For our CA Application, we decided to create a model that mimics the spread of pests in crops. We are hopeful to simulate how the initial density of crops affects the spread of pests. Our model uses the 2D version of our CA general purpose library, with cutoff boundaries as this is most realistic way to model a field. Our crops have three potential states: empty, healthy, infected, and dead. We hope that a model like this can help farmers find the optimal density in which to plant their crops to maximize yield and minimize the risk of pests spreading.

States (represented by integers):
0 → Empty Grid
1 → healthy crop
2 → infected crops
3 → Dead

State transitions:
<u>Initializing grid with 0 or 1:</u>
In the initalize() function, our grid will be set up to hold a (length_ * width_) 2D grid holding the default C++ container values of 0. The function takes a probability parameter that we will use to initialize crop density in our application. This will allow us to model various starting crop densities to study how that impacts pest spread.

<u>Adding pests:</u>
Similar to Dr Drummond's implementation of the fire spreading, we will initialize the square in the center of the grid to hold the value 2 or infested. This allows us to focus on how the introduction of pest will have on the surrounding field.

<u>Infestation spread</u>

For our model, we decided to use a 20x20 square cellular automata model. The average farm size in the US is around 445 acres (USDA), so each square is approximately 1 acre. We use the Von Neumann neighborhoods as we decided that infestations are more likely to spread when there is a lot of surface area between the groups of crops, therefore Von Neumann made more sense compared to the Moore neighborhoods. We also used cut off boundaries, as periodic boundaries would not make sense for our real-life application, and walled boundaries also wouldn't necessarily make sense as farms could be adjacent to each other.

Each day we called the step function with rule 1, which allows the infestation to spread based on the conditional transition rule. Then we called rule 0 with an update_probability of 50%. This is an additional functionality that we added to our cellular automata general purpose library where a random portion of the cells are selected to be updated to the next state. We feel like this best models an infestation as some crops will remain infected longer that others, but we estimated that around every day 50% of the currently infected crops will die.

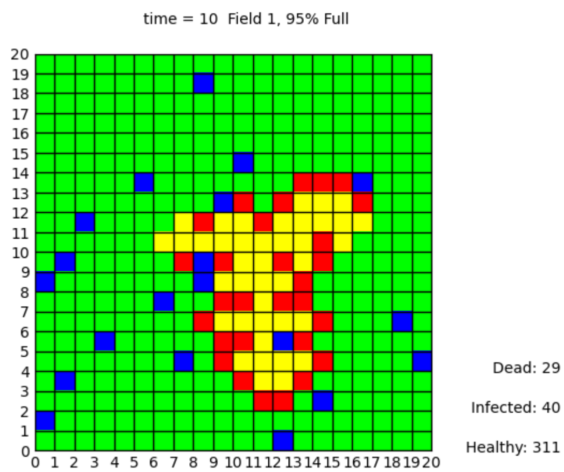
<u>Applicability</u>

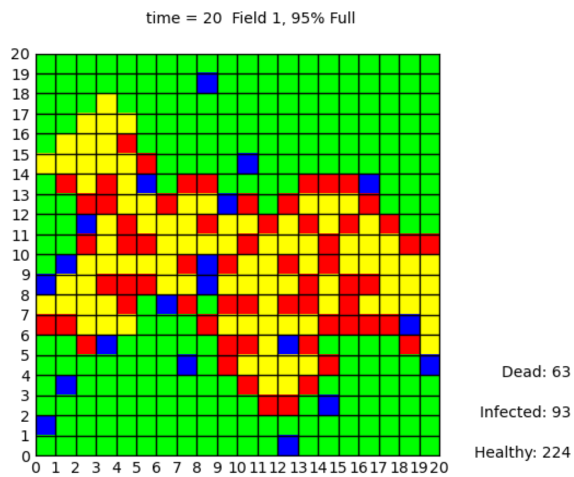
This has a lot of practical applications in pest management and agriculture planning. Costs analysis can be performed to illuminate if a higher crop density will always result in a larger harvest with respects to pest infestation risks.

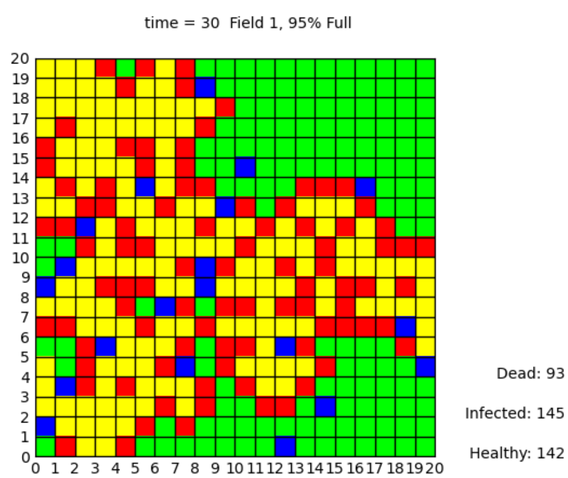
Results

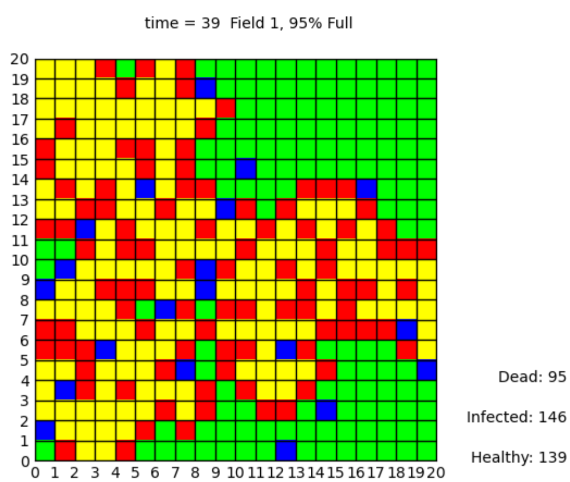
As you can see from our results, starting the fields off with different densities can have drastic impacts on how infection spreads.

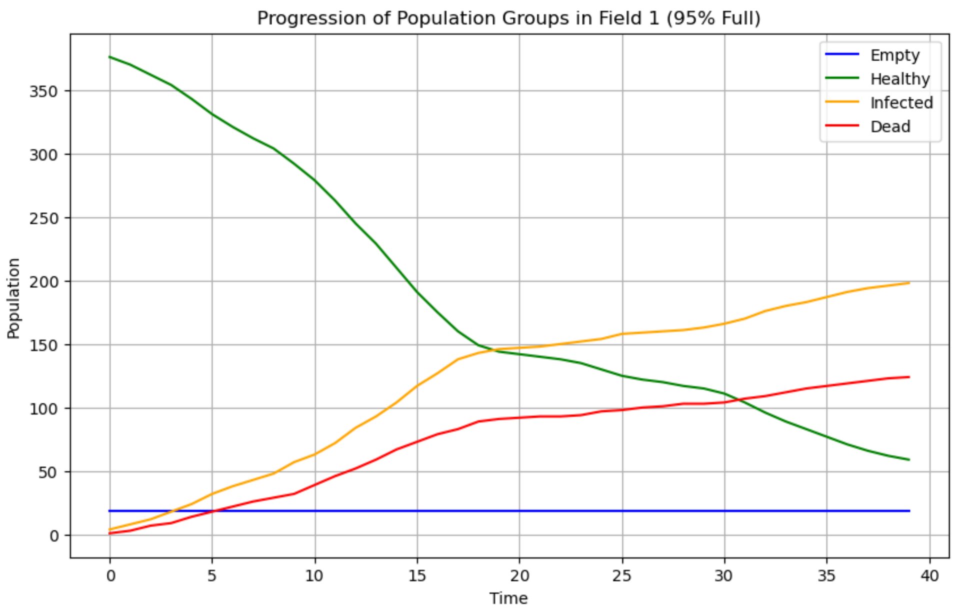
We observe that with 95% starting crop density, the number of Healthy crops drops to 148 after 20 days, and goes down to 59 after 40 days.



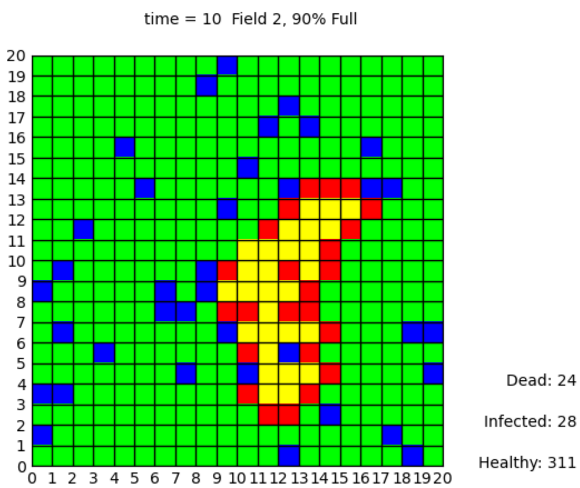


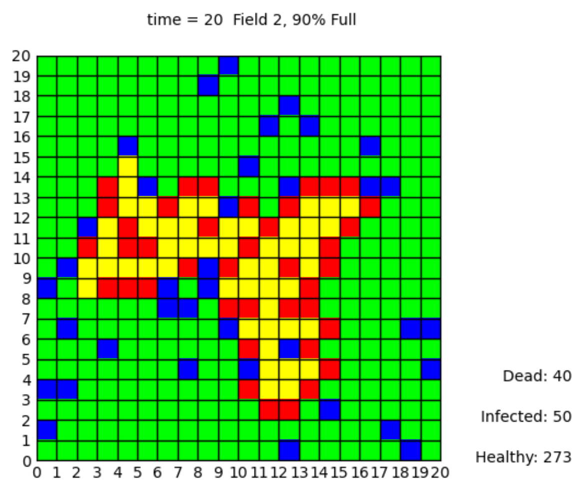


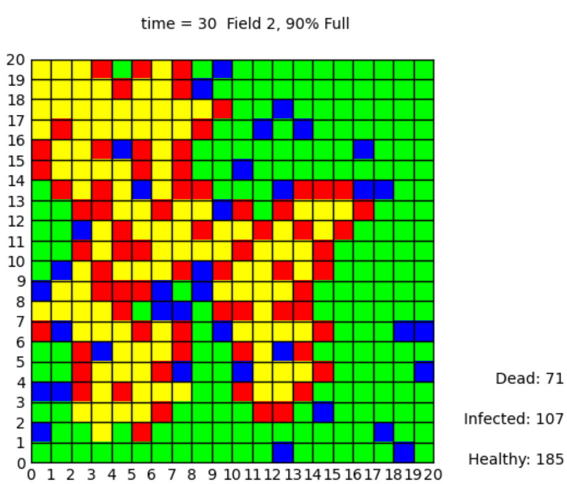


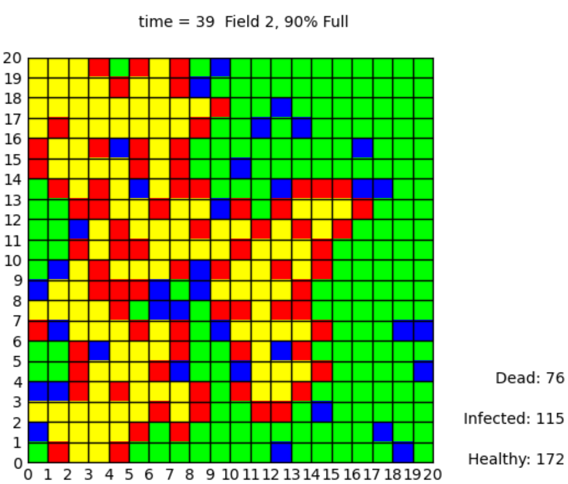


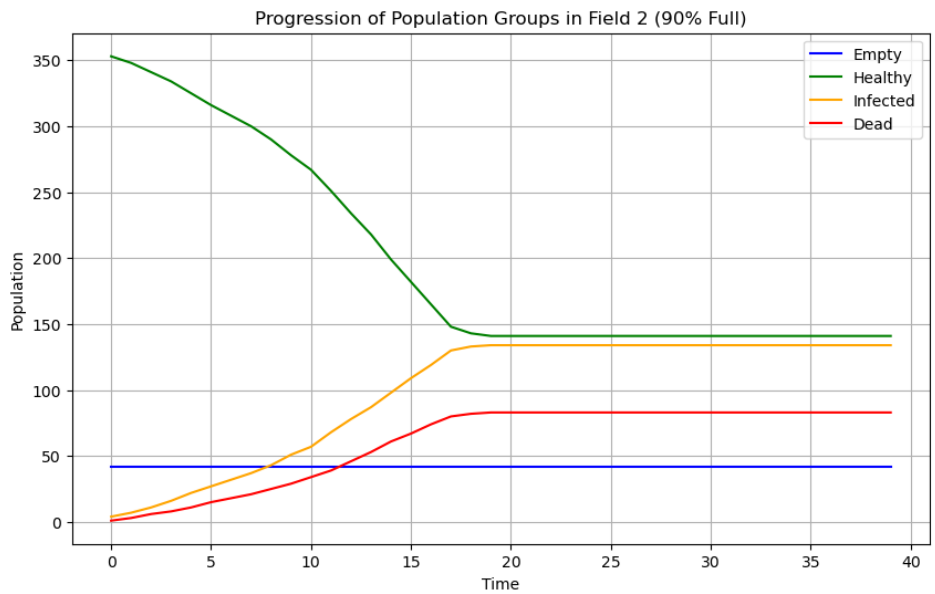
We observed that with 90% starting crop density, the number of Healthy crops drops to after 20 days, and goes down to after 40 days.



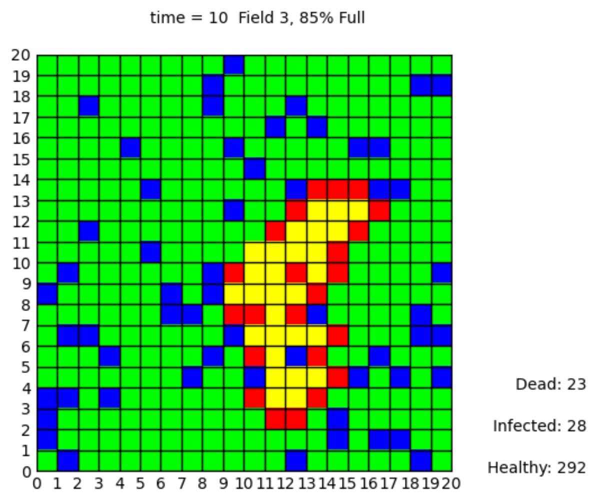


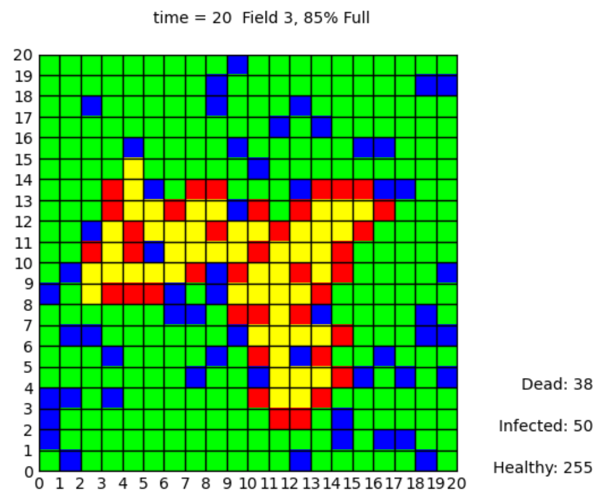


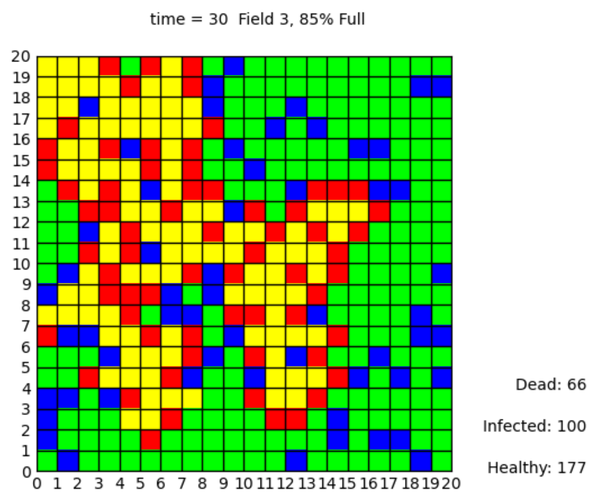


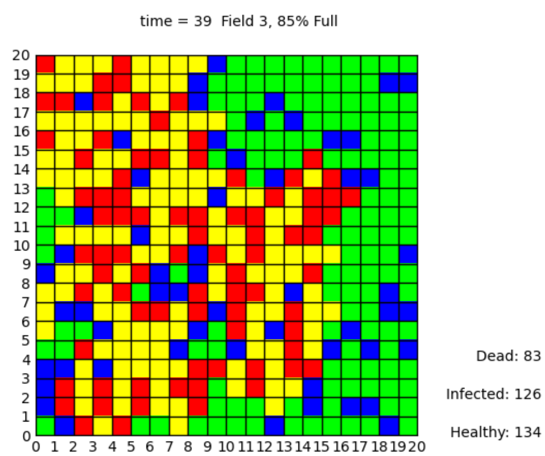


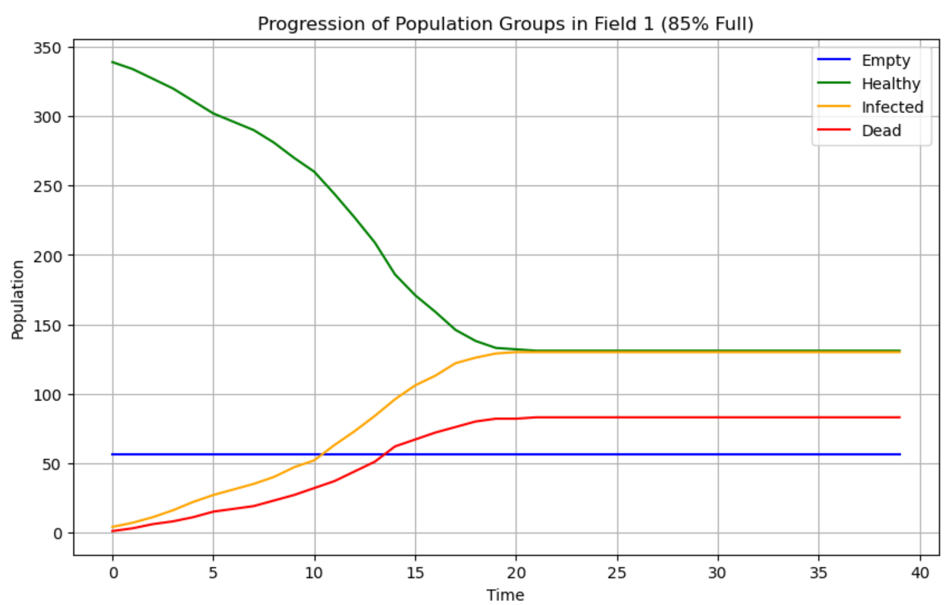
We observed that with 85% starting crop density, the number of Healthy crops drops to 225 after 20 days, and goes down to 134 after 40 days.


time = 10 Field 3, 85% Full
Dead: 23
Infected: 28
Healthy: 292


time = 20 Field 3, 85% Full
Dead: 38
Infected: 50
Healthy: 255


time = 30 Field 3, 85% Full
Dead: 66
Infected: 100
Healthy: 177


time = 39 Field 3, 85% Full
Dead: 83
Infected: 126
Healthy: 134


Progression of Population Groups in Field 1 (85% Full)
Empty
Healthy
Infected
Dead
Population
Time

From these results, we would assume that having a crop density of around 90% ends up yielding the most healthy crops after 40 days. If the crop density is 85% or 95% then there are significantly fewer healthy crops at the end of the simulation. It can be noted that with 85% starting density there are only 126 infected crops after 40 days, whereas with 95% starting density there are 146, so even the sub-optimal solutions have different outcomes. We also observed that both the 85% and 90% models seemed to reach an equilibrium state after around 20 days, whereas the 95% still seemed to be changing even after 40 days.

Sources

https://www.nass.usda.gov/Publications/Todays_Reports/reports/fnlo0222.pdf