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Research Article

AgriForScape Model: Optimization of Agricultural Landscape Design in Karawang District as a Pest Control Strategy with an Ecological Approach

AgriForScape Model: Optimalisasi Desain Lanskap Pertanian di Kabupaten Karawang Sebagai Strategi Pengendalian Hama dengan Pendekatan Ekologis

Selvianing Tiyas[1,2]*, Wildan Maynardy Wicaksono[1,3], Usnil Khotimah[1,4], Ali Dzulfigar[1,5], Danik Septianingrum[1,6], Rahmat Asy'ari[1,7], Muhammad Ferdiansyah[1,8], Neviaty P Zamani[9], Rahmat Pramulya[10], Yudi Setiawan[11,12]

[1] IPB Sustainable Science Research Student Association, IPB University, Bogor Regency 16680, Indonesia

[2] Department of Food Science and Technology, Faculty of Faculty of Agricultural Engineering and Technology, IPB University, IPB Dramaga Campus, Bogor Regency 16680, Indonesia

[3] Department of Civil and Environmental Engineering, Faculty of Faculty of Agricultural Engineering and Technology, IPB University, IPB Dramaga Campus, Bogor Regency 16680, Indonesia

[4] Department of Plant Protection, Faculty of Agriculture, IPB Dramaga Campus, Bogor Regency 16680, Indonesia

[5] Departemen of Silviculture, Faculty of Forestry and Evironment IPB University, IPB Dramaga Campus, Bogor Regency 16680, Indonesia

[6] Departemen of Biology, Faculty of Mathematich and Natural Science, IPB University, IPB Dramaga Campus, Bogor Regency 16680, Indonesia

Abstract: Karawang Regency is one of the national rice barns and a major supplier of rice to Jakarta and surrounding areas. However, the productivity of this rice is threatened by the brown planthopper (*Nilaparvata lugens*) which causes crop failure. The reliance on chemical pesticides to control this pest results in negative impacts on the environment and endangers human health. This caused a decrease in land productivity resulting in the conversion of land use to non-agriculture. This research aims to analyze the conditions and problems of agricultural areas in Karawang Regency and design a strategy for regulating landscape structures in reducing the intensity of pest attacks in Karawang Regency. Optimizing the structure and pattern of agricultural landscapes using the AgriForScape (Agriculture-Forest-Landscape) model can be one of the effective strategies in pest control to increase land productivity by integrating agriculture and forest land covers. Land cover mapping for 2023 and 2000 was conducted using cloud computing, revealing a conversion of 14,000 hectares of rice paddy land over 23 years, leaving 99,713 hectares. AgriForScape focuses on the integration of agriculture and forest conservation to improve ecosystem balance, increase land productivity, and lower the risk of natural disasters. AgriForScape landscape management can be done with several strategies, including the addition of corridors and forest patches as habitat for natural predators of rat pests, and the addition of refugia areas as food sources and natural habitat for insect pest predators. By applying an ecological approach through optimized agricultural landscape design, this strategy aims to reduce pest attack intensity, boost rice productivity, and contribute to food security and climate change mitigation. The findings are expected to advance sustainable agriculture and offer valuable insights for local governments, farmers, and stakeholders seeking environmentally friendly land management solutions.

Keywords: Agricultural landscape, landscape ecology, pest management

Abstrak: Kabupaten Karawang merupakan salah satu lumbung padi nasional dan pemasok utama kebutuhan beras bagi Kota Jakarta dan sekitarnya. Namun, produktivitas padi ini terancam oleh hama wereng batang coklat (*Nilaparvata lugens*) yang menyebabkan gagal panen. Penggunaan pestisida kimia untuk pengendalian hama ini menghasilkan dampak negatif terhadap lingkungan dan membahayakan kesehatan manusia. Hal ini menyebabkan menurunnya produktivitas lahan sehingga terjadinya konversi pemanfaatan lahan menjadi bukan pertanian. Oleh karena itu riset ini bertujuan menganalisis kondisi dan permasalahan kawasan pertanian di Kabupaten Karawang dan merancang strategi pengaturan struktur lanskap dalam menurunkan intensitas serangan hama di Kabupaten Karawang. Optimalisasi struktur dan pola lanskap pertanian menggunakan model AgriForScape (Agriculture-Forest-Landscape) dapat menjadi salah satu strategi efektif dalam pengendalian hama untuk meningkatkan produktivitas lahan dengan mengintegrasikan tutupan lahan pertanian dan

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[7] Departemen of Forest Management, Faculty of Forestry and Evironment IPB University, IPB Dramaga Campus, Bogor Regency 16680, Indonesia

[8] Department of Agronomy and Horticulture, Faculty of Agriculture, IPB Dramaga Campus, Bogor Regency 16680, Indonesia

[9] Department of Marine Science and Technology, Faculty of Faculty of Fisheries and Marine Sciences, IPB Dramaga Campus, Bogor Regency 16680, Indonesia

[10] Center for Low Carbon Development, University of Teuku Umar, Aceh, Indonesia

[11] Departemen of Forest Resources Conservation and Ecoturism, Faculty of Forestry and Evironment IPB University, IPB Dramaga Campus, Bogor Regency 16680, Indonesia

[12] Center of Evironmental Science, Lembaga Penelitian dan Pemberdayaan Masyarakat IPB, IPB University, Bogor Regency 16680, Indonesia

*email:
selvianingsyas@gmail.com

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hutan. Sebelumnya, dilakukan pemetaan penutupan lahan dengan menggunakan data spasial eksisting tahun 2023 dan 2000 berbasis cloud computing. Berdasarkan konversi tutupan lahan sawah, terdapat perubahan sebesar 14.000 hektar dalam jangka waktu 23 tahun dan menyisakan 99.713 hektar lahan sawah. AgriForScape berfokus pada integrasi pertanian dan konservasi hutan untuk meningkatkan keseimbangan ekosistem, meningkatkan produktivitas lahan, dan menurunkan risiko bencana alam. Manajemen lanskap AgriForScape dapat dilakukan dengan beberapa strategi, antara lain penambahan koridor dan patch hutan sebagai habitat predator alami hama tikus, dan penambahan area refugia sebagai sumber pakan dan habitat alami predator hama serangga. Pendekatan ekologis melalui desain lanskap pertanian menjadi salah satu strategi dalam menurunkan intensitas serangan hama di Kabupaten Karawang. Dengan penerapan strategi optimalisasi desain lanskap pertanian ini diharapkan dapat tercapai pengendalian hama yang efektif, sehingga dapat meningkatkan produktivitas padi dan mewujudkan ketahanan pangan serta penanganan perubahan iklim. Selain itu, hasilnya juga diharapkan dapat membantu mengembangkan

Kata kunci: Ekologi lanskap, lanskap pertanian, pengendalian hama

INTRODUCTION

Indonesia's tropical climate and fertile soils create optimal conditions for agriculture, with rice cultivation serving as a cornerstone of the nation's economy and food security. As one of the world's leading rice producers, Indonesia relies heavily on its agricultural sector to sustain economic growth and meet domestic demand. However, recent data from the Indonesian Statistics Agency (BPS 2023) reveals a concerning trend: the rice harvest area in West Java Province shrank by 4.90% in 2023, declining from 1.66 million hectares in 2022 to 1.58 million hectares. This decline is mirrored in Karawang Regency, where rice production fell by 10.61%, from 1.23 million tons of GKG (Dry Milled Grain) in 2022 to 1.10 million tons in 2023, highlighting potential challenges for food production and rural livelihoods.

Karawang Regency, a key food production hub in West Java, boasts extensive agricultural land supporting diverse commodities. However, the region's agricultural sector faces mounting challenges, including pest infestations that threaten crop yields. According to Azhari et al (2021), several critical issues impede rice productivity in Karawang, such as the excessive use of chemical and organic fertilizers leading to soil degradation, damaged land and water infrastructure, inconsistent planting schedules, escalating levels of Plant Pest Organisms (OPT), and insufficient farmer entrepreneurship. Among these threats, the brown planthopper (*Nilaparvata lugens*) poses a significant risk, causing damage ranging from mild to severe, potentially resulting in total crop failure (Alima'fuad and Jadmiko 2023). In response, many farmers resort to synthetic pesticides, often exceeding recommended dosages. This misuse not only pollutes the environment—affecting soil, water, and wildlife—but also endangers farmers' health (Sinambela 2024).

Landscape ecology focuses on the structure, function, and dynamics of heterogeneous areas. Landscape structure encompasses the type, distribution, dimensions, and shape of landscape components. Landscape function pertains to the ecosystem goods and services provided by landscape elements, including production, habitat, regulation, and aesthetics. Meanwhile, dynamics refer to changes in the structure and function of landscapes due to natural or anthropogenic factors. In agricultural landscapes, these variables are crucial for sustainable agricultural systems. Landscape structure significantly impacts the distribution, abundance, and diversity of insects, including pests and beneficial species (Mitchel et al. 2014; Vogel et al. 2023; Pasaribu et al. 2024). These effects arise from the functional roles of landscape elements. Additionally, landscape dynamics, such as disturbances, influence the abundance and distribution of natural predators and pollinators like bees, as noted by Senapathi et al (2016).

The substantial impact of landscape structure and function on pest and disease dynamics underscores the importance of integrating landscape factors into sustainable agricultural management. In Karawang Regency, where agricultural landscapes face pest and disease challenges, these issues demand immediate attention. Adopting a landscape ecology approach offers a sustainable solution to mitigate such challenges. This study aims to evaluate the land cover and land use conditions of Karawang's agricultural areas and propose landscape structure strategies to reduce pest attack intensity in the region.

MATERIALS AND METHODS

Study Area

This study focuses on agricultural areas, specifically rice fields, in Karawang Regency, West Java. The study area is situated in the northern part of the regency, geographically located along the north coast of Java, directly bordering the Java Sea, Subang Regency, and Bekasi Regency. Astronomically, the area spans between -6.4095˚ South Latitude, 107.03˚ East Longitude to 107.47° East Longitude, and 5.93° to 6.65° East Longitude. The study site predominantly comprises an agricultural landscape, with the majority of the land cover dedicated to agriculture. Figure 1 provides a map of the study location.

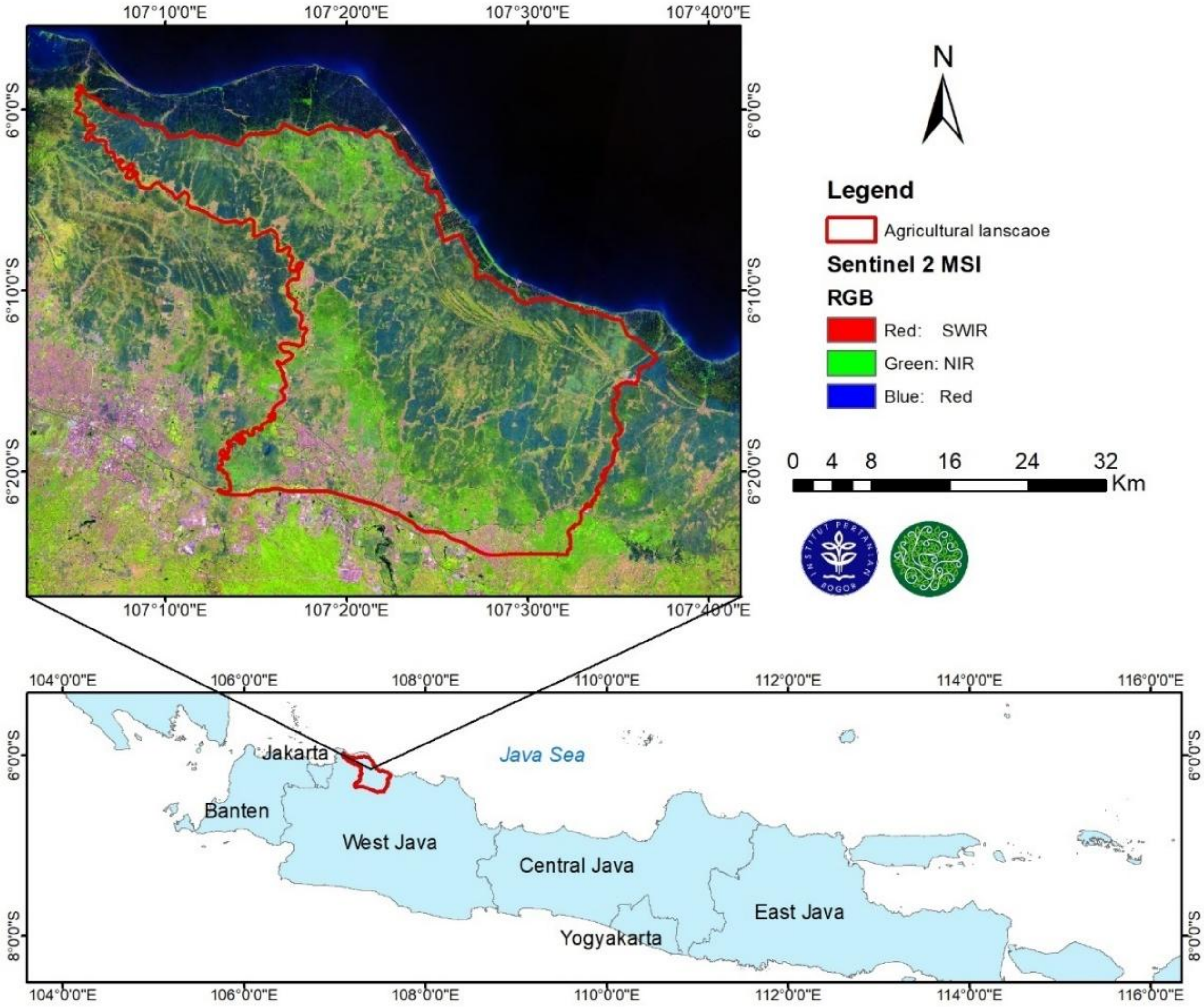

Figure 1. Map of Research location

Data Source Collection dan Research Workflow

The data sources for this study include Landsat-5 TM satellite imagery, used to detect land cover in 2000, and Landsat-9 OLI-2 imagery, used to identify land cover in 2023. Both datasets were obtained from the official United States Geological Survey (USGS) website. Additionally, a literature review was conducted to explore suitable landscape design strategies and identify natural predators of rice pests. The Landsat imagery was utilized to analyze land cover changes from 2000 to 2023, providing critical insights into landscape transformations for evaluating pest and plant disease issues. Based on this analysis, landscape design recommendations were formulated to address agricultural challenges, particularly pest and disease infestations, as part of a sustainable agricultural strategy at the landscape scale. The research design and workflow are illustrated in the research flow diagram in Figure 2.

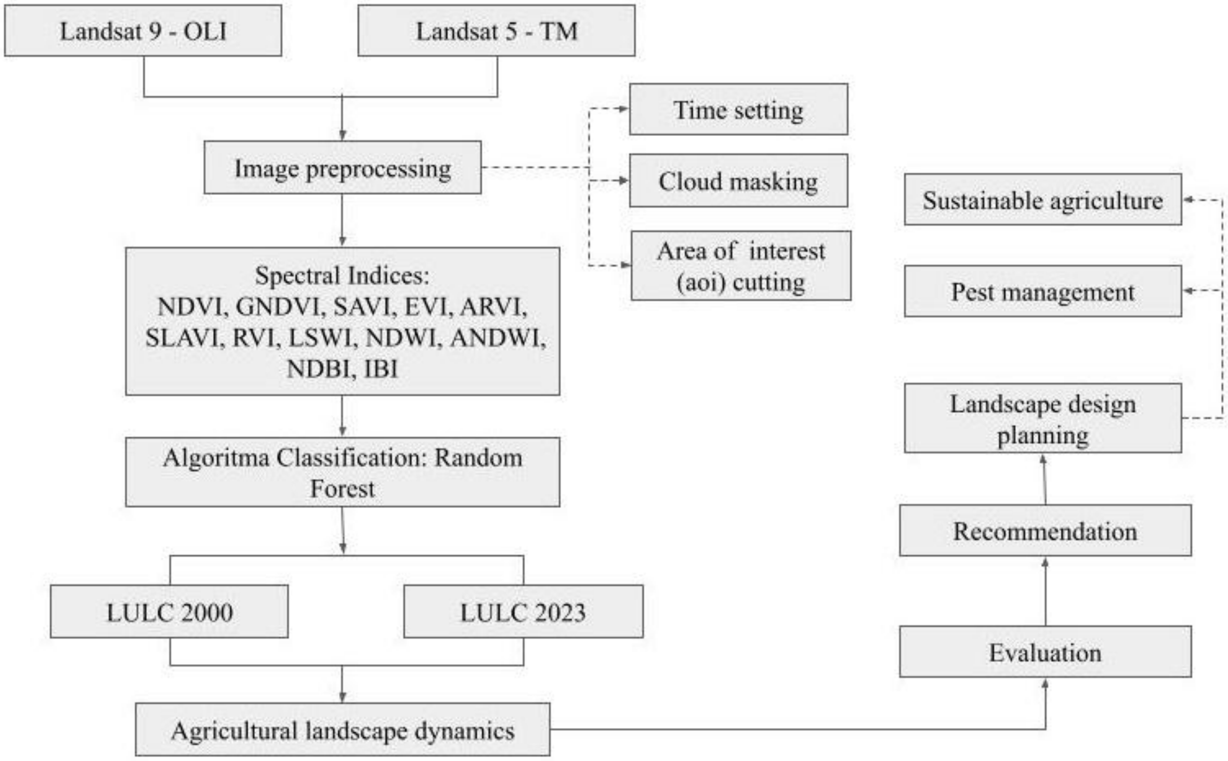

Figure 2. Research workflow employed in this study

LULC Analysis

Land cover and use analysis was conducted using supervised classification of Landsat imagery with the Random Forest (RF) algorithm, which tuned with ntree = 500. The RF algorithm builds on the Decision Tree (DT) approach by incorporating multiple trees built through random resampling, in case of classification, performing majority votes to estimate most probable class (Maxwell et al. 2018). The classification involved creating training data for land cover types such as residential areas and agricultural land. Incorporating spectral indices in this process enhanced classification accuracy by leveraging multiple spectral bands for detailed analysis (Brandel et al. 2019). The training data provided RF with the basis to classify land cover types within the study area (Table 1). This analysis utilized vegetation, water, and built-up indices as key inputs for classification (Table 2). Land cover classifications were applied to imageries from 2000 and 2023, enabling the identification of changes in the agricultural landscape over the study period. To ensure reliability, the accuracy of the classification results was evaluated using Overall Accuracy (OA) and Kappa Statistics methods.

Table 1. Training and validation dataset for classifying LULC

Land Use	**2000**		**2023**	
	Training	**Validation**	**Training**	**Validation**
Agriculture	1850	221	1775	584
Built-up area	1851	221	1756	548

Table 2. Indices involved in LULC classification

Method	**Formula**	**References**
Normalized Difference Vegetation Index (NDVI)	NDVI = (NIR - Red) / (NIR + Red)	Rouse et al. 1973
Green Normalized Difference Vegetation Index (GNDVI)	GNDVI = (NIR - Green) / (NIR + Green)	Dellinger et al. 2008
Enhanced Vegetation Index (EVI)	EVI = 2.5 × ((NIR – Red) / ((NIR) + (C1 × Red) – (C2 × Blue) + L))	Huete et al. 2002
Ratio Vegetation Index (RVI)	RVI = (Red/NIR)	Kogan 1995
Soil Adjusted Vegetation Index (SAVI)	SAVI = ((NIR – Red) / (NIR + Red + L)) × (1 + L) L = 0.5	Huete 1988
Specific Leaf Area Vegetation Index (SLAVI)	SLAVI = NIR / Red + MIR	Lymburner et al. 2000
Atmospherically Resistant Vegetation Index (ARVI)	ARVI = (NIR – (2 Red) + Blue) / (NIR + (2 × Red) + Blue)	Kaufman et al. 1992
Land Surface Water Index (LSWI)	LSWI = NIR – SWIR1 / NIR + SWIR1	Xiao et al. 2002
Normalized Difference Water Index (NDWI)	NDWI = Green - NIR / Green + NIR	Gao 1996
Index-Based Built-up Index (IBI)	IBI = NDBI – ((SAVI + MNDWI) / 2) / NDBI + ((SAVI + MNDWI) / 2)	Xu 2008
Normalized Difference Built Up Index (NDBI)	NDBI = SWIR1- NIR / SWIR1 + NIR	Zha et al. 2003

Design Agricultural landscape

The agricultural landscape design integrates patches and matrices within the agricultural landscape using ArcScene software. These patches are tailored to support specific landscape functions, such as serving as habitats for natural predators of rice pests. The design emphasizes the conservation of natural predator habitats by incorporating wildlife habitat patches and forest corridors into the landscape matrix. This approach draws on findings by Decocq et al (2016), who highlight that forest patches embedded within agricultural matrices provide critical environmental services, including biodiversity conservation, habitat and food resources for pest predators, physical protection, and water supply maintenance. Additionally, Arifin and Nakagoshi (2011) emphasize that landscape-scale land use planning must balance economic, ecological, and cultural factors, making biodiversity conservation—closely tied to ecosystem services—a vital consideration. For managing habitats of natural predators such as eagles, the design considers edge and core areas in forest patches, as these areas significantly influence the presence and spatial distribution of eagles (Syartinilia et al. 2015). ArcScene software was employed to develop the comprehensive landscape design, ensuring an effective spatial representation of the proposed ecological and functional components.

RESULTS AND DISCUSSION

Evaluation of Land Cover as an Existing Landscape Structure

The land cover classification results for Karawang Regency, illustrated in Figure 3, reveal significant changes between 2000 and 2023. In 2000, land use was predominantly agricultural, covering 113,987.87 ha (93%), with built-up land accounting for 8,570.07 ha (7%). By 2023, agricultural land decreased to 99,713.69 ha (81%), while non-agricultural land expanded to 22,849.18 ha (19%), indicating substantial conversion of agricultural land into built-up areas. This transformation was often driven by the growing demand for space due to population growth. Land conversion frequently results in residential areas, industrial zones, or other infrastructure. Ningsih et al (2022) observed that much of Karawang's land conversion involved agricultural land transitioning into housing, offices, and infrastructure, which spurred by rising population, industrial expansion, and low agricultural productivity. Similarly, Irawan et al (2023) attributed these changes to factors like high investor offers, frequent crop failures, government policies, and land ownership dynamics, further accelerating the shift away from agriculture.

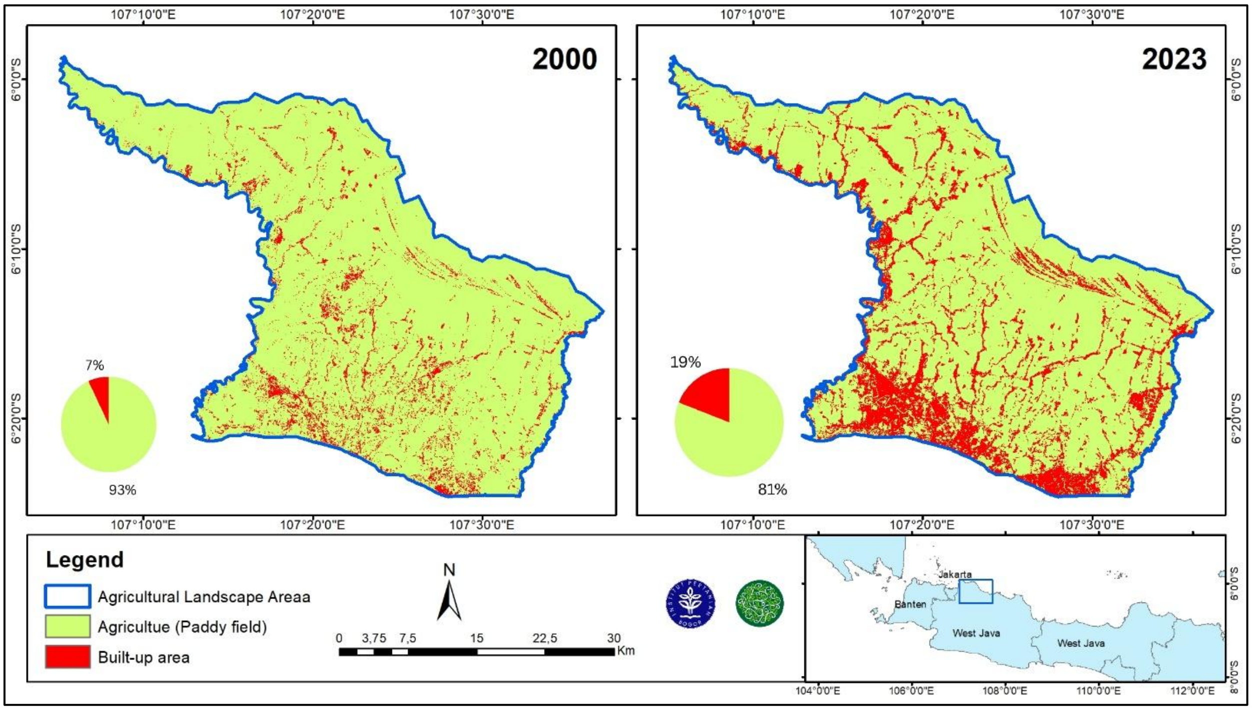

Figure 3. Map of land cover changes from 2000 to 2023

The accuracy assessment of land cover classification in Karawang Regency demonstrated exceptional performance, with overall accuracy values exceeding 90%. The classification results for 2000 achieved an overall accuracy of 98.84% and a kappa statistic of 93.82%. Similarly, the 2023 classification attained an overall accuracy of 98.61% and a kappa statistic of 98.21%. These results highlight the robustness of the random forest algorithm in land cover classification. The effectiveness of the random forest algorithm is supported by previous studies. Rivai et al (2023) classified land cover into four classes using the random forest algorithm and spectral indices, achieving an overall accuracy of 95.50% and a kappa statistic of 93%. Similarly, Rahmawati et al (2023) reported that random forest successfully detected land cover changes over five years, with an overall accuracy of 86% and a kappa statistic of 82%. Despite the comparable capabilities of spectral bands in achieving high accuracy, the use of native bands in some cases has been reported to reduce producer accuracy for certain land cover types. For example, Rwanga et al (2017) found that land cover classification using native bands resulted in relatively low producer accuracy for water bodies (40%) and mixed forest land cover (52%). These findings underscore the importance of integrating spectral indices to enhance land use land cover classification accuracy and reliability.

Changes in land cover significantly affect the surrounding environment, particularly in the agricultural sector. The conversion of agricultural land to non-agricultural uses leads to a decline in productive land area, causing various negative impacts. These include a reduction in soil's ability to absorb rainwater, diminished soil fertility, loss of surrounding biodiversity, and increased vulnerability to pest infestations (Kanianska 2015). A high prevalence of pests adversely impacts rice productivity, with greater pest attacks leading to lower yields. This poses a significant threat to long-term food security. To address these challenges, it is essential to adopt environmentally sustainable approaches to agricultural land analysis and management. Land cover change analysis offers numerous benefits, such as identifying land characteristics, biodiversity levels, area coverage, and the rate of land cover change. It also aids future planning and management for activities like plantation development, urbanization, water resource management, and land expansion (Nurda and Habibie 2020). One effective approach is landscape-scale spatial planning, which supports sustainable agriculture by focusing on pest control in rice fields. This involves managing the functions of various landscape elements and introducing additional components to address regional issues such as pest outbreaks and plant diseases (Conception 2008). The integrated spatial management strategies promote ecological balance and contribute to sustainable agricultural practices.

Pest and Plant Disease Attacks in Karawang Regency

One of the pressing issues in Karawang Regency is the frequent pest and disease attacks on rice plants. According to Sianipar et al (2015), the abundance of rice insect pests in the region is notably high, with the brown planthopper (*Nilaparvata lugens*) being the most prevalent. This challenge is compounded by several agricultural inefficiencies, such as inadequate farmer knowledge regarding pesticide use, suboptimal selection of superior rice varieties by the agricultural department, widespread reliance on environmentally harmful practices, insufficient farming facilities and infrastructure, and inadequate monitoring and guidance from agricultural services (Azhari et al. 2021).

Rice plants with low resistance are particularly susceptible to pest infestations, and pest attacks significantly impact both the productivity and quality of crop yields. Multiple factors contribute to the high intensity of pest infestations. For example, excessive rainfall, poor-quality seeds, and the overuse of nitrogen-based fertilizers have been identified as major contributors to rice stem borer outbreaks (Saleh 2023). Additionally, suboptimal soil conditions, such as low fertility and inappropriate moisture levels, exacerbate the vulnerability of rice plants to pest attacks (Wagiyati et al. 2024). Sarawan et al (2024) further emphasize the relationship between pest attack intensity and population density. Their findings indicate that areas with higher population densities experience a greater frequency of rice stem borer attacks, while areas with lower densities encounter fewer infestations. This underscores the need for targeted pest management strategies. To mitigate these issues, it is essential to enhance farmer knowledge about pest attack intensities and their causes. Educating farmers on sustainable agricultural practices, including the judicious use of fertilizers, integrated pest management, and selection of pest-resistant varieties, can help reduce pest damage and safeguard rice productivity in the region.

AgriForScape Model: Landscape Structure Design

Landscape ecology is a scientific discipline that examines the structure, function, and changes within landscapes, particularly in heterogeneous areas where various elements interact. These changes, whether driven by natural phenomena or human activities, can significantly alter the structure and functionality of the landscape (Prasetyo 2017). Managing these changes requires a comprehensive and integrated approach that considers landscape structure, function, and the ecological interactions influenced by these dynamics. A landscape is characterized by a unique configuration of topographical features, vegetation cover, land use, and settlement patterns that shape and constrain natural processes, human activities, and cultural practices (Budiyanti and Yuslim 2021). Within this context, matrices such as rice field landscapes play a crucial role in determining the function and quality of the overall landscape. Rice field matrices are predominantly agricultural areas used to cultivate staple crops like rice, corn, or sugarcane. These fields serve as vital resources for local communities, providing both sustenance and economic benefits. According to Jayathilake et al (2021), rice fields contribute significantly to food security and act as a primary source of income for farming households. This highlights the importance of understanding and managing the interactions between ecological and socio-economic factors in agricultural landscapes to ensure sustainable use and conservation.

The rice field matrix is often part of a larger, fragmented landscape, characterized by the division of natural areas into smaller, isolated fragments (Fahrig et al. 2003). In such fragmented settings, rice fields may act as patches separated by other land uses, such as settlements or forests. These fragmented landscapes present challenges and opportunities for landscape management, as different components interact in complex ways. Settlements, defined as human-inhabited areas with houses, roads, and other infrastructure, can significantly influence landscape quality. They are often sources of air and water pollution, which can adversely affect adjacent ecosystems, including rice fields (Misso et al. 2018). Conversely, forests, which are dominated by wild trees and vegetation, play a critical role in maintaining ecosystem balance and regulating the global climate (Myers et al. 2013). Forests also act as barriers to fragmentation, helping preserve habitat connectivity and supporting biodiversity (Fahrig et al. 2003). The interactions between these components in a fragmented landscape can have notable environmental and ecological implications. For instance, rice fields located near settlements may face challenges such as air and water pollution from urban activities. On the other hand, forests adjacent to rice fields can contribute positively by improving water and air quality, mitigating pollution, and providing ecosystem services that support agricultural productivity. This interconnectedness underscores the need for integrated landscape management strategies that address fragmentation while balancing ecological and human needs.

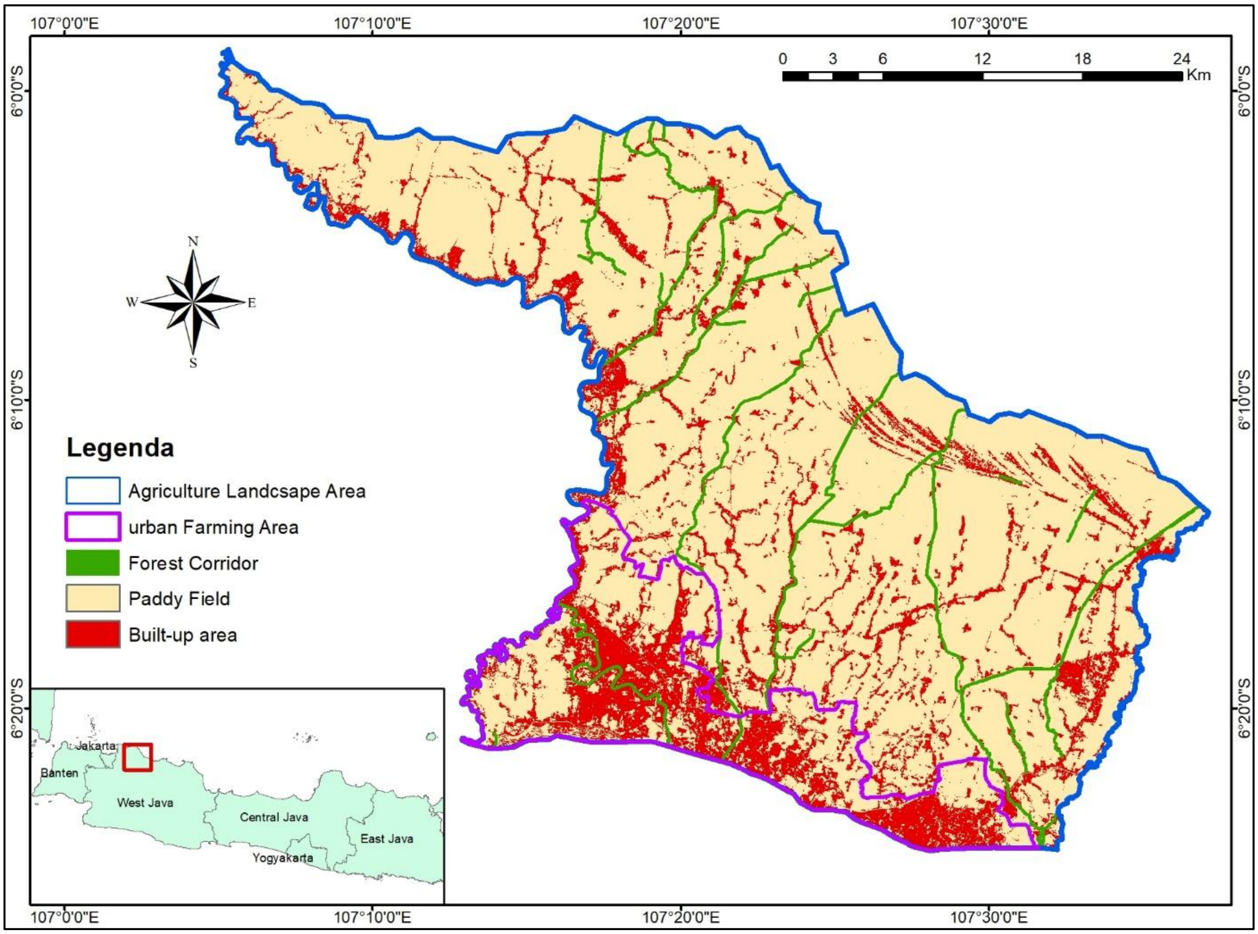

Figure 4. Karawang district landscape structure allocation plan map

AgriForScape is a concept that integrates agriculture and forest conservation to create a sustainable and productive agricultural landscape. As shown in Figure 4, AgriForScape focuses on the integration of agriculture and forest conservation to improve ecosystem balance, increase land productivity, and reduce the risk of natural disasters. Based on the landscape design map, there is some land cover that needs to be added, namely forest corridors. The forest corridor serves as a conservation area for natural predators of paddy field pests. AgriForScape landscape management can be done with several strategies, including through agroforestry, permaculture, and organic farming systems. Agroforestry is an agricultural system that integrates trees into farmland to improve soil fertility, increase crop production, and create habitat for biodiversity (Nair 2013; Nair et al. 2008). Permaculture is a design system that follows natural patterns to create a sustainable and self-sufficient agricultural system (Wahyuni et al. 2019). Meanwhile, organic farming is an agricultural system that uses natural methods to control pests and plant diseases, and does not use synthetic pesticides (Astuti et al. 2019). AgriForScape can also provide additional benefits such as improving soil fertility, lowering the risk of soil erosion, and increasing biodiversity. In addition, AgriForScape can also help mitigate climate change by sequestering carbon dioxide in the soil and forest. In AgriForScape landscape management, factors such as socio-economics, culture, and technology must be considered in the decision-making process. Therefore, cooperation between stakeholders, including farmers, governments, and local communities is needed to achieve the goal of a better AgriForScape.

Plant Pest Management with a Landscape Ecologist Approach

AgriForScape design emphasizes landscape structures that allow habitats for natural predators of rice pests. Table 1 presents the types of natural predators for crop pest management. Based on the design, the forest corridor on either side of the river (riparian ecosystem) as a buffer area can become a natural predator habitat (Figure 5). The existence of riparian ecosystems determines the diversity of species in the landscape, which can be a basic instrument in agricultural landscape management (Paolino et al. 2018). Landscape corridors can be an agricultural management strategy because they connect isolated habitats and increase the connectivity of pest predators (Decocq et al. 2016). According to Mescht et al (2023), the boundary between forest and agricultural land is an important habitat for many invertebrate species, suggesting that forest patches can support biodiversity in human-modified landscapes. Forest patches play a critical role in the conservation of natural predators by providing suitable habitat and supporting biodiversity. Based on research by Holzchuh et al (2009), the highest species abundance of pest predators such as wasps was found at forest edges.

Figure 6 illustrated how forest corridors adjacent to rice fields serve as crucial areas for predator-prey interactions. These corridors create edge zones that offer nesting sites for predatory wasps. On a micro scale, incorporating small forest patches within rice fields introduces landscape heterogeneity, enhancing the function of forest patches. These small forest areas can provide important ecosystem services such as carbon sequestration, nutrient cycling, and climate change mitigation. Additionally, they can regulate agricultural land by acting as wind or flood barriers and providing food for natural predators of pests (Decocq et al. 2016).

Besides many of their potential advantages and vital roles in predator conservation, developing forest corridors and patches within and adjacent of agriculture areas also present potential drawbacks, which can fail to enhance pest control (Tscharntke et al. 2016). These semi-natural areas could become greater and more suitable habitats for pests compared to pest predators. As noted by Laterza et al. (2023), forested areas can harbor insects that may hibernate, and if the surrounding cultivated land is homogeneous and suitable for pests, this could lead to pest outbreaks.

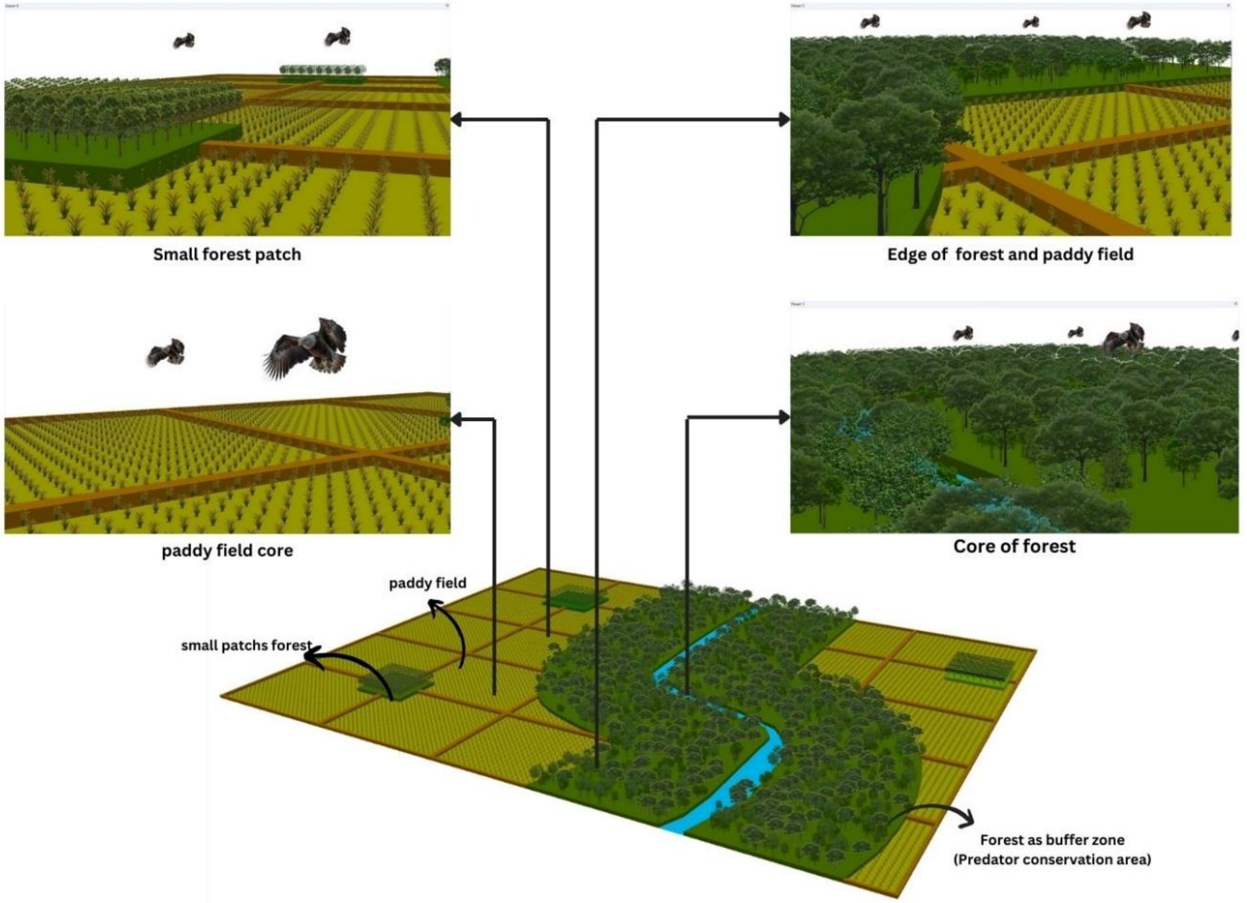

Figure 5. AgriForScape's landscape design model

Table 3. Interactions between species in AgriForScape design

Natural predator species	Prey pests	Interactions between species	Habitat management	Sources
Owl (*Tyto alba*)	Rat (*Rattus argentiventer*)	predation	forest patches and corridors as habitat, food sources, and breeding grounds	Noor et al. 2024
Eagle (*Accipiter gentilis*)	Rat (*Rattus argentiventer*)	predation	forest patches and corridors as habitat, food sources, and breeding grounds	Grande et al. 2018
Snake (*Malayopython reticulatus)*	Rat (*Rattus argentiventer*)	predation	forest patches and corridors as habitat, food sources, and breeding grounds	Talbi et al. 2023

Spyder (*Lycosa psedoalunata*)	Brown planthopper (*Nilaparvata lugens*)	predation	Refugia area as a food source	Boesing et al. 2017
Cyrtorhinus oryzae	Brown planthopper (*Nilaparvata lugens*)	predation	Refugia area as a food source	Boesing et al. 2017
Synharmonia octomaculata	Brown planthopper (*Nilaparvata lugens*)	predation	Refugia area as a food source	Boesing et al. 2017

Effective natural predators of rat (*Rattus argentiventer*) pests are eagles and owls. The eagle (*Accipiter gentilis*) is one of the main predators of rice field rats in Indonesia. This eagle has the ability to capture field mice by jumping and killing them, thus reducing the population of field mice and saving pest control costs (Risdianto et al. 2019). Owls (*Tyto alba*) also play an important role as natural predators of field mice. These owls have the ability to capture field mice by abducting and stomping, thus reducing the population of field mice and preventing the spread of pests (Ardigurnita et al. 2020). The presence of forest fragments and corridors allows good habitat for both predators.

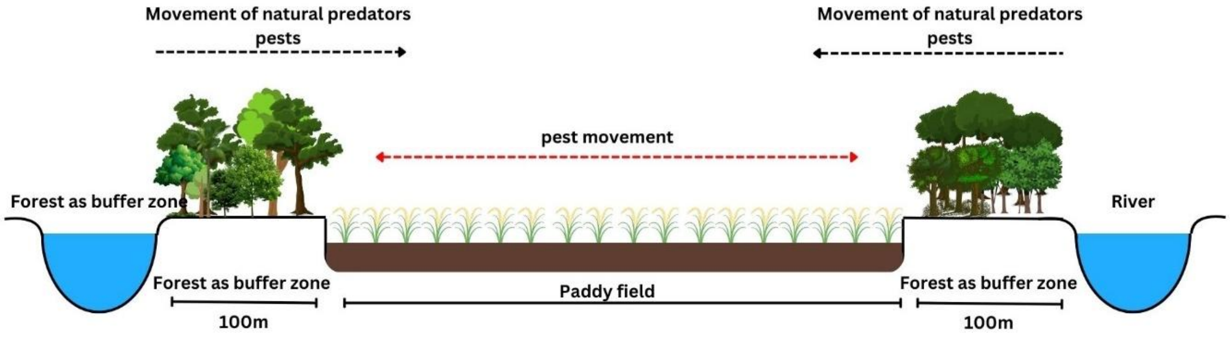

Figure 6. Forest corridor on river buffer

River buffers, also referred to as river protected areas, are vital zones surrounding rivers that serve as essential life buffers for both aquatic and terrestrial ecosystems. These buffers, which can include forests, swamps, or other natural habitats, help maintain the health and stability of river ecosystems. As highlighted by Maryono (2020), river buffers not only contribute to the conservation of natural predators but also play a significant role in regulating water quality by absorbing pollutants, such as waste and sediment, preventing them from contaminating the river. River buffers are crucial in maintaining sustainable water quality by filtering out pollutants and stabilizing the river environment. They serve as natural filters, ensuring that water remains clean for both aquatic life and surrounding communities (Nurdiyana et al. 2019). Additionally, these buffers help control flooding by absorbing excess water during heavy rains, reducing the risk of natural disasters and maintaining environmental balance (Gay et al. 2023). This flood regulation function is especially important in regions prone to extreme weather events, ensuring the resilience of local ecosystems and human settlements.

In addition to using forest patches, the micro AgriForScape landscape design also utilizes road corridors as refugia areas (Figure 7). A refugia area is an area in the form of a patch or corridor planted with refugia plants as a habitat or food source for insect pest predators. According to Erdiansyah and Putri (2017), refugia plants are places where various types of flowering plants grow that function as shelter, food sources, or resources used by natural enemies such as predators and parasitoids. They also function as pollinators which are part of biotic interactions in the ecosystem. Refugia has a natural ability to attract enemies because they are useful not only as a source of food and resting places but also for laying eggs and shelter from danger (Nearti et al. 2022). Based on research by Erdiansyah and Putri (2017), by combining refugia and rice plants, the population of natural predators increased to 438 compared to 305 predators without refugia. Planting refugia is a very important component of agroecosystems because it contributes to the dynamics of natural predators (Allifah et al. 2017), and has the ability to improve ecosystem balance through plant species diversity.

Figure 7. AgriForScape landscape design model for refugia area

Maintaining flowering plants on farms is essential for supporting natural predators and preserving ecosystem balance. Refugia plants, known for their vibrant colors, attract natural enemies and provide microhabitats that enhance the vision spectrum of insects. These plants also offer additional food sources like nectar and honey, and are easy to cultivate (Nearti et al. 2022). Refugia plants, which include broadleaf weeds, flowering plants, and vegetable species, can grow either wild or be cultivated (Horgan et al. 2016). Examples of refugia plants include sunflower (*Helianthus annuus*), paper flower zinnia (*Zinnia elegans*), kenikir (*Cosmos caudatus*), and button flower (*Centaurea cyanus*). Food plants like long beans (*Vigna unguiculata*), spinach (*Amaranthus* sp.), and corn (*Zea mays*) can also serve this function.

CONCLUSIONS

The analysis in this study reveals that land cover in Karawang Regency has significantly changed between 2000 and 2023, particularly in paddy fields, which decreased by 14,000 hectares over 23 years, leaving 99,713 hectares. This reflects a shift from undeveloped to developed land.

One major issue is the brown planthopper (*Nilaparvata lugens*), a pest that can severely damage rice crops, leading to reduced yields or even crop failure. AgriForScape, which integrates agriculture and forest conservation, offers strategies to improve ecosystem balance, increase productivity, and reduce natural disaster risks. Key management strategies include adding corridors and forest patches to support natural predators and incorporating refugia areas to provide food sources and habitats for pest predators. This ecological approach to agricultural landscape design aims to reduce pest attack intensity in Karawang, enhancing rice productivity and supporting the SDGs for food security and climate change management. The findings also provide insights into sustainable agricultural practices, serving as a valuable reference for local governments, farmers, and stakeholders seeking environmentally friendly land management solutions.

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