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SHORT COMMUNICATION

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Tropicalisation of epidemiological models in Africa: A mixed and hybrid approach to better predict COVID-19 indicators

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Abstract

Context: Since the outbreak of the SARS-COV2 epidemic turned into a COVID-19 pandemic, international bodies such as the WHO as well as governments have announced projections for morbidity and mortality indicators related to COVID-19. Most of them indicated that the health situation would be worrying.Although using artificial intelligence with mathematical algorithms and/or neural networks, the results of the SIR models were poorly performing and not very accurate in relation to the observed reality in the African states in general and in Senegal in particular. Hence the imperative need to configure the modelling process and approach considering local contexts.

Method: The model implemented is a mixed prediction model based on the Bucky model developed by OCHA and adapted to the context.The construction of the mixed model was done in two steps (basic model with publicly available data, such as those from United Nations-like organisations such as OCHA or WHO for Senegal), (adding more specific data collected through the mixed epidemiological survey). This survey was conducted in Senegal in six localities (Dakar, Thies, Diourbel, Kedougou, Saint-Louis and Ziguinchor) chosen according to the number of confirmed cases of COVID-19. In total, 1000 individuals distributed in proportion to the size of the regions were interviewed in April 2021.

Results: The projected cases in the baseline model were already considerably higher than the cases reported in April. This may be plausible, given the low detection rates throughout Senegal during this period. However, the hybrid model predicted an even higher infection rate than the baseline, perhaps mainly due to vulnerability related to food insecurity and solid cooking fuels. This may mean that there would be more unreported cases than reported. Overall, the mortality rate of both models would be considerably lower than the government-reported mortality rate, even though the number of confirmed cases remains high. This may be an underestimate of the death rate.

Conclusion: An accurate and reliable prediction in times of epidemics and/or pandemics, such as COVID-19, should be based on mixed or hybrid data integrating a quantitative and qualitative approach to enable better policymaking. The projections resulting from this approach would still be effective and would take better account of local realities and contexts, especially for developing countries.

KEYWORDS
Africa, COVID-19, epidemiological models, mixed and hybrid approach, Tropicalisation

Highlights

- Modelling with publicly available quantitative data provides little guarantee of accurate prediction of COVID-19-related indicators
- Epidemiological surveys with a mixed data collection design allow better adaptation of the models to local contexts
- In Senegal and in some African countries, in addition to health issues, the exploration of vulnerability issues (social, economic, and religious) as well as people's perceptions of public policies adds value to the accuracy of projections in relation to COVID-19 indicators

1 | CONTEXT

Since the outbreak of the SARS-COV2 epidemic turned into a COVID-19 pandemic, international bodies such as the WHO as well as governments have announced projections for morbidity and mortality indicators related to COVID-19. These projections have been remarkable at the African level. Most of them indicated that the health situation would be worrying. They even led to the WHO to call on Africans in March 2020 to 'wake up' and 'prepare for the worst' in the face of the spread of the pandemic, when the new coronavirus had caused a single death in Burkina Faso, the first in sub-Saharan Africa.[1]

In Senegal and other African countries, projections based on quantitative modelling using the SIR method and its variants were made to predict the outcome of the pandemic in terms of the number of cases, hospitalisations and deaths.[2] For example, several dates that were expected to correspond to the epidemic peak were officially announced without much agreement.

Although using artificial intelligence with mathematical algorithms and/or neural networks, the results of the SIR models were poorly performing and not very accurate in relation to the observed reality in the African states in general and in Senegal in particular.

However, these compartmental epidemiological models began to be put into practice with the HIV/AIDS infection in the 1980s, and gained momentum during this COVID-19 pandemic. Modelling, if accurate, should be used in public health policy-making and also contribute to good epidemiological surveillance.

Deviations from the observed reality may be due to a lack of or concern about the reliability of the basic data that feeds these models. These data are often routinely collected and aggregated by central services or organisations, without many guarantees in terms of methodology or validity. Also, it could be added that the models directly imported do not free themselves from Western contingencies to be adapted or adjusted to certain African realities. Hence the imperative need to configure the modelling process and approach taking into account local contexts.

2 | GENERAL PRINCIPLE OF SIR MODELS AND ITS VARIANTS[3]

These models globally divide the population into four categories (or compartments). For example, for a given population, the size of four sub-populations over time t is studied with:

1. $S(t)$ which represents susceptible, that is, uninfected and non-immune individuals;
2. $E(t)$ referring to exposed individuals;
3. $I(t)$ corresponding to infected persons;
4. $R(t)$ representing those who have been withdrawn, that is, cured and immune, or who have died.

Integrating into the models issues of vulnerability (social, economic, religious, etc.) and people's perception of public policy to add value to the accuracy of the prediction of COVID-19 indicators.

It is important to change the paradigm by going off the beaten track; that is, to say, to consider qualitative information collected after a large-scale mixed survey.

Classical epidemiological models do not include enough contextual parameters and the most frequently used risk factors are still the disease (circumstances of contamination, severity, treatment, etc.), age and co-morbidities, which are positively correlated regardless of location. Otherwise, the frequency of comorbidities would increase with age. Also, the elderly in Africa are proportionally less exposed than in most northern countries because they live within the protective family circle rather than in dedicated institutions. There is also the low proportion of elderly people, especially in sub-Saharan Africa. This could reduce the incidence of the disease and therefore the mortality of this group in this continent.

In order to better adapt the models to ensure better epidemiological surveillance of the COVID-19 pandemic, other indicators or markers of social and religious economic vulnerability are often essential for quality projections. These may include poverty including food insecurity, use of cooking fuel (charcoal, wood, butane gas or other forms of indoor pollution…), the existence of basic social services in neighbourhoods or villages such as the availability of drinking water, the frequency of cash transfers in households as well as the perception of the populations regarding institutional measures and non-pharmaceutical interventions. These data should be collected in a mixed epidemiological survey, with a national focus and satisfactory statistical power, calculated in proportion to the demographics of the randomly selected localities.

2.1 | Statistical implementation of the mixed approach

The model implemented is a mixed prediction model based on the Bucky model developed by OCHA[4] and adapted to the context.

This model is a temporal graph that represents regions and mobilities between them with nodes and branches. The construction of the mixed model was done in two steps.

First, we established a basic model with publicly available data, such as those from United Nations-like organisations such as OCHA or WHO for Senegal.

In a second step, we improved this model by adding more specific data collected through the mixed epidemiological survey. This survey was conducted in Senegal, using a three-stage sampling (regions, households, individuals) in six localities (Dakar, Thiès, Diourbel, Kédougou, Saint-Louis and Ziguinchor) chosen according to the number of confirmed cases of COVID-19. In total, 1000 individuals distributed in proportion to the size of the regions were interviewed in April 2021.

This data was ultimately used to create scripts to directly modify the parameters of the graph. This helped to refine the model and obtain more accurate projection results.

2.2 | Comparative prediction results: Baseline versus mixed data

The table below shows the differences in the parameter values of the baseline model, without mixed data, and the hybrid model which contains both quantitative and qualitative data. The difference between these values is shown in green (increased vulnerability) or red (reduced vulnerability; Table 1).

It appears that in the baseline data, food insecurity documented by the Integrated Phase Classification (IPC), for which there were no data available for Senegal, as well as solid cooking fuels, which all households surveyed used in some form, and the ability to wash hands, to which almost all households had access, were underestimated.

In contrast, the prevalence of high blood pressure and diabetes is overestimated in these baseline data.

Taking these parameter variations into account in the hybrid model resulted in an increase in projected cases and a slight decrease in deaths, as shown in Figures 1 and 2.

In the figure below, the projected cases in the baseline model were already considerably higher than the cases reported in April. This may be plausible, given the low detection rates throughout Senegal during this period. However, the hybrid model predicted an even higher infection rate than the baseline, perhaps mainly due to vulnerability related to food insecurity and solid cooking fuels. This may mean that there would be more unreported cases than reported.

In the figure below, the mortality rate of the hybrid model was lower than the mortality rate of the reference model.

Overall, the mortality rate of both models would be considerably lower than the government-reported mortality rate, even though the number of confirmed cases remains high. This may be an underestimate of the death rate.

TABLE 1 Parametric values for basic and hybrid modelling

Parameter	Baseline	Hybrid	Difference
Food insecurity	0	0.452702	0.452702
Solid cooking fuel	0.38060165	1	0.61939835
Handwashing	0.68072253	0.98342862	0.30270609
Hypertension	0.10414529	0.01728019	−0.0868651
Diabetess	0.02264028	0.00902443	−0.0136159
Fraction of vulnerability	0.38060165	0.15966887	−0.2209328

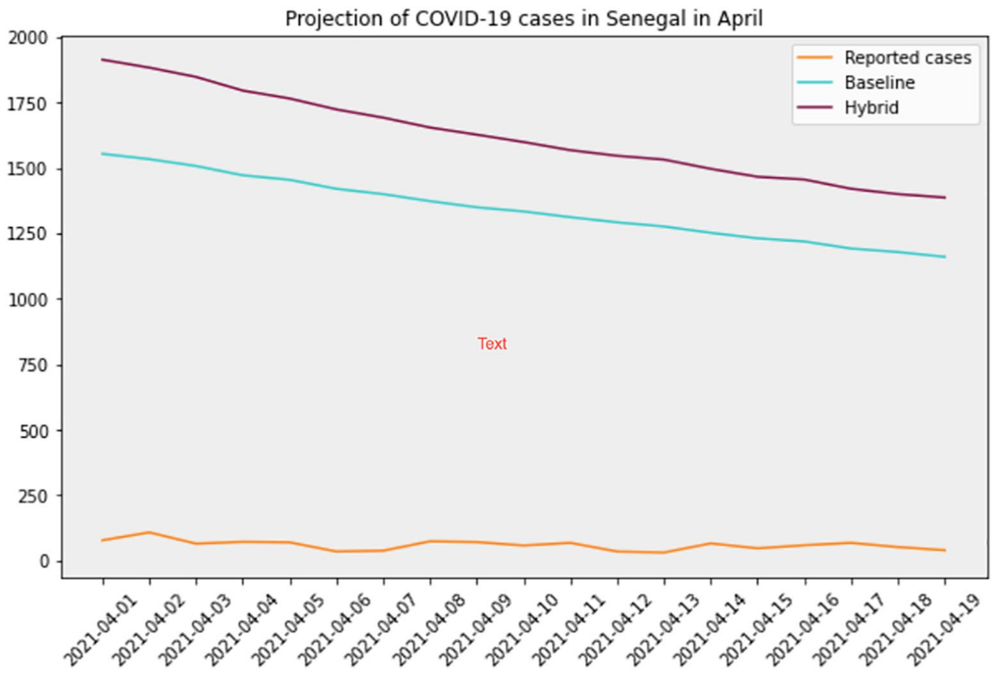

FIGURE 1 Projection of COVID-19 cases in Senegal in April

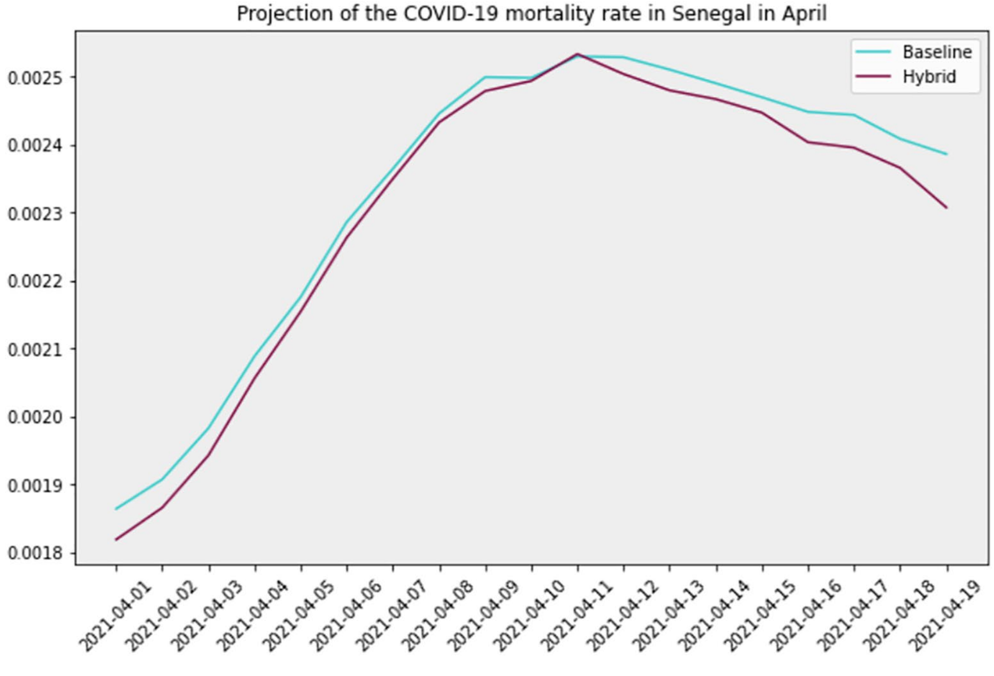

FIGURE 2 Projection of the COVID-19 mortality rate in Senegal in April

Furthermore, the lower mortality rate for the hybrid model compared to the baseline model is due to a reduction in the proportion of co-morbidities (diabetes and high blood pressure) that were overestimated with the baseline data, in contrast to the mixed survey results.

3 | CONCLUSION

An accurate and reliable prediction in times of epidemics and/or pandemics, such as COVID-19, should be based on mixed or hybrid data integrating a quantitative and qualitative approach to enable better policymaking. The projections resulting from this approach would still be effective and would take better account of local realities and contexts, especially for developing countries.

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CONFLICT OF INTEREST

We have no conflict of interest about this work.

ETHICS STATEMENT

This work have received ethic approval of the committee of ethic in the ministry of health of Senegal. People, before their answers, gave their free and informed consent and data were managed with confidentially.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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