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REVISTA BRASILEIRA DE GESTÃO E DESENVOLVIMENTO REGIONAL
V.20, N°2, Mai-Ago/2024 | Taubaté/SP - Brasil | ISSN 1809-239x

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Received: 05/27/2024
Accepted: 08/01/2024

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ABSTRACT

Public administrators struggled to allocate healthcare resources during the last health crisis. The Legal Amazon requires attention in its actions due to its territorial peculiarities and for being the pandemic's epicenter. This study aimed to assess the efficiency of Legal Amazon health regions in allocating resources during the COVID-19 pandemic. Seventy-seven health regions were analyzed using the DEA method, considering health resources as inputs and lethality and mortality rates as outputs. Only 11.69% of the regions were efficient, with Amapá standing out for the best result and Pará, Mato Grosso, Rondônia, Maranhão, Acre, and Roraima as the worst performers. The health regions Northern Araguaia Karajá (Mato Grosso) and Vale do Guaporé (Rondônia) were identified as partners of excellence for many regions. The allocation of health resources was inefficient, with better results in isolated regions. Investing only in the allocation of resources without considering social isolation and other public policies as integral parts of strategies to face the pandemic is not an ideal approach to contain the virus spread and safeguard the population's health.

Keywords: COVID-19. Resource allocation. Efficiency.

RESUMO

Os gestores públicos enfrentaram um árduo desafio na alocação dos recursos de saúde durante a última crise sanitária. A Amazônia Legal, devido às suas peculiaridades territoriais e por ter sido epicentro da pandemia, requer uma atenção da sua atuação. O objetivo deste estudo foi avaliar a eficiência das regiões de saúde na Amazônia Legal na alocação de recursos durante a pandemia da COVID-19. Foram analisadas 77 regiões de saúde por meio da Análise Envoltória de Dados, considerando os recursos de saúde como *inputs* e as taxas de letalidade e mortalidade como *outputs*. Apenas 11,69% das regiões foram consideradas eficientes, com o Amapá em destaque pelo melhor resultado e o Pará, Mato Grosso, Rondônia, Maranhão, Acre e Roraima com os piores desempenhos. A região de saúde Norte Araguaia Karajá e Vale do Guaporé, foram identificadas como parceiros de excelência para maior quantidade de regiões. A alocação de recursos de saúde mostrou-se ineficiente, com melhores resultados em regiões isoladas. Investir apenas na alocação de recursos sem considerar o isolamento social e outras políticas públicas como parte integrante das estratégias para enfrentar a pandemia não é uma abordagem ideal para conter a disseminação do vírus e proteger a saúde da população.

Palavras chave: COVID-19. Alocação de recursos. Eficiência.

INTRODUCTION

The Unified Health System (SUS) was created to guarantee the population's right to universal, accessible, and comprehensive health care (Escorel et al., 2007). Consistent progress has been noted in the thirty years since its creation. However, some factors, such as inadequate financing, unsatisfactory health infrastructure, insufficient human resources, and geographical distances, hinder patients' access to health services (Gómez; Jungmann; Lima, 2018; Castro et al., 2019).

The COVID-19 pandemic has led to the most significant health and hospital collapse in the country's history and put the health systems of several countries, including Brazil, at risk. Patient care has revealed disparities in the supply and access to resources in the public and private sectors and different regions of the country, besides initiatives to preserve healthcare segmentation (Costa et al., 2020; Marckmann et al., 2020).

The spread of cases and mortality from COVID-19 occurred differently between regions, depending on the adoption of social distancing measures, availability of ICU beds and health equipment, labor market structure, and social and sanitation conditions. However, the

disproportionate allocation of health workers to care for patients infected with the coronavirus was one factor that marked critical regional inequality (Santos, Manzano, Krein, 2021). Such conditions led Brazilian states to address a demand greater than SUS available response capacity (de Andrade et al., 2020), even with the participation of supplementary health. An example of this was the occupancy rates of COVID-19 ICU beds for adults in the Brazilian SUS in March 2021, where the values were equal to or greater than 80% in 24 states and the Federal District, with 15 of them having rates equal to or greater than 90% (Brasil, 2021a).

The Legal Amazon, located in the Brazilian North, has a low population density. However, it was marked by a high concentration of COVID-19 cases (Mascarenhas; Vidal, 2021) and a discrepant distribution of health resources, with regions with a high detection rate and neighboring regions in the same situation but with a small number of ICU beds and mechanical ventilators, with resources concentrated in the capitals (Rezende et al., 2023).

Planning and managing the allocation of health resources are essential to meet regional demand, avoid deaths, and prevent the system's collapse. To this end, public managers must understand the system's efficiency to identify areas that require investment and management of existing resources. Due to its territorial characteristics and the pandemic's epicenter in the second wave, the Legal Amazon deserves to be highlighted in the analysis of the distribution of these resources. This research findings can be a valuable support for public health policies in the region, providing information that promotes more effective and equitable management.

Therefore, strategic planning considering regional specificities and actual demand is essential to mitigate healthcare access disparities. By identifying areas in need and directing investments, managers strengthen health infrastructure and ensure access to a universal, accessible, and comprehensive system, promoting the social and economic well-being of the regions. As a result, this study aimed to evaluate the efficiency of health regions in allocating health resources in the Legal Amazon to combat the COVID-19 pandemic.

REGIONAL DEVELOPMENT AND THE UNIFIED HEALTH SYSTEM'S EFFECTIVENESS

Regional development occurs unevenly, strengthening the most dynamic regions to the detriment of the less dynamic ones, and manifests itself in intra- and inter-related aspects (Lima and Simões, 2009). Its concept is dynamic and complex, shaped by a continuous historical process that requires significant transformations in social and economic structures. This process involves regional stakeholders collaborating to promote structural changes and joint strategies. The definition of regional development is not static but rather multifaceted and open to profound interpretations due to its complexity and diversity. Regions face challenges in conceptual construction due to conflicts of interest between different stakeholders, the interaction between internal and external factors, and the continuous adaptation to historical and contextual influences. This comprehensive and interdisciplinary approach highlights the need for a broad and integrated vision to understand and promote regional development sustainably and inclusively (Corrêa et al., 2019).

In the regional development context, it is crucial to consider the participation of local society in the formulation of territorial policies to address issues involving changes in the social structure and the allocation of resources across the several sectors of the economy in order to improve economic and social well-being indicators, such as poverty, unemployment, inequality, health conditions, food, education, and housing (Vasconcellos and Garcia, 1998).

Sen (2010) highlights that development involves the expansion of human freedom, emphasizing that economic aspects are also relevant to overcoming obstacles. This freedom includes access to education, health, and civil rights, allowing participation, choice, and opportunities. He argues that it is crucial to remove the sources of deprivation of freedom, such as poverty, lack of economic opportunities, social exclusion, neglect of public services, and excessive interference by repressive governments.

The National Regional Development Policy (PNDR), established by Decree N° 11.962 of March 22, 2024, aims to reduce intra-regional and inter-regional economic and social inequalities. It promotes sustainable economic growth, income generation, and improved population's quality of life through coordinated action between federal, state, district, and municipal spheres, both public and private. (Brazil, 2024).

The principles that guide the PNDR, according to Brazil (2024), include transparency and social participation; regional solidarity and federative cooperation; integrated planning and cross-sectionality; sustainable development; multi-scale level action in the national territory; recognition and appreciation of the environmental, social, cultural, and economic diversity of the regions; and competitiveness and equity in productive development. Some PDNR objectives are:

I – To promote the reduction of regional inequalities in Brazil, seeking equity in access to development opportunities in areas with low socioeconomic indicators;

II – To create a network of cities with polycentric functions, supporting the decentralization and internalization of development, considering the specific characteristics of each region;

III – To encourage increased productivity and competitiveness in regions facing population decline and high emigration rates;

IV – To foster economic diversification and value aggregation in strategic production chains for regional development, prioritizing criteria such as income generation and sustainability, especially in areas focused on producing agricultural or mineral commodities.

Health has assumed an increasingly strategic role in the development agenda, and its relationship with it has been widely recognized. This interaction between health and development is complex and deeply linked to economics, involving diverse social, political, and economic interests. In this context, health drives regional development, addressing the socioeconomic inequalities manifesting in different areas of the country (Gessi et al., 2020).

The 1988 Federal Constitution established the foundations for a profound restructuring of the Brazilian Health System by formalizing the principle of equality and public commitment to guaranteeing this equality. Establishing the Unified Health System (SUS) is a “founding charter” of a new social order in health based on the principles of universality and equity. Structured based on decentralization, comprehensive care, and community participation, the SUS aims to ensure universal and free access to health services, thus promoting social justice and improving the quality of life of the Brazilian population (Menicucci, 2009). This initiative aims to combat socioeconomic inequalities in health and promote the democratization of access to services, integrating actions to foster, protect, and restore health for the entire population.

The SUS model was a social revolution by guaranteeing free healthcare to the entire population. However, its complexity and the need for a wide range of resources to function efficiently have significant challenges for public managers (Andrade et al., 2017). In developing countries, managing health expenditures is even more critical due to the scarcity of resources (Zucchi, Del Nero, and Malik, 2000).

The SUS faces daunting obstacles in its practical effectiveness. One of these challenges lies in the State's difficulty articulating social and economic policies that consolidate health issues and effectively reduce inequalities. This situation is exacerbated by the complexity of a country with a heterogeneous municipal network and a vast continental territorial extension (Gessi et al., 2021).

In this setting, the more extensive the activities of a given area of government activity, the greater the challenge of conducting effective monitoring and evaluation. An accurate efficiency diagnosis cannot be obtained without properly assessing these activities. Therefore, there is a growing need for tools and methodologies that enable a more accurate evaluation of these activities to formulate strategies to improve public services (Andrade et al., 2017).

The Data Envelopment Analysis (DEA) method stands out among the several methodologies used to assess efficiency. This tool has been successful in public administration efficiency studies. An example of this can be seen in the studies by Santos and Rover (2019), Matosinho et al. (2020), Garmatz et al. (2021), Mazon et al. (2021), and Fochezatto et al. (2022). These works highlight the relevance of objective metrics to assess the performance of public policies, such as those related to municipal health management.

According to Teixeira and Molesini (2002), the municipal health manager is responsible for planning the city's health system. This mainly includes territorializing the population's health conditions and identifying epidemiological and social disparities. Based on this analysis, the manager must develop proposals and implement specific actions to address the community's health problems and risks.

MATERIAL AND METHODS

This descriptive, exploratory, cross-sectional study evaluated the Legal Amazon. The unit of analysis was the health regions, conceptualized as the continuous geographic space established by the union of neighboring municipalities. These regions are based on cultural, economic, and social identities and shared communication networks and transport infrastructure to integrate the organization, planning, and implementation of health actions and services (Brazil, 2011).

Data on COVID-19 cases by municipality of residence were extracted from the Ministry of Health's Coronavirus Dashboard on April 10, 2021 (Brazil, 2021b). We used data on accumulated cases up to March 31, 2021. This period is justified because it was one of the COVID-19 peaks in Brazil, as seen in the graph of cases by epidemiological week on the World Health Organization website (WHO, 2021). Data are constantly updated or corrected. The municipality of notification is not always the same as the municipality where the notified person resides, and corrections are made after the investigation is completed. In total, 1,860,217 cases of COVID-19 were recorded in the reference period of this study. Data on the resident population by municipality corresponding to the IBGE estimates for 2020 were employed to calculate the mortality rates (Brazil, 2020a).

Data concerning mechanical ventilators, intensive care unit (ICU) beds for COVID-19 available, and human resources (general practitioners, physiotherapists, and nurses) were collected from the National Registry of Health Establishments – CNES (Brazil, 2021c; Brazil, 2021d). Data Envelopment Analysis (DEA) was employed to assess the efficiency of health regions in the allocation of health resources, conceptualized as a mathematical programming tool used to measure the relative efficiency of a set of Decision-Making Units (DMUs) with multiple inputs and outputs varying between 0 and 1, being "inefficient" and "efficient", respectively (Charnes; Cooper; Rhodes, 1978).

This study's inputs were the number of ICU beds, mechanical ventilators, and healthcare professionals. The inverse relationship between the mortality rate and COVID-19 lethality rate (1/ outputs) was used as an output since these are undesirable outputs. Seventy-seven health regions were analyzed as DMUs. Although the study object has 78 health regions, one was excluded (Caxias-MA) because it has only one municipality covered by the Legal Amazon.

DMUs have similar production processes and differ in the number of inputs and actions produced (outputs). Health regions' performances are evaluated by comparing inputs and outputs with other regions (Andrade et al., 2014). This modeling allows for the establishment of scores, with the identification of excellence partners (benchmarks), in which inefficient DMUs should aim to perform and perform improvement actions based on the direction of better-performing DMUs (Ferreira; Gomes, 2020).

Data Envelopment Analysis (DEA) can be expressed through the original CCR model by Charnes, Cooper, and Rhodes in 1978, initially conceived as an input-oriented model and worked with a constant return to scale (CRS), that is, the variation in the input produces proportional variation in the outputs. The BCC model expanded by Banker, Charnes, and Cooper in 1984 uses variable returns to scale (VRS), thus seeking to avoid problems in imperfect competition (Banker, 1996; Andrade et al., 2014). The nonparametric Kolmogorov-Smirnov two-sample test suggested by Banker (Ferreira; Gomes, 2020) was adopted to identify which model best fits the data, and operationalization was performed using the R language.

Data manipulation, information georeferencing, spatial analysis, and map production were performed using Excel 2013 and QGIS 3.30.0. Technical efficiency analysis was conducted using the Benchmarking package in the statistical software R, version 4.3.3. Cartographic bases were obtained from the IBGE's 'Map Portal' (territorial boundaries, municipal headquarters, and highways). This study was undertaken exclusively with secondary public domain data, and submitting the project to the Research Ethics Committee was unnecessary.

RESULTS

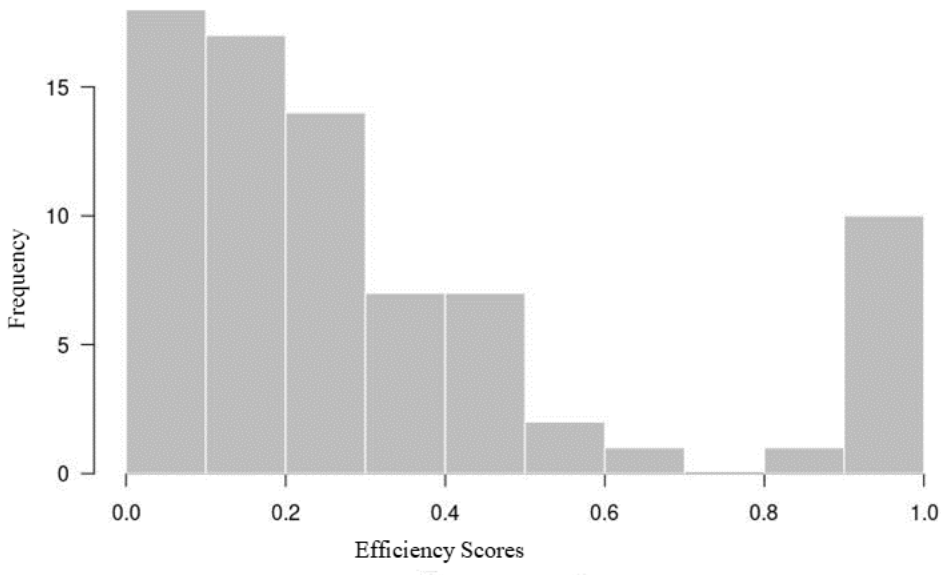
The Kolmogorov-Smirnov test was performed (p=0.003558) after estimating the levels of technical efficiency under the assumption of VRS and CRS returns, which rejected the null hypothesis of absence of scale inefficiency, i.e., the sizes of the DMUs influenced efficiency, and the VRS assumption model was the most appropriate. This result was expected since the CRS model assumes an optimal scale for firms. However, the irregular distribution of health resources, the discrepancy between health regions, and the heterogeneous pattern of COVID-19 rates led the DMUs to operate outside this scale.

According to the calculation with variable returns to scale oriented to the input based on the selected variables, the mean efficiency of the health regions was 0.324, ranging from 0.01026 to 1.000000. Therefore, the municipalities can reduce the inputs used by 67.6% and maintain constant lethality and mortality rates. Given the shortage of inputs in the SUS, this adjustment gains significant relevance and allows the reallocation of these resources to other care areas.

Nine of the seventy-seven health regions are operating at 1 (one) overall efficiency, one in the state of Acre (Alto Acre), two in Amapá (Northern Area and Southwest Area), two in Maranhão (Itapecuru Mirim and Rosário), two in Mato Grosso (Northern Araguaia Karajá and Vale dos Arinos), one in Rondônia (Vale do Guaporé), and one in Tocantins (Southeast). These health regions perform better than the others since they use resources without waste and operate at an optimal production scale, which involves balancing the supply of health services and patient demand, maximizing service capacity without wasting resources.

The histogram of efficiency scores for the Legal Amazon health regions, assuming variable returns to scale, revealed that efficiency levels are concentrated below 0.3, with only 11.69% of DMUs showing efficiency equal to 1 (Figure 1).

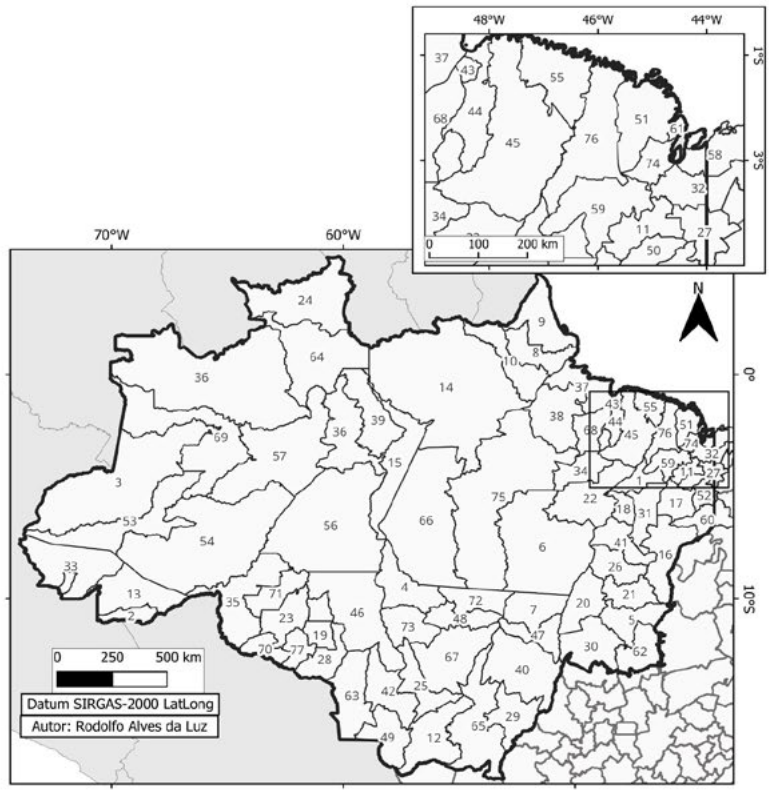
Figure 1 | Histogram of Efficiency Scores of the Legal Amazon's Health Regions



Source: Authors' data

Maps of the Legal Amazon health regions were created (Figure 2) to facilitate visualization. Another map produced revealed that 35 Legal Amazon health regions are classified in the worst efficiency range, which is more evident in Pará, Mato Grosso, Rondônia, and Maranhão, and proportionally in the extension of the state, in Acre and Roraima. Amapá is the region with the best efficiency level (Figure 3).

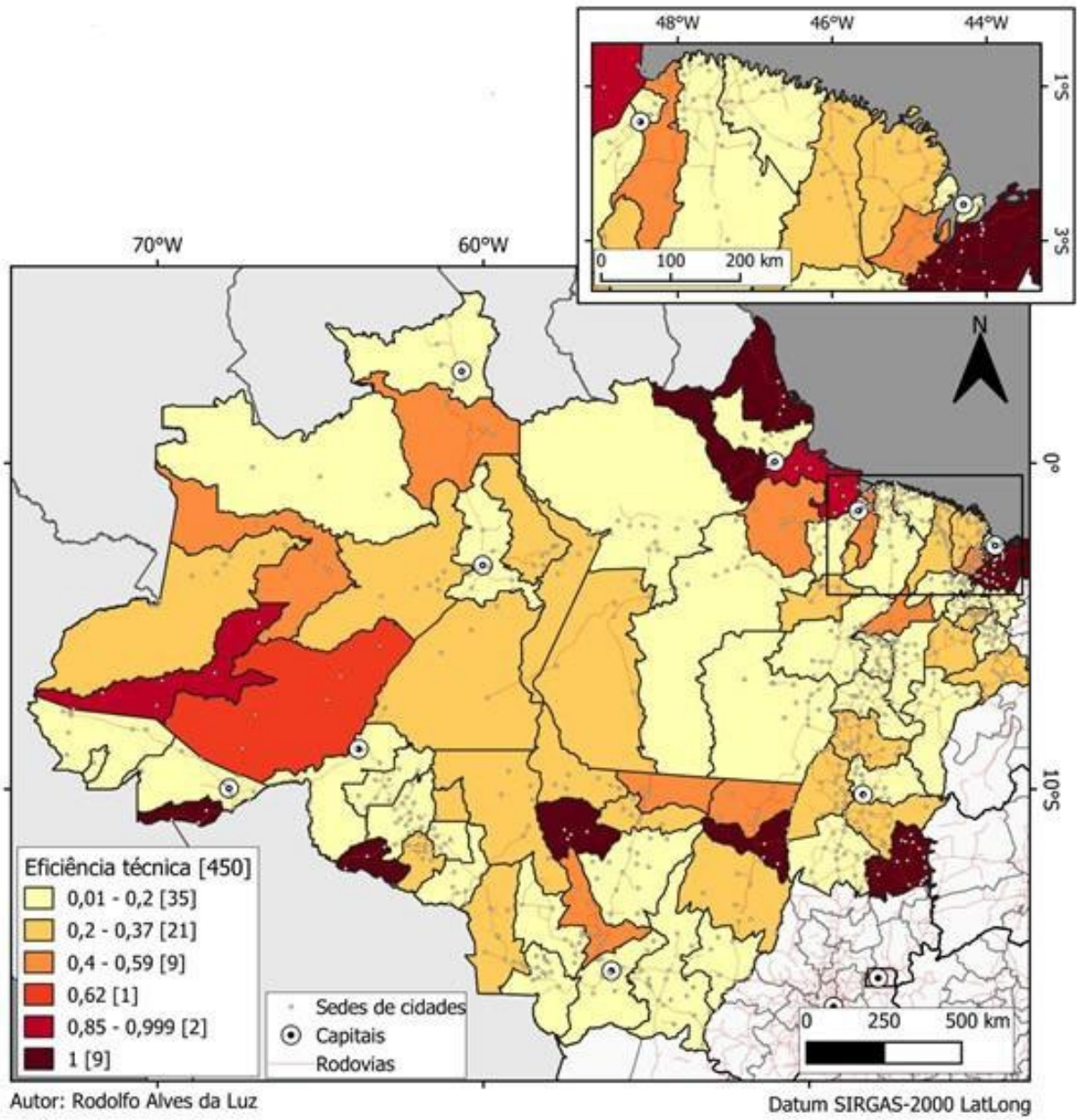
Figure 2 | Legal Amazon's Health Regions



id	Nome	UF
1	Açailândia	MA
2	Alto Acre	AC
3	Alto Solimões	AM
4	Alto Tapajós	MT
5	Amor Perfeito	TO
6	Araguaia	PA
7	Araguaia Xingu	MT
8	Área Central	AP
9	Área Norte	AP
10	Área Sudoeste	AP
11	Bacabal	MA
12	Baixada Cuiabana	MT
13	Baixo Acre e Purus	AC
14	Baixo Amazonas	PA
15	Baixo Amazonas	AM
16	Balsas	MA
17	Barra do Corda	MA
18	Bico do Papagaio	TO
19	Café	RO
20	Cantão	TO
21	Capim Dourado	TO
22	Carajás	PA
23	Central	RO
24	Centro Norte	RR
25	Centro Norte	MT
26	Cerrado Tocantins Araguaia	TO
27	Codó	MA
28	Cone Sul	RO
30	Ilha do Bananal	TO
31	Imperatriz	MA
32	Itapecuru Mirim	MA
33	Juruá e Tarauacá/Envira	AC
34	Lago de Tucuruí	PA
35	Madeira-Mamoré	RO
36	Manaus, Entorno e Alto Rio Negro	AM
37	Marajó I	PA
38	Marajó II	PA
39	Médio Amazonas	AM
40	Médio Araguaia	MT
41	Médio Norte Araguaia	TO
42	Médio Norte Matogrossense	MT
43	Metropolitana I	PA
44	Metropolitana II	PA
45	Metropolitana III	PA
46	Noroeste Matogrossense	MT
47	Norte Araguaia Karajá	MT
48	Norte Matogrossense	MT
49	Oeste Matogrossense	MT
50	Pedreiras	MA
51	Pinheiro	MA
52	Presidente Dutra	MA
53	Regional Juruá	AM
54	Regional Purus	AM
55	Rio Caetés	PA
56	Rio Madeira	AM
57	Rio Negro e Solimões	AM
58	Rosário	MA
59	Santa Inês	MA
60	São João dos Patos	MA
61	São Luís	MA
62	Sudeste	TO
63	Sudoeste Matogrossense	MT
64	Sul	RR
65	Sul Matogrossense	MT
66	Tapajós	PA
67	Teles Pires	MT
68	Tocantins	PA
69	Triângulo	AM
70	Vale do Guaporé	RO
71	Vale do Jamari	RO
72	Vale do Peixoto	MT
73	Vale dos Arinos	MT
74	Viana	MA
75	Xingu	PA
76	Zé Doca	MA
77	Zona da Mata	RO

Source: Authors' data

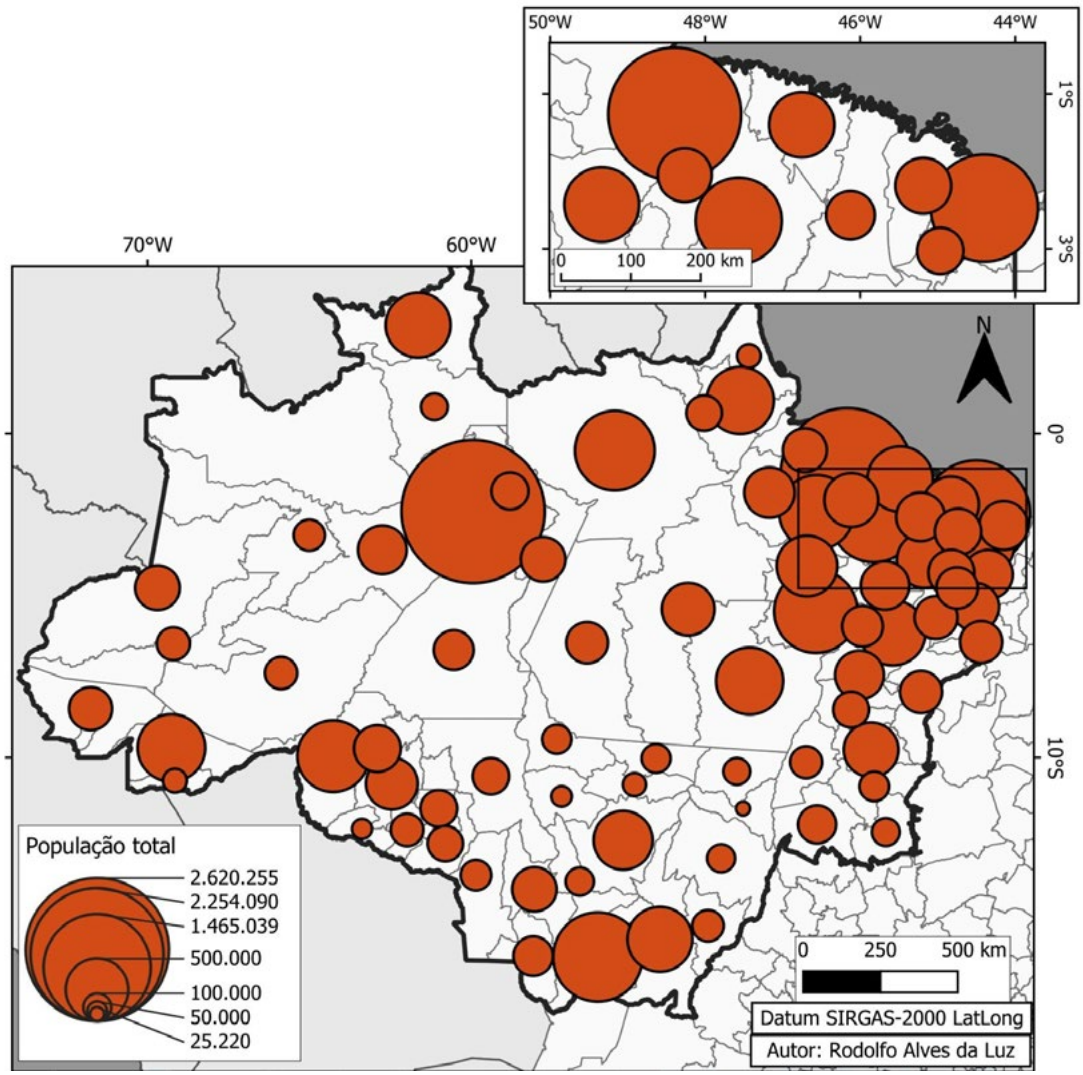
Figure 3 | Efficiency Scores of Health Regions and Road Flows in the Legal Amazon



Source: Authors' data

Figure 4 shows that the populations of efficient health regions are low, and Itapecuru Mirim has the largest population, with 320,006 inhabitants.

Figure 4 | Population of the Legal Amazon's Health Regions in 2020.



Source: Authors' data

All the mean input values of the efficient DMUs were considerably lower than those of the inefficient DMUs, and even so, they had significantly lower differences in mortality and lethality rates, 48.83% and 150.96%, respectively. In other words, although they had fewer physical and human resources than the inefficient DMUs, they had a lower death rate, which justifies that these health regions are more efficient. The health resources with the most significant discrepancy between efficient and inefficient DMUs were ICU beds (97.19%) and mechanical ventilators (95.04%). This fact highlights a discrepant allocation of these resources, essential items in cases of patients with severe COVID-19 complications requiring ventilatory support (Table 1).

Table 1 | Comparison between the mean number of inputs and outputs of efficient and inefficient DMUs

Specifications	Efficient DMUs	Inefficient DMUs	Difference %
ICU beds	1.22	43.48	97.19
Mechanical ventilators	6.44	129.83	95.04
General practitioner	24.22	162.50	85.09
Nurse	116.11	509.23	77.20
Physiotherapist	21.33	115.95	81.60
Mortality rate	435.79	845.06	48.43
Lethality rate	6.24	15.66	150.96

Source: Authors' data

The two regions identified as excellent partners for a more significant number of inefficient DMUs were the North Araguaia Karajá in Mato Grosso, with 65 DMUs, covering Alto Boa Vista, Luciara, Novo Santo Antônio, São Félix do Araguaia, and Serra Nova Dourada; and the Guaporé Valley in Rondônia, with 28 DMUs, comprising Costa Marques, São Francisco do Guaporé and Seringueiras. Figure 2 shows that these two health regions have low road traffic, which may have significantly reduced the COVID-19 virus spread. Furthermore, the efficient DMUs have the smallest relative population, which may have further contributed to the virus containment. Only the Southeast region (TO) is not a benchmark for any other DMU. Also, notably, among the efficient regions, this one had the highest mortality and lethality rates.

DISCUSSION

We found a mean efficiency of 0.324 when analyzing the seventy-seven Legal Amazon health regions, with only nine efficient DMUs, indicating an overall suboptimal performance in allocating health resources. Pará, Mato Grosso, Rondônia, and Maranhão had the worst efficiency scores against the territorial extension of each state. Similarly, Acre and Roraima also faced significant challenges in COVID-19 in their respective health regions.

Although inequalities in the Brazilian health system are a historical problem, the COVID-19 pandemic has caused great concern to the community, particularly health managers who have placed efficiency at the forefront of their current agendas.

DEA is an essential technique for evaluating health services and assisting in decision-making, as it allows for simultaneously addressing different dimensions of health units (Garmatz, Vieira, Sirena, 2021). This method aims to maximize the efficiency of a service unit by comparing a unit's efficiency with other similar units that perform the same work. Furthermore, it identifies opportunities for improving the unit in question and provides a benchmark to compare performance with similar units, thus streamlining available resources and ensuring that the service unit operates more efficiently (Fitzsimmons; Fitzsimmons, 2014).

While corresponding to 58.9% of the Brazilian territory, the Legal Amazon region did not display good technical efficiency in allocating health resources during the COVID-19 pandemic. The uneven distribution of physical health resources was observed by Rezende et al. (2023), when they identified that the highest concentration of ICUs and mechanical ventilators were in the capitals, besides the low number of resources in regions with a High-High pattern of the disease. Although health services can be integrated between locations through health regions, the high demand associated with the difficulty of geographical accessibility can result in unequal access to the most complex care levels.

A study conducted in April 2020 found that Amapá and Roraima had the lowest health infrastructure indices. Regarding significant spatial clusters with a "Low-Low" pattern, the situation in Amazonas and Pará stands out, indicating a possible fragility in health services to serve the population, especially in high demand (Bezerra et al., 2020).

During the analysis of the relative efficiency indices of Brazilian federative units in combating deaths caused by COVID-19 at two critical pandemic stages, we identified that more than 50% of the federative units were inefficient. In July 2020, the mean efficiency was 0.8, while it was 0.67 in March 2021. In the first period evaluated, Mato Grosso obtained the worst index (0.28). In both periods, Roraima stood out with the lowest score, 0.18 (Silva, 2021).

Although the focus of the analysis was the health regions, this research identified a higher inefficiency rate in the allocation of resources (88.31%), with worse efficiency means in the health regions of Pará, Mato Grosso, Rondônia, and Maranhão and proportionally across the state, in Acre and Roraima.

Although Mato Grosso had several regions with low-efficiency levels, two efficiently allocated health resources, and the Northern Araguaia Karajá-MT region had the most significant number of excellent partners (65). On the other hand, Amapá had the highest efficiency level, and two of the three regions were efficient.

None of the nine efficient health regions included the area covered by the capitals. This aligns with Rezende et al. (2023) findings since the high concentration of inputs in the capitals can lead to their underutilization and inefficiency. Notably, technical efficiency is not restricted to the number of resources available in a given area but rather the ability to minimize the relationship between inputs and outputs and ensure streamlined resource use. Thus, it relates to the means, not the ends (Ferreira; Gomes, 2020).

According to Costa (2021), operating systems below the efficiency limit, i.e., using more resources, can provide a more robust response capacity to pandemic events than systems that are most likely efficient in containing costs and resources. This perspective differs from the results of this research, which revealed that the best-performing health regions had a low number of allocated resources.

Efficient DMUs had low lethality and mortality rates during the period. This achievement can be mostly inferred from the fact that many of these regions are isolated and have low road traffic, which favored the COVID-19 spread containment. This is in contrast to more urbanized areas, where the network of urban hierarchies and the intense circulation of people and goods contributed to the virus spread (Bezerra et al., 2020; Jardim et al., 2022).

Disadvantaged socioeconomic groups, who lack adequate access to health services regularly, become even more vulnerable during crises (Chung; Dong; Li, 2020). The spread of misinformation and lack of communication disproportionately affect people with less access to information, which increases the likelihood that they will ignore government health-related guidance (Peters, 2020; Silva; Batista, 2022). This fact may justify inefficient DMUs, given that the Legal Amazon is a region with a heterogeneous and multifaceted socioenvironmental setting, with densely inhabited urban centers in contrast to isolated cities and diverse traditional populations that reside in remote rural areas, such as Indigenous people, riverside communities, fishermen, and quilombolas, sometimes in inaccessible territories (Santos et al., 2018).

The pandemic also highlights issues related to human resources. Despite the increase in the number of health professionals and the availability of jobs in the Brazilian market since the implementation of the SUS, inadequate distribution across the country results in a shortage of specialists in several areas of the system (Scheffer et al., 2018). In general, the states of the North and Northeast regions, particularly Alagoas, Amapá, Maranhão, Roraima, and Rondônia, have the lowest availability of health professionals against the population (Lopes et al., 2020). In this research, when comparing efficient and inefficient DMUs, the most significant disproportionality in the allocation of professionals was that of general practitioners, followed by physiotherapists.

Health plays a crucial role in regional development, and its importance is based on the significant territorial impact of national socioeconomic inequalities. It is fundamental for structuring urban networks and defining scales and territorial limits, influencing space occupation. Moreover, it can define new investment flows, changing traditional production and income concentration patterns in space (Gadelha; Machado; Baptista, 2011).

The Brazilian health sector faces several hardships. Therefore, with thorough cost-effectiveness and cost-benefit analysis, health area actions should be rationalized to reduce errors in guiding investments and implementing public policies for the sector. This is necessary to streamline the use of the limited resources available (Fonseca; Ferreira, 2009).

We should underscore that health infrastructure is not a definitive indicator of a state's vulnerability to COVID-19. However, it is an essential aspect that should be prioritized on the political agenda since Brazil will likely face future pandemics. Adopting the DEA method can support managers' decisions, allowing for an efficient allocation of health resources. Thus, improvements in infrastructure and management of health resources contribute significantly to regional development, promoting a more effective response to health crises and strengthening the social and economic cohesion of the country's different regions.

One of the limitations of this research is the reliability of the data provided by DATASUS since they depend on municipal updating, and, in most cases, there is no inspection or auditing to validate them. COVID-19 rates also require caution in the analyses since testing in Brazil was preferentially performed on symptomatic people, which may have been underreported, besides low testing in more remote regions, especially in vulnerable populations, where access to health services and information is limited.

Although the data is updated daily, there may be discrepancies, as municipal and state health secretariats can correct residence information after investigating the notification and sending it to the Ministry of Health. Furthermore, during the pandemic, the federal government's information system underwent several updates and was designed for epidemiological surveillance. It was completed by individuals unrelated to the research, meaning errors may occur.

However, the results should be interpreted cautiously since being classified as efficient can also be interpreted as an indicator of the balance between inputs and outputs. On the other hand, achieving maximum efficiency does not mean a lack of problems but rather that the unit produces better results with fewer inputs. Therefore, further studies are suggested to verify factors contributing to lower mortality and lethality rates in efficient regions.

Another difficulty in this analysis was selecting health professionals' specialties as inputs for evaluation. Nurses, doctors, and physiotherapists who work in ICUs are not always restricted to intensive care specialties, even more so during a pandemic when the service supply was significantly greater.

FINAL CONSIDERATIONS

The analysis revealed that only 11.68% of the Legal Amazon health regions allocated their health resources efficiently to combat the COVID-19 pandemic. Notably, these efficient regions are predominantly isolated areas with low relative population and low road traffic. Northern Araguaia Karajá in Mato Grosso and Vale do Guaporé in Rondônia stand out, which served as a benchmark for most DMUs, even before a limited amount of available health resources.

These findings spark an essential discussion about the tendency for health resources to be concentrated in capital cities, which is inefficient in these health regions. This concentration can lead to poor resource allocation, hindering the effective fight against the pandemic. Given this outlook, it becomes even more critical for managers to prioritize efforts to correct the gaps identified, be inspired by efficient regions' policies, protocols, and strategies, and consider the region's cultural and socioenvironmental diversity.

The relationship between the efficiency of DMUs and geographic location, with more favorable results in isolated regions with low road traffic flow, reinforces the importance of considering geographic factors when planning actions and measures to combat the pandemic. Furthermore, investing exclusively in health resource allocation strategies without considering social distancing is not ideal. On the contrary, the best strategy for preventing COVID-19 is to combine public policies to contain the virus spread and protect the health of the population more efficiently.

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