India

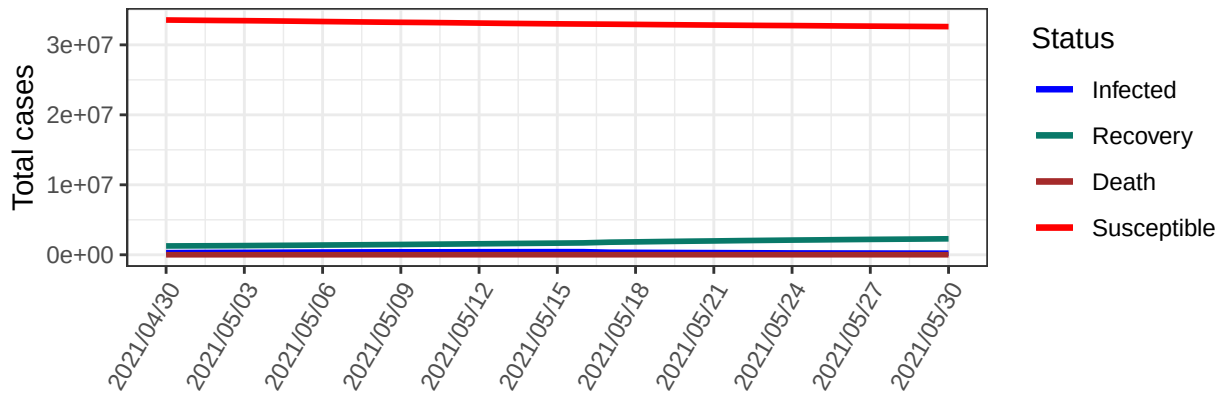
```
library(readr)
library(ggplot2)
library(dplyr)
library(deSolve)
library(tidyr)
```

```
# population 2020
n1 <- 35122966
# population 2021
n2 <- 35336581
```

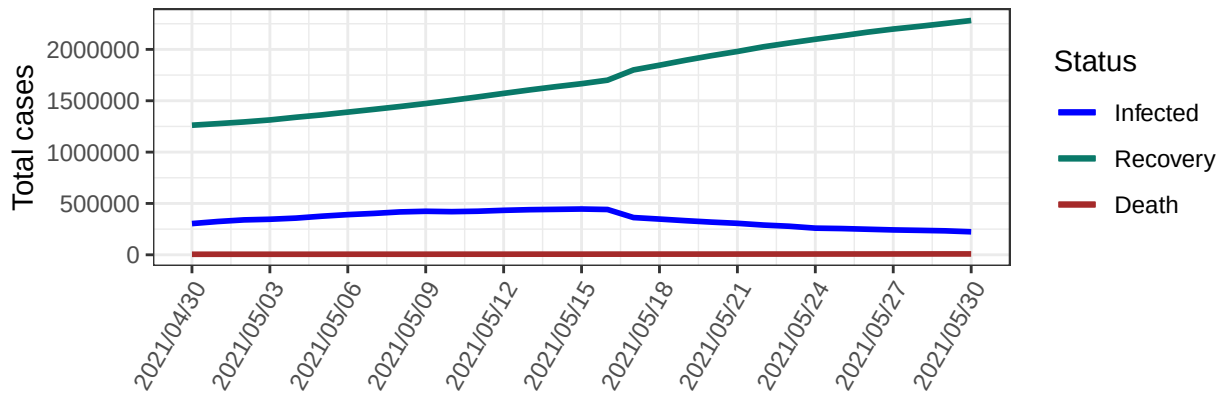
```
Kerala_daily <- read.csv("covid_data_kerala.csv")
Kerala_daily$Date <- as.Date(Kerala_daily$Date, format= "%Y-%m-%d")
Kerala_daily <- Kerala_daily %>% mutate(Confirmed = replace_na(Confirmed, 0),
                        Recovered = replace_na(Recovered, 0),
                        Deceased = replace_na(Deceased, 0))
Kerala_daily <- Kerala_daily %>% mutate(Icum = cumsum(Confirmed),
                         Rcum = cumsum(Recovered),
                         Dcum = cumsum(Deceased),
                         Iactive = Icum -Rcum - Dcum)
Kerala_daily$Susceptible <- n1 - Kerala_daily$Iactive - Kerala_daily$Dcum - Kerala_daily$Rcum
Kerala_daily <- Kerala_daily[,-c(2, 3, 4, 5)]
colnames(Kerala_daily) <- c("Date", "Recovery", "Death", "Infected", "Susceptible")
# write.csv(Kerala_daily, "Kerala_daily.csv", row.names=FALSE)
```

```
K2021 <- Kerala_daily %>% filter(Date >= as.Date('2021-04-30') &
                                   Date <= as.Date('2021-05-30'))
```

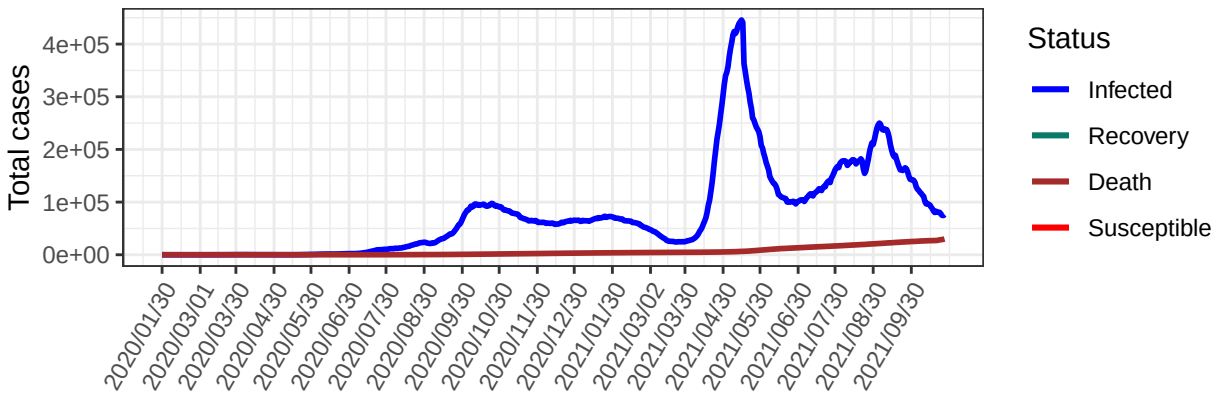
```
breaks_qtr <- seq(from = min(K2021$Date),
                          to = max(K2021$Date), by = "3 days")
labels_year <- format(seq(from = min(K2021$Date),
                          to = max(K2021$Date), by = "3 days"), "%Y/%m/%d")

p <- ggplot(K2021, aes(x=Date, y=Infected)) +
  geom_line(aes(color="Infected"), lwd = 1) +
  xlab("")  + ylab("Total cases") +
    scale_x_date(labels = labels_year, breaks = breaks_qtr) +
  theme_bw() + theme(aspect.ratio = 0.3) +
  theme(axis.text.x=element_text(angle=60, hjust=1))
p <- p + geom_line(aes(y=Recovery, color = "Recovery"), lwd = 1)
p <- p + geom_line(aes(y=Death, color = "Death"), lwd = 1)
p <- p + geom_line(aes(y=Susceptible, color = "Susceptible"), lwd = 1)
p <- p + scale_color_manual(name = "Status", values=c("Infected"="blue",
                                                      "Recovery"="#097969",
                              "Death"="brown","Susceptible"="red"))
p
```




```
p <- ggplot(K2021, aes(x=Date, y=Infected)) +
  geom_line(aes(color="Infected"), lwd = 1) +
  xlab("")  + ylab("Total cases") +
    scale_x_date(labels = labels_year, breaks = breaks_qtr) +
  theme_bw() + theme(aspect.ratio = 0.3) +
  theme(axis.text.x=element_text(angle=60, hjust=1))
p <- p + geom_line(aes(y=Recovery, color = "Recovery"), lwd = 1)
p <- p + geom_line(aes(y=Death, color = "Death"), lwd = 1)
p <- p + scale_color_manual(name = "Status", values=c("Infected"="blue",
                                                      "Recovery"="#097969",
                                "Death"="brown"))
p
```




```
breaks_qtr <- seq(from = min(Kerala_daily$Date),
                          to = max(Kerala_daily$Date), by = "1 month")
labels_year <- format(seq(from = min(Kerala_daily$Date),
                          to = max(Kerala_daily$Date), by = "1 month"), "%Y/%m/%d")

p <- ggplot(Kerala_daily, aes(x=Date, y=Infected)) +
  geom_line(aes(color="Infected"), lwd = 1) +
  xlab("")  + ylab("Total cases") +
    scale_x_date(labels = labels_year, breaks = breaks_qtr) +
  theme_bw() + theme(aspect.ratio = 0.3) +
  theme(axis.text.x=element_text(angle=60, hjust=1))
# p <- p + geom_line(aes(y=Recovery, color = "Recovery"), lwd = 1)
p <- p + geom_line(aes(y=Death, color = "Death"), lwd = 1)
p <- p + scale_color_manual(name = "Status", values=c("Infected"="blue",
                                                      "Recovery"="#097969",
                              "Death"="brown","Susceptible"="red"))
p
```




```
Kerala_daily$Date[which.max(Kerala_daily$Infected)]
```

```
## [1] "2021-05-15"
```

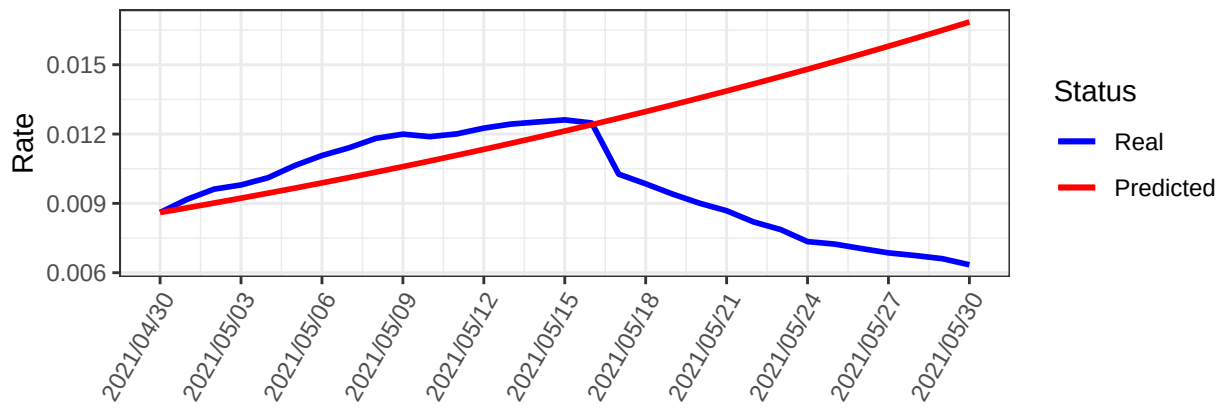
```
K2021_R <- K2021
K2021_R$Recovery <- K2021$Recovery / n2
K2021_R$Death <- K2021_R$Death / n2
K2021_R$Infected <- K2021_R$Infected / n2
K2021_R$Susceptible <- K2021_R$Susceptible / n2
```

```
## Load deSolve package
library(deSolve)

## Create an SIR function
sird <- function(time, state, parameters) {

  with(as.list(c(state, parameters)), {

    dS <- -beta * S * I
    dI <-  beta * S * I - gamma * I - mu * I
    dR <-                 gamma * I
    dD <-                             mu * I

    return(list(c(dS, dI, dR, dD)))
  })
}
```

```r
### Set parameters
## Proportion in each compartment: Susceptible 0.999999, Infected 0.000001, Recovered 0
init       <- c(S = 0.9494915, I = 0.008605190, R = 0.03570793, D = 0.0001502126)
## beta: infection parameter; gamma: recovery parameter mu:deceased parameter
parameters <- c(beta = 0.075663, gamma = 1/22, mu = 0.0031)
## Time frame
times      <- seq(0, 30, by = 1)

## Solve using ode (General Solver for Ordinary Differential Equations)
out <- ode(y = init, times = times, func = sird, parms = parameters)
## change to data frame
out <- as.data.frame(out)
## Delete time variable
out$time <- NULL
## Show data
head(out, 10)
```

```
##            S           I          R            D
## 1  0.9494915 0.008605190 0.03570793 0.0001502126
## 2  0.9488662 0.008807727 0.03610368 0.0001772026
## 3  0.9482267 0.009014601 0.03650873 0.0002048272
## 4  0.9475726 0.009225881 0.03692329 0.0002331000
## 5  0.9469036 0.009441631 0.03734752 0.0002620329
## 6  0.9462196 0.009661936 0.03778168 0.0002916422
## 7  0.9455201 0.009886863 0.03822595 0.0003219417
## 8  0.9448048 0.010116485 0.03868056 0.0003529457
## 9  0.9440736 0.010350874 0.03914570 0.0003846688
## 10 0.9433260 0.010590101 0.03962162 0.0004171261
```

```r
breaks_qtr <- seq(from = min(K2021$Date),
                          to = max(K2021$Date), by = "3 days")
labels_year <- format(seq(from = min(K2021$Date),
                          to = max(K2021$Date), by = "3 days"), "%Y/%m/%d")
p <- ggplot(K2021_R, aes(x=Date, y=Infected)) +
  geom_line(aes(color="Real"), lwd = 1) +
  xlab("")  + ylab("Rate") +
    scale_x_date(labels = labels_year, breaks = breaks_qtr) +
  theme_bw() + theme(aspect.ratio = 0.3) +
  theme(axis.text.x=element_text(angle=60, hjust=1))

p <- p + geom_line(aes(y=out$I, color = "Predicted"), lwd = 1)
p <- p + scale_color_manual(name = "Status", values=c("Real"="blue",
                                "Predicted"="red"))
p
```

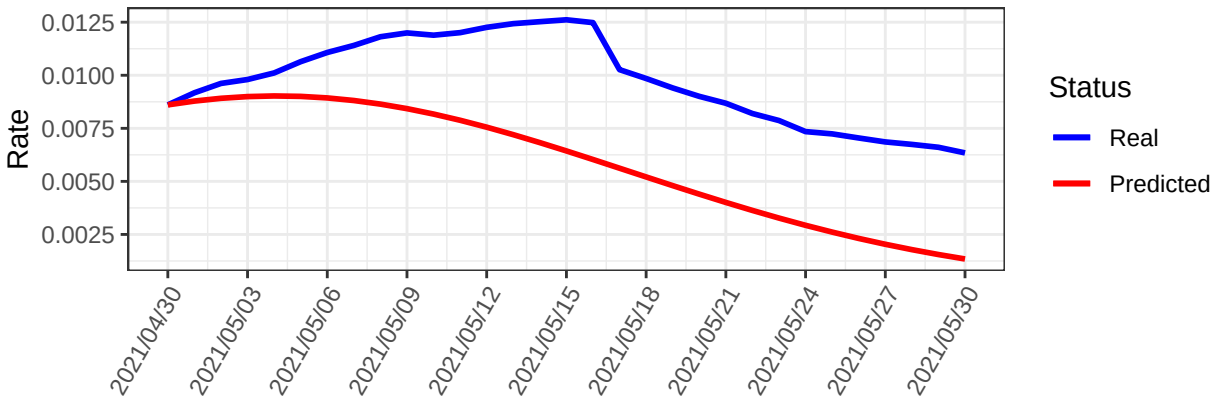



```
## Create an SIR function
sirdv <- function(time, state, parameters) {

  with(as.list(c(state, parameters)), {

    dS <- -beta * S * I                                                - alpha
    dI <-  beta * S * I + beta * (1 - eta) * V * I - gamma * I - mu * I
    dR <                                             gamma * I
    dD <                                                      mu * I
    dV <-               - beta * (1 - eta) * V * I                     + alpha

    return(list(c(dS, dI, dR, dD, dV)))
  })
}

### Set parameters
## Proportion in each compartment: Susceptible 0.999999, Infected 0.000001, Recovered 0
init       <- c(S = 0.9494915, I = 0.008605190, R = 0.03570793, D = 0.0001502126, V = 143293/n2)
## beta: infection parameter; gamma: recovery parameter mu:deceased parameter
## eta: vaccine effectiveness alpha: vaccination rate
parameters <- c(beta = 0.075663, gamma = 1/22, mu = 0.0031, eta = 0.75, alpha = 0.1)
## Time frame
times      <- seq(0, 30, by = 1)

## Solve using ode (General Solver for Ordinary Differential Equations)
out2 <- ode(y = init, times = times, func = sirdv, parms = parameters)
```

```r
## change to data frame
out2 <- as.data.frame(out2)
## Delete time variable
out2$time <- NULL
## Show data
head(out2, 10)
```

```
##            S           I          R            D          V
## 1  0.9494915 0.008605190 0.03570793 0.0001502126 0.00405509
## 2  0.8489003 0.008783199 0.03610312 0.0001771646 0.10404612
## 3  0.7483659 0.008913847 0.03650533 0.0002045951 0.20402027
## 4  0.6478930 0.008994972 0.03691235 0.0002323537 0.30397721
## 5  0.5474852 0.009025384 0.03732218 0.0002603048 0.40391688
## 6  0.4471457 0.009004316 0.03773215 0.0002882641 0.50383946
## 7  0.3468761 0.008932242 0.03813999 0.0003160790 0.60374549
## 8  0.2466767 0.008810431 0.03854342 0.0003435930 0.70363577
## 9  0.1465468 0.008640927 0.03894022 0.0003706546 0.80351136
## 10 0.0464843 0.008426657 0.03932828 0.0003971205 0.90337357
```

```r
p <- ggplot(K2021_R, aes(x=Date, y=Infected)) +
  geom_line(aes(color="Real"), lwd = 1) +
  xlab("")  + ylab("Rate") +
    scale_x_date(labels = labels_year, breaks = breaks_qtr) +
  theme_bw() + theme(aspect.ratio = 0.3) +
  theme(axis.text.x=element_text(angle=60, hjust=1))

p <- p + geom_line(aes(y=out2$I, color = "Predicted"), lwd = 1)
p <- p + scale_color_manual(name = "Status", values=c("Real"="blue",
                                "Predicted"="red"))
p
```


Rate
0.0125
0.0100
0.0075
0.0050
0.0025
2021/04/30
2021/05/03
2021/05/06
2021/05/09
2021/05/12
2021/05/15
2021/05/18
2021/05/21
2021/05/24
2021/05/27
2021/05/30
Status
Real
Predicted