Modelling COVID-19 Risk in Kenya To Enhance Humanitarian Response

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Abstract

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is a highly transmissible and pathogenic coronavirus that emerged in late 2019 in Wuhan, China. The SARS-CoV-2 has caused a pandemic of acute respiratory disease named 'coronavirus disease of 2019' - COVID-19 - which has threatened human health and public safety. COVID-19 was first reported in Kenya on the 12th March 2020. Since March till November 2020, the rate of COVID-19 infection is high in Kenya, with over 60,000 cases being reported in all 47 counties in Kenya resulting in over 1000 deaths and approximately 40,000 recoveries. This study looked at structural risk factors to COVID-19 that existed before the outbreak and may have direct and indirect effects on COVID-19 risk across all the 47 counties in Kenya. These factors are COVID-19 exposure and vulnerability and lack of adaptive capacity to COVID-19. The Index for Risk Management (INFORM) COVID-19 risk index was used as a composite index to combine the various risk factors through assigning weights. From the COVID-19 risk index counties such as Nairobi, Kiambu, Meru, Kakamega and Nakuru have been identified to be at high risk from health and humanitarian impacts of COVID-19 that could potentially overwhelm national response capacity. These counties are characterized by high COVID-19 cumulative confirmed cases, high number of vulnerable populations such as the elderly, disabled and population of street persons/ outdoor sleepers. These counties also have low numbers of ICU (Intensive Care Unit) and COVID-19 isolation centres. Therefore, the KRCS and other humanitarian organizations are recommended to prioritize COVID-19 preparedness and response efforts in these counties with high COVID-19 risk score. Such efforts would include conducting mass campaigns through public address systems, distribution of personal protective equipment (PPEs) to vulnerable communities, community sensitization and advocacy for prepositioning of adequate ICU and isolation centres. The INFORM COVID-19 risk index composite index approach employed in this study could be downscaled at subcounty to ward level to better understand COVID-19 risk at community level. The approach used in this study could be replicated to other countries to better help humanitarian organization in prioritizing their COVID-19 preparedness and response efforts in counties with high COVID-19 risk score.

Keywords: COVID-19, Index for Risk Management, COVID-19 risk index

1. Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is a highly transmissible and pathogenic coronavirus that emerged in late 2019 in Wuhan, China (Hu et al., 2020). The coronavirus 2 has caused a pandemic of acute respiratory disease named 'coronavirus disease of 2019' - COVID-19 - which has threatened human health and public safety. The first onset of the first recorded case of COVID-19 was in Wuhan, China (Liu et al., 2020). This was recorded on the 8th of December 2019. 27 cases of pneumonia with unknown cause in Wuhan were first reported on 31st December 2019 (WHO, 2020). Within 6 days, the coronavirus had spread to all 34 provinces across China prompting the World Health Organization (WHO) to declare a public health emergency of international concern (PHEIC) alert. As of 28th February 2020, WHO risk assessment increased to very high on the global scale. WHO defined COVID-19 as a pandemic on the 11th March 2020 (WHO, 2020).

In Africa, it was first reported in Egypt on 14th February 2020 (Lone & Ahmad, 2020). Within three months the virus had spread throughout the African continent. COVID-19 was first reported in Kenya on the 12th March 2020 (Aluga, 2020). As of then the virus had spread to over 110 countries worldwide with over 44000 cases confirmed and 1400 deaths according to WHO. Since March till November 2020, the rate of COVID-19 infection in Kenya has been high, with over 60,000 cases being reported in all 47 counties resulting into over 1000 deaths and approximately 40,000 recoveries (OCHA, 2020). The Kenyan government put a lot of stringent measures to stop the spread of the virus. Such measures included regularly washing of hands, maintaining social distance, suspension of public gatherings, cessation of movement, nationwide curfew, closure of recreational facilities among others (Mbae, 2020). Humanitarian organizations such as the Kenya Red Cross Society (KRCS) began initiating key actions to alleviate the impact of COVID-19 pandemic by complimenting government and other partner efforts at both National and county level. Such key actions included conducting mass campaigns through public address systems, distribution of PPEs to vulnerable communities, community sensitization, conducting household visits among others (KRCS, 2020).

The European Commission, Joint Research Centre (JRC) came up with the index for risk management (INFORM) COVID-19 Risk Index to support prioritization of preparedness and response actions to COVID-19 by humanitarian organization (De Groeve et al., 2015). The main scope of the INFORM COVID-19 Risk Index is global and regional risk-informed resource allocation where comparable understanding of countries' risk is important (Marin Ferrer, M. & Vernaccini, L, n.d.)L, n.d.. The INFORM COVID-19 Risk Index is primarily concerned with structural risk factors that existed before the outbreak and may have direct and indirect effects on COVID-19 spread. These factors consist of hazard and exposure, vulnerability and lack of coping capacity dimensions. These factors include cumulative COVID-19 cases within the hazard dimension, movement and behavior components, comorbidities and demographic characteristics of affected population within the vulnerability dimension and health system capacity under lack of coping capacity.

Besides the INFORM COVID-19 Risk Index, there exists other frameworks that have been used to map COVID-19 vulnerability in Africa. The Africa COVID community vulnerability index (CCVI) is an index that assesses health, economic and social impacts of COVID-19 in 48 African countries (Surgo Ventures, 2020). The CCVI looks at age, epidemiological, fragility, health system, population density, socio-economic, transport availability and housing indicators.

In Kenya, a vulnerability index for COVID-19 has been developed by (Macharia et al., 2020) at a subnational level. This study used geospatial indicators to create the socio-epidemiological vulnerability index (SEVI) that is a combination of social (socio-economic deprivation, access to services and population dynamic indicators that affect the spread of COVID-19) and epidemiological (comorbidities associated with COVID-19 severe disease progression) vulnerabilities.

While CCVI and SEVI approaches look into socio-economic, demographic, epidemiological and health system factors, they immensely miss out on the person-to-person component of COVID-19 hazard and exposure. This is the most relevant indicator to COVID-19 and at times can be used alone to define COVID-19 risk. Therefore, this study uses the INFORM COVID-19 Risk Index in order to identify counties in Kenya at risk from health and humanitarian impacts of COVID-19 that could potentially overwhelm national response capacity. The study also shows how the INFORM COVID Risk Index can be used to support humanitarian organizations such as KRCS in prioritization of preparedness and early response activities for the pandemic.

2. Materials and Methods

This study used openly available data on COVID-19 exposure, vulnerability and lack of adaptive capacity to model COVID-19 risk in Kenya. Data on exposure was obtained from the Ministry of Health daily press releases and situation reports (MoH, 2020). This data contains cumulative confirmed cases across all 47 counties. Data on vulnerability was obtained from the 2019 Kenya National and Population Census (KNBS, 2020). This data contains information in all 47 counties on human population, number of population of street persons/ outdoor sleepers, population below 14 years, population between 15-29 years, population between 30-59 years and population above 60 years across all counties in Kenya. Adaptive capacity indicators at county level were obtained from the Ad Hoc Committee on the COVID-19 situation in Kenya report. The specific adaptive capacity indicators used for this study were number of isolation beds and ICU (INTENSIVE CARE UNIT) beds across all counties in Kenya.

COVID-19 indicators were normalized in order to make them have the same scale so that they could be of equal importance. Minimum-maximum normalization was applied on vulnerability and exposure indicators as they positively associate with COVID-19 where minimum values were transformed into 0 and maximum values were transformed into 100 (Patro & Sahu, 2015).

$$Xmin.max = (X - Xmin / Xmax - Xmin) * 100$$

Equation 1 Min-max standardization formula

Reverse minimum-maximum normalization was applied for adaptive capacity indicators that negatively associate with COVID19 where minimum values were transformed into 100 and maximum values were transformed into 0 (Patro & Sahu, 2015). .

$$Xmax.min = (Xmax - X / Xmax - Xmin) * 100$$

Equation 2 Max-min standardization formula

After standardization, each COVID-19 dimension was given varied weightings based on their importance to COVID-19 that added up to 1 in order to generate COVID-19 exposure, vulnerability and adaptive capacity indices. This as shown below.

$$Exposure = 1.0*_{\text{cumulative covid-19 cases}}$$

$$Vulnerability = 0.3*_{\text{population above}}60 + 0.3*_{\text{disabled population}} + 0.3*_{\text{street population}} + 0.1*_{\text{population}}$$

$$Adaptive\ capacity = 0.25*_{\text{isolation beds}} + 0.25*_{\text{isolation ICU beds}} + 0.25*_{\text{ventilators}} + 0.25*_{\text{ICU beds general}}$$

Equation 3 Weighting of COVID-19 dimensions

The 3 COVID-19 dimensions were then combined using equation 4 to generate the COVID-19 risk index

$$\text{COVID-19 risk} = \text{Exposure} + \text{Vulnerability} + \text{Adaptive capacity}$$

Equation 4 Multi-hazard combination equation

Thematic maps were generated to compare spatial distribution of COVID-19 dimensions across all 47 counties in Kenya. The quantile classification method was used in classification of thematic maps into 5 classes, namely very low, low, medium, high, and very high. This classification method is well suited to linearly distributed data where the same number of data values are assigned for every class (Guimera & Amaral, 2005).

Results

Exposure

Cumulative COVID-19 cases were used as the only COVID-19 exposure indicator. This indicator positively influenced COVID-19 risk where more numbers of cumulative COVID-19 cases imply high risk. The counties with the most cumulative COVID-19 cases were Nairobi, Mombasa, Busia, Kajiado, Kiambu, Machakos, Migori, Kisumu and Uasin Gishu. The exposure index was calculated at county level to show the inter-county differences in COVID-19 cumulative cases (Figure 1). The choropleth map shows that counties with higher cumulative cases are more likely to be at higher risk of COVID-19.

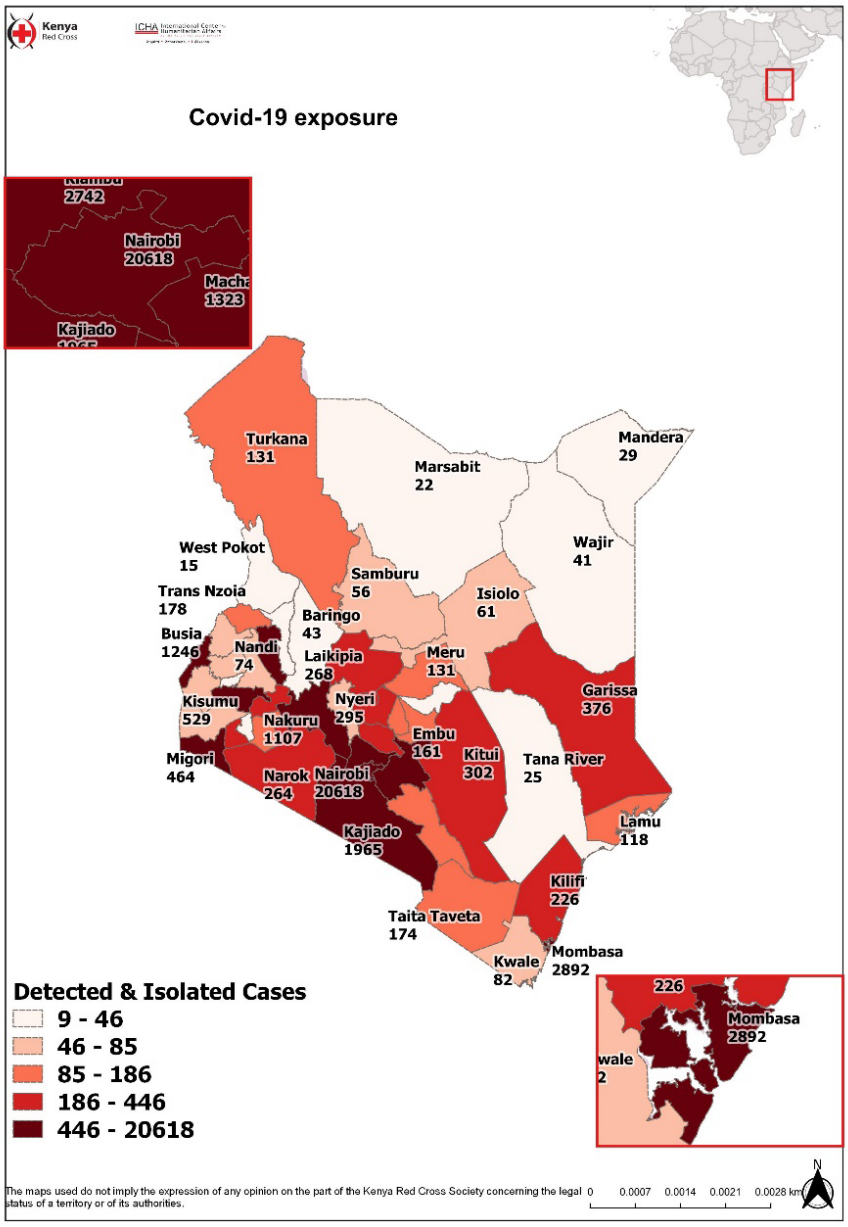


Figure 1 Cumulative confirmed COVID-19 cases

Cumulative COVID-19 cases were given weightings of 1 in order to generate COVID-19 exposure index.

$$\text{Exposure} = 1.0 * \text{cumulative covid-19 cases}$$

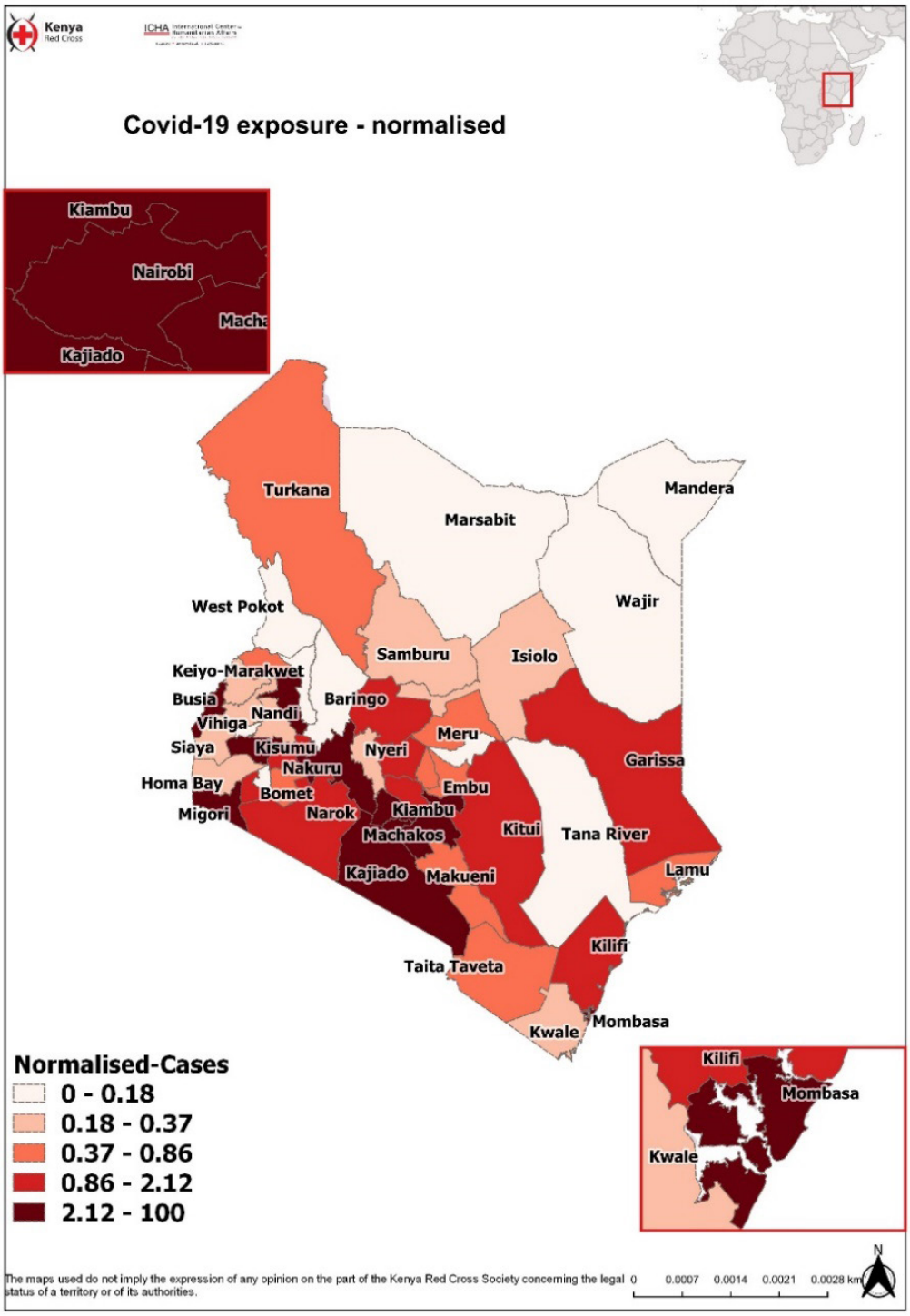


Figure 2 Normalized cumulative confirmed COVID-19 cases

Vulnerability

Population above 60 years old, disabled population, population of street persons and human population were used as COVID-19 vulnerability indicators. These indicators positively influence COVID-19 risk where more numbers imply high risk.

Counties such as Nairobi, Kiambu, Mombasa, Kilifi, Nakuru, Meru, have the highest human population thereby making them to be more vulnerable to COVID-19 (Figure 3). Counties such as Mandera, Wajir, Marsabit, Tana River have the least human population thereby making them to be less vulnerable to COVID-19.

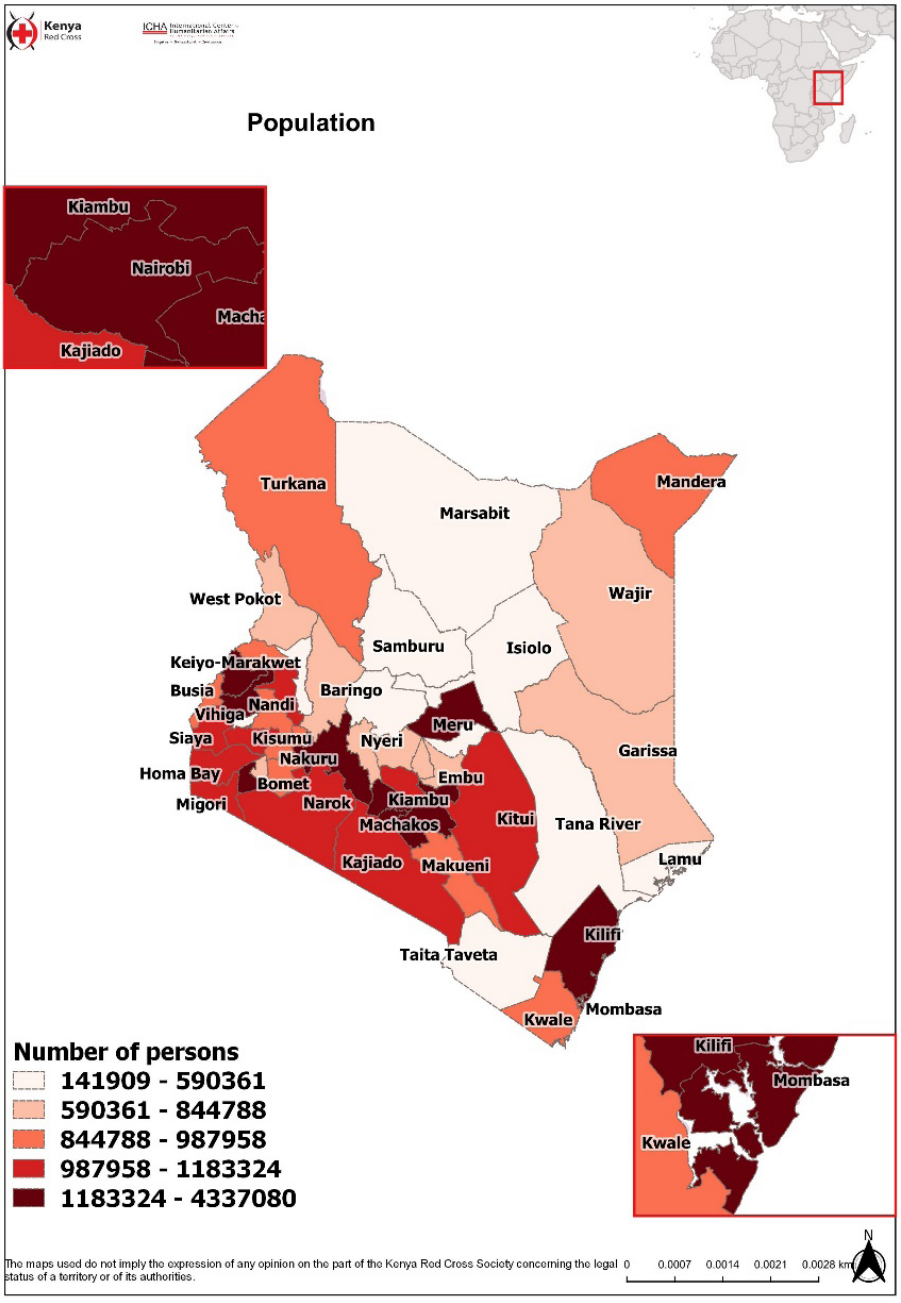


Figure 3 Population distribution across counties

Kakamega, Kiambu, Meru, Murang'a and Machakos counties have the highest number of people above the age of 60 years (figure 4) thereby making these counties to be vulnerable to COVID-19. Lamu, Isiolo, Samburu, Tana River and Wajir counties are less vulnerable to COVID-19 due to their low number of persons above the age of 60 years as well low human population numbers.

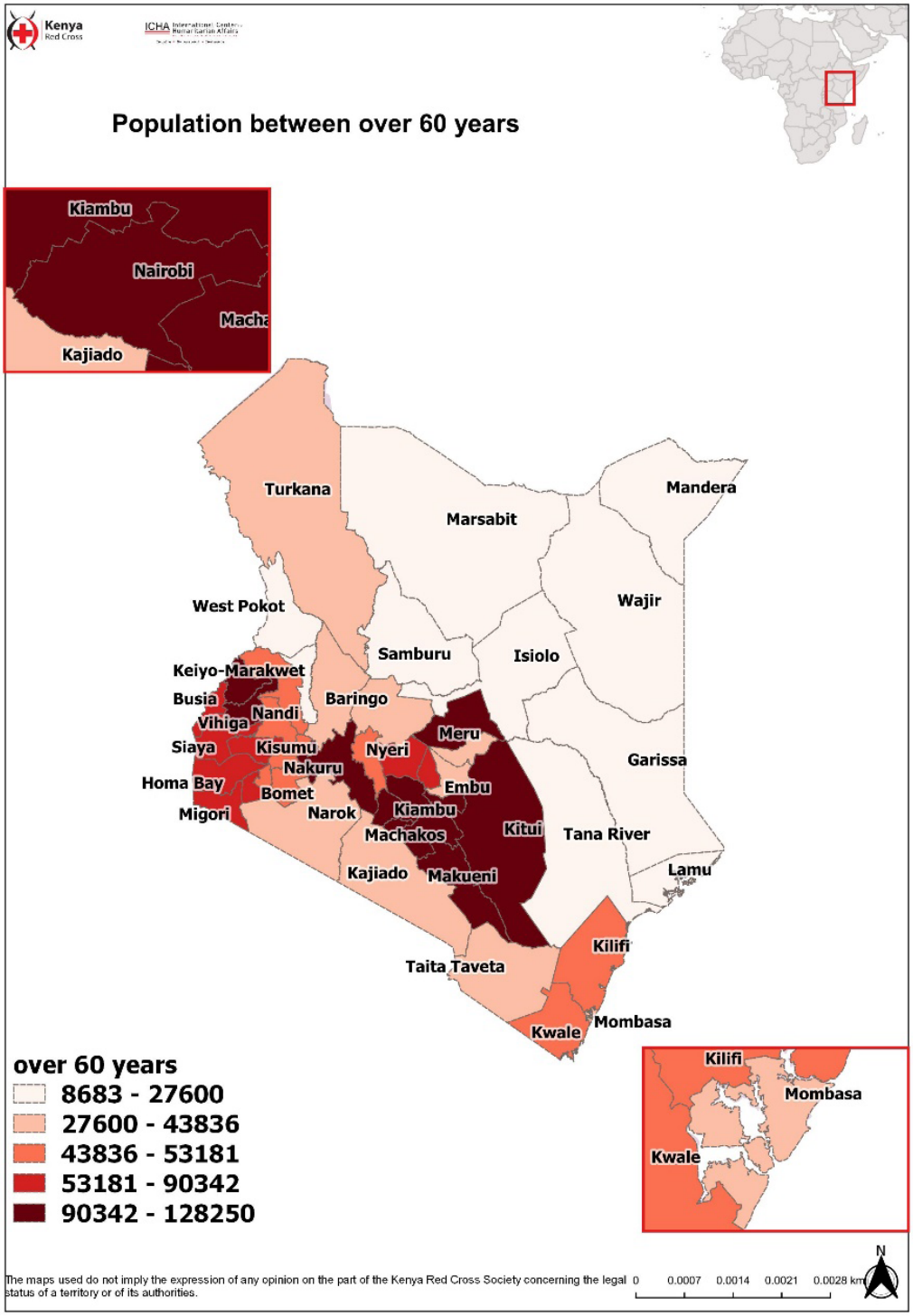


Figure 4 Population above 60 years

Meru, Kakamega, Kiambu, Homa Bay and Kisumu have the highest number of disabled persons (figure 5) making them to be more vulnerable to COVID-19. Lamu, Isiolo, Marsabit, Samburu and Tana River have the least number of disabled persons thereby making them to be less vulnerable to COVID-19.

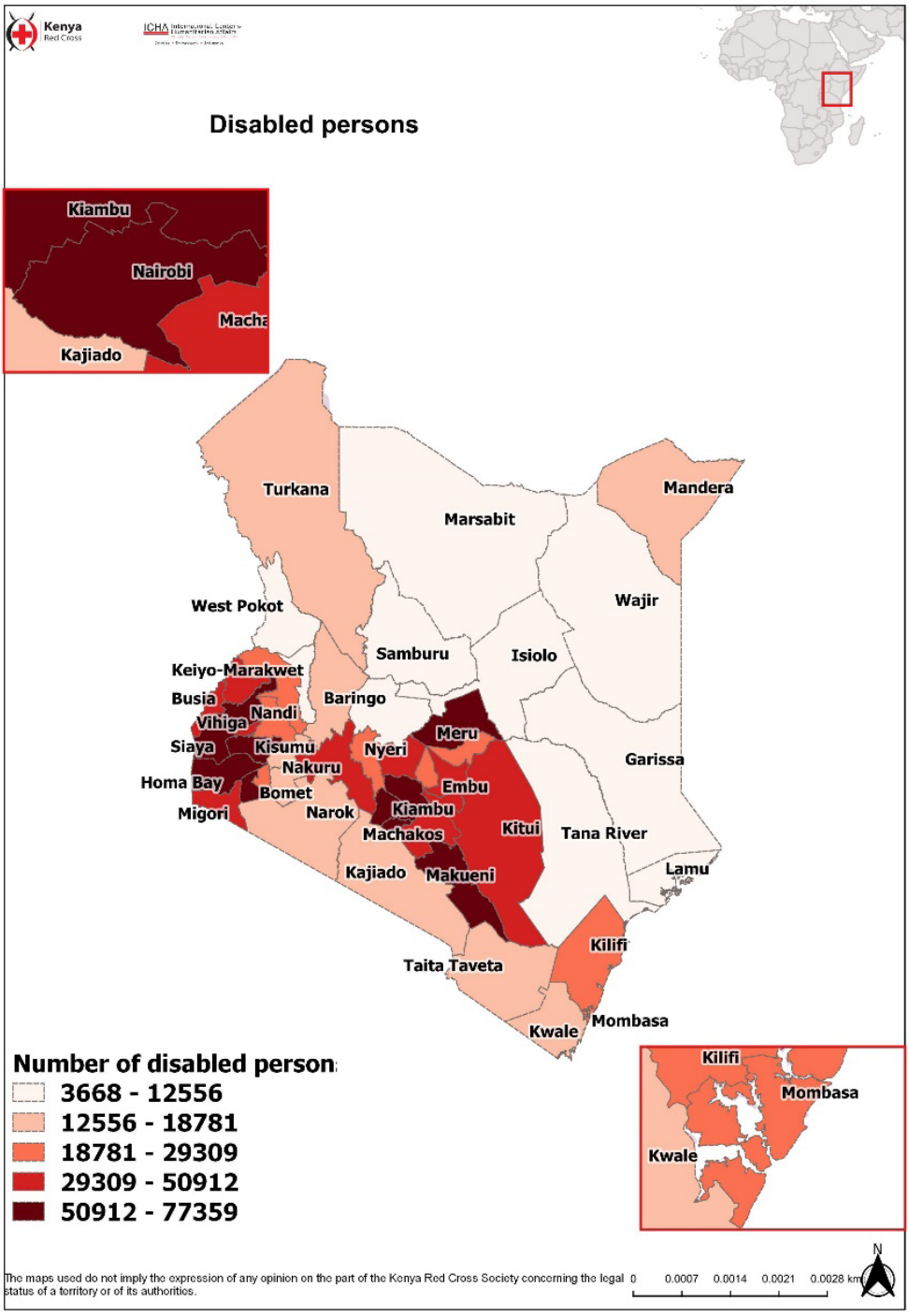


Figure 5 Number of disabled persons

Nairobi, Mombasa, Meru, Uasin Gishu and Kajiado counties have the highest number of population of street persons/ outdoor sleepers (figure 6) thereby making them to be vulnerable to COVID-19 while Isiolo, Elgeiyo Marakwet, Nyandarua, Bomet and Taita Taveta counties are less vulnerable due to their low number of population of street persons/ outdoor sleepers.

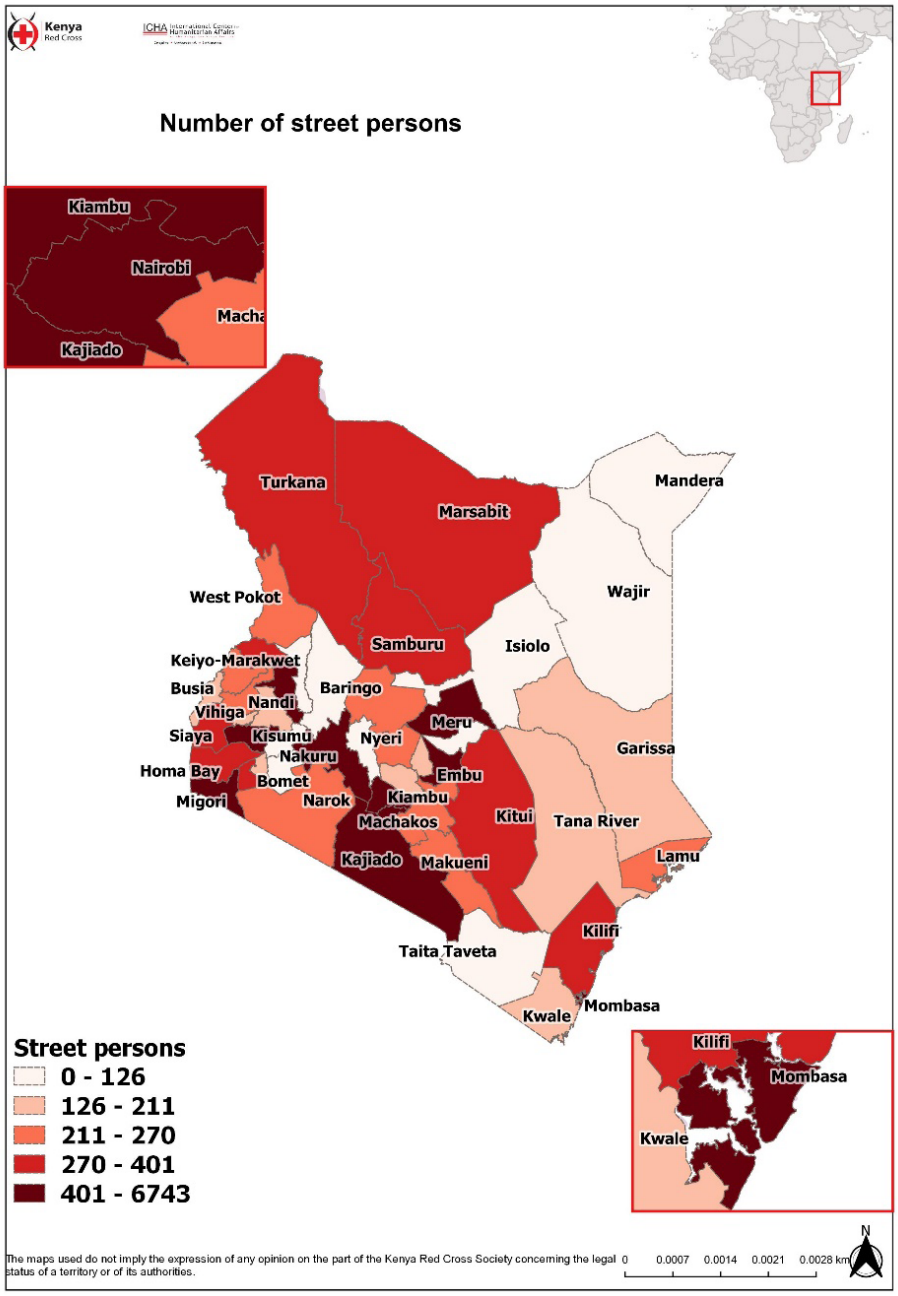


Figure 6 Number of population of street persons/ outdoor sleepers

After standardization, COVID-19 vulnerability indicators were given varied weightings - based on their importance to COVID-19 - that added up to 1 - in order to generate the COVID-19 vulnerability index.

$$\text{Vulnerability} = 0.3*_{\text{population above}}\ 60 + 0.3*_{\text{disabled population}} + 0.3*_{\text{street population}} + 0.1*_{\text{population}}$$

Equation 5 Weighting of COVID-19 vulnerability indicators

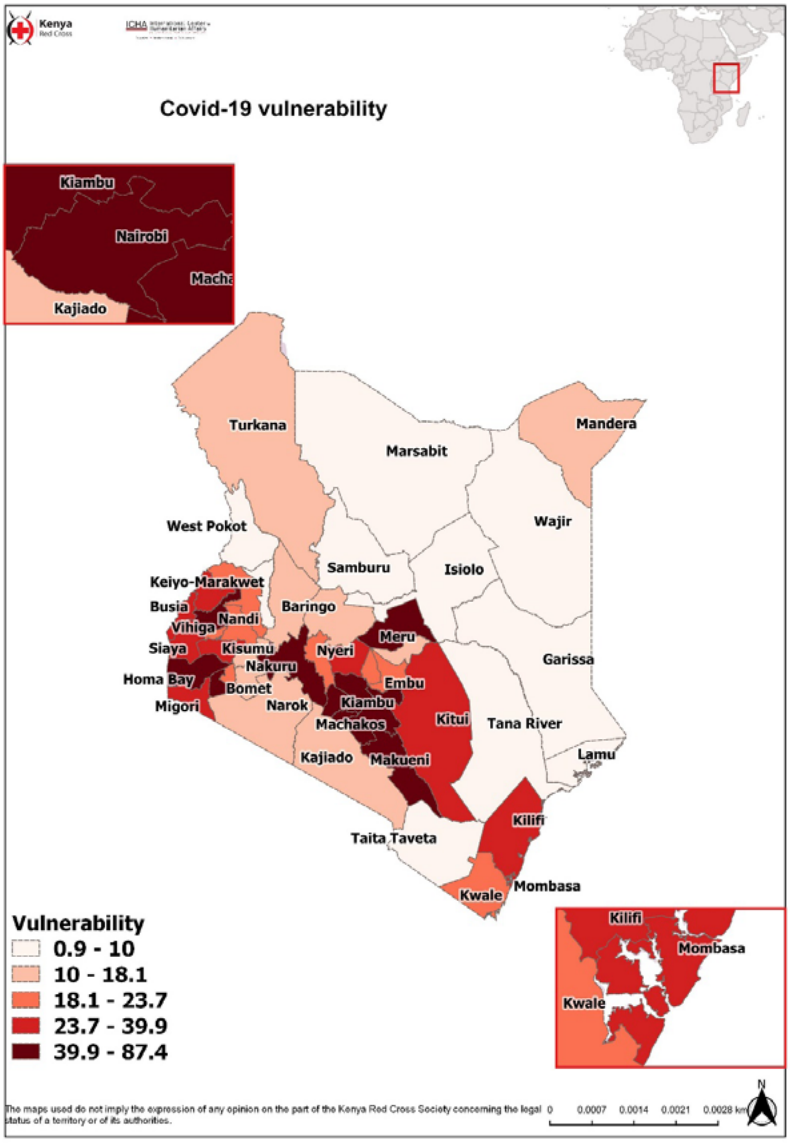


Figure 7 COVID-19 vulnerability index

The COVID-19 vulnerability index indicates that Nairobi, Kiambu, Meru, Kakamega and Nakuru are the most vulnerable counties while taking into account population above 60 years, disabled population, population of street persons and human population. These counties have the highest number of persons above 60 years, disabled persons, population of street persons/ outdoor sleepers and human population.

The vulnerability index was calculated at county level to show the inter-county differences in vulnerability to COVID-19 (Figure 7). The choropleth map shows that counties with higher vulnerability are more likely to be at higher risk of COVID-19.

Adaptative capacity

Number of isolation beds and ICU beds were used as COVID-19 adaptive capacity indicators. These indicators negatively influence COVID-19 risk where few numbers imply high risk.

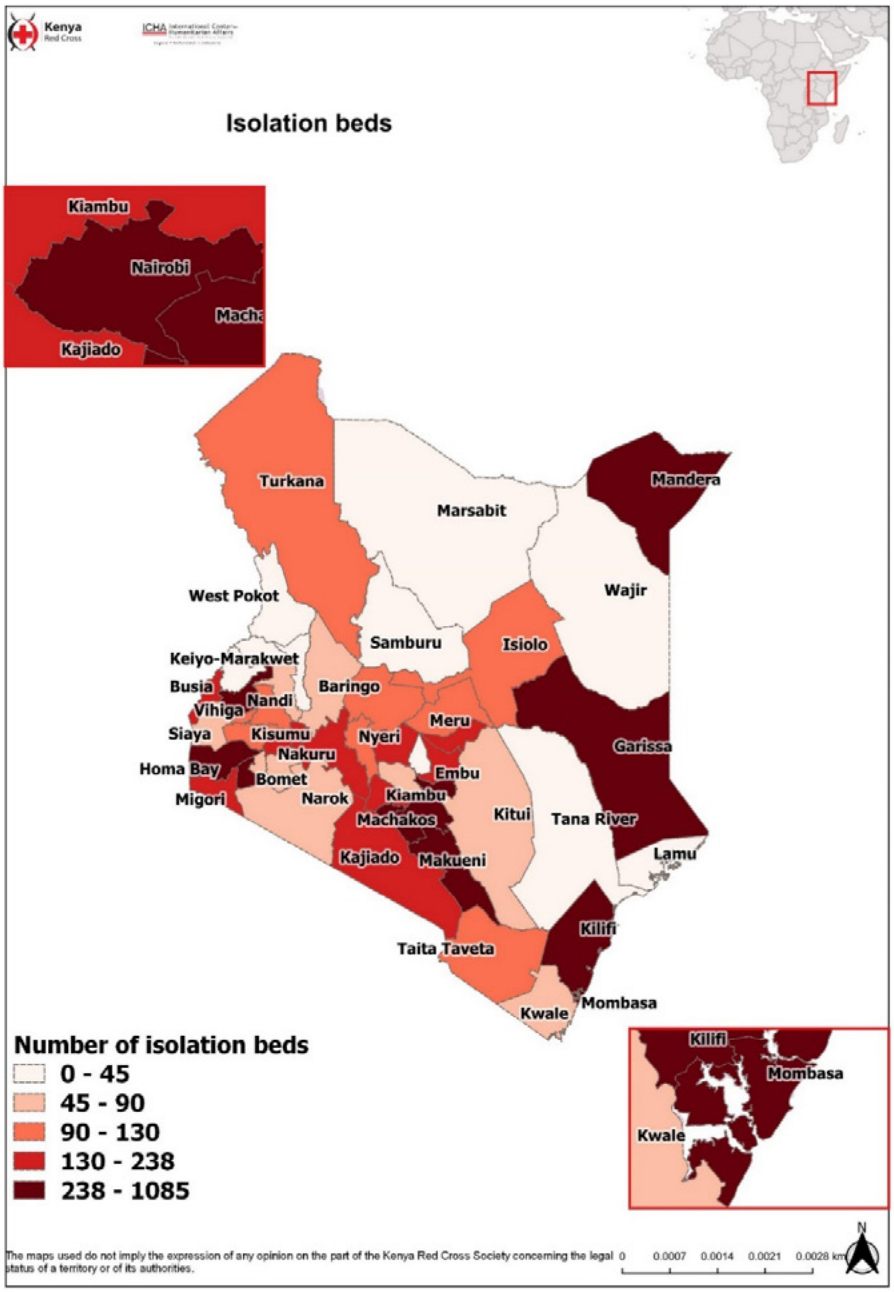


Figure 8 Number of isolation beds

Kirinyaga, Lamu, Elgeiyo Marakwet, Bungoma and Samburu have the lowest number of isolation beds thereby making them to have less adequate COVID-19 adaptive capacity. Counties such as Nairobi, Mombasa, Machakos, Makueni and Garissa have the highest number of isolation beds thereby making them to have more COVID-19 adaptive capacity.

Kirinyaga, Lamu, Bungoma, Samburu and Tana River have the lowest number of ICU beds thereby making them to have less adequate COVID-19 adaptive capacity. Nairobi, Murang'a, Mandera, Mombasa and Tharaka Nithi have the highest number of ICU beds thereby making them to have more adequate COVID-19 adaptive capacity.

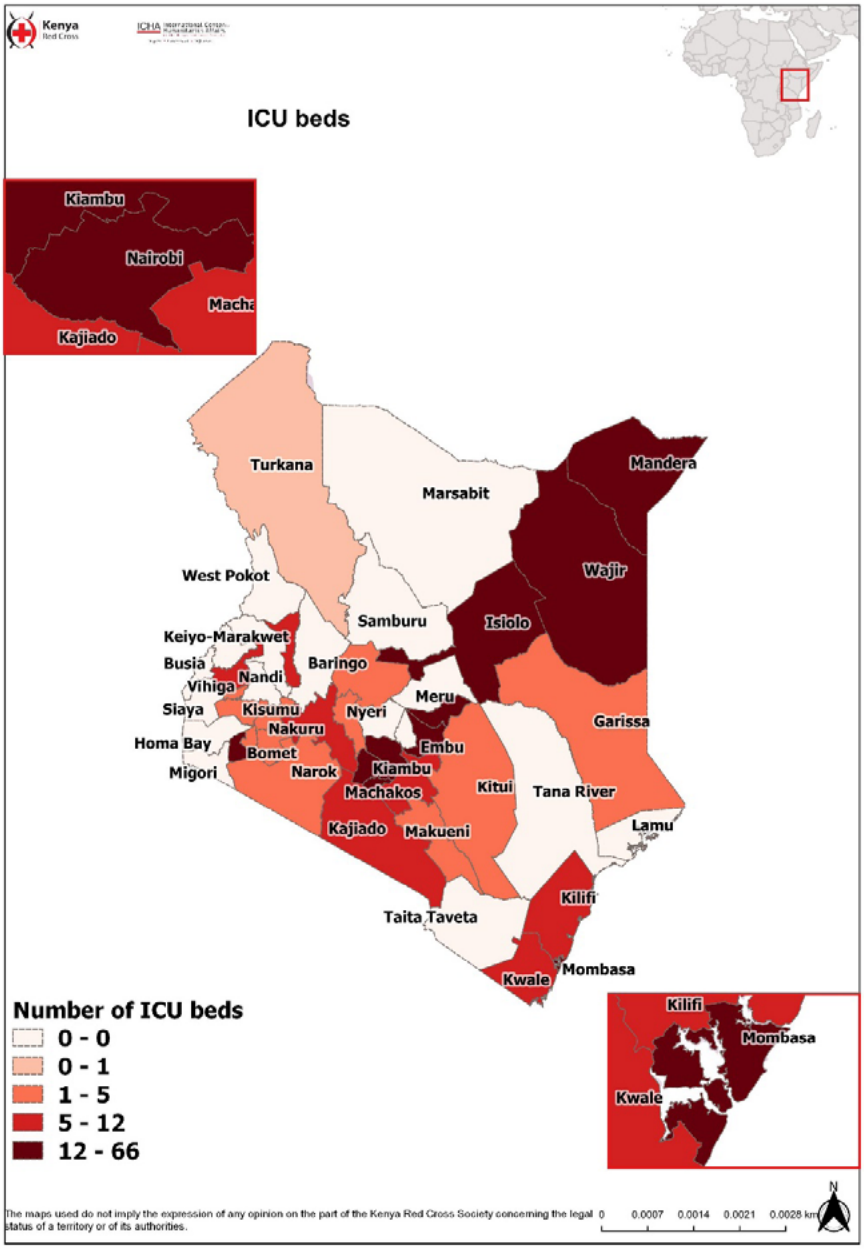


Figure 9 Number of ICU beds

After standardization, COVID-19 adaptive capacity indicators were given equal weightings based on their importance to COVID-19 that added up to 1 in order to generate the COVID-19 adaptive capacity index.

$$\text{Adaptive capacity} = 0.25*_{\text{isolation beds}} + 0.25*_{\text{isolation ICU beds}} + 0.25*_{\text{ventilators}} + 0.25*_{\text{ICU beds general}}$$

Equation 6 Weighting of COVID-19 adaptive capacity indicators

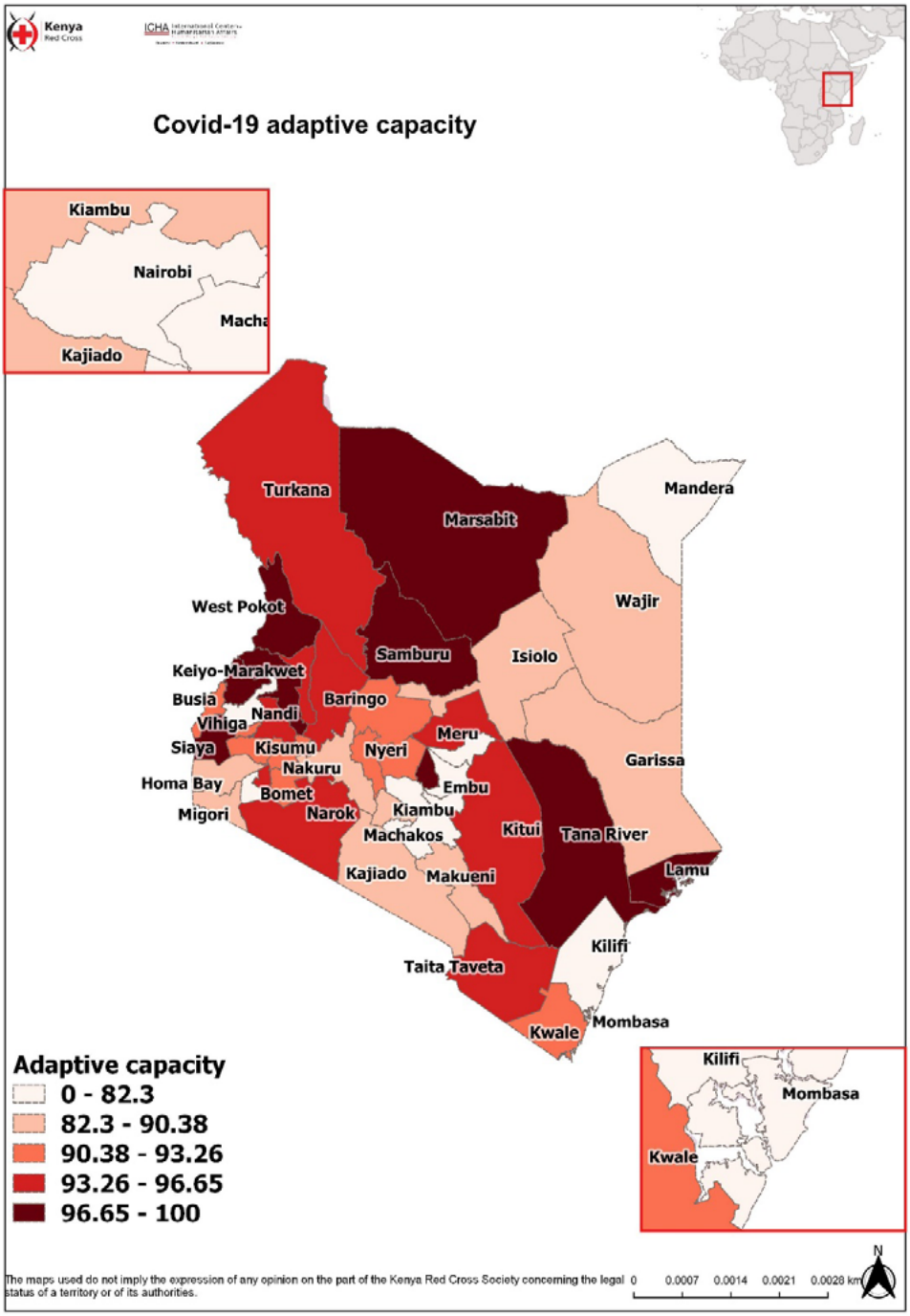


Figure 10 COVID-19 adaptive capacity

The COVID-19 adaptive capacity index indicates that Kirinyaga, Lamu, Bungoma, Samburu and Tana River have the most inadequate COVID-19 capacities while taking into account number of isolation and ICU beds. These counties have the lowest number of isolation and ICU beds.

The adaptive capacity index was calculated at county level to show the inter-county differences in adaptation to COVID-19 (Figure 10). The choropleth map shows that counties with lower adaptive capacity are more likely to be at higher risk of COVID-19.

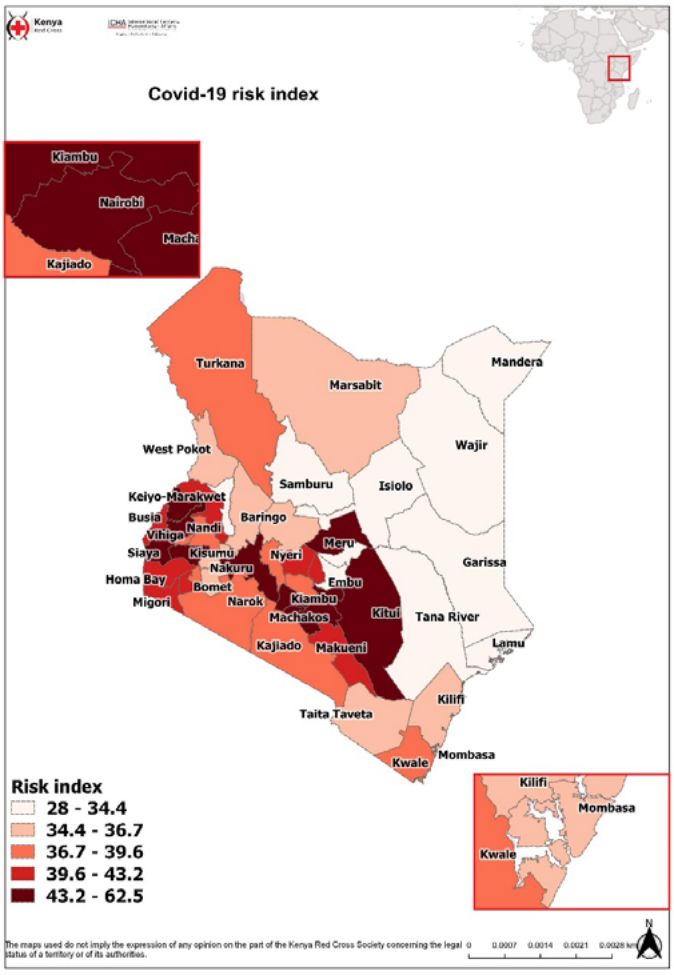
COVID-19 Risk Index

The three COVID-19 dimensions were then combined using equation 7 to generate the COVID-19 risk index

COVID-19 risk = Exposure + Vulnerability + Adaptive capacity

Equation 7 COVID-19 risk index equation

The COVID-19 risk index indicates that Nairobi, Kiambu, Meru, Kakamega and Nakuru are counties with the highest COVID-19 risk while taking into account exposure, vulnerability and inadequate adaptive capacities. Baringo, Bomet, Bungoma, Busia and Embu are counties with the least COVID-19 risk index.



Equation 8 COVID-18 risk index

4. Discussions

COVID-19 risk is attributed to three factors namely exposure, vulnerability and adaptive capacity. This is according to the European Commission, Joint Research Centre (JRC) index for risk management (INFORM) COVID-19 Risk Index that aims at supporting prioritization of preparedness and response actions to COVID-19 by humanitarian organization such as the Kenya Red Cross Society (KRCS). This study looked at structural risk factors to COVID-19 – that existed before the outbreak that may have direct and indirect effects on COVID-19 risk across all the 47 counties in Kenya.

From exposure analysis, counties with the most cumulative COVID-19 cases are Nairobi, Mombasa, Busia, Kajiado, Kiambu, Machakos, Migori, Kisumu and Uasin Gishu. These counties are characterised by a high human population and high population movement. Some of these counties like Nairobi serve as business centres where people from other towns come in for goods and services thereby predisposing people to COVID-19 infections. These counties also have international airports and are in close proximity to neighbouring countries, which makes them to be more exposed to COVID-19 due to the high likelihood of people travelling into the Kenya from other countries with high COVID-19 cases. The counties with least reported COVID-19 cases were Baringo, West Pokot, Samburu, Tharaka Nithi, Nyandarua, Tana River and Lamu. These counties are mostly characterised by a low human population and are located far away from the major towns in Kenya such as Nairobi.

From vulnerability analysis, Nairobi, Kiambu, Meru, Kakamega and Nakuru counties are the most vulnerable to COVID-19. Comparatively, these counties are characterised by having high population of people above the age of 60 years, high number of disabled population, high number of population of street persons/ outdoor sleepers and lastly high number of human populations. The adaptive capacity analysis indicates that Kirinyaga, Lamu, Bungoma, Samburu and Tana River have the most inadequate COVID-19 capacities. Comparatively, these counties are characterised by having low number of isolation and ICU beds.

From the COVID-risk index, counties such as Nairobi, Kiambu, Meru, Kakamega and Nakuru have been identified to be at high risk from health and humanitarian impacts of COVID-19 that could potentially overwhelm national response capacity. This is because of their high exposure and high vulnerability to COVID-19 well as their low adaptive capacity to COVID-19. These counties are characterized by high COVID-19 cumulative confirmed cases, high number of vulnerable populations such as the elderly, disabled and population of street persons/ outdoor sleepers. These counties also have low numbers of ICU and isolation centres.

5. Conclusions and Recommendations

This study heavily relied on structural risk factors to COVID-19 within the hazard and exposure, vulnerability and lack of coping capacity dimensions with a focus on cumulative confirmed cases, demographic characteristics of affected population within the vulnerability dimension and health system capacity under lack of coping capacity.

This study recommends the prioritization of COVID-19 preparedness and response efforts in counties with high COVID-19 risk score. Such efforts would include conducting mass campaigns through public address systems, distribution of COVID-19 PPEs to vulnerable communities, COVID-19 community sensitization and advocacy for prepositioning of adequate ICU and isolation centres.

With the likelihood of a second wave of COVID-19 and with Kenya having community infections, this study recommends measures to be undertaken amongst the vulnerable communities to COVID-19 such as the elderly, disabled persons and street persons/ outdoor sleepers. Adequate ICU and isolation centres should be placed in counties with the most vulnerable community members.

Further research is required to include other vulnerability and adaptive capacity risk factors such as comorbidities, population movement and behavioral components as eluded by (Macharia et al., 2020) and (Surgo Ventures, 2020). Therefore, there is need to do further research on other COVID-19 risk influencers. The INFORM COVID-risk index is a composite index approach that combines the various risk factors through assigning weights. There is need to explore other methods such as elementary modelling by looking at statistical relationship between COVID-19 cumulative confirmed cases and vulnerability and lack of adaptive capacity factors.

Advanced predictive models could be used in order to understand the relationship between historical data on COVID-19 cases across all 47 counties with the vulnerability and lack of adaptive factors as explanatory variables. With the likelihood of second waves these models would be able to predict the likelihood of having COVID-19 cases in the 47 counties. The study also proposes the use of spatial models to look at spatial dependence and spatial autocorrelation in order to investigate whether counties that are close to each other influence each other more in as far as COVID-19 risk is concerned. The INFORM COVID-risk index composite index approach employed in this study could be downscaled at subcounty (Macharia et al., 2020) or ward level to better understand COVID-19 risk at community level. The approach used in this study could be replicated to other countries to better help humanitarian organization in prioritizing their COVID-19 preparedness and response efforts in counties with high COVID-19 risk score.

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References

Aluga, M. A. (2020). Coronavirus Disease 2019 (COVID-19) in Kenya: Preparedness, response and transmissibility. Journal of Microbiology, Immunology and Infection, 53(5), 671–673.

De Groeve, T., Poljansek, K., & Vernaccini, L. (2015). Index for risk management-INFORM. JRC Sci Policy Reports—Eur Comm, 96(10.2788), 636388.

Guimera, R., & Amaral, L. A. N. (2005). Functional cartography of complex metabolic networks. Nature, 433(7028), 895–900.

Hu, B., Guo, H., Zhou, P., & Shi, Z.-L. (2020). Characteristics of SARS-CoV-2 and COVID-19. Nature Reviews Microbiology, 1–14.

KNBS. (2020). KNBS Downloads. https://www.knbs.or.ke/knbs-downloads/

KRCS. (2020). KRCS COVID-19 updates. https://www.redcross.or.ke/images/KRCS-COVID-UPDATES-15-April.pdf

Liu, Y.-C., Kuo, R.-L., & Shih, S.-R. (2020). COVID-19: The first documented coronavirus pandemic in history. Biomedical Journal, 43(4), 328–333.

Lone, S. A., & Ahmad, A. (2020). COVID-19 pandemic–an African perspective. Emerging Microbes & Infections, 9(1), 1300–1308.

Macharia, P. M., Joseph, N. K., & Okiro, E. A. (2020). A vulnerability index for COVID-19: Spatial analysis at the subnational level in Kenya. BMJ Global Health, 5(8), e003014.

Marin Ferrer, M., P., K., & Vernaccini, L. (n.d.). INFORM Covid-19 Risk Index [2020]. European Union. https://ec.europa.eu/jrc/en/publication/annual-reports/inform-covid-19-risk-index

Mbae, N. (2020). COVID-19 in Kenya. Electronic Journal of General Medicine, 17(6).

MoH. (2020). Press statements on COVID-19 Kenya. https://www.health.go.ke/press-releases/

OCHA. (2020). Kenya Situation Report. https://reliefweb.int/sites/reliefweb.int/files/resources/Situation%20Report%20-%20Kenya%20-%2010%20Aug%202020.pdf

Patro, S., & Sahu, K. K. (2015). Normalization: A preprocessing stage. ArXiv Preprint ArXiv:1503.06462.

Surgo Ventures. (2020). Africa COVID-19 Community Vulnerability Index: Methodology. https://covid-static-assets.s3.amazonaws.com/Africa+CCVI+methodology.pdf

WHO. (2020, December 3). WHO announces COVID-19 outbreak a pandemic. https://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19/news/news/2020/3/who-announces-covid-19-outbreak-a-pandemic

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