Modeling and Simulation -

Lab Assignment 4

Vaibhav Amit Patel (201401222)* and Tanmay Patel (201401409)*

E-mail: vaibhav290797@gmail.com; tanmaypatel273@gmail.com

Problem 1

Modeling of Malaria

Part A:

Draw the compartment model for malaria spread.

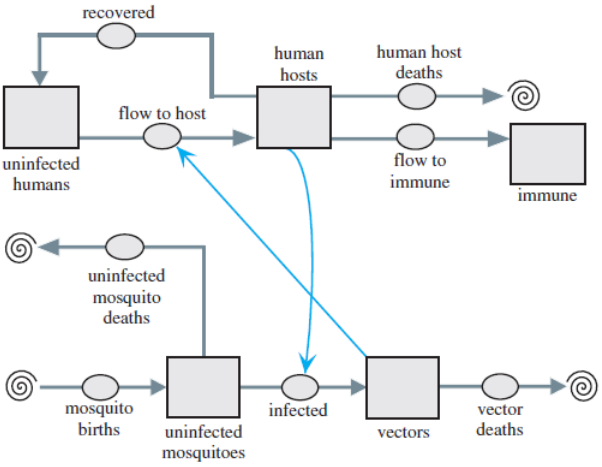

Figure 1

Part B:

Identify all the variables and write differential equations for malaria spread assuming that except were interactions takes place all other changes are unconstrained growth and decay.

Susceptible Humans: S_h

Infected Humans: I_h

Immune Humans: Im_h

Susceptible Mosquitoes: S_m

Infected Mosquitoes: I_m

p = Probability of mosquito biting a susceptible/infected human

r_1 = Conversion rate of Infected human to Susceptible human

d_1 = Death rate of the Infected human

r_2 = Immunity rate (Infected human to Immune human)

b = Birth rate of the mosquito

d_2 = Death rate of mosquitoes (both infected and Susceptible death rate are same)

$$S_h' = -pS_h(\frac{I_m}{I_m + S_m}) + r_1 I_h$$

$$I_h' = pS_h(\frac{I_m}{I_m + S_m}) - r_1 I_h - r_2 I_h - d_1 I_h$$

$$Im_h' = r_2 I_h$$

$$S_m' = b(S_m + I_m) - pS_m(\frac{I_h}{Im_h + I_h + S_h}) - d_2 S_m$$

$$I_m' = pS_m(\frac{I_h}{Im_h + I_h + S_h}) - d_2 I_m$$

Part C:

Using the following information in your model implement on the computer and com- ment on the observations (Make a single figure with all the susceptibles and infected): i. (Initial values (t=0)): Susceptible humans = 300, Infected human = 1, immune humans = 0, susceptible mosquitoes = 300, infected mosquito= 0. ii. Constants: recovery rate of humans = 0.3, immunity rate = 0.01, malaria induced death rate = 0.005, mosquito birth rate = 0.01, probability of mosquito biting a susceptible human = probability of mosquito biting an infected human = 0.3.

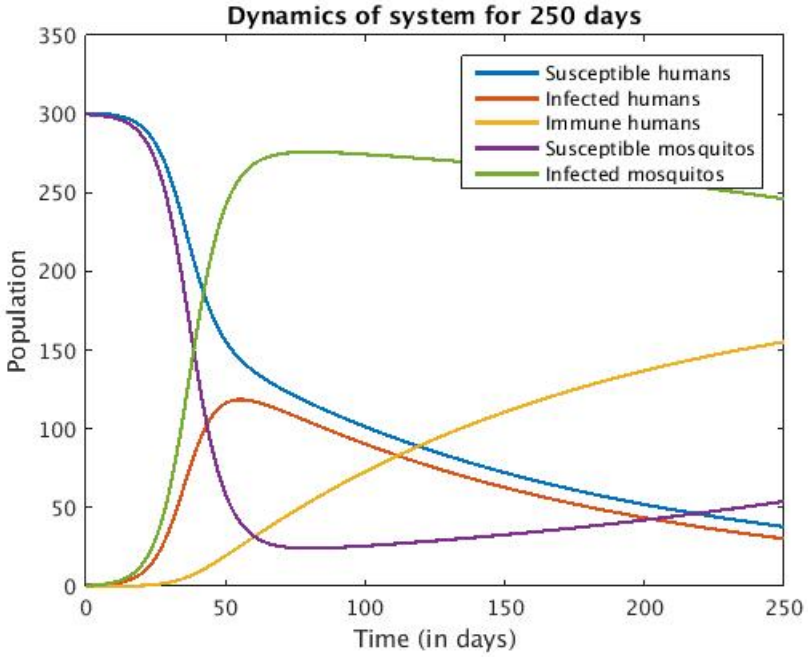

Figure 2

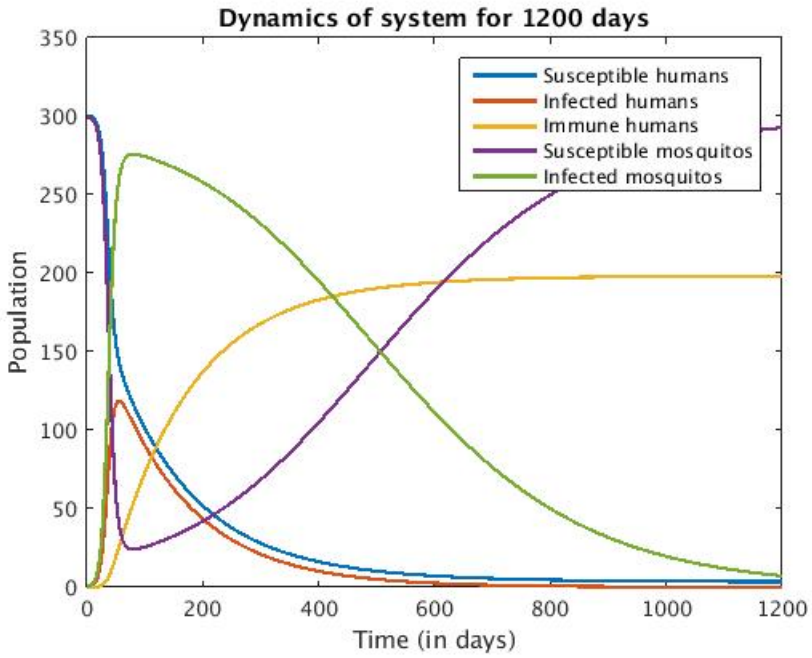

Figure 3

The number of susceptible mosquitoes initially decreases sharply till 50 days as those are converted to infected mosquitoes due to contact with infected humans. After some time number of infected mosquitoes decreases slowly due to death and that of susceptible mosquitoes increases due to birth. The number of infected human increases rapidly initially till 50 days then reaches saturation and decreases because of immune and deaths. Number of infected humans is always less than susceptible humans. Also the number of susceptible humans decreases rapidly initially (due to infection) till 50 days and then slowly (due to deaths and immune). Number of immune increases continuously and becomes almost constant after stable state of no spread in malaria disease. Infected mosquitoes becomes zero after nearly 1200 days. The total number of humans is reduced to one-third of initial population (nearly 200).

Part D:

If you we take into account spraying or fumigation which quantity changes in your equations. How does this change reflect in the figure that you made in part(c) .

Changes due to fumigation :

f = Death rate due to fumigation

$$S'_m = b(S_m + I_m) - pS_m(\frac{I_h}{Im_h + I_h + S_h}) - d_2 S_m - fS_m$$

$$I'_m = pS_m(\frac{I_h}{Im_h + I_h + S_h}) - d_2 I_m - fI_m$$

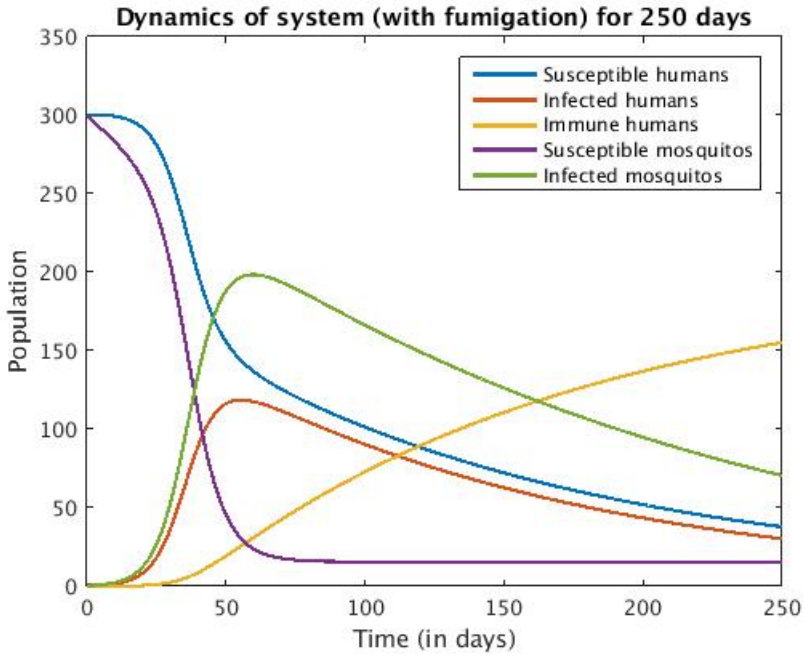

Figure 4

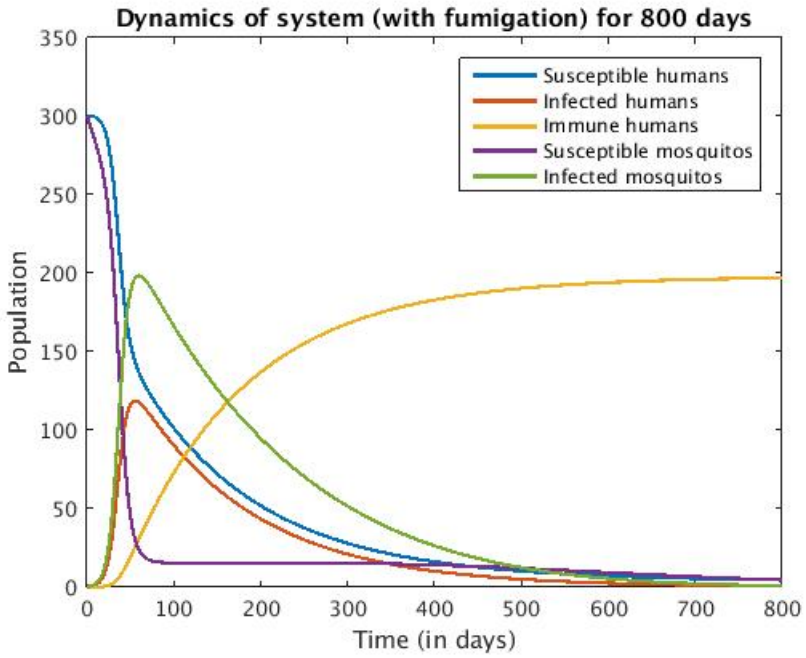

Figure 5

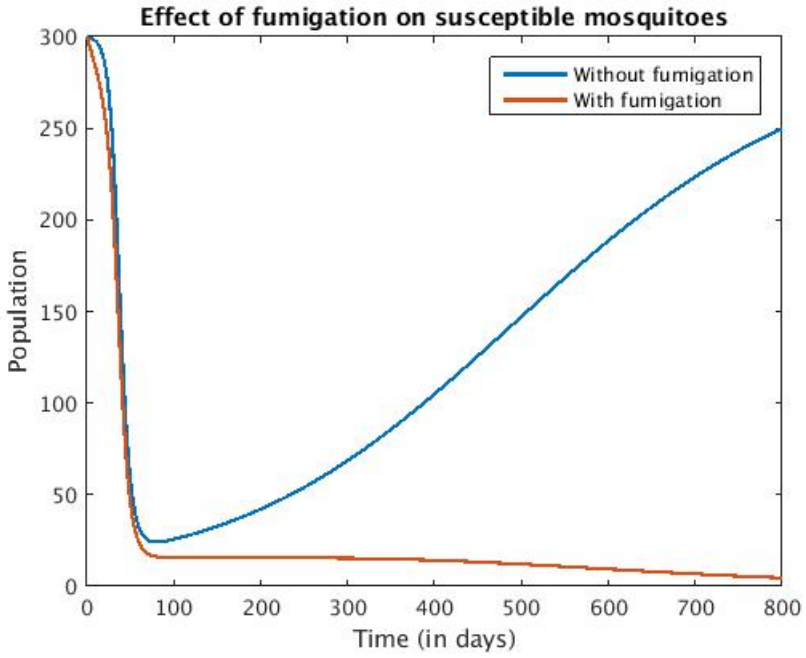

Figure 6

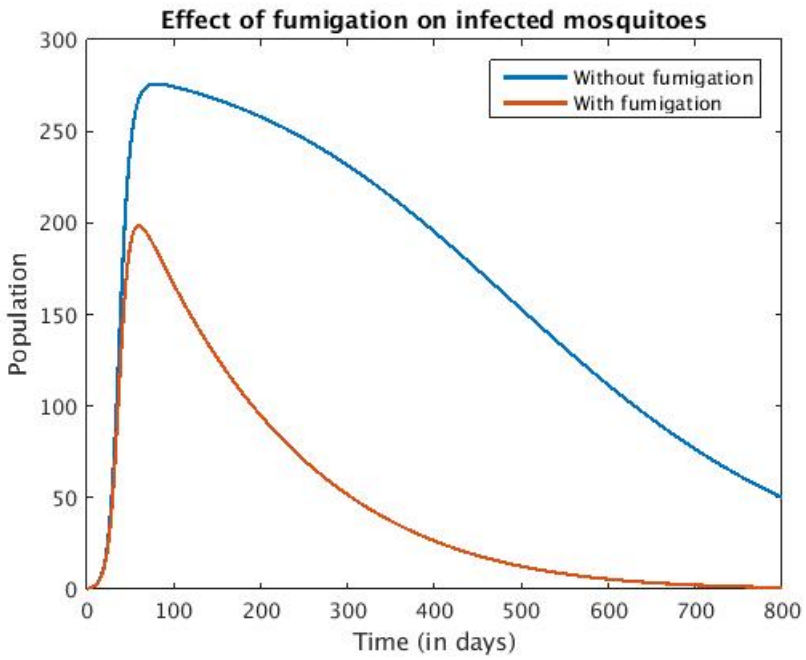

Figure 7

Due to fumigation number of susceptible mosquitoes decreases even after a rapid decrease after 50-60 days because of fumigation. Also the maximum number of infected mosquitoes reached is less compared to case without fumigation. There is almost no effect of fumigation on susceptible humans and infected humans.

Part E:

If instead of spraying we went for vaccination what would you change and again how does it impact malaria spread.

Changes due to fumigation :

v = Conversion rate from susceptible human to immune human due to vaccination.

$$S_h' = -pS_h(\frac{I_m}{I_m + S_m}) + r_1 I_h - vS_h$$

$$Im_h' = r_2 I_h + vS_h$$

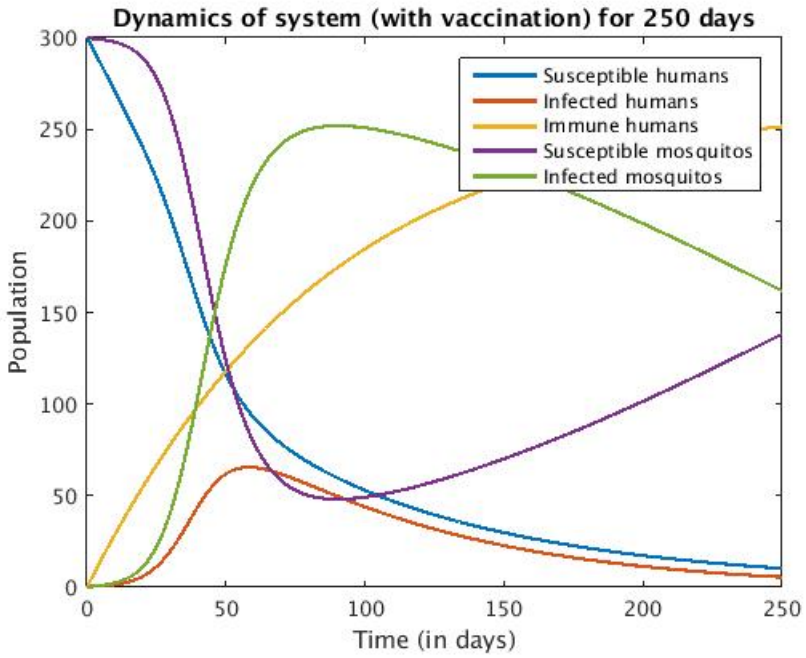

Figure 8

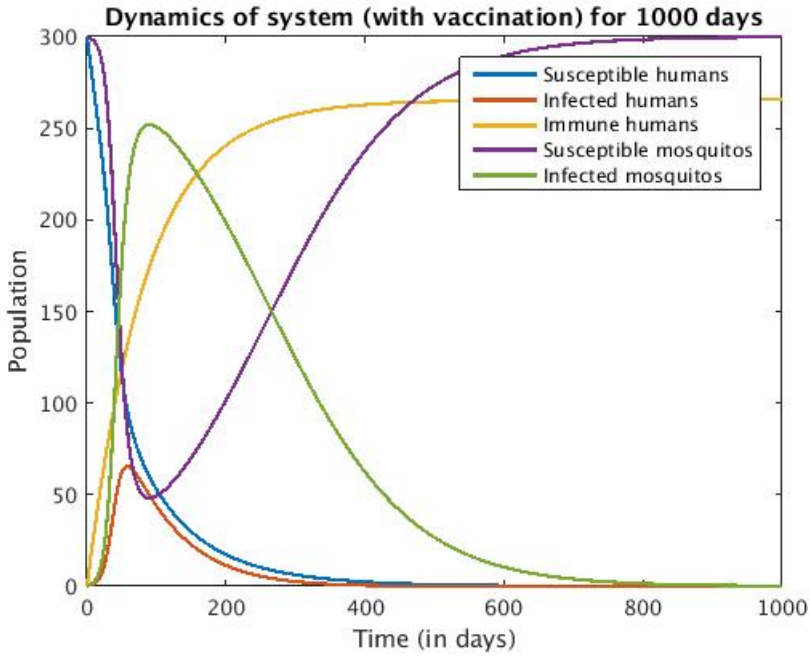

Figure 9

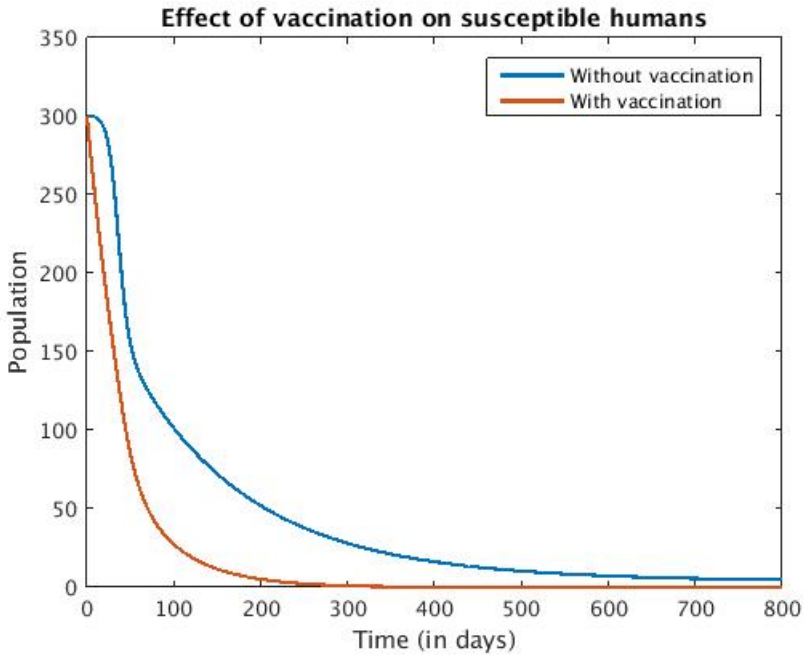

Figure 10

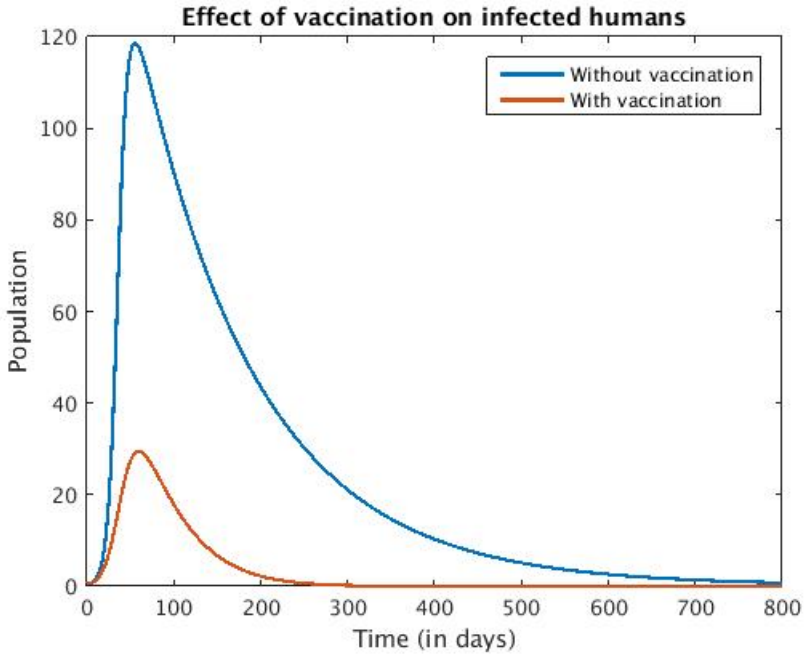

Figure 11

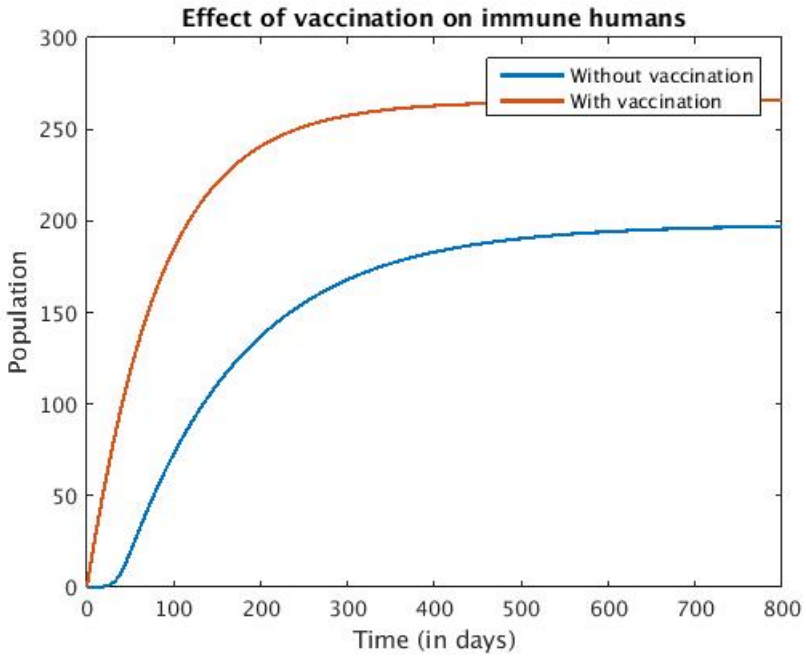

Figure 12

Due to vaccination, maximum number of infected people is decreased and also the spread of malaria stops faster, this is because susceptible humans are converted to immune humans due to vaccination and hence less number of infected humans.

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