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Influence of population density and access to sanitation on Covid-19 in Mozambique

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ABSTRACT

In 2020, as COVID-19 spread worldwide, prestigious entities published faulty predictions about the level of dissemination, especially when describing African countries and others with "weak healthcare systems." How could the best fall so short, even when using well-known epidemiological variables to predict the behavior of a hygiene-related malady? It might have been due to insufficient data since COVID-19 was a novelty, still poorly understood. The current study aimed to analyze how two variables – population density and percentage of people with access to improved sanitation – affected the number of confirmed COVID-19 cases in Mozambique by February 2021, almost one year since the first case in the country. All data were publicly available: population density in Census 2017, access to sanitation in the Mozambique Public Expenditure Review 2014, and the number of COVID-19 cases in the Ministry of Health's COVID-19 daily bulletin (no. 332). JASP 0.13.1.0 allowed correlating all variables, and Microsoft Excel™ was chosen to perform fitting analysis to model the algebraic relationship between the number of cases and the other variables. The cases showed a positive correlation ($r = 0.663$) with density, and their relationship was consistent with a cubic function. Sanitation coverage also showed a positive correlation ($r = 0.679$), but the most straightforward algebraic representation was a quadratic function. The impact of population density on the number of COVID-19 cases was intuitive, but the logic points towards the highest number of cases where sanitation facilities lacked the most. Thus, the influence of other factors outweighed the effect of sanitation, or people tend to be careless before the sense of security where the sanitation is better. Nevertheless, these findings can support predictions and decision-making, and the population needs to abide by the Government's recommendations.

Keywords: Population density; Sanitation; Covid-19; Mozambique

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INTRODUCTION

As COVID-19 entered African countries, there were uncertainties due to lack of data, combined with misinformation and infodemic. Therefore, it was hard to deliver clear-cut accurate analyses of the factors affecting the pandemic. Some variables intuitively affected the dissemination of COVID-19, as the article "African miracle"[1] mentioned in June 2020. However, there were by then only three months of data to make any sense of the evidence. A "usual suspect" was population density because the logic points to a higher risk of COVID-19 the more people inhabits a particular area. On the other hand, in the same article, I said predicting a tragedy in Africa solely based on the population's poor hygiene and sanitation access was an oversimplification. Nevertheless, I never meant that poor sanitation would not affect the dissemination of COVID-19 because the disease is hygiene-related.

The Mozambican Government reported the first confirmed case of COVID-19 on 23 March 2020. By now, it has been approximately one year, and it seems to be an excellent time to make some sense of the data available. For instance, it is reasonable to assume that COVID-19 would take some time to develop a distribution pattern according to the population density, in part as a function of the virus reproduction rate (R0). Furthermore, there is an overwhelming body of evidence supporting the population density's impact on disseminating COVID-19[2-4], besides the logic and common sense. Arnaldo et al.[5] published an attempt to predict the risk of COVID-19 in all Mozambique districts based based on factors, including population density. However, they did not provide tangible evidence of the association between the variables in the country, thus writing a merely speculative analysis.

Poor sanitation, hygiene, and weak healthcare systems were the pillars of argumentation for Tedros Ghebreyesus[6] and Melinda Gates[7], who wrongly predicted a higher impact of COVID-19 in Africa than anywhere else. Their logic seemed reasonable, with historical examples of diarrheal and other hygiene-related maladies[8]. However, they overlooked several variables such as immunity, weather, and the leaders' commitment to the World Health Organization guidelines[1,9]. Poor sanitation was not initially a major problem because COVID-19 entered Mozambique through people from the upper classes who came from European countries or South Africa, had access to the best sanitation, and had little contact with the "common" population [10], transmitting to few people. Eventually, the disease reached crowded areas with poor hygiene practices such as markets[11,12], and only then, sanitation became a significant issue.

The current study aims to validate that population density and access to sanitation are among the variables influencing the dissemination of COVID-19 in Mozambique. In addition, the results will provide support to health personnel, policy-makers, and scholars who need to understand better the pattern of dissemination of COVID-19 in Mozambique and countries with similar natural and social settings.

MATERIAL AND METHODS

Mozambique (10°27'S and 26°52'S;30°12'E and 40°51'E) is a country on the southeastern coast of Africa (Map 1), bordered by the Indian Ocean (east), Tanzania and Malawi (North), Zambia and Zimbabwe (West), South Africa, and Eswatini (southwest)[13]. The population is approximately 27,909,798, with 28.7 inhabitants/km^2 as density[14]. Mozambique has ten provinces plus the capital and largest urban area, Maputo City (considered a province), located in the southern area [15].

By 2015, approximately 46% of the population lived below the poverty line (US $1.9 purchasing power parity), and 40% had access to improved sanitation[16]. Limited access to sanitation is among the causes of Cholera[17] and other hygiene-related diseases[18], certainly increasing the risk of COVID-19 among the Mozambican population. According to World Bank Group[16], only 14% of the population below the poverty line and 42% above it had sanitation facilities in 2015.

Map 1 - Mozambique. Source: Library of Congress[19], under public domain.

Data retrieval and analysis

The data was retrieved the data on 11 February 2021:Mozambican population density (in inhabitants/km^2) per province from Census 2017 report [20] and data on the percentage of the population with access to sanitation facilities per province in the Mozambique Public Expenditure Review 2014[21], and the number of confirmed cases from the Ministry of Health's COVID-19 daily bulletin number 332[22]. JASP 0.13.1.0 (University of Amsterdam, Amsterdam, The Netherlands, 2020) computed Pearson correlations. Microsoft Excel 2016 (Microsoft Corporation, Washington DC, USA, 2016) was used to perform curve fitting between the number of confirmed cases of COVID-19 and the other two variables and analyze the determination coefficients. Maputo City was included in the study because it is administratively a province.

Table 1 - Mozambique's provinces, population densities, percentage of people with access to sanitation facilities, and the number of COVID-19 confirmed cases by 8 February 2021

Province	Density (inhabitants/km^2)	People with access to sanitation facilities (%)	COVID-19 confirmed cases
Maputo City	3,131	73	21,828
Maputo Province	87	46	7,236
Gaza	19	32	2,646
Inhambane	22	17	2,469
Manica	31	20	1,724
Sofala	33	22	2,576
Tete	27	17	1,528
Zambézia	49	6	2,641
Nampula	73	21	1,617
Cabo Delgado	28	6	1,976
Niassa	14	28	1,549

Sources: Maunze et al. [20], The World Bank Group [21], and Ministério da Saúde [22].

As Figure 1 shows, the number of COVID-19 confirmed cases showed significant Pearson correlations with the population density (p = 0.037) and the percentage of people with access to sanitation (p = 0.031). However, both correlations did not differ much in value.

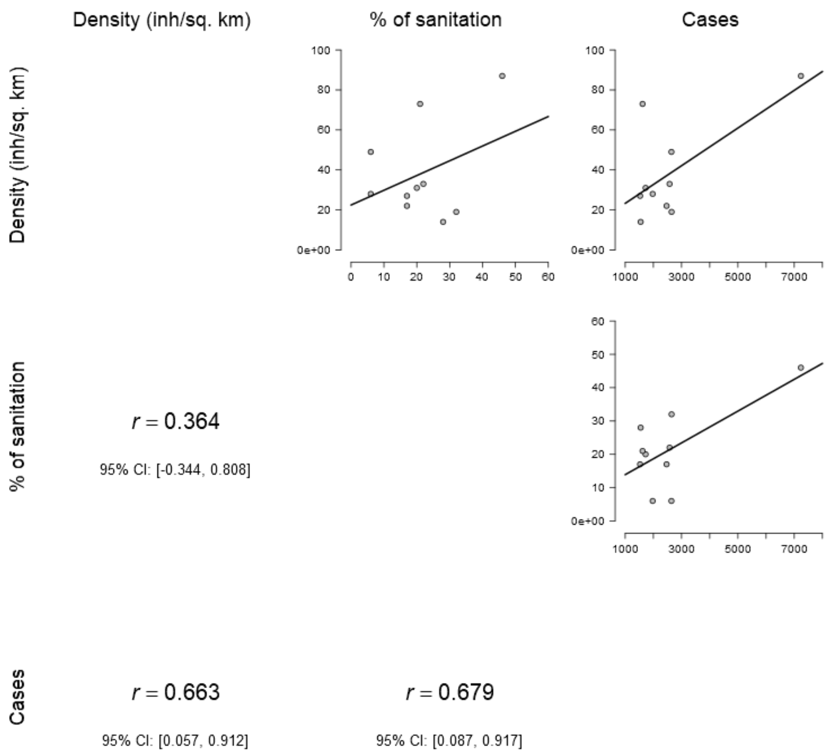

Figure 1. Correlation matrix between population density, percentage of people with access to sanitation, and the number of confirmed cases by 8 February 2021 in Mozambique. Note: inh/sq. km = inhabitants/km2; % of sanitation = percentage of people with access to sanitation.

The density did not seem related to the percentage of people with access to sanitation, reinforcing the idea that these variables had an independent impact on the number of cases. This independence is essential because both variables could be "two sides of the same coin," i.e., one could be affecting the other as the root of the impact both present on the number of cases. Thus, only one would be enough to perform the analysis from this point forward.

Figure 2 presents the result of a fitting analysis showing the simplest algebraic curves representing how de values population density and the number of people with access to sanitation facilities can serve as predictors of the number of confirmed cases by 8 February 2021 in Mozambique. Both independent variables presented strong coefficients of determination (R2 > 0.5).

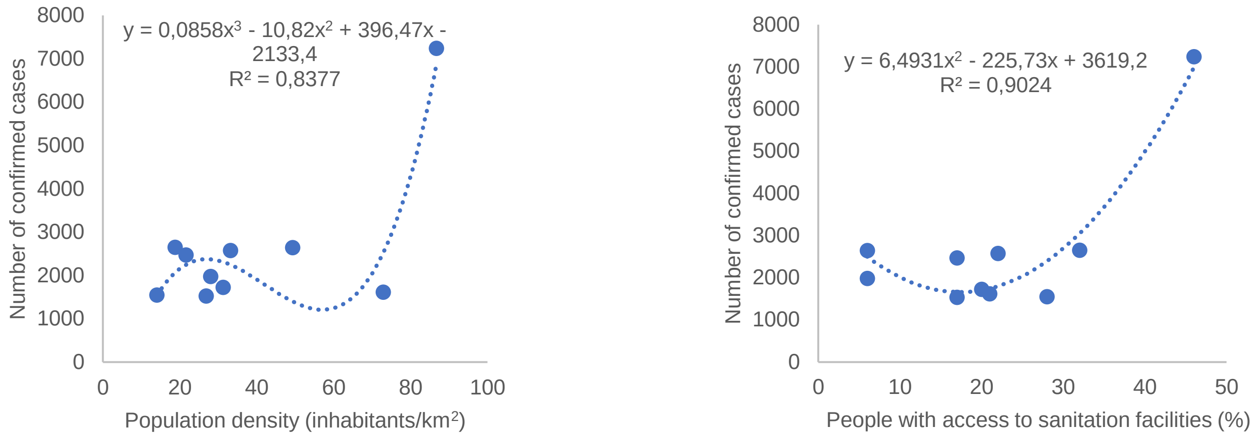

Figure 2. Regression analysis of the number of confirmed COVID-19 cases as a function of (a) population density and (b) percentage of people with access to sanitation in Mozambique.

The curve of population density and number of cases presented some consistency ($R^2 = 0{,}84$) with a cubic function, being such regression more complex than the square function (with $R^2 = 0{,}9$) between access to sanitation and the confirmed cases. From this data, access to sanitation seems to be a more reliable predictor of the number of cases, although this curve's shape seems counterintuitive, an aspect discussed in the following section.

Discussion

The results suggested that the number of COVID-19 confirmed cases present positive correlations with population density and the percentage of people accessing sanitation in Mozambique. Furthermore, as predictors of the number of cases, the population density showed a relationship consistent with a cubic function, and the access to sanitation presented a quadratic curve. In advance, it is essential to know that the literature presents plenty of studies about the impact of population density on the number of cases of COVID-19 but not as frequently discussing the relationship between access to sanitation and the pandemic.

Maputo City, its considerably dense population, high access to sanitation facilities, and many COVID-19 confirmed cases. As the capital, Maputo City is the country's most developed and arguably the busiest area, with people arriving every day from all over the country to study or search for labor opportunities, and it is among the main entry points for people coming from abroad. As mentioned in a previous study [9], the city's features turned it into a "hotspot" of COVID-19 dissemination since the pandemic entered the country. Due to the New Year-related events, the situation worsened in Maputo City, with many tourists from South Africa and the weak enforcement of COVID-19 preventive measures[23]. Other areas were also busy, had New Year parties, and received tourists, but not likely as much as Maputo City. Thus, the city was the "stage" of a unique situation for peculiar reasons.

The correlation cubic regression analyses reinforced the idea that population density influences COVID-19 cases in Mozambique. The correlation suggested that, from a simplistic perspective, the intuitive idea that the more people live in a particular area, the more susceptible it is for COVID-19 dissemination. More than intuitive, there is evidence backing up the idea [3,24,25]. Some studies did not find enough evidence to conclude that population density affects COVID-19 spreading 2,4, but they resulted from early analyses when data was insufficient to find consistent patterns The impact of density on disseminating the pandemic compares to a network of pipes and tanks as water runs through it. In the beginning, water is more abundant in the source, but it takes the system's shape as it fills, and in the end, it is more abundant in the tanks. By the same logic, highly populated areas imply more encounters among people, thus, more occasions for COVID-19 transmission. Still, the relationship between density and the number of cases seemed more complex, more easily represented through a cubic function. This complex relationship might result from other factors such as weather[9], reinforcement of methods to control the pandemic, and the pattern of migration or people's behavior[1]. Several correlation-based and linear regression-based studies analyze the influence of population density on the pandemic, but they do not search for algebraic functions that had better represent such influence.

To the best of the author's knowledge, the only peer-reviewed study published (locally) in Mozambique about the influence of density on the number of COVID-19 cases, by Arnaldo et al.[5], assumed a relationship between the variables, arbitrarily using the idea for further analyses. The authors aimed to predict the risk of COVID-19 dissemination based on different variables, including population density. However, they had no clear information on how severely density could affect the number of cases, resting their proposition on speculation. The current study attempts to clarify and provide statistical support to Arnaldo et al.[5].

Regarding how access to sanitation facilities affected the number of confirmed cases, the result seemed counterintuitive, i.e., more people with access to sanitation should imply more hygiene and fewer cases of COVID-19. There are some possible explanations: (1) the country's more developed areas have more people with access to sanitation, but are also the busiest, where the disease can spread more easily; (2) people with limited sanitation facilities tend to value more such resources, using more adequately. Ekumah et al.[26] collected data on access to sanitation and the number of COVID-19 cases in 25 countries of Sub-Saharan Africa, including Mozambique, but their overall result indicate that lack of sanitation, combined with lack of clean water and food storage, is associated with a higher level of violation of lockdown regulations, and a higher risk of COVID-19. The authors analyzed the issue at an international level, thus using data biased due to differences in COVID-19 emergency or lockdown policies and other social and natural factors. Ha et al.[27] and Amaechina et al.[28] also discussed the importance of sanitation for COVID-19 prevention, but they were more concerned about policies to facilitate the distribution of water and sanitation facilities. Thus, this might be the first study analyzing at a country level how the sanitation coverage affected the cases of COVID-19. Perhaps time will allow gathering more robust data to understand the phenomenon, but so far, it is crucial to persuade the population in densely inhabited areas to abide more responsibly by COVID-19 preventive measures, particularly hygiene.

Future studies shall revisit how COVID-19 dissemination in Mozambique relates to population density, access to sanitation, and include other variables such as the access to healthcare services and the variables mentioned in the paper about the "African miracle" [1]: level of implementation of the Strategic Preparedness and Response Plan[29] and other guidelines from the World Health Organization (WHO), population migration patterns, the dynamics and management of other illnesses, population age profile, immunity, and vaccination.

CONCLUSION

The study suggests that the number of COVID-19 cases is directly proportional to population density and sanitation access. The correlations were significant ($p < 0.05$) and high enough to admit their strength ($r > 0.5$). Fitting analysis showed consistency with algebraic curves representing the predictability of COVID-19 confirmed cases through the population density (cubic function) and access to sanitation in percent (square). More important than understanding a phenomenon is to reason on what to do about it. In this case, population density is a good tool for predictions and decision-making. Knowing how density affects COVID-19 dissemination allows one to understand the spatial pattern of the number of cases throughout the country if the situation does not change. Regarding sanitation, the mere availability of facilities is not enough to ensure the control of COVID-19. It is also essential to promote good hygiene practices and strict fulfillment of the Government's recommendations.

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