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Development of Regional Infrastructure with a Geographic Information System (GIS) Approach for National Food Security

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ABSTRACT

Geographic Information Systems (GIS) have become a vital tool in Development of Regional Infrastructure with a Geographic Information System (GIS) Approach for National Food Security, supporting spatial data management, infrastructure mapping, monitoring, and planning. Adequate regional infrastructure positively influences food security by improving accessibility, productivity, distribution networks, and the value-added potential of local production, thereby strengthening the independence of communities and regions. This research examines the role of GIS in optimizing infrastructure to enhance food security and analyzes spatial patterns, trends, and risks in planning and management. A qualitative-descriptive approach combined with spatial analysis techniques was used, drawing from both primary and secondary data sources. Primary data were collected from government agencies and infrastructure reports, while secondary data included spatial datasets, remote sensing imagery, and existing GIS databases. Data were analyzed using GIS software for mapping, spatial modeling, and scenario simulations to assess infrastructure conditions and their relation to regional food security indicators. The results show that GIS facilitates identification of infrastructure gaps, optimizes resource allocation, and supports decision-making in development planning. It contributes to equitable food access and reduces vulnerability to regional disruptions. The findings highlight the importance of integrating GIS into regional policies to increase infrastructure efficiency and resilience, providing a framework for evidence-based decision-making that supports national and local food security objectives.

KEYWORDS *Planning System, Regional Infrastructure, Geographic Information System (GIS), Food Security.*

INTRODUCTION

In the Development of Regional Infrastructure with a Geographic Information System (GIS) Approach for National Food Security, it is essential to assess the characteristics of each region in relation to infrastructure availability and service distribution (Burrough et al., 2015; Chan et al., 2022; Chang, 2018; Lü et al., 2019; Team, 2022). The service aspect that requires examination is the extent to which infrastructure exists and meets regional needs, including accessibility between areas, adequacy of clean water supply, irrigation systems, drainage networks, and other essential facilities. Furthermore, understanding the availability of natural resources in a region through geographical, topographical, and climatological analysis is crucial. The relationship characteristics between urban and rural areas in regional development often involve connections within strategic zones—urban centers serving as hubs for economic, business, and service activities—and rural areas functioning as hinterlands that supply goods and resources. Therefore, the role of Geographic Information Systems (GIS) in infrastructure development to support food security is indispensable (Bacon & Baker, 2017; Edmondson et al., 2019; Phromsin & Suksawang, 2023; Rejeb et al., 2022; Skydan et al., 2023).

When designing programs such as urban and rural infrastructure development, it is necessary to conduct analyses that account for existing needs and previously established plans. The underlying principle of this approach is illustrated in Figure 1 below.

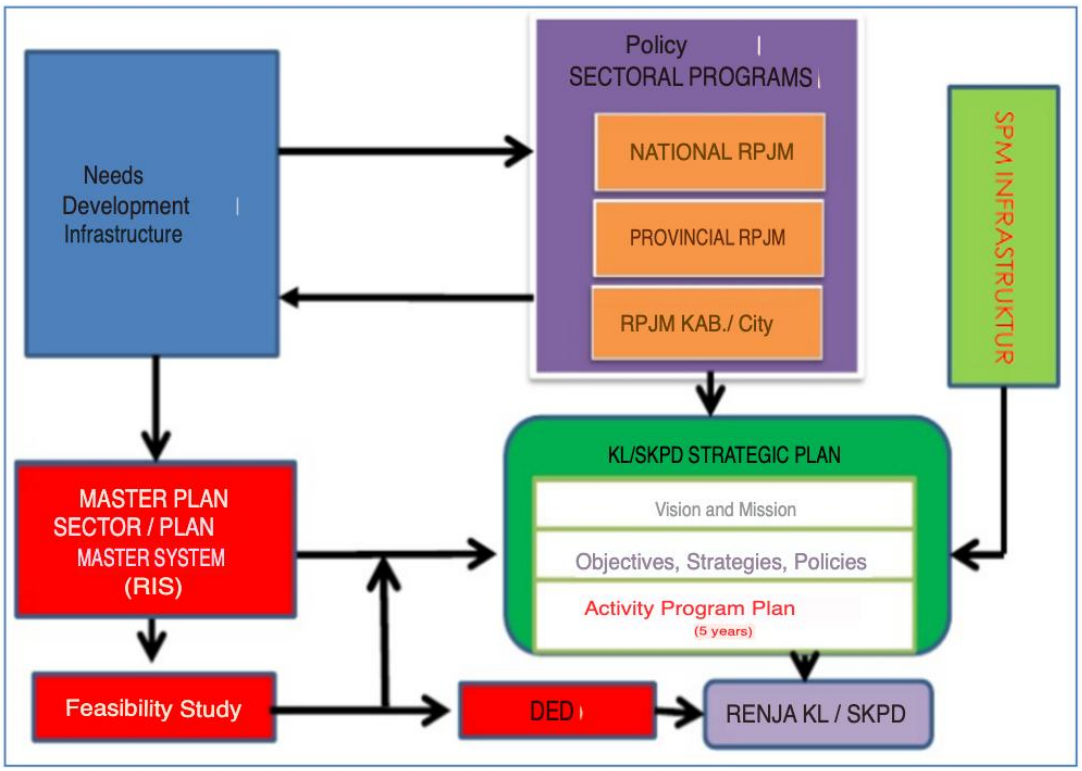

Figure 1. Principles of Infrastructure Development Program Preparation

The basis for consideration in preparing the *Development of Regional Infrastructure with a Geographic Information System (GIS) Approach for National Food Security* program includes: (a) the spatial utilization plan of an area, (b) community needs to be developed in accordance with the prepared master plan, (c) financial availability based on analysis of existing financial capacities, (d) stages of infrastructure development suited to the characteristics of an area, (e) choice of technology to be used, (f) distribution of financing authority for regional infrastructure development, and (g) characteristics of the infrastructure service system to be built.

Previous research has demonstrated the positive impact of infrastructure on food security. For example, Fan and Hazell (2000) highlighted that rural roads in developing countries significantly increase agricultural productivity by facilitating market access. Similarly, Dorosh et al. (2010) found that irrigation infrastructure improves crop yields and reduces vulnerability to droughts. More recent studies, such as Gebreselassie et al. (2020) and Abebe et al. (2021), confirm that integrating *GIS* in infrastructure planning enhances decision-making by identifying spatial patterns of resource distribution, food production potential, and areas with accessibility gaps. Collectively, these studies indicate that infrastructure development guided by spatial analysis tools like *GIS* effectively supports food security objectives.

Despite these insights, gaps remain in understanding how infrastructure development can be optimized for food security at the regional level using integrated spatial data. Most previous studies examine either infrastructure availability or agricultural productivity without explicitly addressing the relationship between infrastructure quality, accessibility, and actual food distribution outcomes. This research seeks to fill that gap by using *GIS* to holistically

assess infrastructure readiness and its impact on food accessibility, considering topography, population distribution, and regional production patterns.

This study aims to map, analyze, and evaluate the spatial characteristics of infrastructure related to food production, distribution, and accessibility, providing actionable insights for policymakers. The expected benefits include optimized resource allocation, improved accessibility in underserved areas, and enhanced regional resilience against climatic and logistical challenges. Ultimately, this research contributes to evidence-based planning that aligns infrastructure development with national and regional food security objectives.

METHOD

The approaches taken in the analysis of regional infrastructure development include as follows.

Spatial Analysis

This analysis is needed as a basis for designing the framework for regional infrastructure development of an area with existing natural resource potential, or an area that is in accordance with development principles and various applicable regulations. The main aspects that need to be considered are the carrying capacity and carrying capacity of the environment. The purpose of this spatial analysis is to ensure that the spatial plan and space utilization for infrastructure needs are connected to the existence of natural resources with various considerations on several constraints of space utilization, such as utilization problems, regional development opportunities, utilization trends and spatial patterns according to the regulations that have been set. Spatial analysis is in accordance with the need to support the development of spatial structures by paying attention to landforms, spatial dimensions and issues in food security. In conducting spatial analysis, a mapping of food potential with its supporting infrastructure is produced in the form of a thematic map in accordance with the needs for the development of an area based on existing potential, for example, mapping of agricultural areas, prone to disasters, water sources/groundwater reserves or other natural resources, in accordance with the superior potential of an area.

Economic and Social Analysis

Analysis of regional economic growth is needed as a basis for developing related infrastructure development strategies. With local government policies in developing potential areas for the need to improve food products. Economic analysis is to ensure that the strategy for developing regional infrastructure to be built is in accordance with the current economic potential of a region by considering various constraints. To conduct economic analysis, data and information are needed as basic materials to be analyzed and studied. The data and information needed include: regional economic data and characteristics of its population such as labor; economic trend (per capita income), the amount of natural resources as the basis for infrastructure development in a region to support economic activities.

Institutional/Policy Analysis

Institutional/policy analysis aims to ensure the integrity of regional infrastructure development from the planning and implementation of regional infrastructure development

itself. This institutional/policy analysis will provide an overview of the institutional forms that will be developed so that integrated infrastructure development can be achieved in an area with various potentials.

Environmental analysis

Environmental Analysis aims to ensure that regional infrastructure development projects pay attention to environmental issues and take into account natural assets that must be protected or strictly controlled by the environment. To conduct environmental analysis, data is needed regarding environmental problems in an area such as pollution, environmental damage and other types of environmental damage.

RESULT AND DISCUSSION

In infrastructure management, there is always a tradeoff between infrastructure development, environmental impact and economic growth, and there may not even be a solution that can solve all the problems of infrastructure development (balance between needs and environmental sustainability). This difficulty is always spurred by human actions in resource management. Problems in an area are behaviors in its use that do not pay attention to the balance or carrying capacity of the local environment.

Efforts for a very comprehensive regional infrastructure handling and management can be translated more concretely. Some of the terms that are often used in water resource management are described by Grigg, 1988 & 1996) as follows:

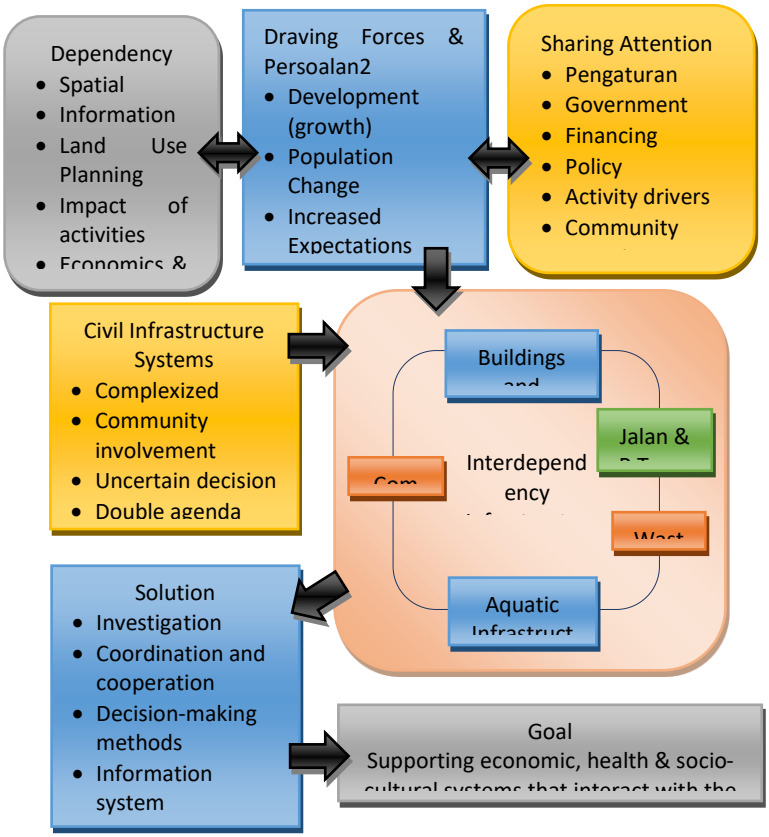

Figure 2. Illustration of Infrastructure at a Glance (Grigg & Fontane, 2000 with modifications by Kodoatie & Suripin, 2001)

The transfer of new growth centers and activities must be in accordance with their natural powers, not only focused on a region such as Java but need to be developed in other places such as Sumatra, Kalimantan, Sulawesi, Irian/Papua and other regions. For example, industrial centers for processing agricultural, plantation, fishery and mining products so that they are not concentrated in areas where natural resources are excessive but can be distributed to areas with limited natural resources. In areas with high agricultural intensity, it is necessary to increase production in accordance with the capabilities of human resources.

According to Albertson (1999) Sustainable and environmentally sound regional infrastructure system management has several dimensions that must be integrated into all aspects of its development:

a. sustainable environmental protection for future generations (Environmental sustainability).
b. development of variables in an economically sustainable manner (economic sustainability).
c. Socio-cultural sustainability: innovation must be balanced between local knowledge, social and cultural conditions, practices and appropriate technology (TTG).
d. Political sustainability: formal and non-formal institutional arrangements need to be taken care of so that communication can be established with a healthy political and bureaucratic structure.

Furthermore, Grigg, (1992, 1988 & 1996) explained that the management of complex and comprehensive infrastructure systems, is not a result of planning but rather a result of needs. The relationship with the management aspect includes the following:

a. Coordination
b. Artifact and Engagement
c. Harmonization
d. Integration/Interconnection
e. Politics and culture

The management of regional infrastructure systems as part of the spatial planning system, both national, provincial and regency/city, plays a very important role in improving national food.

Law No. 26 of 2007 concerning spatial planning, mandates that national, provincial, regency/city spatial planning is carried out through a process and preparation procedure based on the provisions of applicable laws and regulations and can be periodically reviewed in accordance with the specified time scale, for example once every 5 years. The principles of infrastructure development are carried out by considering the following things:

a. Compatibility, harmony, and balance of cultivation functions and protective functions.
b. Aspects of integrated management of various resources, environmental functions and aesthetics as well as space quality.
c. Patterns of land use management, water use, air use, and natural resource management
d. An intensive and disincentive device that respects the rights of residents as citizens.

National Food Development Region

Referring to the results of Hadi Santoso et al's 2019 research in the Thesis, it is stated that adequate infrastructure in an area has a positive and significant relationship with resilience.

It is further stated that the mechanism of positive relationships can be in the form of:

a. Improving Accessibility and Productivity

b. Improve distribution networks and their availability.
c. Development of Added Value from each production produced.
d. Supporting the independence of the community or region.

Miguel Angel Esquivias et al (2023). The results show that infrastructure spending is not always directly proportional to increasing food security. Improper management can divert resources and have a negative impact, so sustainable and effective investment is needed. Recently, infrastructure development in Indonesia is being intensively carried out, such as roads, dams or reservoirs, irrigation, ports, etc., but the condition of food security has not increased significantly. Different infrastructure conditions in each province are also the cause of food security problems. Viewed from various countries, especially developing countries, food security is a very important global concern, and is considered a fundamental goal for each country and society as a whole. In 2000, world leaders committed to tackling hunger through the Millennium Development Goals (MDGs), with a similar focus seen in Indonesia's economic development agenda, which emphasizes improving social welfare (de Jong & Vijge, 2021; Hickmann et al., 2023; Kannengießer, 2023; Weststrate et al., 2019). The social dimensions of food security include human health, demographics, and socio-political factors, with health-related challenges including nutrition and limited access to clean water and medicines. The socio-economic implications of inadequate food security include threats to social stability, increased cost of living, and dependence on foreign supplies. The exodus of the population from the agricultural sector poses a demographic threat to national food security.

Indonesia faces challenges reflected in the low ranking of the global food security index, Indonesia ranks 102nd in terms of food diversity in the 2019 Global Food Security Index (GFSI), ranked 103rd in terms of the availability of micronutrients, and 97th in terms of protein quality. Proving the difficulty of disadvantaged groups in accessing affordable and high-quality food. Agricultural challenges in Indonesia, such as reduced agricultural land and increasing input costs, lack of efficiency in food supply. Although Foreign Investment (FDI) is seen as a potential solution, FDI in Indonesia's agricultural sector is still limited, with a primary focus on the palm oil industry. Foreign investment is seen as a potential contributor to the development of Indonesia's agricultural sector, increasing access to high-quality food through increased production and technological capabilities. The positive impact of foreign investment on food security includes not only technology transfer, but also infrastructure development and sustainable agricultural practices. However, research on the overall impact of investment on food security remains inconclusive, with results varying across different sectors of the economy.

Various factors affecting food security in Indonesia, present a comprehensive analysis from 2011 to 2019 in 34 provinces in Indonesia. The researchers used key component analysis (PCA) on indicators such as daily protein and calorie consumption, as well as agricultural production, to build a food security index. This study aims to address gaps in the existing literature by examining the impact of foreign investment (FDI) and domestic (DDI), including human resources (HDI), infrastructure (INFRASTR), on food security (FSINDEX). The report also considers socio-economic factors such as poverty, income inequality, unemployment, and population density. The economic structure of a country and the potential consequences of shifting resources between sectors will be explored. The study contributes to the literature by

estimating the impact of economic activities in the primary, secondary, and tertiary sectors on food security, taking into account three sources of capital, and using four measures to assess overall food security.

Regional Infrastructure Development with a Geographic Information System (GIS) Approach

Regional infrastructure development with the principle of integration in accordance with the PUPR Strategic Plan until 2019, includes:

1. Infrastructure Program in the Field of Highways
    a) Accelerating the development of a multimodal transportation system
    b) Accelerating the construction of transportation to support the National Logistics System
    c) Trying to strike a balance between nationally oriented transportation and local and regional oriented transportation
    d) Establishing the linkage of transportation systems and networks with investment to support the Economic Corridor,
    e) Priority Industrial Estates, National Logistics Systems, Priority National Tourism Strategic Areas and other growth centers in non-economic corridor areas.
2. Infrastructure Program in the Field of Creation
    a) Not all communities have access to drinking water (National Service Coverage 2013 ± 67.7%).
    b) There are still urban slums (Urban slum area 38,431Ha = 10%).
    c) Not all communities have access to sanitation (National Service Coverage ± 59.7%, and lack of adequate waste management facilities).
3. Water Resources Infrastructure Program
    a) Water Availability. Of the total potential of 3.9 trillion m3 of water in Indonesia, only ± 15 billion m3 or 63.5 m3 per capita can be managed through reservoirs. water distribution and it has not been evenly distributed on each island.
    b) Floods and Droughts. Climate change; the impact of land conversion in watershed areas; improvement of the built-up area; flood facilities and infrastructure that are not optimal; etc.
    c) Irrigation Land Needs. Most of the irrigation areas are under the authority of the Government with damaged conditions (Province: 53% and Regency/City: 59%).
    d) Switch the Catchment Area function. Due to population growth and economic activities, land use changes to built-up land are increasing, especially in catchment areas. Indonesia is among the 10 countries with the highest deforestation in the world at a rate of 0.9-7% per year.

The integration of the National Program with the Provincial RTRW pays attention to the strategic value of the province and involves two study objects, namely the Provincial, Kabuaten and City RTRW which are both integrated so as to produce the following complete integration results:

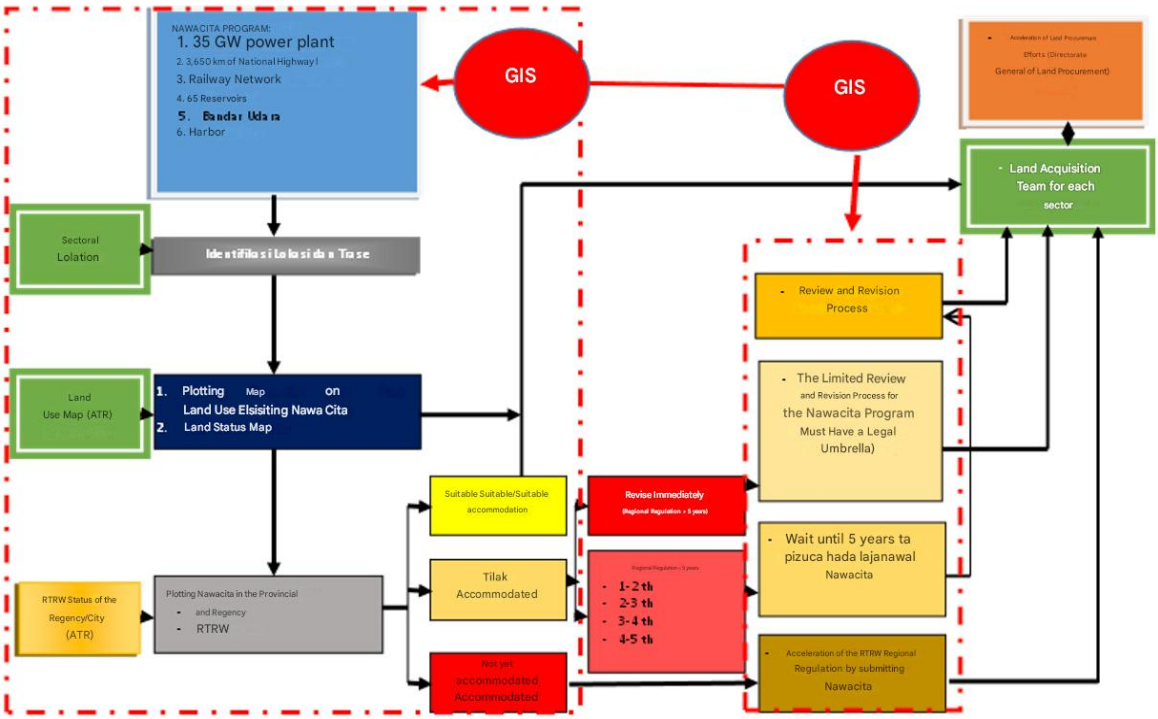

Figure 3. The Role Of Information System In The Preparation Of Priority Programs

a) National Road Network Development Plan on the Island of Sumatra

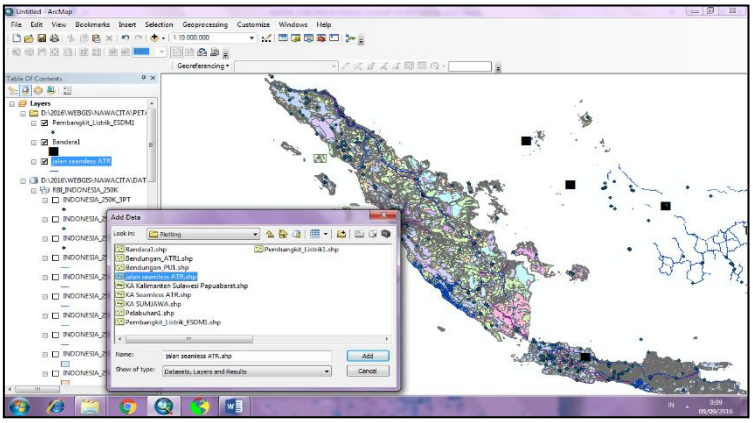

Figure 4. Network Development Plan

b) Airport Development Plan

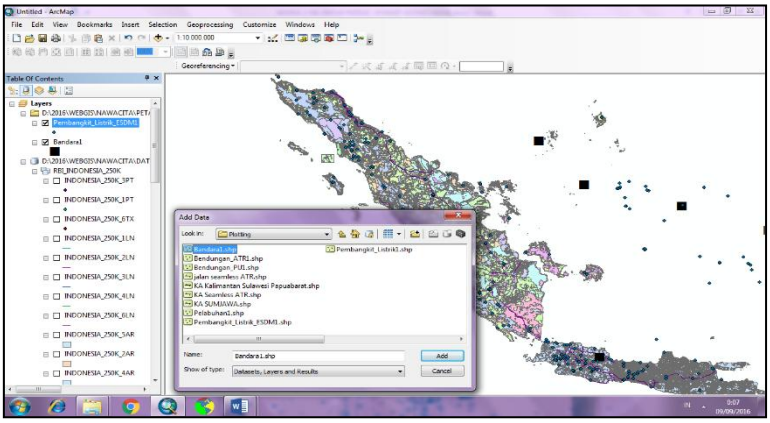

Figure 5. Airport Development Plan

c) Dam Construction Plan

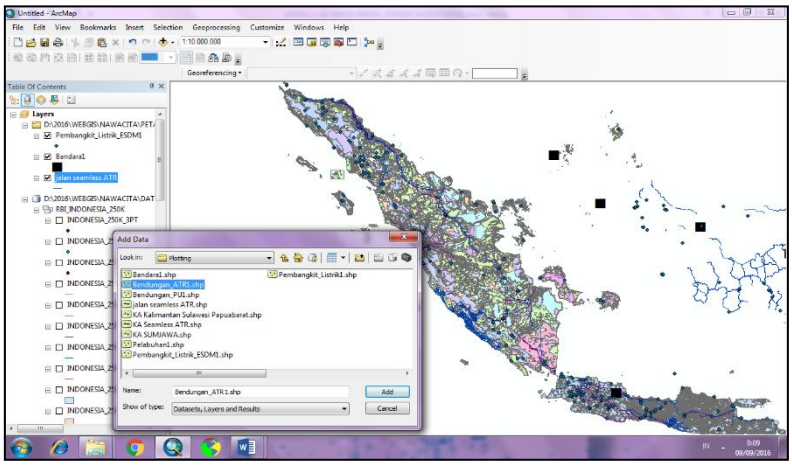

Figure 6. Dam Development Plan

d) Train Development Plan

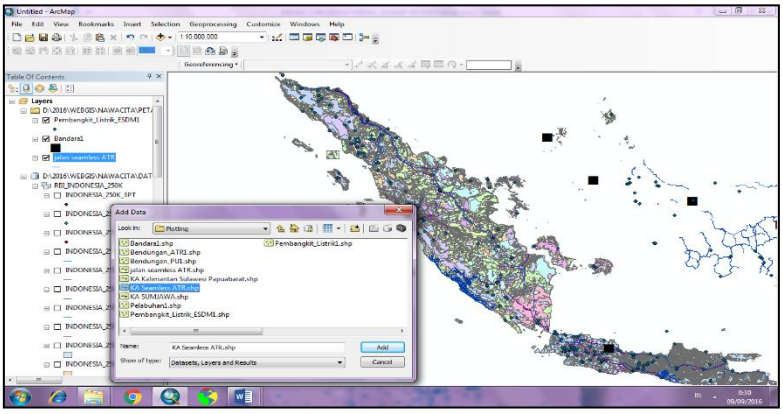

Figure 7. Train Development Plan

e) Port Development Plan

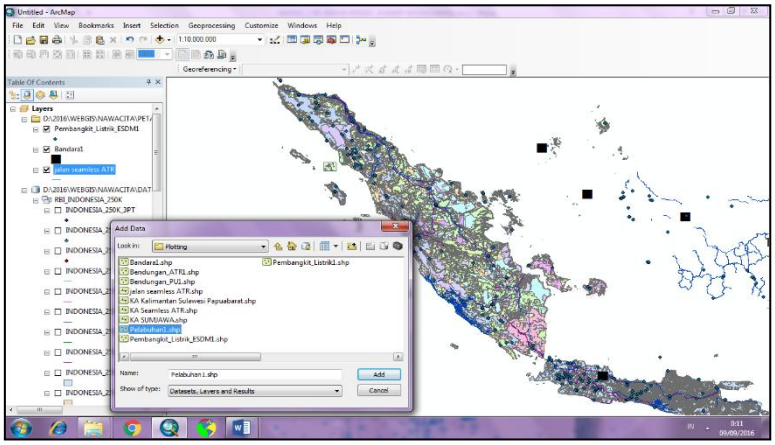

Figure 8. Port Development Plan

f) Power Plant Development Plan

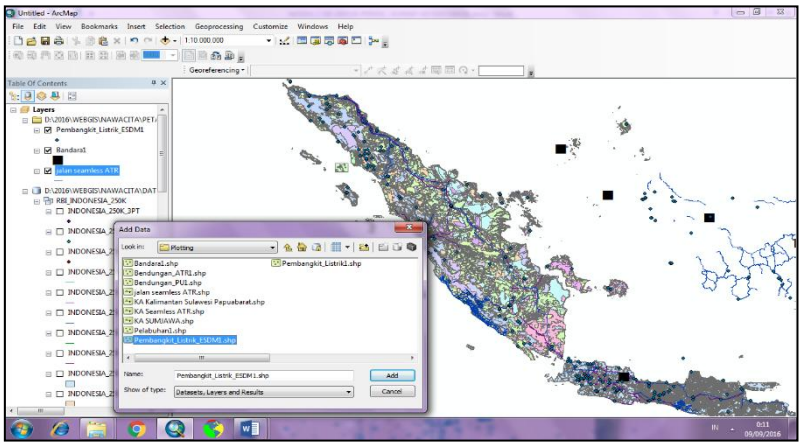

Figure 9. Power Plant Development Plan

The crucial role of infrastructure in supporting food security, yet gaps remain in understanding its effectiveness and integration with economic and social factors. Santoso et al. (2019) demonstrated that adequate infrastructure improves accessibility, productivity, distribution networks, and adds value to production outputs, thereby enhancing regional resilience. However, Esquivias et al. (2023) emphasized that infrastructure spending alone does not automatically translate into improved food security, as improper management can divert resources and limit impact, highlighting the need for strategic and sustainable investment. This research addresses these gaps by examining the impact of both foreign and domestic investment, human resources, and infrastructure on food security across 34 provinces in Indonesia from 2011 to 2019, integrating Geographic Information System (GIS) data to assess spatial distribution and regional disparities. By combining quantitative indicators such as protein and calorie consumption, agricultural output, and socio-economic factors including poverty, income inequality, and population density, this study provides a more holistic understanding of the mechanisms linking infrastructure and food security.

CONCLUSION

Geographic Information Systems (GIS) play a crucial role in regional infrastructure development by enabling efficient spatial data management, analysis, and visualization to support planning, monitoring, and decision-making. Through functions such as spatial data management, infrastructure mapping, spatial analysis, risk reduction, and efficiency enhancement, GIS facilitates the identification of optimal locations for development, monitors infrastructure conditions, and reduces operational costs. Research by Hadi Santoso et al. (2019) emphasizes that adequate infrastructure positively influences regional resilience by improving accessibility, productivity, distribution networks, and community independence. Future research should focus on integrating GIS with real-time data systems and predictive modeling to enhance adaptive infrastructure planning and strengthen regional resilience against environmental and socio-economic challenges.

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