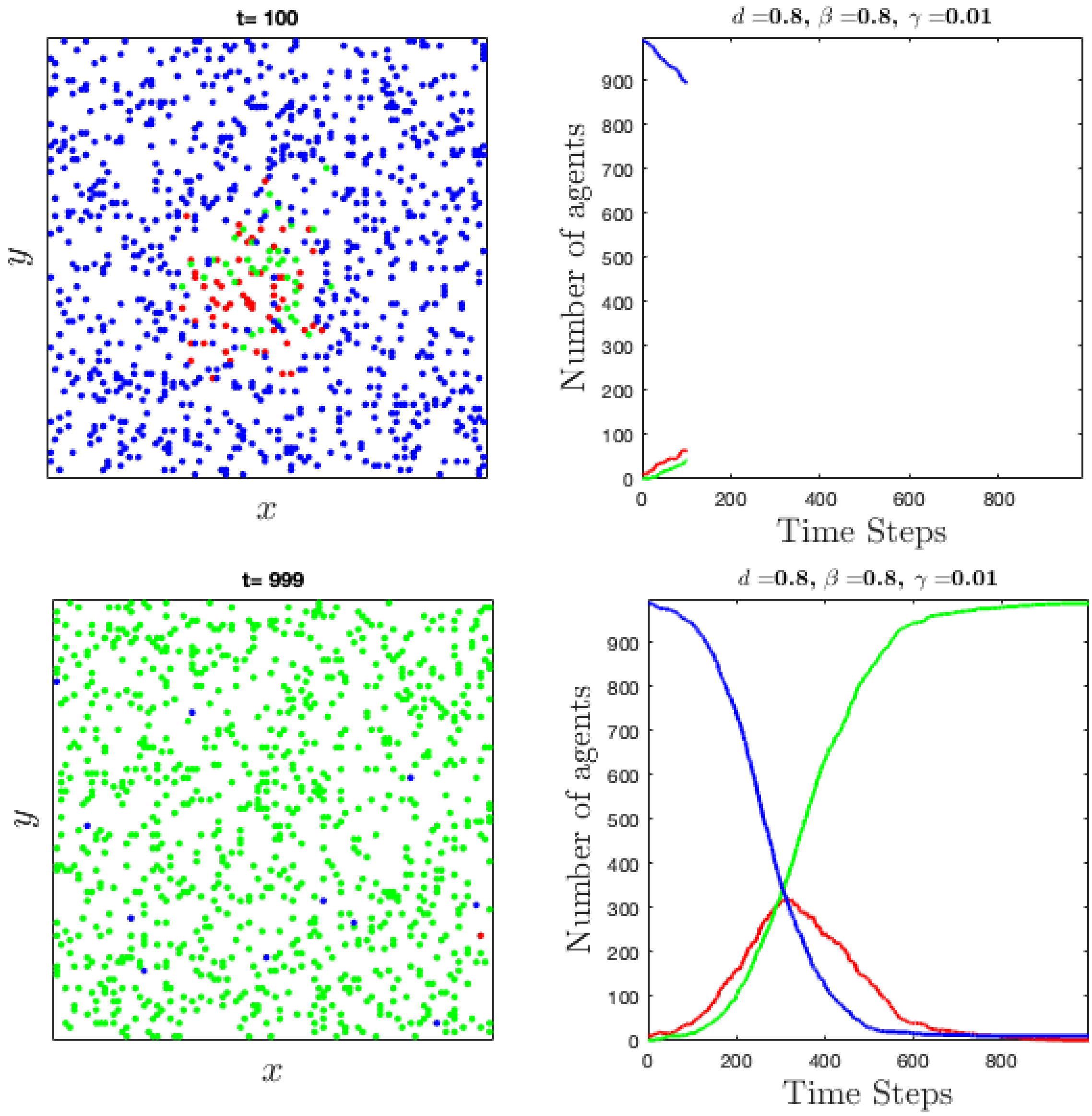
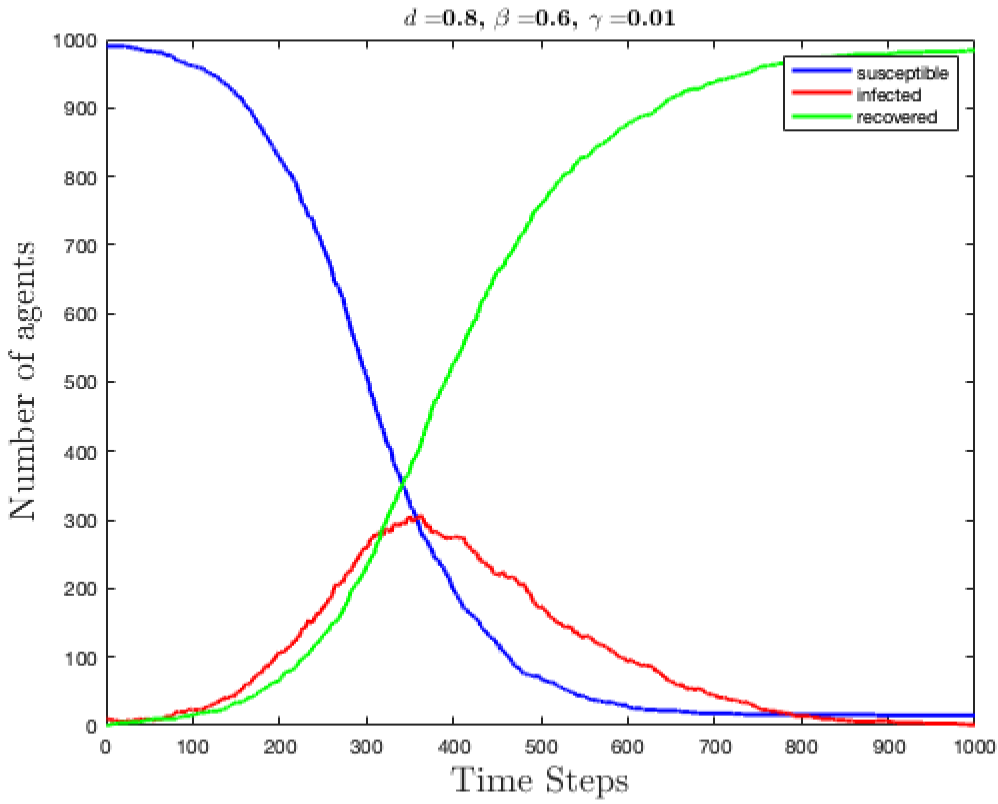
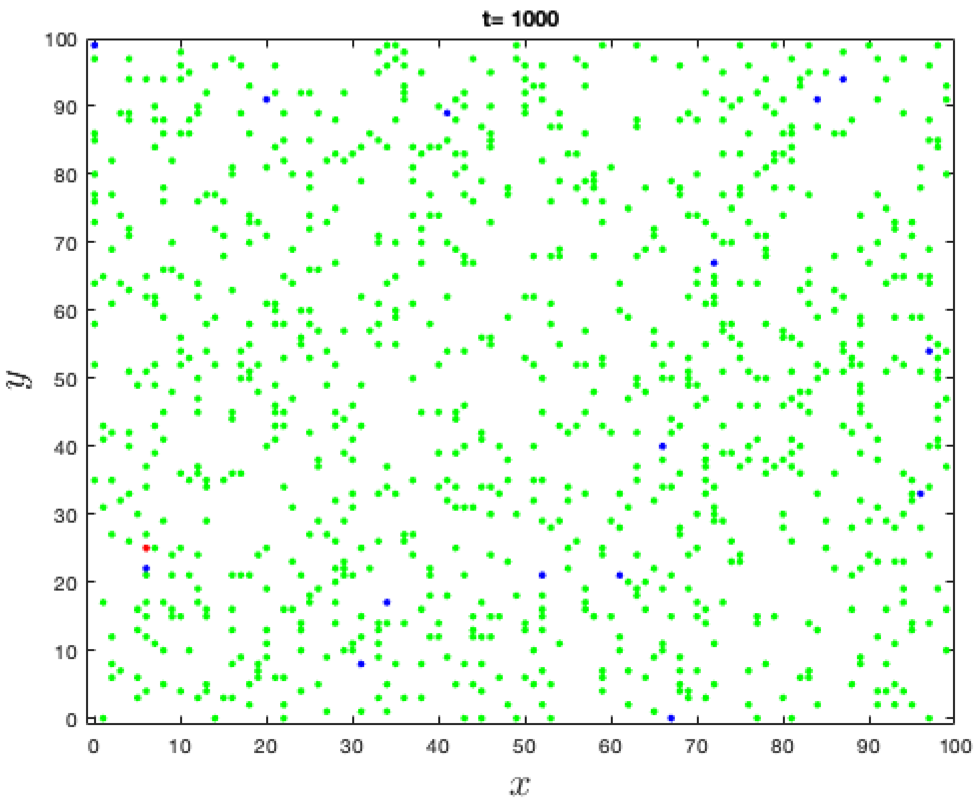
11.1 Simulation of the SIR model.

c)d) Showing limited disease spreading with doubling the recovery rate and halving the infection rate.

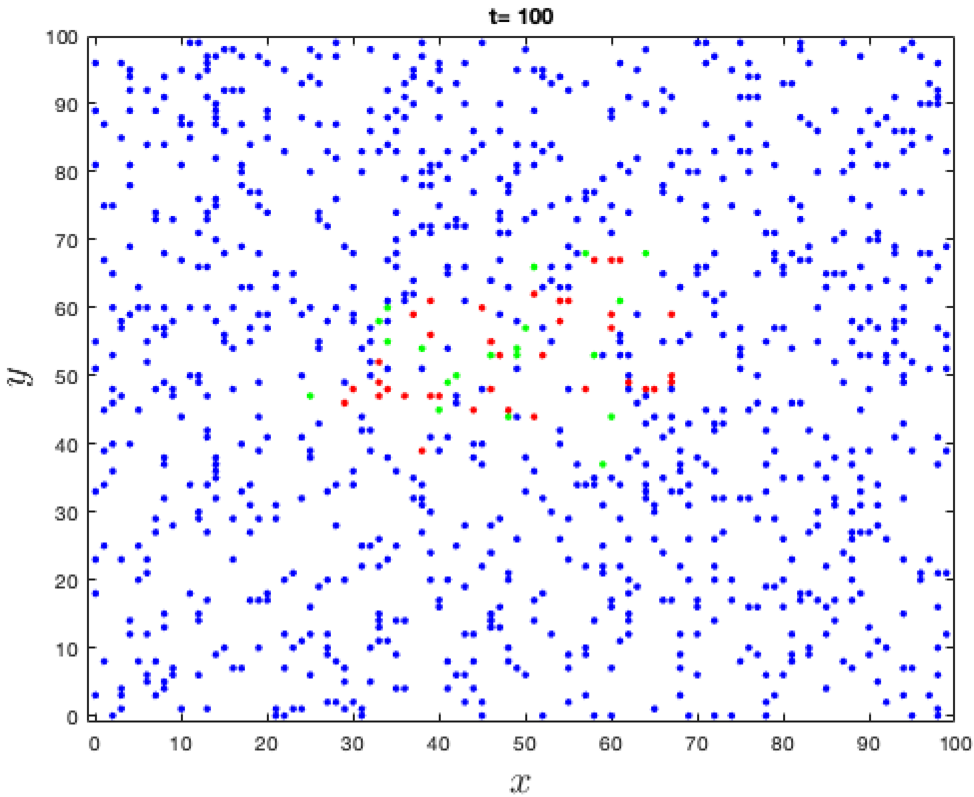


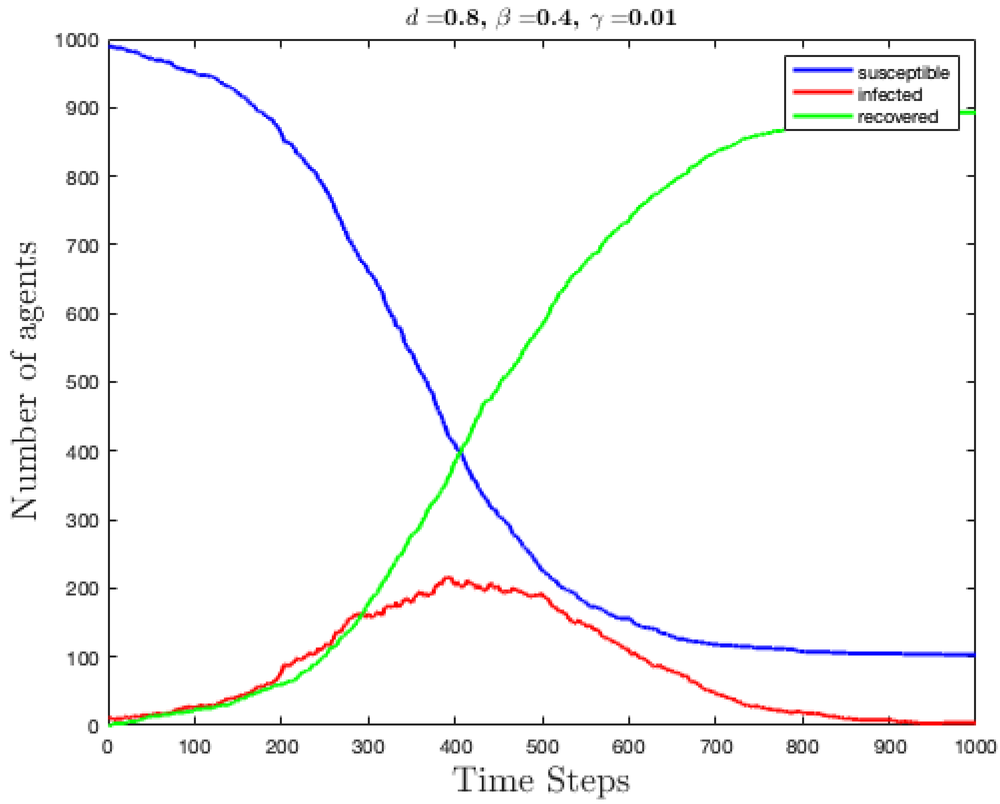


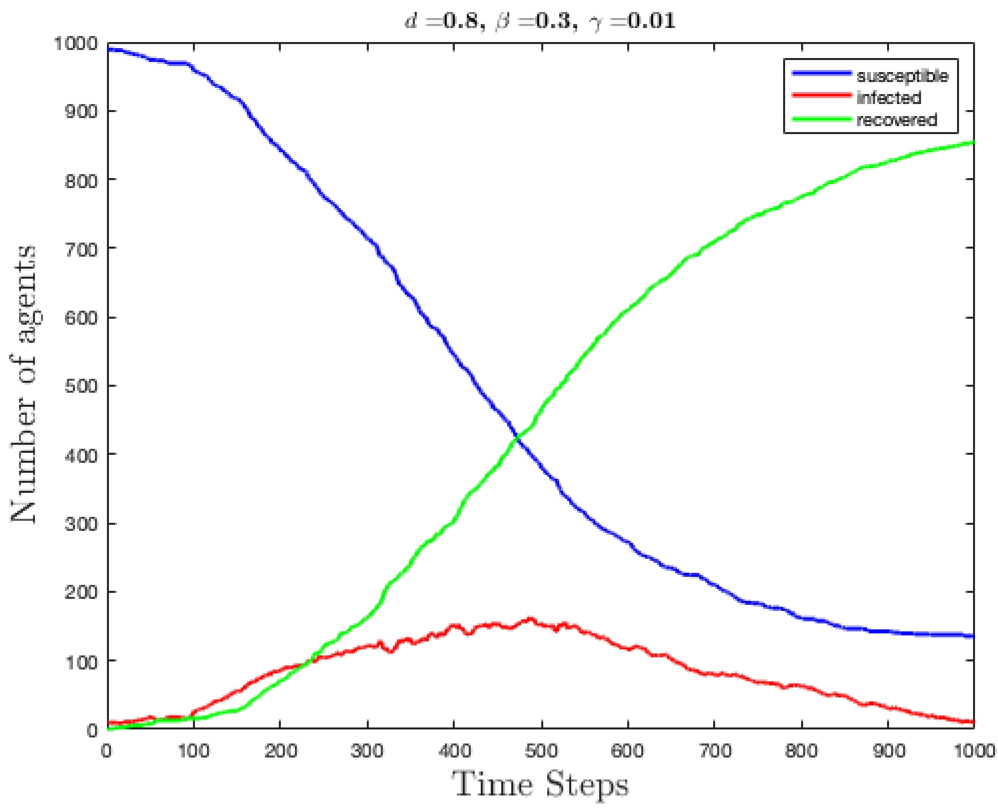
$d = \mathbf{0.8}$, $\beta = \mathbf{0.6}$, $\gamma = \mathbf{0.01}$
susceptible
infected
recovered
Number of agents
Time Steps

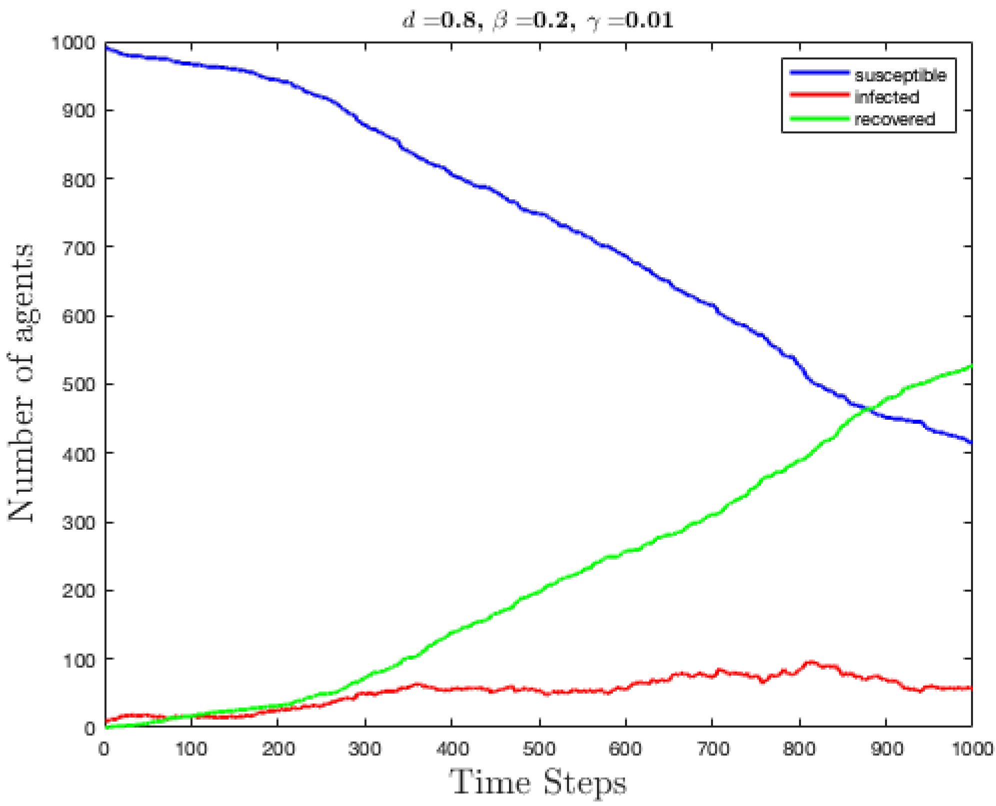


t= 1000
y
x

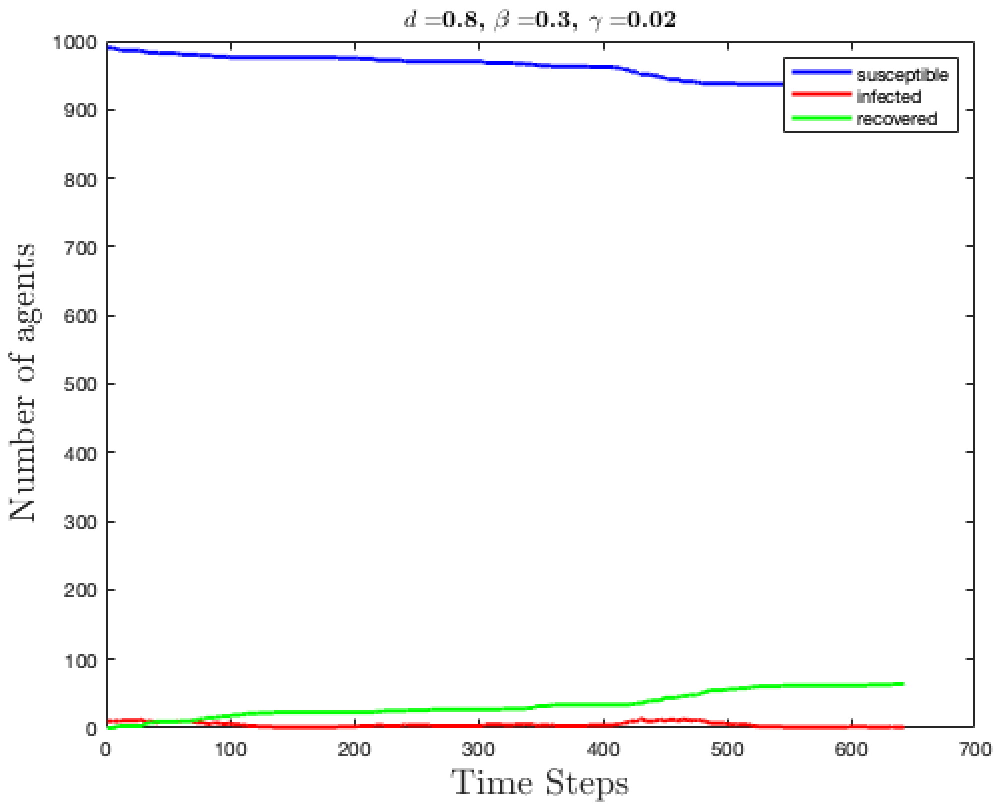

t= 100
y
x
0
10
20
30
40
50
60
70
80
90
100


d =0.8, β =0.4, γ =0.01
susceptible
infected
recovered
Number of agents
Time Steps
0
100
200
300
400
500
600
700
800
900
1000

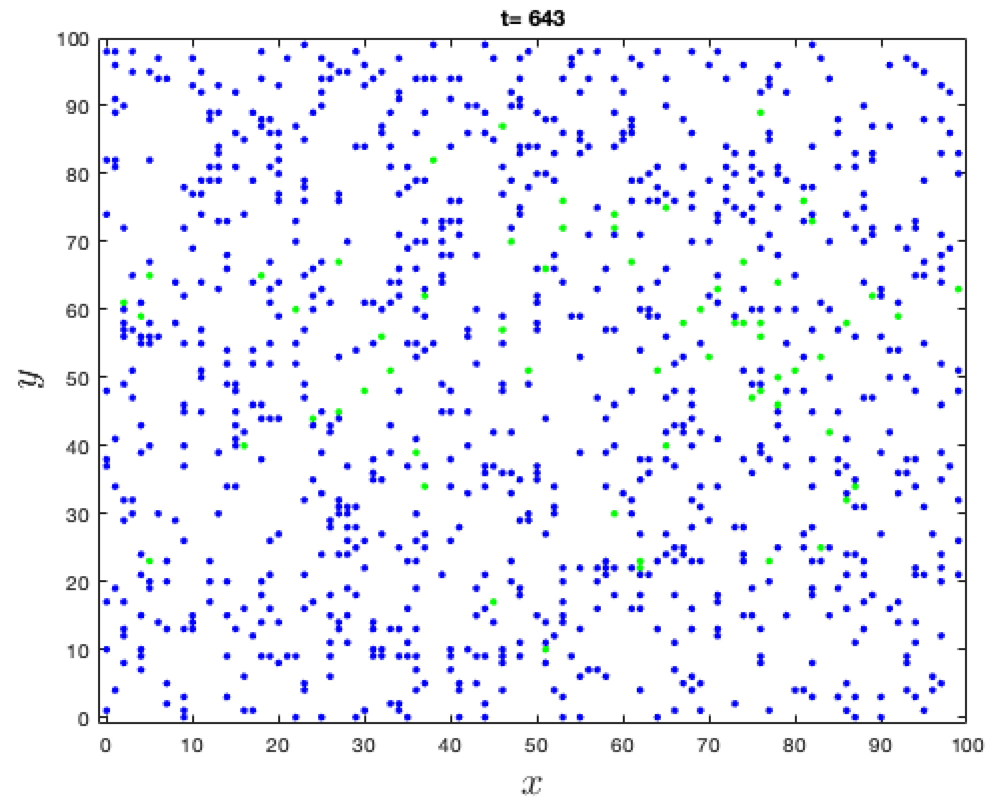

d =0.8, β =0.3, γ =0.01
susceptible
infected
recovered
Number of agents
Time Steps
0
100
200
300
400
500
600
700
800
900
1000

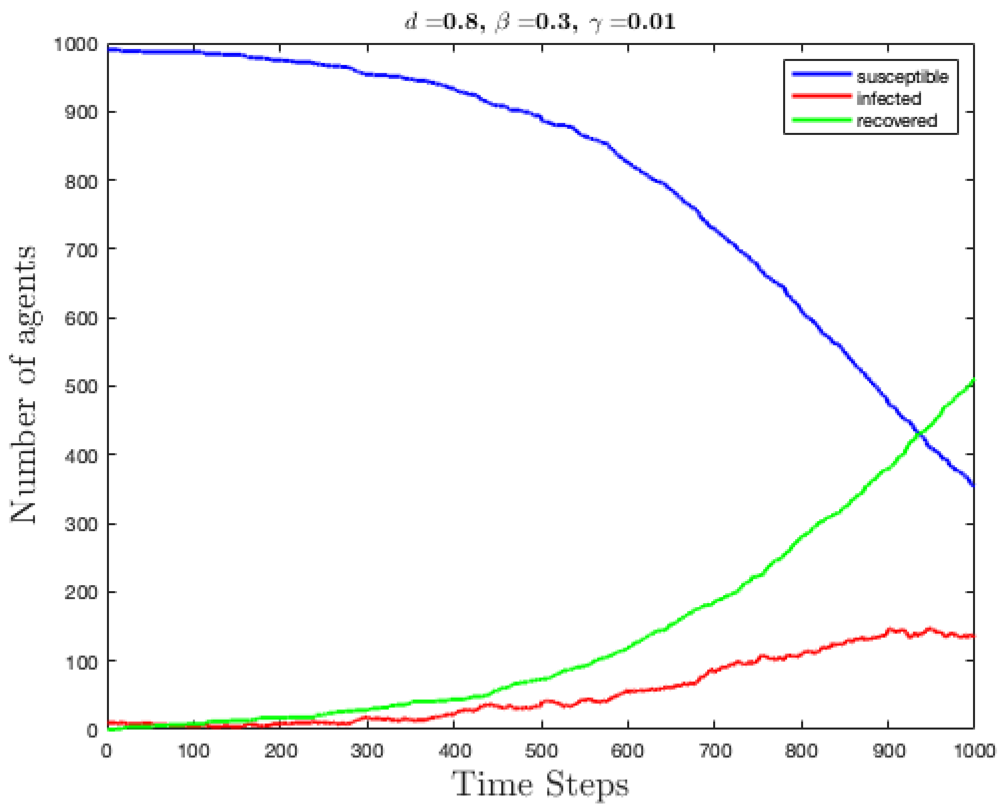


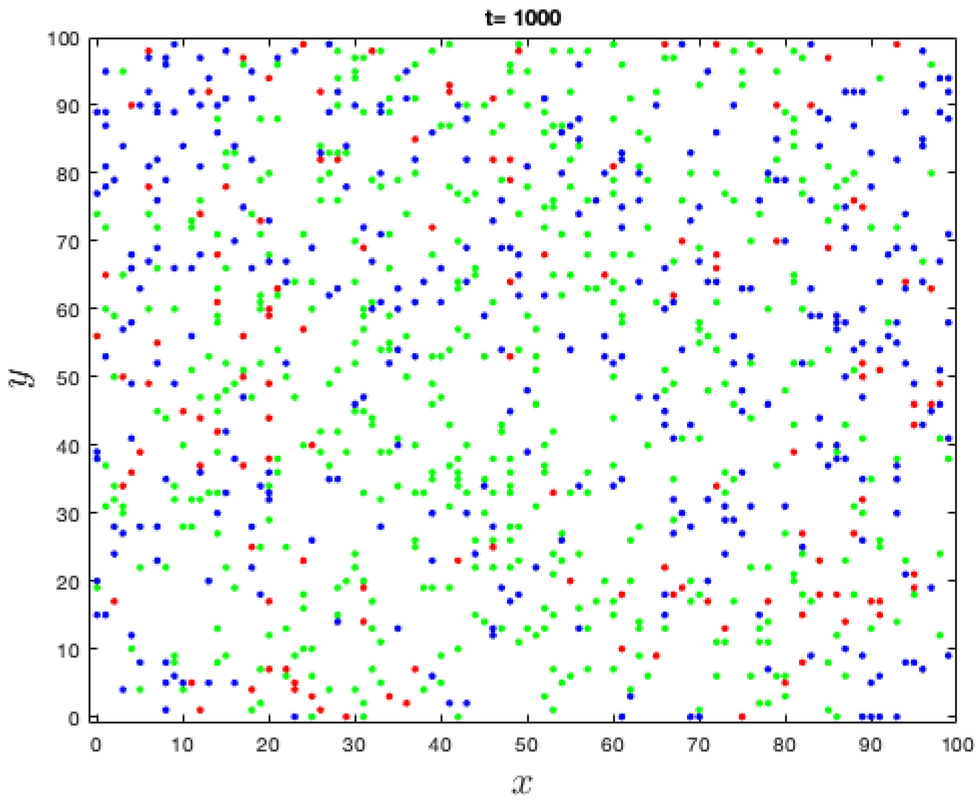
d =0.8, β =0.2, γ =0.01
susceptible
infected
recovered
Number of agents
Time Steps
0
100
200
300
400
500
600
700
800
900
1000

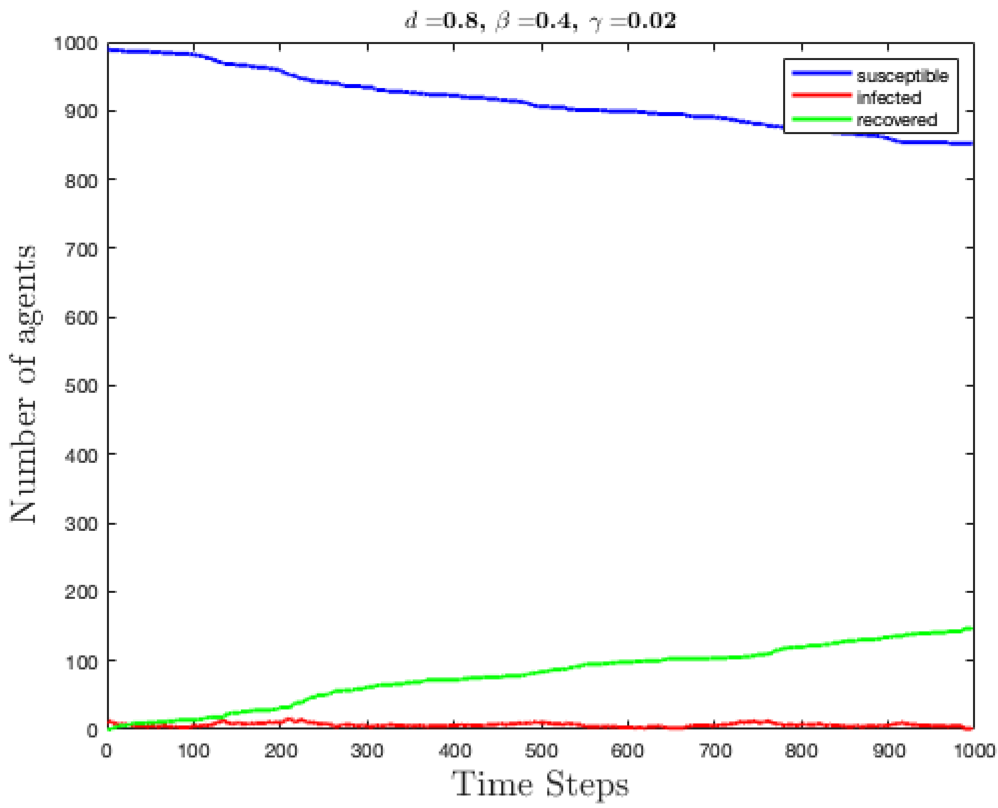


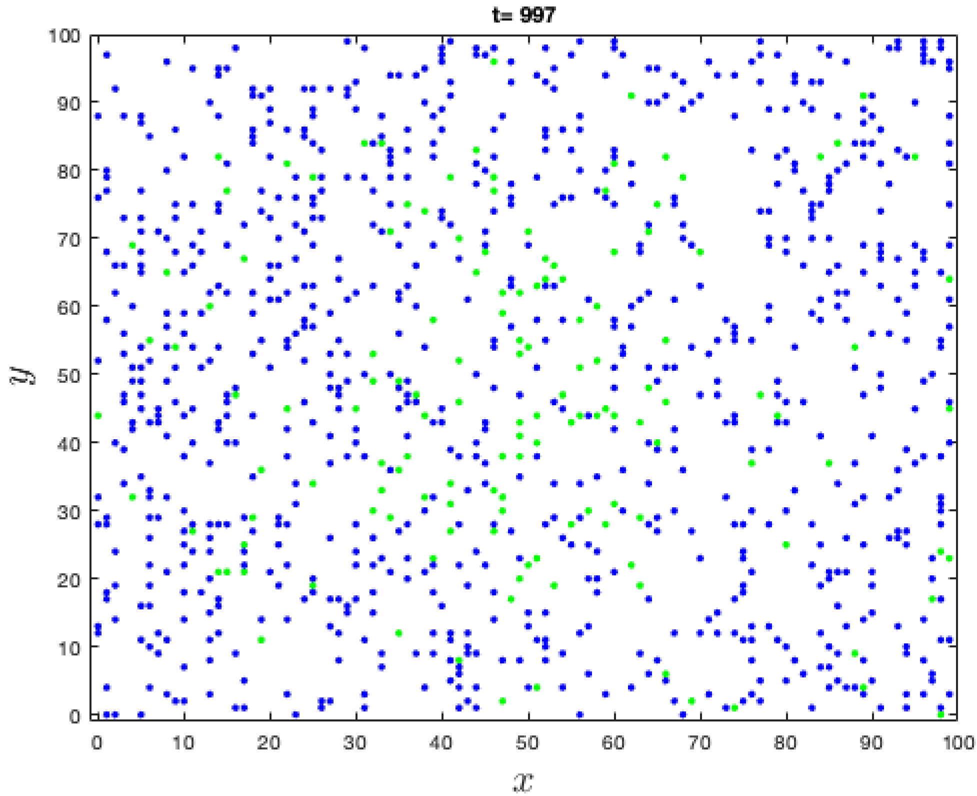
d =0.8, β =0.3, γ =0.02
susceptible
infected
recovered
Number of agents
Time Steps
0
100
200
300
400
500
600
700
800
900
1000

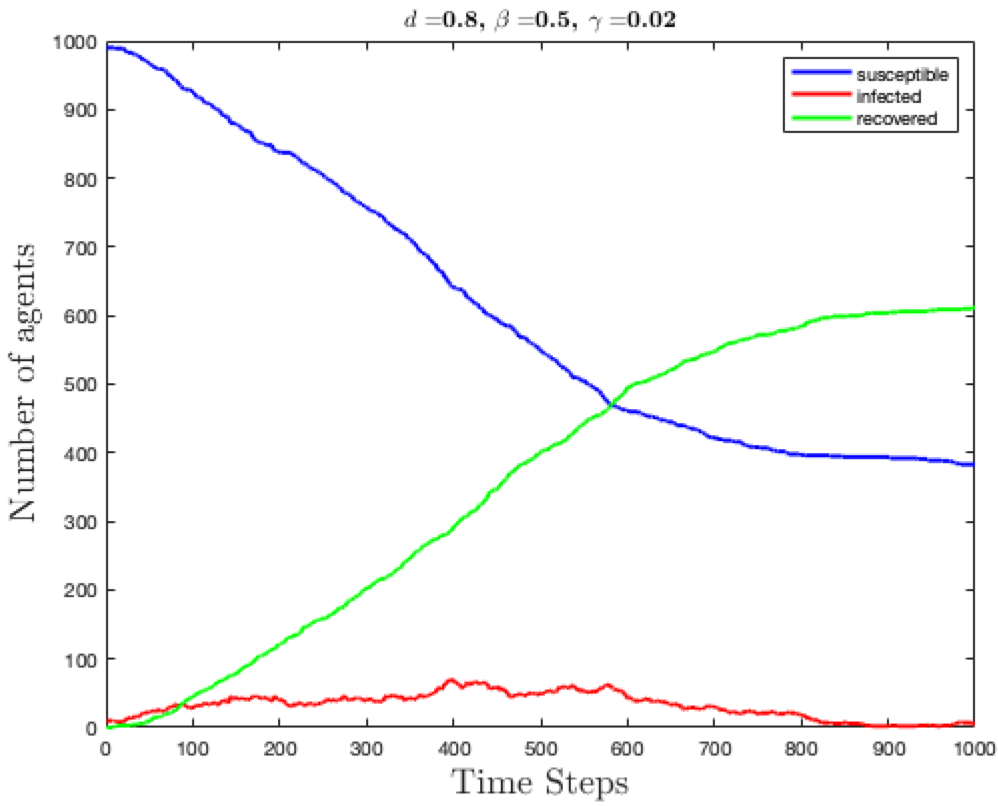

t= 643
y
x

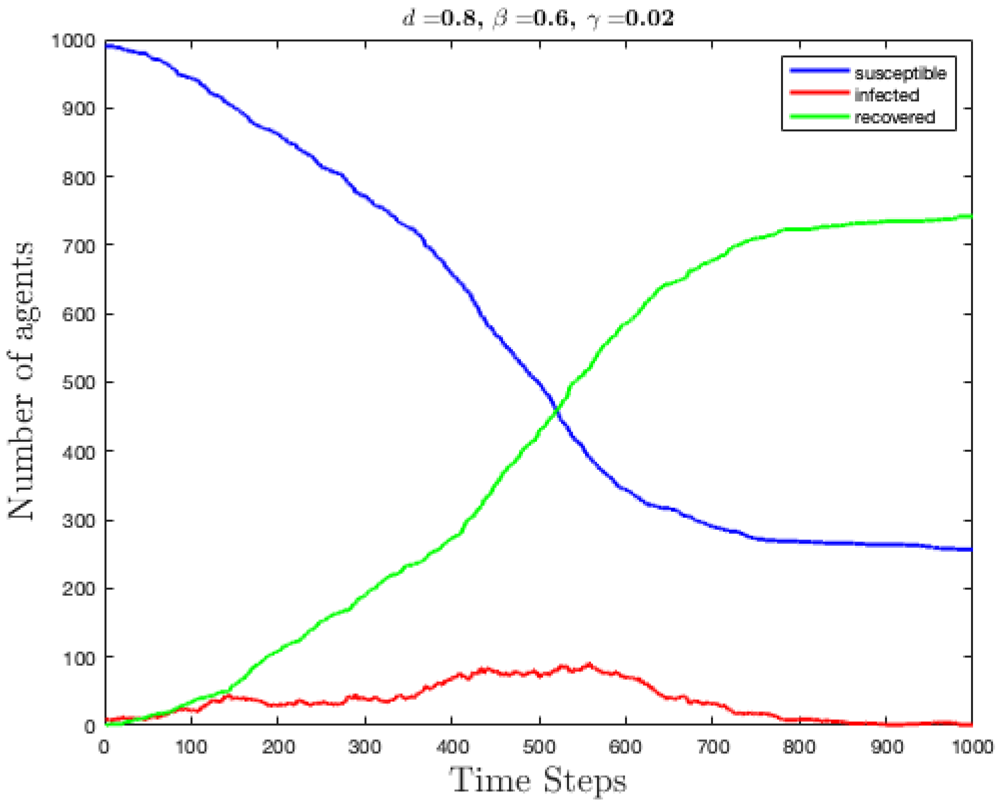

d =0.8, β =0.3, γ =0.01
susceptible
infected
recovered
Number of agents
Time Steps

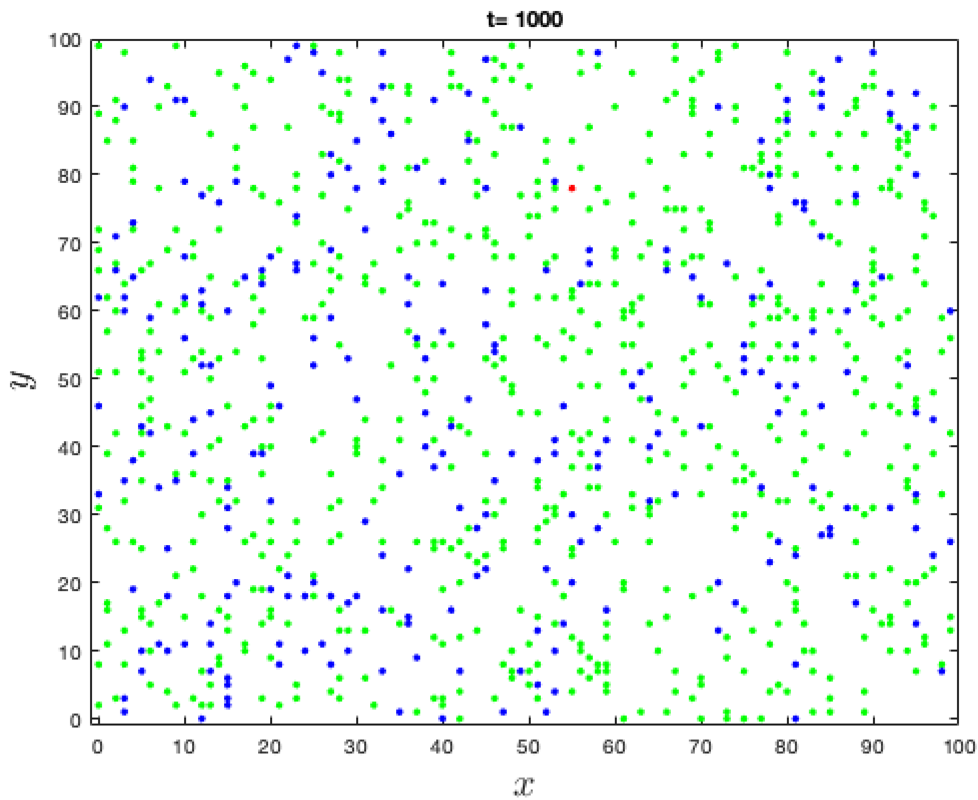

t= 1000
y
x

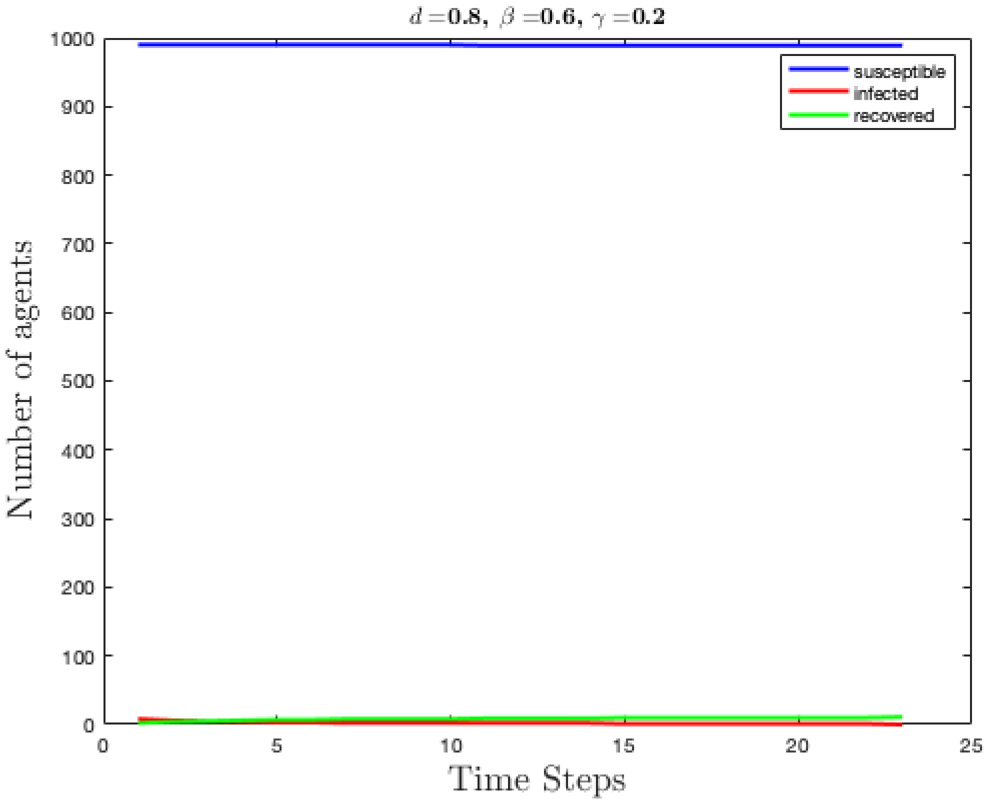

d =0.8, β =0.4, γ =0.02
susceptible
infected
recovered
Number of agents
Time Steps

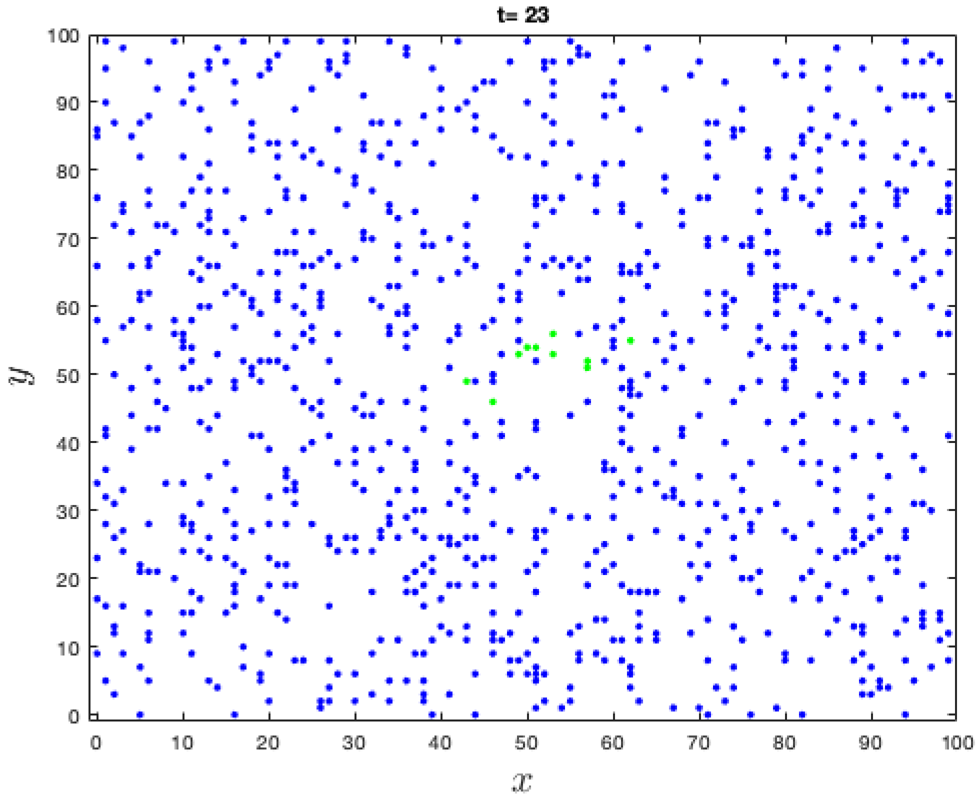

t= 997
y
x

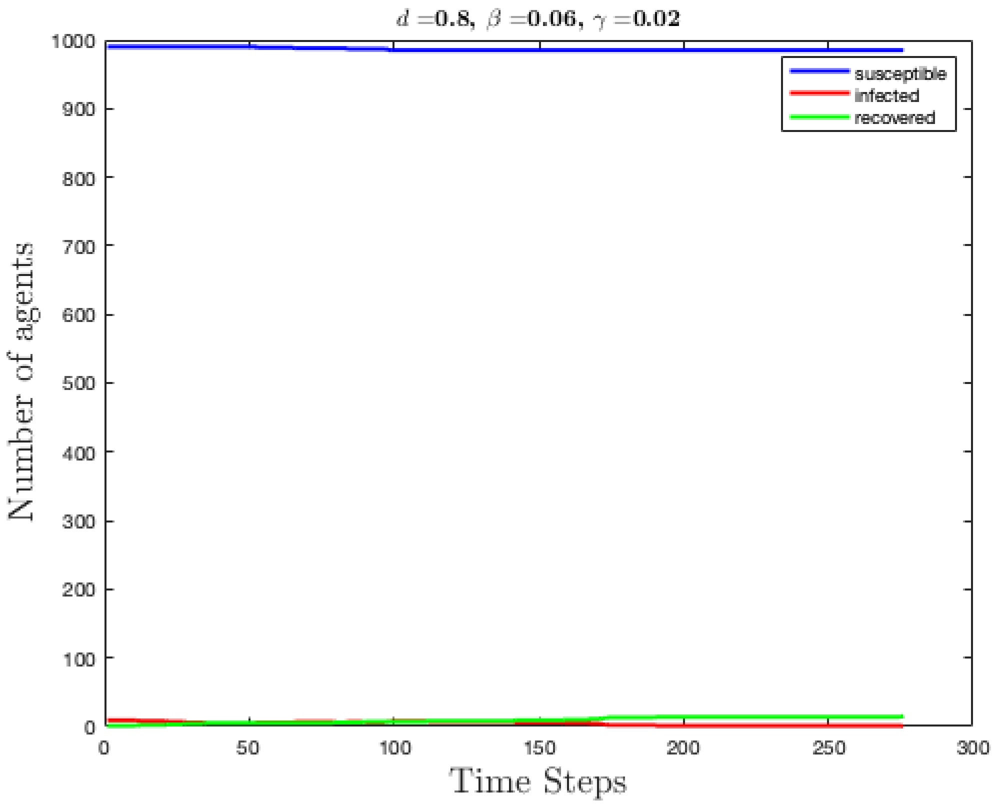

d =0.8, β =0.5, γ =0.02
susceptible
infected
recovered
Number of agents
Time Steps

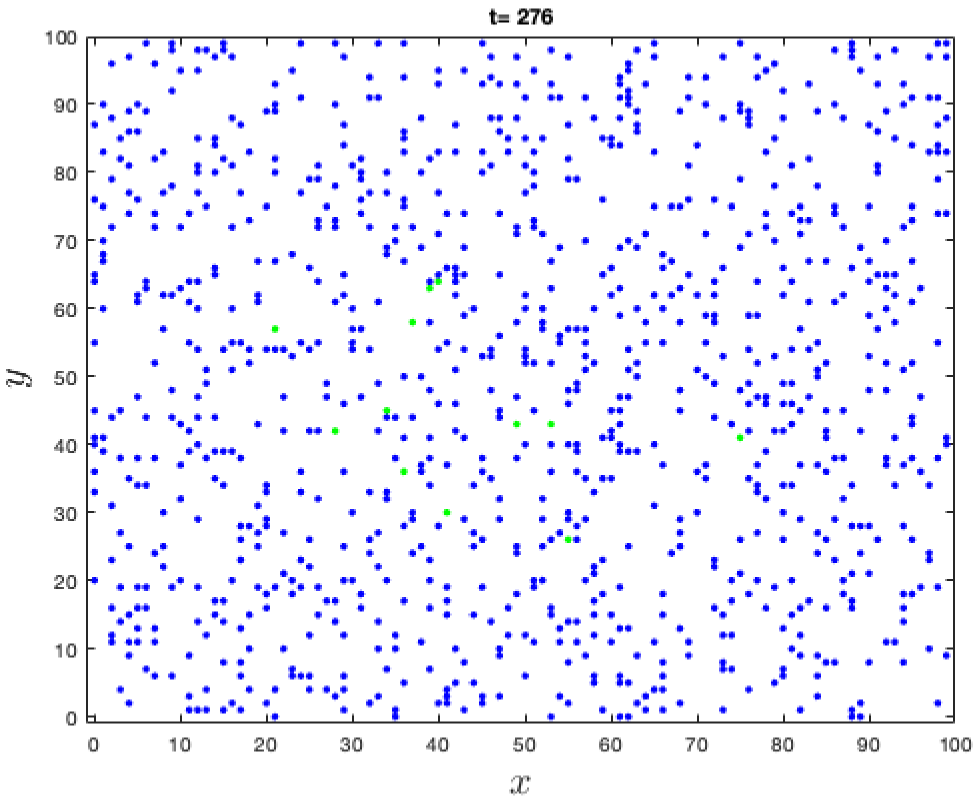

d =0.8, β =0.6, γ =0.02
susceptible
infected
recovered
Number of agents
Time Steps


t= 1000
y
x


$d = 0.8,\ \beta = 0.6,\ \gamma = 0.2$
susceptible
infected
recovered
Number of agents
Time Steps

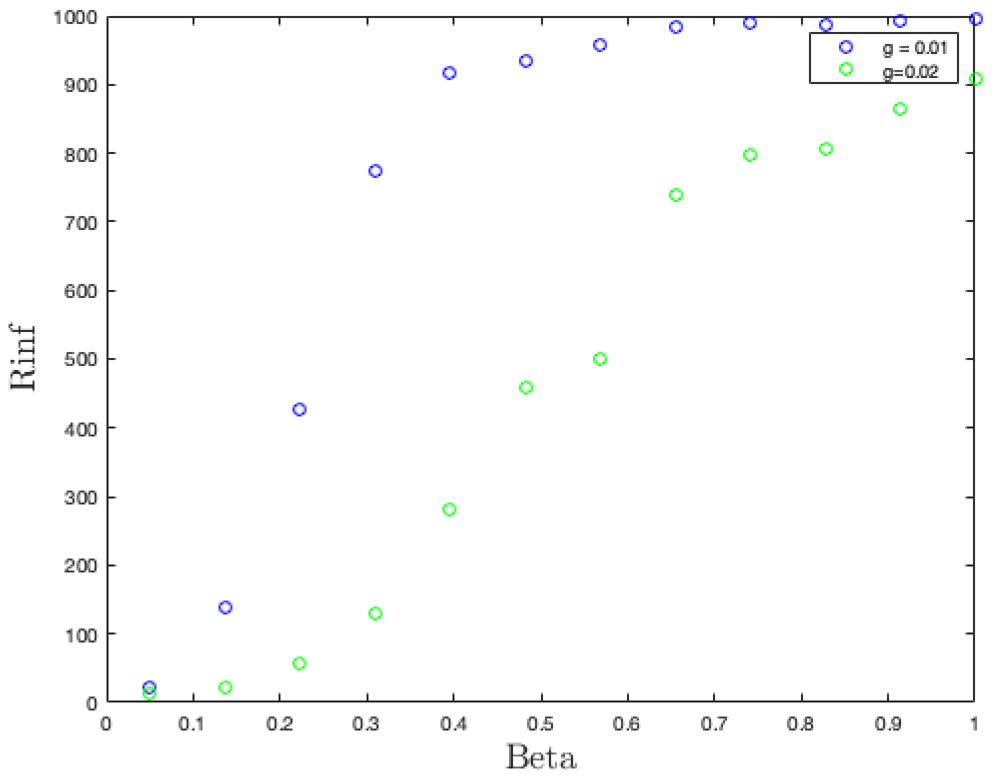

t= 23
y
x

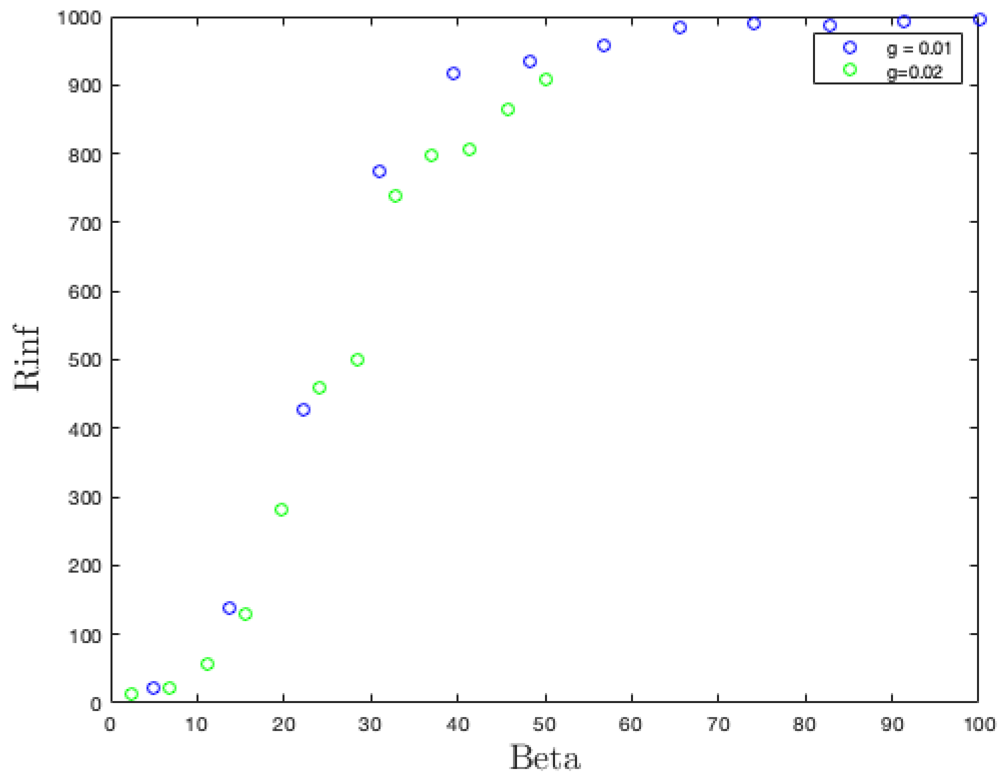

$d = 0.8,\ \beta = 0.06,\ \gamma = 0.02$
susceptible
infected
recovered
Number of agents
Time Steps


t= 276
y
x

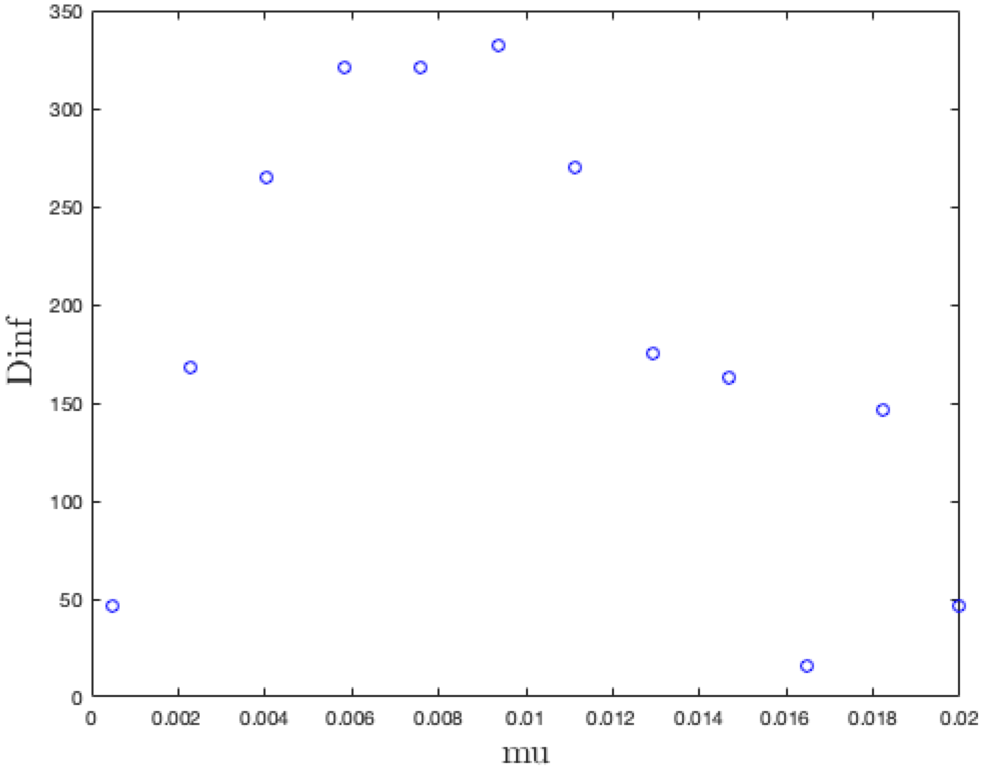
11.2 Dependence of the final number of recovered agents on the infection rate

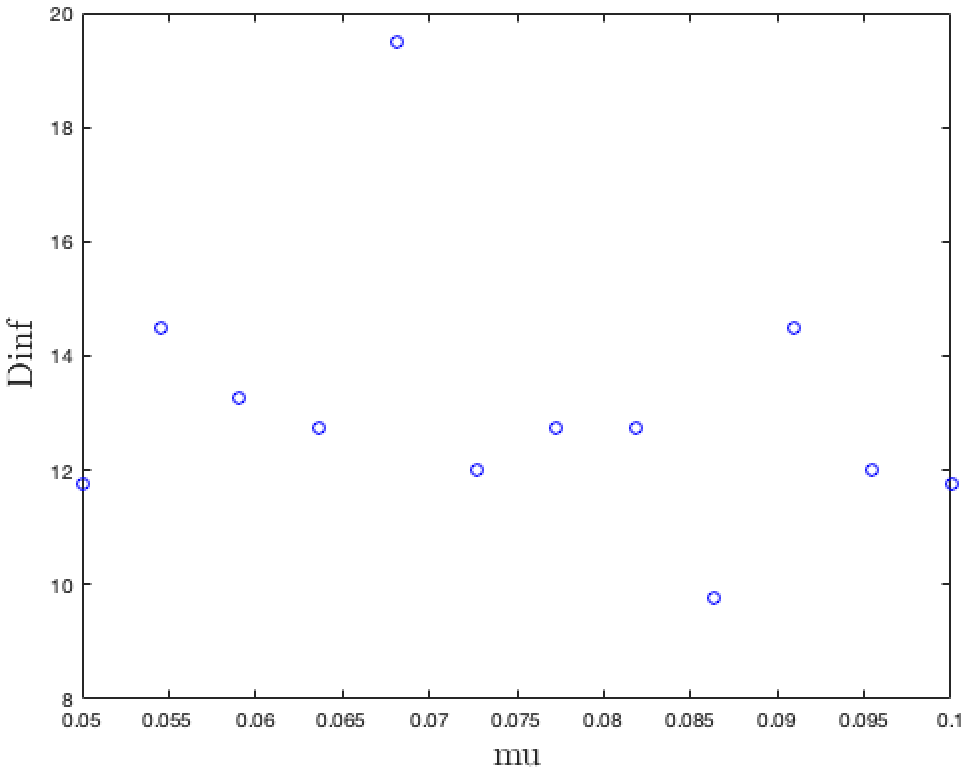
R∞ depends strongly on the infection rate β. This dependence is demonstrated in figure

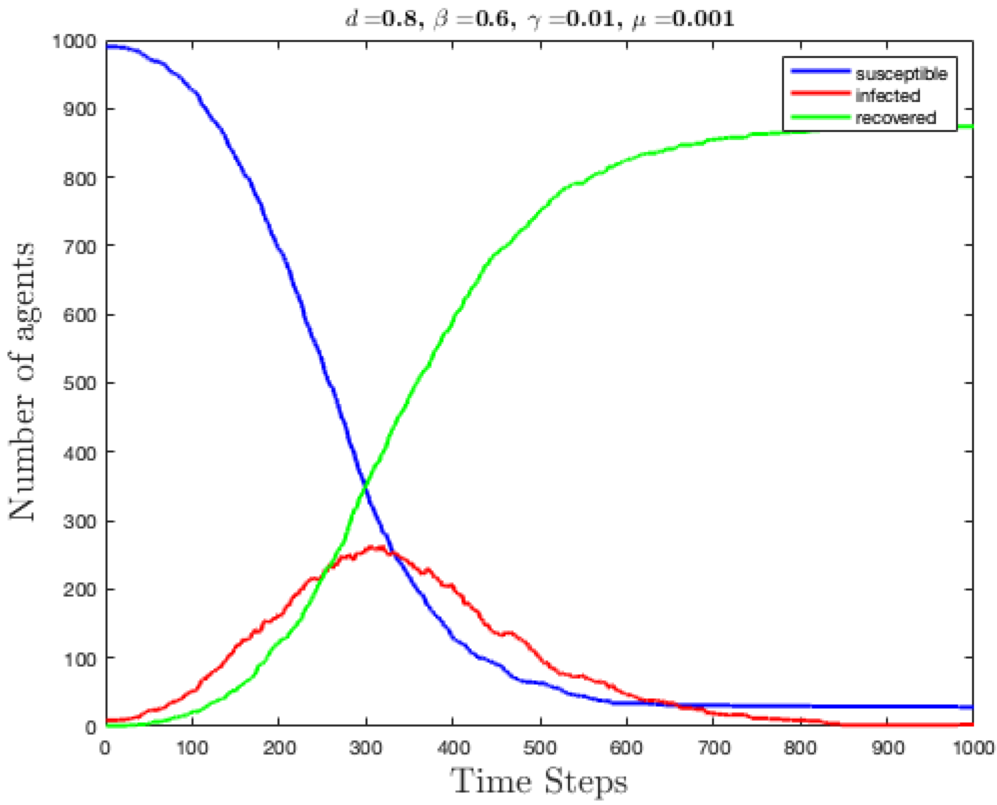




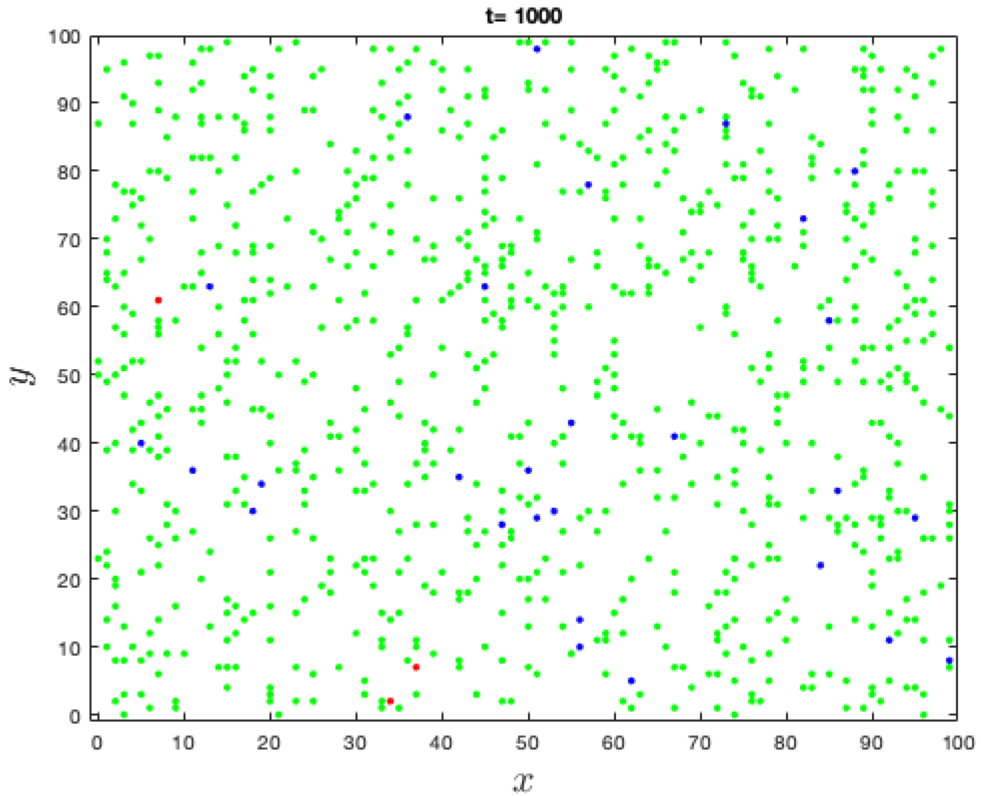
11.3 SIR model with mortality.



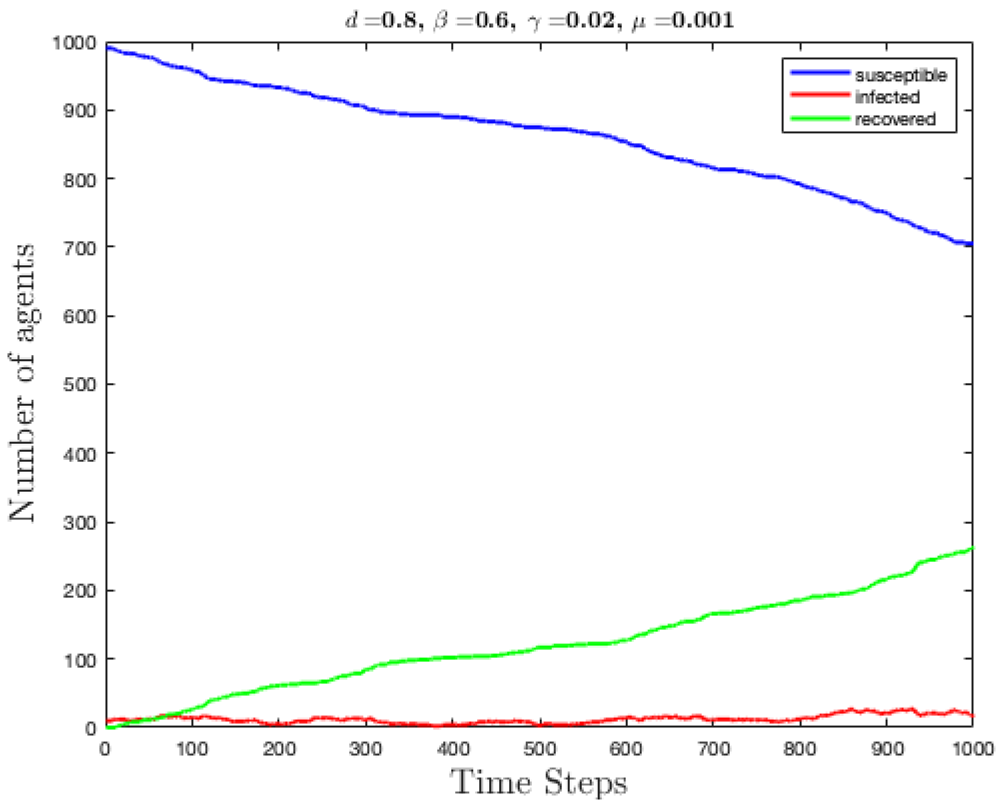


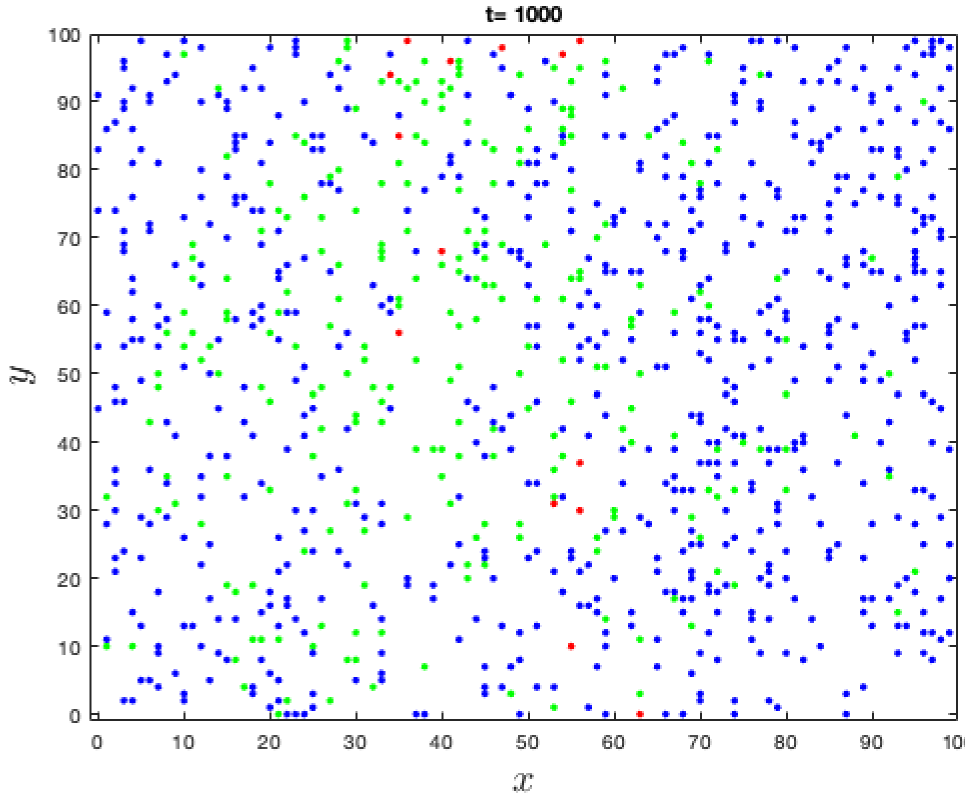


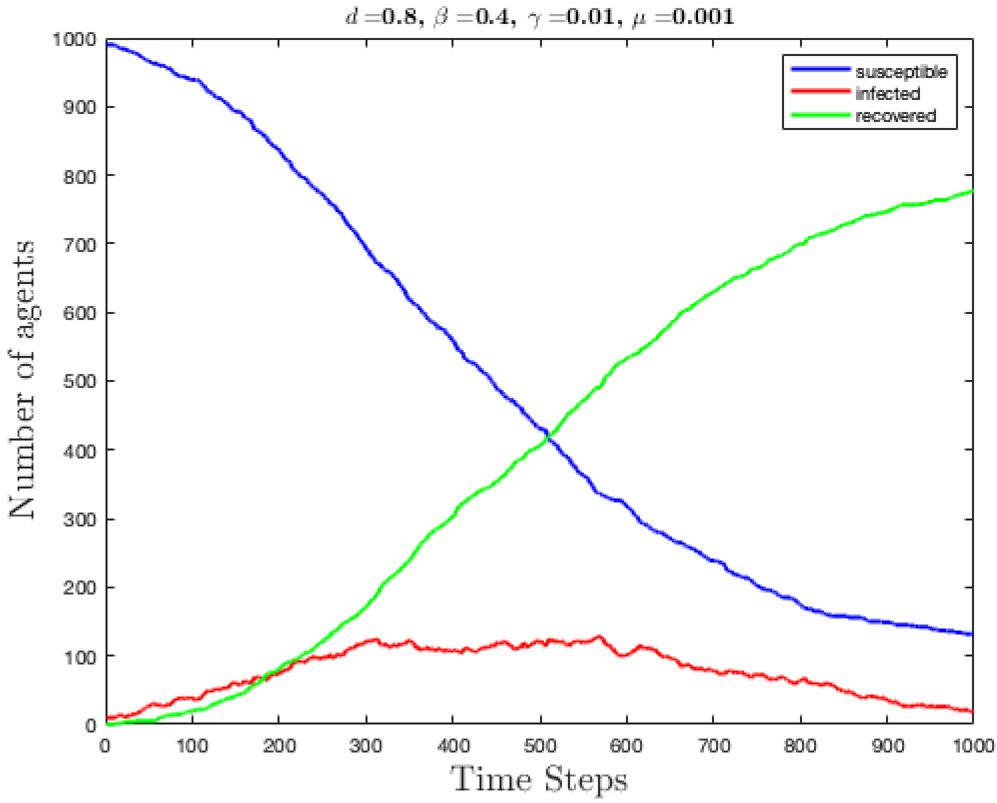
$d = 0.8$, $\beta = 0.6$, $\gamma = 0.01$, $\mu = 0.001$
susceptible
infected
recovered
Number of agents
Time Steps



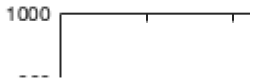
t= 1000
y
x

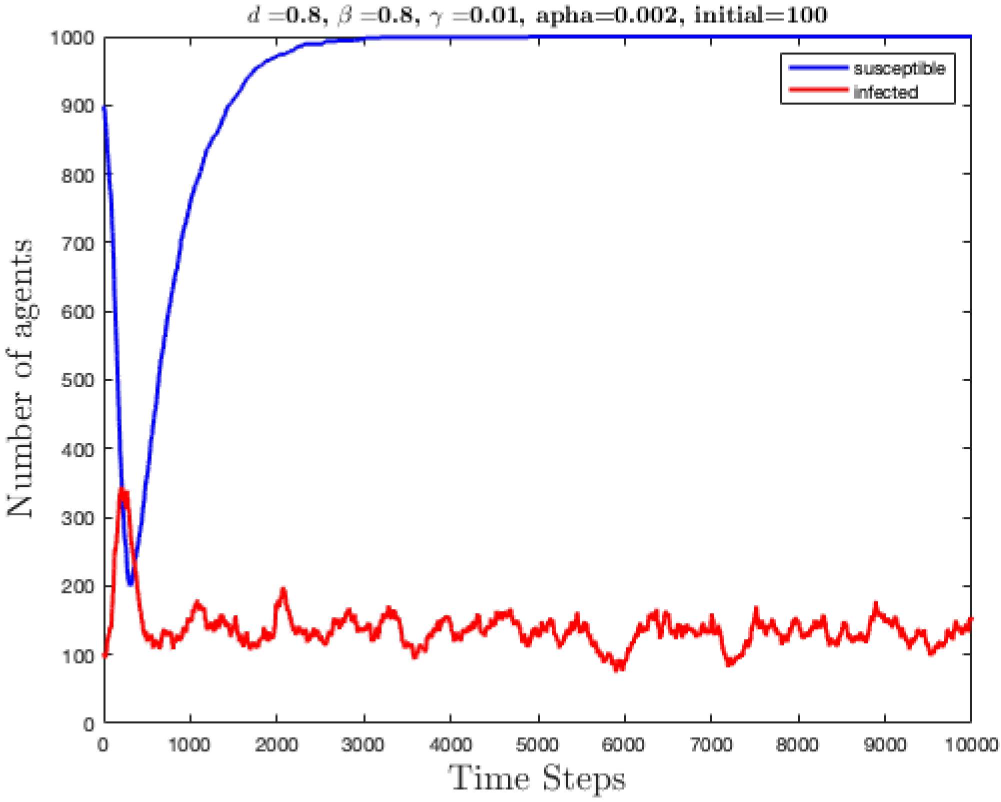

$d = \mathbf{0.8},\ \beta = \mathbf{0.6},\ \gamma = \mathbf{0.02},\ \mu = \mathbf{0.001}$
susceptible
infected
recovered
Number of agents
Time Steps
0
100
200
300
400
500
600
700
800
900
1000

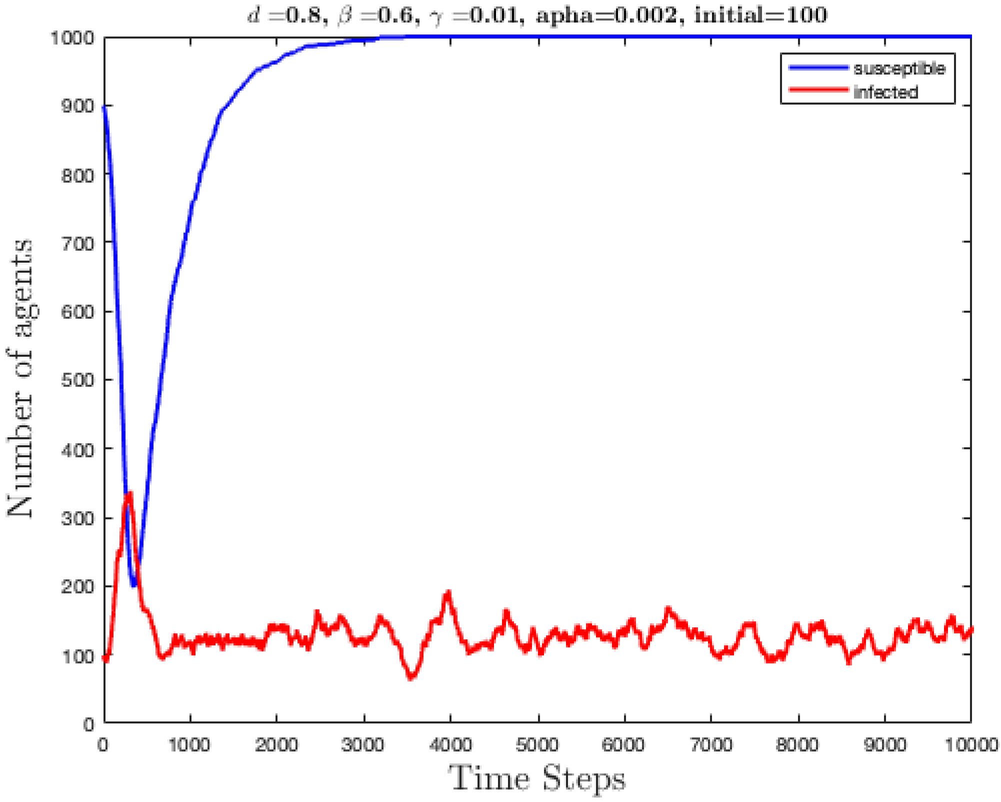

t= 1000
y
x
0
10
20
30
40
50
60
70
80
90
100

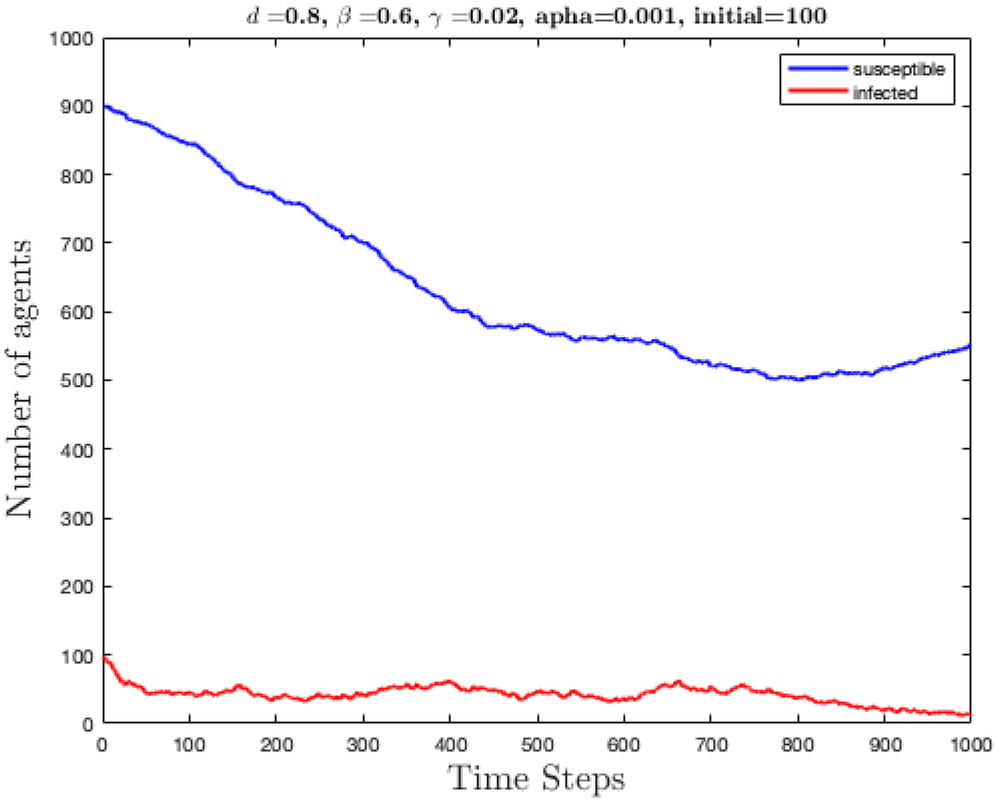

$d = \mathbf{0.8}$, $\beta = \mathbf{0.4}$, $\gamma = \mathbf{0.01}$, $\mu = \mathbf{0.001}$
susceptible
infected
recovered
Number of agents
Time Steps
0
100
200
300
400
500
600
700
800
900
1000

11.4 SIR model with temporary immunity.

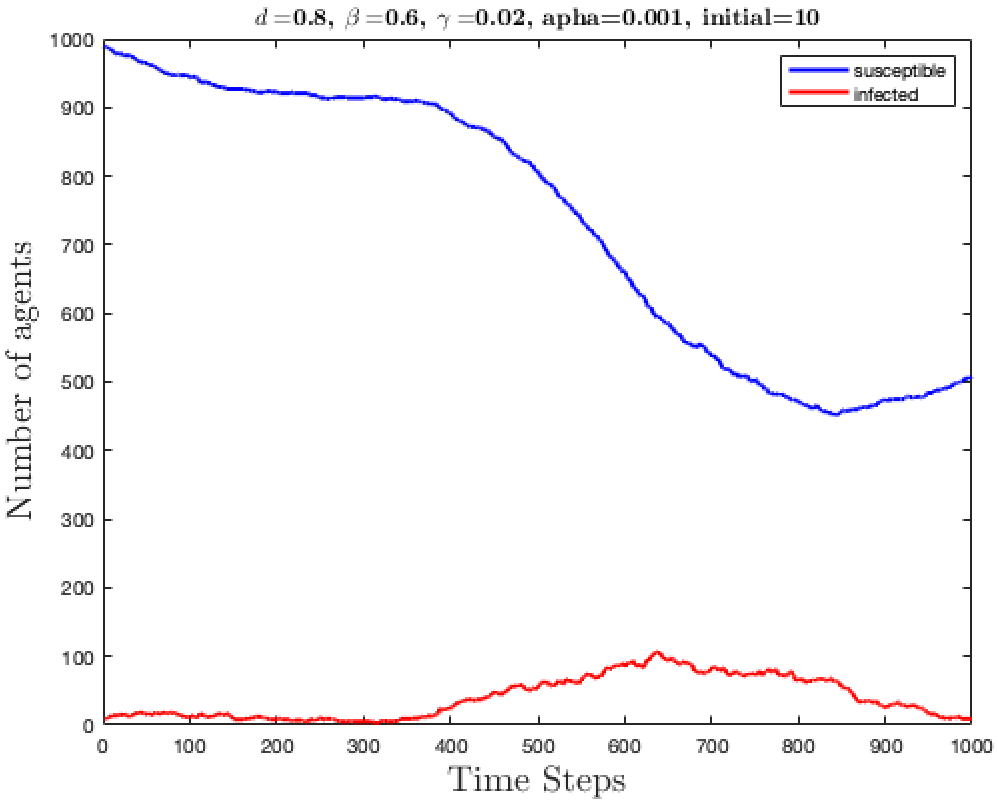




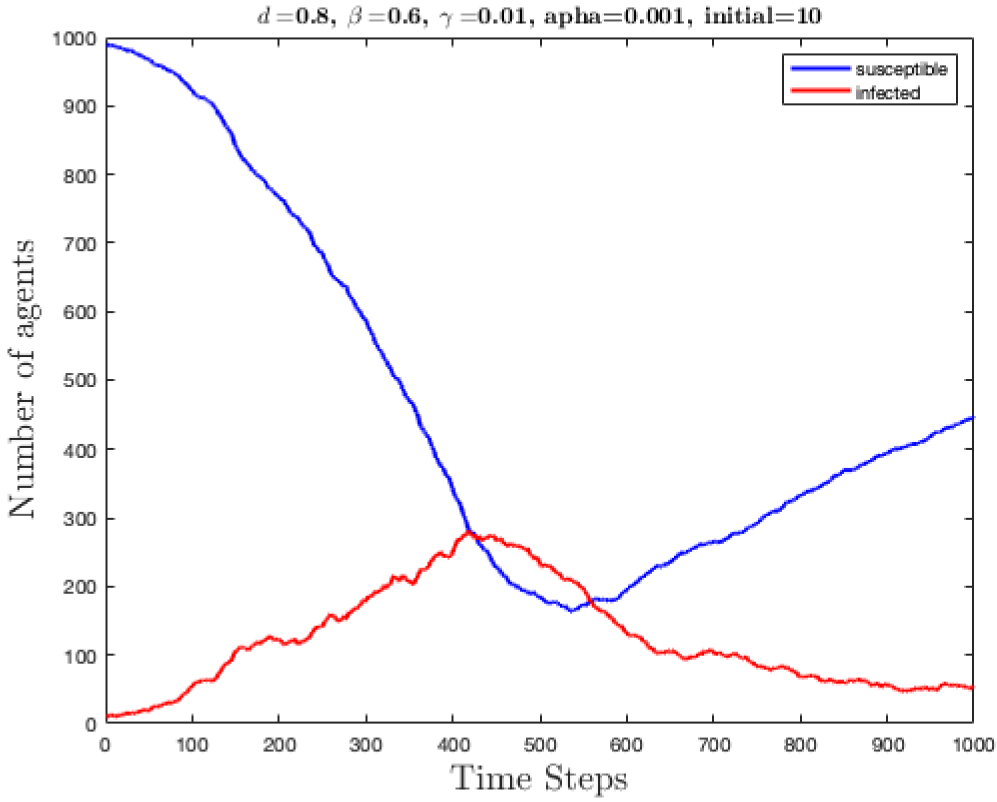


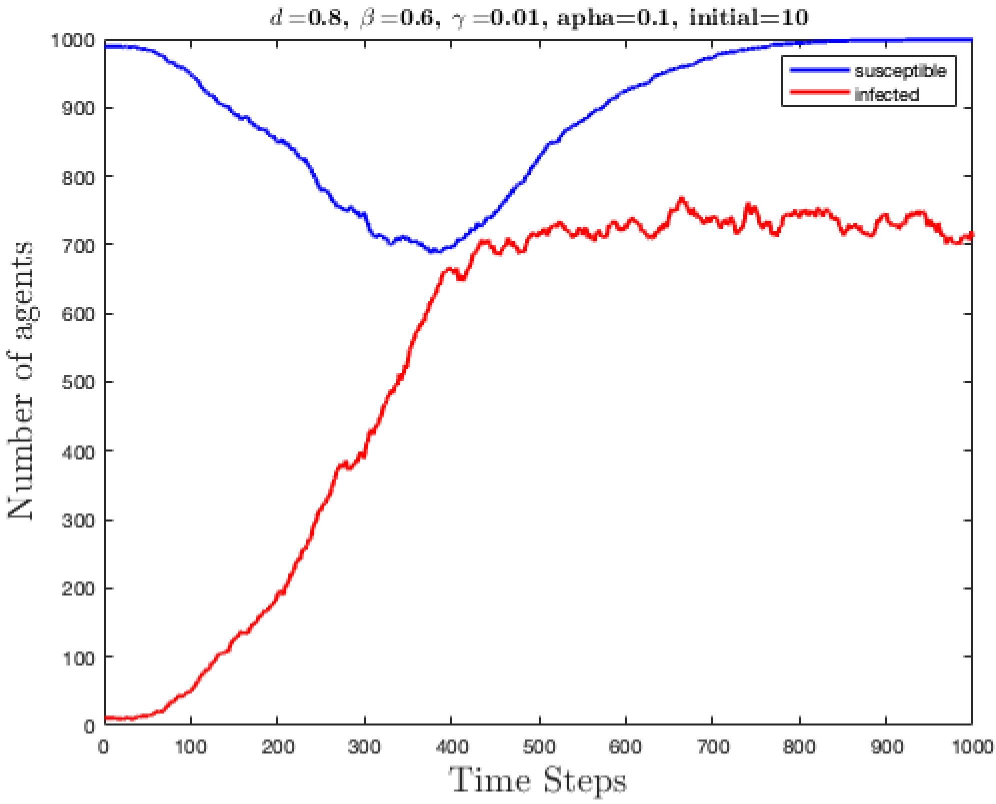


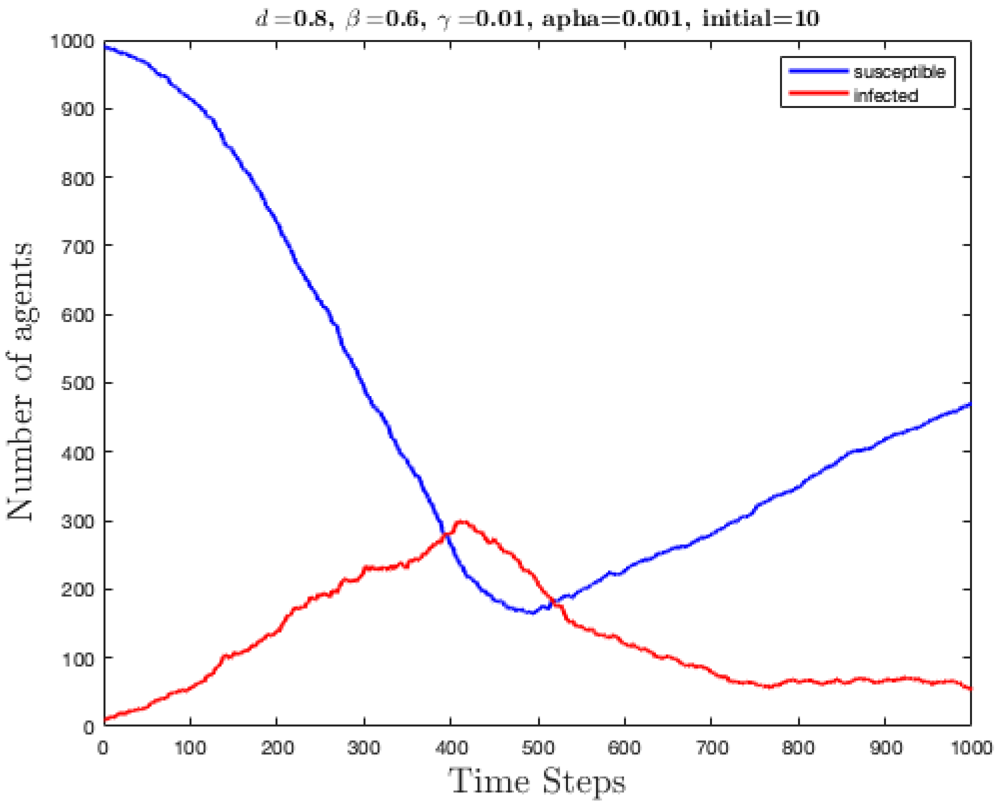
d =0.8, β =0.6, γ =0.02, apha=0.001, initial=100
susceptible
infected
Number of agents
Time Steps
0
100
200
300
400
500
600
700
800
900
1000



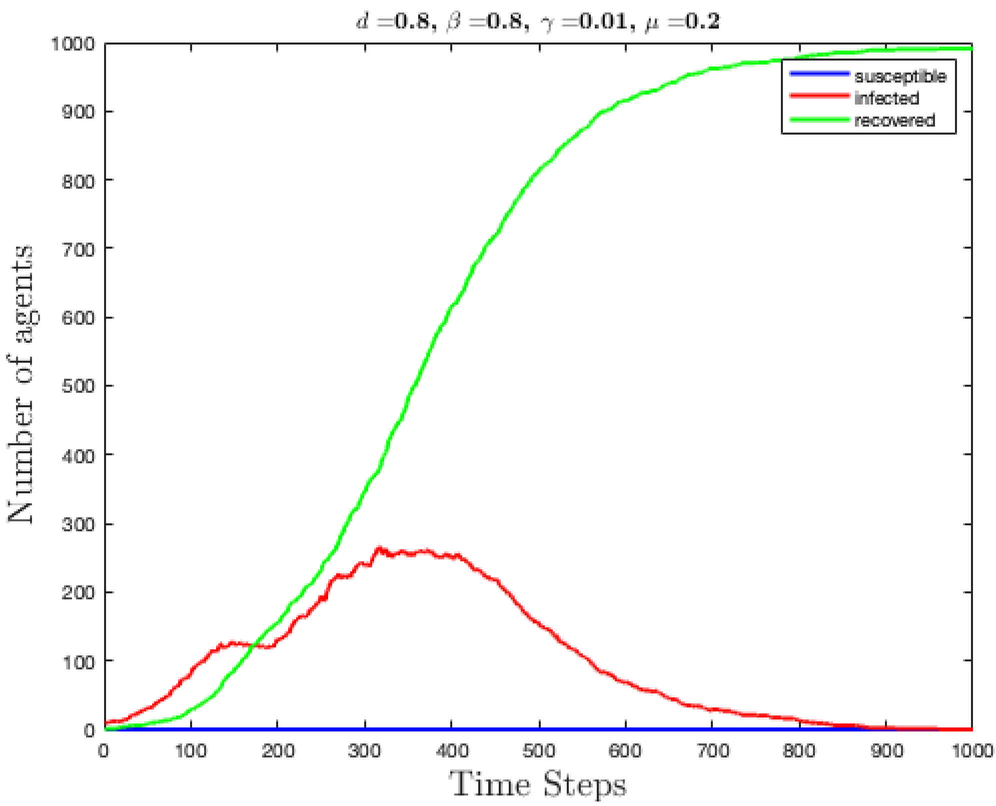
d =0.8, β =0.6, γ =0.02, apha=0.001, initial=10
susceptible
infected
Number of agents
Time Steps
0
100
200
300
400
500
600
700
800
900
1000


d =0.8, β =0.6, γ =0.01, apha=0.001, initial=10
susceptible
infected
Number of agents
Time Steps


d =0.8, β =0.6, γ =0.01, apha=0.1, initial=10
susceptible
infected
Number of agents
Time Steps



$d = 0.8$, $\beta = 0.6$, $\gamma = 0.01$, apha=0.001, initial=10
susceptible
infected
Number of agents
Time Steps



$d = 0.8$, $\beta = 0.8$, $\gamma = 0.01$, $\mu = 0.2$
susceptible
infected
recovered
Number of agents
Time Steps

Code

I had 4 scripts but will only insert the two for the firsts to exercises because the other two scripts were a combination of the two.

```
% Homework 3: Disease Spreading, Simulation of Complex Systems FFR120
% Nicole Adamah 2022
%11.1
clear all;
close all;
clc;
%% Parameters:
N=1000;
n=100;
infect=10;
d=0.8;     % Probability of random walk
g=0.01;    % Recovery rate
B=0.6;     % Infection rate
trials = 1;

for m = 1:trials
disp(m);
t = 0;
x=randi(n,1,N)-1;                  % Random location along x
y=randi(n,1,N)-1;                  % Random location along y
[~,I]=sort((x-n/2).^2+(y-n/2).^2);     % Find closest ones to the center
preI=zeros(1,N);
preI(I(1:infect))=1;
I=logical(preI);                   % Infection status array
R=false(1,N);                      % Recovered status array
S=logical(1-I);                    % Susceptible status array
for h = 1:1000
%% SIMULATION
    dx=2*(round(rand(1,N))-0.5).*(rand(1,N)<d);    % Random Walks along x
    dy=2*(round(rand(1,N))-0.5).*(rand(1,N)<d);    % Random Walks along x
    x=mod(x+dx,n);
    y=mod(y+dy,n);                  % Performing walks, Periodic Boundary Conditions
    for i=1:N
     if (I(i)==true)&&(rand<B)      % Only infected agents can infect others,roll the dice for infection
       infection=(x==x(i))&(y==y(i));  % Determine the indices for the agents who sit at the site of infection
       S(infection)=false;           % There are no longer any susceptibles at infection area
       I(infection)=not(R(infection)); % the not recovered agents will turn infected at infection site
     end
    end
    recovery=(rand(1,N)<g);        % Recovery array
    R = R | (I&recovery);          % Recovery operation, the output is true if either or both of the inputs are true
    I = I & not(recovery);         % The recovered are no longer infected, the output is true when both inputs are true
    nrI(t+1)=sum(I);
    nrR(t+1)=sum(R);
    nrS(t+1)=sum(S);
    finalR = nrR(end);
    t=t+1;
  end
end
%% PLOT 11.1
h=figure;
set(h,'Color','w','Units','Pixels');
a1=axes('Units','Pixels');
box on;
hold on;
xlabel('$x$','FontSize',20,'Interpreter','Latex');
ylabel('$y$','FontSize',20,'Interpreter','Latex');
plot(x(I),y(I),'r.','MarkerSize',7);
plot(x(R),y(R),'g.','MarkerSize',7);
plot(x(S),y(S),'b.','MarkerSize',7);
title(['t= ' num2str(t)]);
xlim([-1 n]);
ylim([-1 n]);

h1=figure; set(h,'Color','w','Units','Pixels')
```

```
set(h1,'Color','w','Units','Pixels');
a2=axes('Units','Pixels');
box on;
hold on;
xlabel('Time Steps','FontSize',18,'Interpreter','Latex');
ylabel('Number of agents','FontSize',18,'Interpreter','Latex');
title(['\bf{$d=$' num2str(d) ', $\beta=$' num2str(B) ', $\gamma=$' num2str(g) '}'],'FontSize',12,'Interpreter','Latex')
plot(nrS,'b','LineWidth',2);
plot(nrI,'r','LineWidth',2);
plot(nrR,'g','LineWidth',2);
y1 = linspace(0,1000,6);
ylim([0 1000]);
legend('susceptible', 'infected','recovered');


% Homework 3: Disease Spreading, Simulation of Complex Systems FFR120
% Nicole Adamah 2022
% 11.2
clear all;
close all;
clc;
%% Parameters:
N=1000;
n=100;
infect=10;
d=0.8;
b_list=linspace(0.05,1,12);
g_list=[0.01,0.02];
trials = 4;
data1 = zeros(trials,length(b_list));
data2 = zeros(trials,length(b_list));

for m = 1:trials
disp(m);
a = 1;
for k =1:length(g_list)
    g = g_list(1,k);
for j = 1:length(b_list)
    B = b_list(1,j);
    t = 0;
    x=randi(n,1,N)-1;                     % Random Location along x
    y=randi(n,1,N)-1;                     % Random Location along y
    [~,I]=sort((x-n/2).^2+(y-n/2).^2);      % Find closest ones to the center
    preI=zeros(1,N);
    preI(I(1:infect))=1;
    I=logical(preI);                      % Infection status array
    R=false(1,N);                         % Recovered status array
    S=logical(1-I);                       % Susceptible status array
    for h = 1:1000
%% SIMULATION
      dx=2*(round(rand(1,N))-0.5).*(rand(1,N)<d);     % Random Walks along x
      dy=2*(round(rand(1,N))-0.5).*(rand(1,N)<d);     % Random Walks along x
      x=mod(x+dx,n);
      y=mod(y+dy,n);                  % Performing walks, Periodic Boundary Conditions, Alternative -solid walls- would be x(x>n)=n;
      for i=1:N
        if (I(i)==true)&&(rand<B)       % Only infected agents can infect others, and we also roll the dice for infection
          infection=(x==x(i))&(y==y(i));  % Determine the indices for those who sit at the site of infection
          S(infection)=false;            % There are no longer any susceptibles at infection area
          I(infection)=not(R(infection)); % All non-recovered agents will turn infected at infection site
        end
      end
      recovery=(rand(1,N)<g);        % Recovery array
      R = R | (I&recovery);          % Recovery operation
      I = I & not(recovery);         % The ones recovered are no longer infected
      nrI(t+1)=sum(I);
      nrR(t+1)=sum(R);
      nrS(t+1)=sum(S);
      finalR = nrR(end);
      t=t+1;
    end
```

```
    if k == 1
        data1(a,j) = data1(a,j) +  finalR;
    else
        data2(a,j) = data2(a,j) +  finalR;
    end
end
end
if (m == 1)
    avgData1 = data1;
    avgData2 = data2;
else
    avgData1 = data1/trials;
    avgData2 = data2/trials;
end
end
%% PLOT 11.2 a & b
h1=figure; set(h1,'Color','w','Units','Pixels')
set(h1,'Color','w','Units','Pixels');
a2=axes('Units','Pixels');
box on;
hold on;
scatter(b_list, avgData1(1,:), 'b')
scatter(b_list, avgData2(1,:),'g')
xlabel('Beta','FontSize',18,'Interpreter','Latex');
ylabel('Rinf','FontSize',18,'Interpreter','Latex');
legend('g = 0.01', 'g=0.02');



%% PLOT 11.2 c
```