ACADEMIA | Letters

Lessons from Modelling COVID-19 Scenarios in Kenya and Implications for Policy and Planning

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Abstract

This study examined and modelled the cross-country spread of the novel coronavirus disease of 2019 (COVID-19) in Africa and outside Africa, finally converging on Kenya as the country of interest. A review of the models widely used to calibrate policy and strategic responses confirmed the suitability of statistical models for predicting the spread of COVID-19, within a 10% margin of error. The main objective was to provide insights into the spread of COVID-19 and present "what-if" scenarios in aid of policy simulations within a compact bandwidth of future scenarios, as required for policy and planning. The models proved resourceful in predicting the end-month cases within 10% and the likelihood of subsequent waves, both in terms of the magnitudes and the time of starting and flattening. In the case of Kenya, the period of the waves tended to be approximately four months within the study period presented here, from April 2020 to May 2021. The key lessons imply a greater role of modelling, digitalisation, geospatial and mapping technologies, and transdisciplinary research in the aspirational future of disease and disaster governance.

Keywords*: *digitalisation, disease and disaster governance, geomedicine, Health 4.0, policy simulation

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Introduction

In recent years, disease and disaster governance has become a public policy concern of borderless geopolitical implications. The novel coronavirus disease (COVID-19), first reported in China in December 2019, epitomises this scenario. These disruptive developments have accelerated the pace of the Fourth Industrial Revolution (Industry 4.0), expected to be more pronounced in the health and education sectors with increasing uptake of digitalisation and immersive technologies.

Since January 2020, publicly available COVID-19 data has been increasing, from barely a million cases at the beginning of April 2020 to more than 157 million cases by May 7, 2021 (Republic of Kenya [Ministry of Health, 2021]; WHO, 2020; Worldometer, 2020; Worldometer, 2021). The increasing COVID-19 data volume has enabled the development of multi-scale data-driven models to inform critical trends and containment policies globally, across Africa, and within Kenya. The World Health Organization (2020) has since confirmed community transmission as the dominant form of spread of COVID-19, Africa not spared the brunt.

This paper illustrates the critical role of data-driven models in the science-policy interface, using mathematical models to calibrate policies and strategies towards influencing behaviour change and containment action. The rest of the paper details the recent developments in COVID-19 containment, the modelling theory and methodology used in the study, the results obtained, and the implications of the findings for containing the pandemic in Kenya with respect to policy and planning.

Recent developments in understanding and containing COVID-19

Chaari and Golubnitschaja (2020) confirmed from their research in Tunisia that reliable "real-time" monitoring based on randomised laboratory tests is the optimal predictive strategy for evidence-based preventive measures. This approach should aid in calibrating policy decisions to avoid long-term economic recession from over-protection or eventually explosive health risks that can arise from over-relaxation of containment measures and pandemic fatigue. Timeliness and testing are key to disaster and disease governance, as are tracing, transparency, training, transdisciplinary research, and trust-building among the public to own the recommended containment policy and strategic measures (Adero, 2021).

The critical importance of timing has further been reinforced by Read et al. (2020), who used a transmission model at the time the novel coronavirus began spreading fast in China to estimate a basic reproductive number, R0, of 3.11 and further that 58-76% of transmissions must be prevented to stop the surge. In terms of tracing, actionable, pin-pointed location-

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based results are critical to containing fast-spreading disasters, the case of COVID-19 further aggravated by random mutations. Such an achievement was demonstrated using geospatial technologies in Germany to trace the first COVID-19 case to a saltshaker in a Bavarian restaurant.

Africa's first COVID-19 case was recorded in Egypt on February 14, 2020, making the first of a series of imported cases through travellers from the hotspots in Europe, Asia, and the USA. Recently, there have been active community transmissions in Africa, aggravated by the high population densities and poor living conditions in most African towns. By March 17, 2020, the whole of Africa had confirmed a total of only 450 COVID-19 cases (Worldometer, 2020).

The spread of COVID-19 is a dynamic process, hence the justified application of dynamic models. Model development is both art and science calibrated and matured over time through passion and experience. Intervening variables are central to system functioning while moderating variables are mostly attitudinal or cultural factors, which usually end up modifying system response. The uptake of modelling in the science-society-policy nexus has surged during the COVID-19 pandemic.

In Kenya, a raft of containment measures since March 2020 included partial lockdowns, dusk-to-dawn curfew, and restrictions on mass gatherings in public places, restaurants, and places of worship. Political rallies, known to be among the super-spreader activities, continued in several places on several occasions despite the ban on gatherings. This realisation was a weak link in the war against the pandemic.

In terms of data and technical details, the models applied can be mechanistic or statistical (Bala, Arshad, & Noh, 2017; Bellinger & Fortmann-Roe, 2013; Brailsford & Hilton, 2001; Kelton & Law, 2000). Based on the writings of these authors, it is evident that system dynamics models are mostly applied to handle interactions in complex adaptive systems towards understanding the big picture at higher strategic and conceptual levels with policy-oriented simulations, so as to understand long-term system behaviour over months or years. Discrete event simulation (DES) models find application in addressing specific questions at the operational and tactical levels over short time scales such as hours or days. Agent-based models are useful where there is a good understanding of how individual agents influence changes and respond in a system. Statistical models are data-intensive; they thrive in data abundance to serve the need to establish a model of dependencies. Again, the taxonomy could be based on the purpose of the models, hence a further classification into narrative models that are meant to create a convincing storyline for behaviour change agency, inferential models for hypothesis testing, or predictive models for projections within a specified error margin (Bellinger & Fortmann-Roe, 2013).

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Methodology

Predictive modelling was chosen to fit the intended purpose of this study. Though the modelling exercise has covered thirty-two countries across the world for comparisons, the scope of this paper has been limited to Kenya's COVID-19 curves since March 2020. Informed by intervening and moderating variables, this research reviewed the success of system dynamics models, agent-based models, and statistical models in simulating COVID-19 scenarios. Reducing uncertainties into quantifiable risks to inform containment measures within a compact bandwidth of future scenarios was the underpinning philosophy.

The abundance of cumulative COVID-19 data justified the choice of statistical modelling based on data-driven mathematical simulations using the best-fitting equations — keeping the coefficient of determination, R-squared, to at least 0.995. The trend in population-normalised testing rates, sampling efficacy, community behaviour, infection rates, and the effect of lockdowns were used to generate assumptions for three model scenarios: optimistic, business-as-usual (BAU), and pessimistic scenario.

Based on experience in the model development process, the suitable update period for the models came to be every three to four weeks. Based on nationally reported data from Wordometer (2020), reference to eleven selected countries in Africa[1] revealed leading metrics on the spread of COVID-19 across Africa by April 16, 2020. The metrics were compared to the ones derived for 14 selected countries outside Africa with leading metrics by then.

Results and discussion

The key metrics from the country models showed that it was taking an average of 16 days to start the fast-rising phase of the country COVID-19 curves. This figure was lower than the average of 33 days this study established for the 14 countries with leading cases in Europe, Asia, and North America by mid-April 2020. By April 16, 2020, six out of the eleven African countries had displayed exponential growth phases. The highest exponential rates in the group were in South Africa (26%), Cameroon (23%), Kenya (18%), and Egypt (14%). The rest of the countries in the study group displayed simulation curves that fitted a rising quadratic trend (Niger) or a rising linear trend (Rwanda, Nigeria, Burkina Faso, and Algeria — in the order of increasing gradients).

The daily average population-normalised testing rate in Kenya, at only 74 tests/million people/day by May 7, 2021, was still low even in Africa when compared to Ghana's 83, Rwanda's 241, and ranging about 400–500 in Morocco, South Africa, India, and Brazil. The global leaders on this normalised testing score by May 8, 2021, included the UK (about 5,000),

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Israel (over 3,500), and the USA (about 2,900). Country comparisons are shown in Figure 1.

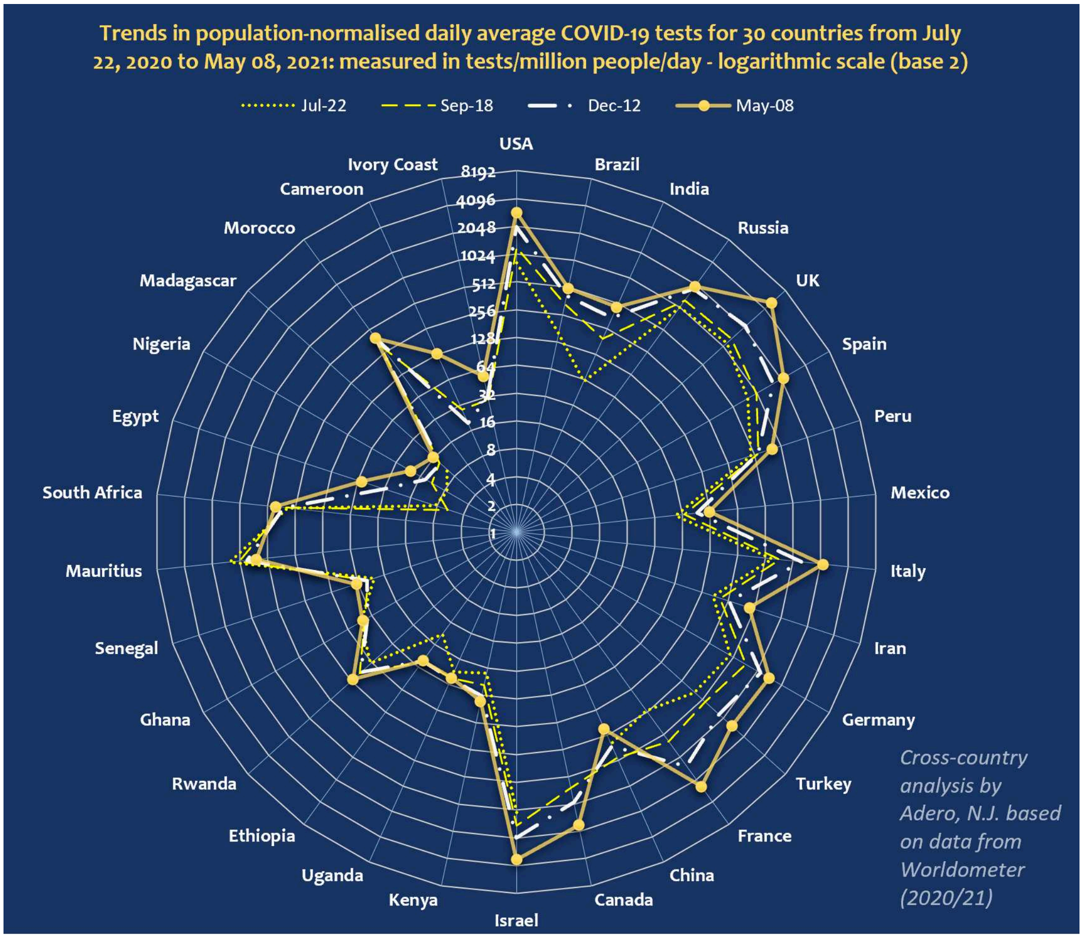

Figure 1: Daily average population-normalised testing rates across thirty countries between July 2020 and May 2021.

A heat map of the shares of COVID-19 cases in May across the 47 counties in Kenya showed the dominance of the caseload in the main urban centres along the major transport corridors, the Nairobi City County maintaining a share of 46% of late followed by 7% in Mombasa County (Figure 2). The metropolitan region deeply and functionally connected to Nairobi through employment and commerce formed the "COVID-19 ring of fire" in Kenya, together holding 58% of the country's caseload. The share rose to 63% with the addition of Nakuru, a key urban centre connecting the metropolitan region to the western ring. The centres that hosted major public gatherings, mainly because of political rallies as the country

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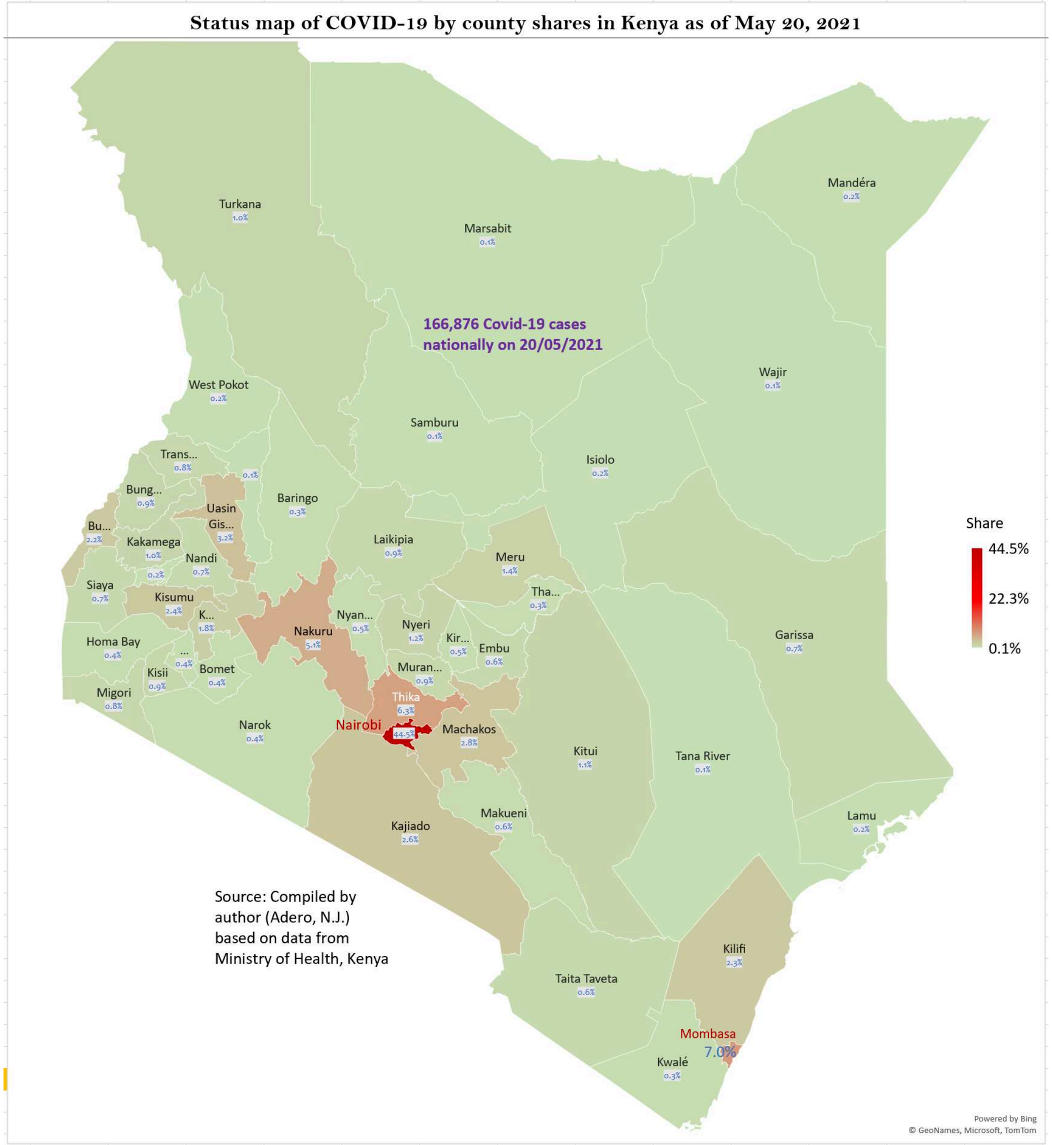
was nearing the 2022 general elections, tended to experience a faster and remarkable increase in the share of confirmed COVID-19 cases. Nakuru, Kisumu, and Kisii were particularly noted for such remarkable changes.



Source: Compiled by author (Adero, N.J.) based on data from Ministry of Health, Kenya

Figure 2: Heat map of the relative shares of COVID-19 cases by county across Kenya as of May 20, 2021.

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The models developed have been projecting Kenya's end-month COVID-19 cases within 0.1%–10% from the BAU and optimistic scenarios for more than 90% of the instances. The highest difference of 16.7% was realised at the end of August 2020 following a 50% reduction in the population-normalised testing rates observed after August 16, 2020, and 11.1% at the end of November 2020, after the surge in October following the reopening on September 28, 2020. Between January 1 and January 14, 2021, the simulation assuming the second wave would peak on January 14 remained within 4.6–5.5% above the actual reported cases (Figure 3).

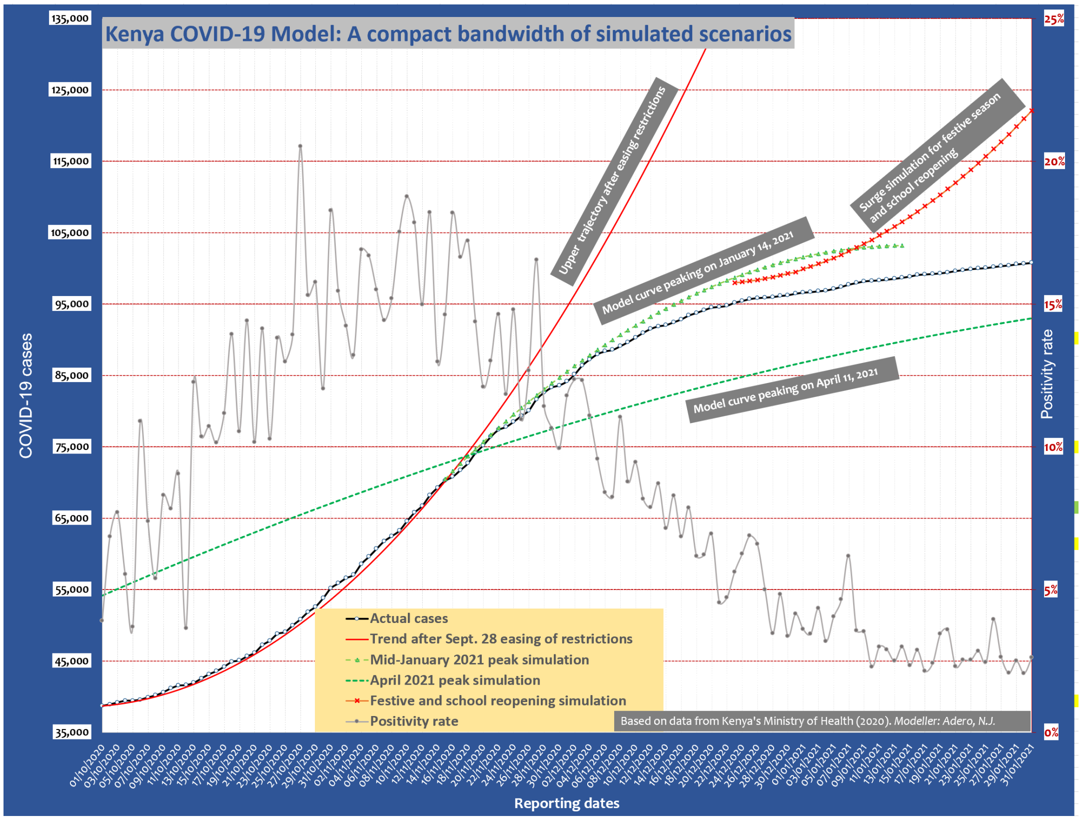

Figure 3: Simulated scenarios of COVID-19 cases in Kenya against actual reported cases between October 1, 2020 and January 31, 2021.

This yearlong modelling and testing of the character of Kenya's COVID-19 curves simulated the possibility of a fourth wave picking up the pace in July 2021 and the third wave ebbing from May 26 after reaching a simulated figure of 166,775 cases (+/- 1%). The confirmation of the first case of the Delta variant in Kisumu, Kenya, in May 2021, however, changed this

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optimism. The new surging trend in the actual curve became evident in the observed change in the magnitude and sign of differences between the model results and the reported COVID-19 cases. Table 1 presents the model equations and the accompanying scenario of differences between the model and reported cases from April 30 to May 26, 2021. It is evident that the trend started changing noticeably from May 14, only made more pronounced from May 19, 2021, as the more contagious Delta variant started spreading in Kenya. The displayed differences are between the COVID-19 model results and the actual reported cases before and after the entry of the Delta variant in May 2021.

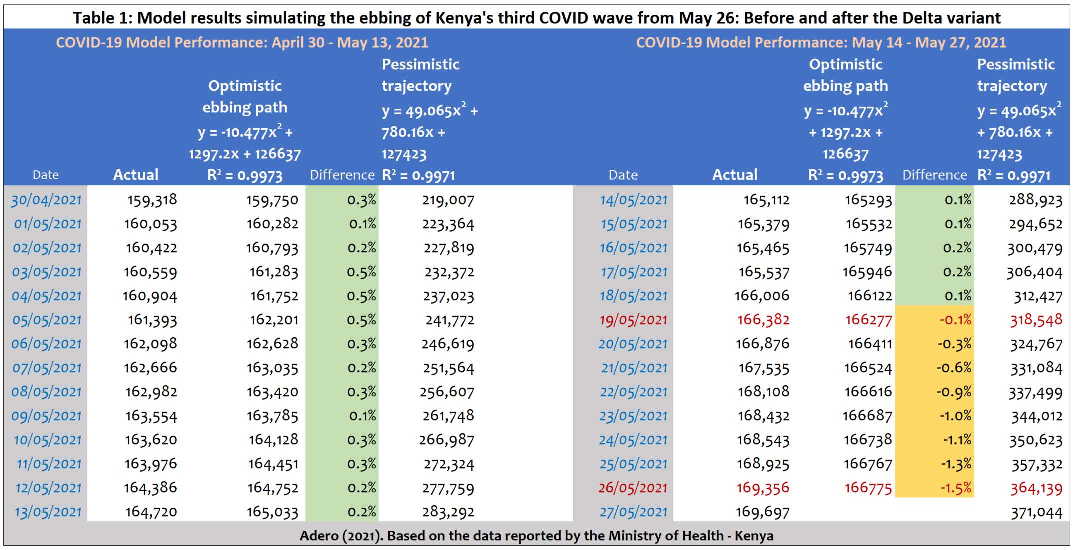

Table 1: Model results simulating the ebbing of Kenya's third COVID wave from May 26: Before and after the Delta variant

COVID-19 Model Performance: April 30 - May 13, 2021					COVID-19 Model Performance: May 14 - May 27, 2021				
Date	Actual	Optimistic ebbing path $y = -10.477x^2 + 1297.2x + 126637$ $R^2 = 0.9973$	Difference	Pessimistic trajectory $y = 49.065x^2 + 780.16x + 127423$ $R^2 = 0.9971$	Date	Actual	Optimistic ebbing path $y = -10.477x^2 + 1297.2x + 126637$ $R^2 = 0.9973$	Difference	Pessimistic trajectory $y = 49.065x^2 + 780.16x + 127423$ $R^2 = 0.9971$
30/04/2021	159,318	159,750	0.3%	219,007	14/05/2021	165,112	165293	0.1%	288,923
01/05/2021	160,053	160,282	0.1%	223,364	15/05/2021	165,379	165532	0.1%	294,652
02/05/2021	160,422	160,793	0.2%	227,819	16/05/2021	165,465	165749	0.2%	300,479
03/05/2021	160,559	161,283	0.5%	232,372	17/05/2021	165,537	165946	0.2%	306,404
04/05/2021	160,904	161,752	0.5%	237,023	18/05/2021	166,006	166122	0.1%	312,427
05/05/2021	161,393	162,201	0.5%	241,772	19/05/2021	166,382	166277	-0.1%	318,548
06/05/2021	162,098	162,628	0.3%	246,619	20/05/2021	166,876	166411	-0.3%	324,767
07/05/2021	162,666	163,035	0.2%	251,564	21/05/2021	167,535	166524	-0.6%	331,084
08/05/2021	162,982	163,420	0.3%	256,607	22/05/2021	168,108	166616	-0.9%	337,499
09/05/2021	163,554	163,785	0.1%	261,748	23/05/2021	168,432	166687	-1.0%	344,012
10/05/2021	163,620	164,128	0.3%	266,987	24/05/2021	168,543	166738	-1.1%	350,623
11/05/2021	163,976	164,451	0.3%	272,324	25/05/2021	168,925	166767	-1.3%	357,332
12/05/2021	164,386	164,752	0.2%	277,759	26/05/2021	169,356	166775	-1.5%	364,139
13/05/2021	164,720	165,033	0.2%	283,292	27/05/2021	169,697			371,044

Adero (2021). Based on the data reported by the Ministry of Health - Kenya

Generally, the period the COVID waves have taken to flatten in Kenya has tended to be about four months within the study period. The entry of the Indian (Delta) variant reported in Kenya in May, the recent easing of movement restrictions in the "disease-infected zone" on May 1, 2021, giving way to more community interactions and school reopening, and the slow pace of vaccination that cannot assure herd immunity any time soon, implied the possibility of a more vicious fourth wave surpassing 300,000 cases by July 2021 in Kenya. Avoiding this pessimistic scenario calls for heightened civic discipline for compliance with COVID-19 health protocols and strict policy enforcement.

Conclusion

Since the model projections have largely remained within a 10% margin of error, they are within the boundary recommended for countrywide policy and planning purposes. To effectively contain the pandemic's resurgent waves in Kenya and attain herd immunity, vaccination rates, contact tracing and population-normalised testing rates need to be enhanced, together with timely containment responses informed by transdisciplinary scientific research. Building public trust in all the containment strategies is also crucial, attainable through data transparency and overall data integrity with regular sharing of mapped visual evidence. Applying geospatial technologies (GIS) promises to enhance visualisation for a shared understanding and location-based intelligence that can easily be appreciated and acted upon collectively by the media, decision-makers, health workers, and the general citizenry for effective containment. The disruption COVID-19 has caused goes beyond the health sector to include education and the economy. The main research and policy implications for the future of medical diagnostics, clinical practice and public health management are: enhanced technology adoption to embrace digitalisation and spatial mapping for precise and effective tracing and disease governance at the intersection of geography and health (geomedicine), developing integrated databases of health informatics with spatially referenced variables for timely and sound decision support, enhanced application of predictive models, and generally embracing the rhythm of Industry 4.0 in healthcare - hence developments in "Health 4.0" complete with increasing uptake of telemedicine.

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[1] Egypt, South Africa, Algeria, Cameroon, Ghana, Ivory Coast, Niger, Burkina Faso, Nigeria, Kenya, and Rwanda. Data from Worldometer (online).

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