Open Access

International journal of Rural Development, Environment and Health Research (IJREH)
[Vol-4, Issue-4, Jul-Aug, 2020]
ISSN: 2456-8678
https://dx.doi.org/10.22161/ijreh.4.4.1

Assessment of the Spatial and Temporal Trend of the COVID-19 Pandemic in Senegal

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***Abstract*—*Following the declaration of COVID-19 as a global pandemic and the reporting of one case in Senegal, the number of regions with confirmed cases of infection increased considerably, with the disease now being reported throughout the country after 3 months of evolution. It is therefore necessary to assess the evolution of the disease in the country as the situation evolves in order to rapidly identify best practices for adoption. The objective of this paper is to make a preliminary spatial and temporal assessment and comparison of the results of the COVID-19 pandemic in the regions of Senegal. Data on the evolution of COVID-19 (confirmed cases of infection, deaths, recoveries), population, density and area of each region were analysed using a set of statistical tools. The results show that the COVID-19 pandemic has spread stubbornly in Senegal. In the space of 112 days (from March 2 to June 21), Senegal reached a number of 5888 infected cases for 3919 cured, 1885 active and 84 deaths for a total of 67855 tests performed. About 40 people out of 10,000 have been tested so far and 4 out of 10,000 have tested positive. The Mann-Kendall test indicates that the number of confirmed daily cases is slowly increasing, with the slope of Sen estimated at about 1.2 person/day across the country. In addition, the Pettitt test indicates a sharp change in the upward trend across the country on April 26, 2020. Among the main affected regions, Dakar, Thies and Touba are noted with an extremely high rate of increase. Principal component analysis and hierarchical ascending classification have made it possible to divide Senegal's 14 regions into 3 groups in terms of the number of confirmed cases, active cases, recovered cases and reported deaths, and the population, area and density of the region. The 1st group concerns the Dakar region, the 2nd Diourbel and Thies and the 3rd the other regions. Furthermore, statistics related to COVID-19 in the regions of Senegal are highly correlated with population size and density. This study revealed convincing spatial differences in the evolution of the pandemic between the regions of Senegal. The study recommends that the approaches adopted by regions that have achieved very low levels of COVID-19 be incorporated into health care management plans for the pandemic throughout the country, even as the situation evolves.*

***Keywords*— COVID-19, global pandemic, assessment, trend, Senegal.**

I. INTRODUCTION

Coronavirus 2019 (COVID-19) disease originating in Wuhan, China, was declared a public health emergency of international concern on 30 January 2020 (**Cucinotta and Vanelli, 2020**). In Africa, the first confirmed case of COVID-19 in Africa was reported in Egypt on 14 February 2020, followed by a second case reported in Algeria on 25 February 2020, when the Algerian government confirmed that an Italian man who had recently entered the country had tested positive for COVID-19 (**WHO, 2020a;**

Makoni, 2020). Since the reporting of a case in Africa, the number of African countries with confirmed cases of the infection has increased considerably, with the disease now being reported in all countries on the continent (WHO, **2020b**).

Screening for severe acute coronavirus-2 respiratory syndrome (SARS-CoV-2) in Africa is expected to be very difficult. Molecular diagnostic technique by RT-PCR (Real Time - Polymerase Chain Reaction) remains the main diagnostic method for SARS-CoV2 worldwide and even on the African continent. Although RT-PCR remains a very sensitive diagnostic method, it has been associated with a significant cost, averaging $60 per sample (**Adebayo *et al.*, 2020**). This has been a major setback for extensive testing in Africa. A second challenge is the lack of accredited level 3 and 4 laboratories for testing and also the low level of manpower required to perform these tests (**Nkengasong and Mankoula, 2020**). At the beginning of the epidemic, only two reference laboratories, one in South Africa and one in Senegal, were capable of performing the test (**WHO, 2020c**). The vast majority of national laboratories in Africa did not have the reagents needed to perform the test because it is a new virus. Therefore, testing capacity needed to be rapidly scaled up to give the continent a chance. Although some countries have experience in the control of communicable diseases such as Ebola and influenza, with 28 countries in the WHO African Region being members of the WHO Global Influenza Surveillance Network (**WHO, 2020c)**, the testing capacity for COVID-19 on the continent at the beginning of the epidemic was certainly a major concern. The huge instant demand for reliable test reagents and test kits also placed many constraints on supply chains and led to bottlenecks in production and delivery worldwide. This limited capacity to test for COVID-19 infection was expected to be a major stumbling block to disease management on the continent (**Adebayo *et al.*, 2020**).

Due to the poor state of health infrastructure, poverty concerns, unfavorable living conditions in cities, population densities and the prevalence of underlying diseases such as low respiratory infections, malaria, diarrhea, HIV/AIDS and tuberculosis, there are serious concerns that the impact of COVID-19 on the continent could be devastating (**World Bank, 2020; Martinez-Alvarez, 2020**). According to **UNECA (2020**), Africa could see 300,000 deaths from coronavirus this year, even in the best case scenario. Africa's largest cities have grown relentlessly for decades to become home to tens of millions of people living in overcrowded central cities and branches of satellite cities and unplanned urban sprawl. Countries with large urban populations face the logistical and communication challenge of informing, monitoring and possibly isolating more people at risk (**Hoogeveen *et al.*, 2004**). There is concern that the pandemic is difficult to control in Africa and that it could cause huge economic problems if it spreads widely (**Gibbs, 2005**). Protecting vulnerable people from IDVOC-19 could involve a mix of traditional and standard medical advice approaches of early identification of confirmed cases, rapid contact tracing with physical isolation, community engagement and targeted care, possibly by those who have recovered from the virus (**Gilbert *et al.* , 2020**). These measures will be more effective if they are based on local innovations adapted to particular social contexts and if they are designed with the participation of those affected. They could build on practices of respect for older persons and community organization in many African contexts, as well as on the experience of previous epidemics. Not surprisingly, therefore, many African countries have developed various approaches to disease management, with varying degrees of success (**Adebayo *et al.*, 2020**).

Senegal, like most African countries, already suffers from several existing vulnerabilities, including: poverty and difficult socio-economic conditions, poor governance, the impact of climate change, low resilience, and limited access to capital, low level of technology and poor emergency preparedness, among others (**Boko *et al.*, 2007**). Since the first case of COVID-19 was confirmed in Senegal on 2 March 2020 (**MSAS, 2020**), the Government of Senegal has taken measures to minimize the spread and impact of the virus. Senegal has therefore not waited for the increase in cases to take rigorous measures. Thus, in addition to curfews, schools and universities were closed, prayers in places of worship were banned, transport was reduced and strict hygiene rules were imposed (**UNESCO, 2020**). Despite the rapid and decisive actions of the Senegalese government, COVID-19 still poses a high threat to the country (**ANSD, 2020**). This is due to the size of the high-risk population, such as the high prevalence of tuberculosis and other previous conditions, the high population density in informal settlements, and the low capacity of the health system to handle large numbers of patients. As of 21 June 2020, a total of 5888 infected persons have been recorded, 1885 active cases of the virus, 84 deaths, 21 in critical condition and more than 3919 recoveries (**WHO, 2020d)**. COVID-19 also poses a threat to the economic stability of Senegal (**ANSD, 2020**).

During this period, Senegal adopted many responses to the pandemic: preserving public health and strengthening health systems, social protection and economic stabilization (**ANSD, 2020**). In order to limit the economic impact of this health crisis, a response and solidarity fund, Force-COVID-19, has been created by the government and will be endowed with CFAF 1,000 billion. An envelope of CFAF 50 billion will be devoted to the purchase of food for emergency food aid, particularly on the eve of Ramadan. The aim is to minimize the health, social and economic impact on the population, especially the poor and vulnerable. To achieve this, health systems must develop strategies to stop the chain of transmission. This requires Senegal to have functional health facilities that can provide symptomatic treatment and hospitalization of cases, as well as infrastructure, equipment and human resources that can manage the disease and prevent mortality (**MSAS, 2020**).

In such emergencies, the social and health implications of response measures to limit the spread of the COVID-19 virus must be considered and interventions carefully planned (**Faye *et al.* , 2020**). This can be achieved through sound and responsible government approaches. The objective of this paper is to make a preliminary spatial and temporal assessment and comparison of the results of the COVID-19 pandemic in the regions of Senegal.

II. MATERIALS AND METHODS

2.1. Data

The statistics on COVID-19 used in this study come from the databases of the World Health Organization (https://www.worldometers.info/coronavirus/) and the Ministry of Health and Social Action (MSAS) of Senegal (http://www.sante.gouv.sn/Pr%C3%A9sentation/coronavirus-informations-officielles-et-quotidiennes-du-msas), and are dated Sunday, June 21, 2020. The analysis of quantitative data is combined with population health and economic data based on literature reviews. It consisted essentially of a consultation of documents (publications, reports, articles, journal publications) that are of great interest for this theme. This allowed us to collect various data and available information related to the COVID-19 pandemic in Senegal and in areas where similar studies have been conducted. Other information used on this article comes from structures such as the WHO, the World Bank, the MSAS of Senegal and other ministries that are related to the fight against COVID-19.

2.2 Methods

For the spatial and temporal analysis of the results of the COVID-19 pandemic across Senegal, a set of statistical methods were used.

2.2.1. Principal Component Analysis

Principal component analysis (PCA) is a widely used statistical technique (**Faye, 2014; Baba-Hamed and Bouanan, 2016**). It reduces the number of variables to those that are most significant among a set of variables and is used to find a relationship between variables and individuals in order to group them into homogeneous regions. One of the objectives of PCA is to obtain useful information from a data matrix, and to provide a graphical representation of the data to facilitate analysis. The method was applied to data on variables for the 14 regions of Senegal, which are the number of confirmed cases, active cases, recovered cases, and reported deaths, the population of the region, the area of the region, and the density of the region. Rank correlation and Spearman regression analysis were performed to determine the relationship between the different variables.

2.2.2. Ascending Hierarchical Classification (AHC)

Hierarchical ascending classification (HAC) is an iterative classification method whose principle is to calculate the dissimilarity between the N objects. It seeks to ensure that individuals grouped within the same class (intra-class homogeneity) are as similar as possible while classes are as dissimilar as possible (inter-class heterogeneity). CAH was carried out to classify the regions of Senegal and group them into groups on the basis of similarities or disparities using the criteria chosen (**Hammer *et al.*, 2001; Ogbeibu, 2014**). To facilitate spatial analysis, the AHC was applied to data on variables for the 14 regions of Senegal, which are the number of confirmed cases, active cases, recovered cases and reported deaths, the population of the region, the area of the region and the density of the region.

2.2.3. Mann-Kendall test

The Mann-Kendall test detected possible gradual changes in the series of extreme variables. According to Mann **(1945)** and **Kendall (1975)**, this non-parametric, rank-based test can be used to determine whether or not the correlation between time and the study variable is significant. Let $(x1,\dots ,xn)$ be a sample of independent values for a random variable X whose stationarity is being assessed. To determine the magnitude of change, the Sen slope method (**Sen, 1968**) was applied. The method was applied to daily data from Senegal of 6 variables related to COVID-19 which are the number of confirmed cases, new cases, active cases, recovered cases, deaths, new deaths.

2.2.4. Pettitt's test

A break is defined as a change in the probability law of random variables whose successive realizations define the time series under study (**Servat *et al.*, 1998**). The **Pettitt**

ISSN: 2456-8678
https://dx.doi.org/10.22161/ijreh.4.4.1

(1979) test was chosen for its power and robustness (**Lubès-Niel *et al.*, 1998**). The **Pettitt's test** is a non-parametric test for the detection of a single break at an unknown date. It can be noted that the test also provides an estimate of the position of the rupture using the *k* index corresponding to the maximum $U(k)|$. The hydrological deficit with respect to the ruptures identified by the Pettitt test was evaluated. The method was applied daily data from Senegal of 6 variables related to COVID-19 which are the number of confirmed cases, new cases, active cases, restored cases, deaths, new deaths.

III. RESULTS AND DISCUSSION

3.1 Spatial evolution of the pandemic

As of 21 June 2020, a total of 5888 infected persons have been recorded, 1885 active cases of the virus, 84 deaths, 21 in critical condition and more than 3919 recoveries (**WHO, 2020d)**. COVID-19 also poses a threat to the economic stability of Senegal (**ANSD, 2020**).

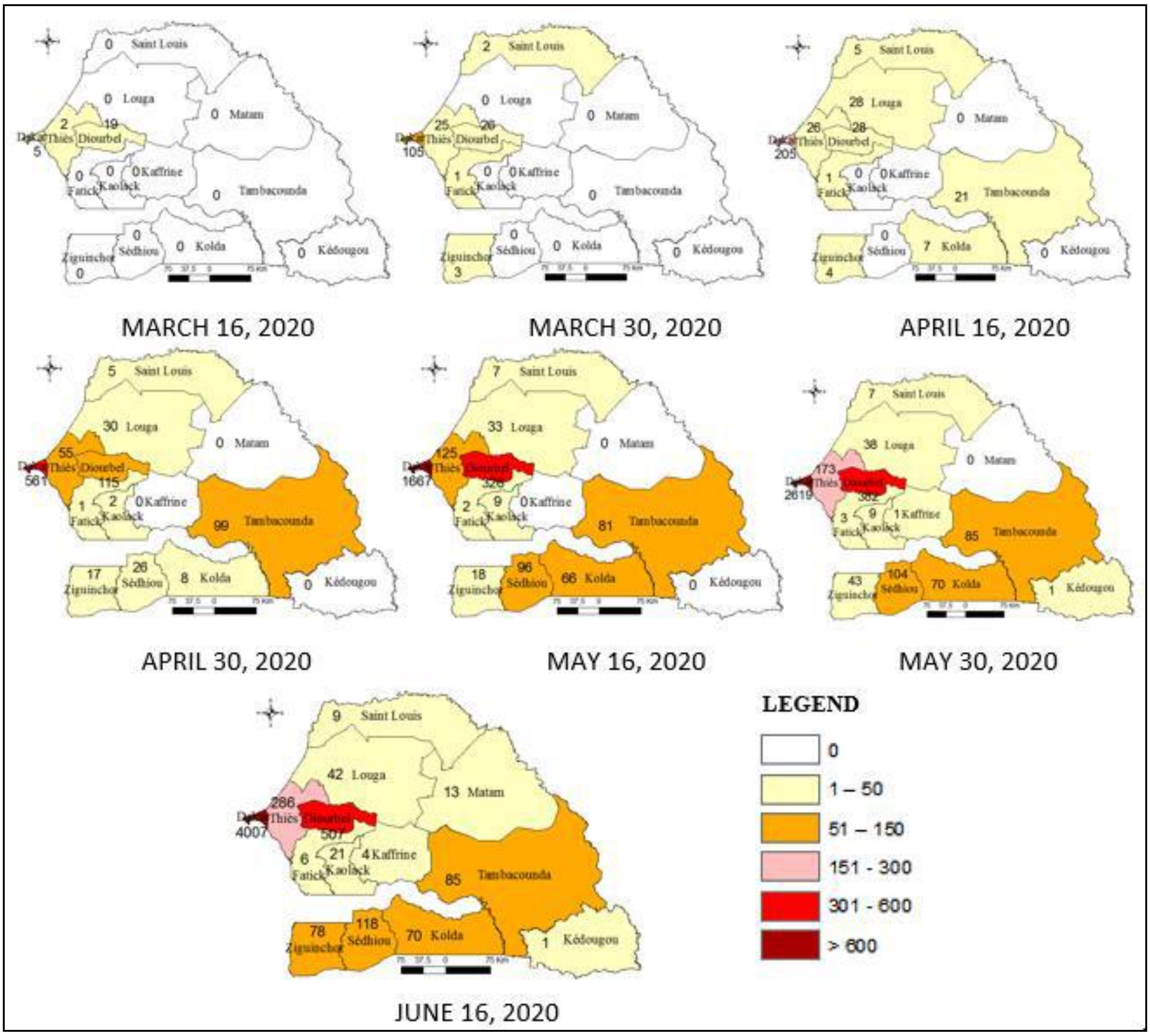

Fig. 1: Spatial evolution of the number of COVID-19 infected cases in Senegal

Despite rapid and decisive action by the Senegalese government, COVID-19 still poses a high threat to the country (ANSD, **2020**). This is due to the size of the high-risk population, such as the high prevalence of tuberculosis and other previous conditions, the high population density in informal settlements, and the low capacity of the health system to handle large numbers of patients. In terms of the number of infected cases, the Dakar region represents the

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epicentre of the pandemic with 80.5% of the country's infected cases, followed by Diourbel with 8.3%, Thiès with 3.9%, Sédhiou with 2%. For the rest of the regions, the percentage remains below 1.5.

The same is true for the total of active cases, recovered cases and deceased cases for which Dakar records 69.1%, 85.8% and 73.8% respectively. Diourbel also records a high percentage of deaths with 21.4%. The regions that recorded the highest values of COVID-19 infection are logically those that concentrate most of the country's population (23% in Dakar, 11.1% in Diourbel and 12.9% in Thiès) and therefore have the highest population densities (7011 inhabitants/km2 in Dakar, 385 in Diourbel and 324 in Thiès). However, some regions such as Kaolack (with 222 inhabitants/km2) and Fatick (with 132 inhabitants/km2) have high densities, even if their number of infections remains low (19 cases in Kaolack and 4 in Fatick). The spatial evolution of the number of COVID-19 infected cases in Senegal is given in Fig. 1.

While as of 16 March 2020 (15 days after the first case was reported in Senegal), only the regions of Diourbel (19 cases), Dakar (5 cases) and Thiès (2 cases), by 16 June 2020, all regions of Senegal had recorded cases of contamination, with a still much wider distribution in the western part of the country (4007 cases in Dakar, 507 in Diourbel and 286 in Thiès). The configuration of COVID-19 at the regional scale has hardly changed. The Dakar region still remains the epicentre of the pandemic and accounts for 80.5% of cases. It is followed by Diourbel and Thiès, which account for a little over 10%. Ziguinchor, Sédhiou, Kolda and Tambacounda are the regions in the interior of the country that have recorded a significant number of cases. However, the situation is under control in regions such as Kédougou, Matam and Kaffrine, which have the lowest contamination Fig.

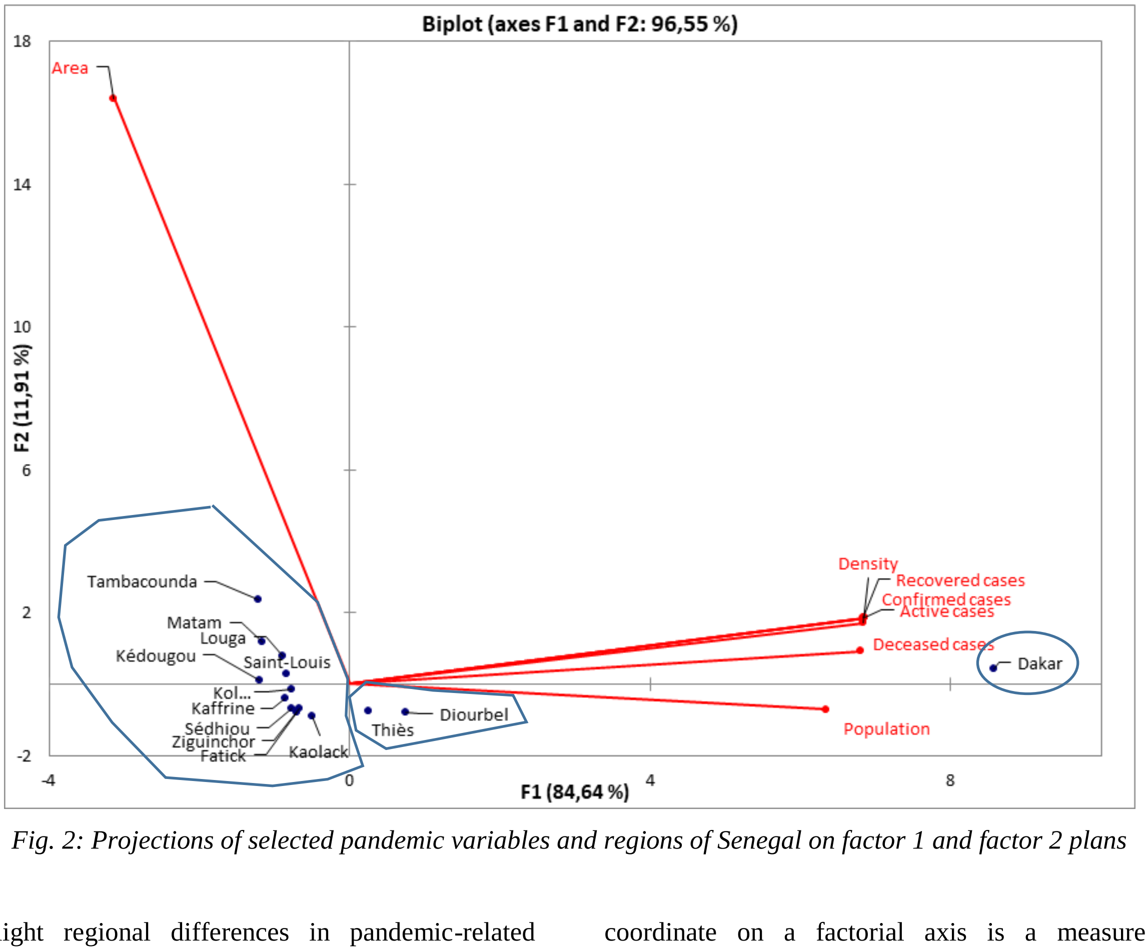

Fig. 2: Projections of selected pandemic variables and regions of Senegal on factor 1 and factor 2 plans

To highlight regional differences in pandemic-related variables, Principal Component Analysis (PCA) was carried out and allowed a projection of the selected pandemic-related variables and regions of Senegal on factor plans 1 and 2 (Fig. 2). Each pandemic-related variable in COVID-19 is associated with a point whose coordinate on a factorial axis is a measure of the correlation between that variable and the factor (axis 1 or axis 2). By projection on a factorial plane, the variables studied fit into a side 2 plane. They are all the closer to the side of the plane the more the variable is well represented

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by the factorial plane, i.e. the variable is well correlated with the two factors making up this plane.

For the variables, for Plan I-II (84.64% cumulative inertia), Axis I is determined by the variables related to the COVID-19 pandemic such as the number of confirmed cases, active cases, recovered cases and reported deaths, the population and density of the region, and Axis II the area of the region.

For the regions, in the U.S. plan, Plan I-II highlights three groups. The first is the Dakar region, which has the highest number of confirmed cases, active cases, recovered cases and reported deaths, and which has the largest population and the highest density. Its position on the map also indicates its relatively small size with 547 km2 (0.3% of the country's total surface area) for a population of 3835019 inhabitants (23% of the country's total population). The second group is made up of the regions of Diourbel and Thiès which have recorded COVID-19 values (confirmed cases, active cases, recovered cases and declared deaths), a large population (2162831 in Thiès and 1859503 in Diourbel) and density (385 in Diourbel and 324 in Thiès), much less than those of Dakar. Finally, the last group consists of the 11 other regions (Sédhiou, Tambacounda, Kolda, Ziguinchor, Louga, Kaolack, Matam, Saint-Louis, Kaffrine, Fatick, Kédougou) which correspond to the lowest COVID-19 values (confirmed cases, active cases, recovered cases and reported deaths), the smallest population and the lowest density. Some of the regions also have a very large surface area (Tambacounda with 21.5% of the country's surface area, Matam with 15% and Louga with 12.6%).

In the end, the CPA synthesized information crossing regions (individuals) and variables (quantitative). It produced a summary of information (Fig. 2) by establishing similarity between the regions of Senegal, searching for groups of homogeneous regions, highlighting a typology of regions and variables related to the COVID-19 pandemic studied, but also highlighting linkage budgets between variables related to the COVID-19 pandemic, using synthetic parameters or variables. The CPA has generally established the linkages between these two typologies (**Kouani *et al.*, 2007**).

To confirm the PCA, hierarchical bottom-up classification (HOC) was performed, an iterative classification method whose principle is to calculate the dissimilarity between regions. The results of the AHC are given in Table 1 and Fig. 3.

Table 1: Classes' barycentres after the application of CAH

Classes	Objects	Total	Intra-class variance	Min. distance to canter of gravity	Mean distance to canter of gravity	Max. distance to canter of gravity	Regions
1	1	1	0,00	0,00	0,00	0,00	Dakar
2	2	2	46004025292	151664	151664	151664	Diourbel, Thiès
3	11	11	76894792793	17613	202463	613872	Sédhiou, Tambacounda, Kolda, Ziguinchor, Louga, Kaolack, Matam, Saint-Louis, Kaffrine, Fatick, Kédougou

The subdivision into three groups obtained with the PCA is confirmed with the AHC, which resulted in a binary classification tree (dendrogram) (Fig. 3), the root of which corresponds to the class grouping all the regions. This dendrogram represents a hierarchy of partitions and groups the most similar regions possible within the same class (intra-class homogeneity). The AHC was carried out to classify the 14 regions of Senegal and group them into classes on the basis of similarities or disparities according to the number of confirmed cases, active cases, recovered cases and reported deaths, and the population, area and density of the region. Depending on these different variables, the three groups of the PCR are confirmed by the CAH: the 1st group with Dakar, the 2nd group with Diourbel and Thiès and the 3rd group consisting of the 11 other regions (Sédhiou, Tambacounda, Kolda, Ziguinchor, Louga, Kaolack, Matam, Saint-Louis, Kaffrine, Fatick, Kédougou). This last group shows clearly visible disparities between the regions within it, given the differences in COVID-19 values (confirmed cases, active

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cases, recovered cases and reported deaths), population and density.

Analysis of the correlation matrix of COVID-19 pandemic variables shows that there is a relationship between COVID-19 pandemic (confirmed cases, active cases, recovered cases and reported deaths), population and density, suggesting that generally the more densely populated an area is, the more it tends to be affected by the Coronavirus pandemic, and vice versa. The axes 1 and 2 thus selected highlight their relationships with the parameters studied (Table 2).

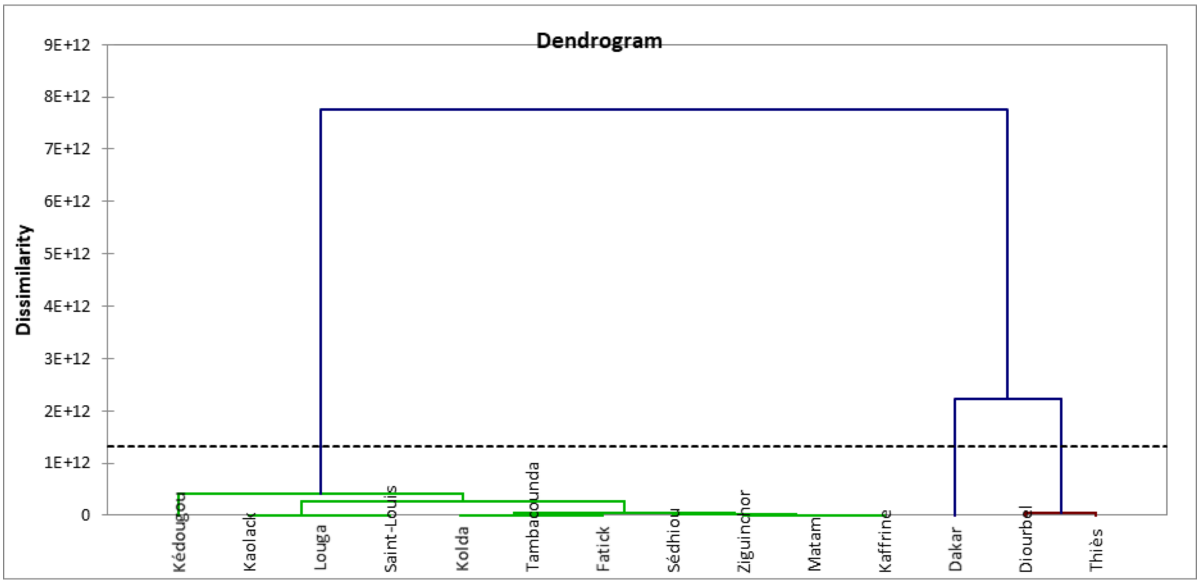

Fig. 3: Dendrograms obtained after the application of CAH

Table 2: Vectors of the correlation matrix of selected pandemic-related variables at the regional level in Senegal

	F1	F2
Confirmed cases	0,99	0,10
Active cases	0,99	0,10
Recovered cases	0,99	0,10
Deceased cases	0,98	0,05
Population	0,92	-0,04
Area	-0,45	0,89
Density	0,99	0,09

The correlation matrix of COVID-19 pandemic variables and variance weight factors (Table 2 and Fig. 2) show that axis 1 (main axis of inertia), which accounts for over 84.64% variance, is highly positively correlated with the number of confirmed cases, active cases, recovered cases and reported deaths, population and density. On the other hand, it is weakly but negatively correlated with the area of the region. Axis 2, with 11.91% variance, is positively, strongly correlated with the surface area of the region and weakly correlated with the pandemic variables and density. On the other hand, it is negatively correlated, albeit very weakly, with the population of the region.

Table 3: Correlation matrix between COVID-19 data, population, density and area of the regions of Senegal

Variables	Confirmed cases	Active cases	Recovered cases	Deceased cases	Population	Area	Density
Confirmed cases	**1**						
Active cases	0,99	**1**					
Recovered cases	1,00	0,99	**1**				

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Deceased cases	0,98	0,96	0,98	**1**			
Population	0,87	0,90	0,86	0,88	**1**		
Area	-0,37	-0,36	-0,37	-0,40	-0,43	**1**	
Density	1,00	0,99	1,00	0,97	0,86	-0,37	**1**

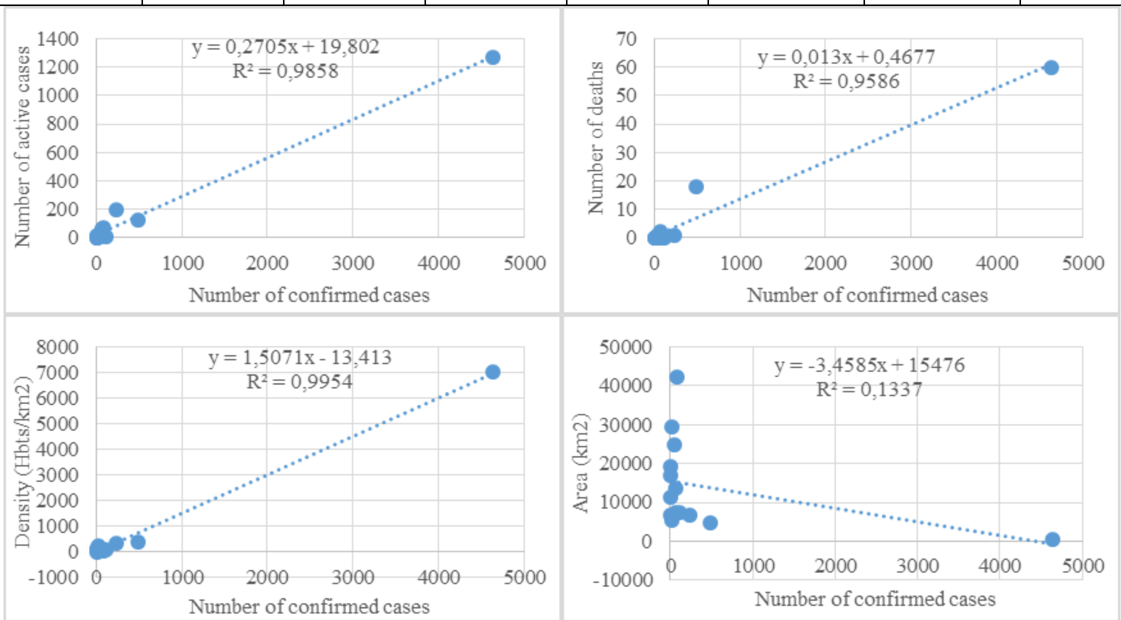

Fig. 4: Correlation between the total number of confirmed cases and some selected variables

In order to group the variables related to COVID-19 based on correlating trends in confirmed cases, deaths and confirmed recoveries, Pearson correlation matrices were calculated between the variables. These matrices are shown in Table 3. The total number of confirmed cases has its strongest relationship with density (1), total number of recovered cases (1), total number of active cases (0.99), total number of deaths (0.98) and population (0.87). On the other hand, the weakest relationship is noted with area and is negative (-0.37) (Fig. 4). The number of active cases also correlated strongly with the total number of deaths (0.96) and the total number of cases recovered (0.99). The total number of deaths is also highly correlated with population (0.88) and density (0.97).

4.2 Temporal evolution of the pandemic

The analysis of the temporal evolution of the pandemic was done with daily data from Senegal of 6 variables related to COVID-19 which are the number of confirmed cases, new cases, active cases, recovered cases, deaths, new deaths. On these different data, trend lines are represented and Mann-Kendall and Pettitt tests are applied to detect possible gradual changes and breaks in the series respectively. The results are shown in Fig. 5, 6, 7 and 8, and in Table 5.

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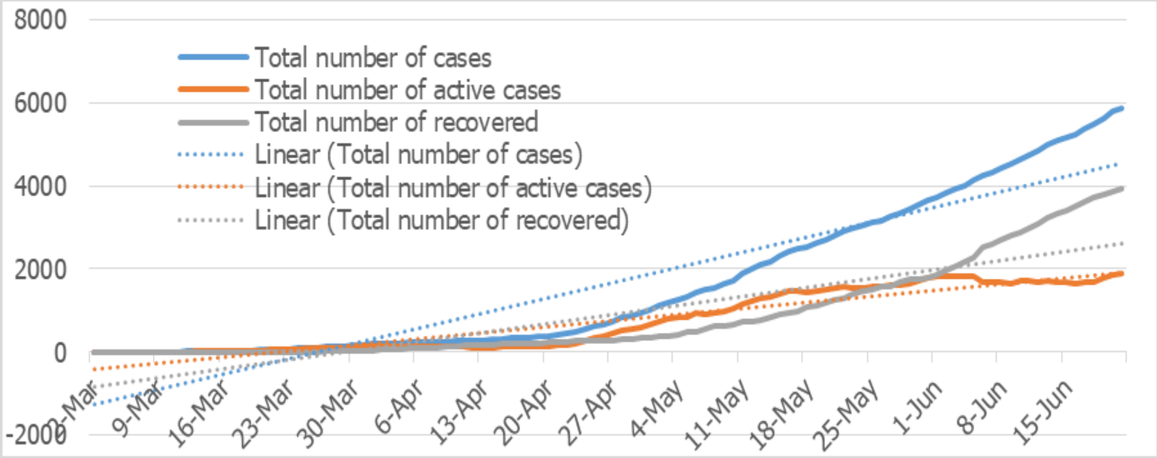

Fig. 5: Daily trend lines for total number of cases, active cases and recovered cases of COVID-19 in Senegal

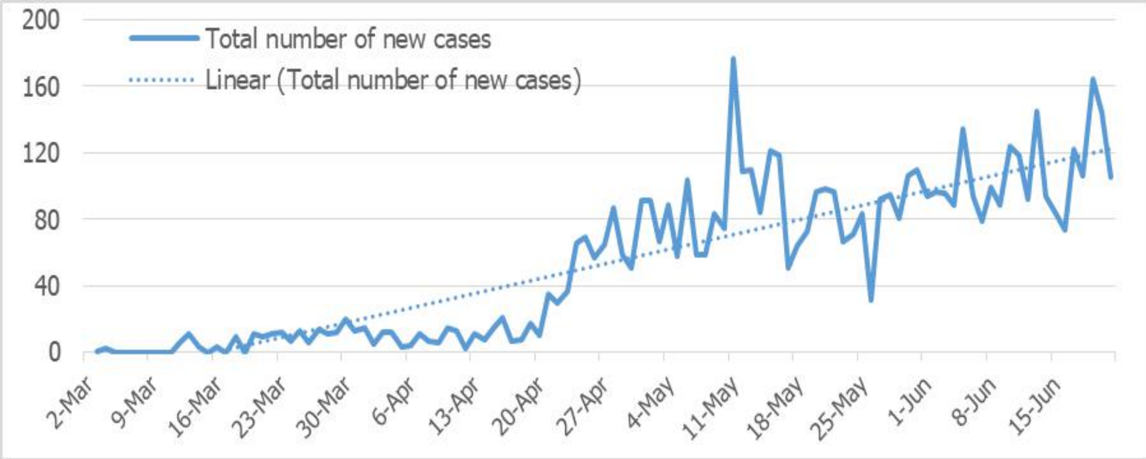

Fig. 6: Daily trend lines for the number of new cases of COVID-19 in Senegal

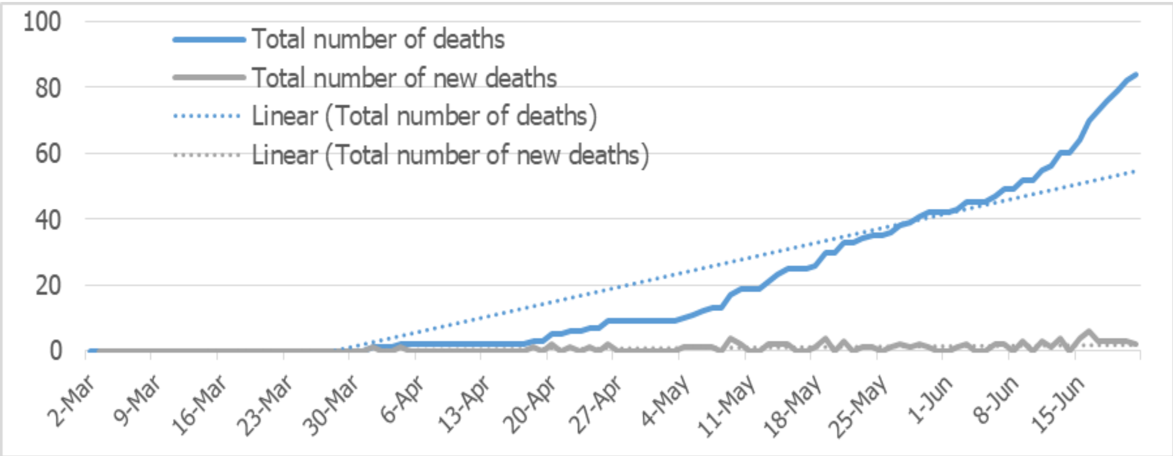

Fig. 7: Daily trend lines of total number of deaths and new deaths of COVID-19 in Senegal

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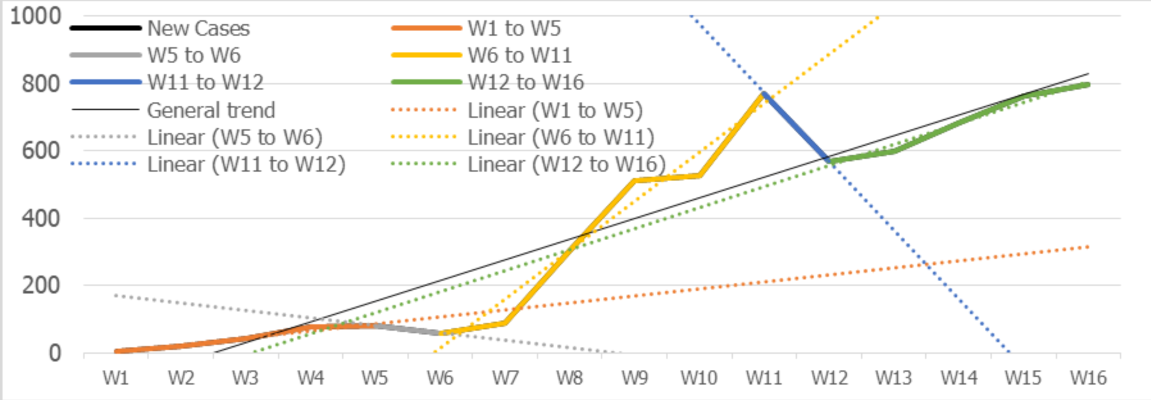

Fig. 8: Weekly Trend Lines for Number of New Cases of COVID-19 *in Senegal*

From March 2 to June 21, 2020, the total number of confirmed and active cases of COVID-19 increased drastically (Fig. 5 and 6). The total number of confirmed cases increased from one case on March 2, 2020 to 5888 cases on June 21, 2020. The number of active cases increased from one case on 2 March 2020 to 1,884 cases on 21 June 2020. However, the number of active cases started to drop below the cumulative number of cases in early April. This means that the cases of COVID-19 are retracting, which may be the result of recovery or death (**Magongo, 2020**). Fig. 7 confirms that, cumulatively, new cases of COVID-19 in Senegal, which was very low between 2 March and 20 April (the number of cases rarely reaching 20 cases per day), incre0sed significantly ove0r the period from 21 April to 21 June. Over this period (particularly between 24 April and 21 June), the number of new cases generally remains stable, despite an increase in the period from 11 to 16 May with values exceeding 100 cases per day.

Table 4: Identification of trends and breaks in the series of variables related to COVID-19

Settings	Mann-Kendall test		Pettitt's test	
Number of confirmed cases	p-value	< 0,0001	p-value	< 0,0001
	τ from Kendall	0,9974	Date of break	25-Apr
	Sen Slope	52	Surplus or Deficit in %	1665
Number of new cases	p-value	< 0,0001	p-value	< 0,0001
	τ from Kendall	0,714	Date of break	23-Apr
	Sen Slope	1,2	Surplus or Deficit in %	895
Number of active cases	p-value	< 0,0001	p-value	< 0,0001
	τ from Kendall	0,894	Date of break	25-Apr
	Sen Slope	20	Surplus or Deficit in %	1387
Total number of deceased cases	p-value	< 0,0001	p-value	< 0,0001
	τ from Kendall	0,951	Date of break	25-Apr
	Sen Slope	0,6	Surplus or Deficit in %	2540
Number of new deaths	p-value	< 0,0001	p-value	< 0,0001
	τ from Kendall	0,4985	Date of break	03-May
	Sen Slope	0	Surplus or Deficit in %	948
Number of cases	p-value	< 0,0001	p-value	< 0,0001

recovered	τ from Kendall	0,995	Date of break	25-Apr
	Sen Slope	24	Surplus or Deficit in %	1981

Based on current statistics, the Fig. show that we expect a significant number of recovery cases. Proportionally, of the total confirmed cases, 3919 have recovered, representing 66.5% of all cases (**MSAS, 2020**). Since the first reported case on March 2, 2020, we began to see (beyond the first case that recovered 6 days later) actual recovery cases around March 20, 2020. This means that there is a time lag between the time of diagnosis and when the test for the disease is negative. Thus, in the health care system, hospital beds are occupied by a COVID-19 patient for an extended period of time until recovery. Each day, the number of new positive cases is added to the pool of those who will be hospitalized for a period of time, the time it takes for these patients to be tested and to test negative. The protocol for managing this disease in Senegal requires that each positive case be isolated and quarantined until the test is negative.

Table 4 shows the results of the Mann Kendall test, the slope of Sen and the point of change by the Pettitt test. All results are considered significant at α=0.01, so there is a significant change in the transmission pattern. The calculated Sen slope shows a rate of increase in transmission of COVID-19 of 1.2 persons/day across the country, while the rate of increase in the number of new deaths is 0. Regionally, Dakar has the highest rate of increase (753 persons/week) followed by Diourbel (84 persons/week) and Thiès (36 persons/week), while Kédougou has the lowest rate of increase (0.15 persons/week). Analyses also show that the trend in weekly new cases (Fig. 8) has changed (sometimes increasing, sometimes decreasing) across Senegal : first increase in the first 5 weeks (4 cases on 2 March to 80 cases on 5 April); first decrease in week 6 (80 cases on 5 April to 58 cases on 12 April); second increase from week 6 to week 11 (58 cases on 12 April to 771 cases on 17 May); second decrease from week 11 to week 12 (771 cases on 17 May to 567 cases on 24 May); third increase from week 12 to week 16 (567 cases on 24 May to 798 cases on 21 June). It was also noted that all major affected areas showed a more rapid increase in the transmission rate after the change point generally noted on 25 April by the Mann Kendall test. Over the period from 26 April to 21 June, compared to the period from 2 March to 25 April, the rate of increase is 895% for the number of new cases and 948% for the number of new deaths. Thus, throughout the country, and particularly in the most affected areas, the rate of transmission increased alarmingly during the lock-in period (through curfew and state of emergency).

Basically, lockdown was implemented with a brief social distancing guideline to reduce the occurrence of human-to-human transmission by avoiding gatherings in workplaces and other public places. Thus, national lock-in has been very effective in reducing the rate of growth of transmission in different countries around the world such as China, Italy, France, Germany, the UK, etc. (**Gatto et al., 2020; Leung et al., 2020; Wurtzer et al., 2020**). However, in Senegal, while the initial growth rate up to April was low, thereafter growth was multiplied. The reason for this low initial growth rate was the lack of testing facilities before 25 April, but as soon as the number of tests increased, the number of infected cases increased sharply as well (**Gupta and Pradhan, 2020**). This shows that the likelihood of getting confirmed cases also increases weekly, which may be a sign of community transmission. The trend of daily new cases in the main affected areas also indicates the sharp increase in daily transmission, starting in May. It also shows that regions located on the coastal or western part of the country with a larger population have experienced a higher rate of increase in transmission. Beyond the capital Dakar, the number of daily transmissions is increasing in most regions. One of the likely reasons for this peak in transmission could be the reopening of inter-city transport and allowing people to return to their areas of origin, which has resulted in large crowds in various cities and more people in the transport sectors, as reported by many local and national newspapers, which could lead to an unexpected rate of increase in new daily cases throughout the country.

Other variables need to be monitored to make responsible decisions about this pandemic. These variables are important to know the extent of the existence of this virus in the population, the extent to which infected people recover from the disease, the extent to which infected people do not recover and eventually die from complications related to the virus. For new cases, in the first few weeks since the start of the pandemic, testing of individuals was based on the presentation of clinical symptoms. This means that people were tested when they presented to health care practitioners with one of the symptoms of IDVOC-19. This was the case of the first case that tested positive for COVID-19 and actually stayed only

International journal of Rural Development, Environment and Health Research (IJREH)
[Vol-4, Issue-4, Jul-Aug, 2020]
ISSN: 2456-8678
https://dx.doi.org/10.22161/ijreh.4.4.1

6 days on hospital beds to test negative. The limitations of this approach are that it does not really allow us to know the level of spread of the virus in the population. By using this approach, many people who do not have symptoms but are infected cannot be counted in the pandemic statistics.

IV. CONCLUSION

In this study, the daily trend of confirmed cases in the regions of Senegal as well as a comparison of the country as a whole were also inspected. This study revealed convincing spatial differences in the incidence, deaths and recoveries of COVID-19 among the regions of Senegal. The wide variation in disease outcomes in Senegal is attributable to several factors such as international connectivity, climate, health care infrastructure, population density, initial responses to epidemics, and testing capacity. Testing capacity for COVID-19 is extremely low relative to the population throughout the country. The COVID-19 pandemic has led to a state of recrudescence in Senegal. In the space of 112 days (from 2 March to 21 June), Senegal reached a number of 5888 infected cases for 3919 cured, 1885 active and 84 deaths for a total of 67855 tests performed. About 40 people out of 10,000 have been tested so far and 4 out of 10,000 have tested positive. The daily confirmed cases are increasing with a daily score of 1.2 persons since March 2, 2020, however, this rate has been rising steadily, and especially since April 26 (the number of cases has increased from 1 on March 2, 2020 to 5888 on June 21, 2020). On the other hand, the lowering of the rigour in the subsequent phases of lock-out as well as the consent of interurban migration have inevitably facilitated transmission, which has led to an inextricable situation throughout the country. The most populated areas have seen a higher rate of increase in daily cases. In addition, the gradual change in the upward trend in all major affected areas was also noted in mid-May, i.e. at the margin of the first and second lock-ups. This means that the imposed lock-in did not reduce the transmission of COVID-19 in Senegal, unlike in European countries which seem to have the pandemic under control, etc.

Despite several conclusions, this study had limitations because the scale is regional and many affected localities were not able to integrate it due to the lack of available data. However, Senegal, which has a very high cure rate for the disease (66.5 per cent of all cases), has adopted strict adherence to certain WHO protocols in order to contain the disease, test mainly those with symptoms of the disease, isolate all those who are positive for the disease and provide rapid treatment of patients with a range of drugs, in particular hydroxychloroquine, chloroquine and the chloroquine-azithromycin combination. The study recommends that these approaches adopted by Senegal, which has achieved high cure rates for COVID-19, be integrated into health care management plans for the disease across the continent, even as the situation evolves.

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