# covid_tbl.final.R

mac

2023-06-02

```r
#Shital Bhandary
#2 June 2023
#Based on 21st Lecture of Statistical Computing with R course
#Masters in Data Science program, School of Mathematical Sciences
#Tribhuvan University, Kirtipur, Nepal

covid_tbl_final <- read.csv("~/Documents/covid19_nepal/data/covid_tbl_final.csv")
str(covid_tbl_final)
```

```
## 'data.frame':    495 obs. of  14 variables:
##  $ SN                   : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ Date                 : chr  "23-Jan" "24-Jan" "25-Jan" "26-Jan" ...
##  $ Confirmed_cases_total : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ Confirmed_cases_new   : int  1 0 0 0 0 0 0 0 0 0 ...
##  $ Confirmed._cases_active: int  1 1 1 1 1 1 0 0 0 0 ...
##  $ Recoveries_total      : int  0 0 0 0 0 0 1 1 1 1 ...
##  $ Recoveries_daily      : int  0 0 0 0 0 0 1 0 0 0 ...
##  $ Deaths_total          : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ Deaths_daily          : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ RT.PCR_tests_total    : int  NA NA NA NA NA 3 4 5 5 NA ...
##  $ RT.PCR_tests_daily    : int  NA NA NA NA NA NA 1 1 0 NA ...
##  $ Test_positivity_rate  : num  NA NA NA NA NA ...
##  $ Recovery_rate         : num  0 0 0 0 0 0 100 100 100 100 ...
##  $ Case_fatality_rate    : num  0 0 0 0 0 0 0 0 0 0 ...
```

```r
mean(covid_tbl_final$Confirmed_cases_total)
```

```
## [1] 138125.2
```

```r
mean(covid_tbl_final$Confirmed_cases_new)
```

```
## [1] 1133.943
```

```r
mean(covid_tbl_final$Confirmed._cases_active)
```

```
## [1] 14243.52
```

```r
mean(covid_tbl_final$Recoveries_total)
```

```
## [1] 122680.1
```

```r
mean(covid_tbl_final$Recoveries_daily)
```

```
## [1] 903.9313
```

```r
mean(covid_tbl_final$Deaths_total)
```

```
## [1] 1201.515
```

```r
mean(covid_tbl_final$Deaths_daily)
```

```
## [1] 14.92121
```

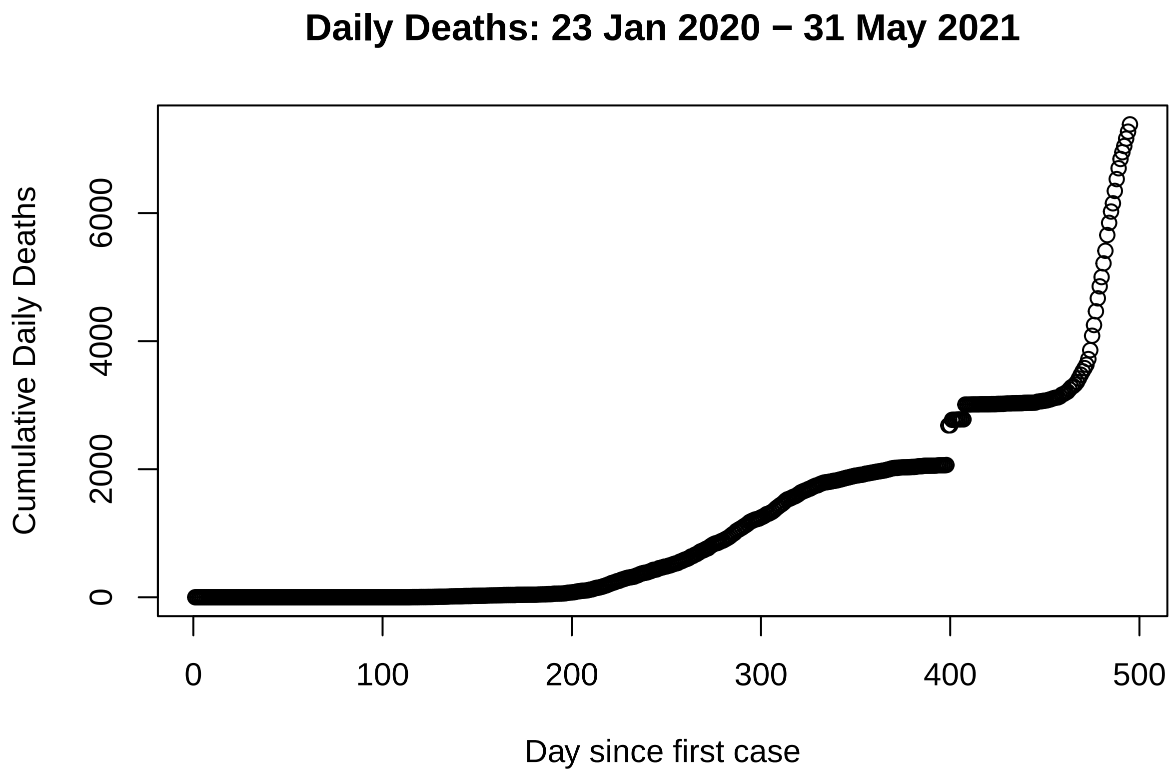
```r
mean(covid_tbl_final$RT.PCR_tests_total)
```

```
## [1] NA
```

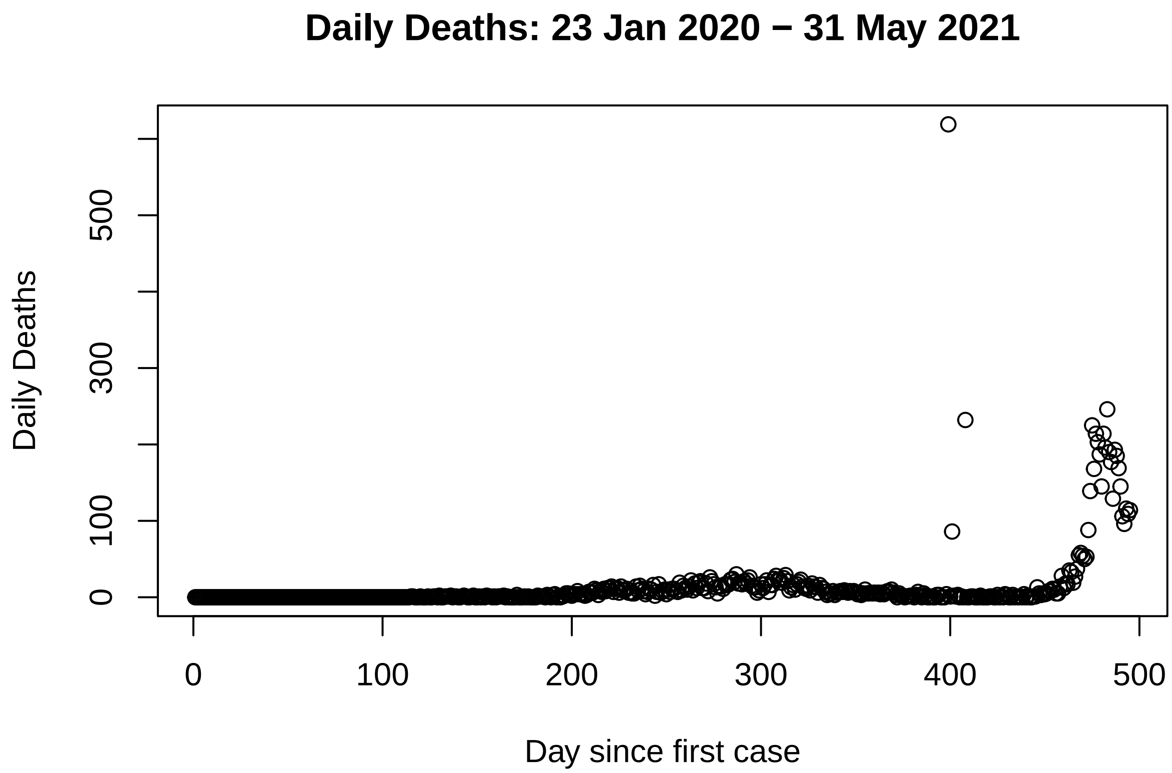
```r
mean(covid_tbl_final$RT.PCR_tests_daily)
```

```
## [1] NA
```

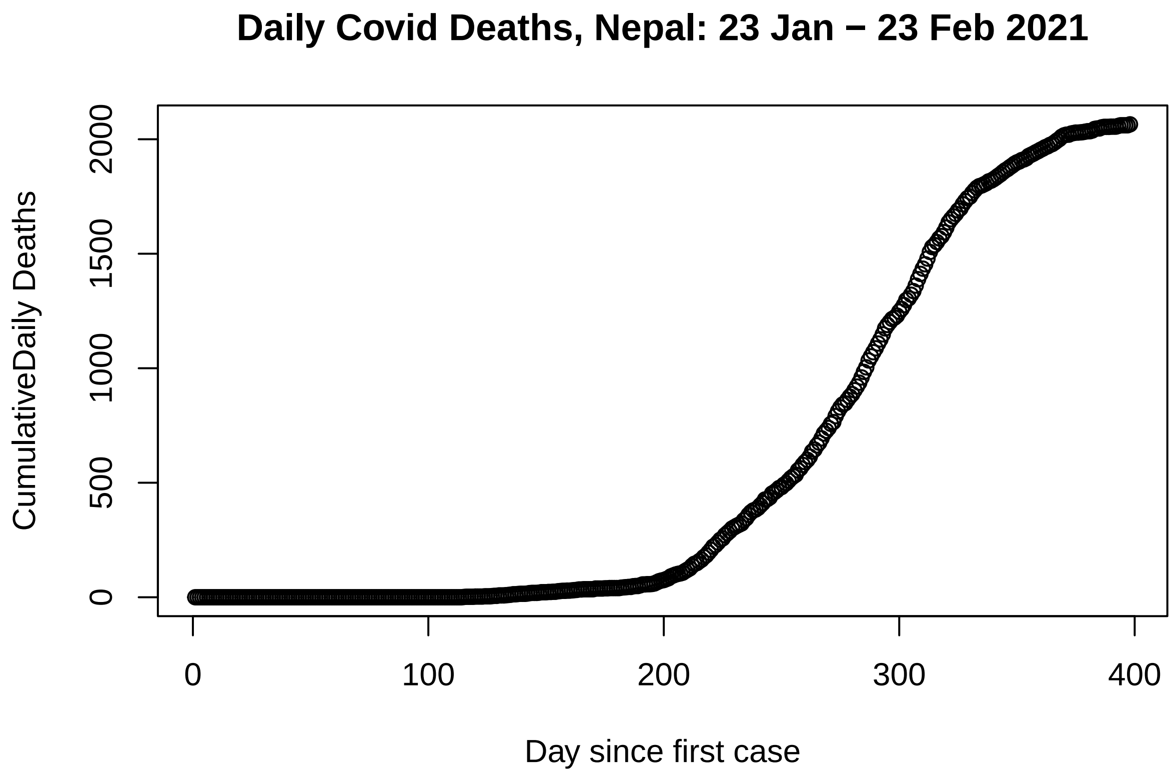
```r
#Cumulative Daily deaths
#There is a gap and we need to find why
plot(covid_tbl_final$SN, covid_tbl_final$Deaths_total,
     main = "Daily Deaths: 23 Jan 2020 - 31 May 2021",
     xlab = "Day since first case",
     ylab = "Cumulative Daily Deaths")
```




```
#Daily deaths
#There are problems as we can see three daily death values that are way more thann usual
#This happened as the death tally from MoHP and Nepali Army did not match
plot(covid_tbl_final$SN, covid_tbl_final$Deaths_daily,
     main = "Daily Deaths: 23 Jan 2020 - 31 May 2021",
     xlab = "Day since first case",
     ylab = "Daily Deaths")
```




```
#Cumulative deaths upto 398 cases i.e. 23 Feb 2021
#There are the cumulative daily deaths without adding the deaths reported by Army
plot.data <- covid_tbl_final[covid_tbl_final$SN <=398,-15]
plot(plot.data$SN, plot.data$Deaths_total,
     main = "Daily Covid Deaths, Nepal: 23 Jan - 23 Feb 2021",
     xlab = "Day since first case",
     ylab = "CumulativeDaily Deaths")
```



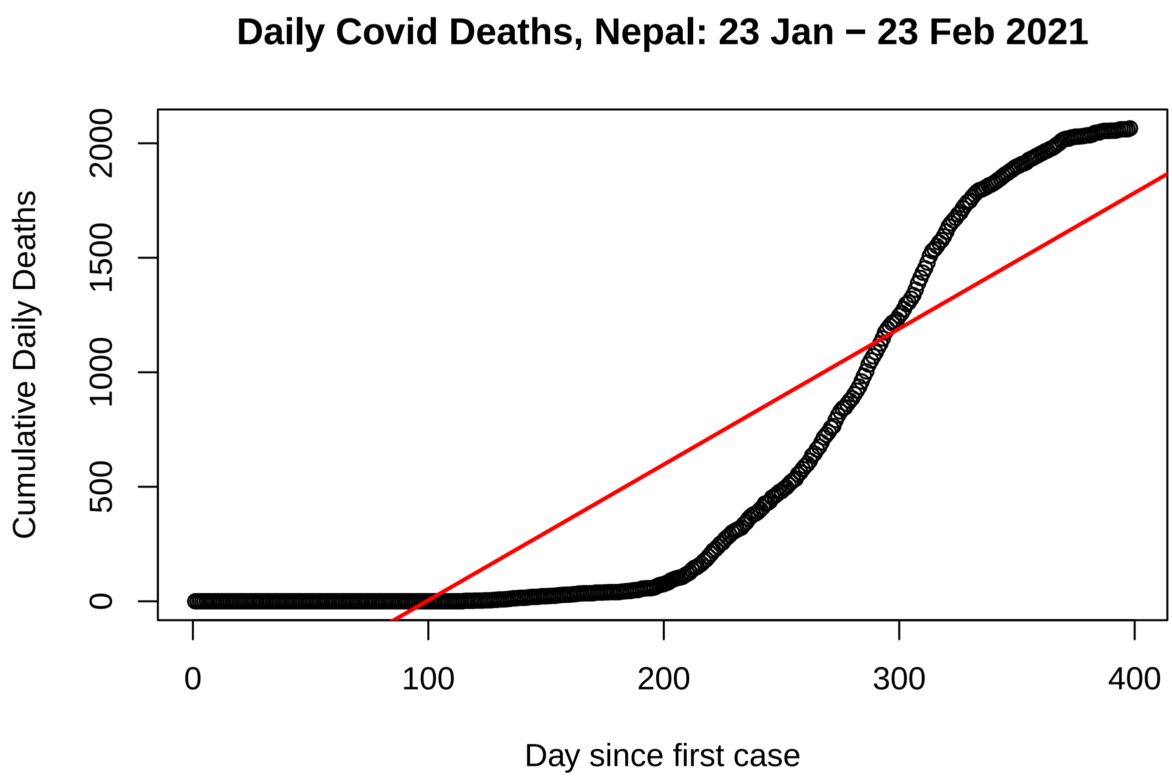

```r
#We will fit polynomial models on this data now
#Linear model

#Linear model:
#R-square = 0.7921, F-test is statistically significant
#Coefficient is also statistically significant
lm <- lm(Deaths_total ~ SN, data = plot.data)
summary(lm)
```

```
##
## Call:
## lm(formula = Deaths_total ~ SN, data = plot.data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -537.91 -344.76   22.38  351.50  582.90
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -588.8326    35.1575  -16.75   <2e-16 ***
## SN             5.9315     0.1527   38.84   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 350 on 396 degrees of freedom
## Multiple R-squared:  0.7921, Adjusted R-squared:  0.7916
```

```
## F-statistic:  1509 on 1 and 396 DF,  p-value: < 2.2e-16
```

```
#Plot with linear model
#Clearly shows the underfitting
plot(plot.data$SN, plot.data$Deaths_total,
     main = "Daily Covid Deaths, Nepal: 23 Jan - 23 Feb 2021",
     xlab = "Day since first case",
     ylab = "Cumulative Daily Deaths")
abline(lm(Deaths_total ~ SN, data = plot.data), col = "red", lwd=2)
```

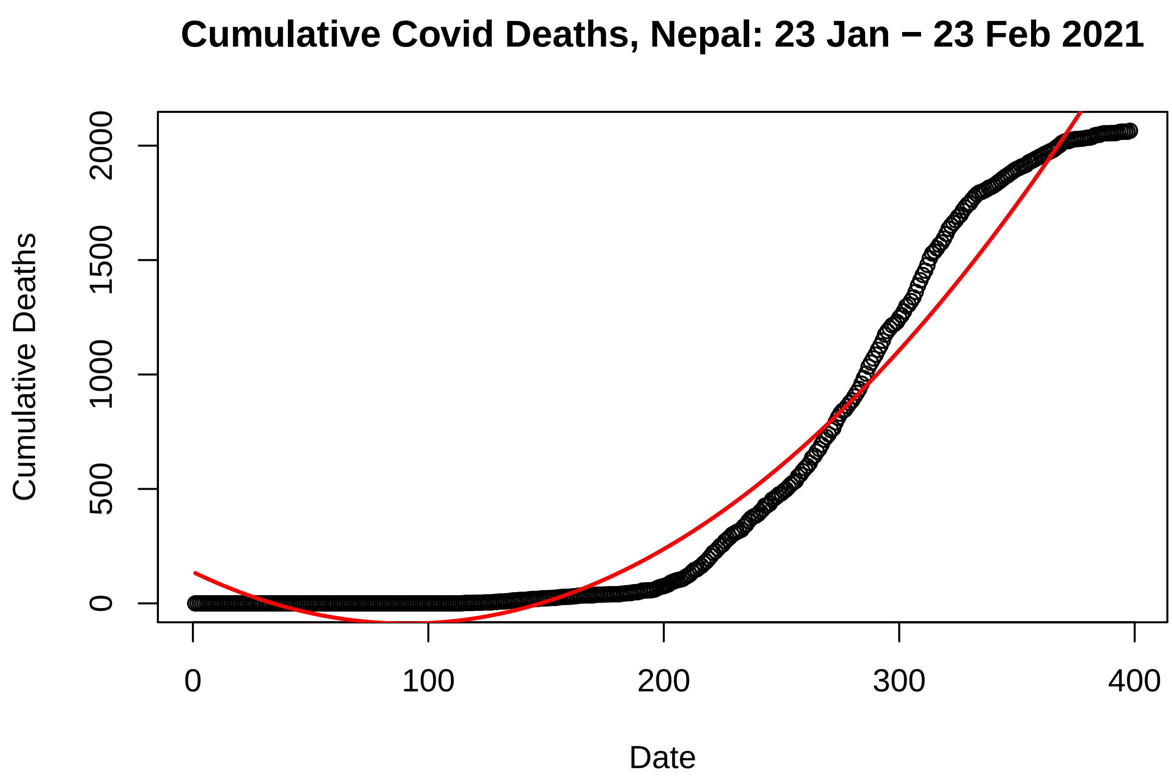



```
#Quadratic Linear model
#R-squared = 0.9692, F-test is statistically significant
#Coefficients are also statistically significant
qlm <- lm(Deaths_total ~ poly(SN, 2, raw=T), data = plot.data)
summary(qlm)
```

```
##
## Call:
## lm(formula = Deaths_total ~ poly(SN, 2, raw = T), data = plot.data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -422.04 -110.87    8.94   81.97  282.94
##
## Coefficients:
```

```
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)             1.372e+02  2.039e+01   6.727 6.11e-11 ***
## poly(SN, 2, raw = T)1 -4.959e+00  2.360e-01 -21.009  < 2e-16 ***
## poly(SN, 2, raw = T)2  2.729e-02  5.728e-04  47.646  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 134.9 on 395 degrees of freedom
## Multiple R-squared:  0.9692, Adjusted R-squared:  0.969
## F-statistic:  6211 on 2 and 395 DF,  p-value: < 2.2e-16
```

```
#Plot with quadratic linear model
#Clearly shows the good fit but can we do it better
plot(Deaths_total ~ SN, data=plot.data,
     main = "Cumulative Covid Deaths, Nepal: 23 Jan - 23 Feb 2021",
     xlab = "Date",
     ylab = "Cumulative Deaths")
lines(fitted(qlm) ~ SN, data=plot.data, col="red", lwd=2)
```

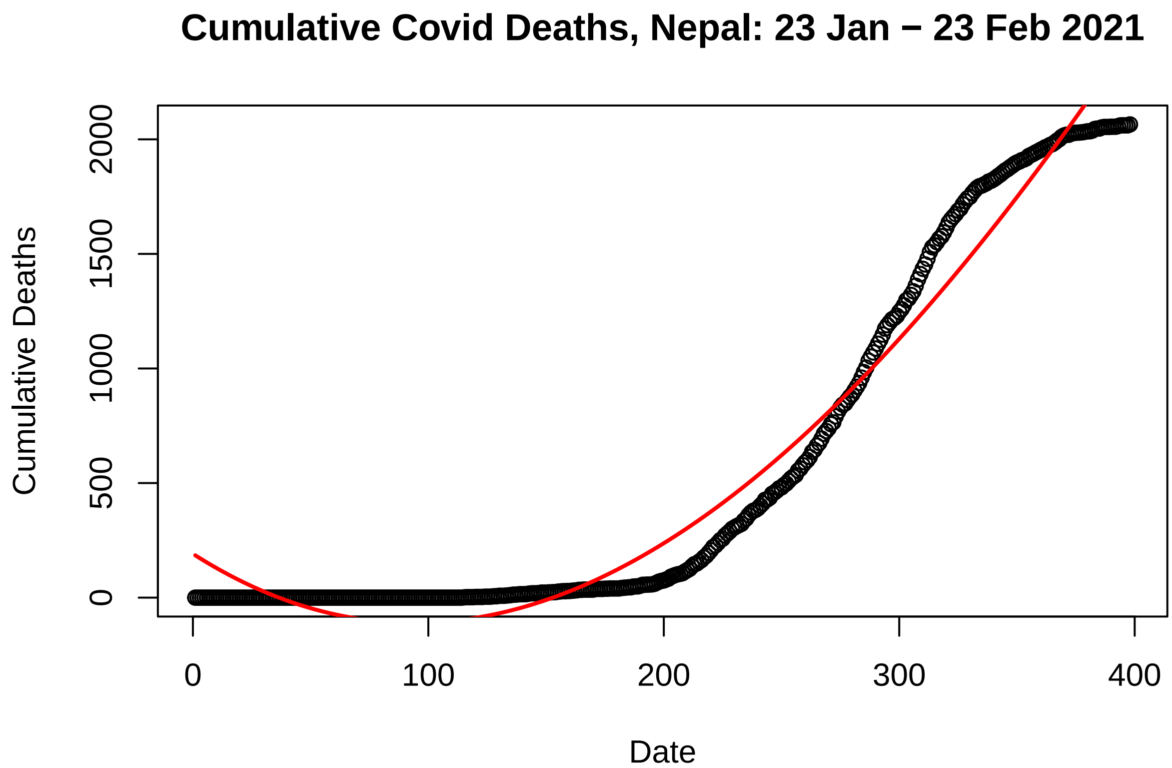



```
#Cubic Linear model
#R-squared = 0.9699, F-test is statistically significant
#Coefficients are also statistically signfincat
clm <- lm(Deaths_total ~ poly(SN, 3, raw=T), data = plot.data)
summary(clm)
```

```
##
```

```
## Call:
## lm(formula = Deaths_total ~ poly(SN, 3, raw = T), data = plot.data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -369.58 -123.49   12.82   99.36  267.65
##
## Coefficients:
##                         Estimate Std. Error t value Pr(>|t|)
## (Intercept)            1.912e+02  2.704e+01   7.073 6.95e-12 ***
## poly(SN, 3, raw = T)1 -6.574e+00  5.861e-01 -11.217  < 2e-16 ***
## poly(SN, 3, raw = T)2  3.740e-02  3.411e-03  10.966  < 2e-16 ***
## poly(SN, 3, raw = T)3 -1.689e-05  5.620e-06  -3.006  0.00282 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 133.6 on 394 degrees of freedom
## Multiple R-squared:  0.9699, Adjusted R-squared:  0.9696
## F-statistic:  4228 on 3 and 394 DF,  p-value: < 2.2e-16
```

```
#Plot with cubic linear model
#Clearly shows the good fit but can we do it better?
plot(Deaths_total ~ SN, data=plot.data,
     main = "Cumulative Covid Deaths, Nepal: 23 Jan - 23 Feb 2021",
     xlab = "Date",
     ylab = "Cumulative Deaths")
lines(fitted(clm) ~ SN, data=plot.data, col="red", lwd=2)
```

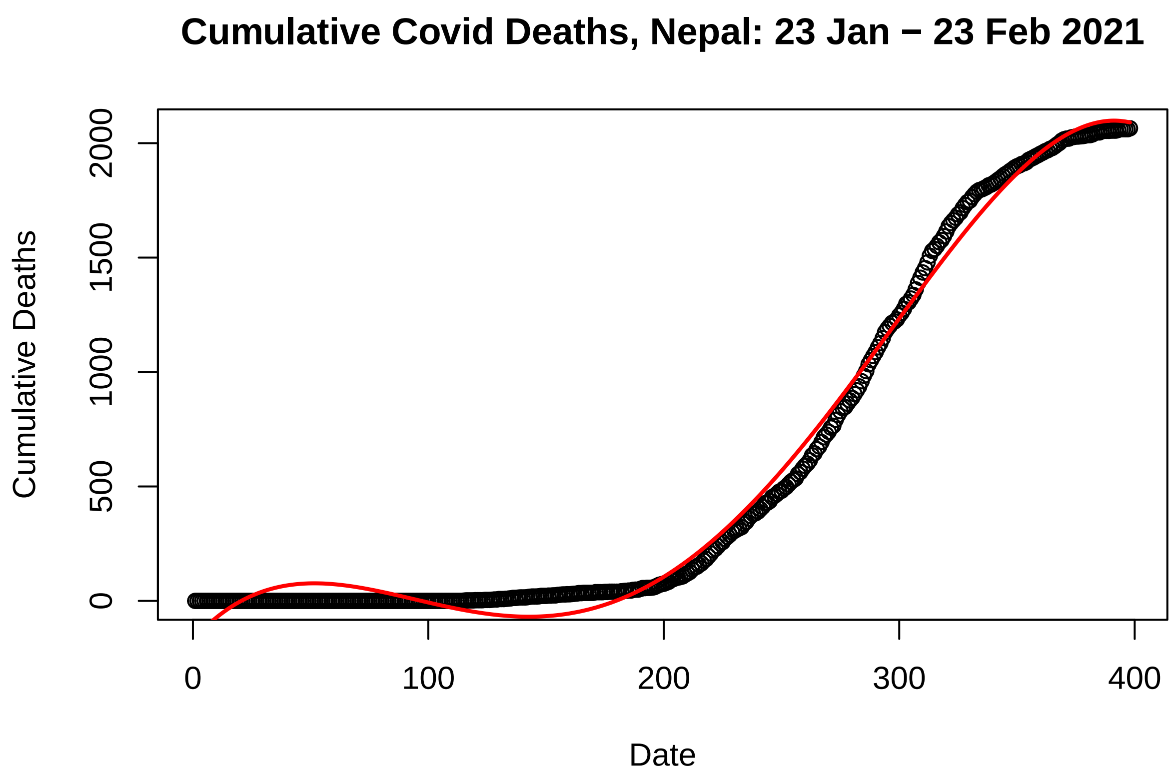



```r
#Double quadratic or 4th order linear model
#R-squared = 0.9934, F-test is statistically significant
#All the coefficients are also significant
dqlm <- lm(Deaths_total ~ poly(SN, 4, raw=T), data = plot.data)
summary(dqlm)
```

```
##
## Call:
## lm(formula = Deaths_total ~ poly(SN, 4, raw = T), data = plot.data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -105.44  -53.22  -12.50   53.61  159.13
##
## Coefficients:
##                         Estimate Std. Error t value Pr(>|t|)
## (Intercept)           -1.703e+02  1.589e+01  -10.72   <2e-16 ***
## poly(SN, 4, raw = T)1  1.135e+01  5.504e-01   20.61   <2e-16 ***
## poly(SN, 4, raw = T)2 -1.641e-01  5.599e-03  -29.31   <2e-16 ***
## poly(SN, 4, raw = T)3  7.681e-04  2.107e-05   36.45   <2e-16 ***
## poly(SN, 4, raw = T)4 -9.837e-07  2.620e-08  -37.55   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 62.45 on 393 degrees of freedom
## Multiple R-squared:  0.9934, Adjusted R-squared:  0.9934
```

```
## F-statistic: 1.486e+04 on 4 and 393 DF,  p-value: < 2.2e-16
```

```
#Plot with fourth order polynomial model
#Clearly shows the good fit but can we do it better?
plot(Deaths_total ~ SN, data=plot.data,
     main = "Cumulative Covid Deaths, Nepal: 23 Jan - 23 Feb 2021",
     xlab = "Date",
     ylab = "Cumulative Deaths")
lines(fitted(dqlm) ~ SN, data=plot.data, col="red", lwd=2)
```

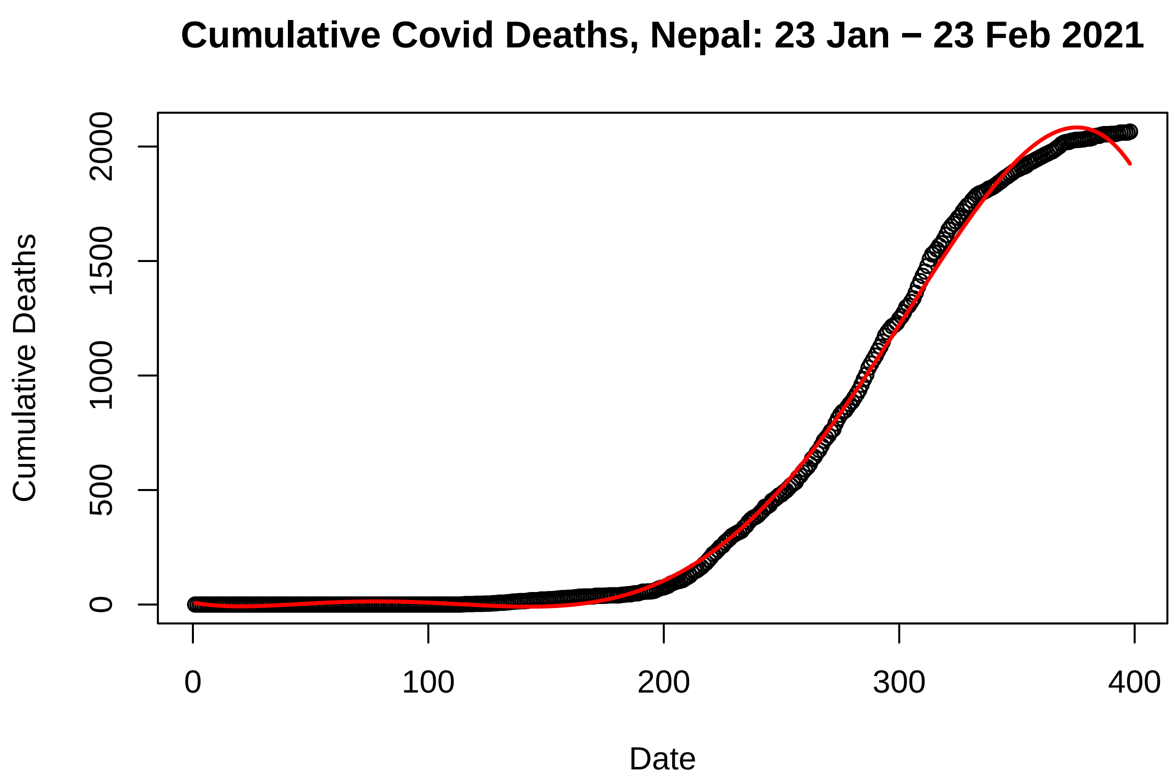



```
#Fifth order polynomial fit
#R-squared = 0.998, F-test is statistically significant
#All the coefficients are also statistically significant
folm <- lm(Deaths_total ~ poly(SN, 5, raw=T), data = plot.data)
summary(folm)
```

```
##
## Call:
## lm(formula = Deaths_total ~ poly(SN, 5, raw = T), data = plot.data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -77.300 -16.980  -3.571  19.199 140.089
##
## Coefficients:
```

```
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)            8.510e+00  1.053e+01   0.808 0.419427
## poly(SN, 5, raw = T)1 -1.867e+00  5.309e-01  -3.517 0.000488 ***
## poly(SN, 5, raw = T)2  6.653e-02  8.219e-03   8.095 7.31e-15 ***
## poly(SN, 5, raw = T)3 -7.705e-04  5.216e-05 -14.773  < 2e-16 ***
## poly(SN, 5, raw = T)4  3.352e-06  1.440e-07  23.270  < 2e-16 ***
## poly(SN, 5, raw = T)5 -4.346e-09  1.437e-10 -30.251  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 34.24 on 392 degrees of freedom
## Multiple R-squared:  0.998,  Adjusted R-squared:  0.998
## F-statistic: 3.973e+04 on 5 and 392 DF,  p-value: < 2.2e-16
```

```r
#Plot with fourth order polynomial model
#Clearly shows the good fit but can we do it better?
#Is this a overfitting?
#Does the cumulative death declined? NO!
plot(Deaths_total ~ SN, data=plot.data,
     main = "Cumulative Covid Deaths, Nepal: 23 Jan - 23 Feb 2021",
     xlab = "Date",
     ylab = "Cumulative Deaths")
lines(fitted(folm) ~ SN, data=plot.data, col="red", lwd=2)
```



```r
#Based on the results obtained above the most likely/plausible model is the 4th order polynomial model

#Let us use the validation set approach in this model
#Creating partition variable ind with 70% and 30% probabilities
ind <- sample(2, nrow(plot.data), replace=T, prob=c(0.7,0.3))
#Creating training data with 70% cases
train.pd <- plot.data[ind==1,]
trest.pd <- plot.data[ind==2,]


#Fifth order polynomial fit on train data
#R-squared = 0.9931, F-test is statistically significant
#All the coefficients are also statistically significant
dqlm.train <- lm(Deaths_total ~ poly(SN, 4, raw=T), data = train.pd)
(dqlm.train.summary <- summary(dqlm.train))
```

```
##
## Call:
## lm(formula = Deaths_total ~ poly(SN, 4, raw = T), data = train.pd)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -99.05 -52.31 -12.98  54.50 171.16
##
## Coefficients:
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)           -1.828e+02  1.956e+01  -9.348   <2e-16 ***
## poly(SN, 4, raw = T)1  1.182e+01  6.911e-01  17.099   <2e-16 ***
## poly(SN, 4, raw = T)2 -1.684e-01  7.041e-03 -23.913   <2e-16 ***
## poly(SN, 4, raw = T)3  7.811e-04  2.648e-05  29.503   <2e-16 ***
## poly(SN, 4, raw = T)4 -9.964e-07  3.289e-08 -30.299   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 63.54 on 273 degrees of freedom
## Multiple R-squared:  0.9928, Adjusted R-squared:  0.9927
## F-statistic:  9431 on 4 and 273 DF,  p-value: < 2.2e-16
```

```r
#Plot with fourth order polynomial model of train data
plot(train.pd$Deaths_total ~ train.pd$SN,
     main = "Cumulative Covid Deaths, Nepal",
     xlab = "Date",
     ylab = "Cumulative Deaths")
lines(fitted(dqlm.train) ~ SN, data=train.pd, col="red", lwd=2)

#MSE and RMSE
(MSE.dqlm.train <- mean(dqlm.train$residuals^2))
```

```
## [1] 3964.652
```

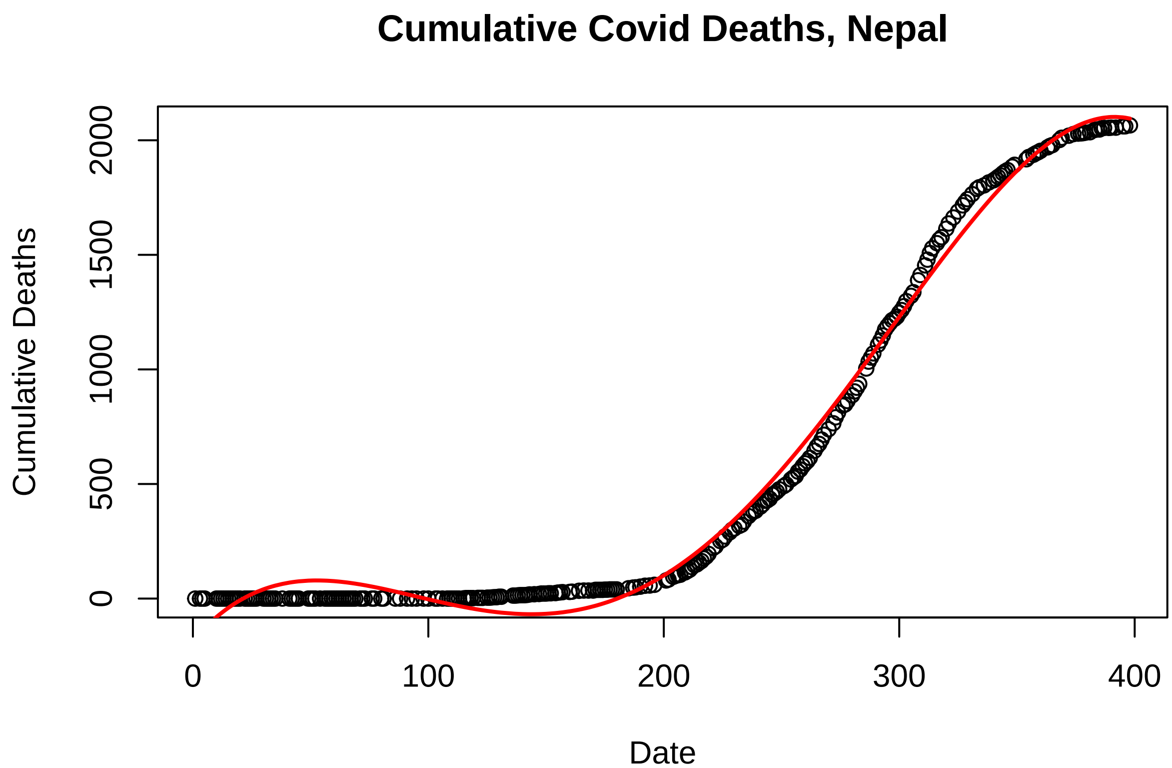
```r
(RMSE.dqlm.train <- sqrt(MSE.dqlm.train))
```

```
## [1] 62.96548
```

```r
#Prediction with test data
prediction <- predict(dqlm.train, trest.pd)
library(caret)
```

```
## Loading required package: ggplot2
```

```
## Loading required package: lattice
```




```r
(R2.test.pd <- R2(prediction, trest.pd$Deaths_total))
```

```
## [1] 0.9945643
```

```r
(RMSE.test.pd <- RMSE(prediction, trest.pd$Deaths_total))
```

```
## [1] 60.37892
```

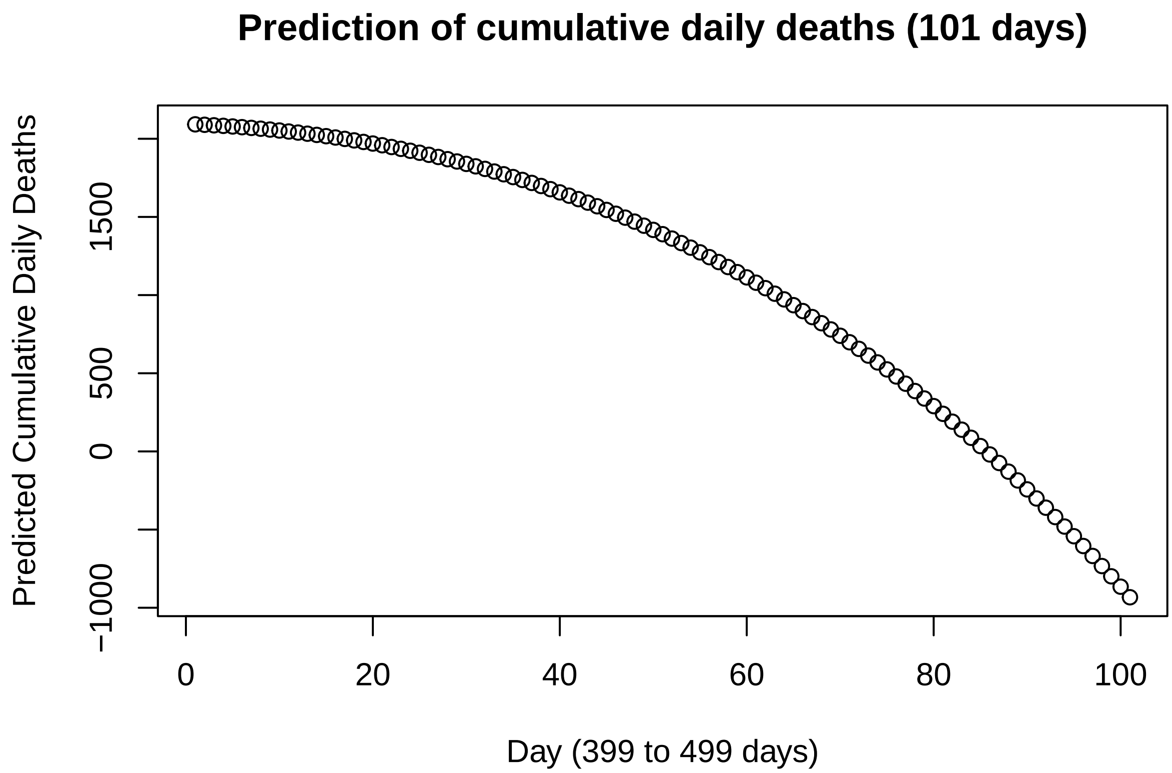
```r
#Comparing R-square and RMSE
fit_indices_train <- c(R2 = dqlm.train.summary$r.squared, RMSE = RMSE.dqlm.train)
fit_indices_test <- c(R2 = R2.test.pd, RMSE = RMSE.test.pd)
(fit_indices <- cbind(train=fit_indices_train, test=fit_indices_test))
```

```
##            train       test
## R2    0.9928153  0.9945643
## RMSE 62.9654787 60.3789186
```

```r
#Prediction for new data
new_death <- data.frame(SN=seq(399,499,1))
predicted_cd <- predict(dqlm.train, newdata = new_death)
predicted_cd
```

```
##          1          2          3          4          5          6          7
## 2092.15536 2089.32268 2086.11485 2082.52696 2078.55411 2074.19135 2069.43373
##          8          9         10         11         12         13         14
## 2064.27625 2058.71391 2052.74166 2046.35446 2039.54723 2032.31484 2024.65219
##         15         16         17         18         19         20         21
## 2016.55410 2008.01541 1999.03091 1989.59538 1979.70356 1969.35019 1958.52996
##         22         23         24         25         26         27         28
## 1947.23756 1935.46764 1923.21483 1910.47374 1897.23895 1883.50502 1869.26649
##         29         30         31         32         33         34         35
## 1854.51786 1839.25363 1823.46825 1807.15617 1790.31181 1772.92955 1755.00377
##         36         37         38         39         40         41         42
## 1736.52880 1717.49897 1697.90857 1677.75188 1657.02314 1635.71658 1613.82640
##         43         44         45         46         47         48         49
## 1591.34678 1568.27186 1544.59578 1520.31264 1495.41653 1469.90150 1443.76157
##         50         51         52         53         54         55         56
## 1416.99077 1389.58308 1361.53246 1332.83284 1303.47814 1273.46226 1242.77904
##         57         58         59         60         61         62         63
## 1211.42235 1179.38599 1146.66376 1113.24942 1079.13673 1044.31941 1008.79116
##         64         65         66         67         68         69         70
##  972.54564  935.57652  897.87741  859.44192  820.26364  780.33610  739.65285
##         71         72         73         74         75         76         77
##  698.20739  655.99320  613.00375  569.23247  524.67277  479.31803  433.16163
##         78         79         80         81         82         83         84
##  386.19689  338.41715  289.81568  240.38576  190.12063  139.01351   87.05759
##         85         86         87         88         89         90         91
##   34.24606  -19.42795  -73.97131 -129.39092 -185.69369 -242.88659 -300.97658
##         92         93         94         95         96         97         98
## -359.97065 -419.87583 -480.69915 -542.44769 -605.12853 -668.74880 -733.31562
##         99        100        101
## -798.83616 -865.31761 -932.76718
```

```r
#Plot
SNN = seq(1,101,1)
plot(SNN, predicted_cd, main="Prediction of cumulative daily deaths (101 days)",
     xlab="Day (399 to 499 days)", ylab="Predicted Cumulative Daily Deaths")
```




```
#The question is "Does it make sense?"
#Did it happen like this in Nepal between 399 and 499 days since the first COVID19 case?
#Can we improve it further with cross-validation methods?
```