

1 **Article Summary Line**

2 Based on current trends, almost all African countries are likely to report over 1 000 COVID-19  
3 cases by the end of April 2020, and over 10 000 a few weeks after that.

4 **Running Title / Title**

5 Projected early spread of COVID-19 in Africa

6 **Keywords**

7 Africa, COVID-19, Computer Simulation, Epidemics

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## 18 **Abstract**

19 For African countries currently reporting COVID-19 cases, we estimate when they will report  
20 more than 1 000 and 10 000 cases. Assuming current trends, more than 80% are likely to exceed  
21 1 000 cases by the end of April 2020, with most exceeding 10 000 a few weeks later.

## 22 **Main Text**

23 The World Health Organization (WHO) declared COVID-19 a public health emergency of  
24 international concern (1) and then a pandemic (2), citing its rapid global spread and risk of  
25 overwhelming healthcare services with patients requiring critical care. As of 24 March 2020,  
26 WHO situation reports (SITREPs), indicated 45 African countries reported at least one  
27 laboratory-confirmed infection (“reported case”) of COVID--19 (World Health Organization  
28 2020). Reported cases underestimate actual infections due to the mix of mild symptoms (3, 4),  
29 the similarity of symptoms common to the region (5), and weak surveillance (6). However,  
30 assuming constant reporting activity, reported cases grow in proportion to the underlying  
31 epidemic, and even with under-ascertainment of the number of actual cases, reported cases  
32 provide a useful indicator of stress on healthcare systems. We can use this surrogate for the real  
33 epidemic to forecast future trends, and understand the consequences of a slow public health  
34 response and what preparations need to be made now.

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## 35 **The Study**

36 We use a branching process model to project the number of future cases of COVID-19 in each  
37 country. This model assumes each case produces a number of new cases (distributed  
38  $N \sim \text{NegBinom}(R = 2, k = 0.58)$ ) (7, 8) which occur after some delay (distributed  
39  $T \sim \text{LogNormal}(E[X] = 4.7, SD[X] = 2.9)$ ) (9). We start with cases corresponding to the first 25  
40 (or fewer) reported cases in the WHO SITREPs up to 23 March 2020 (10). Using those epidemic  
41 parameters and initial cases and dates, we simulate the accumulation of the reported cases. We  
42 assume there are always sufficient unreported infections to continue transmission, and that new  
43 cases represent a reporting sample from both identified and unidentified transmission chains. As  
44 long as a constant reporting fraction persists during this period, and unreported spread is large  
45 relative to reported cases (or reporting has negligible impact on control), this is a reasonable  
46 approximation.

47 For each set of country-specific initial conditions, we generate  $n=10\,000$  epidemics, discarding  
48 any that fade out, consistent with our assumption of unreported transmission chains. We identify  
49 the dates when each simulation run crosses 1 000 and 10 000 reported cases, and then evaluate  
50 the 50% and 95% quantiles of those dates to determine the forecast interval. The model was built  
51 in the R statistical programming language, using the *bpmodels* package (11), and the  
52 *data2019nCoV* package for the SITREP data (12). All analysis code is available from  
53 <https://github.com/SACEMA/COVID10k>.

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54 We project that almost all African countries are likely to pass 1 000 reported cases by the end of  
55 April 2020 and 10 000 within another few weeks (Figure 1 and Table 1); alarmingly, these are  
56 largely synchronized continent- wide and real disease burden will certainly exceed reported  
57 cases. Since our projections assume failed containment of initial cases and no interventions  
58 reducing early transmission, they are pessimistic relative to any benefits of local action.  
59 However, containment measures, e.g. travel restrictions, increased testing, contact tracing,  
60 isolation of cases and quarantine of contacts, are likely to slow, but not halt, real epidemic  
61 growth (13). Indeed, increased testing may accelerate the time to reporting these numbers, as  
62 improved ascertainment increases the identified fraction of real cases. However, the model also  
63 optimistically assumes surveillance capacity is not overwhelmed or stymied, which would slow  
64 reaching 1 000 reported cases while the real disease burden grows uncontrolled. Because we  
65 ignore these effects, the model is only appropriate for short-range forecasts.

66 As model validation, we applied this same forecasting approach to countries world-wide that  
67 have now exceeded 1 000 reported cases; we did not consider those with more than 10 000 cases,  
68 as they have all undergone substantial control measures modifying epidemic growth. We found  
69 that 44% of actual reporting dates fell within the 50% prediction intervals, and 79% within the  
70 95% interval (Figure 2), indicating the forecast prediction interval is too certain, as expected for  
71 a rapid but low detail model. We further showed that forecast performance is not a random  
72 outcome by performing a randomization test: we shuffle the assignment of forecast days-to-1

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73 000-cases to different countries, and score 1 000 shuffled predictions; the real forecast score is  
74 significantly different from random at the  $p < 0.001$  level (Figure 2 inset).

75 Specific to Africa, the forecast for South Africa fell within the 50% prediction interval (SITREP  
76 69; 29 March 2020). From 23 March 2020, we projected a few other countries would also likely  
77 be crossing this threshold soon: Algeria, Egypt, Morocco, Senegal and Tunisia. As of SITREP 75  
78 (4 April 2020), the first three are still fast approaching this limit, while fast and intense responses  
79 in the latter two may have successfully slowed the epidemic.

## 80 **Conclusions**

81 Using reporting to date, and assuming similar epidemiological trends to those seen globally, we  
82 project that almost all African countries are likely to exceed 1 000 reported cases by the end of  
83 April 2020, and 10 000 within another few weeks. This timing is largely synchronized continent-  
84 wide and real disease burden will certainly exceed reported cases. Our projections assume no  
85 substantive changes between the initially reported cases and the forecast points; while some  
86 countries have taken drastic actions, many have not or have acted slowly. As seen in other  
87 regions, because onset of severe symptoms can be delayed weeks from infection and last several  
88 weeks, interventions have limited immediate impact on new hospitalizations or facility demand,  
89 meaning that most of the countries in our projection would be well past 1 000 cases by the time  
90 the effects of interventions started today would be observed.

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91 These results call for accelerated preparations across Africa to ready healthcare systems and  
92 citizens for the incoming wave of COVID-19 infections. Augmented staffing, personal protective  
93 equipment stores and training, general isolation beds and equipped critical care units are all  
94 urgently needed. Citizen awareness will also be critical, and officials should encourage  
95 preventive measures such as physical distancing and regular hand washing.

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## 120 **Table & Figure Captions**

121 Table 1. Projected Timing of Reporting 1 000 and 10 000 COVID-19 cases for all African  
122 Countries Reporting Cases as of 23 March 2020.

Country / Territory	Date of 1K Cases, 50% interval (95%)	...10K Cases
Algeria	Mar 23-Mar 28 (Mar 18-Apr 05)	Apr 06-Apr 12 (Apr 01-Apr 20)
Angola	Apr 18-Apr 29 (Apr 12-May 17)	May 07-May 21 (Apr 28-Jun 12)
Benin	Apr 15-Apr 26 (Apr 08-May 16)	May 03-May 17 (Apr 24-Jun 09)
Burkina Faso	Apr 03-Apr 08 (Mar 31-Apr 15)	Apr 18-Apr 23 (Apr 14-May 01)
Cabo Verde	Apr 17-Apr 28 (Apr 11-May 16)	May 05-May 20 (Apr 27-Jun 11)

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Cameroon	Apr 02-Apr 08 (Mar 27-Apr 17)	Apr 17-Apr 23 (Apr 12-May 03)
Central African Republic	Apr 14-Apr 26 (Apr 07-May 14)	May 02-May 18 (Apr 23-Jun 09)
Chad	Apr 17-Apr 29 (Apr 11-May 18)	May 06-May 21 (Apr 28-Jun 12)
Congo	Apr 13-Apr 24 (Apr 06-May 13)	Apr 30-May 16 (Apr 22-Jun 06)
Cote d'Ivoire	Apr 07-Apr 15 (Apr 02-May 02)	Apr 23-May 03 (Apr 16-May 24)
Democratic Republic of the Congo	Apr 05-Apr 10 (Apr 01-Apr 19)	Apr 19-Apr 25 (Apr 15-May 06)
Djibouti	Apr 17-Apr 29 (Apr 11-May 18)	May 05-May 21 (Apr 27-Jun 12)
Egypt	Mar 20-Apr 07 (Mar 09-Apr 26)	Apr 08-Apr 29 (Mar 28-May 22)
Equatorial Guinea	Apr 12-Apr 22 (Apr 06-May 10)	Apr 28-May 12 (Apr 21-Jun 04)
Eritrea	Apr 20-May 02 (Apr 11-May 17)	May 10-May 24 (May 02-Jun 11)
Eswatini	Apr 15-Apr 26 (Apr 07-May 15)	May 02-May 19 (Apr 23-Jun 10)
Ethiopia	Apr 09-Apr 16 (Apr 04-May 01)	Apr 23-May 02 (Apr 18-May 26)
Gabon	Apr 12-Apr 23 (Apr 06-May 10)	Apr 29-May 13 (Apr 21-Jun 05)
Gambia	Apr 17-Apr 29 (Apr 10-May 19)	May 07-May 21 (Apr 28-Jun 12)
Ghana	Apr 05-Apr 10 (Apr 01-Apr 17)	Apr 19-Apr 25 (Apr 15-May 03)
Guinea	Apr 14-Apr 26 (Apr 06-May 15)	May 01-May 18 (Apr 22-Jun 09)
Kenya	Apr 08-Apr 14 (Apr 03-Apr 24)	Apr 23-Apr 30 (Apr 18-May 12)
Liberia	Apr 14-Apr 26 (Apr 08-May 14)	May 02-May 17 (Apr 24-Jun 09)
Madagascar	Apr 11-Apr 16 (Apr 08-Apr 25)	Apr 25-May 01 (Apr 21-May 11)
Mauritania	Apr 12-Apr 24 (Apr 06-May 14)	May 02-May 17 (Apr 23-Jun 07)
Mauritius	Apr 10-Apr 17 (Apr 06-May 01)	Apr 25-May 03 (Apr 19-May 25)
Mayotte	Apr 08-Apr 12 (Apr 04-Apr 19)	Apr 21-Apr 27 (Apr 17-May 05)
Morocco	Mar 30-Apr 06 (Mar 24-Apr 16)	Apr 14-Apr 21 (Apr 08-May 04)
Mozambique	Apr 19-Apr 30 (Apr 13-May 19)	May 08-May 23 (Apr 29-Jun 14)
Namibia	Apr 12-Apr 25 (Apr 05-May 13)	Apr 30-May 16 (Apr 22-Jun 07)
Niger	Apr 17-Apr 29 (Apr 11-May 19)	May 07-May 22 (Apr 28-Jun 12)
Nigeria	Mar 31-Apr 09 (Mar 23-Apr 18)	Apr 16-Apr 24 (Apr 09-May 04)
Reunion	Apr 04-Apr 11 (Mar 31-Apr 23)	Apr 19-Apr 27 (Apr 14-May 11)
Rwanda	Apr 06-Apr 12 (Apr 02-Apr 22)	Apr 21-Apr 28 (Apr 16-May 11)
Senegal	Mar 28-Apr 04 (Mar 23-Apr 12)	Apr 11-Apr 18 (Apr 07-Apr 29)
Seychelles	Apr 10-Apr 19 (Apr 05-May 08)	Apr 26-May 09 (Apr 20-Jun 02)
Somalia	Apr 15-Apr 27 (Apr 06-May 12)	May 05-May 19 (Apr 27-Jun 06)
South Africa	Mar 29-Apr 04 (Mar 26-Apr 15)	Apr 12-Apr 19 (Apr 09-May 03)
Sudan	Apr 13-Apr 25 (Apr 05-May 14)	Apr 30-May 17 (Apr 22-Jun 08)
Togo	Apr 07-Apr 13 (Mar 30-Apr 19)	Apr 21-Apr 27 (Apr 15-May 05)
Tunisia	Mar 30-Apr 04 (Mar 25-Apr 11)	Apr 13-Apr 18 (Apr 08-Apr 27)



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Uganda	Apr 15-Apr 23 (Apr 10-May 08)	Apr 30-May 10 (Apr 24-May 31)
United Republic of Tanzania	Apr 11-Apr 18 (Apr 06-May 02)	Apr 25-May 04 (Apr 20-May 26)
Zambia	Apr 15-Apr 27 (Apr 09-May 15)	May 04-May 19 (Apr 25-Jun 11)
Zimbabwe	Apr 17-Apr 28 (Apr 11-May 17)	May 07-May 21 (Apr 28-Jun 11)

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124 Figure 1. Distribution of times to 1 000 (red to yellow) and 10 000 (grey) cases, with inset map  
125 indicating median expected arrival dates by country (red to yellow, corresponding to time  
126 distributions; countries not reporting cases by 23 March 2020 SITREP in grey).

127 Figure 2. Forecast validation for countries having already reached 1 000 cases; inset distribution  
128 indicates randomization results for actual forecast (red) versus randomly assigned forecast  
129 (grey), with 0.975 quantile indicated by the line. For actual reporting dates, 44% fell within the  
130 50% prediction intervals, and 79% within the 95%.

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