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ORIGINAL

The Impact of Rice Field Land Conversion on Food Security Threats in Padang City, West Sumatra, Indonesia

El impacto de la conversión de tierras de arrozales en las amenazas a la seguridad alimentaria en la ciudad de Padang, Sumatra Occidental, Indonesia

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ABSTRACT

Introduction: agricultural land conversion poses a global threat to food security, particularly in developing nations experiencing rapid urbanization and population growth. This study aims to analyze the impact of rice field land conversion on food security threats in Padang City, West Sumatra, Indonesia, where population pressure continues to drive agricultural land loss.
Method: a quantitative approach was applied using four methodological stages: (1) calculating rice field changes across three time periods (2009, 2015, and 2022) using supervised classification of Landsat 7 and 8 imagery; (2) measuring agricultural land carrying capacity using standardized formulas; (3) determining rice availability based on harvested area and productivity data; (4) predicting rice requirements for food self-sufficiency. Data were obtained from Landsat imagery (2009, 2015, 2022), field surveys conducted in 2023, and Statistics Indonesia (BPS). Analysis was conducted using Geographic Information Systems (GIS) software and carrying capacity, rice availability, and demand formulas. The study encompassed all 11 administrative districts of Padang City, with sample areas identified as rice-producing zones.
Results: rice field area declined significantly from 6827,40 hectares in 2015 to 4809,35 hectares in 2022, representing a loss of 1918,05 hectares, predominantly converted to built-up land. Agricultural land carrying capacity was calculated at 0,0125 (Class III), indicating that Padang City has not achieved food self-sufficiency. Rice availability was 1 026 762,57 tons, while rice demand reached 11 801 533,26 tons, resulting in a deficit of approximately 10,77 million tons.
Conclusions: rice field conversion significantly reduces agricultural productivity and threatens food security. Padang City experiences a major rice deficit and has not achieved self-sufficiency. Urgent interventions including farmer regeneration, creation of new agricultural zones, and implementation of sustainable agricultural land protection policies are necessary to address population pressure and land conversion challenges.

Keywords: Land Degradation; Agricultural Land; Population Pressure; Land Conservation; Food Security.

RESUMEN

Introducción: la conversión de tierras agrícolas representa una amenaza global a la seguridad alimentaria, particularmente en naciones en desarrollo que experimentan rápida urbanización y crecimiento poblacional. Este estudio tiene como objetivo analizar el impacto de la conversión de tierras de arrozales en las amenazas

a la seguridad alimentaria en la ciudad de Padang, Sumatra Occidental, Indonesia, donde la presión poblacional continúa impulsando la pérdida de tierras agrícolas.
Método: se aplicó un enfoque cuantitativo con cuatro etapas metodológicas: (1) calcular los cambios en la superficie de arrozales en tres períodos (2009, 2015 y 2022) utilizando clasificación supervisada de imágenes Landsat 7 y 8; (2) medir la capacidad de carga de las tierras agrícolas utilizando fórmulas estandarizadas; (3) determinar la disponibilidad de arroz basada en datos de área cosechada y productividad; (4) predecir los requisitos de arroz para la autosuficiencia alimentaria. Los datos se obtuvieron de imágenes Landsat (2009, 2015, 2022), encuestas de campo realizadas en 2023 y de la Oficina de Estadística de Indonesia (BPS). El análisis se realizó utilizando software de Sistemas de Información Geográfica (SIG) y fórmulas de capacidad de carga, disponibilidad de arroz y demanda. El estudio abarcó los 11 distritos administrativos de la ciudad de Padang, con áreas de muestra identificadas como zonas productoras de arroz.
Resultados: la superficie de arrozales disminuyó significativamente de 6827,40 hectáreas en 2015 a 4809,35 hectáreas en 2022, representando una pérdida de 1918,05 hectáreas, convertida predominantemente a suelo urbanizado. La capacidad de carga de tierras agrícolas se calculó en 0,0125 (Clase III), lo que indica que la ciudad de Padang no ha logrado la autosuficiencia alimentaria. La disponibilidad de arroz fue de 1 026 762,57 toneladas, mientras que la demanda alcanzó 11 801 533,26 toneladas, generando un déficit de aproximadamente 10,77 millones de toneladas.
Conclusiones: la conversión de arrozales reduce significativamente la productividad agrícola y amenaza la seguridad alimentaria. La ciudad de Padang enfrenta un gran déficit de arroz y no ha logrado la autosuficiencia. Se requieren intervenciones urgentes incluyendo regeneración de agricultores, creación de nuevas zonas agrícolas e implementación de políticas sostenibles de protección agrícola para abordar los desafíos de presión poblacional y conversión de tierras.

Palabras clave: Degradación del Suelo; Tierras Agrícolas; Presión Poblacional; Conservación de la Tierra; Seguridad Alimentaria.

INTRODUCTION

Agricultural land conversion represents a critical global challenge to food security, particularly as developing nations experience rapid urbanization and population growth.[1] Across Southeast Asia and Indonesia specifically, the conversion of productive agricultural land, especially rice fields, into residential settlements and commercial zones has intensified over the past two decades.[2] This trend threatens the capacity of regional and national systems to achieve food self-sufficiency and maintain stable food prices for growing populations.

Padang City exemplifies this broader phenomenon. The city has experienced substantial population growth, increasing from 777 044 people in 2020 to 913 448 people in 2021.[3,4] Simultaneously, rice field area has declined dramatically from 6827,40 hectares in 2015 to 4809,35 hectares in 2022. This decline of approximately 1918,05 hectares represents a significant loss of productive agricultural capacity in a relatively short period. The primary driver of this conversion is population pressure, which creates demand for residential land and urban expansion.[5] Economic factors, including land value appreciation and income opportunities from non-agricultural land use, further incentivize farmers to convert rice fields into settlements and commercial properties.

Population pressure on agricultural land represents a fundamental challenge to food production capacity. As urban areas expand and populations increase, the carrying capacity of existing agricultural land to support population nutritional needs diminishes.[6,7] Rice field conversion has become particularly concerning because its impacts are permanent, cumulative, and progressive—once converted, land rarely returns to agricultural use, and each conversion reduces the total productive capacity available to future generations.[8,9] Research from Tanah Darat Regency and similar regions indicates that both economic factors (income opportunities) and structural factors (land area availability) significantly influence farmers' decisions to convert rice fields.[10]

While Indonesia is recognized as an agricultural nation, it continues to face food security challenges. National projections estimate that rice field area in Indonesia will decline to approximately two million hectares by 2025.[11] In response, the Indonesian government has implemented policies such as mapping Sustainable Food Agricultural Land (LP2B) and establishing Sustainable Food Agricultural Reserve Land (LCP2B).[12,13] However, LP2B mapping efforts face obstacles due to incomplete spatial data on physical, economic, and social characteristics of agricultural lands relative to documented land conversion patterns.[14]

Padang City specifically has not yet achieved food self-sufficiency despite its agricultural heritage. The relationship between land conversion, agricultural productivity, and food availability remains inadequately documented at the local level.[15] Food security can only be achieved when available food supply meets the nutritional needs of the entire population. Understanding the quantitative impact of rice field conversion on food security is essential for developing targeted policy interventions.[16] This research analyzes the impact of

rice field land conversion on food security threats in Padang City by examining changes in rice field area over time, the carrying capacity of remaining agricultural land, and the gap between rice production and population requirements.

METHOD

Study Design and Type

This research employs a descriptive quantitative approach, designed to characterize and quantify the relationship between agricultural land conversion and food security indicators in Padang City. The study was non-observational, utilizing secondary satellite data, government statistics, and primary field survey data collected in 2023.

Research Location and Population

The research encompasses Padang City, which has a total area of approximately 69 496 hectares divided into 11 administrative districts: Bungus Teluk Kabung, Koto Tangah, Kuranji, Lubuk Begalung, Lubuk Kilangan, Nanggalo, Padang Barat, Padang Selatan, Padang Timur, Padang Utara, and Pauh. The study universe consisted of all rice-producing agricultural areas within these districts. The sample included areas currently under rice cultivation and areas that had been converted from rice cultivation during the study period (2009-2022).

Study Variables

The study employed the following variables:

1. Land Use Classification: categorical variable including forest, built-up land, mining, mixed crops, shrubland, water bodies, and rice fields.
2. Rice Field Area: continuous variable measured in hectares (ha).
3. Population Number: continuous variable measured in persons.
4. Agricultural Land Carrying Capacity: calculated continuous variable (dimensionless ratio).
5. Rice Productivity: continuous variable measured in kg/hectare.
6. Rice Availability: continuous variable measured in tons.
7. Rice Demand: continuous variable measured in tons.
8. Rice Self-Sufficiency: continuous variable calculated as the difference between availability and demand (tons).

Data Sources and Collection

Secondary Data

Historical land use data were obtained from supervised classification of Landsat 7 satellite imagery (2009) and Landsat 8 imagery (2015, 2022). Population data and agricultural productivity statistics were obtained from Statistics Indonesia (Badan Pusat Statistik—BPS), specifically from the 2020 Census and annual agricultural reports.

Primary Data

Field surveys were conducted during 2023 to validate satellite classification results, measure rice productivity on sample plots, verify current land use patterns, and collect local information on agricultural practices and land conversion drivers.

Data Sources Summary

The study integrated four primary information sources: (1) satellite imagery from NASA's Landsat program; (2) official government statistics from Indonesia's Central Statistical Agency; (3) field surveys and ground-truthing; (4) agricultural extension office records.

Data Analysis Methods

Land Use Change Analysis

Supervised classification was applied to Landsat imagery using maximum likelihood classification within ArcGIS 10.5. Post-classification change detection was performed by comparing classifications between time periods (2009, 2015, 2022).

Agricultural Land Carrying Capacity

Calculated using the standardized formula:[17]

$$\tau = \frac{\mathrm{Lp/Pd}}{\mathrm{KFM/Pr}}$$

Where:

- τ = Rice food agricultural regional carrying capacity.
- Lp = Rice field area (hectares).
- Pd = Population number (persons).
- KFM = Minimum physical caloric requirements (2100 calories/capita/day).
- Pr = Average land production per hectare (kg/ha).

Classification System

- Class I (α < 1): region unable to achieve food self-sufficiency; population exceeds optimal carrying capacity.
- Class I (α > 1): region capable of achieving food self-sufficiency; population below optimal carrying capacity.

Rice Availability Analysis

Calculated as:

$$S = \{(PrL \times Lpp) - Pgl\} \times \alpha$$

Where:

- S = Rice availability (tons).
- PrL = Land productivity (tons/hectare).
- Lpp = Rice harvested area (hectares).
- Pgl = Other rice uses/losses (hectares equivalent).
- α = Conversion index from paddy (GKG) to rice (0,6274).

Rice Requirements Analysis

Calculated as:

$$D = JP\ (Stdb \times 112/\ 1000)$$

Where:

- D = Rice requirement (tons).
- JP = Population number (persons).
- Stdb = Rice requirement standard per capita (113,48 kg/capita/year).
- 112 = Adjustment factor for nutritional equivalency.

Rice Self-Sufficiency Analysis

Calculated as:

$$Swb = S - D$$

Where:

- Swb = Rice self-sufficiency surplus or deficit (tons).
- S = Actual rice availability (tons).
- D = Rice requirements (tons).

If Swb ≥ 0, the region achieves rice self-sufficiency; if Swb < 0, the region experiences a rice deficit.

Ethical Standards

This research involved analysis of publicly available satellite imagery and government-published statistics. Field surveys were conducted with permission from local agricultural extension offices and village administrations. No human subjects were directly interviewed or observed in a manner requiring formal ethical review. All data were analyzed at the aggregate administrative level without identifying individual landowners or farmers. The research complies with the research ethics guidelines of Universitas Negeri Padang and the Indonesian government's requirements for academic research.

RESULTS

Land Use Changes

Land use changes for 2015 and 2022 were documented through supervised classification of Landsat 8 satellite

imagery. Comparison of classifications across the two dates provides a seven-year perspective on land use transformation in Padang City.

Table 1. Land Use in Padang City in 2015

No	Land Use	Land Use Area 2015 (ha)
1	Forest	30 824,37
2	Built-up Land	9844,02
3	Mining	549,81
4	Mixed Crops	3061,17
5	Shrubland	18 148,59
6	Water Bodies	240,64
7	Rice Fields	6827,40
Tota Area		69 496,00

Source: Primary Data Processing, 2023

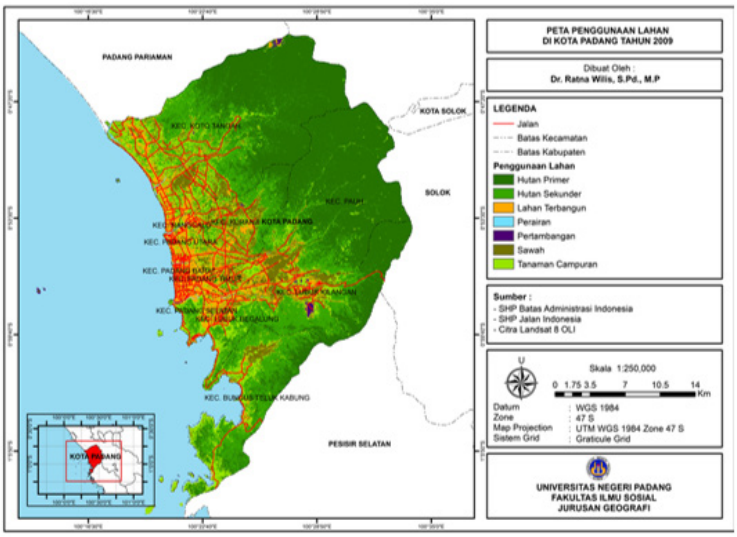

Figure 1. Land Use Map of Padang City in 2009

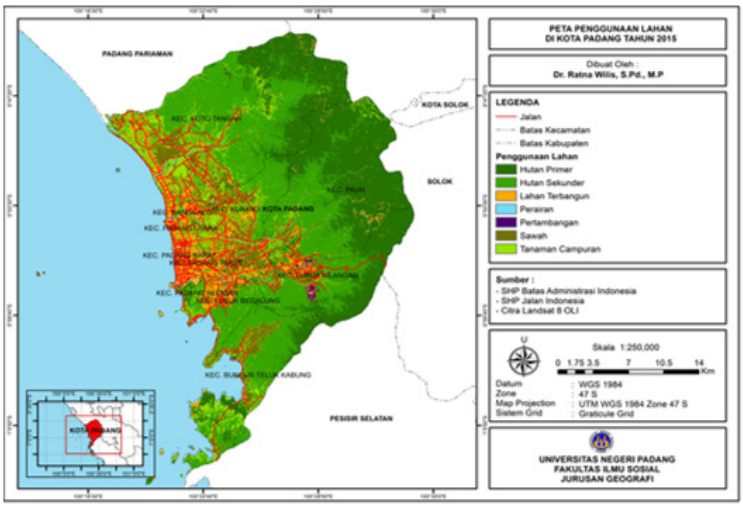

Figure 2. Land Use Map of Padang City in 2015

In 2015, rice fields occupied 6827,40 hectares, representing approximately 9,8 % of Padang City's total area of 69 496 hectares. Built-up land comprised 844,02 hectares, with shrubland and forest constituting the largest land cover types at 18 148,59 hectares and 30 824,37 hectares respectively.

By 2022, significant changes had occurred in the city's land use composition:

Table 2. Land Use in Padang City in 2022

No	Land Use	Land Use Area 2022 (Ha)
1	Forest	27 782,01
2	Built-up Land	12 352,90
3	Mining	1207,62
4	Mixed Crops	6865,15
5	Shrubland	16 238,33
6	Water Bodies	240,64
7	Rice Fields	4809,35
Total Area		69 496,00

Source: Primary Data Processing, 2023

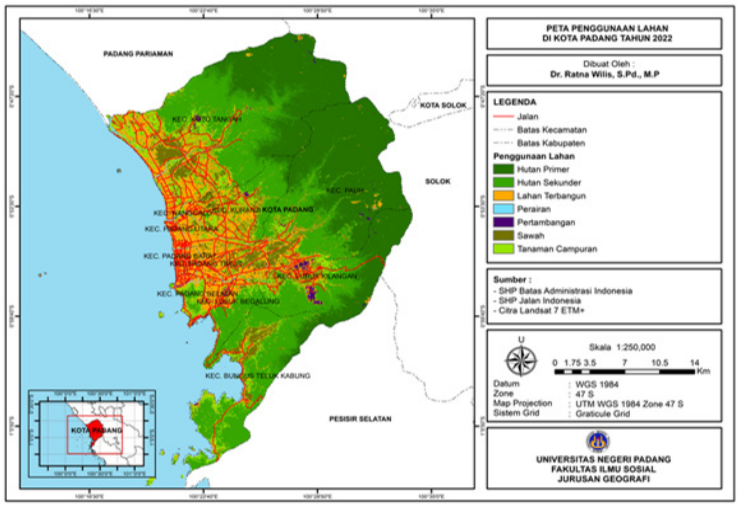

Figure 3. Land Use Map of Padang City in 2022

The comparison reveals that rice field area declined from 6827,40 hectares in 2015 to 4809,35 hectares in 2022, representing a net loss of 2018,05 hectares over seven years. This conversion resulted in rice fields declining from 9,8 % to 6,9 % of the city's total area.[18] Concurrently, built-up land increased from 9844,02 hectares to 12 352,90 hectares, an expansion of 2508,88 hectares. Mixed crops expanded from 3061,17 hectares to 6865,15 hectares, an increase of 3804 hectares. Forest area contracted from 30 824,37 hectares to 27 782,01 hectares, and shrubland decreased from 18 148,59 hectares to 16 238,33 hectares. Mining operations nearly doubled from 549,81 hectares to 1207,62 hectares.[19]

The most significant finding is that rice field conversion occurred predominantly into built-up residential land and mixed crop areas, indicating that urbanization and economic land-use changes are the primary drivers of agricultural land loss.[20] The loss of rice cultivation area occurred in multiple districts but was most pronounced in areas adjacent to urban centers.

Analysis of Rice Field Land Carrying Capacity in Padang City

Table 3. Agricultural Carrying Capacity Data for Padang City, 2023

No	Parameter	Value
1	Population Number	928 541 People
2	Rice Field Area	4,809 Ha
3	Minimum Physical Requirement Rate	2100 calories/capita/day
4	Average Land Production	5,52 tons/hectare

Source: Primary Data Processing, 2023

Agricultural land carrying capacity represents the capacity of available land resources to support the caloric and nutritional needs of the resident population. Population pressure creates stress on agricultural systems when the population exceeds the carrying capacity of available arable land. As populations increase and agricultural area declines simultaneously, the carrying capacity of the region diminishes.

Carrying Capacity Calculation

$$\tau = \frac{\text{Lp/Pd}}{\text{KFM/Pr}} = \frac{0{,}00518}{380{,}43} = 0{,}0125$$

The calculated rice food agricultural regional carrying capacity for Padang City is 0,0125. According to the classification system, this value falls into Class III (where τ < 1), indicating that Padang City is unable to achieve rice food self-sufficiency.[21,22] The region's population significantly exceeds the optimal population that existing agricultural land can support. This low carrying capacity value reflects both the substantial population size (928 541 persons) and the limited rice-producing land (4809 hectares), resulting in a ratio of approximately 193 persons per hectare of rice land—far exceeding the approximately 0,38 persons per hectare that would be required for self-sufficiency.[23,24]

The inverse relationship between population pressure and carrying capacity is evident: as the population has grown from 777 044 (2020) to 928 541 (2023) while rice field area has declined from 6827,40 (2015) to 4809,35 hectares (2022), the carrying capacity has deteriorated.[25] This dynamic indicates that Padang City's population growth has outpaced agricultural productivity, creating a structural food security deficit.

Agricultural land carrying capacity analysis demonstrates that land carrying capacity depends on two principal factors: harvested rice area and agricultural productivity per hectare.[26] Improvements in either factor could theoretically enhance carrying capacity. However, given the ongoing conversion of rice land to non-agricultural uses and the limited potential for productivity gains on remaining land, the carrying capacity of Padang City is projected to decline further in coming years unless land conversion is substantially restricted.[27]

Rice Self-Sufficiency Analysis in Padang City

Rice represents one of the primary staple foods for Indonesian populations and constitutes a critical component of national food security strategy. Although Indonesia is recognized as an agricultural nation, national self-sufficiency in rice has been challenged in recent years. Rice imports during 2016-2020 averaged approximately 356 000 to 2 203 000 tons annually, indicating that domestic production has not consistently met national consumption demands. At the local level, regional rice deficits create dependency on imports from other regions or nations.[28]

Determining Rice Availability (S)

Rice availability was calculated based on existing productive capacity of remaining rice-growing areas in Padang City.

Table 4. Rice Availability Calculation Data

No	Type	Amount
1	Land Productivity (PrL)	5,52 tons/hectare
2	Rice Harvested Area (Lpp)	296 492 hectare
3	Other Rice Uses (Pgl)	100 hectare (loss equivalent)
4	Conversion Index from Rice to Rice (α)	62,74 %

Source: Primary Data Processing, 2023

$$S = \{(5{,}52 \text{ x } 296\,492) - 100\} \text{ x } 0{,}6274 = \{1\,638\,798{,}84 - 100\} \text{ x } 0{,}6274 = 1\,026\,762{,}57 \text{ tons}$$

Total rice availability in Padang City is 1 026 762,57 tons annually. This calculation reflects actual production capacity based on existing harvested area (296,492 hectares) and demonstrated productivity levels (5,52 tons/hectare), with adjustment for post-harvest losses and processing waste through the conversion index.[29]

Determining Rice Food Requirements (D)

The primary target for household food security in Indonesian communities is rice consumption. Each region should ideally achieve food self-sufficiency, meaning that local rice production meets local consumption needs, reducing vulnerability to regional or national supply disruptions.

Table 5. Rice Food Requirements Padang City, 2023

No	Type	Amount
1	Population Number (JP)	928 541 People
2	Rice Requirement Standard per Capita (Stdb)	113 48 kg/capita/ year

Source: Primary Data Processing, 2023

$$D = 928\,541 \text{ x } \left(113{,}48 \times \frac{112}{1000}\right) = 928\,541 \text{ x } 12{,}71 = 11\,801\,533{,}26 \text{ tons}$$

The annual rice requirement for Padang City's population is 11 801 533,26 tons based on a per capita consumption standard of 113,48 kg per person per year. This standard reflects documented consumption patterns in Indonesia and represents a reasonable estimate of nutritional requirements when rice is the primary source of dietary carbohydrates.

Determining Food Self-Sufficiency Analysis (Swb)

Food security at the global, national, and local levels depends fundamentally on whether food production meets food demand. The agricultural sector is recognized as essential for achieving Sustainable Development Goal 2 (Zero Hunger) and related objectives including food security, improved nutrition, and sustainable agricultural practices. These goals are aligned with Indonesian national development priorities, particularly the commitment to achieve food security by 2030.[30,31]

Table 6. Rice Self-Sufficiency Analysis for Padang City, 2023

No	Type	Amount
1	Rice Availability (S)	1 026 762,5686 tons
2	Rice Requirement (D)	11 801 533,2602 tons
3	Self-Sufficiency Surplus/Deficit (Swb)	-10 774 770,69 tons

Source: Primary Data Processing, 2023

$$Swb = 1\,026\,762{,}57 - 11\,801\,533{,}26 = -10\,774\,770{,}69\ tons$$

Padang City experiences a significant rice deficit of approximately 10 774 770,69 tons annually. The self-sufficiency value (Swb) is negative, indicating that local rice production meets only approximately 8,7 % of the city's annual rice requirements.[32,33] To meet the complete nutritional needs of its population, Padang City must import the remaining 91,3 % of required rice from other regions or nations.[34]

This substantial deficit reflects the fundamental mismatch between Padang City's population size and its remaining agricultural capacity.[35] The city's function as an urban center with significant non-agricultural employment and commercial activities means that the majority of the population does not engage in agricultural production. Simultaneous population growth and rice field conversion have created a structural food security vulnerability.[36] The conversion of rice fields to residential and commercial land uses, while meeting short-term urban development objectives, has reduced the city's capacity to contribute to regional and national food security.[37]

The calculated deficit indicates that land conversion will reduce agricultural sector productivity and threaten local, regional, and national food security objectives. This finding aligns with international research demonstrating that rapid urbanization in developing nations frequently creates local food security deficits and increases dependency on national and international food markets.[38,39]

DISCUSSION

Land Use Conversion Dynamics and Drivers

The documented decline in rice field area from 6827,40 hectares (2015) to 4809,35 hectares (2022) represents a significant transformation in Padang City's land use composition and agricultural capacity. The loss of approximately 2018,05 hectares over seven years corresponds to an average annual rate of rice field conversion of 288,3 hectares per year, or approximately 4,2 % annually. This rate of conversion is substantial and, if continued, would eliminate all remaining rice cultivation in the city within approximately 16-17 years.

The finding that rice field conversion occurred predominantly into built-up residential land (2508,88 hectares increase) and mixed crop areas (3804 hectares increase) is consistent with urbanization patterns documented in other Southeast Asian cities experiencing rapid economic development. Similar studies in Tanah Datar Regency, West Sumatra, identified income opportunities and land market values as primary drivers of rice field conversion. The present research confirms that economic incentives remain powerful factors in agricultural land conversion decisions.

However, the mechanisms differ from rural agricultural areas. In Padang City, conversion to residential land reflects population pressure and housing demand created by urban migration and natural population increase. The increase in mixed crop areas may represent transition zones where rice cultivation is being replaced with less water-intensive or more commercially attractive crops. The expansion of mining operations (from 549,81 to 1207,62 hectares) indicates that resource extraction also competes with agricultural land use. These dynamics suggest that multiple economic sectors are simultaneously competing for agricultural land, with non-agricultural uses generally commanding higher land prices and returns.

The expansion of built-up land in Padang City (2508,88 hectares) exceeded the loss of rice fields (2018,05 hectares), indicating that urbanization draws from multiple sources of land conversion, not solely rice fields. Forest area also declined by 3042,36 hectares and shrubland by 1910,26 hectares, suggesting that urbanization is consuming diverse land cover types according to spatial proximity to existing urban centers and transportation networks. However, rice fields, which typically occupy accessible lowland areas near settlements, are preferentially converted to urban uses relative to forest or distant marginal lands.

Agricultural Carrying Capacity and Food Security Vulnerability

The calculated carrying capacity value of 0,0125 (Class III) indicates that Padang City cannot sustain its current population on locally-produced rice. This finding is consistent with the city's character as an urban center where the majority of the population engages in non-agricultural economic activities. The carrying capacity value reflects the fundamental structural reality that urban centers function as population concentration zones that depend on inter-regional food flows.

The concept of agricultural land carrying capacity has been extensively applied in geographic and environmental management research to assess whether regions can achieve food self-sufficiency. Research by Muta'ali Lutfi and others has established that carrying capacity analysis provides a quantitative basis for determining the optimal population that can be sustainably supported by existing environmental resources. The inverse relationship between population size and carrying capacity—wherein increasing population reduces per-capita access to productive land—is well-documented and confirmed in the present research.

The deterioration of carrying capacity in Padang City from 2015 to 2023 reflects dual pressures: population increase (777,044 to 928,541 persons, a 19,5 % increase) and agricultural land decline (6827,40 to 4809,35 hectares, a 29,6 % decrease). The cumulative effect of these opposing trends is a substantial erosion of food production capacity relative to population nutritional requirements. Similar patterns have been documented in rapidly urbanizing regions of Bangladesh, Java, and other areas of intensive agricultural development, where carrying capacity has declined as urbanization consumed productive agricultural land.

The carrying capacity analysis demonstrates that improvements in agricultural productivity could theoretically compensate for land area losses. However, existing rice productivity in Padang City (5,52 tons/hectare) is below the national average for irrigated rice cultivation (6-8 tons/hectare), suggesting that productivity improvements may be constrained by factors such as limited irrigation infrastructure, aging farm equipment, or inadequate agricultural extension services. Achieving productivity improvements while simultaneously reducing land area presents a significant technical and resource management challenge.

Rice Availability, Demand, and the Food Security Deficit

The calculated rice deficit of 10 774 770,69 tons represents the most striking finding of the research. This deficit indicates that local rice production meets only 8,7 % of population requirements, with 91,3 % of rice consumed in Padang City sourced from external regions. This extreme dependency creates significant vulnerability to supply disruptions, price volatility in regional and national markets, and transportation infrastructure failures.

Research on rice consumption patterns in Indonesia indicates that rice remains the dominant staple food,

with per capita consumption averaging approximately 113,48 kg annually, consistent with the present study. National rice imports during 2016-2020 ranged from 356 000 tons (2020) to 2,203 million tons (2018), reflecting years when domestic production failed to meet national consumption. The import data demonstrates that Indonesia as a nation, despite its agricultural heritage, has periodically experienced rice deficits, suggesting that local and regional deficits are increasingly common in rapidly urbanizing areas.

The rice deficit in Padang City is not unique but rather represents an extreme manifestation of a pattern found in major urban centers throughout Asia. Bangkok, Manila, Jakarta, and other metropolitan areas have experienced similar structural food security gaps for decades, managed through inter-regional and international trade networks. However, the scale of Padang City's deficit (91,3 % dependency) is more extreme than in many comparable cities, reflecting the combined effects of dense urban population, limited remaining agricultural land, and geographic constraints that limit agricultural expansion possibilities.

The conversion of rice fields to other land uses, as documented in the present research, directly reduces rice production capacity and increases the magnitude of the city's food security deficit. Between 2015 and 2022, the rice field loss of 2018,05 hectares would have produced approximately 223 000 tons of rice annually (at 5,52 tons/hectare productivity), representing additional food security burden that must now be met through imports or inter-regional transfers. This observation underscores the permanent and cumulative nature of agricultural land conversion impacts on food security.

Padang City's rice deficit is fundamentally linked to its urban function and economic structure. As long as the city remains a major commercial, administrative, and educational center, the population will continue to exceed agricultural carrying capacity, and food security will depend on functioning inter-regional and international food supply systems. However, the present research suggests that accelerating rice field conversion may exceed the capacity of regional food supply systems to provide adequate supplies at stable prices.

Implications and Policy Considerations

The research findings indicate that immediate interventions are necessary to address Padang City's declining agricultural capacity and growing food security vulnerability. Several policy approaches merit consideration:

Farmer Regeneration and Extension Support

The conversion of rice fields reflects, in part, aging rural populations and limited economic incentives for younger individuals to enter rice agriculture. Supporting farmer regeneration through training, financial incentives, and improved agricultural technology could maintain productive agricultural engagement in areas suitable for continued rice cultivation.

Agricultural Land Protection Policies

The Indonesian government has established protocols for identifying and protecting Sustainable Food Agricultural Land (LP2B) and reserving additional areas as Sustainable Food Agricultural Reserve Land (LCP2B). Effective enforcement of these designations and penalties for unauthorized conversion could reduce the rate of rice field loss. However, the present research indicates that existing policies have not prevented substantial land conversion, suggesting that enforcement mechanisms require strengthening or economic incentives for conversion are too powerful for current regulatory approaches to manage.

Productivity Enhancement

Research and extension programs targeting productivity improvement in remaining rice-growing areas could partially compensate for land area losses. Current productivity levels (5,52 tons/hectare) are below national averages, suggesting opportunities for improvement through improved irrigation management, adoption of high-yielding crop varieties, integrated pest management, and soil conservation practices.

Zoning and Urban Planning Integration

Municipal land use planning should incorporate food security objectives by designating rice cultivation zones where development restrictions limit non-agricultural conversions. Strategic placement of agricultural preserves in relation to urban expansion patterns can maintain productive capacity in areas where agriculture remains viable.

Integrated Food Security Strategy

Given that Padang City cannot achieve rice self-sufficiency under any realistic agricultural expansion scenario, food security strategy should encompass multiple elements: (1) maintaining rice cultivation in suitable areas to preserve regional and national production capacity; (2) developing stable inter-regional supply relationships; (3) supporting agricultural diversification in areas less suitable for rice; (4) enhancing food storage and logistics infrastructure to buffer supply disruptions; (5) supporting household food production through urban and peri-urban farming initiatives.

The research demonstrates that land conversion threatens food security not only locally in Padang City but also contributes to regional and national food security stress. Every hectare of rice field converted to other uses reduces the nation's productive capacity and increases dependency on imports. This emphasizes that food security is not solely a local or regional issue but requires coordination across multiple administrative levels and policy sectors.

CONCLUSIONS

This research analyzed the impact of rice field land conversion on food security in Padang City through examination of land use changes, agricultural carrying capacity, and rice availability-demand relationships between 2009 and 2023.

Land use analysis revealed that rice field area declined from 6827,40 hectares (2015) to 4809,35 hectares (2022), representing a loss of 2018,05 hectares (29,6 % reduction) predominantly converted to built-up residential land and mixed crop areas. This conversion reflects ongoing urbanization driven by population growth and economic land market dynamics. The spatial pattern of conversion—concentrated in areas adjacent to urban centers—confirms that urbanization represents the primary driver of agricultural land loss in Padang City. If current conversion rates persist, remaining rice cultivation capacity could be substantially eliminated within 15-20 years.

Agricultural carrying capacity analysis demonstrated that Padang City's rice production capacity is fundamentally inadequate to meet population nutritional needs. The calculated carrying capacity value of 0,0125 (Class III) indicates that the region cannot achieve food self-sufficiency. This low carrying capacity results from the combination of large population size (928 541 persons) and limited agricultural land (4809 hectares), creating a structural mismatch that cannot be resolved through incremental improvements in agricultural productivity alone. Population growth and agricultural land decline have created a deteriorating trend in carrying capacity that threatens long-term food security.

Rice availability and demand analysis revealed a substantial and persistent food security deficit. Rice production of 1 026 762,57 tons annually can meet only 8,7 % of Padang City's rice requirements of 11 801 533,26 tons, resulting in a deficit of approximately 10 774 770,69 tons. This extreme dependency on food imports from other regions creates vulnerability to supply disruptions, price volatility, and transportation infrastructure failures. The deficit is fundamentally linked to Padang City's function as an urban center where the majority of the population engages in non-agricultural activities.

The research confirms that rice field conversion significantly reduces agricultural productivity and threatens food security at local, regional, and national scales. Padang City exemplifies the challenges that rapidly urbanizing centers in developing nations face as population pressure conflicts with agricultural land conservation. The city's food security depends entirely on functioning inter-regional and international food supply systems.

Immediate interventions are urgently needed to address population pressure, land conversion, and food security vulnerability. Recommended actions include:

1. Farmer regeneration programs to encourage agricultural continuation in suitable areas through financial incentives, training, and improved access to agricultural technology.
2. Strengthened agricultural land protection policies through more effective enforcement of sustainable food agricultural land designations and stricter penalties for unauthorized conversion.
3. Agricultural productivity enhancement through research and extension programs targeting adoption of improved crop varieties, irrigation technology, integrated pest management, and soil conservation practices.
4. Integrated urban-agricultural planning that designates rice cultivation zones with development restrictions and strategically places agricultural preserves relative to urban expansion.
5. Comprehensive food security strategy encompassing multiple elements: maintenance of local rice cultivation where viable, development of stable inter-regional supply relationships, agricultural diversification in suitable areas, enhancement of food storage and logistics infrastructure, and support for household food production initiatives.

These interventions must be implemented at multiple administrative levels—municipal, provincial, and national—and should integrate food security objectives into broader urban development, economic development, and environmental management strategies. The research demonstrates that food security is not merely a local issue but requires coordination across administrative boundaries and policy sectors to be effectively addressed.

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