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Original Article

Reinforcing Local Food Security through Agrogeological Perspectives: South Lampung, Indonesia

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Abstract: Local food security is a critical priority for the coming decades, especially in Indonesia. As the population grows, it is essential to meet local food needs before participating in the national supply. South Lampung, a key region in Sumatra, plays a vital role in the nation's food supply. However, rapid population growth in this area has raised concerns about the conversion of agricultural land to residential use. To address these challenges, this study raises agrogeology as an alternative approach to reinforcing local food security. By re-evaluating the regional geological characteristics, the study aims to understand the distribution of productive, traditional paddy fields. Field surveys and spatial analyses were conducted for this study. The findings reveal that the silicate-rich lithology in the region's pyroclastic deposits significantly contributes to maintaining fertile soils, particularly in areas such as Candipuro, Jatiagung, and Palas. Natural drainage systems further support rice cultivation. In alignment with the Sustainable Development Goals, the agrogeological perspective emphasizes the need to mitigate land conversion and improve land-use planning. This approach offers a sustainable pathway to enhance paddy field productivity and ensure water and nutrient availability, thereby supporting long-term local food security.

Keywords: *Sumatra, Agrogeology, Geobotany, SDGs, Food Security.*

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INTRODUCTION

South Lampung in southern Sumatra has substantial food production potential, particularly rice, due to its extensive paddy fields [1]. Despite the availability of several hectares of arable land, by 2019 [2], only a portion was fully utilized for optimizing food output. Ensuring local food security is required, especially given the region's rapid population growth [3]. such as South Lampung. The wave in economic activities, including industry and trade, has further fueled local economic development, attracting people from outside the region for various reasons such as education, employment, and tourism [4]. Consequently, the rising population and economic expansion have significantly increased the demand for food [5], particularly rice[6]. This poses a significant challenge in balancing the need to meet local food requirements while addressing the growing outward demand.

To optimize rice paddy land, it is essential to assess various land characteristics in more detail. This study aimed to re-evaluate the distribution of paddy fields in South Lampung from an agrogeological perspective to enhance local food security. Key agrogeological factors include the natural plant nutrient supply from the bedrock, adequate water availability, and soil properties [7]. Nutrients from the bedrock play a vital role in enriching the soil with minerals essential for plant growth [8]. Water availability, whether sourced naturally or through irrigation, is crucial for maintaining the soil moisture required for rice cultivation [9]. Additionally, soil substrate characteristics, such as texture, pH, and water-holding capacity, significantly influence the productivity of paddy fields [10].

Agrogeology is a scientific study that explores the relationship between geology and agriculture, focusing on how a region's geological conditions impact crop productivity and agricultural yields [11]. It involves analyzing factors such as lithological soil type, structure, and mineral composition, and how these influence crop fertility and plant growth [12]. Key elements of agrogeology include the study of minerals, water resources, and land management [13]. By providing insights into geological and lithological properties, agrogeology supports more efficient land management through soil conservation, optimized fertilizer use, and irrigation planning. It also addresses geological risks to agriculture, such as landslides, erosion, and soil contamination. Yet, agrogeology promotes sustainable and adaptive agricultural practices that are tailored to the specific geological conditions of a region [14].

MATERIALS AND METHODS

This study employed comprehensive geospatial information analysis, integrating multiple mapped data sources to represent the study area [11]. Key data sources included Digital Elevation Models (DEMs), which provided detailed information on land contours and slopes (tanahair.go.id), and official data from the Central Bureau of Statistics (BPS, *lampung.bps.go.id*). The steps for obtaining spatial data can be accessed directly through the tanah.air.go.id website by selecting the required raw data format (e.g., TIFF and SHP files). In this case, DEM data (raster data) can be downloaded directly, with georeferencing adjustments based on the Universal Transverse Mercator (UTM) Zone 48S, allowing spatial estimations in meters. Meanwhile, raw data on paddy field productivity can be traced from the official BPS data records on the *lampung.bps.go.id* website, covering data from Jan 2018 to Dec 2022 (as of the February 2024 update), see **Figure 1**.

Data processing was conducted using the open-source spatial analysis software QGIS (*qgis.org*) [15] to visualize administrative boundaries and regional structures, land distribution maps identifying various types of rock in the area, drainage maps detailing river flow systems, and regional geological maps [16]. The major productive paddy fields in South Lampung, identified through spatial analysis, were specifically reviewed and verified through field observations to confirm the results or ground checking.

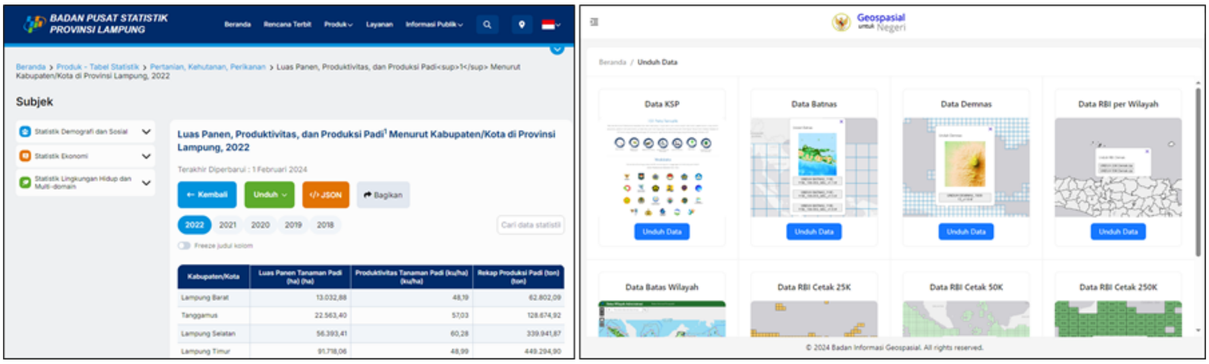

Figure 1. Screenshots of website *lampung.bps.go.id* and *tanah.air.go.id* as portals for obtaining raw data in this study.

RESULT AND DISCUSSION

Our data analysis shows that rice production in South Lampung plays a crucial role in food security in Lampung Province (**Figure 1**), as reflected in the ratio of rice production to available rice land. Rice production in Lampung Province has increased, particularly between 2018 and 2022. However, this increase in production coincides with population growth in South Lampung, which recorded a rise of 4.9% between 2020 and 2021. This population growth is expected to continue as economic activities in the region develop further. Currently, South Lampung contributes approximately 12% of the total rice production in Lampung Province

Based on our spatial study, we have identified the nine largest area productive paddy fields in South Lampung Natar, Jatiagung, Tanjungsari, Waysulan, Candipuro, Pulas, Sragi, Penengahan, and Ketapang. However, several challenges could prevent long-term food security in South Lampung if these issues are not addressed. Rice production in South Lampung may not be able to expand exponentially further due to the potential conversion of agricultural land into residential areas [17]. This phenomenon is increasingly observed in several regions of South Lampung, particularly near Bandar Lampung, including the Natar and Jatiagung paddy fields, as confirmed by our ground checks (**Figure 2**). A study on agricultural land conversion in the Natar and Jatiagung areas of South Lampung was also highlighted in previous research [18]. This issue arose because of a decline in the income of local farmers to IDR 1,057,088 per month. This has led many local farmers to sell their land to local property developers. However, local farmers recognize that most of the eastern part of South Lampung has fertile agricultural land that better supports paddy growth. The rice productivity in this area has provided food for the local community for decades [19]. Recently, rice production has been unstable due to weather factors and unpredictable fertilizer prices [20]. Additionally, population growth in South Lampung affects the demand for rice.

Adopting sustainable agricultural technologies, such as climate-resistant rice varieties and improved irrigation systems, is essential to address these challenges. Government interventions, such as fertilizer subsidies, can also help stabilize production. Moreover, balancing productivity with sustainability is crucial for ensuring long-term food security. Collaboration among farmers, the government, and researchers is key to finding effective solutions [21].

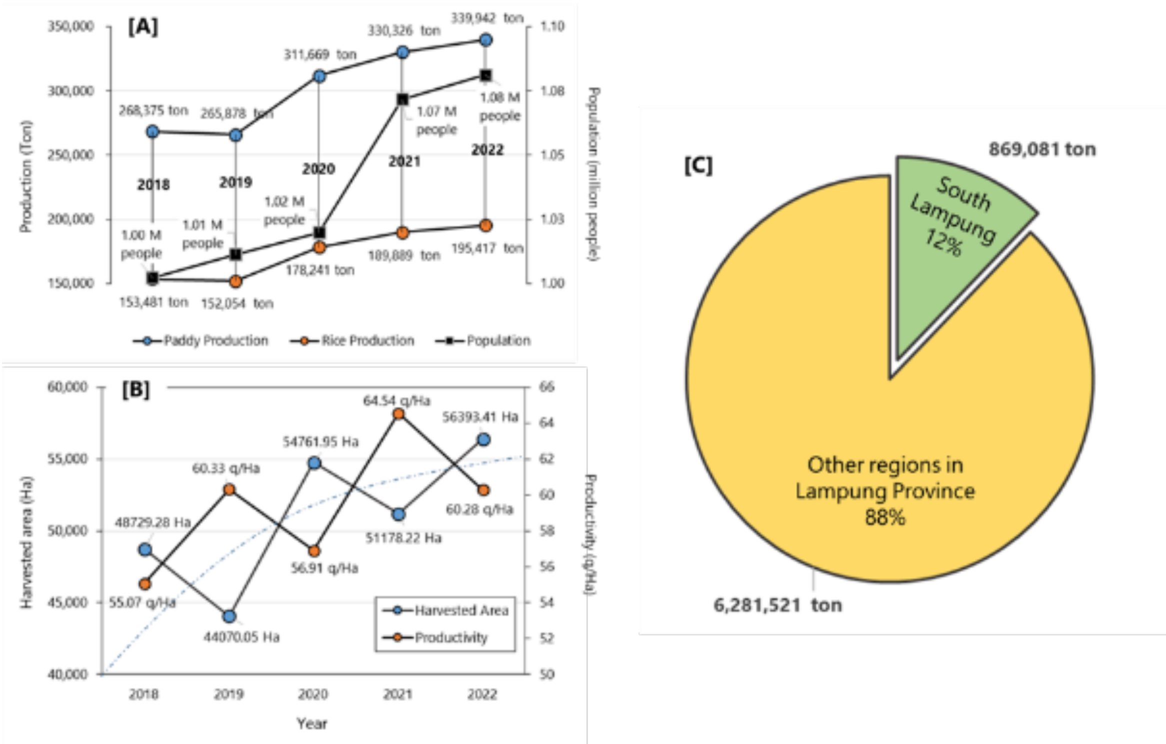

Figure 1 Visualization of comparison of paddy and rice production alongside population growth (A); Comparison of harvested area and land productivity in South Lampung (B); Proportion of average rice production contribution in South Lampung compared to other regions in Lampung Province (C). Raw data source: *lampung.bps.go.id*.

Our field survey results indicate that the paddy fields in South Lampung remain functional for traditional cultivation and play a crucial role in meeting local food needs. However, there is a potential threat of decreased production due to unmanaged land conversion for residential purposes. The most vulnerable areas are the paddy fields in Natar and Jatiagung.

Paddy fields in Natar and Jatiagung are particularly vulnerable because of their proximity to urban centers (Bandar Lampung), making them more attractive to property developers. This poses a threat to the local agricultural ecosystem and could lead to the loss of fertile land, which is difficult to replace. Additionally, this shift may negatively impact the income of local farmers who rely on crop yields as their primary source of livelihood. To address these challenges, clear policies are needed to manage land conversion, including establishing sustainable agricultural zones and regulating residential area development [21]. Furthermore, educating communities and farmers on preserving agricultural land is crucial. Collaboration among the government, communities, and the private sector is essential to balance development needs with agricultural sustainability, ensuring long-term food security in South Lampung.

Topographically, South Lampung exhibits diverse geomorphological features, ranging from the east lowlands to the west mountains and hills (**Figure 3**). The western region borders Lampung Bay, though most rivers in South Lampung flow toward Sumatra's eastern coast. Mount Rajabasa, a prominent volcano in the area, is directly linked to primary paddy fields in the southern part of the region. Rajabasa is a conical volcano with fumarolic activity on its foothills and slopes [22]. It was reported to have increased activity in April 1863, and May 1892 (*volcano.si.edu*), and geothermal manifestations around the volcano [23] signaled the remaining volcanic activity. The eroded volcanic material from Mount Rajabasa serves as a rich nutrient source for plant growth [24], particularly for paddy fields, especially when connected to the drainage system.

Figure 2 Some documentation of mapped productive paddy fields in South Lampung.

Most of the paddy field areas in South Lampung are situated on lithology derived from Quaternary paleovolcanic deposits. Geologically, this lithology is part of the Lampung Formation. These paleovolcanic deposits contain high levels of silica and essential minerals that support paddy growth and biomass formation [25]. These volcanic deposits release minerals as nutrient-rich dissolved ions [24]through a series of weathering processes.

The eastern part of South Lampung is located in fertile lowlands, particularly along the banks of major rivers, which greatly support agricultural activities. High rainfall and relatively stable temperatures [26] create ideal conditions for rice cultivation [27]. The potential for paddy fields in South Lampung is significant [28], with extensive wetlands and adequate irrigation systems, enabling efficient agricultural development [29]. Additionally, several dams and irrigation channels ensure water availability for farming, especially during the dry season.

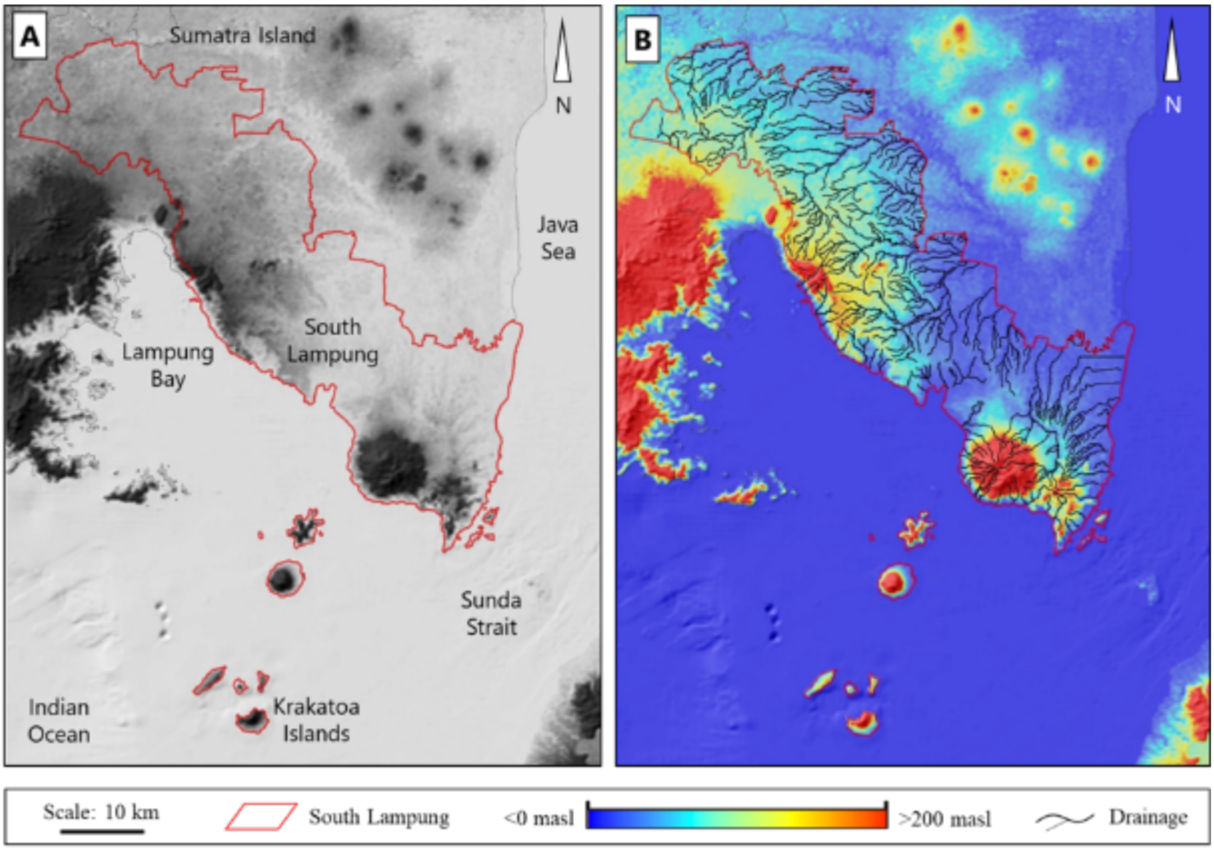

Figure 3 Geographical Digital Elevation Model/DEM (A) and distribution of drainage in the topographical map of South Lampung and its surrounding areas (B).

The geological map of South Lampung shows the distribution of major rock formations primarily associated with ancient volcanic activity (**Figure 4**). The volcanic rocks mainly consist of Plio-Pleistocene pyroclastic materials, which account for over 80% of the distribution. In the geological map of Tanjungkarang [16], these rocks are classified as the Lampung Formation (Qtl), which includes rhyolitic tuff, massive tuff, pumice tuff, tuffaceous claystone, and tuffaceous sandstone. Furthermore, Cretaceous plutonic rocks dominate the northern part (10-15%). In contrast, metamorphic rocks from the Paleozoic era (Carboniferous-Permian) are exposed in the central region [30], identified as part of the Gunungkasih Complex (Pgz). In the eastern part, andesitic rocks from the Pliocene indicate past volcanic activity. The map also marks the locations of active and inactive volcanoes, such as Rajabasa, Sebesi, and Krakatoa [31], which play significant roles in shaping the geological landscape of the region [32].

When compared to the land cover map, particularly for paddy fields, it is evident that traditional paddy fields initiated by the community and continuously utilized at least until 2019 are located around the Plio-Pleistocene pyroclastic rocks (Lampung Formation) and the associated alluvium. From the mapping of paddy fields in 2019, it can be seen that the primary paddy fields are found in several locations, including Natar, Jatiagung, Tanjungsari, Waysulan, Candipuro, Palas, Sragi, Penengahan, and Ketapang. Mount Rajabasa is the drainage source that irrigates the paddy fields in Candipuro, Palas, Sragi, Penengahan, and Ketapang, the main paddy fields in the southern part of South Lampung. Meanwhile, traditional paddy fields have developed in the northern area in the upstream regions covered by Plio-Pleistocene pyroclastic rocks from the Lampung Formation.

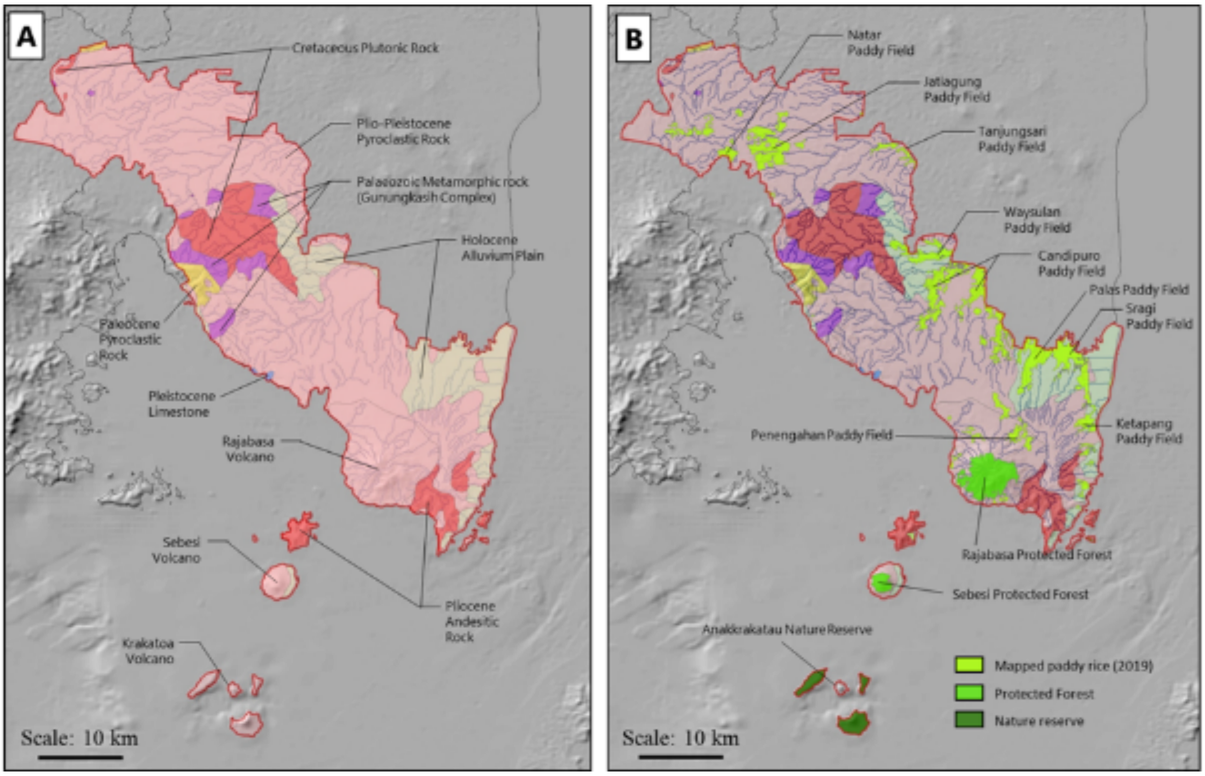

Figure 4 Lithological characteristics (A) and the distribution of mapped paddy fields in South Lampung.

The geochemical composition of rocks is crucial as a primary mineral source for plant growth, especially in paddy fields. Our study shows that the Plio-Pleistocene pyroclastic tuff in South Lampung consists of over 50% SiO_2 (w/w). Fresh outcrops have a SiO_2 abundance of 78% (weight/weight). Additionally, Al_2O_3 is ranging from 12-30%, and total Fe varies between 1.5–4.5%. This composition is significantly influenced by the characteristics of felsic volcanic materials and the weathering of rhyolitic rocks in the underlying geology. SiO_2, or silicon dioxide, is commonly found in rocks; however, its abundance offers significant benefits for rice plant growth and resilience [33]. SiO_2 enhances production by strengthening resistance to pests and diseases by forming protective layers on plant tissues and reinforcing cell walls against physical stress such as drought [34] and dynamic wet conditions in paddy fields. Moreover, silica improves the efficiency of nitrogen and phosphorus uptake, which are essential for plant health and yield. Silicon (Si) also plays a vital role in photosynthesis, supporting photolysis reactions on leaf surfaces, thereby enhancing the effectiveness of rice biomass production [35].

This study highlights the significant role of agrogeology in supporting local food security, particularly in sustaining rice production. Understanding the characteristics of the parent rock is crucial for soil fertility and its ability to provide natural nutrients and water. With this knowledge, appropriate land management practices can be implemented to enhance rice productivity without degrading the soil's natural properties. Furthermore, agrogeology plays a significant role in reducing dependency on chemical fertilizers. Geochemical insights offer an alternative perspective on the mineral sources and natural nutrients necessary in paddy fields. The agrogeological insights from this study also lead to valuable information for water resource management by mapping drainage systems and water flows. This enables the design of efficient irrigation systems, ensuring adequate water availability during the growing season. Furthermore, the information from this agrogeological study can serve as a foundation for developing sustainable agricultural policies, including land use and farming techniques that align with local geological conditions. By leveraging the agrogeological approach, rice production can be sustainably increased, supporting local food security and meeting the growing needs of the local community in South Lampung.

CONCLUSION

This study demonstrates that significant paddy fields in South Lampung, such as those in Candipuro, Jatiagung, and Palas, are associated with a silicate-rich lithology. The nutrient and drainage conditions shaped by this lithology make these areas highly suitable for rice production in the region. From an agrogeological perspective, analyzing the distribution of paddy fields in South Lampung offers essential insights for strengthening local food security. Understanding a region’s geological characteristics and water resources can achieve sustainable land management. The productivity of paddy fields in South Lampung is closely tied to their location over the Plio-Pleistocene silicate-rich pyroclastic rocks, which are associated with river flow on the eastern side of the region. The high silica content of these bedrock materials potentially enhances the resilience of rice plants. This study shows that the agrogeological approach provides new insights into maintaining rice productivity and supports more effective and sustainable land-use planning. Therefore, integrating agrogeological insights into agricultural planning in South Lampung is essential to meet local food needs.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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