

Final validation of the forecast for the spread of the Ebola virus disease 2018-20 (EVD 2018-20) done with the Be-CoDiS mathematical model

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Technical Report

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I. Context of this report

The World Health Organization (WHO) declared an outbreak of Ebola Virus Disease (EVD) in the Democratic Republic of Congo (DRC) on 1 August 2018 (see [1]). On 25 June 2020 the DRC Ministry of Health declared the end of this outbreak (see [8]), after no new cases were reported for 42 days since the last patient tested negative for the virus.

Our research group (see [2]) performed an analysis of this situation by using the Be-CoDiS model (see [3, 4]).



<http://www.mat.ucm.es/~ivorra/softbecodis.htm>

On 23 July 2019 we proposed a forecast of the possible evolution of this epidemic. This document is available at (see [5])

<https://doi.org/10.13140/RG.2.2.13267.63521/2>

To obtain this forecast, we followed the following strategy:

Step 1 - Parameter calibration: We started the simulation considering 1 index case in DRC on 29 April 2018, and we simulated the epidemic up to 21 July 2019, calibrating some parameters to get results similar to the available data for the whole outbreak evolution.

Step 2 - Forecast: Using the estimated values for those parameters, we started the simulation considering 1 index case in DRC on 29 April 2018, and we simulated the outbreak up to its end.

II. Validation

Considering the data reported by the WHO and the results obtained with our forecast up to 25 June 2020, we show the following data:

- In **Figure 1**, we show the evolution of the cumulative number of cases and deaths.
- In **Table 1**, we report the cumulative number of cases and deaths, each month.

We observe that our forecast estimates quite well the number of cases reported by the WHO. A new vaccine introduced on 14 November 2019 (see [6, 7]), which was not taken into account in the forecast, explains in part a slight overestimation in the last months.

The authorities reported that the last patient with Ebola was discharged from the treatment center on 3 March 2020 (see [6]). However, new cases were detected in April. After that, the last recovered person left the hospital on 14 May 2020 (see [6]). According to our forecast, the last patient with Ebola would leave the hospital on 1 May 2020 (see [5]). Thus, our estimation of the final date of the outbreak was also quite close to reality.

As it can be seen in **Table 1**, between the 1st and the 14th of May 2020, new cases or deaths were neither reported nor predicted. On 21 June 2020 the WHO updated the final reported data by adding some additional cases and deaths corresponding to historical cases that were validated by the Ministry of Health with onset dates reported between March 2019 and November 2019 (see [6]). In **Figure 1**, those final reported numbers of cases and deaths are represented by a separated point. Considering this update, the final relative errors between our forecast and reported data are 3.11% for the number of cases and 7.08% for the number of deaths (see **Table 1**), which indicates a good accuracy of our forecast.

The main comparisons between our forecast and the reported data are the following:

- Last day of the outbreak (no people being treated):
 - Forecast: 1 May 2020
 - Reported data: 14 May 2020
- Final number of cases:
 - Forecast: 3578
 - Reported data: 3470
- Final number of deaths:
 - Forecast: 2449
 - Reported data: 2287

Acknowledgments

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References

- [1] <https://www.who.int/emergencies/diseases/ebola/drc-2019>
- [2] <https://www.ucm.es/momat/epidemics>
- [3] <http://www.mat.ucm.es/~ivorra/softbecodis.htm>
- [4] B. Ivorra, D. Ngom and A.M. Ramos, *Be-CoDiS: A Mathematical Model to Predict the Risk of Human Diseases Spread Between Countries—Validation and Application to the 2014–2015 Ebola Virus Disease Epidemic*. *Bulletin of Mathematical Biology*. 2015. Volume 77, Issue 9, pp 1668–1704. DOI: <http://dx.doi.org/10.1007/s11538-015-0100-x> - Preprint: <https://eprints.ucm.es/28809/>
- [5] M. R. Ferrández, B. Ivorra, J. L. Redondo, A. M. Ramos and P. M. Ortigosa, Application of the Be-CoDiS model to the 2018-19 Ebola Virus Disease outbreak in the Democratic Republic of Congo. *ResearchGate preprint*: <https://doi.org/10.13140/RG.2.2.13267.63521/2>
- [6] Ebola DRC, 2019, situation reports. <https://www.who.int/emergencies/diseases/ebola/drc-2019/situation-reports>
- [7] <https://www.who.int/news-room/detail/23-09-2019-second-ebola-vaccine-to-complement-ring-vaccination-given-green-light-in-drc>
- [8] <https://www.afro.who.int/news/building-ebola-response-tackle-covid-19-drc>

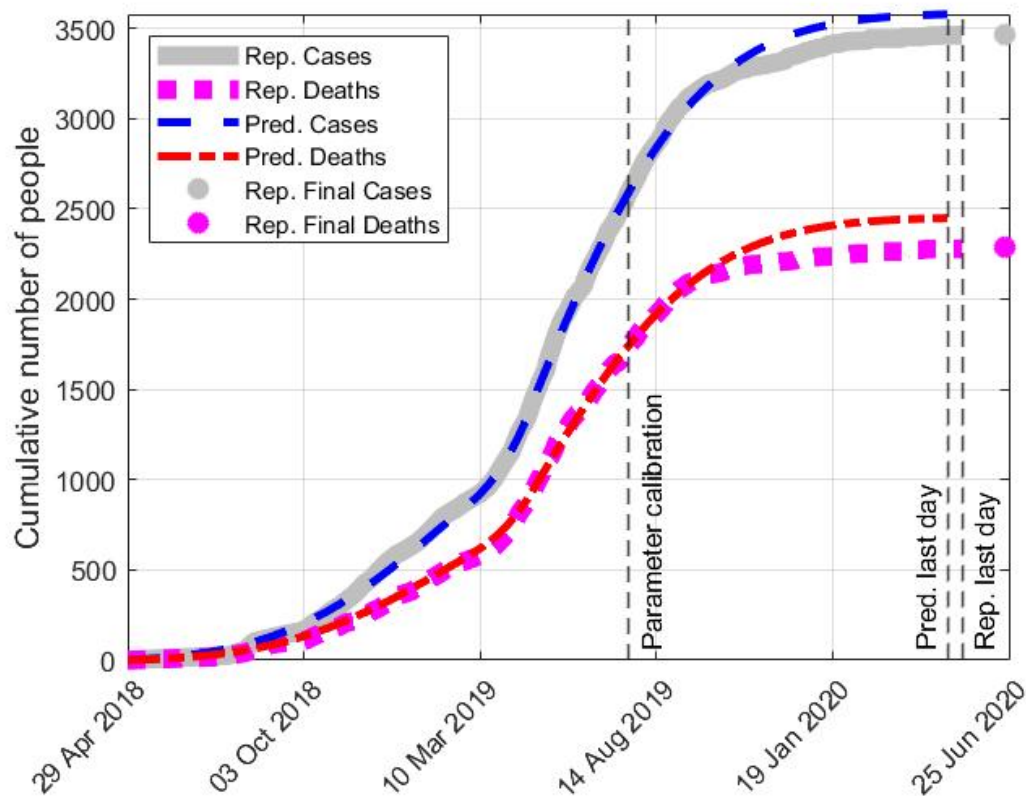


Figure 1. Cumulative number of cases reported by the WHO and estimated by our forecast. Vertical lines also show the day of the parameter calibration and the last day of the outbreak, as predicted by the model and reported by authorities

DATE	FORECASTED CASES	REPORTED BY WHO CASES	RELATIVE ERROR IN CASES	FORECASTED DEATHS	REPORTED BY WHO DEATHS	RELATIVE ERROR IN DEATHS
21 Jul 2019	2593	2592	0.04%	1743	1743	0.00%
21 Aug 2019	2895	2926	1.06%	1956	1959	0.15%
21 Sep 2019	3127	3156	0.92%	2121	2112	0.43%
21 Oct 2019	3290	3248	1.29%	2238	2169	3.18%
21 Nov 2019	3406	3299	3.24%	2322	2198	5.64%
21 Dec 2019	3479	3358	3.60%	2375	2224	6.79%
21 Jan 2020	3526	3416	3.22%	2410	2238	7.69%
21 Feb 2020	3554	3444	3.19%	2430	2264	7.33%
21 Mar 2020	3568	3444	3.60%	2441	2264	7.82%
21 Apr 2020	3576	3461	3.32%	2447	2279	7.37%
1 May 2020	3578	3462	3.35%	2449	2279	7.46%
14 May 2020	3578	3462	3.35%	2449	2279	7.46%
21 Jun 2020	3578	3470	3.11%	2449	2287	7.08%

Table 1. Cumulative number of deaths reported by the WHO and estimated by our forecast for each month. We also report the relative error (in %) between reported and forecasted data.