Cellular automata and grid-based models

In this assignment you are asked to create and analyse a number of cellular automata. You need to do at least two out of three simulations.

1) Forest fire propagation. In principle, such a model can be quite simple. On a grid, cells can be in each of four or more states: barren, vegetation, burning, burnt. A burning cell will ignite all neighbouring cells with vegetation. The behaviour of the fire will depend on the density of the vegetation. E.g., if it is very sparse, the fire cannot spread. It will also depend on the definition of the neighbourhood. A symmetrical neighbourhood like a four cell Von Neumann neighbourhood or an eight cell Moore neighbourhood will correspond to a situation where there is no wind. Obviously, the fire will spread more easily with the larger Moore neighbourhood. Asymmetrical neighbourhoods could represent the effect of wind. The model can be implemented in various ways: examine every cell on every time step, or make a list of all burning cells (the only type of cells that can actually affect neighbour cells), and examine only those.
   With your model, perform the following experiment: ignite a row of trees at x = 0 and investigate what fraction of the vegetation is burned, if the fire reaches the other side of the forest and how long this takes. Vary the density of the vegetation and the size of the grid. You should find that there is a critical density below which the fire does not reach the other side, and above which it does. The larger your grid, the sharper this transition will be; experiment with grid sizes of e.g. 125 by 125, 250 by 250 and at least 500 by 500 cells. Compare Moore and Von Neumann neighbourhoods.
   Part of the challenge in this case is writing efficient but correct code. At every time step only a few cells are burning; stepping through an entire 500^2 grid to process those is not efficient.
2) Spread of malaria. This is not really a CA, but an individual-based simulation on a grid. Populate the grid with a number of humans, at most one to a cell. Each human can be susceptible, infected, immune, or eventually dead. For each death, create a new human somewhere on the grid. People can die of malaria, or from other causes. Also create a population of mosquitoes. Other than humans, mosquitoes can move over the grid, performing a random walk, from one cell to the next. Mosquitoes can be hungry, or not (they only bite when hungry, and in the same cell as a human), and infected, or uninfected. The probability of an actual bite can also be influenced by measures, like mosquito nets taken by the human population. Does everybody need to use a mosquito net for the disease to die out (assuming there is no animal reservoir like birds or monkeys)? Assume that mosquitos live for 15 days and get hungry two day after their last blood meal. Keep track of the numbers of the numbers of infected and uninfected mosquitoes and the various categories of humans, including deaths. Run your simulation for various numbers of mosquitoes (keep the number constant in each run) and various human population densities, and see how your results change.
3) Create a grid-based model that simulates a predator-prey model. Of each type of animal, there can be at most one per grid cell. Both perform a random walk across the grid. Both have an energy or health status. For prey, this is increased on every time-step. If it reaches a certain threshold and if there is a free adjacent cell, the animal splits into two new animals, each with at most half of the original energy. For predators, the energy is decreased on every time-step; if it reaches zero, the predator dies/disappears. If the predator enters a cell that already contains a prey animal, the prey animal gets eaten and its energy it transferred to the predator. Use various parameter settings and compare your results with the Lotka-Volterra model. Predators can also procreate when their energy exceeds a certain threshold. Can you find settings where both species survive? Can you reproduce the oscillatory behaviour?