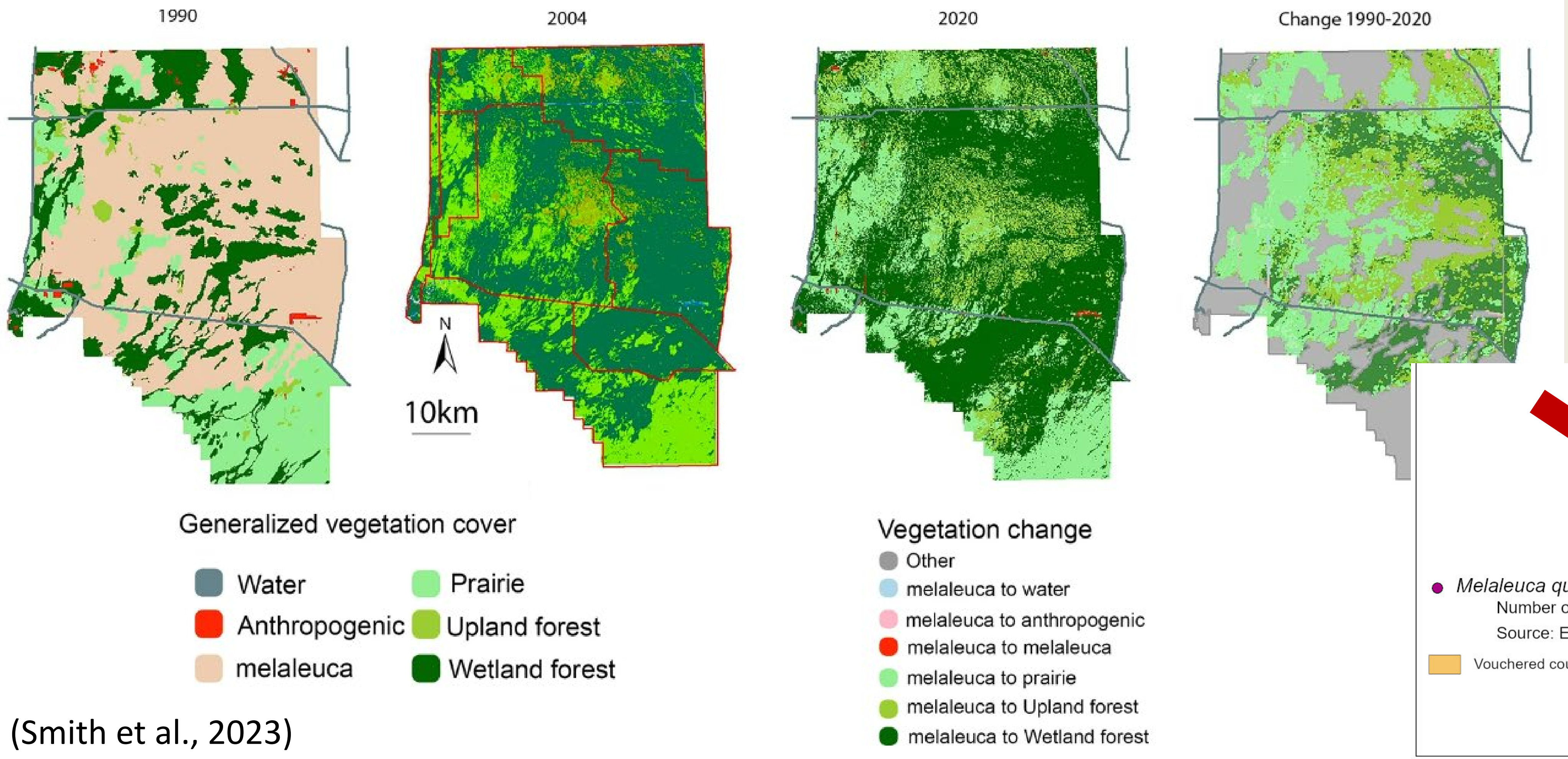
- 1997: Australian weevil (*Oxyops vitiosa*);
- 2002: Melaleuca psyllid (*Boreioglycaspis melaleucae Moore*).



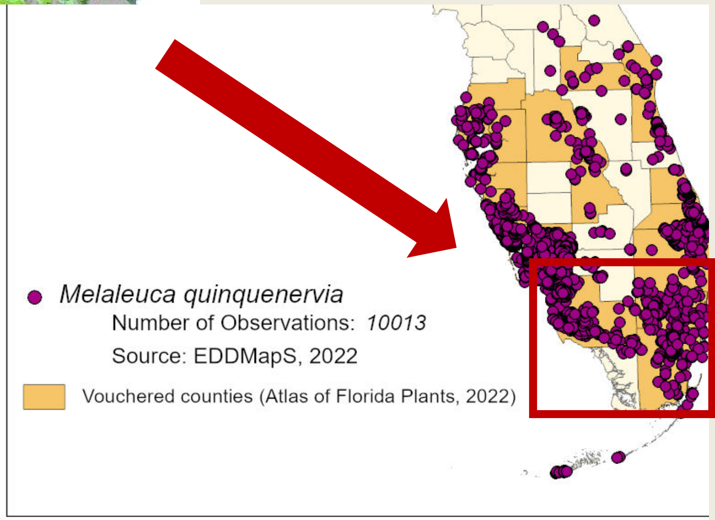


3.3 million individual biological control agents
407 locations
15 Florida counties

Effective control outcomes



(Smith et al., 2023)



Previous model version

Agent-based modeling of competition of *Melaleuca quinquenervia* and hardwood hammock has been studied using the model ManHam (Lu et al. 2022, 2023).

- Basic structure of model
- Major results

Lu, Y., DeAngelis, D.L., Xia, J. and Jiang, J., 2022. Modeling the impact of invasive species litter on conditions affecting its spread and potential regime shift. *Ecological Modelling*, *468*, p.109962.

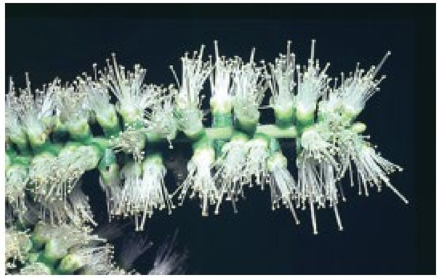
Lu, Y., Xia, J., Magee, L.J. and DeAngelis, D.L., 2023. Seed dispersal and tree legacies influence spatial patterns of plant invasion dynamics. *Frontiers in applied mathematics and statistics*, *9*, p.1086781.

Objectives

Weed alert

Melaleuca

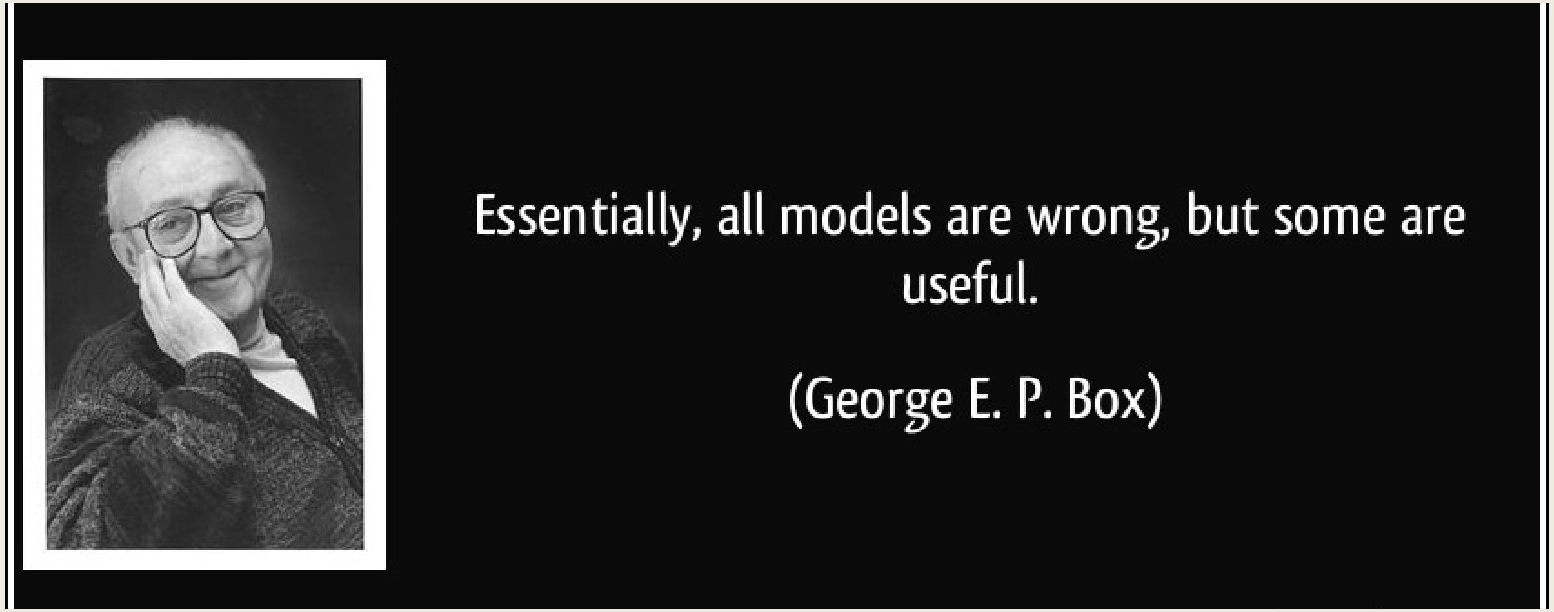
(Melaleuca quinquenervia)



Melaleuca flowers

- How can my model be made more realistic?
- Can the model be used to improve the way that biocontrol is applied to Melaleuca?

Agent-Based Model



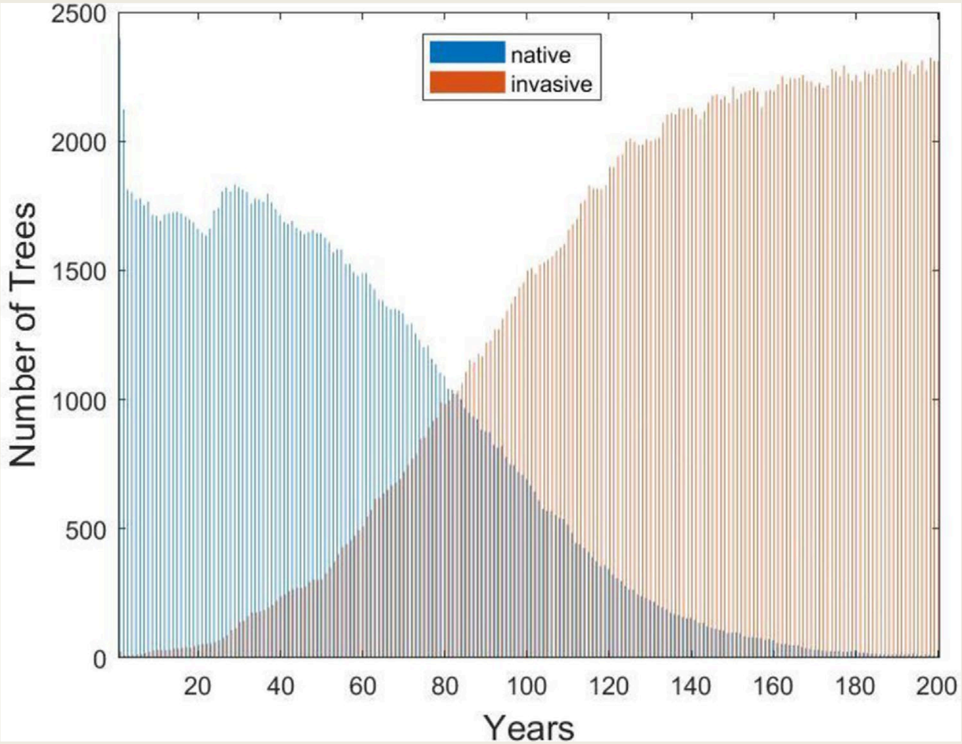
- An initial distribution of native trees and a few invaders can be set.
- Growth, competition, litterfall and, when mature, seed dispersal, for each tree are followed.
- New saplings enter through stochastic simulation, depending on local litter and light conditions where seeds have fallen.
- Tree mortality depends on several factors, including chronic slow growth and density dependent.

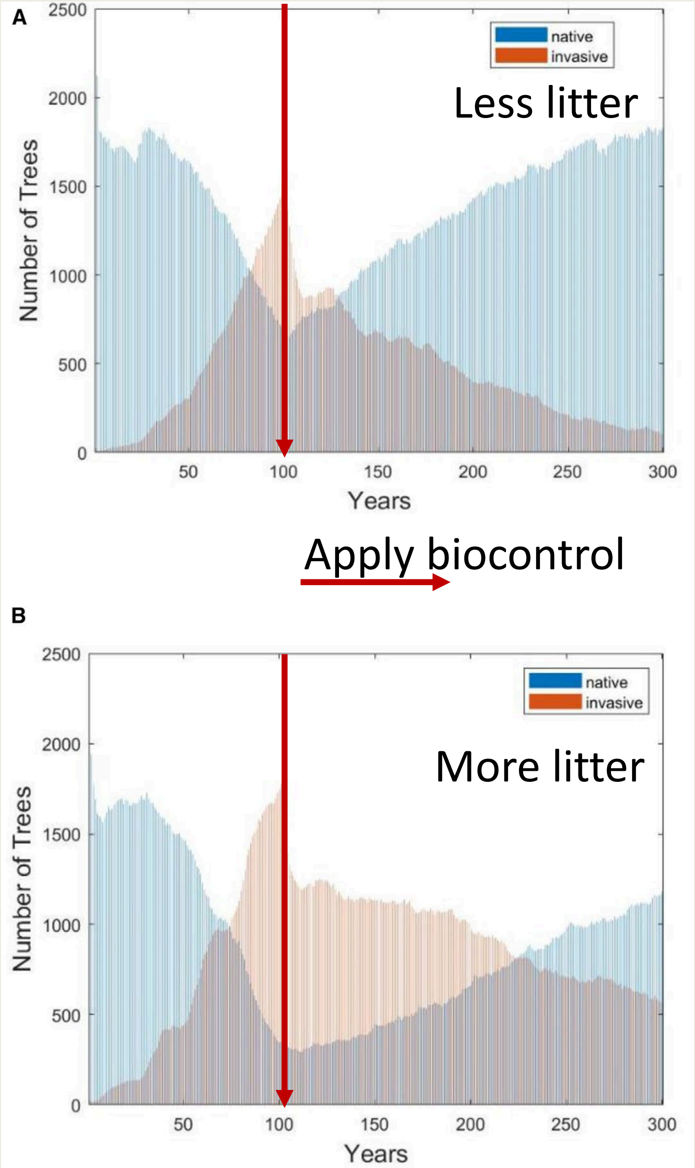
(Lu et al., 2022)

Previously in Lu et al., 2022…

→ Reductions of **growth** rate
And **birth rate** of 80%

Previously in Lu et al., 2022...

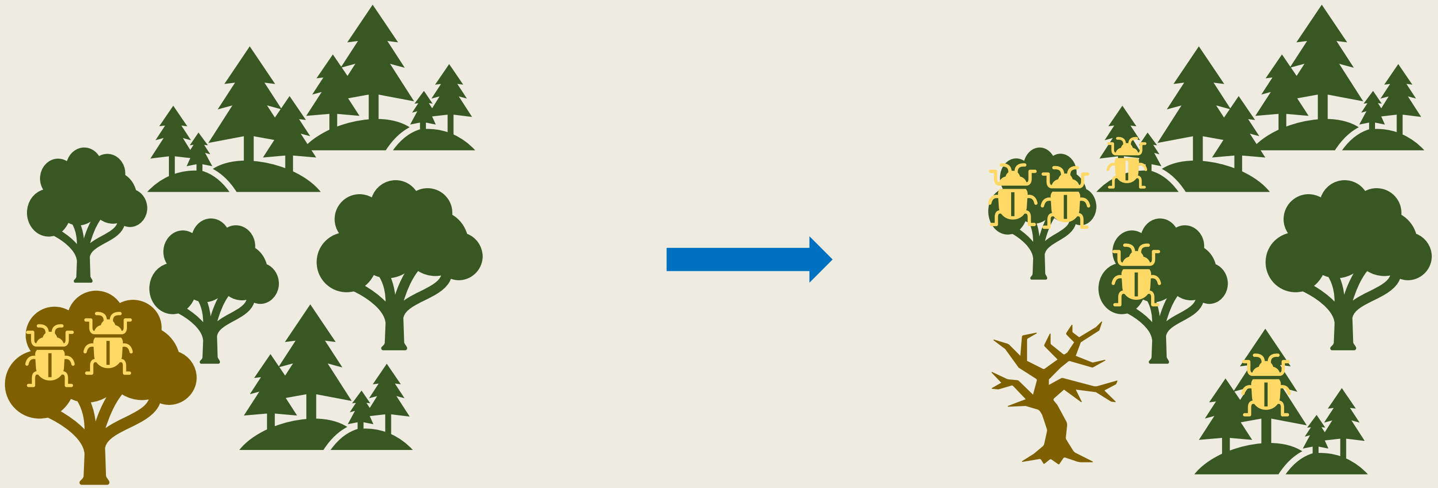


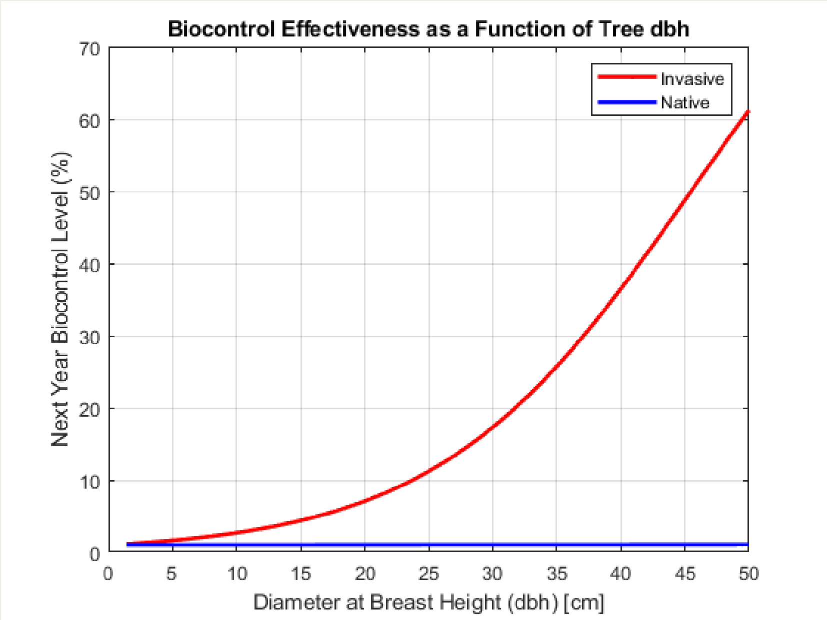


(Lu et al., 2022)

Biocontrol 2.0 beta

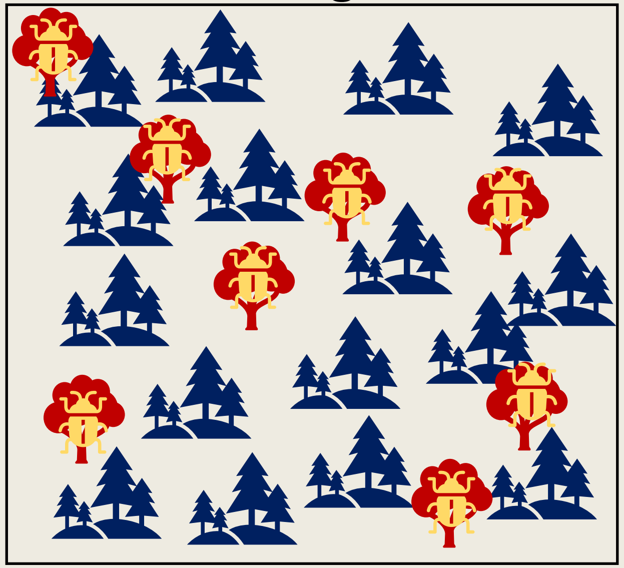
- Biocontrol causes NO harm to native species.
- Biocontrol accumulates more in invasive species.
- Larger dbh facilitates longer dispersal distance of biocontrol agents.
- Higher levels of biocontrol, lower reproduction rates.
- Higher levels of biocontrol, higher mortality rates.



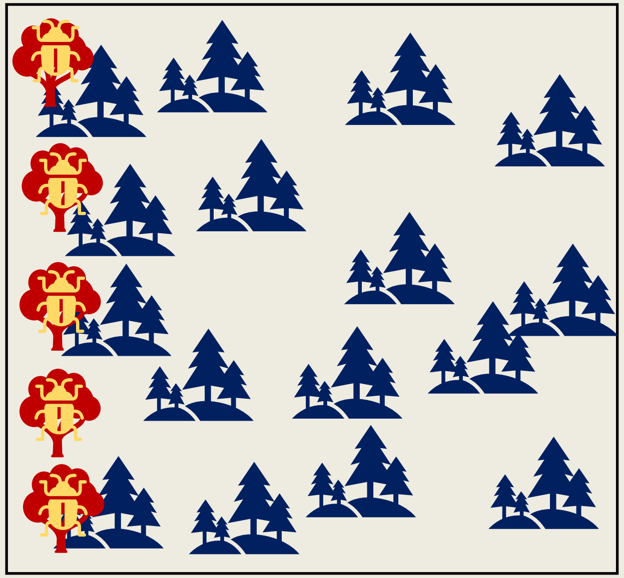


Biocontrol 2.0 beta

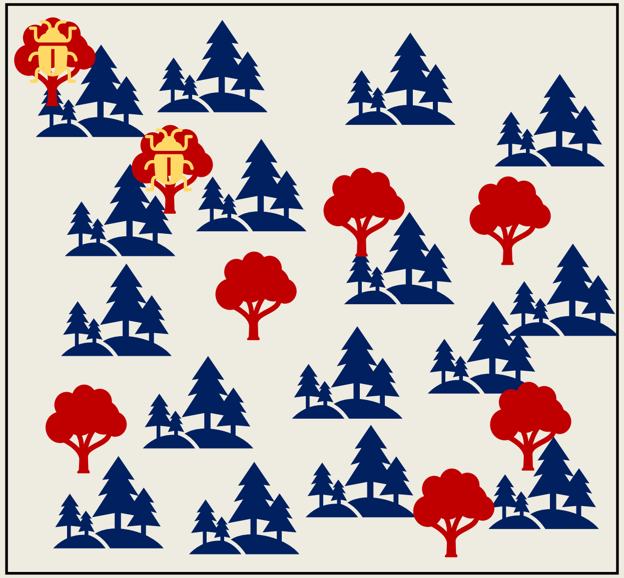
- Biocontrol measures kick in 65 years after the invasion begins.
- **Scenario 1** : Invasive species are randomly distributed, with biocontrol measures starting on each one.
- **Scenario 2**: Both invasive species and biocontrol measures start on the left side.
- **Scenario 3**: Invasive species are randomly distributed, with biocontrol measures are set in a limited region.



Scenario 1



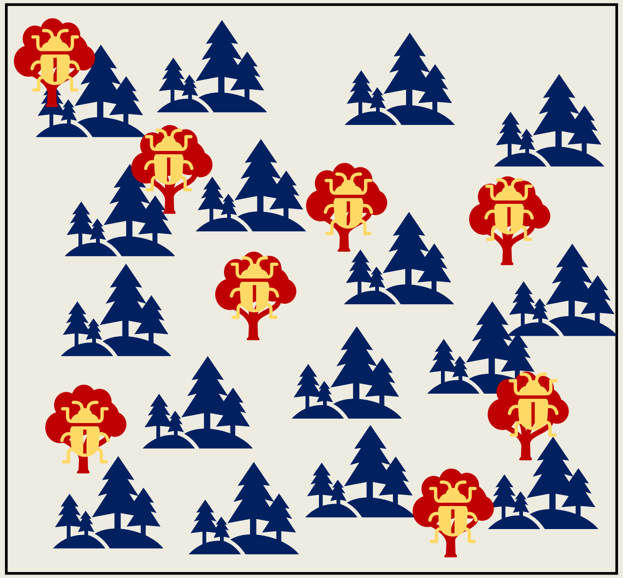
Scenario 2

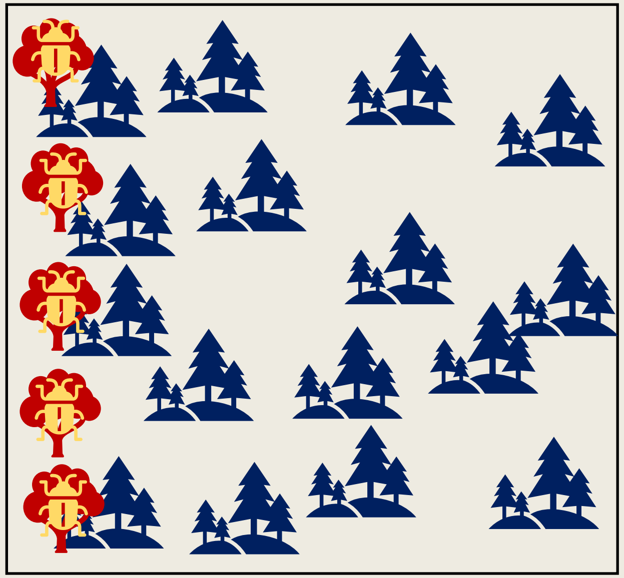


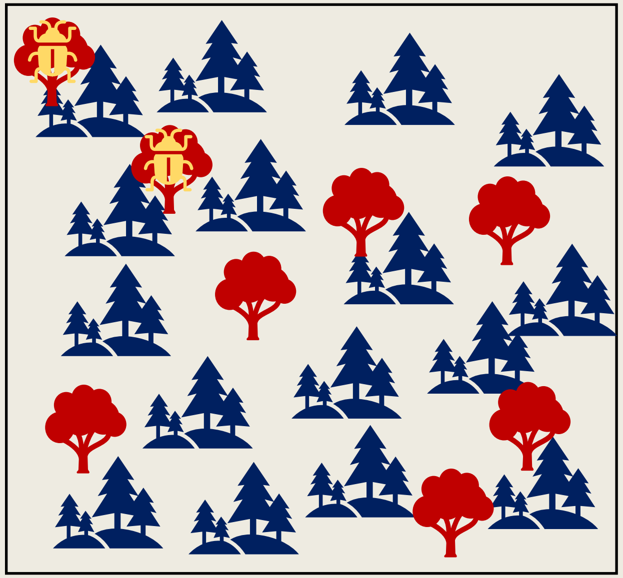
Scenario 3

Background	Objectives	Methods	Results	Conclusion

Biocontrol 2.0 beta


Scenario 1

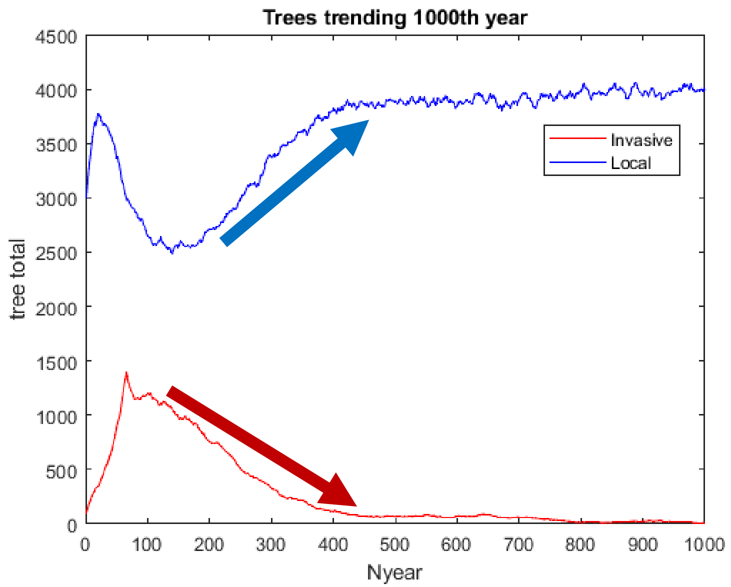

Scenario 2

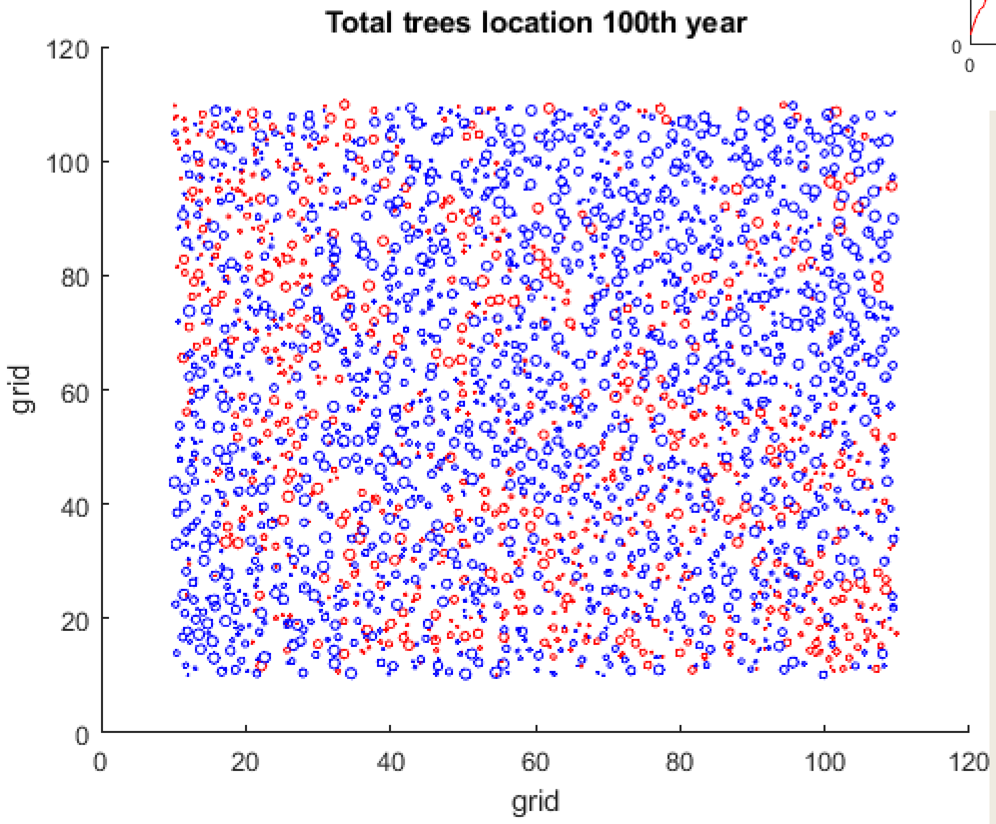

Scenario 3

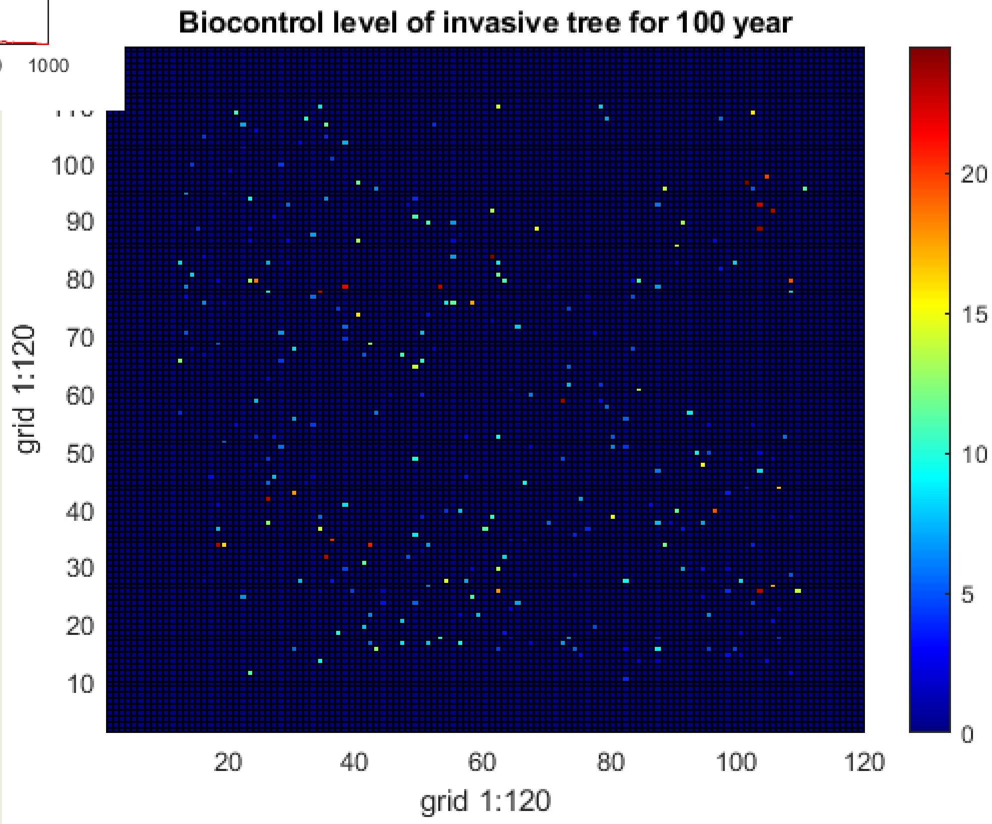
Initial setting:
Native species population = 3000 individuals
Invasive species population = 100 individuals

Biocontrol setting:
Timing of application = 65 years post invasion

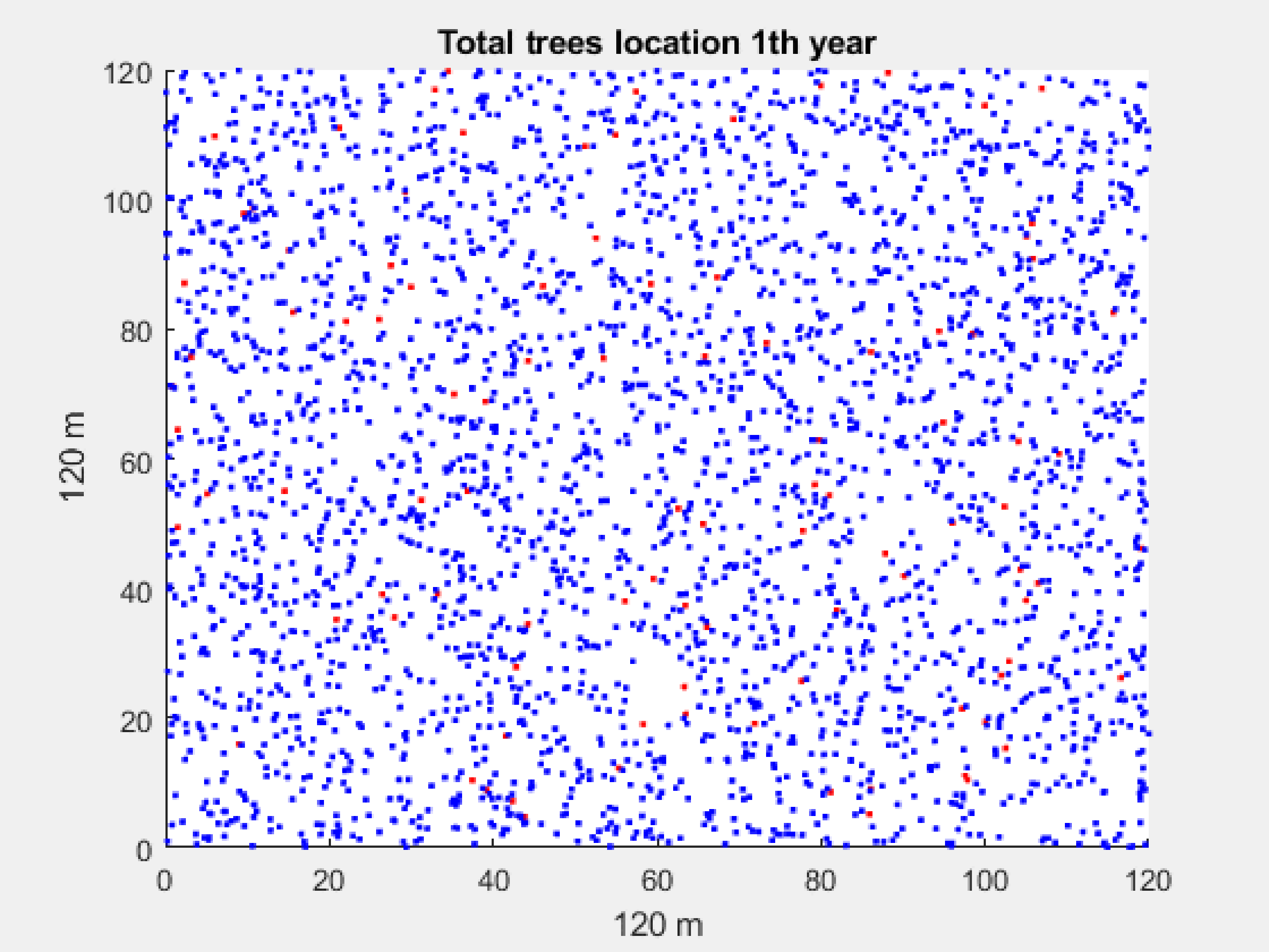
Results – Scenario 1





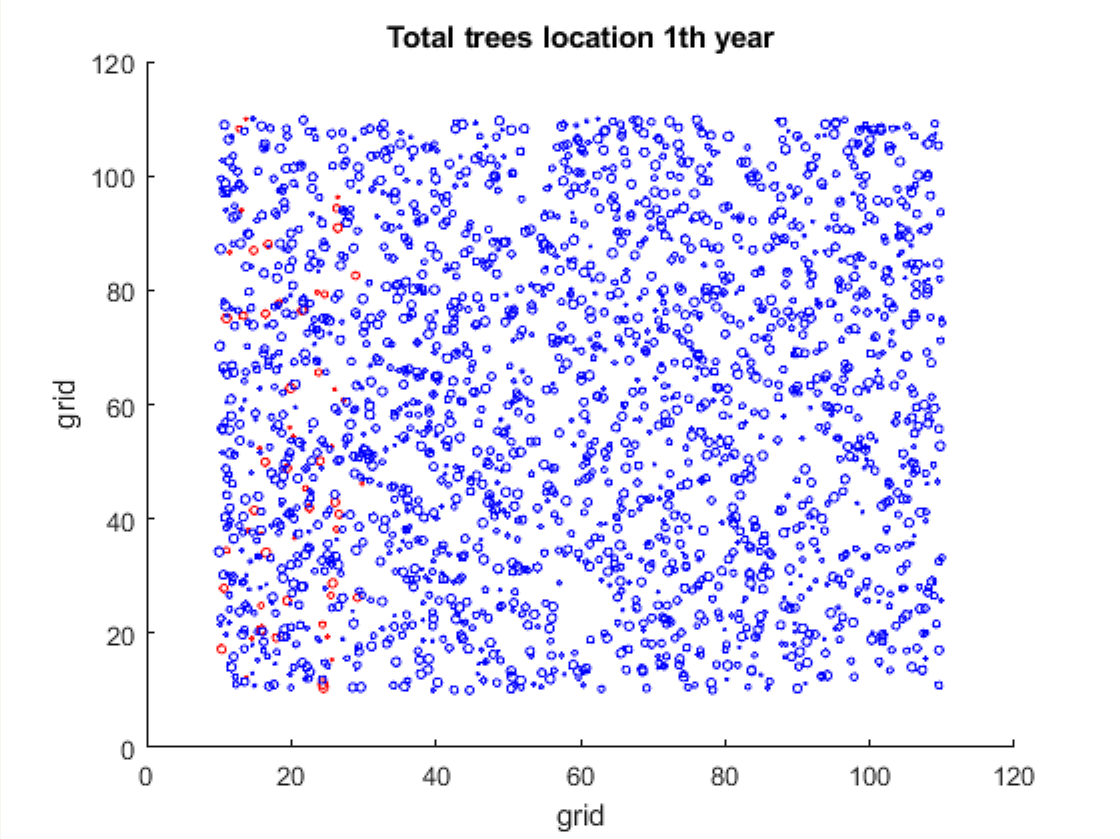


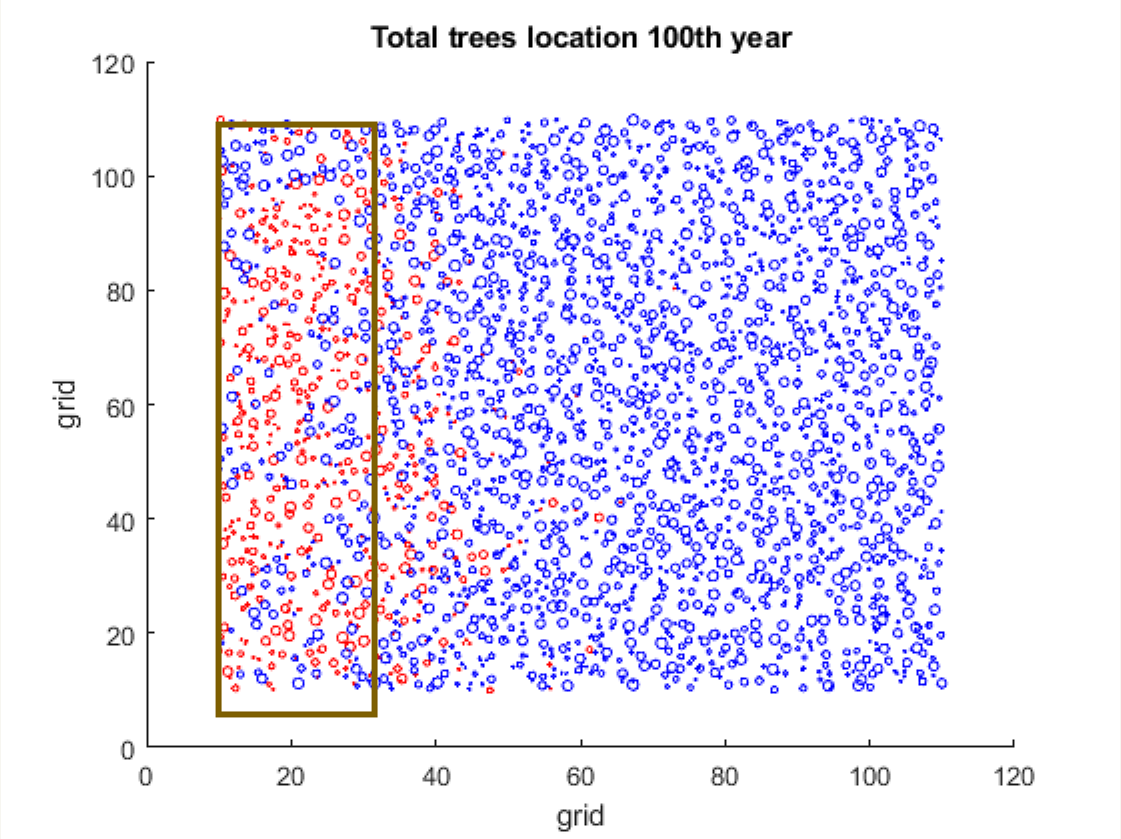
Results – Scenario 1



Background	Objectives	Methods	Results	Conclusion

Results
– Scenario 2





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Results
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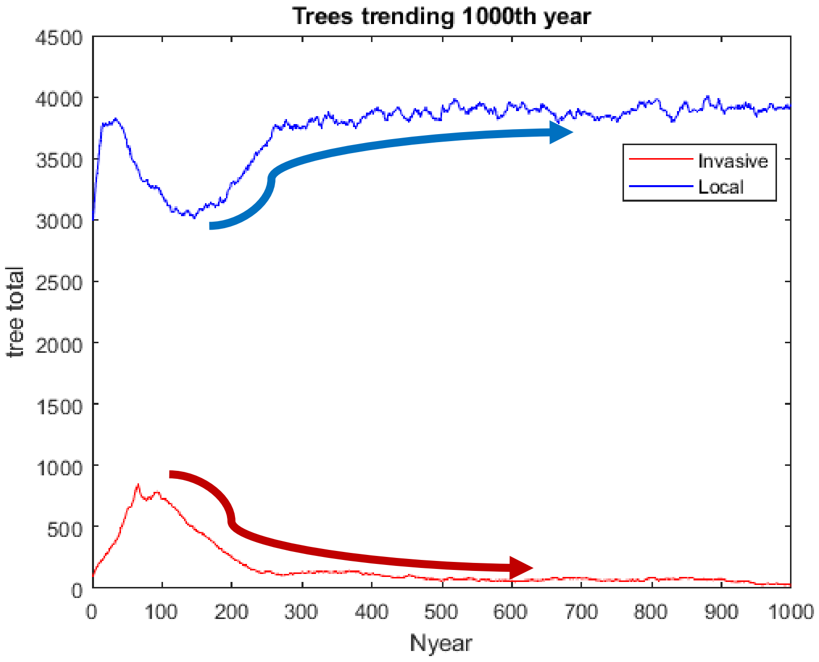

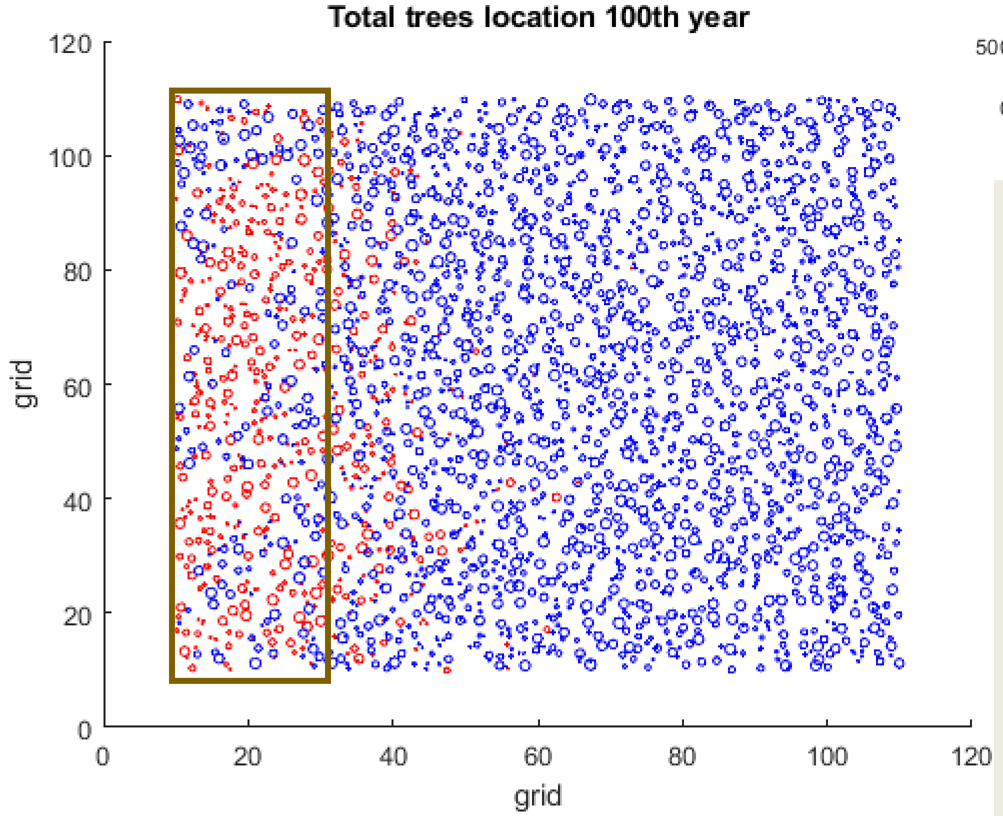

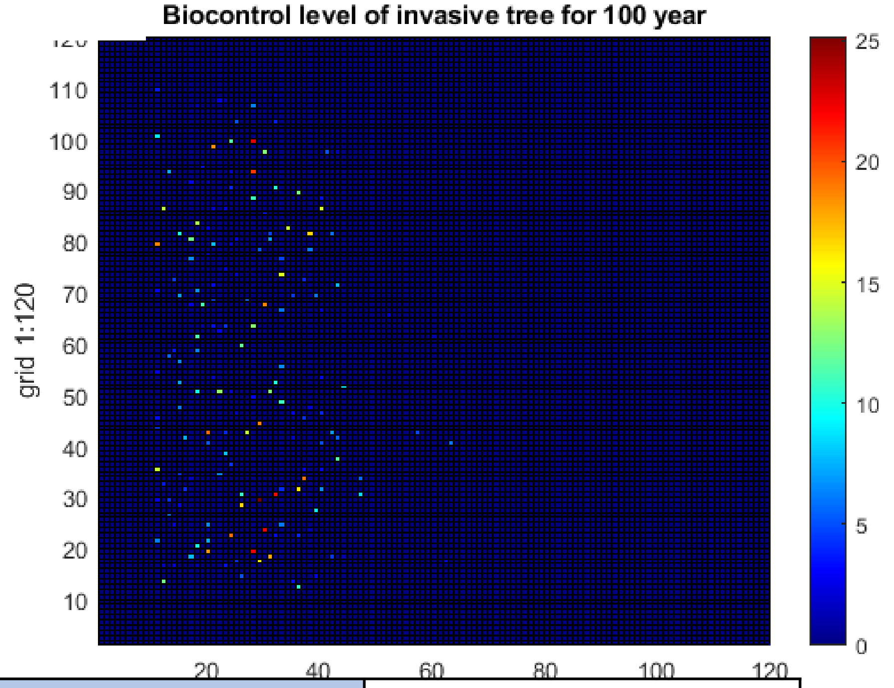

Results
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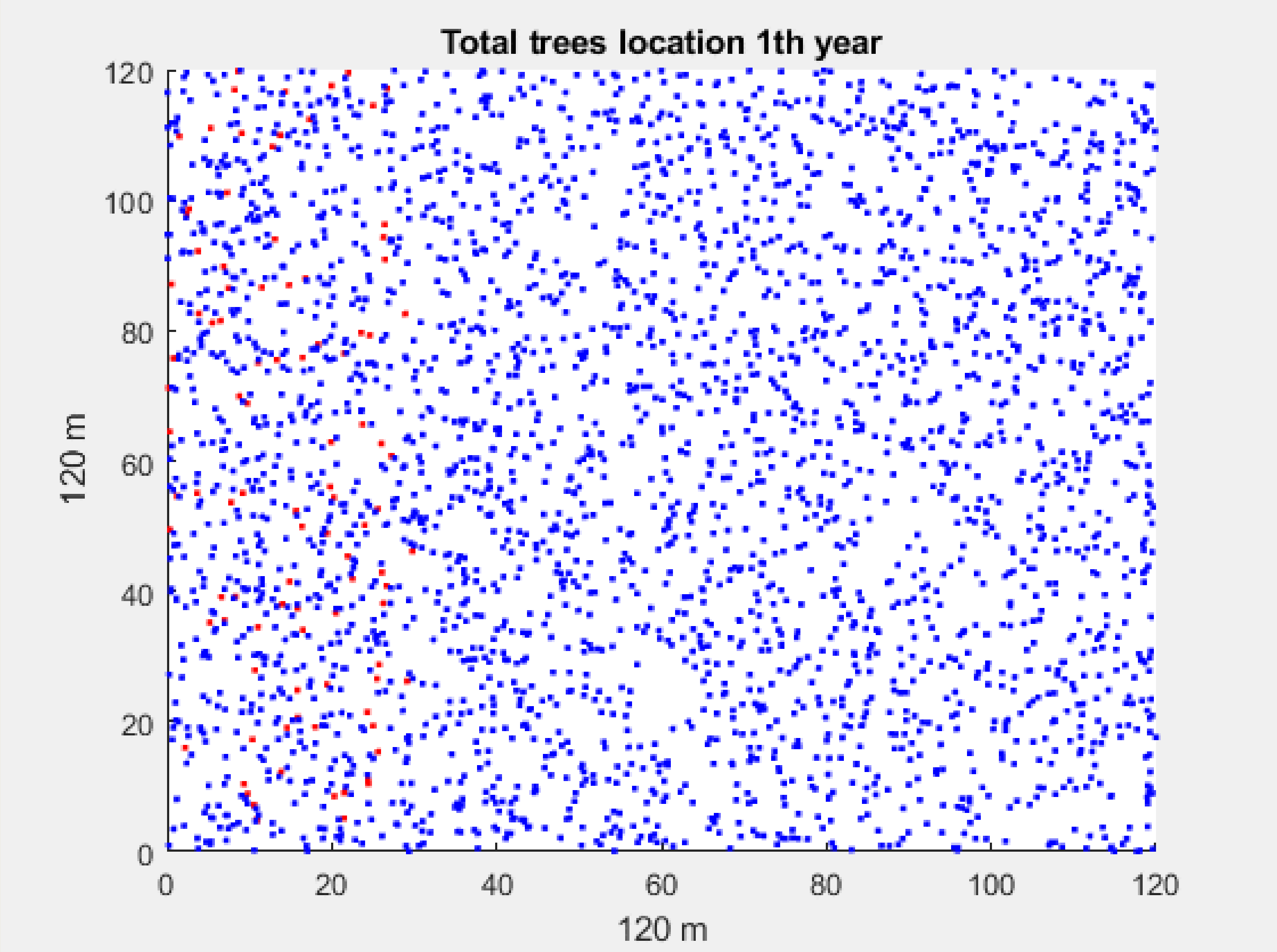

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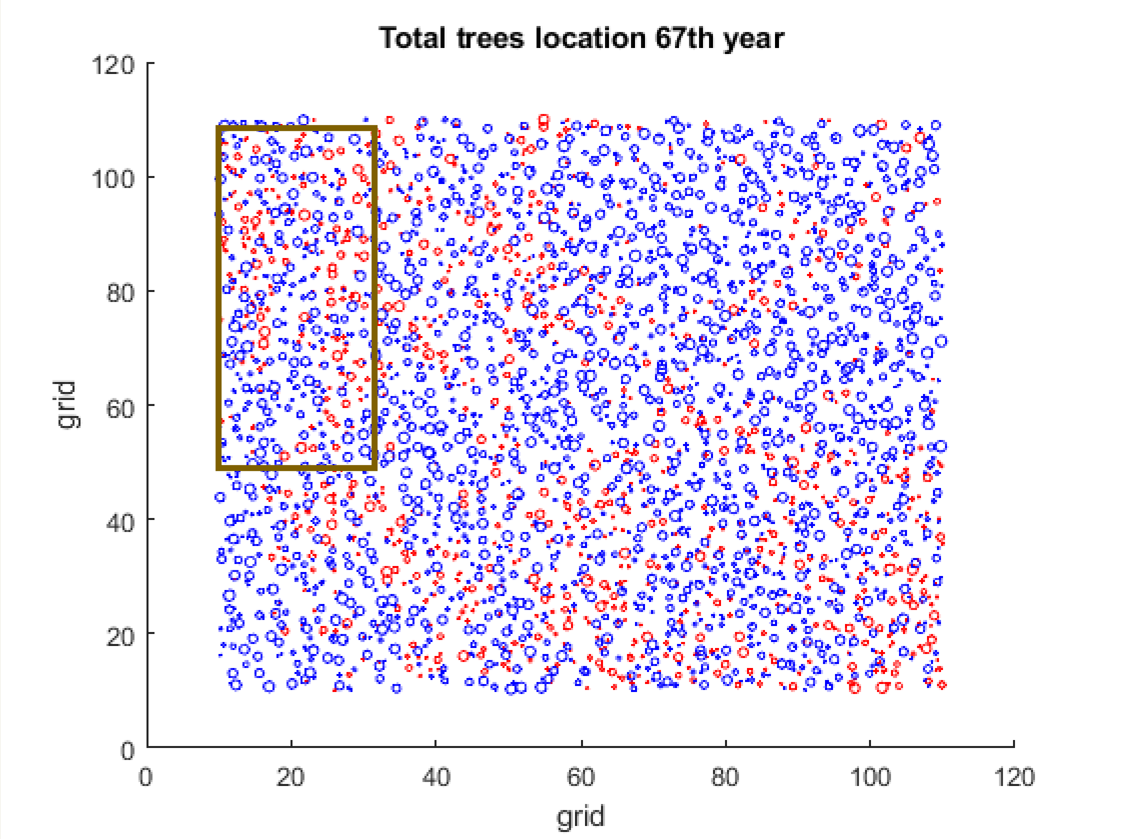
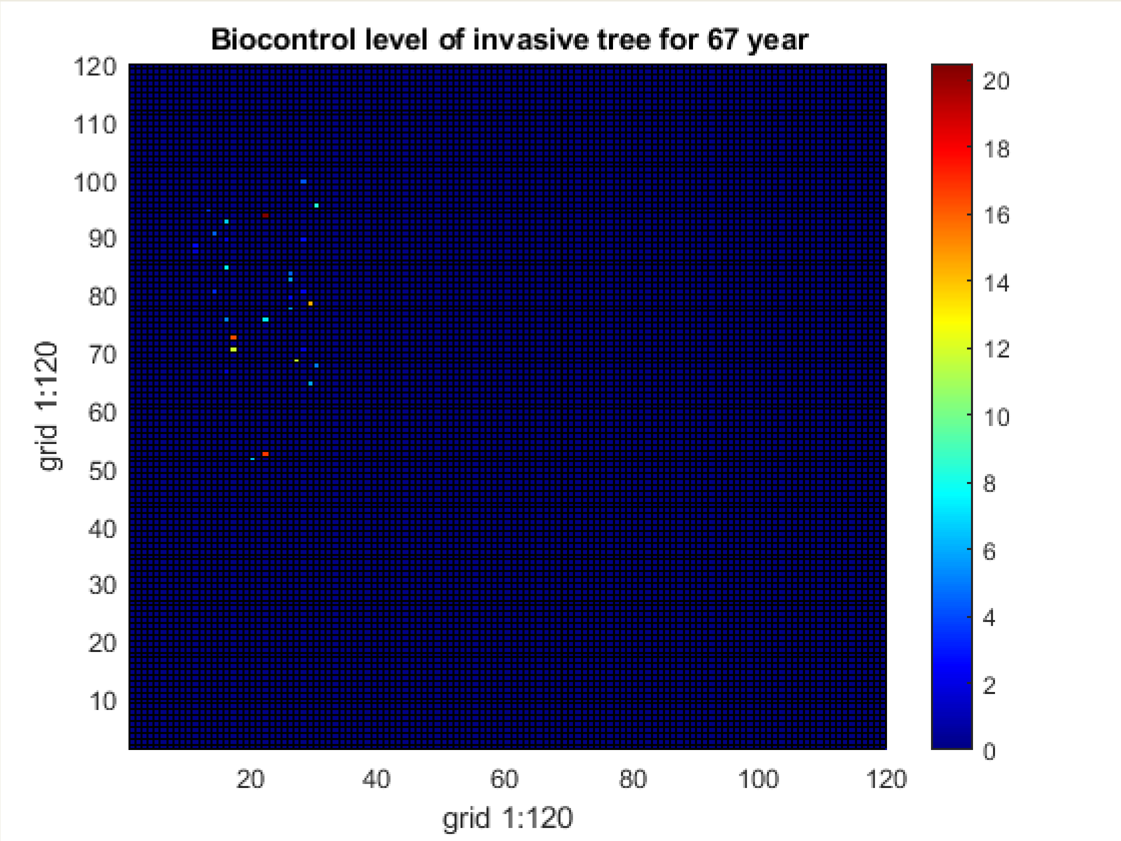
Results
– Scenario 3





Results
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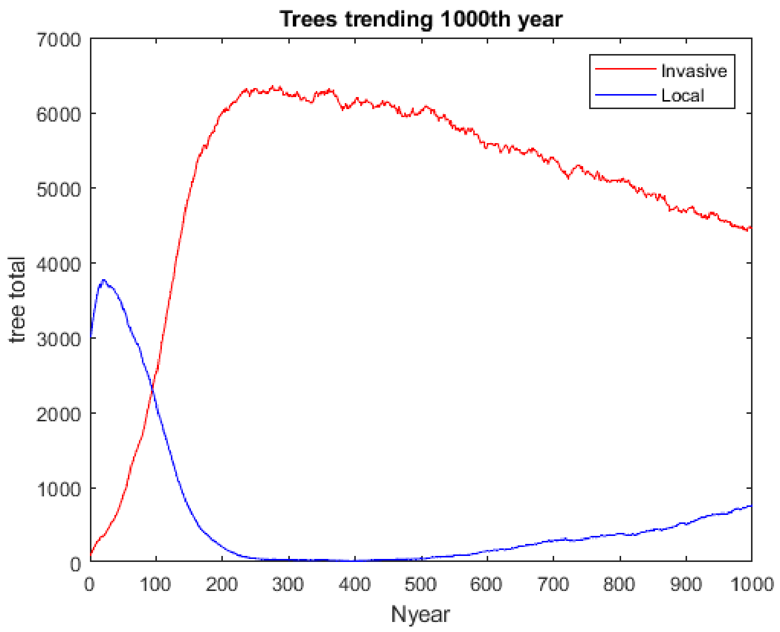

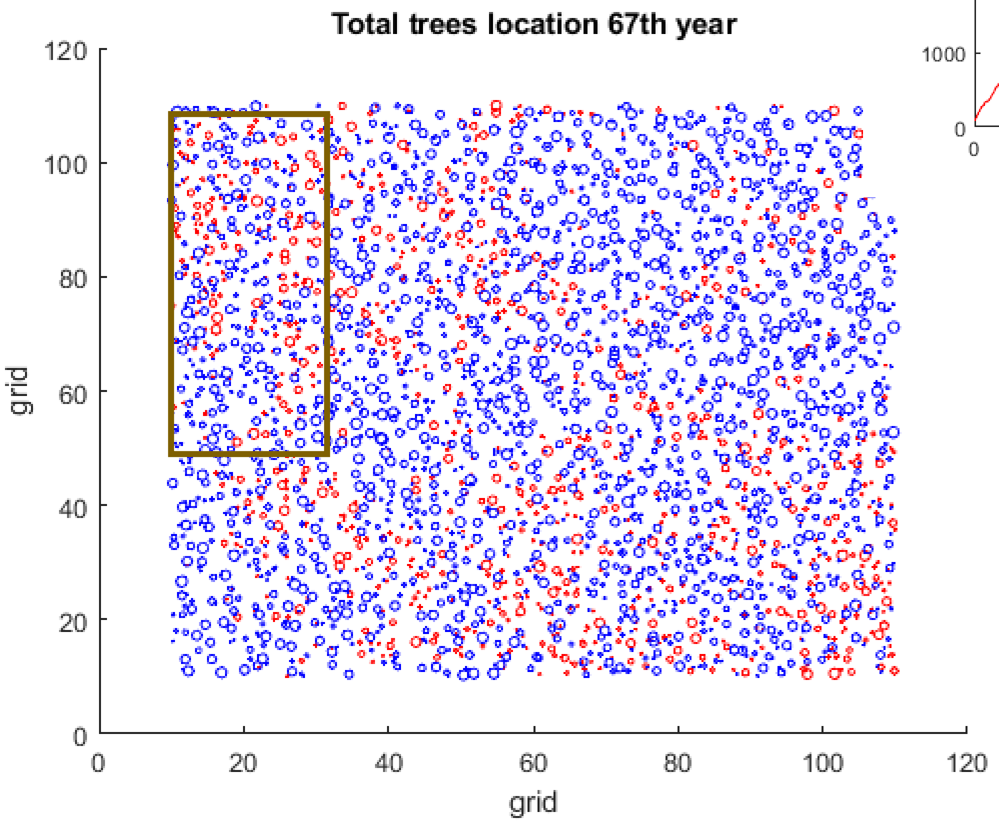

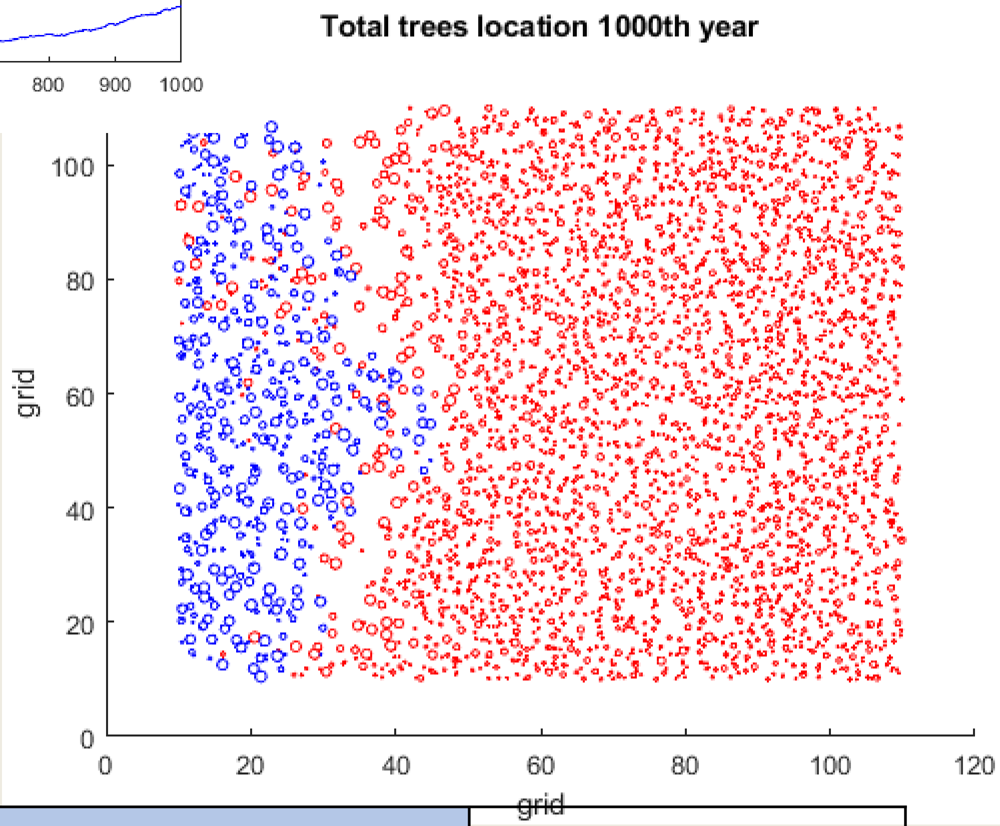

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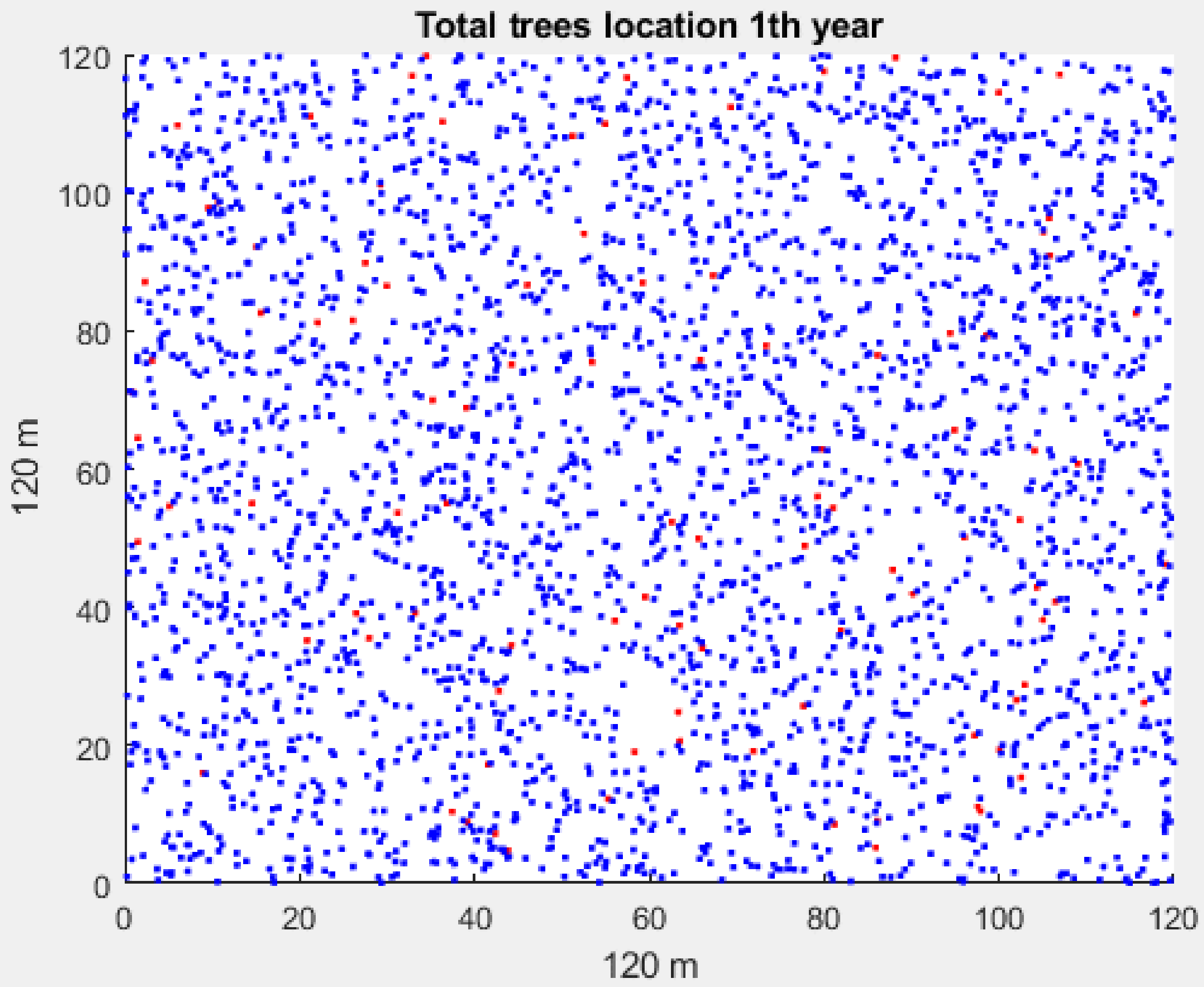
Results
– Scenario 3



Background	Objectives	Methods	Results	Conclusion

Conclusion

- The best control results are achieved by uniformly spread biocontrol agents on invasive species.
- Insufficient biocontrol establishment in the vegetation leads to poor outcomes.
- Regularly reapplying biocontrol will boost the control outcomes.

Acknowledgments

- Funding resources: Greater Everglades Priority Ecosystem Science (GEPES)
- UF CLAS Biology Department
- DeAngelis's lab
- Holt's lab

Background	Objectives	Methods	Results	Conclusion

bio_control_individual = true;
bio_control_dispersal_range = 2.2; % biocontrol disperse range
bio_control_increase_coeff = 1.001; % biocontrol infectious level

```
% settings for the region
x_len = 120; y_len = 120; % settings for the simualtion grid
Nyear = 1000;              % Time span in years

% settings for the species
Nspec = 2;                 % Number of species;
phi = 0.2;                % Light extinction coefficient
G = [400 267];            % Growth constants for the two species
D_max=[90 100];           % Maximum d.b.h. for the two species(cm)
H_max=[2540 4000];        % Maximum height for the two species (cm)
AGE_max=[200 250];        % Maximum age for the two species (year)
b2=[53.4 77.26];          % Constant in height to d.b.h. relationship
b3=[0.3 0.396];           % Constant in height to d.b.h. relationship
cLW=[38.90 27.55];        % Constant in leaf weight to d.b.h. relationship
cLF=[5.4 0.74];           % Leaf fall coefficient
bLW=[1.79 1.79];          % Constant in leaf weight to d.b.h. relationship
cLA=6.181;                %       leaf area to leaf weight, both species
bLA=0.9726;               %       leaf area to leaf weight, both species
cRT=0.1193;               %       tree biomass to dbh
bRT=2.393;                %       tree biomass to dbh
eta = 0.3;                %       allocate to root biomass
turnover_invasive = 0.65; %      turnover rate for invasive
turnover_local = 0.90;     %      turnover rate for local
c1 = 10;                  % coefficient for ZOI
c2 = 0.5;                 % coefficient for ZOI
```

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```
if Bio_Control(j)>0
    while di(k)~=0 & di(k)< (bio_control_dispersal_range * 0.05*dbh(j))

        if Ntype(j) == 1
            Bio_Control_nextyear(j) = 100 / (1 + ((100 - Bio_Control(j)) / Bio_Control(j)) * exp(-bio_control_increase_coeff * dbh(j)*0.1));
        %Bio_Control_nextyear(j) = (bio_control_increase_coeff + 0.005*dbh(j)) * Bio_Control(j);
        else
            Bio_Control_nextyear(j) = 100 / (1 + ((100 - Bio_Control(j)) / Bio_Control(j)) * exp(-bio_control_increase_coeff * dbh(j)*0.001));
        end

        if Bio_Control_nextyear(j) > Bio_Control_nextyear(Neib(k,j))
            Bio_Control_nextyear(Neib(k,j)) = Bio_Control_nextyear(Neib(k,j)) + (bio_control_increase_coeff-1) * Bio_Control(j);
        end
```

```
if Birthrate_control && (t > BRc_year) && Bio_Control(j) >= 1
    %brate = birth_rate(1)*0.1;
    individual_br_effect = 1/Bio_Control(j);
    brate = birth_rate(1) * individual_br_effect;
end
```

```
case 1
    if Deathrate_control && (t > DRc_year) && Bio_Control(j) >= 10
        mc3 = 0.042*0.5*Bio_Control(j)*exp(-10.0*DNC(j));    % mortality due to poor growth rate
    else
        mc3 = 0.042*exp(-10.0*DNC(j));    % mortality due to poor growth rate
    end
```