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RCMOS – Multidisciplinary Scientific Journal of Knowledge.
ISSN: 2675-9128. Sao Paulo-SP.

Year I, v.1 2021. | submission: 2021-07-11 | accepted: 2021-07-13 | publication: 2021-07-15

Geographic Information Systems (GIS) in Distribution Logistics Planning Food in Vulnerable Regions

Geographic Information Systems (GIS) in the Logistics Planning of Food Distribution in Vulnerable Regions

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SUMMARY

This scientific article aims to evaluate how Geographic Information Systems (GIS) can be used in the logistical planning of food distribution in vulnerable regions, with a special focus on areas marked by chronic food insecurity.
Through a methodological approach based on a literature review and analysis of national and international case studies, this work highlights the strategic role of GIS in optimizing logistics, accurately mapping population needs, and improving food assistance coverage. Based on research promoted by organizations such as FAO, WFP, and renowned academics in the field of geotechnology and food security, it is argued that GIS are essential tools for more equitable and effective public policies. The use of geospatial data allows evidence-driven interventions, enabling more efficient allocation of resources and greater reach among marginalized populations. The articulation between technology, planning, and social justice is the core of this work, which proposes practical solutions to one of the greatest challenges of our time: hunger.

Keywords: Geographic Information Systems; Food Security; Humanitarian Logistics; Vulnerable Regions; Food Distribution.

ABSTRACT

This scientific article aims to assess how Geographic Information Systems (GIS) can be employed in the logistical planning of food distribution in vulnerable regions, with special focus on areas characterized by chronic food insecurity. Using a methodological approach based on bibliographic review and analysis of national and international case studies, this work highlights the strategic role of GIS in optimizing logistics, accurately mapping population needs, and improving food assistance coverage. Based on research promoted by organizations

such as FAO, WFP, and renowned scholars in geotechnology and food security, it is argued that GIS are essential tools for more equitable and effective public policies. The use of geospatial data enables evidence-based interventions, allowing for more efficient allocation of resources and broader outreach to marginalized populations. The articulation between technology, planning, and social justice is the core of this work, which proposes practical solutions to one of the greatest challenges of modern times: hunger.

Keywords: Geographic Information Systems; Food Security; Humanitarian Logistics; Vulnerable Regions; Food Distribution.

1. INTRODUCTION

Food insecurity is one of the greatest contemporary global challenges, directly or indirectly affecting billions of people in different parts of the world. According to data from the Food and Agriculture Organization of the United Nations (FAO, 2020), the number of people experiencing extreme hunger has increased again in the last decade, especially in countries in sub-Saharan Africa, South Asia and Latin America. These territories face structural limitations such as chronic poverty, armed conflicts, environmental degradation and logistical deficiencies, which compromise the regularity and quality of food supply.

In Brazil, although there are public policies aimed at food security, there are still millions of people in vulnerable situations. Data from the Brazilian Institute of Geography and Statistics (IBGE, 2020) indicate that around 10% of the Brazilian population lived in households with some degree of severe food insecurity, with higher incidences in rural areas and urban outskirts.

In this scenario, the development and application of technologies capable of supporting the logistical planning of food distribution become essential. Geographic Information Systems (GIS) emerge as essential technological tools to assist in the identification of priority territories, in the mapping of food demands and in the optimization of logistical operations. According to Longley et al. (2015), GIS allows the integration, analysis and visualization of georeferenced data, enabling more precise, economical and effective interventions.

This article aims to analyze the role of GIS in the logistical planning of food distribution in vulnerable regions. To this end, it is organized into six sections: theoretical foundations of GIS; logistical overview of food distribution; intersections between GIS and food security; case studies; operational challenges; and conclusions and recommendations. The intention is to offer a critical and proactive approach on how technology can contribute to social justice through public policies based on territorial evidence.

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2. THEORETICAL FUNDAMENTALS OF GEOGRAPHICAL INFORMATION SYSTEMS (GIS)

Geographic Information Systems (GIS) are computational tools designed to collect, store, analyze, manipulate and visualize spatially referenced data. Their origins date back to the 1960s, with studies conducted by Roger Tomlinson in Canada, who is considered the pioneer of the integration of spatial data and computerized systems (TOMLINSON, 2003). Since then, GIS have evolved into highly complex platforms capable of gathering and processing large volumes of data from various sources.

The basic structure of GIS is organized through informational layers that represent different aspects of geographic space, such as road network, population density, topography, land use and socioeconomic indicators. According to Burrough and McDonnell (1998), this multilayer approach allows detailed spatial analyses, with the intersection of variables that would be difficult to visualize in conventional data formats.
This ability to combine multiple pieces of information into a single analytical environment makes GIS particularly useful in spatial planning and public decision-making.

In the field of food security, GIS makes it possible to map areas of greater nutritional vulnerability and identify logistical bottlenecks, contributing to a fairer and more rational allocation of resources. FAO (2020) uses systems such as GIEWS (Global Information and Early Warning System) to monitor, in real time, critical regions in terms of agricultural production, food stocks, prices and climate conditions. This type of platform provides a robust basis for emergency interventions and long-term strategies.

Another highlight is the democratizing nature of GIS. According to Clarke (2003), these technologies are not restricted to specialists or central governments, and can be accessed by NGOs, local communities and research institutions. This accessibility contributes to strengthening territorial governance and social participation in the development of public policies, in line with the principles of equity and social justice.

Furthermore, GIS has become increasingly compatible with other emerging technologies. Interoperability with remote sensors, drones, the Internet of Things (IoT) and cloud databases allows for continuous and up-to-date monitoring of territories. Studies such as that by Chen et al. (2018) indicate that the integration of GIS with real-time sensors significantly increases response capacity in emergency situations, such as natural disasters and outbreaks of food insecurity.

Finally, the importance of GIS in monitoring and evaluating public policies is highlighted. The use of georeferenced indicators makes it possible to monitor the effectiveness of government actions, identify operational failures and redirect strategies according to the evolution of territorial needs. In countries with large territorial extensions and high

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socioeconomic heterogeneity, such as Brazil, this tool represents an indispensable technical support for effective public management.

3. LOGISTICAL OVERVIEW OF FOOD DISTRIBUTION IN VULNERABLE REGIONS

Food distribution in vulnerable regions represents a multifaceted challenge that encompasses geographic, social, political and logistical aspects. In these areas, which are generally far from urban centers and have poor infrastructure, food transportation faces significant obstacles. The lack of paved roads, the lack of refrigerated warehouses, climate instability and public insecurity are factors that compromise the efficiency of logistics operations (BALLOU, 2006).

According to Arvis et al. (2018), in many regions with poor infrastructure, logistics costs can represent up to one-third of the final value of food. This data highlights the direct impact of logistics on the economic viability of food security actions.
In emergency situations, such as prolonged droughts or floods, these costs tend to rise even further, making it difficult to maintain regular and efficient distribution.

One of the main problems faced is the lack of adequate territorial planning, which makes it difficult to forecast demands and allocate resources. According to Van Wassenhove (2006), a specialist in humanitarian logistics, the effectiveness of operations in vulnerable contexts depends on robust inter-institutional coordination and the integration of information systems that allow decisions based on reliable data. However, in many contexts, fragmentation between public agencies and non-governmental organizations results in overlapping efforts or gaps in assistance coverage.

Decentralizing storage and distribution centers has also proven to be an effective strategy for expanding the reach of food assistance. Field studies conducted by Kovács and Spens (2009) indicate that the implementation of micrologistics centers, distributed based on geospatial criteria, allows for greater flexibility in operations and significantly reduces delivery times in crisis contexts. This approach is particularly useful in regions with complex topography or limited access via traditional routes.

Another critical aspect concerns the traceability and quality control of distributed food. In hard-to-reach regions, there is a greater risk of spoilage of sensitive products, such as fruits, vegetables and dairy products. Logistics planning needs to consider not only the shortest route, but also the type of cargo, the means of transport available and the weather conditions. The use of GIS-based systems can contribute significantly to the modeling of these routes and to the optimization of travel time (HEYWOOD et al., 2011).

Furthermore, the presence of food insecurity is often associated with geographic variables such as isolation, low population density and socio-environmental vulnerability.

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In this sense, it is essential to produce thematic maps that integrate socioeconomic and environmental indicators with logistical data, enabling a systemic view of the territory. This practice has been successfully adopted by government programs in Brazil, such as the Food Acquisition Program (PAA), which seeks to prioritize municipalities with high vulnerability rates (CONAB, 2020).

Therefore, overcoming food logistics obstacles in vulnerable regions requires not only investments in infrastructure, but also the adoption of integrative technologies such as GIS, capable of offering technical and strategic support for smarter, fairer and more efficient decisions.

4. THE ROLE OF GIS IN MAPPING FOOD NEEDS

Geographic Information Systems (GIS) play a fundamental role in identifying and mapping food needs in territories marked by social vulnerability and nutritional insecurity. By integrating georeferenced data – such as population density, human development index, poverty indicators and access to basic services – it is possible to obtain a detailed spatial portrait of the most affected regions, supporting food distribution actions with greater precision and efficiency (HEYWOOD et al., 2011).

According to FAO (2020), territorial mapping using GIS has been a strategic tool in several humanitarian interventions. In emergency situations, such as natural disasters or economic crises, the application of GIS allows communities at risk to be quickly identified, facilitating the definition of priorities and the mobilization of resources.

This response capacity makes GIS important allies both in emergency actions and in medium and long-term policies.

The ability of GIS to cross-reference different layers of information offers a significant analytical advantage over traditional models of social diagnosis. While conventional statistical indicators are useful for macroeconomic analyses, GIS enables the spatialization of data, revealing patterns and inequalities that are not perceptible by other approaches. Clarke (2003) emphasizes that this granularity in reading the territory favors the formulation of public policies that are more in line with local reality.

Another significant benefit of GIS is its communication potential. The creation of thematic maps and georeferenced infographics allows public managers and social organizations to communicate the needs and actions developed in a given location in a clearer and more accessible way. The spatial visualization of complex data makes it easier for decision-makers and civil society to understand, which reinforces transparency and social control.

Furthermore, GIS allows for the constant updating of territorial information. Through integration with remote sensing data, satellite images and official statistical databases, It is possible to perform dynamic diagnostics and monitor the evolution of the socioeconomic conditions of a region. This continuous updating is essential in contexts of rapid transformation, such as those caused by climate change, health crises or migration processes.

The practical application of this technology can be observed in projects conducted by public and academic institutions in Brazil. The Institute of Applied Economic Research (IPEA, 2020) points out that the incorporation of GIS into policies to combat hunger has enabled more effective management of food delivery in riverside areas, quilombolas and urban peripheries, often neglected by traditional planning methods.

Finally, the potential of GIS as an instrument of territorial justice is highlighted. By offering an empirical and spatialized basis for the allocation of public resources, GIS contributes to the reduction of regional inequalities and the promotion of the human right to adequate food. It is, therefore, a tool that articulates technique, planning and social ethics in tackling one of the most urgent problems of contemporary times.

5. OPTIMIZATION OF DISTRIBUTION ROUTES THROUGH GIS

The application of Geographic Information Systems (GIS) to optimize logistics routes is one of the most pragmatic and effective functions of these technologies, especially in food distribution contexts in vulnerable regions. By enabling the analysis of road networks, geographic conditions, accessibility and location of strategic points, GIS provides support for defining shorter, safer and more economically viable routes (BALLOU, 2006).

Routing based on geospatial data involves the use of algorithms and computational models capable of considering multiple criteria in constructing the most efficient routes. Among the factors analyzed, the following stand out: distance, travel time, displacement, vehicle capacity, road conditions, traffic and environmental risks. According to Heywood et al. (2011), this multi-criteria approach is essential in humanitarian contexts, where logistical conditions can change suddenly due to extreme weather events or political instability.

In addition to reducing delivery times, optimizing logistics routes with the help of GIS helps reduce food losses and waste, which is crucial in regions where resources are scarce. Perishable foods, such as vegetables and dairy products, require speed and care during transportation, which is only possible with efficient logistics planning.
In case studies carried out in Colombia by Ortega et al. (2017), it was found that the use of GIS to restructure distribution routes for fruit and vegetables resulted in a reduction of up to 35% in losses due to deterioration during transportation in mountainous regions.

Another relevant aspect concerns route security. In places affected by armed violence, natural disasters or geographic blockades, GIS allows the identification of

RCMOS - Multidisciplinary Scientific Journal of Knowledge.
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alternative routes that minimize risks to the integrity of teams and the cargo being transported. According to Longley et al. (2015), the integrated analysis of data on crime, topography and infrastructure allows the development of contingency scenarios in real time, which are essential for operations in risk zones.

GIS also favors medium- and long-term planning by generating historical databases on logistics flows. By accumulating information on delivery frequency, average travel times, seasonality and consumption patterns, institutions can continually refine their strategies, anticipating bottlenecks and improving operational efficiency (TOMLINSON, 2003).

The incorporation of this technology into Brazilian public policies has already yielded positive results. According to the National Supply Company (CONAB, 2020), the use of GIS to plan routes for the Food Acquisition Program (PAA) has enabled broader and more equitable coverage of the vulnerable population, while reducing operating costs. The cross-referencing of vulnerability maps, transportation networks, and warehouse locations was crucial in reaching isolated communities, such as indigenous and quilombola communities.

Finally, we highlight the potential of GIS to integrate with artificial intelligence and machine learning systems, creating increasingly accurate predictive models. This integration, although still in its early stages in many developing countries, represents a promising prospect for the creation of self-adaptive logistics systems, capable of reacting in real time to territorial changes and new food demands.

6. INTEGRATION BETWEEN GIS AND PUBLIC FOOD SECURITY POLICIES

The effectiveness of Geographic Information Systems (GIS) in combating food insecurity is directly related to their integration with public policies. When inserted in a structured manner into the planning and execution of government programs, GIS have the potential to transform the management of food assistance in vulnerable regions, promoting greater efficiency, transparency and social justice (CLARKE, 2003).

In Brazil, programs such as the National School Feeding Program (PNAE) and the Food Acquisition Program (PAA) have gradually incorporated geotechnology tools to improve the identification of priority territories and the logistics of distribution. According to the National Supply Company (CONAB, 2020), the use of geospatial maps has allowed a more detailed analysis of nutritional vulnerability in municipalities, optimizing the allocation of food and expanding coverage of marginalized populations.

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However, the integration of GIS and public policies requires alignment between the information systems existing in public agencies and the georeferenced databases used in territorial analyses. In many cases, the lack of interoperability between systems and the fragmentation of data sources make it difficult to construct comprehensive diagnoses. Van Wassenhove (2006) points out that this gap is one of the main obstacles to creating coordinated and effective responses in humanitarian emergency situations.

One of the main benefits of adopting GIS in public management is the possibility of continuous monitoring of implemented actions. The generation of thematic maps allows visualization, in real time, of the evolution of program coverage, the regularity of deliveries and the social impacts of interventions. This not only improves management, but also strengthens accountability and social control mechanisms.

Furthermore, GIS provides relevant technical support for the design of public policies that are more in line with territorial realities. In a country with continental dimensions like Brazil, with large regional socioeconomic disparities, planning based on national averages tends to hide local vulnerabilities. The spatialization of data through GIS allows the development of differentiated strategies for indigenous, quilombola, riverside, urban and rural populations, respecting their cultural, environmental and logistical specificities (HEYWOOD et al., 2011).

Another crucial point for the successful integration of GIS and public policies is the technical training of the professionals involved. Many municipalities lack specialists in geotechnology and the minimum technological infrastructure to implement these tools. In this sense, it is essential to invest in the formation of interdisciplinary teams, composed of geoprocessing technicians, public managers, nutritionists and community agents.

Finally, the institutionalization of GIS in public food security policies also depends on intergovernmental coordination and the support of partnerships with universities and civil society organizations. The construction of collaborative networks, based on the exchange of data and experiences, contributes to the strengthening of territorial governance and the consolidation of sustainable and evidence-based policies.

7. FINAL CONSIDERATIONS AND CONCLUSION

Combating food insecurity requires interdisciplinary approaches that are sensitive to the territorial reality and based on reliable data. In this context, Geographic Information Systems (GIS) have proven, throughout this study, to be instruments of high strategic value, capable of integrating logistical planning, socio-spatial analysis and public policy management in regions marked by structural vulnerabilities.

Based on the theoretical review and applied studies, it was observed that GIS not only facilitates the visualization of food needs through maps and spatial models, but also qualifies decisions regarding the allocation of resources, definition of logistics routes and monitoring of government actions. This capacity stands out, above all, in scenarios

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where there is a shortage of time, budget and infrastructure — typical conditions for emergency interventions and food security programs in peripheral, rural and isolated areas.

By optimizing distribution routes, GIS helps reduce costs, delivery times and waste of perishable foods. By mapping food risk areas, they enable preventive action, reducing the effects of climate, economic or health crises. Furthermore, their incorporation into public management systems promotes transparency and social control, since data can be opened and monitored by different sectors of society, strengthening democratic mechanisms and co-responsibility in the fight against hunger.

However, the full application of GIS in food security policies still faces significant challenges. The lack of professionals trained in geotechnologies, the fragmentation of government databases, the lack of interoperability between systems and the limited technological resources in the poorest municipalities constitute real barriers. In many cases, the existence of outdated or inaccessible data compromises the effectiveness of spatial analyses and, consequently, of the logistical and social decisions derived from them.

To overcome these obstacles, it is essential to create a culture of evidence-based territorial governance that understands GIS not as isolated or auxiliary tools, but as structuring devices for public planning. This implies, on the one hand, investing in technical training, infrastructure and data updates; on the other, fostering partnerships between universities, research centers, public managers and organized civil society, with a view to collaboratively building territorialized solutions to hunger.

The experience of countries that have institutionalized GIS in public management indicates that its positive impact goes beyond logistics. By enabling the cross-referencing of economic, environmental and demographic information, GIS favors the development of integrated policies, articulating food security, education, health, agriculture and social assistance. In Brazil, its application in the PNAE and PAA programs, although still limited, already offers relevant lessons on how to plan with greater equity and efficiency, respecting local singularities and enhancing family farming.

It is therefore concluded that Geographic Information Systems are key elements in the construction of a more effective and fair public agenda to address food insecurity. Their integration into logistical planning and food security policies should be seen as a technical, ethical and social commitment, necessary to promote the human right to adequate food. In a world marked by territorial inequalities and global uncertainties, investing in GIS is investing in the capacity of the State and society to respond, with intelligence and solidarity, to the most urgent challenges of the 21st century.

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ISSN: 2675-9128. Sao Paulo-SP.

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