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Integrating ecological footprint in spatial planning: assessing land use, food security, and sustainability in Indonesia

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ABSTRACT

Background: Rapid urbanization and population growth in Indonesia have placed immense pressure on land resources and biodiversity, with spatial planning policies often failing to adequately incorporate ecological footprint considerations. This study aims to assess the impact of Indonesia's regional spatial plans on sustainable land use, food security, and biodiversity preservation by examining how these plans account for agricultural needs and ecological carrying capacity. Previous studies have highlighted the importance of ecological footprint management in supporting sustainable development, but few have addressed its application within the Indonesian spatial planning context. **Methods**: A mixed-methods approach was utilized, combining quantitative data analysis of land allocation and agricultural productivity data from the Indonesian Central Bureau of Statistics with a qualitative review of policies, including the Law on Job Creation and strategic spatial planning documents. These data were analyzed to determine the relationship between land-use allocation and ecological sustainability, particularly focusing on urban areas such as Jabodetabek. **Findings:** Results indicate that over 50% of regional spatial plans allocate insufficient land for agriculture, contributing to reduced biodiversity, elevated carbon emissions from transportation, and increased vulnerability in food security, as exemplified by the low agricultural allocation in urban agglomerations. The study also finds that existing policies favor residential and industrial land use, which intensifies pressure on agricultural land and undermines the potential for regional self-sufficiency. **Conclusion**: The study underscores the need for spatial planning policies in Indonesia to incorporate ecological footprint assessments to better support sustainable development and food security goals. **Novelty/Originality of this article:** This research introduces an ecological footprint perspective to spatial planning in Indonesia, providing a unique model for integrating sustainability considerations into land-use policy. It offers innovative insights into balancing urban growth with ecological sustainability in the Indonesian context, an approach that has been largely unexplored in previous studies.

KEYWORDS: ecological footprint; spatial planning; sustainable development.

1. Introduction

Human interaction with the environment to meet their needs has led to the extinction of at least 50% of species since the discovery of fire approximately 800,000 years ago (Harari, 2011). Since that time, human needs have continued to rise, culminating in 2019 when humans required at least 1.5 to as much as 5 times the Earth's capacity to meet daily needs (Almond et al., 2020; Sack, 1983). As noted, since 1972, awareness of the interplay between human needs and the environment has steadily increased, driven by eight global

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conferences and the emergence of various national and international policies regarding environmental issues. Nevertheless, by 2020, approximately 70% of terrestrial biodiversity and 50% of marine biodiversity were still facing extinction due to human needs (Świądera et al., 2020; Almond et al., 2020; Van den Bergh, 1999).

In response to human needs, 169 indicators were derived from the concept of sustainable development (since 1987); however, half of the countries worldwide possess less than 67% of the valid data required (United Nations, 2019; 2020; 2021). On the other hand, the ecological footprint (since 1990) illustrates how human habits significantly impact land use necessary to fulfill daily requirements. Although both concepts provide insight into the extent of the gap between the ideal state and the current reality, neither directly identifies the planning areas that require improvement to achieve sustainable development, nor how existing development affects human culture and influences the surrounding environment.

Since 2020, Indonesia, recognized as one of the world's lungs with a population of 270 million (Badan Pusat Statistik, 2020), has implemented digital business licensing through the Single Online Submission (OSS) application. In this framework, every permit issued is directly verified if a Detailed Spatial Plan (RDTR) exists or requires approval when only a Regional Spatial Plan (RTRW) is available (Law No. 11 on Job Creation, 2020). To enhance economic development, the Indonesian government has proposed the creation of 2,000 RDTRs, requiring that a ministry establishes an RDTR within no more than 20 days from the cross-sectoral meeting. Given the brief timeframe for revisions until the Spatial Plan Draft is approved, a spatial-based model is needed to evaluate and promptly indicate which areas require improvement or preservation to ensure food security, land availability, energy, clean water, and ecology can meet future human needs.

2. Methods

This research employs a mixed-methods approach, combining quantitative and qualitative data collection and analysis to evaluate spatial plans and the ecological footprint of regional and urban areas in Indonesia. First, a quantitative analysis is conducted using secondary data from the Badan Pusat Statistik (BPS) and spatial planning documents, including national strategic area spatial plans (RTR KSN) and regional spatial plans (RTRW) at the kabupaten/city level. Data on land allocation for forest, agriculture, industry, residential areas, and green open spaces in each region, such as Jabodetabek and across provinces, provides a baseline for understanding spatial distribution and urban expansion patterns. Additionally, the study includes analysis of biodiversity indicators, per capita ecological footprint, and population growth trends to assess the environmental implications of current spatial plans and policy decisions.

The qualitative aspect of the research involves a review of relevant policy documents, including the Law on Job Creation (2020) and spatial planning regulations (Kepmen ATR/BPN 399, 2018; Perpres 59, 2019). By evaluating these policies, the study explores the extent to which the ecological footprint and carrying capacity are considered within current land use and resource management practices. Comparisons with sustainable planning frameworks, such as those suggested by Lynch (1960) and Hardin’s concept of the "Tragedy of the Commons" (1968), offer insights into potential gaps in Indonesia’s spatial planning approach. Through these methods, the research aims to propose a model that can guide policy improvements for sustainable land use, food security, and ecological preservation to support the growing population's needs in a balanced and resilient manner.

3. Results and Discussion

The ecological footprint is a concept used to measure the impact of human activities on the amount of resources consumed by individuals within a specific area (Van den Bergh, 1999). Calculations can encompass aspects such as food, land use, fisheries, energy, water,

and carbon emissions, expressed in hectares to represent the ecological value per person (Świądera et al., 2020).

In 2020, the ecological footprint per capita was 2.5 hectares, which is 0.9 hectares above the Earth's maximum sustainable capacity, resulting in the loss of at least 70% of terrestrial biodiversity and 50% of marine biodiversity, primarily due to food production for human needs (Almond et al., 2020). The reduction in biodiversity can negatively impact the sustainability of ecosystems, which includes humans themselves.

A common approach to evaluating the ecological footprint involves examining carrying capacity and resilience in a region. The carrying capacity of an area depends heavily on the volume of resources produced and the size of the population utilizing those resources. The calculations of carrying capacity are influenced by the specific phenomenon being assessed. For instance, in the "Tragedy of the Commons," humans attempt to exploit freely available natural resources without considering the environment's inherent limits (Hardin, 1968). Ensuring resource sustainability necessitates policies that account for continuity, harmony, justice, and accessibility, both in terms of area and the distances required for resource distribution. One policy instrument that can be utilized is the Spatial Plan.

In Indonesia, the Spatial Plan serves as a legal framework divided into three processes: planning, utilization, and spatial control (Law No. 11 on Job Creation, 2020). According to Gosling (1992) and Southworth (1985) in Shipley (2002), spatial planning is a tool that assists planners in envisioning future development while considering various elements, such as routes, angles, centers, districts, and points of interest (Lynch, 1960), all of which are inherently linked to urban growth centers or city centers (Christaller, 1955).

Current urban spatial planning models must extend beyond mere considerations of resilience, sustainability, and multifunctionality. Reducing ecological footprints can serve as an effective means to enhance ecological resource efficiency in pursuit of sustainable urban development (Long, 2020). Population size, green technology, social participation, and economic attitudes are key factors influencing the ecological index (Fatemi, 2021).

Although various studies have emphasized sustainability aspects, the application of the ecological footprint concept in Indonesia appears to be inadequately considered, particularly in policy-making, such as spatial planning. This is evident in several policies, such as the procurement of raw materials for infrastructure or energy sources, which often fail to take into account the diversity and strengths of each province in Indonesia.

Policy measures like the Food Estate initiative, which focuses on developing only one region (Central Kalimantan) as a food supplier, exemplify a lack of consideration for distance or the costs associated with food distribution, which also contributes to high emissions during transportation. Additionally, this policy is vulnerable to national food security, as a disaster in the designated area could lead to a food crisis across Indonesia.

The National Strategic Area Spatial Plan (RTR KSN) and urban agglomeration areas similarly reflect planning that neglects ecological footprint factors. For instance, in Jabodetabek, agricultural allocations are below 3%, while residential areas occupy over 75% of the total land area. This indicates a lack of concern among local governments regarding how to sustain the food needs of their residents (see Table 1).

Table 1. Classification of regional spatial plans in Jabodetabek in hectares

District/City	Tangerang City	South Tangerang City	Bekasi City	Bogor City	Depok City
Forest	0	0	0	109.29	558.78
	0.00%	0.00%	0.00%	1.00%	2.90%
Agriculture	114.28	0	0	239.04	508.39
	0.70%	0.00%	0.00%	2.20%	2.70%
Industry	3,309.75	261.26	1,268.03	190.53	342.82
	18.80%	1.60%	6.20%	1.70%	1.80%
Settlement	13,334.27	14,984.66	18,899.47	10,040.66	16,050.08
	75.90%	94.20%	92.60%	91.10%	84.70%
Green Open Space	680.83	446.26	99.4	346.93	1,253.47

	3.90%	2.80%	0.50%	3.10%	6.60%
Others	127.14	207.88	144.23	95.79	235.23
	0.70%	1.30%	0.70%	0.90%	1.20%
Total Area	17,566.28	15,900.06	20,411.13	11,022.23	18,948.78

These planning deficiencies are not isolated to national strategic area policies but are also apparent in nearly all regional spatial plans (RTRW) at the kabupaten/city level across Indonesia. Nationally, agricultural planning accounts for only 16.45% or 28.31 million hectares (see Table 2) designated as agricultural areas. Of this, only 7.1 million hectares are classified as protected sustainable wetland agriculture (LP2B) (Kepmen ATR/BPN 399, 2018; Perpres 59, 2019). This figure underscores the government's commitment—both regional and national—to preserving and managing agricultural land.

Table 2. Area of agricultural and settlement zones in regional spatial plans at the kabupaten/city level per province in hectares

Island	Province	Agriculture	Percentage	Settlement	Percentage
Sumatera	Aceh	794.456,97	12,71%	150.569,85	2,41%
Sumatera	Bengkulu	213.634,58	9,93%	135.810,88	6,31%
Sumatera	Jambi	844.602,23	17,53%	154.702,51	3,21%
Sumatera	Bangka Belitung Islands	221.258,84	14,62%	115.075,71	7,61%
Sumatera	Riau Island	101.795,25	13,91%	97.711,02	13,36%
Sumatera	Lampung	1.065.801,50	29,09%	247.267,11	6,75%
Sumatera	West Sumatera	716.559,64	12,11%	160.654,36	2,72%
Sumatera	South Sumatera	2.909.364,72	30,82%	391.343,04	4,15%
Sumatera	North Sumatera	1.076.311,86	18,80%	169.026,69	2,95%
Java Bali	Bali	230.523,93	41,04%	65.231,24	11,61%
Java Bali	Banten	297.203,74	31,22%	200.646,50	21,08%
Java Bali	Special Region of Yogyakarta	107.069,28	34,23%	98.855,51	31,61%
Java Bali	DKI Jakarta	169,13	0,24%	54.955,61	78,04%
Java Bali	West Java	1.250.144,45	33,16%	632.990,58	16,79%
Java Bali	Jawa Tengah	1.254.499,29	36,29%	681.325,44	19,71%
Java Bali	East Java	1.684.777,81	36,60%	836.225,98	18,17%
Kalimantan	West Kalimantan	4.113.424,05	27,88%	436.794,33	2,96%
Kalimantan	South Kalimantan	617.499,86	16,69%	281.947,75	7,62%
Kalimantan	Center Kalimantan	446.503,65	5,45%	236.858,62	2,89%
Kalimantan	East Kalimantan	1.624.197,56	11,21%	273.598,36	1,89%
Kalimantan	North Kalimantan	507.328,22	6,88%	118.599,83	1,61%
Nusa Tenggara	West Nusa Tenggara	603.002,28	30,13%	35.612,13	1,78%
Nusa Tenggara	East Nusa Tenggara	1.638.954,42	31,76%	246.731,78	4,78%
Sulawesi	Gorontalo	175.832,79	15,41%	21.255,31	1,86%
Sulawesi	West Sulawesi	105.193,81	8,93%	29.717,51	2,52%
Sulawesi	South Sulawesi	1.546.092,68	33,03%	128.144,72	2,74%
Sulawesi	Central Sulawesi	972.523,58	12,59%	277.282,81	3,59%
Sulawesi	Southeast Sulawesi	567.056,19	10,92%	152.161,25	2,93%
Sulawesi	North Sulawesi	234.208,28	14,61%	43.866,15	2,74%
Maluku	Maluku	364.899,84	7,02%	60.348,49	1,16%
Maluku	North Maluku	238.203,36	3,96%	60.705,50	1,01%
Papua	Papua	1.574.767,80	7,58%	361.314,21	1,74%
Papua	West Papua	216.708,67	2,40%	165.858,93	1,84%
	Total	28.314.570,28	16,45%	7.123.189,72	4,14%

While the findings demonstrate that more than 50% of regional spatial plans fail to adequately allocate for agriculture, the growing human population is also considered. In 2020, it was noted that Indonesia's population has continued to increase rapidly (Badan Pusat Statistik, 2020). In addition, the impact of agricultural land reduction contributes to a reduction in agricultural productivity, causing food supply concerns for the future. The rapid

increase in population also raises concerns regarding food security. Therefore, establishing a model is necessary to help identify which areas need improvement or preservation, to enhance food security, land availability, energy, clean water, and ecology for future human needs.

4. Conclusions

The ongoing human impact on biodiversity and ecosystems presents an escalating challenge, particularly as the demands of a growing population place ever greater pressure on natural resources. In Indonesia, where population growth and urbanization continue at a rapid pace, traditional spatial planning approaches are proving inadequate for addressing the full scope of ecological needs. Present policies tend to prioritize immediate economic gains, often overlooking the longer-term environmental costs and risks, including the depletion of agricultural land, loss of biodiversity, and reduced ecosystem resilience. This trend poses a serious threat to food security, public health, and environmental sustainability. As such, spatial planning must evolve to incorporate comprehensive ecological considerations, ensuring that development aligns with the capacity of natural ecosystems and respects the ecological balance.

To meet these demands, new planning models should be developed and adopted to better integrate ecological footprint metrics into regional and national planning frameworks. These models can help guide sustainable development by highlighting areas that require conservation or responsible management to preserve agricultural zones and critical ecosystems. Additionally, by addressing the ecological footprint directly, such models can aid policymakers in anticipating and mitigating the adverse effects of unchecked urban expansion. Implementing these strategies requires commitment from both national and local governments to enforce policies that prioritize ecological sustainability over short-term gains. Balancing development with ecological sustainability is essential not only for protecting the environment but also for ensuring a stable and prosperous future for Indonesia's growing population.

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