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ANALYSIS OF FOOD FULFILLMENT IN PERI-URBAN AREAS OF SURAKARTA CITY IN 2025

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ABSTRACT

The rapid growth of urbanisation in the city of Surakarta has led to the conversion of agricultural land into residential and industrial areas, significantly impacting the food security of peri-urban areas. This study aims to analyse the land carrying capacity (σ), optimal population, and agricultural land needs for the viability of residents in the peri-urban area of Surakarta City. Data were obtained through the analysis of Sentinel-2A imagery and population statistics, utilising a guided classification approach with the CART algorithm. The results showed that most villages in eight peri-urban sub-districts were in a state of food deficit, with a σ value of < 1, indicating a high dependence on external food supply. Only a few villages in the northern part of Gondangrejo show surplus status. This condition highlights the urgency of implementing a strategy to protect agricultural land and control population growth rates to achieve sustainable food security in suburban areas. These findings make an important contribution to spatial planning and food policy in metropolitan areas.

Keywords: *carrying capacity; food security; peri-urban*

INTRODUCTION

Urbanisation is an inevitable phenomenon and will continue to increase every year (Noviani, Utomowati, Saputra, & Marfu'ah, 2022; Saputra, Nugraha, & Noviani, 2023). Urbanisation has an important role in accelerating regional development by encouraging economic growth, reducing inequality, increasing human resources, and improving infrastructure (ASEAN, 2022; Hana & Pujiati, 2023; Marfu'ah, Noviani, Wijayanti, & Susilawati, 2024; Noviani, Ahmad, Sarwono, Sugiyanto, & Prihadi, 2022; Sakketa, 2022; Taufiq & Kombaitan, 2019). The rapid flow of urbanisation causes the rapid growth of urban areas (urban growth) (Noviani, Muta'ali, & Nasruddin, 2018; Rahman, 2023; Wilonoyudho, Rijanta, Keban, & Setiawan, 2017). Rapid and uncontrolled urban growth has led to the phenomenon of urban sprawl (Marfu'ah et al., 2024;

Noviani, Utomowati, et al., 2022; Permatasari & Pradoto, 2019) Where the city is no longer able to accommodate activities in the city so that the city develops outwards uncontrollably (Marfu'ah et al., 2024; Noviani, Ahmad, & Marfu'ah, 2024; Rizal, Pamungkas, & Sejati, 2024) As a result of the city's inability to provide space to meet the needs of its residents, both the need for space for housing and other activities due to the increasingly limited availability of urban space while the population continues to increase (Marfu'ah et al., 2024; Mayca & Sri, 2015; Noviani et al., 2024).

The conversion of non-developed land into built-up land is a non-negotiable impact of urbanisation (Abu Hatab, Cavinato, Lindemer, & Lagerkvist, 2019a; Aini, Putri, & Istanabi, 2022; Bhat, Shafiq, Mir, & Ahmed, 2017; Fu, Xu, Zheng, & Chen, 2019; Kumalasari, Sarwono, & Noviani, 2023; Noviani et al., 2024; Noviani, Utomowati, et al., 2022). The shift from agricultural land to urban land use reduces the availability of fertile land for food production, exacerbating food security problems. The conversion of agricultural land to non-agricultural land causes a decline in food yields and threatens food security (Ayun, Kurniawan, & Saputro, 2020). The more farmland is converted, the more food security will decrease due to the reduction of land available for food production. Surakarta City, as the centre of the SUBOSUKOWONOSRATEN metropolitan area, is one of the cities with rapid growth due to urbanisation (Noviani et al., 2023). Currently, the city of Surakarta has reached the stage of overcapacity, causing its development to spread irregularly to the suburbs (Aini et al., 2022; Dewi & Rita Noviani, 2024). The expansion of the city of Surakarta to its suburbs has had a significant impact on population growth and the expansion of built land (Kusumastuti, 2017; Sugestiadi & Basuki, 2020). The urban fairy area of Surakarta City includes eight sub-districts, namely Grogol, Baki, Kartasura, Colomadu, Ngemplak, Gondangrejo, Jaten, and Mojolaban, which are spread across Sukoharjo, Karanganyar, and Boyolali Regencies. The urban fairy area of Surakarta City has a medium to high level of urbanisation, with most of it having a built-up land cover of more than 75% of the total area (Buchori, Pangi, Pramitasari, Basuki, & Wahyu Sejati, 2020). These jurisdictions represent critical zones of observation due to their

accelerated demographic growth and the systematic conversion of agricultural landscapes driven by expanding urban economic pressures (Buchori et al., 2020; Dewi & Rita Noviani, 2024; Sugestiadi & Basuki, 2020). The problem of food availability has become an increasingly complex strategic issue due to the pressure of urbanisation, land conversion, and dependence on out-of-town supplies (Mubarokah, Rachman, & Tarigan, 2020; Sarastika & Anggrasari, 2024; Wibowo, 2015). Studies related to the fulfillment of food needs in urban fair areas are important things that need to be prioritized. The peri-urban area of Surakarta City faces temporary food insecurity due to its disaster-prone nature, which affects food access. The relatively rapid population growth is inversely proportional to the shrinking of agricultural land, which has an impact on the region's ability to meet the food needs of its population (Wibowo, 2015). This study presents a factual picture of food availability in the peri-urban area of Surakarta City, along with its spatial distribution, as a contribution to achieving sustainable regional development. While urbanization and the evolution of peri-urban zones in Surakarta have been extensively documented, existing literature primarily concentrates on spatial expansion, land-use shifts, and morphological changes (Buchori et al., 2020; Rizal et al., 2024; Wilonoyudho et al., 2017). Furthermore, although the ecological and developmental impacts of converting agricultural land have been explored (Abu Hatab, Cavinato, Lindemer, & Lagerkvist, 2019b; Kumalasari et al., 2023), a significant oversight remains regarding how these conversions affect localized food security and land carrying capacity at the micro-scale. Current assessments of food security in Indonesia often operate at broad administrative levels, such as regencies or watersheds, and do not adequately capture the spatial heterogeneity of peri-urban areas experiencing intense urbanization pressure. Therefore, this study addresses a critical research gap by integrating agricultural land carrying capacity, optimal population, and food land requirements using a spatially explicit village-level approach in the peri-urban area of Surakarta City.

MATERIALS AND METHODS

1. Study Area

The research was conducted in the peri-urban area of Surakarta City. The area of

the suburbs of Surakarta City is 26,039.49 Hectares, which covers the areas of Karanganyar Regency, Sukoharjo Regency, and Boyolali Regency, spread across eight sub-districts: Jaten District, Gondangrejo District, Ngemplak District, Colomadu District, Kartasura District, Baki District, Grogol District, and Mojolaban District. The selection of Surakarta's peri-urban fringe as the study area is justified by its pivotal role within the SUBOSUKOWONOSRATEN metropolitan framework and its subjection to intense urban encroachment. By examining eight specific sub-districts, Grogol, Baki, Kartasura, Colomadu, Ngemplak, Gondangrejo, Jaten, and Mojolaban. This research captures a diverse spectrum of peri-urban characteristics across the regencies of Sukoharjo, Karanganyar, and Boyolali. The region is classified into four WPU zones, namely the Northern Zone (Gondangrejo & Ngemplak), the Eastern Zone (Jaten & Mojolaban), the Southern Zone (Grogol & Baki), and the Western Zone (Kartasura & Colomadu). A map of the research area is presented in **Figure 1**.

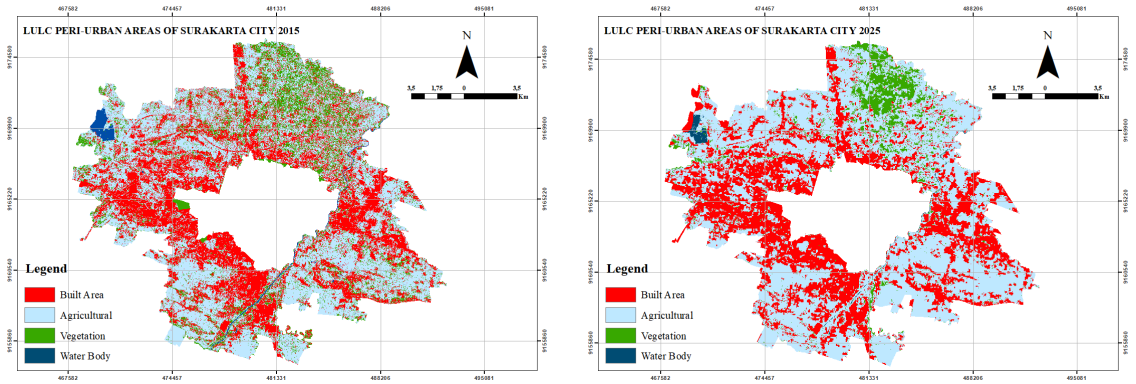

Figure 1. Study Area
Source: Researcher, 2025

The location of the research was determined based on the impact of Surakarta's city development and the level of urbanisation in each area that directly borders the city. The high growth of occupations and the conversion of agricultural land are also factors in selecting research locations, as illustrated in **Figure 1**.

2. Data Sources

Land cover data were obtained from a Sentinel-2A image in 2025 and analysed using supervised classification with the

Classification and Regression Trees (CART) algorithm in Google Earth Engine (GEE), a powerful image classification technique with good predictive ability (Basheer et al., 2022; Zhao et al., 2024). The Sentinel 2-A image is an image with a medium resolution of 10 meters with a data level of 1C, which means that the image has been corrected geometrically and radiometrically in the form of a Top of Atmospheric value (TOA reflectance) (Basheer et al., 2022; Purhartanto, Danoedoro, & Wicaksono, 2020; Putri, Sukmono, & Sudarsono, 2018). The classification of land cover in this study involves categorising it into four main classes: vegetation, agricultural land, water bodies, and built-up land. Based on the accuracy assessment using the error matrix table (confusion matrix), an overall accuracy value of 99.99% was obtained, which met the minimum limit of the accuracy value suitable for use, which is 0.8-0.85 (80%-85%) (Rwanga & Ndambuki, 2017). The flowchart of image processing is presented in **Figure 2.** Land cover data are used to obtain information on the agricultural land area in the peri-urban area of Surakarta City. Data on population and productivity of food crops is obtained from the Central Statistics Agency (BPS) Report and Data.

3. Data Analysis

a. Carrying Capacity of Agricultural Land

The calculation of the carrying capacity of agricultural land is carried out based on a comparison between the harvest area of rice field agricultural land per capita and the land area required for food self-sufficiency (rice). The formula used in the research is shown in **equation 1**:

$$\sigma = \frac{X}{K} \quad (1)$$

Source: (Harini et al., 2025; Sarastika & Anggrasari, 2024)

Description:

σ : Carrying Capacity of Agricultural Land

X : The area of harvest of food crops per capita

K : Area of land for food self-sufficiency

With the formula, the area of harvest of food crops per capita is shown in **equation 2**, and the Area of land for food self-sufficiency is shown in **equation 3**.

$$X = \frac{Harvest\ Area\ (Ha)}{Population\ (Person)} \quad (2)$$

$$K = \frac{MPN}{PFC\ (Kg/Ha)} \quad (3)$$

Description:

MPN : Minimum Physical Need

PFC : Productivity of Food Crops

Source: (Harini et al., 2025; Sarastika & Anggrasari, 2024)

The value of the minimum fiscal need (KFM) used in this calculation is 113.48 kg. The figure of 113.48 kg/capita/year is the standard value of rice consumption needs per capita set by the Central Statistics Agency (BPS). This figure means that each resident needs 113.48 kg of rice per year. This study assumes that each population has the same number of rice consumption needs

The Carrying Capacity of Agricultural Land (σ). So agricultural land is classified into three, namely:

σ<1 : The area is not able to implement rice self-sufficiency, or it can be interpreted that the number of people has exceeded the optimal population.

σ>1 : The region can achieve rice self-sufficiency

σ=1 : The area has an optimal carrying capacity of agricultural land.

b. Optimal Population

The population increase is quite high and accompanied by a decline in agricultural land in the suburbs, indicating pressure on agricultural resources. Population pressure on agricultural land is an indicator of excess population, a symptom related to the limited availability of agricultural land in an area. The optimal population is the number of people whom food crops from agricultural land can support in the area concerned. The optimal population can be determined by paying attention to the parameters of land carrying capacity and population. The formula used is shown in **equation 4**.

$$OP = \sigma \times \text{Tp} \quad (4)$$

Source: (Harini et al., 2025)

with:

OP : Optimal Population Size

σ : Carrying Capacity of Agricultural Land

Tp : Total Population

The calculation will provide a value of the actual ability of the land to meet the food needs of the population.

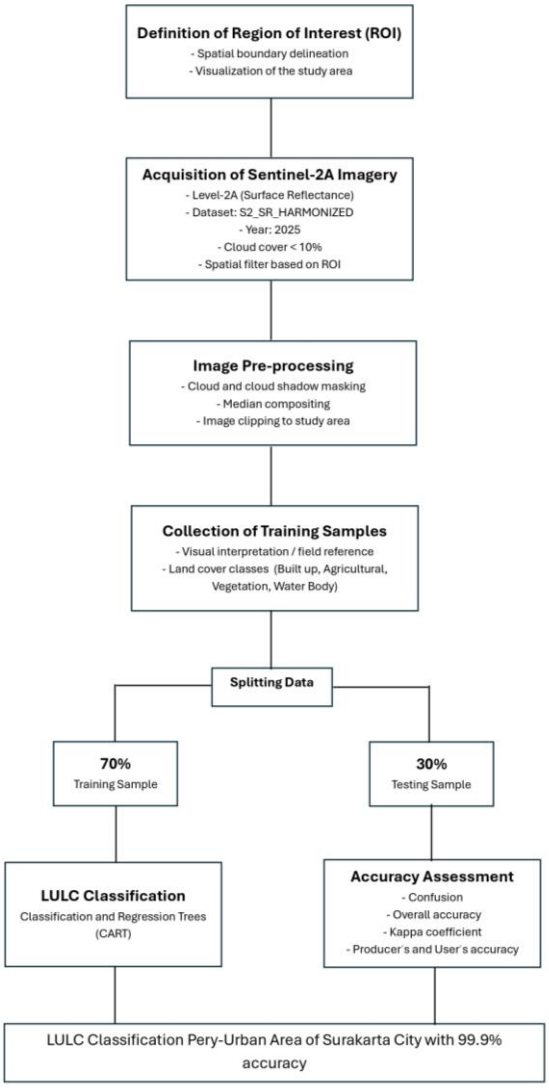

Figure 2. Image Processing Flowchart
Source: Researcher, 2025

c. The Need for Agricultural Land for the Livelihood of the Population

The Need for Agricultural Land for the Livelihood of the Population is assessed from the results of the calculation of the total land needed, equivalent to rice, which is the area of productive land needed to meet the rice consumption of an area. The

demand for rice equivalent land is measured using **equation 5**.

$$Le = Tp \times Dl \quad (5)$$

Source: (Harini et al., 2025)

with:

Le : land requirement equivalent to rice (*Ha*)

Tp : Total Population

Dl : Decent living needs per capita (*ton/years*)

The flowchart of the research is presented in **Figure 3**.

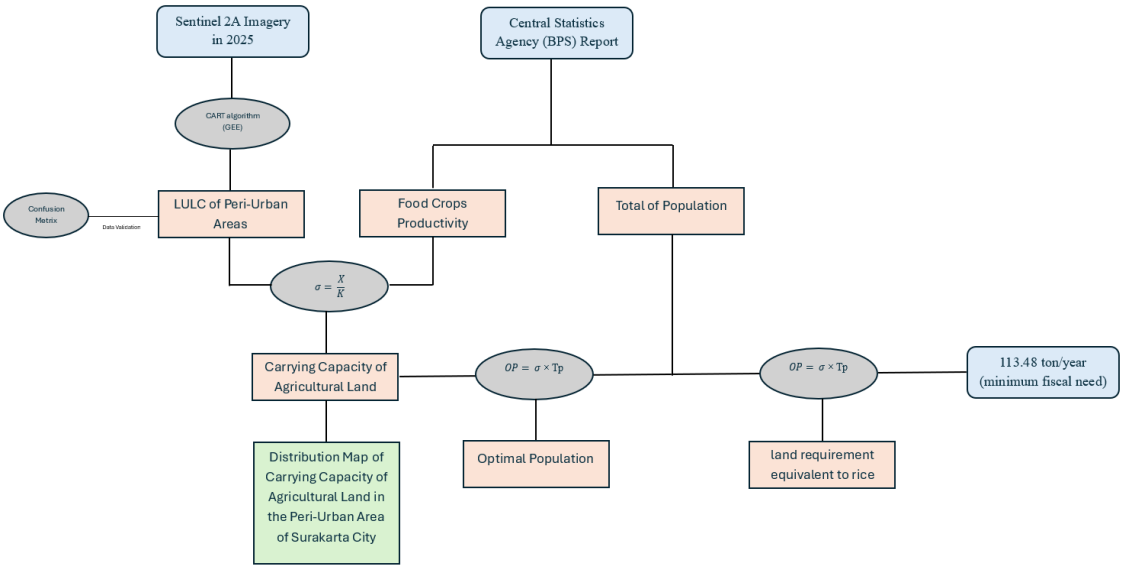

Figure 3. Research Flowchart

Source: Researcher, 2025

RESULTS AND DISCUSSION

Rapid urbanisation has led to a drastic decline in agricultural land areas throughout the suburbs (Abu Hatab et al., 2019b; Fadlli, Soedwiwahjono, & Hardiana, 2016; Selang, Iskandar, & Widodo, 2018). Grogol, Kartasura, and Mojolaban sub-districts, which were previously food barns, have now become residential, trade, and service areas due to urbanisation. Rapid population growth has led to a continued decline in the region's ability to produce local food. The results of the analysis of the carrying capacity of agricultural land in the peri-urban area of Surakarta City show the significant impact of land conversion due to urban sprawl in

Surakarta City on the ability of agricultural land to meet the food needs of its residents, as found by (Mayca & Sri, 2015) The city of Surakarta experienced a phenomenon in its suburbs, leading to an inevitable change in land use. The carrying capacity of good agricultural land will enable the community to fulfil its food needs. The calculation of the carrying capacity of agricultural land for food crops is conducted by considering aspects such as population, harvested land area, and food crop production. The research is also equipped with optimal population analysis to determine the population limit that can meet their food needs, considering the carrying capacity of the available agricultural land. An analysis of land needs for viability is also conducted to determine the land area required by each region, ensuring that the food needs of the population are met. Based on the results of the research, almost all villages in the peri-urban area of Surakarta City have a carrying capacity value of <1, which means that each village is not able to meet the food needs of its residents independently. Of the 100 villages studied, only 4 villages show a carrying capacity value greater than 1, namely Dayu (4.31), Rejosari (4.32), and Krendowahono (1.81), all of which are located in the northernmost part of Gondangrejo District. On the other hand, almost all villages in Grogol, Mojolaban, Baki, Jaten, Colomadu, and Ngemplak districts showed a value of $\sigma < 1$, even close to zero, such as Cemani Village (0.00), Baturan (0.00), and Klumprit (0.02), which means that the land carrying capacity is almost non-existent. This phenomenon is a concrete reflection of the massive conversion of agricultural land due to urbanisation pressures. These results indicate that the peri-urban area of Surakarta City lacks the capacity to meet the food needs, particularly rice, of its residents. The results of the study will be explained in more detail in each peri-urban zone. The distribution of the carrying capacity of agricultural land is presented in **Figure 4.**

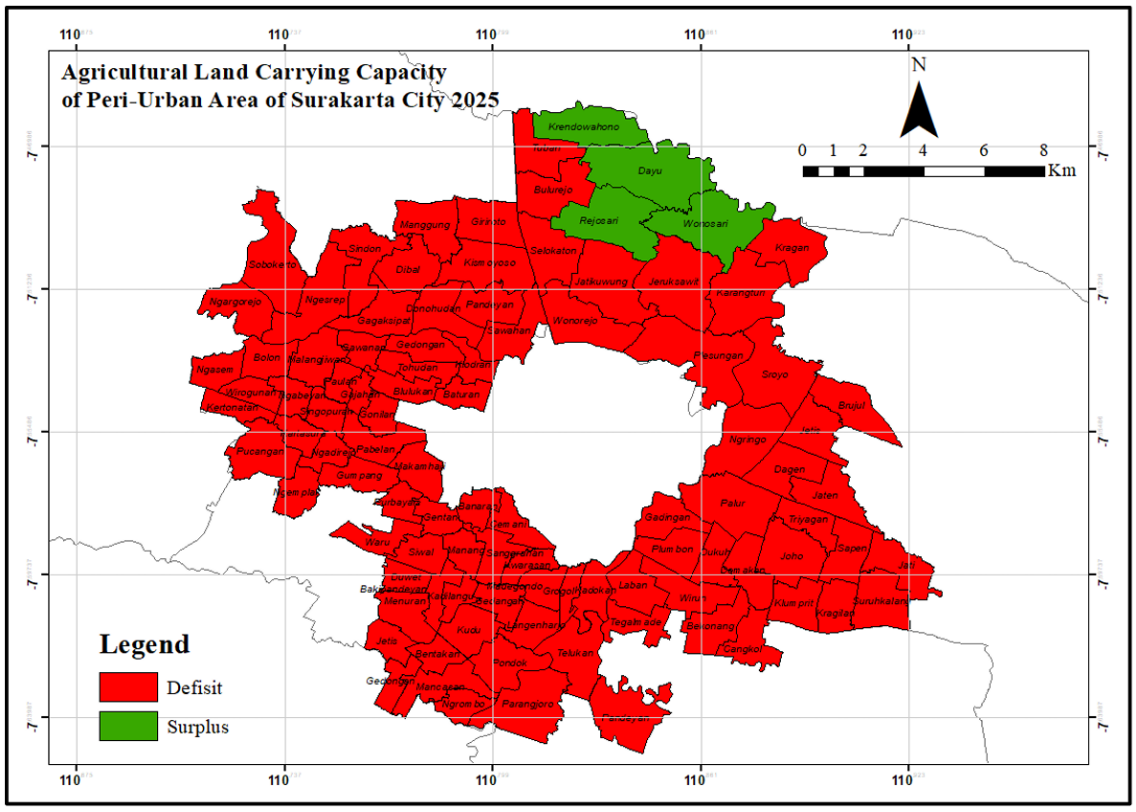

Figure 4. Distribution of Carrying Capacity of Agricultural Land in the Peri-Urban Area of Surakarta City

Source: Researcher Analysis, 2025

1. Peri-Urban Region of the Northern Zone

The northern zone includes Gondangrejo and Ngemplak Districts. As presented in **Table 1**, the Northern zone indicates that there are still areas with a surplus status, located in Gondangrejo District, specifically in a village at the northernmost end of the district, which is not directly adjacent to the city of Surakarta or areas with high industrial activity. As for Ngemplak District, all village areas are at a deficit level, meaning that the availability of agricultural land is currently insufficient to meet the food needs of the residents. The deficit status also indicates that the region is experiencing high population pressure on agricultural land. The value of the optimal population indicates that the area of agricultural land in Gondangrejo District, currently 1,250.94 hectares, is only sufficient to meet the food needs of 63. 043 people, or 74.75% of the current total population, necessitate an increase in the area of agricultural land of around 1673.57 hectares to meet the minimum

area required for food production to support the population's life expectancy. As for Ngemplak District, it currently only has an agricultural land area of 146.79 hectares, which can only meet the food needs of 7398 residents, or only 7.84% of the population in its area, so it requires the expansion of a minimum agricultural land area of 1872.21 hectares to meet the minimum food needs of the population in Ngemplak District.

Table 1. Carrying Capacity of Agricultural Land, Optimal Population, and Minimum Agricultural Land Needs in the Northern Zone

Village	Agricultural land (Ha)	Population	Carrying Capacity	Optimal Population (People)	Land Requirements	Status
Gondangrejo Subdistrict						
Karangturi	40.51	3573	0.57	2042	70.90	Defisit
Kragan	15.38	3739	0.21	775	74.19	Defisit
Krendowahono	153.00	4271	1.81	7711	84.75	Surplus
Jeruksawit	72.22	6162	0.59	3640	122.27	Defisit
Jatikuwung	98.69	7190	0.69	4974	142.67	Defisit
Rejosari	299.52	3498	4.32	15095	69.41	Surplus
Selokaton	20.29	9403	0.11	1023	186.58	Defisit
Plesungan	63.40	10317	0.31	3195	204.72	Defisit
Wonorejo	11.56	13447	0.04	583	266.82	Defisit
Wonosari	104.51	4243	1.24	5267	84.19	Surplus
Tuban	7.34	7857	0.05	370	155.90	Defisit
Bulurejo	37.53	6816	0.28	1891	135.25	Defisit
Dayu	326.98	3826	4.31	16479	75.92	Surplus
Total	**1250.94**	**84342**	**0.75**	**63043**	**1673.57**	**Defisit**
Ngemplak Subdistrict						
Kismoyoso	18.39	9831	0.09	926.64	195.07	Defisit
Sawahan	8.16	11904	0.03	411.44	236.21	Defisit
Manggung	8.81	7602	0.06	444.22	150.84	Defisit
Pandeyan	6.00	8751	0.03	302.41	173.64	Defisit
Ngesrep	19.74	7041	0.14	994.99	139.71	Defisit
Ngargorejo	37.78	3749	0.50	1903.77	75.28	Defisit
Sindon	4.43	5712	0.04	223.11	113.34	Defisit
Sobokerto	23.01	7583	0.15	1159.51	150.47	Defisit
Dibal	5.37	7133	0.04	270.83	141.54	Defisit
Donohudan	5.16	7982	0.03	260.11	158.38	Defisit
Gagaksipat	5.76	10181	0.03	290.39	202.02	Defisit
Giriroto	4.17	6839	0.03	210.18	135.70	Defisit
Total	**146.79**	**94353**	**0.08**	**7398**	**1872.21**	**Defisit**

Source: Data Analysis, 2025

2. Peri-Urban Region of the Eastern Zone

The eastern zone of the peri-urban area of Surakarta City includes Jaten and Mojolaban districts, located in Karanganyar Regency and Sukoharjo Regency. In the Eastern Zone, as presented in **Table 2,** the results

indicate that the carrying capacity of agricultural land in this region is experiencing a food deficit, meaning that the entire area relies on an external food supply. Mojolaban District has the highest carrying value of agricultural land, at 0.25, in Tegalmade Village, and the lowest value, at 0.13, in Bekonang Village. The optimal population value for the Mojolaban District is 3541 people, which can only meet 4.52% of its current total population. The minimum agricultural land that the Mojolaban District must own to support the food self-sufficiency of its population is 1,554.37 hectares.

Table 2. Carrying Capacity of Agricultural Land, Optimal Population, and Minimum Agricultural Land Needs in the Eastern Zone

Village	Agricultural land (Ha)	Population	Carrying Capacity	Optimal Population (People)	Land Requirements	Status
Mojolaban Subdistrict						
Laban	15.77	5401	0.15	794.70	107.17	Defisit
Klumprit	2.42	5417	0.02	121.97	107.49	Defisit
Kragilan	3.05	3655	0.04	153.49	72.52	Defisit
Joho	2.45	7886	0.02	123.31	156.48	Defisit
Plumbon	3.29	5609	0.03	165.75	111.30	Defisit
Sapen	3.59	5109	0.04	180.79	101.38	Defisit
Palur	8.03	14902	0.03	404.46	295.69	Defisit
Wirun	2.45	7900	0.02	123.70	156.76	Defisit
Tegalmade	11.01	2234	0.25	554.98	44.33	Defisit
Triyagan	3.53	5721	0.03	177.70	113.52	Defisit
Dukuh	2.80	4578	0.03	141.04	90.84	Defisit
Gadingan	4.79	6692	0.04	241.29	132.79	Defisit
Demakan	3.20	5732	0.03	161.29	113.74	Defisit
Cangkol	2.39	6061	0.02	120.68	120.27	Defisit
Bekonang	1.51	5911	0.01	76.20	117.29	Defisit
Total	**70.27**	**78335**	**0.05**	**3541**	**1554.37**	**Defisit**
Jaten Subditrict						
Jaten	5.38	15280	0.02	271	303.20	Defisit
Jati	3.72	8371	0.02	187	166.10	Defisit
Jetis	4.30	5662	0.04	216	112.35	Defisit
Ngringo	14.04	24551	0.03	708	487.16	Defisit
Sroyo	8.08	10343	0.04	407	205.23	Defisit
Suruhkalang	3.33	5613	0.03	168	111.38	Defisit
Dagen	3.26	5784	0.03	165	114.77	Defisit
Brujul	2.49	6408	0.02	125	127.15	Defisit
Total	**44.60**	**82012**	**0.03**	**2248**	**1627.33**	**Defisit**

Source: Data Analysis, 2025

Jaten District is one of the peri-urban areas of Surakarta City, characterised by high industrial and trade activities. Currently, the area of agricultural land in Jaten District is only 44.60 hectares, with an optimal population that can accommodate food needs of only 2,248 people, or approximately 2.74% of the

total population. Jaten District has a general Land Carrying Capacity value of 0.03, with the highest value of 0.04, namely Jetis and Sroyo Villages. Even for the highest niali, the carrying capacity of agricultural land in Jaten District is still at the lowest level compared to other sub-districts.

3. Peri-Urban Region of the Southern Zone

The South Zone is the zone with the highest land conversion, considering the direction of development in Surakarta City, which tends to move south. This zone comprises Grogol and Baki Districts, which are renowned as industrial and commercial centres in Sukoharjo Regency (Kurnianingsih, Pratami, & Putri, 2021; Marfu'ah et al., 2024; Permatasari & Pradoto, 2019). As industrial and commercial centres, these two sub-districts are both located in the food deficit, as can be seen in **Table 3**, with a land carrying value of less than 1 (< 1).

Grogol District has an average carrying value of agricultural land of 0.03, with the highest value, namely Kadokan Village, of 0.15, and Baki District far with an average of 0.02, and the highest value of 0.03, lower than Jaten District. The current area of agricultural land in Grogol District is only 73.64 hectares and is only able to meet the needs of 3711 residents. At the same time, the population has currently reached 121,584 people, or only 3.05% with the minimum agricultural land needs that must be owned to meet the minimum needs of a decent life being 2412.55 hectares. As for Baki District, it only has an area of 26.31 hectares of agricultural land, which is only able to meet the food needs of 1.84% of the population, or 1326 people out of 72147 people today. This condition shows that the Southern Zone is the area with the highest dependence on external food supply in the peri-urban area of Surakarta City.

Table 3. Carrying Capacity of Agricultural Land, Optimal Population, and Minimum Agricultural Land Needs in the Southern Zone

Village	Agricultural land (Ha)	Population	Carrying Capacity	Optimal Population (People)	Land Requirements	Status
Grogol Subdistrict						
Banaran	1.27	8225	0.01	64	163.21	Defisit
Madegondo	1.19	8832	0.01	60	175.25	Defisit
Manang	1.33	6737	0.01	67	133.68	Defisit
Kwarasan	1.85	7301	0.01	93	144.87	Defisit
Langenharjo	2.79	8277	0.02	141	164.24	Defisit
Grogol	1.78	5338	0.02	90	105.92	Defisit
Kadokan	17.22	5651	0.15	868	112.13	Defisit
Pondok	5.37	8346	0.03	271	165.61	Defisit
Sanggrahan	1.50	12726	0.01	76	252.52	Defisit
Pandeyan	12.12	5380	0.11	611	106.75	Defisit
Parangjoro	5.17	5367	0.05	261	106.50	Defisit
Telukam	17.84	12132	0.07	899	240.73	Defisit
Cemani	1.30	20777	0.00	65	412.27	Defisit
Gedangan	2.90	6495	0.02	146	128.88	Defisit
Total	**73.64**	**121584**	**0.03**	**3711**	**2412.55**	**Defisit**
Baki Subdistrict						
Bentakan	1.06	2936	0.02	53	58.26	Defisit
Kudu	1.35	4334	0.02	68	86.00	Defisit
Mancasan	4.33	6638	0.03	218	131.72	Defisit
Jetis	1.81	5290	0.02	91	104.97	Defisit
Kadilangu	0.42	3165	0.01	21	62.80	Defisit
Purbayan	1.34	7731	0.01	68	153.40	Defisit
Menuran	3.18	5957	0.03	160	118.20	Defisit
Ngrombo	2.98	3247	0.05	150	64.43	Defisit
Waru	3.25	6970	0.02	164	138.30	Defisit
Siwal	1.34	4918	0.01	68	97.59	Defisit
Gedongan	2.02	3569	0.03	102	70.82	Defisit
Gentan	1.22	9448	0.01	61	187.47	Defisit
Duwet	0.88	3915	0.01	44	77.68	Defisit
Bakipandeyan	1.13	4029	0.01	57	79.95	Defisit
Total	**26.31**	**72147**	**0.02**	**1326**	**1431.59**	**Defisit**

Source: Data Analysis, 2025

4. Peri-Urban Region of the Western Zone

Based on **Table 4,** the Western Zone includes Kartasura and Colomadu Districts in Sukoharjo Regency and Karanganyar Regency. Colomadu District has an agricultural land area of 41.18 hectares with a carrying value of agricultural land of 0.03. The highest score of 0.10 is in Ngasem Village. Kartasura District has a village with the lowest carrying value of agricultural land compared to other peri-urban areas, which is 0.00 in Banaran Village. The current area of agricultural land is only able to meet the needs of 2,075 people out of the total population of 68,663. Meanwhile, Kartasura District has an

agricultural land area of 44.60 hectares with a population of 111,207 people, resulting in a carrying capacity of agricultural land of only 0.02, which is lower than the carrying capacity of agricultural land in other Sukoharjo Regency areas. The land needed to meet the food needs of the residents in the Kartasura District is 2206.4 hectares.

Table 4. Carrying Capacity of Agricultural Land, Optimal Population, and Minimum Agricultural Land Needs in the Western Zone

Village	Agricultural land (Ha)	Population	Carrying Capacity	Optimal Population (People)	Land Requirements	Status
Colomadu Subdistrict						
Blulukan	4.08	6088	0.03	206	120.80	Defisit
Bolon	12.16	7459	0.08	613	148.01	Defisit
Baturan	0.39	8173	0.00	20	162.17	Defisit
Malangjiwan	4.13	10683	0.02	208	211.98	Defisit
Klodran	1.93	5305	0.02	97	105.27	Defisit
Ngasem	9.86	5232	0.10	497	103.82	Defisit
Paulan	0.93	3281	0.01	47	65.10	Defisit
Tahoudan	0.58	5790	0.03	29	114.89	Defisit
Gedongan	4.42	8066	0.01	223	160.05	Defisit
Gajahan	0.51	2132	0.01	26	42.30	Defisit
Gawanan	2.18	6454	0.02	110	128.06	Defisit
Total	**41.18**	**68663**	**0.03**	**2075**	**1362.45**	**Defisit**
Kartasura Subdistrict						
Kartasura	2.07	15158	0.01	104.26	30.77	Defisit
Gonilan	1.16	6782	0.01	58.32	134.57	Defisit
Gumpang	1.76	11486	0.01	88.56	227.91	Defisit
Pucangan	11.37	14499	0.04	573.18	287.70	Defisit
Ngemplak	2.97	4848	0.03	149.73	96.20	Defisit
Ngabeyan	0.98	5839	0.01	49.56	115.86	Defisit
Ngadirejo	3.00	10719	0.01	151.04	212.69	Defisit
Pabelan	3.89	7907	0.02	196.07	156.90	Defisit
Wirogunan	1.87	5078	0.02	94.30	100.76	Defisit
Singopuran	1.62	7407	0.01	81.84	146.97	Defisit
Total	**36.1267**	**111207**	**0.02**	**1821**	**2206.64**	**Defisit**

Source: Data Analysis, 2025

The carrying capacity of agricultural land in the suburbs of Surakarta City is significantly influenced by urbanisation and changes in land use. Along with significant urban development, the availability of agricultural land has been converted into built-up land, increasing population pressure on the carrying capacity of agricultural land (Harini et al., 2025). The conversion of agricultural land to residential and commercial use has resulted in a decline in available agricultural land, thereby impacting food production capacity. According to Feni Mardila Putri, Hamdi Nur, and Rini Asmariati (2019), the carrying capacity

of agricultural land is directly threatened by population growth; if the area of agricultural land and its productivity do not increase, then the ability of the land to support the population will decrease, thus threatening food security in suburban areas. The findings are also supported (Arsianti, Astuti, Candraningtyas, & Primabudi, 2024) that the larger the population, the greater the demand for land, which can exceed the available carrying capacity. According to (Mubarokah et al., 2020), There is a variation in the level of land carrying capacity and influencing factors, caused by differences in aspects of population, natural resources, and their management. Controlling the rate of population growth is a concrete step to

increase food security in peripheral areas, as found by Setyati, Yusran, Asmu'i, & Priatmadi (2021), who found that suppressing the population growth rate can overcome the food crisis. The results of the study indicate that the entire peri-urban area of Surakarta City is highly reliant on food supplies from outside. This condition indicates that efforts to achieve food self-sufficiency in the suburbs of Surakarta City present a new challenge that requires attention.

CONCLUSIONS

The peri-urban area of Surakarta City faces significant challenges in achieving food security due to the pressure of urbanisation and extensive land conversion. The analysis reveals that nearly all regions face a deficit in the carrying capacity of agricultural land, with only a small number of villages in Gondangrejo able to meet their food needs independently. This condition reflects a high dependence on food supplies from outside and the potential for increased food vulnerability in the future. Therefore, a spatial strategy that integrates agricultural land protection, increased productivity, and population growth control is needed to maintain a balance between population needs and land capacity in supporting sustainable food security in the peri-urban area of Surakarta City. The results of this study offer critical insights for regional spatial planning and the reinforcement of peri-urban food security. Local authorities must strengthen the protection of extant agricultural zones through stringent zoning ordinances and sustainable land-use policies, coupled with strategic population management and controlled urban growth. Despite these contributions, the scope of this research

was constrained by its singular focus on rice and the reliance on medium-resolution satellite data. Consequently, future inquiries should adopt a multi-commodity framework and utilise high-resolution spatial datasets alongside dynamic modelling to more accurately project the evolving food security landscape in peri-urban environments.

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REFERENCES

Abu Hatab, A., Cavinato, M. E. R., Lindemer, A., & Lagerkvist, C. J. (2019a). Urban sprawl, food security and agricultural systems in developing countries: A systematic review of the literature. *Cities*, *94*(July 2018), 129–142. https://doi.org/10.1016/j.cities.2019.06.001

Abu Hatab, A., Cavinato, M. E. R., Lindemer, A., & Lagerkvist, C. J. (2019b). Urban sprawl, food security and agricultural systems in developing countries: A systematic review of the literature. *Cities*, *94*(May), 129–142. https://doi.org/10.1016/j.cities.2019.06.001

Aini, A. N., Putri, R. A., & Istanabi, T. (2022). Kajian Pola Persebaran Permukiman Di Kecamatan Kartasura Kabupaten Sukoharjo. *Desa-Kota*, *4*(2), 241. https://doi.org/10.20961/desa-kota.v4i2.63661.241-257

Arsianti, A., Astuti, W., Candraningtyas, C. F., & Primabudi, E. (2024). Jurnal Presipitasi Developing Causal Loop Diagram for Urban Development and Land Carrying Capacity in Surakarta. *Jurnal Presipitasi Media*, *21*(3), 879–893. https://doi.org/10.14710/presipitasi.v21i3.879-893

ASEAN. (2022). *Urbanisation, people mobility, and inclusive development across urban-rural continuum in asean*.

Ayun, Q., Kurniawan, S., & Saputro, W. A. (2020). Perkembangan Konversi Lahan Pertanian Di Bagian Negara Agraris. *Vigor: Jurnal Ilmu Pertanian Tropika Dan Subtropika*, *5*(2), 38–44. https://doi.org/10.31002/vigor.v5i2.3040

Basheer, S., Wang, X., Farooque, A. A., Nawaz, R. A., Liu, K., Adekanmbi, T., & Liu, S. (2022). Comparison of Land Use Land Cover Classifiers Using Different Satellite Imagery and Machine Learning Techniques. *Remote Sensing*, *14*(19), 1–18. https://doi.org/10.3390/rs14194978

Bhat, P. A., Shafiq, M. ul, Mir, A. A., & Ahmed, P. (2017). Urban sprawl and its impact on landuse/land cover dynamics of Dehradun City, India. *International Journal of Sustainable Built Environment*, *6*(2), 513–521.

https://doi.org/10.1016/j.ijsbe.2017.10.003

Buchori, I., Pangi, P., Pramitasari, A., Basuki, Y., & Wahyu Sejati, A. (2020). Urban Expansion and Welfare Change in a Medium-sized Suburban City: Surakarta, Indonesia. *Environment and Urbanization ASIA*, *11*(1), 78–101. https://doi.org/10.1177/0975425320909922

Dewi, R. K., & Rita Noviani, N. (2024). Typology of rural transformation in Grogol, Sukoharjo 2009-2022. *IOP Conference Series: Earth and Environmental Science*, *1314*(1). https://doi.org/10.1088/1755-1315/1314/1/012009

Fadlli, Y. I., Soedwiwahjono, & Hardiana, A. (2016). Faktor yang Mempengaruhi Konversi Lahan Pertanian Studi Kasus : Kecamatan Jaten , Kabupaten Karanganyar. *Arsitetkura*, *4*(1). https://doi.org/10.20961/arst.v14i1.9220

Feni Mardila Putri, Hamdi Nur, & Rini Asmariati. (2019). Kajian Spasial Tekanan Penduduk Terhadap Lahan Sawah Di Kota Pariaman. *Jurnal Rekayasa*, *9*(1), 31–47. https://doi.org/10.37037/jrftsp.v9i1.33

Fu, Q., Xu, L., Zheng, H., & Chen, J. (2019). Spatiotemporal dynamics of carbon storage in response to urbanization: A case study in the Su-Xi-Chang region, China. *Processes*, *7*(11), 0–18. https://doi.org/10.3390/pr7110836

Hana, Z. A., & Pujiati, A. (2023). The Influence of Urbanization on Environmental, Economic, and Social Performance. *Journal of Economic Education*, *12*(1), 42–54. https://doi.org/10.15294/jeec.v12i1.71485

Harini, R., Ariani, R. D., Kuncoro, A. B., Buana, A. S., & Nuari, I. (2025). Impact of Land Conversion on Agricultural Carrying Capacity and Sustainable Food Agricultural Land in Sleman Regency. *Jurnal Geografi*, *17*(1), 15–31. Retrieved from https://doi.org/10.24114/jg.v17i1.57795

Kumalasari, D., Sarwono, & Noviani, R. (2023). Analisis Dampak Alih Fungsi Lahan Pertanian Ke Non Pertanian Terhadap Ketahanan Pangan Di Kecamatan Gondangrejo Kabupaten Karanganyar Tahun 2011-2020. *Indonesian Journal of Environment and Disasater (IJED)*, *02*(01), 68–75. https://doi.org/10.20961/ijed.v2i1.702

Kurnianingsih, N. A., Pratami, M., & Putri, M. B. (2021). Karakteristik Pertumbuhan Penduduk Perdesaan pada Perkembangan Wilayah Peri-urban di Perbatasan Kota Surakarta. *Journal of Science and Applicative Technology*, *5*(1), 138. https://doi.org/10.35472/jsat.v5i1.420

Kusumastuti, K. (2017). Proses Dan Bentuk "Mewujudnya" Kota Solo Berdasarkan Teori City Shaped Spiro Kostof. *Region: Jurnal Pembangunan Wilayah Dan Perencanaan Partisipatif*, *7*(1), 33. https://doi.org/10.20961/region.v7i1.5782

Marfu'ah, I. N., Noviani, R., Wijayanti, P., & Susilawati, S. A. (2024). Analysis of Urban Form Dynamics in The Suburbs of Surakarta City. *Geosfera Indonesia*, *9*(2), 157–

175. https://doi.org/10.19184/geosi.v9i2.44499

Mayca, S. N., & Sri, R. G. (2015). Analisis Fragmentasi Spasial Berbasis Citra Multitemporal Untuk Mengidentifikasi Fenomena Urban Sprawl Di Surakarta, 1–10.

Mubarokah, N., Rachman, L. M., & Tarigan, S. D. (2020). Analysis of Carriying Capacity of Crop Agricultural Land in Cibaliung Watershed, Banten Province. *Jurnal Ilmu Pertanian Indonesia*, *25*(1), 73–80. https://doi.org/10.18343/jipi.25.1.73

Noviani, R., Ahmad, & Marfu'ah, I. N. (2024). Spatial patterns analysis of land use changes using spatial metrics in the peri-urban area of Surakarta City 2023. *IOP Conference Series: Earth and Environmental Science*, *1314*(1). https://doi.org/10.1088/1755-1315/1314/1/012089

Noviani, R., Ahmad, Sarwono, Sugiyanto, & Prihadi, S. (2022). Urbanization rate in SUBOSUKAWONOSRATEN. *IOP Conference Series: Earth and Environmental Science*, *986*(1). https://doi.org/10.1088/1755-1315/986/1/012073

Noviani, R., Muryani, C., Ahmad, Sarwono, Sugiyanto, & Prihadi, S. (2023). Modelling of urban growth based on a Geographic Information System (GIS) and cellular automata at Sukoharjo Regency in 2032. *IOP Conference Series: Earth and Environmental Science*, *1190*(1). https://doi.org/10.1088/1755-1315/1190/1/012042

Noviani, R., Muta'ali, L., & Nasruddin, N. (2018). Facing Solo Raya Metropolitan City: Analysis of the Development Planning. *GeoEco*, *4*(2), 152. https://doi.org/10.20961/ge.v4i2.22508

Noviani, R., Utomowati, R., Saputra, A. E., & Marfu'ah, I. N. (2022). Predictions of Food Security Based on Land Requirements in Sukoharjo Regency in 2032, *9*(Smbpsb), 356–363. https://dx.doi.org/10.20961/shes.v5i4.68980

Permatasari, D., & Pradoto, W. (2019). Analisis Perkembangan Kecamatan Colomadu Dan Kecamatan Grogol Sebagai Pklp Dan Wpu Surakarta Berdasarkan Faktor Internal. *Jurnal Pengembangan Kota*, *7*(2), 172–180. https://doi.org/10.14710/jpk.7.2.172-180

Purhartanto, L. N., Danoedoro, P., & Wicaksono, P. (2020). Kajian Transformasi Indeks Vegetasi Citra Satelit Sentinel-2A untuk Estimasi Produksi Daun Kayu Putih Menggunakan Linear Spectral Mixture Analysis. *Jurnal Nasional Teknologi Terapan (JNTT)*, *3*(1), 63. https://doi.org/10.22146/jntt.56618

Putri, D. R., Sukmono, A., & Sudarsono, B. (2018). Analisis Kombinasi Citra Sentinel-1a Dan Citra Sentinel-2a Untuk Klasifikasi Tutupan Lahan (Studi Kasus: Kabupaten Demak, Jawa Tengah). *Jurnal Geodesi Undip*, *7*(2), 85–96. https://doi.org/10.14710/jgundip.2018.20660

Rahman, A. (2023). Laju urbanisasi dan pertumbuhan kota di Indonesia.

Jurnal Predestination, *5*(1), 60–73. https://doi.org/10.26858/prd.v5i1.53039

Rizal, M., Pamungkas, F., & Sejati, A. W. (2024). Urban Growth and Clustering Surakarta Peri-Urban Area, *9*(1), 42–53. https://doi.org/10.14710/ijpd.9.1.42-53.

Rwanga, S. S., & Ndambuki, J. M. (2017). Accuracy Assessment of Land Use/Land Cover Classification Using Remote Sensing and GIS. *International Journal of Geosciences*, *08*(04), 611–622. https://doi.org/10.4236/ijg.2017.84033

Sakketa, T. G. (2022). *Urbanisation and rural development in developing countriesA review of pathways and impacts*. *German Development Institute*. Retrieved from https://doi.org/10.23661/dp5.2022

Saputra, A. E., Nugraha, S., & Noviani, R. (2023). Analysis of Urbanisation's Relationship with Clean Water Supply Ecosystem Services in Sukoharjo Regency, Indonesia. *Forum Geografi*, *37*(2), 178–190. https://doi.org/10.23917/forgeo.v37i2.21218

Sarastika, T., & Anggrasari, H. (2024). Analisis Daya Dukung Lahan Pertanian Sebagai Upaya Mendukung Ketersediaan Pangan Di Kawasan Sleman Tengah. *Jurnal Tanah Dan Sumberdaya Lahan*, *11*(2), 413–421. https://doi.org/10.21776/ub.jtsl.2024.011.2.12

Selang, M. A., Iskandar, D. A., & Widodo, R. (2018). Tingkat Perkembangan Urbanisasi Spasial Di Pinggiran Kpy (Kawasan Perkotaan Yogyakarta) Tahun 2012-2016. *Kota Layak Huni "Urbanisasi Dan Pengembangan Perkotaan*, 32–40.

Sugestiadi, M. I., & Basuki, Y. (2020). Pengaruh Interaksi Spasial Antara Kota Surakarta Dengan Kawasan Perkotaan Sekitarnya Terhadap Pertumbuhan Perkotaan. *Jurnal Pembangunan Wilayah Dan Kota*, *16*(3), 173–186. https://doi.org/10.14710/pwk.v16i3.21948

Taufiq, M., & Kombaitan, B. (2019). Urban Area Entities in Affecting Regional Development: A Case Study for Mebidangro. *Jurnal Wilayah Dan Lingkungan*, *7*(3), 153–165. https://doi.org/10.14710/jwl.7.3.153-165

Wibowo, C. S. (2015). DAMPAK PENGALIHAN FUNGSI LAHAN SAWAH PADA PRODUKSI PADI SAMPAI TAHUN 2018 DAN IMPLIKASINYA TERHADAP KETAHANAN PANGAN WILAYAH (Studi di Kecamatan Jaten Kabupaten Karanganyar Propinsi Jawa Tengah). *Jurnal Ketahanan Nasional*, *21*(2), 107. https://doi.org/10.22146/jkn.10154

Wilonoyudho, S., Rijanta, R., Keban, Y. T., & Setiawan, B. (2017). Urbanization and regional imbalances in Indonesia. *Indonesian Journal of Geography*, *49*(2), 125–132. https://doi.org/10.22146/ijg.13039

Zhao, Z., Islam, F., Waseem, L. A., Tariq, A., Nawaz, M., Islam, I. U., … Hatamleh, W. A. (2024). Comparison of Three Machine Learning Algorithms Using Google Earth Engine for Land Use

Land Cover Classification. *Rangeland Ecology and Management*, *92*, 129–137. https://doi.org/10.1016/j.rama.2023.10.007