Short-Term Projection of COVID 19 Cases in Kenya using an Exponential Model

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Research article

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Abstract

Introduction: The COVID-19 disease has spread to over 200 countries and territories since the first case was recorded in Wuhan, China in December 2019. In Kenya, the first case of COVID-19 was recorded on 13th March 2020, since then over one hundred cases have been confirmed, and three deaths recorded as of 2nd April 2020. With the rapid changing situation, timely and reliable data is required for monitoring, planning and rapid decision making with an aim of reversing the already deteriorating situation (economic, health, learning among others) in the country.

Methods: The study used the exponential model to project the expected daily cumulative cases in Kenya within the first 40 days. The study opted to do a short time prediction owing to the fact that the scenario is rapidly changing. Data used in the analysis was obtained from the daily updates by the Kenya Ministry of Health, and analysis was done using Stata Version 15 and MS Excel 2010.

Results: The Case Fatality Rate on day 21 was estimated as 2.7% (95% CI 0.01 – 7.80), with varying daily estimates as expected. The model estimated that the 1,000 confirmed cases will be reached by 14th April 2020 while the 4,000 cases will be reached by 21st April 2020. The results indicate that it will take 33 days for Kenya to reach the 1,000 confirmed cases and 40 days to reach the 4,000 cases

Conclusion: Massive screening and contact tracing of all individuals who entered the country within 28 days prior to the mandatory screening should be planned and implemented immediately with an aim of increasing the chances of getting active cases, and possible transmission through such contacts. Continuous modeling of data is needed in order to cater for other factors which were not considered in this study such as the impact of mandatory quarantine, night curfews and suspension of international flights

Introduction

The World Health Organization (WHO) defines the Coronavirus Disease (COVID 19) as an infectious disease caused by a newly discovered coronavirus [1] and is characterized by several symptoms including fever, cough, fatigue, shortness of breath, sore throats and headache [2, 3]. The disease was first reported in Wuhan, China and was declared a Public Health Emergency of International Concern on 30th January 2020. The World Health Organization further recognized the disease as a pandemic on 11th March 2020. As of 3rd April 2020 (19:47 Hours GMT), the disease had spread in over 207 countries, with 976,586 confirmed cases and 50,492 confirmed deaths [4].

In Africa, the first case of COVID 19 was confirmed on 14th February 2020 in Egypt and as of 3rd April (15:40 Hours GMT), about 50 countries in the continent had reported the outbreak of the diseases (*Figure 1*). As of the reference date, only four African countries had not reported any confirmed case of COVID 19 and they include Comoros, Lesotho, South Sudan and São Tomé and Príncipe. In the same period, 7,177 confirmed cases of COVID 19 had been recorded in Africa, with South Africa recording the highest

number of 1,505 followed by Algeria with 986 cases [6]. Additionally, over 290 deaths and 650 recoveries respectively have been in continent.

Kenya recorded the first confirmed case of COVID 19 on 13th March 2020, and as of 3rd April 2020 (06:00 GMT) 110 cases had been confirmed [7]. In the same duration, the Ministry of Health had confirmed three mortality cases and four recoveries from COVID 19. The confirmed cases of COVID 19 were spread in over five counties, with Nairobi recording the highest number (*Figure 7*).

To curb the spread of the disease in the country, the Kenya government instituted a number of measures including closure of school and all social and public gatherings in excess of 10 people. In addition, all international flights to and from the country were suspended as of 25th March 2020. The government also instituted mandatory quarantine for all returning Kenyans and residents from 22nd March 2020; and from 28th March 2020, a night curfew (7.00 p.m. to 5.00 a.m.) was implemented. Over the days, the government has also intensified contact tracing for all individuals who were exposed to infected cases.

To estimate the COVID 19 caseloads for coming days in Kenya, this paper has developed a statistical model based on the already available data. The projected data is critical for early preparedness, awareness creation and informed decision making in the country.

Methods

The statistical model for an epidemic has five phases as described in the Figure 3 adopted from Batista M. Phase 1 and Phase 2 are characterized by exponential growth. While phase 1 is characterized by a slow growth, phase 2 is characterized by an accelerated fast growth. Phase 3 and 4 are characterized by a negative growth, with phase 4 recording an accelerated negative growth. Phase 5 is the ending phase where limited cases are recorded or are completely not there.

As noted by Chen *et. al.* [10], the coronavirus epidemic appear to be nonlinear and chaotic, as such, this paper focused on a short-term prediction of COVID-19 cases specifically under phase 1 and 2 of the epidemic in Kenya. Using data from the Ministry of Health on the reported COVID-19 cases, the model was developed to provide estimates until the 21st of April 2020 which is the 40th day since the 1st case was confirmed in Kenya.

Assuming a continuous spread of the disease, the number of detected cases are expected to follow an exponential model [11]. The daily cumulative confirmed cases have been estimated using the exponential distribution (equation 1), by fitting the observed confirmed cases in Kenya,

$$f(x) = \alpha e^{\beta(t)} \ldots. (I)$$

α is the number of expected COVID 19 cases at the beginning of the pandemic, β is the daily growth rate and t is the time, in this case day numbers from the 1st day when COVID 19 was confirmed in Kenya (t:1,2,3……. Day 1 is 13th March 2020)

This paper also analyzed the COVID-19 Case Fatality Rate (CFR) in Kenya. The CFR also called case fatality ratio in epidemiology is the proportion of people who die from a specified disease among all individuals diagnosed with the disease over a certain period of time [12].

Data used in the analysis was compiled by the author from the daily updates given by the Ministry of Health from 13th March to 2nd April 2020; a total of 21 days. Data Analysis was done using Stata Version 15 and MS Excel 2010.

Results

Descriptive Analysis

As of 2nd April 2020, a total of 110 COVID 19 confirmed cases had been reported in Kenya. In addition, three mortality cases and four recoveries had also been reported in the same duration. Figure 4 presents the cumulative confirmed COVID 19 cases in Kenya in the first 21 days.

Table 1 presents the number of daily new cases reported, the cumulative cases and the percentage change in new cases compared with the previous day. The average percentage daily change in the period under consideration was 32%, with the least change being 0% and the highest change being 200%. The highest number of new daily-confirmed cases was in Day 21 when 29 cases were reported. Worth to note is that Day 20 and 21 recorded over 20 new confirmed cases apiece and this could be attributed to the massive testing of individuals specifically those under the mandatory quarantine. Further analysis indicated that a total of 51 cases were confirmed on day 20 and 21, and out of these, 44 were in the mandatory quarantine centers representing 86% of new cases confirmed in both days.

Table 1: Daily and Cumulative COVID-19 Cases in Kenya

Date	Cumulative Number of Cases	Number of New Cases	% Change from Previous Day
Day 1	1	1	-
Day 2	1	0	0%
Day 3	3	2	200%
Day 4	3	0	0%
Day 5	4	1	33%
Day 6	7	3	75%
Day 7	7	0	0%
Day 8	7	0	0%
Day 9	7	0	0%
Day 10	15	8	114%
Day 11	16	1	7%
Day 12	25	9	56%
Day 13	28	3	12%
Day 14	31	3	11%
Day 15	31	0	0%
Day 16	38	7	23%
Day 17	42	4	11%
Day 18	50	8	19%
Day 19	59	9	18%
Day 20	81	22	37%
Day 21	110	29	36%

Case Fatality Rate

The Case Fatality Rate (CFR) in Kenya on COVID-19 as of day 21 is estimated as 2.7% ranging between 3.2% in Day 14 when the 1st mortality case was recorded to 1.2% in Day 20. The CFR has been on a downward trend from Day 14 to Day 20, but picked in Day 21 (Figure 5).

Additionally, the CFR on closed cases (cases with an outcome) was calculated for Day 21 and recorded as 42.9% ranging from 50% in Day 14 to 25% in Day 20.

Projection of COVID 19 Cases in Kenya

The parameters of interest were estimated using a linear and non-linear exponential model (equation 1) and the parameters of interest are presented in Table 2 and 3 respectively.

Table 2: Estimated Exponential Model Parameters for Kenya (Linear Model)

```
      Source |       SS       df       MS      Number of obs   =        21
-------------+------------------------------   F(1, 19)        =    35.93
       Model |  35.93666      1  35.93666   Prob > F        =    0.0000
    Residual |  1.5344495    19  .0807605   R-squared       =    0.9590
-------------+------------------------------   Adj R-squared   =    0.9569
       Total |  37.4711095   20  1.87355548  Root MSE        =    .28418

------------------------------------------------------------------------------
      log_ke |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        days |   .2160347   .0102413    21.09   0.000     .1945994    .2374699
       _cons |   .2296469    .128595     1.79   0.090    -.0395055    .4987994
------------------------------------------------------------------------------
```

Table 3: Estimated Exponential Model Parameters for Kenya (Non-Linear Model)

```
      Source |       SS       df       MS
-------------+------------------------------   R-squared     =    0.9878
       Model |  31505.162      2  15752.5812   Adj R-squared =    0.9865
    Residual |  388.83751     19  20.465132   Res. dev.     =   120.8868
-------------+------------------------------
       Total |     31894      21  1518.7619
------------------------------------------------------------------------------
          ke |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         /a0 |    1.70771   .3274513     5.22   0.000     1.022347    2.393073
      /delta |    .194143   .0100564    19.31   0.000     .1730948    .2151912
------------------------------------------------------------------------------
```

The graphical presentation of both models against the actual number of reported in Kenya in the 21 days span is presented in Figure 6. As evidenced in Figure 6, there was a near perfection in estimation of cases by both models until day 16, when the linear model started to overestimate the cases. On the other hand, the non-linear model seems better in estimating the cases.

Figure 7 presents the trends in projected cases of COVID-19 in Kenya for 40 days since the 1st case was recorded. The presentation is based on the non-linear exponential growth model. According to the model, there will be sharp acceleration of confirmed cases from Day 32 (13th April 2020) until the end of the projection period.

Using the non-linear model, Kenya will record 1,000 confirmed cased of COVID-19 on 14th April 2020, and 4,000 confirmed COVID 19 cases on 21st April 2020. On the other hand, using the linear model, then 1,000 COVID-19 cases will be reached on 12th April and 4,000 cases will be reached on 19th April 2020. The daily predicted COVID-19 cumulative cases are presented in Table 4.

Table 4: Projected Daily Cumulative COVID-19 Cases in Kenya

Date	Reported Cases (Actual)	Linear Estimation	Non-Linear Estimation
13th Mar	1	2	2
14th Mar	1	2	3
15th Mar	3	2	3
16th Mar	3	3	4
17th Mar	4	4	5
18th Mar	7	5	5
19th Mar	7	6	7
20th Mar	7	7	8
21st Mar	7	9	10
22nd Mar	15	11	12
23rd Mar	16	14	14
24th Mar	25	17	18
25th Mar	28	21	21
26th Mar	31	26	26
27th Mar	31	32	31
28th Mar	38	40	38
29th Mar	42	50	46
30th Mar	50	61	56
31st Mar	59	76	68
1st Apr	81	95	83
2nd Apr	110	117	100
3rd Apr	122	146	122
4th Apr		181	148
5th Apr		225	180
6th Apr		279	218
7th Apr		346	265
8th Apr		429	322
9th Apr		533	390
10th Apr		662	474
11th Apr		821	575
12th Apr		1,019	699
13th Apr		1,265	848
14th Apr		1,570	1,030
15th Apr		1,949	1,250
16th Apr		2,418	1,518
17th Apr		3,002	1,843
18th Apr		3,725	2,238
19th Apr		4,624	2,717
20th Apr		5,739	3,298
21st Apr		7,123	4,004

Discussion

The estimation indicate that Kenya will likely record the first 1,000 confirmed cases on 14th April 2020 which is Day 33 since the 1st case was confirmed. Comparing with some selected countries, the result indicate that the 1,000 confirmed cases would likely be achieved later in Kenya than in South Africa and

Italy. In South Africa, it took 23 days to reach 1,000 cases, while in Italy it took 30 days. However, the 1,000 cases in Kenya are likely to be achieved earlier than the United State and Spain. It took 40 days in Spain to reach 1,000 cases and 51 days in the United States of America.

This study found that the CFR in Kenya on Day 21 was 2.7% (95% CI 0.01 – 7.80). The CFR as documented in other countries have be changing overtime. This is orchestrated by the fact that the indicator is not constant and changes with time, specifically being higher at the on-set of an epidemic. Comparison of CFR on day 21 in Kenya with other countries show mixed results. For instance, the CFR in Kenya was higher than in China where the CFR on Day 21 was estimated as 1.3% [13], Italy with an estimated CFR of 1.5%, in Spain and South Africa where no death had been recorded by Day 21. On the other hand, the CFR in Kenya was slightly lower than in Ghana on Day 21 which recorded a CFR of 3.3% [13].

Using the CFR estimate, then it is expected that 27 deaths will be recorded in Kenya from COVID-19 by 14th April 2002. Additionally, by the 40th day of COVID-19 in Kenya, 108 deaths are expected to be recorded.

Conclusion

With the high CFR Rate, there is need to document the possibility of the existing and underlying comorbidities through a detailed study and establish their possible acceleration of mortality among the infected cases. Further, massive screening and contact tracing of all individuals who entered the country within 28 days prior to the mandatory screening should be envisioned with an aim of increasing the chances of getting active cases, and possible transmission through such contacts. With the country likely to hit the 1,000 mark on 14th April 2020, then the Ministry of Health should explore possibilities of mapping soonest possible facilities which could hold such capacity and ensure their functionalities. Continuous modeling of data and in-depth study is important in order to cater for other factors which were not considered in this study including the impact of mandatory quarantine, suspension of international flights, night curfew among others.

Declarations

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Ethics Approval and Consent to Participate

Not Applicable

Competing Interests

None

Consent for publication

Yes

Authors' Contributions

Kirichu S. K. came up with the idea to predict the daily cumulative cases of COVID 19 in Kenya and wrote the manuscript based on data collated from the Kenya Ministry of Health. The author approves the final manuscript

References

1. https://www.who.int/health-topics/coronavirus#tab=tab_1 (3rd April 2020)
2. Guan WJ, Ni ZY, Hu Y, Liang WH, Ou CQ, He JX, et al. Clinical characteristics of coronavirus disease 2019 in China. N Engl J Med. 2020. https://doi.org/10. 1056/NEJMoa2002032
3. Chen N, Zhou M, Dong X, Qu J, Gong F, Han Y, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. Lancet. 2020;395(10223):507–13
4. https://www.who.int/emergencies/diseases/novel-coronavirus-2019 (3rd April 2020)
5. James Wan, https://africanarguments.org/2020/04/02/coronavirus-in-africa-tracker-how-many-cases-and-where-latest/ (3rd April 2020)
6. https://africanarguments.org/2020/04/02/coronavirus-in-africa-tracker-how-many-cases-and-where-latest/ (3rd April 2020)
7. Ministry of Health (Kenya) daily updates by the Cabinet Secretary of Health (latest update on 2nd April 2020)
8. https://en.wikipedia.org/wiki/2020_coronavirus_pandemic_in_Kenya (3rd April 2020)
9. Batista, Estimation of the final size of coronavirus epidemic by the logistic model, ResearchGate, (2020)
10. Chen, X., Yu, B. First two months of the 2019 Coronavirus Disease (COVID-19) epidemic in China: real-time surveillance and evaluation with a second derivative model. glob health res policy 5, 7 (2020). https://doi.org/10.1186/s41256-020-00137-4
11. Nelson KE, Wiliams CM. Infectious disease epidemiology: Theory and practice (3rd edition). Burlington: Jones & Bartlett Learning; 2014

12. Rebeca A. Encyclopedia Britannica. https://www.britannica.com/science/case-fatality-rate (3rd April 2020)
13. https://ourworldindata.org/coronavirus (3rd April 2020)

Figures

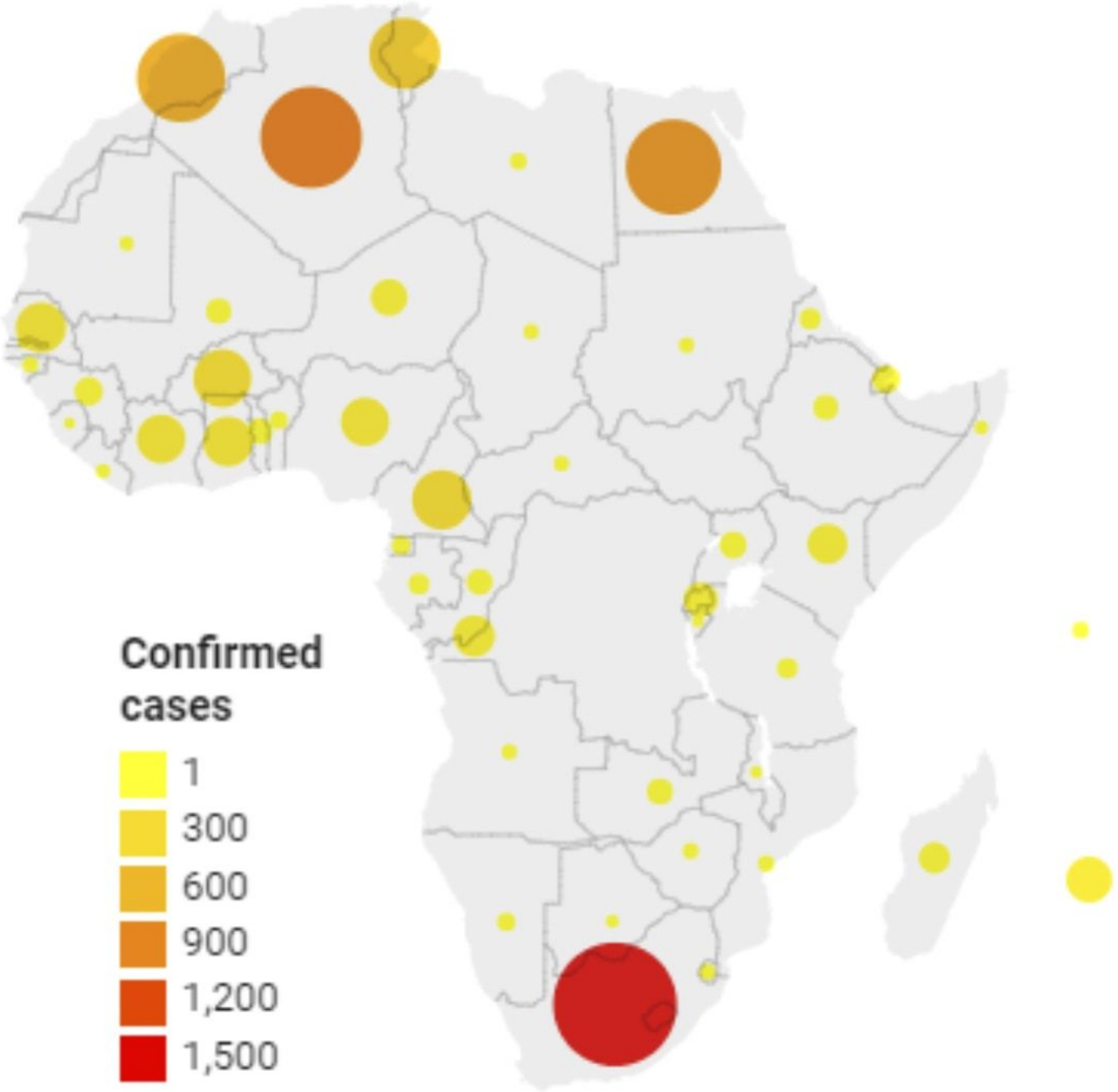

Figure 1

Distribution of confirmed COVID-19 Cases in Africa (as of 3rd April 2020, 15:40 GMT) (Map Adopted from African Arguments [5])

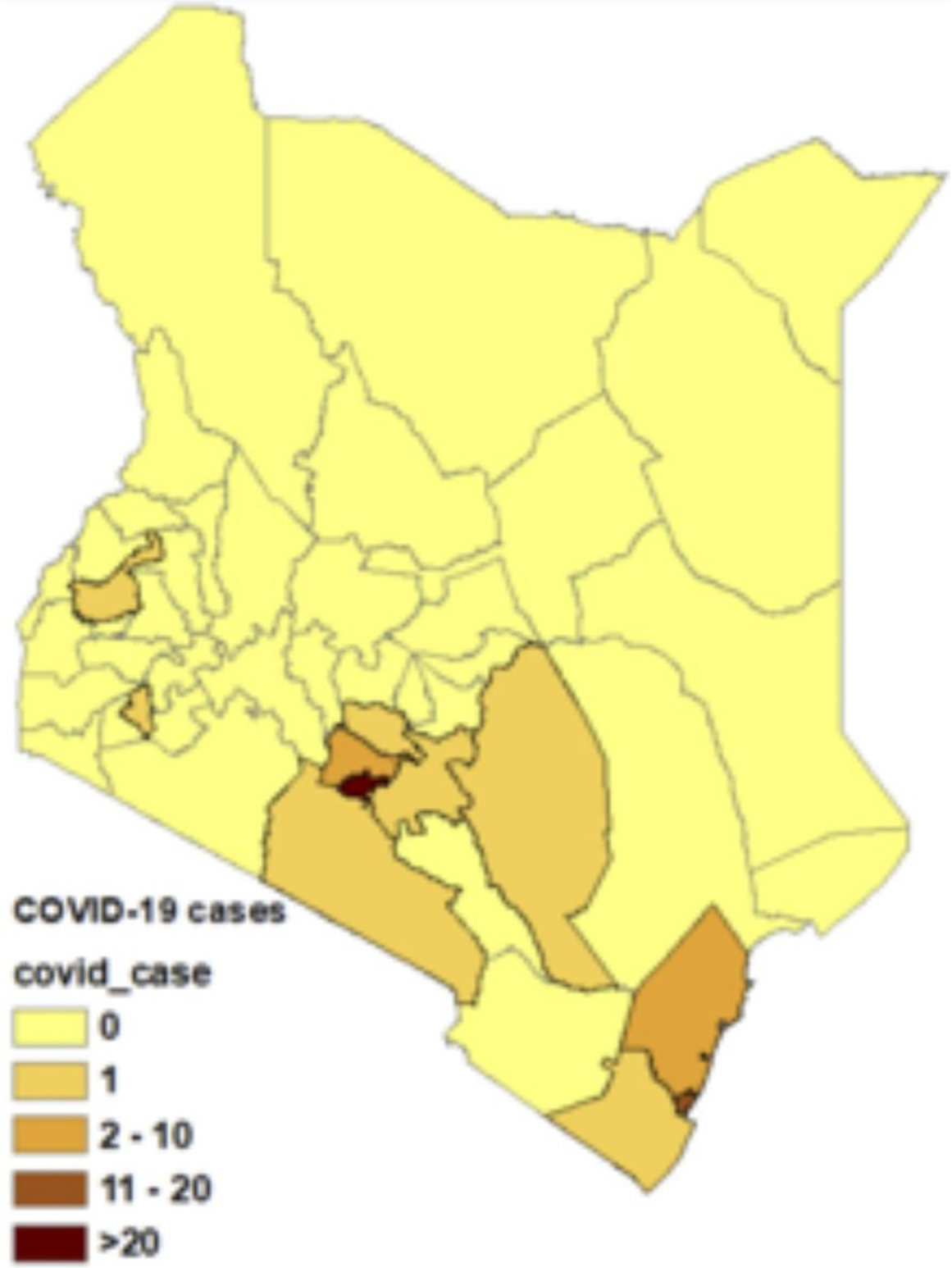

Figure 2

Map of Kenya showing counties with confirmed COVID-19 cases (as of 3rd April 2020, 08.00 GMT) [8]

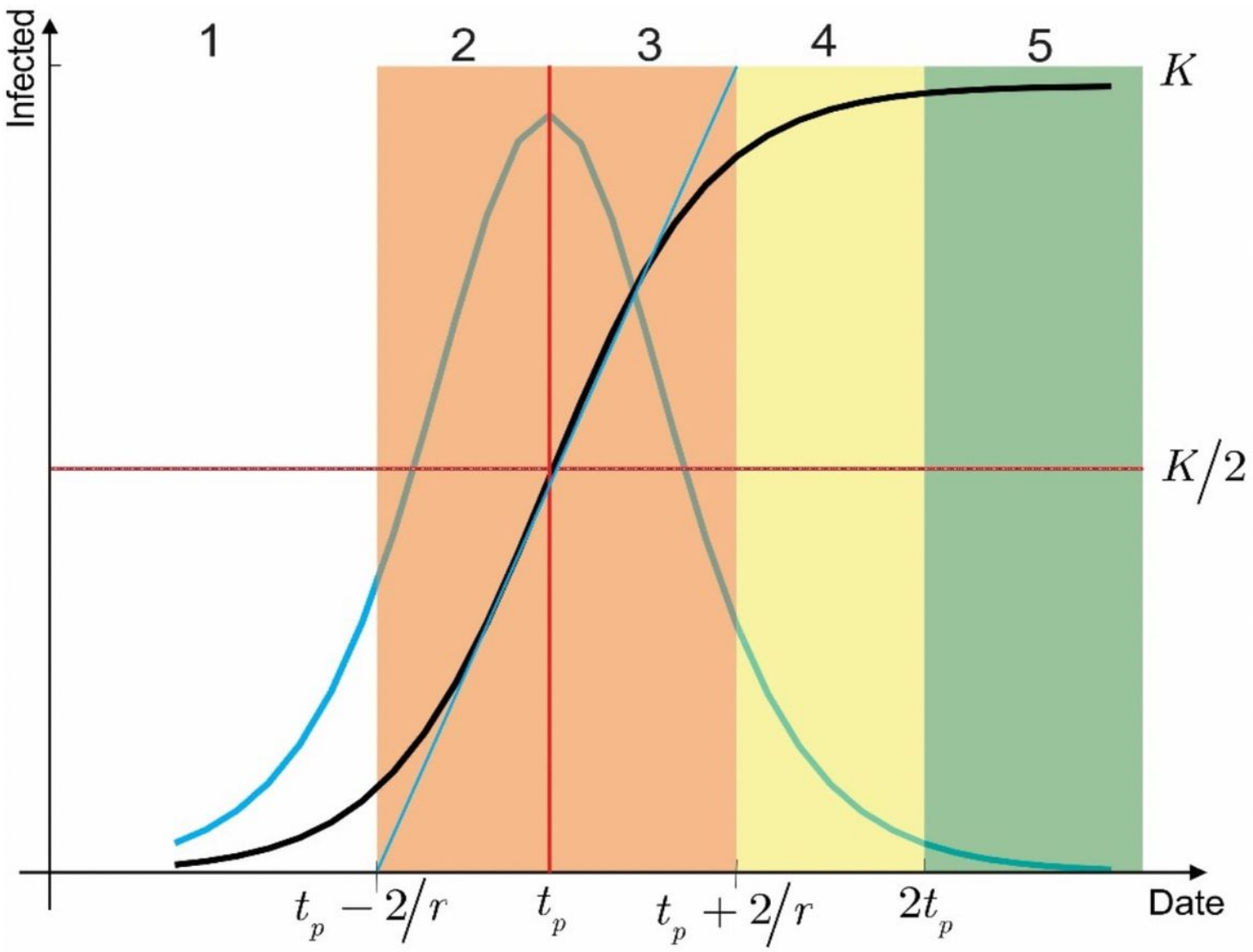

Figure 3

Epidemic Phases [9]

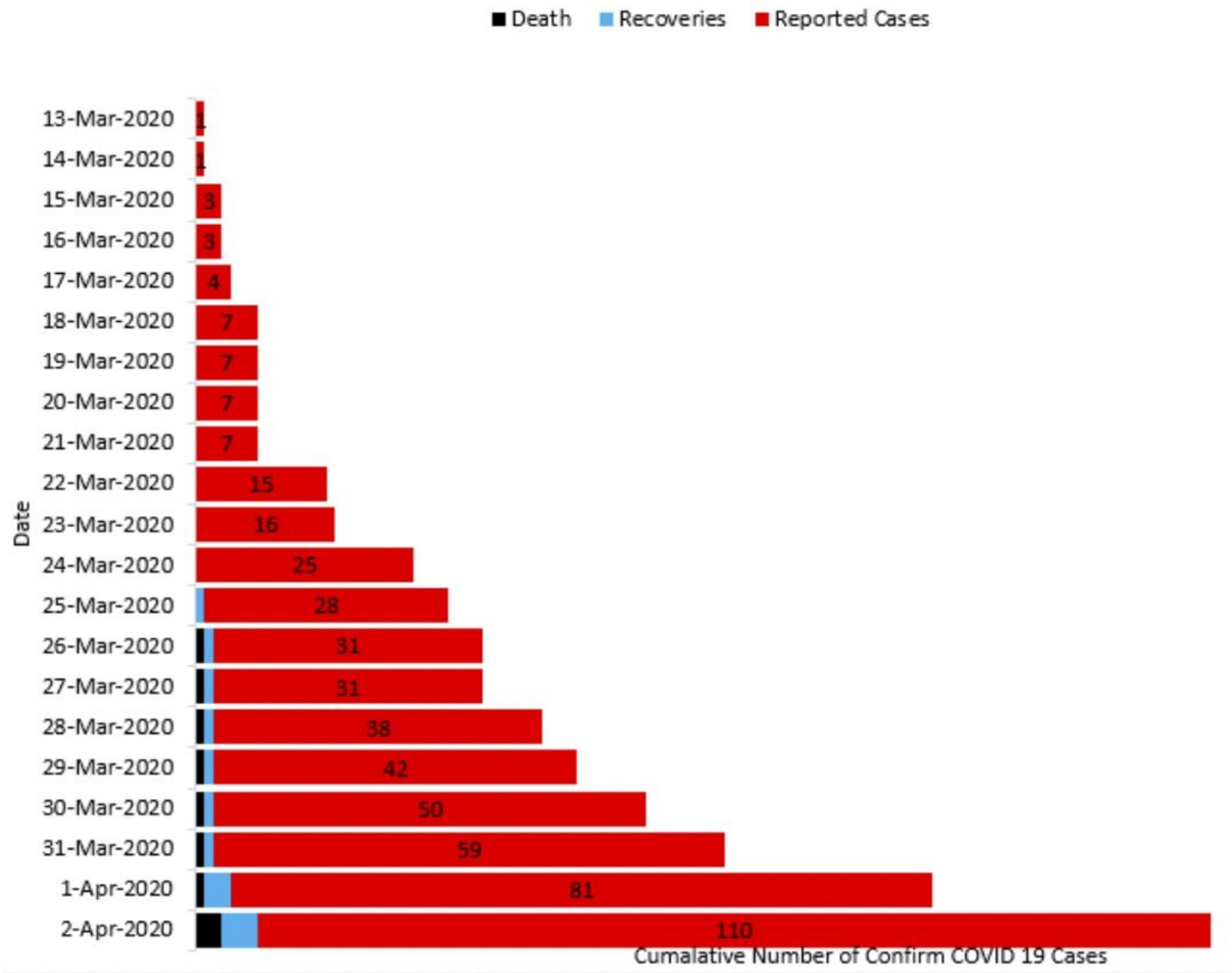

Figure 4

Cumulative Confirmed Cases of COVID 19 in Kenya

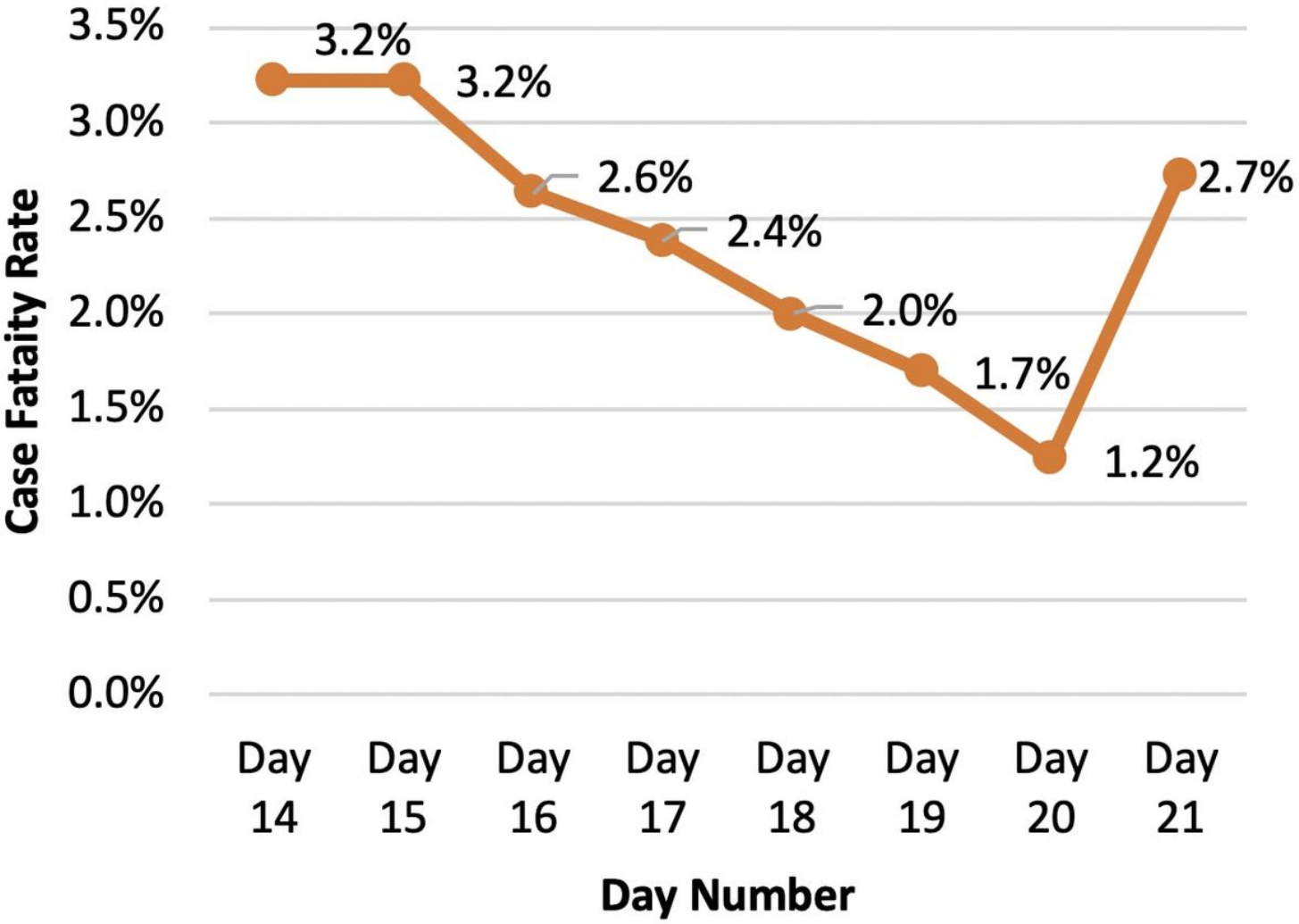

Figure 5

Trend in Case Fatality Rate in Kenya

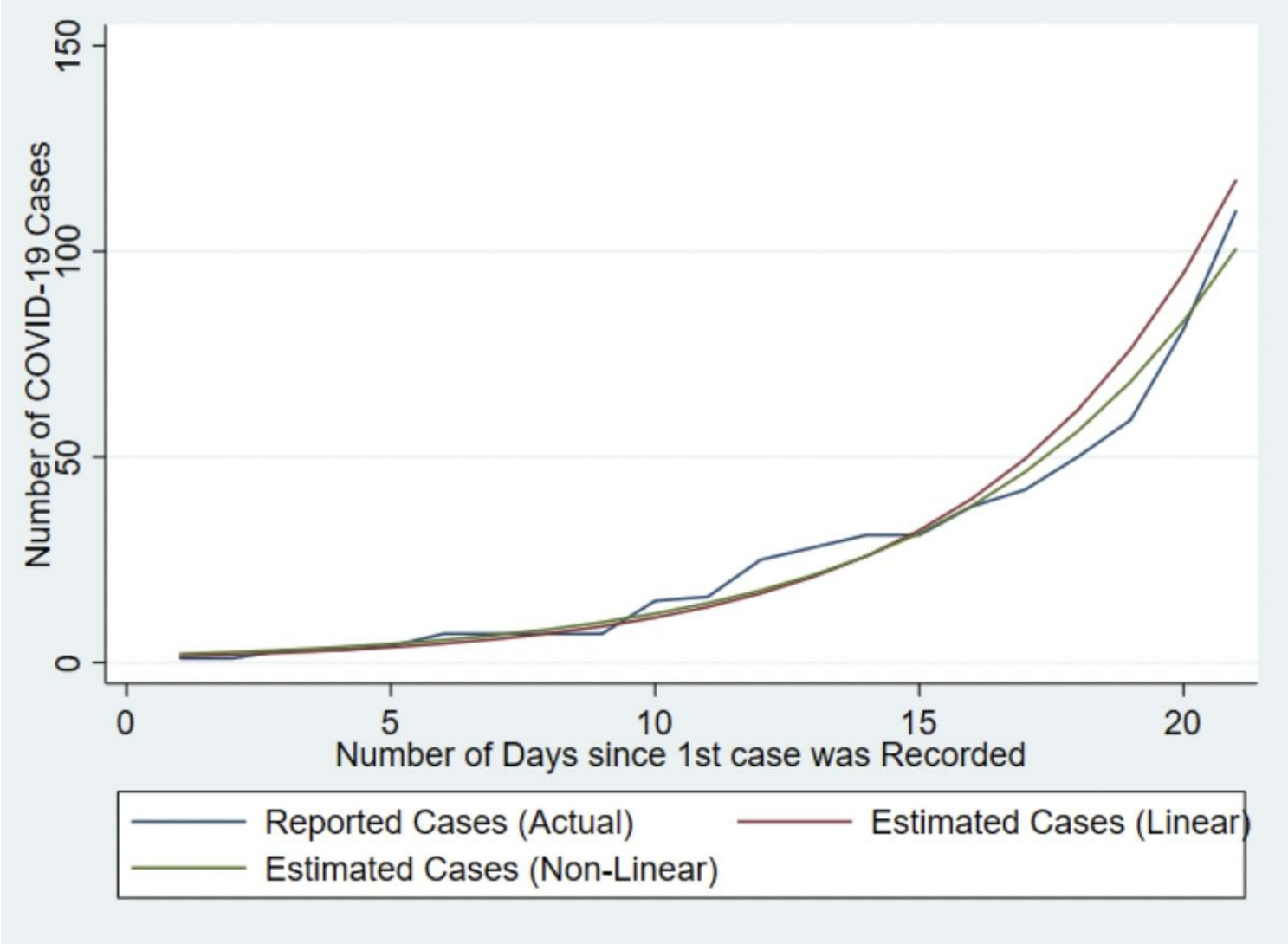

Figure 6

Exponential Model estimating COVID-19 Cases in Kenya

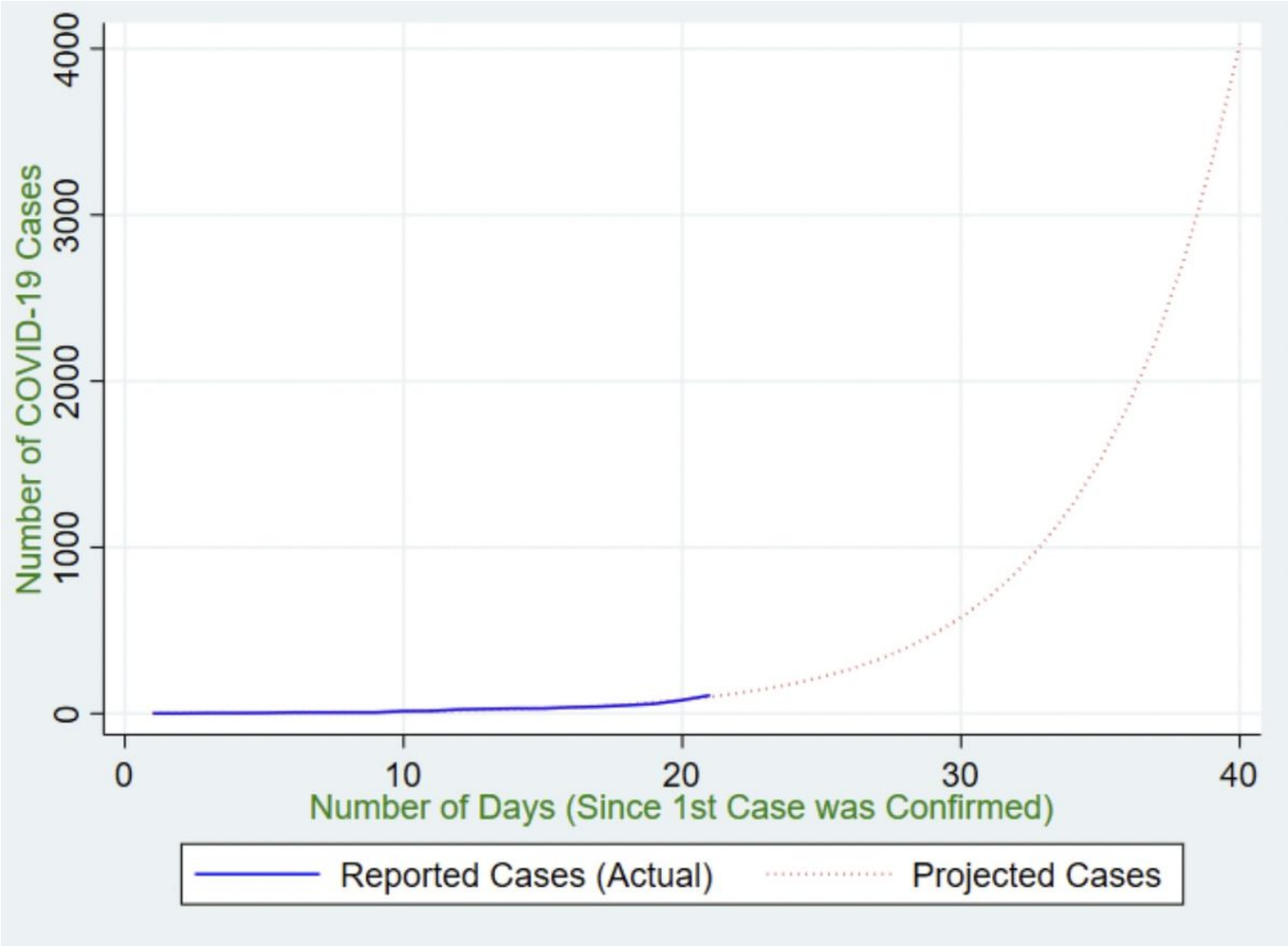

Figure 7

Projected COVID-19 Cases in Kenya (Until 21st April 2020)