ANALYSIS OF URBAN GREEN OPEN SPACE DEVELOPMENT IN NORTH DENPASAR DISTRICT, DENPASAR CITY, BALI, INDONESIA

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ABSTRACT

Denpasar City is the capital of Bali Province, Indonesia and requires the provision of high public infrastructure. The high conversion of functions that has occurred, until now has not been balanced with information on the potential of green open space and the allocation of new public RTH. The method used in this study is quantitative descriptive with geographic information system technology and remote sensing. The research was conducted in three stages, namely the input phase, the process phase, and the output phase. The input phase includes the literature study stage on regional regulations and journals or books related to variables and parameters for developing potential land for public RTH. In this phase, research materials were also collected in the form of downloading Sentinel-2 satellite imagery and downloading shapefiles (shp) for the data analysis process. The process phase is the stage of processing and analyzing research data. The stages carried out in this phase include the Normalized Different Vegetation Index (NDVI), accuracy testing, overlaying/overlaying subak shp, and scoring. Ubung Kaja Village has been identified as the most suitable and prioritized location for the development of green open space, in line with the specified development guidelines of 2.83 hectares. This study underlines the importance of not ignoring government initiatives aimed at preserving Sustainable Food Crop Lands and Balinese cultural heritage by ensuring their sustainability and maintenance.

Key-words: *Green open space; GIS; NDVI; Remote Sensing; Spatial Analysis; Subak; Sentinel-2.*

1. INTRODUCTION

The Sustainable Development Goals (SDGs) represent a global commitment to urban development with the aim of fostering enduring human well-being. By 2030, all cities and residential areas should feature freely accessible public spaces and ample green open areas as part of a comprehensive design and management approach, ensuring inclusivity, resilience, safety, and sustainability (United Nation, 2020). Moreover, a substantial presence of green open spaces can enhance the microclimate, air quality, groundwater reserves, vegetation, and wildlife habitats, as well as the absorption of pollutants, all of which contribute to an overall increase in ecological value (Semeraro et al., 2021). Additionally, public green spaces, particularly parks, serve as important gathering spots for urban dwellers, offering a reprieve from the hustle and bustle of city life and serving as recreational hubs (Heikinheimo et al., 2020; Wolch et al., 2014; Yan et al., 2024). Conversely, the evolving development paradigm, which currently places a heavier emphasis on economic growth, has an impact on both the quantity and quality of green open spaces as well as the extent of developed areas. This trend is particularly notable in emerging nations (Cheshmehzangi et al., 2021).

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As a prominent hub for international tourism, Denpasar City in Bali, Indonesia, has witnessed a rapid increase in population and urban development. Studies have shown that the city's population growth has led to the replacement of vegetated spaces, such as rice fields and agricultural land, with urban infrastructure on the outskirts of the city center (Christiawan, 2019). The government aims to develop the river border areas in accordance with Regional Regulation No. 8 of 2021, which outlines the Denpasar City Spatial Plan for 2021–2041 (Mayor of Denpasar City, 2021). However, as these areas have become predominantly residential, implementing the plan has become challenging. Additionally, the availability of public green spaces, including parks, remains limited and unevenly distributed across the villages and sub-districts of the North Denpasar Sub-District. Given these circumstances, constructing parks presents a viable solution to meet the need for urban public green spaces, thereby enhancing the city's overall green infrastructure.

Images from remote sensing earth observation satellites can be leveraged to bridge the information gaps about green open space and assess the distribution of vegetation within urban areas. Employing pixel-based techniques and spatial analysis enables the identification and classification of vegetation distribution. By utilizing an unsupervised classification method, which involves processing image combination bands into pixel groups using Geographic Information Systems (GIS), one can systematically differentiate between green and non-green open space features. Sentinel-2, a satellite image with a 10-meter resolution, is widely utilized to evaluate the city's vegetation status and the presence, distribution, and extent of green open space in urban areas (Giuliani et al., 2021; Ju et al., 2022; Shahtahmassebi et al., 2021).

Previous research by Haryanti and Anggraini (2020), studied the function of Green Open Space in the Kauman Area, Semarang City, Indonesia. The approach used in this study was descriptive qualitative which was carried out inductively. The results of this study differentiate the function of Green Open Space in the Kauman Area, both private Green Open Space and public Green Open Space. Cellindita, et al (2021), used qualitative methods and literature review to analyze the management of green open spaces in Malang City. The results of the study found that the development of Green Open Spaces in Malang City has not been fully managed properly, with the percentage of Public Green Open Spaces in Malang City only 12.38%. Meanwhile Dollah, et al (2023) analyzed green open spaces and their influence on the welfare, health, happiness, and satisfaction of city residents with their environment as a social function. This study was conducted using a survey method with descriptive analysis. Data collection was carried out using observation and documentation techniques. The results of the study showed that the social performance of green open spaces in the Karebosi Field Complex was 49 percent, still in the low category. Of the nine variables observed, it can be seen that pedestrian paths have the highest performance rating, while the lowest are volleyball courts, softball, and non-sports facilities.

This study aims to identify potential land locations for public green open spaces in North Denpasar Sub-District and evaluate the condition of existing green open spaces in Denpasar City using the Normalized Difference Vegetation Index (NDVI) method. Spatial distribution and development potential are the objectives of the study that distinguish it from other studies. The use of qualitative methods through scoring and overlay makes this study provide information on the distribution and classification of green open spaces, supporting urban spatial planning and the implementation of efficient public green open spaces in the city.

2. STUDY AREA

The North Denpasar Sub-District is an administrative region within Denpasar City, situated on Bali Island in Indonesia. The geographical coordinates of the sub-district span from approximately -8°35'33.38" to -8°39'22.04" latitude South and from 115°11'7.94" to 115°14'14.88" longitude East. North Denpasar exhibits urban and rural traits, encompassing diverse residential sectors, commercial areas, and traditional Balinese villages. The district also has numerous cultural and historical landmarks, contributing to its lively ambiance within Denpasar City (Christian et al., 2020; Lanya et al., 2017). **Fig. 1** shows the research location

North Denpasar District spans an area of around 31.42 square kilometers, characterized by a mix of agricultural land, residential areas, and trade service industries at an elevation of approximately 500 meters above sea level (BPS-Statistics Indonesia Denpasar City, 2024b). The region experiences a tropical climate featuring two distinct seasons: the rainy and dry seasons. Typically, the weather is partly cloudy, with average temperatures ranging from 29°C to 31°C and humidity levels between 64% and 94%. Throughout the year, temperatures fluctuate between 22°C and 31°C. During the rainy season, which typically occurs from November to April, the sub-district sees high levels of rainfall, with monthly averages peaking at 200-300 mm (BPS-Statistics Indonesia Denpasar City, 2024a).

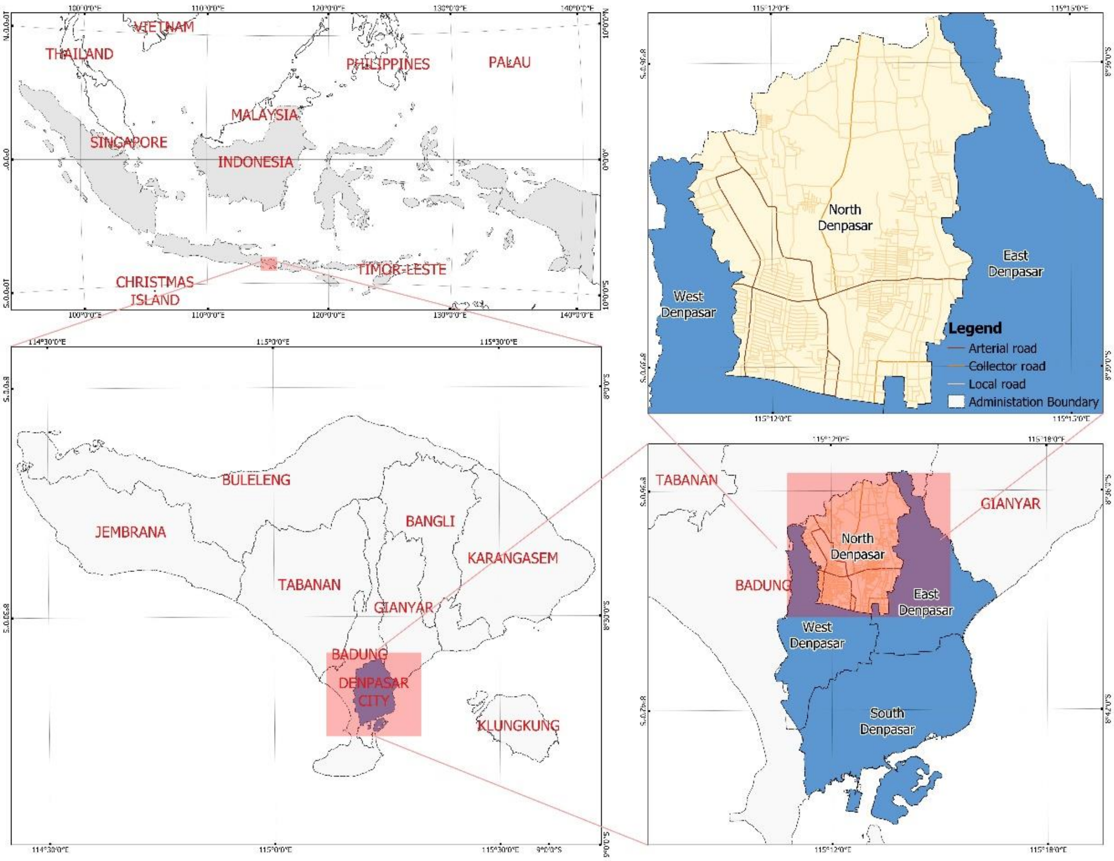

Fig. 1. Research Location.

3. DATA AND METHODS

3.1. Dataset

The research examined the development of green open green spaces, emphasizing the ecosystem services they provide and the demand for ecological spaces among residents. The dataset to indicate the potential urban green open space is shown in **Table 1**, i.e., (1) land use type, (2) accessibility, (3) land use pattern, (4) land ownership, and (5) minimum area of urban green open space. The whole dataset was used to generate (6) the potential of urban green open space development.

Table 1.

The dataset used to indicate green open space.

No	Data Set	Parameter	Score	References
1	**Land Use**	Empty/ abandoned land river border, moor	3	(Miller et al., 1998), (Baghel, 2022), (Gelan, 2021), (Manlun, 2003), (Syaifudin B.A, 2018)
		Field, park	2	
		Other land uses	1	
2	**Accessibility**	Arterial Roads	3	(Artandio, 2019), (Baghel, 2022), (Gelan, 2021), (Chandio et al., 2011)
		Collector roads	2	
		Local and neighboarhood roads	1	
3	**Land spatial pattern plan**	Direction for green open space as the main function	3	(Artandio, 2019), (Miller et al., 1998), (Manlun, 2003)
		Protected area directive	2	
		Cultivation area directions	1	
4	**Land ownership**	Government Assets	3	(Artandio, 2019), (Miller et al., 1998), (Chandio et al., 2011), (Gelan, 2021)
		Apart from government assets and private land	2	
		Private land	1	
5	**Minimun Area of Parks**	Land area ≥ 15.000 m2	3	(Artandio, 2019)
		5.000 m2 ≤ Land area < 15.000 m2	2	
		250 m2 ≤ Land area < 5.000	1	

The first to fourth and sixth data were sourced from the Indonesian basemap dataset by Geospatial Information Agency (BIG) of Indonesia, accessed at https://tanahair.indonesia.go.id/portal-web/ and the local government information based on the Denpasar City Spatial Plan for 2021–2041 (Mayor of Denpasar City, 2021). Meanwhile, the minimum area of urban green open space is analyzed by the Normalized Difference Vegetation Index (NDVI) algorithm based on Sentinel-2 Imagery. The Sentinel-2 Imagery L-1C Level data was acquired from the European Space Agency's dataspace through the Copernicus program at https://dataspace.copernicus.eu/. The primary observation date is April 11th, 2024, with supplementary image patching observation on September 29th, 2023, due to cloud cover. The NDVI is the key metric for assessing natural environmental conditions and identifying significant ecological corridors and nodes (Bai et al., 2022). The NDVI was classified into four categories, i.e., (1) Non-vegetation, (2) Low, (3) Medium, and (4) High vegetation as shown in **Table 2.**

Table 2.

The vegetation density level based on NDVI values interval.

No.	Vegetation Density Level	NDVI values interval	Land use
1.	**Non-vegetation**	-1 to 0.15	Rivers/rivers, canals, reservoirs, settlements, roads and other infrastructure
2.	**Low vegetation**	0.15 to 0.25	Rice fields are in the resting phase/starting planting, empty land with no/little vegetation
3.	**Medium vegetation**	0.25 to 0.35	Field, grassy area, fields, newly planted/after harvest rice fields
4.	**High vegetation**	0.35 to 1	Swamps, fields, rice fields approaching harvest, dense tree vegetation like a forest

(*Idrees et al., 2022*)

3.2. Methodology

The research's conceptual framework of methodologies is visually represented in Fig. 2. This framework is composed of two primary components: first, the process of consolidating all data into the requirement score, as outlined in Table 1, and second, the calculation of the overall score to assess the potential of green open space.

3.2.1. Vegetation density level based on NDVI Sentinel-2

The Sentinel-2 comprises two polar-orbiting satellites, Sentinel-2A and Sentinel-2B, as part of the ESA Copernicus mission. Sentinel-2A was launched in June 2015, followed by Sentinel-2B in March 2017. These satellites offer global coverage by revisiting the same area every two to three days and capturing multispectral imagery with a spatial resolution ranging from 10 to 60 meters. The images contain thirteen spectral bands covering the visible, near-infrared, and shortwave-infrared ranges. The Sentinel-2 MultiSpectral Instrument (MSI) provides radiometrically and geometrically corrected Top-of-Atmosphere (TOA) reflectance, which was utilized for our investigation. The use of NDVI for environmental analysis in Bali Province is still limited, including for analysis of mangrove distribution (Wiguna et al., 2022) and land surface temperature (Wiguna and Sutari, 2023).

Our focus was particularly on bands 4 and 8, which have a 10 m spatial resolution for capturing Red and Near-Infrared light (NIR). Those bands are used to form NDVI with classification following Table 2. The formulation of NDVI is shown in Eq.1. **Fig 2** shows the conceptual framework for the mapping of green open space.

$$\text{NDVI} = \frac{(\text{NIR Band} - \text{Red Band})}{(\text{NIR Band} + \text{Red Band})} \quad (1)$$

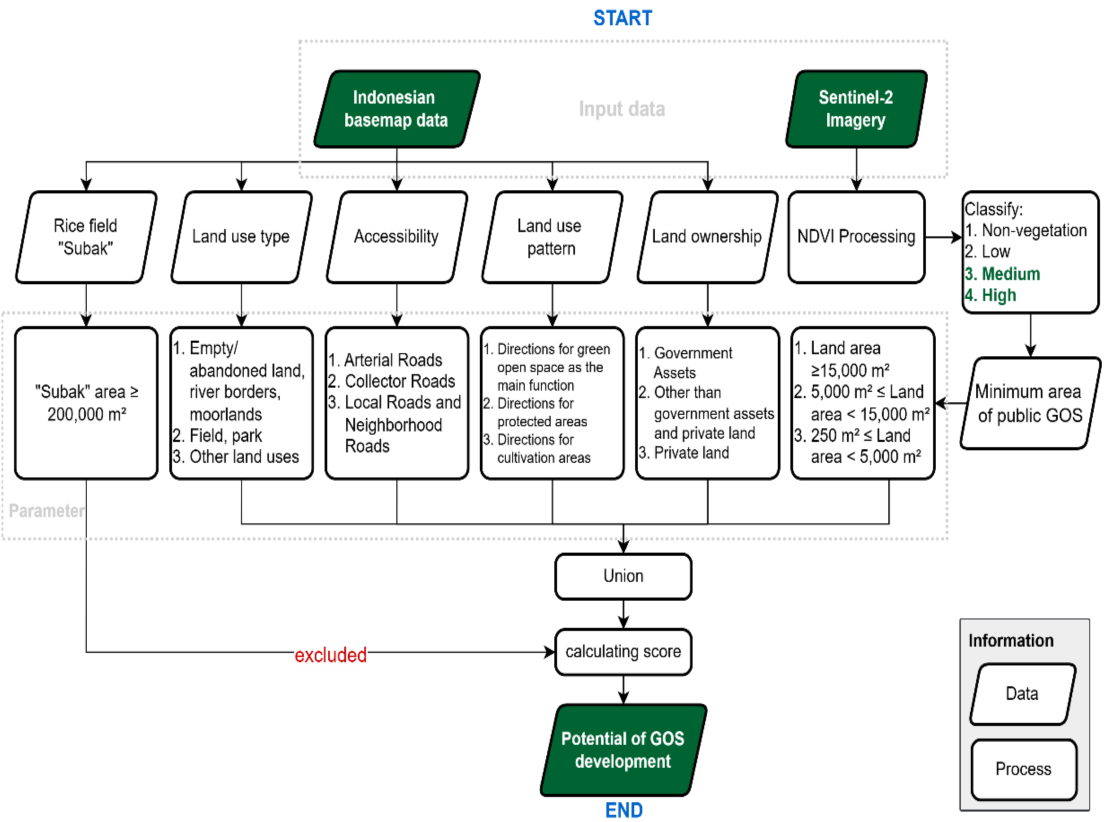

Fig. 2. The conceptual framework for the mapping of green open space.

3.2.2. Green Open Space parameter

The data from Indonesian Geospatial Agency and spatial planning data from local government was processed through Geographic Information System (GIS) tools. The entire dataset was classified into three scores. First, land use is classified as empty/abandoned land, river borders, moorlands; fields, parks; and other land uses with scores 3, 2, and 1, respectively. Second, the accessibility was buffered with 400 m-radius, then classified as arterial road; collector road; and local roads and neighborhood roads with scores 3, 2, and 1, respectively. In accessibility cases, the arterial road is considered the most important, followed by the collector road and then the local and neighborhood roads.

Third, land use pattern, the class of land use pattern classified as directions for green open space as the main function; directions for protected areas; and directions for cultivation areas with scores 3, 2, and 1, respectively. Fourth is land ownership; this data is obtained from information provided by the local government. The land ownership is classified as government assets; other than government assets and private land; and private land with scores 3, 2, and 1, respectively. The fifth point pertains to the minimum area of GOS, which is determined using data from the NDVI Sentinel-2 Imagery in medium and high vegetation density classes. Subsequently, the vegetation density is classified as more than equal to 15,000 m² with a three-score; more than equal to 5,000 m² and less than 15,000 m² with a two-score; and more than equal to 250 m² and less than 5,000 m² with one-score.

Fifth, rice field “Subak”, Bali's “Subak” irrigation system is a unique example of Hinduism and the *Tri Hita Karana* philosophy, which maintains three balances and harmonies: *parhyangan*, *pawongan*, and *palemahan*, all of which are necessary for sustainability (Wijayanti et al., 2020). In social anthropology, “Subak” are identified as associations of irrigators that integrate resource management with ritual. On Bali, inscriptions suggest that antecedent forms date back at least millennia (Jha & Schoenfelder, 2011). In accordance with Indonesian law No. 41 of 2009 on Sustainable Food Crop Land Protection and Government Regulation No. 1 of 2011 on the Determination and Conversion of Sustainable Food Crop Land, the issue of converting food cropland, particularly agricultural land (rice fields), to non-rice cropland is regulated, with land conversion occurring annually. Therefore, it is crucial to prioritize building food security and sovereignty to enhance the welfare of the people. Under these regulations, "Subak" rice fields with an area exceeding 200,000 m² or 20 ha will be exempted from conversion, even if the land has the potential for development into green open space (Presiden Republik Indonesia, 2009, 2011).

3.2.3. Potential of Urban Green Open Space Development

The score of each parameter calculates the potential of urban green open space development. The calculation is using overlaying with the union method on the GIS application. sing the Union approach, all of the features from two or more spatial polygon datasets are preserved when superimposed. This implies that all features from each input dataset are included in the output, regardless of how they overlap or do not. By using this methodology, the formulation is shown in Eq.2.

Potential of green open space development = (Land use type + Accesibility + Land use pattern + Land ownership + minimum area of urban green open space) - subak area (2)

4. RESULTS AND DISCUSSIONS

4.1. Vegetation density level

The analysis of green areas, grounded on NDVI values from Sentinel-2, appears to be satisfactory. With the latest release of Sentinel-2 data, land cover mapping and green open space monitoring should reach previously unheard-of heights. This development holds significant promise for the academic community, particularly for those involved in environmental studies, geography, remote sensing, and related fields. Enhancing data quality and increased availability can facilitate more accurate and comprehensive research on land cover changes, green open space management, and environmental monitoring (Ju et al., 2022; Kopecká et al., 2017; Ludwig et al., 2021).

The findings regarding vegetation density levels, as derived from NVDI Sentinel-2 data, are depicted in **Fig 3**. The total area of the North of Denpasar Sub-district is 2607.76 ha, with 29.39% (766.39 ha) being non-vegetation, 22.97% (598.98 ha) being low vegetation, 13.73% (358.10 ha) being medium vegetation, and 33.91% (884.29 ha) being high vegetation. Thus, 47.64% or 1,242.39 ha area consisting of medium and high vegetation in the North Denpasar Sub-district can develop as green open space.

Based on the area in villages, the highest medium and high-density vegetation area is in Peguyangan Kaja Villages, with 80.32 ha or 18.69% for medium and 215.80 ha or 50.22% of its total area. This is because Peguyangan Kaja Village still has many areas of rice fields and dense tree vegetation. Furthermore, this village is in a suburban area, and its development has not yet reached a massive scale. Compared to Peguyangan Kaja Village, the medium and high vegetation cover is notably low in Dangin Puri Kauh Village, at 4.24 ha (10.22%) and 3.80 ha (9.16%), respectively. The lowest area is caused by high non-vegetation areas, and the total area is the smallest compared to other villages. The comprehensive details for each class categorized by their respective areas are depicted in **Fig 4.**

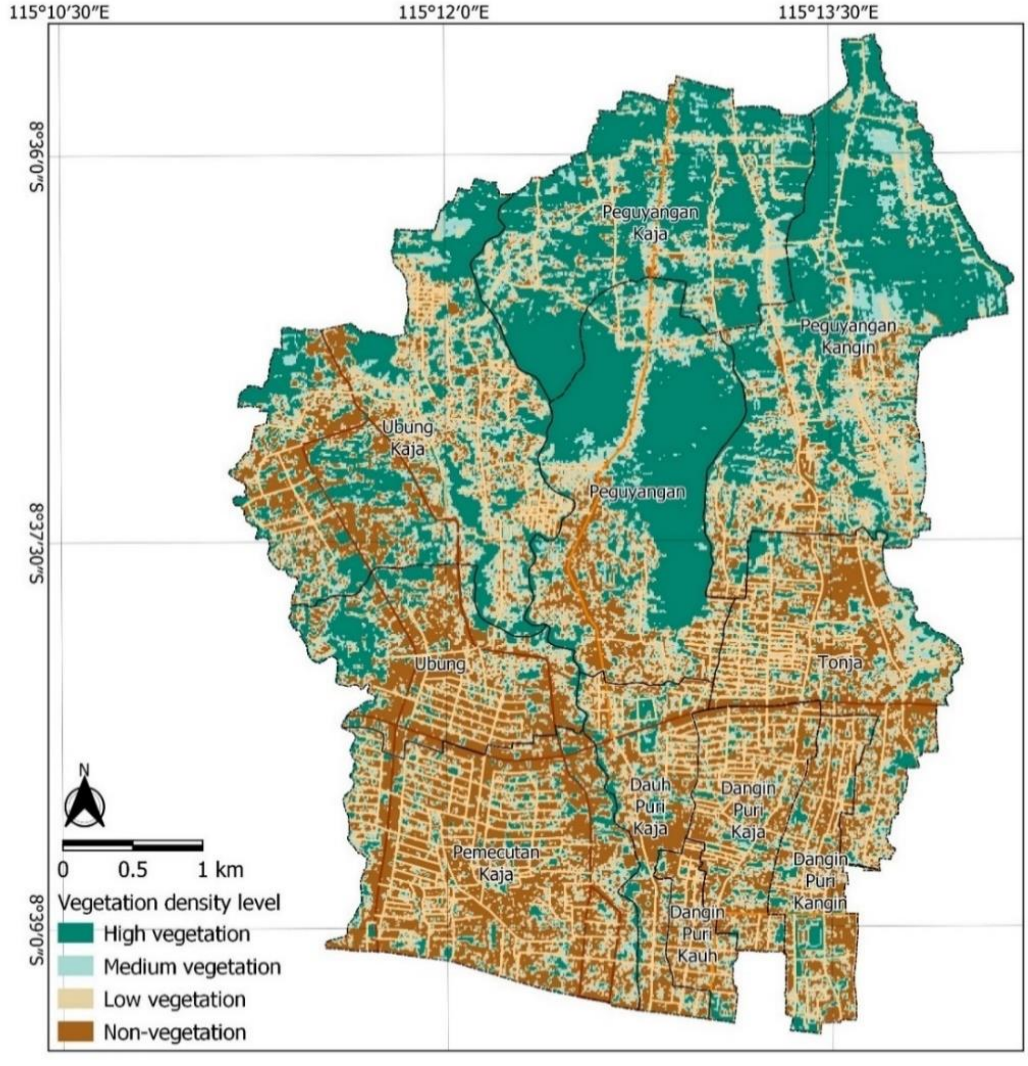

Fig. 3. Vegetation density level.

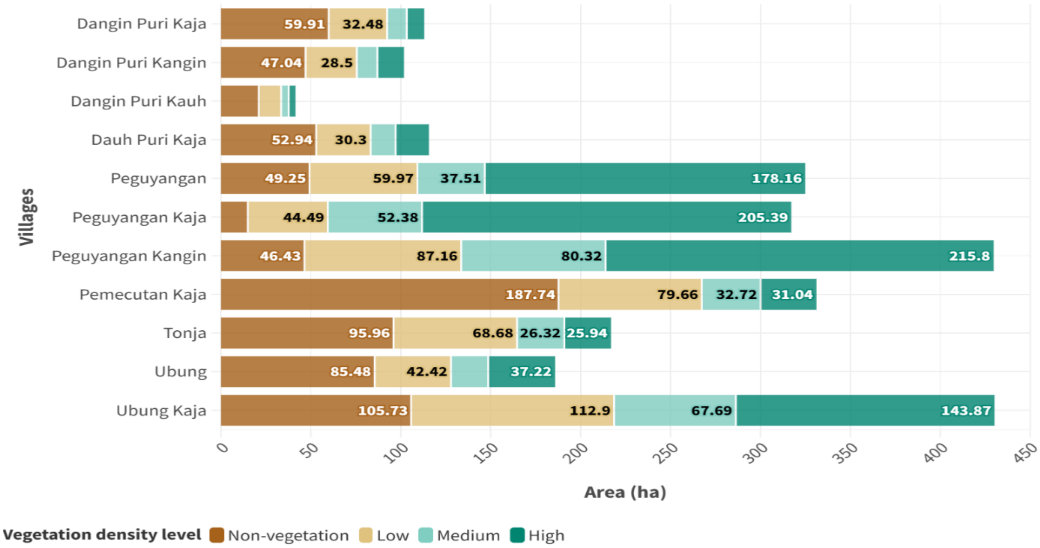

Fig. 4. Land analysis of vegetation density level.

4.2. Classification of Green Open Space Parameter

The classification of green open space parameter is shown in **Fig 5**, from Figures 5(a) to 5(e).

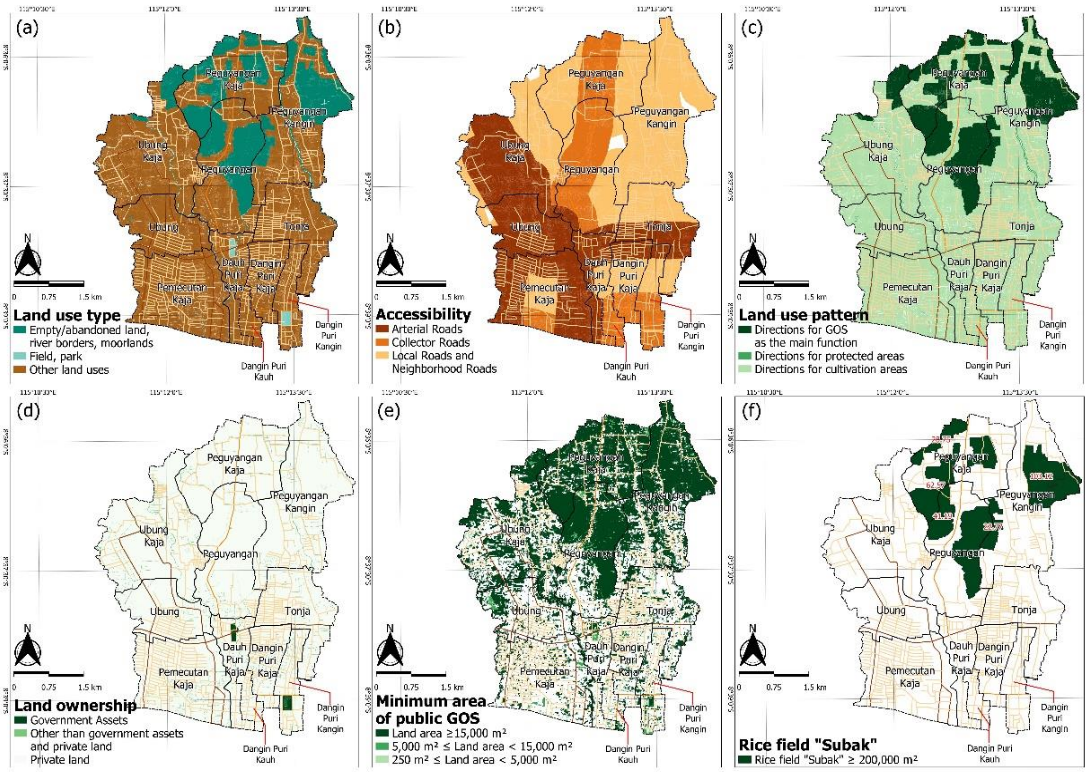

Fig. 5. Green Open Space Parameter Classification (a) Land use type; (b) Accessibility; (c) Land use pattern; (d) Land ownership; (e) Minimum area of public green open space; and (f) Rice field "Subak".

Figure 5(a) shows the land use type with the areas of other land uses is 1,935.37 ha (78.65%); field, the park is 10.75 ha (0.44%), and the empty/abandoned land, river borders, moorlands is 514.71 ha (20.92%). The primary land use type in North Denpasar District is predominantly categorized as other, which includes buildings and other man-made structures and facilities. At the village level, the highest areas of other land use are at the Ubung Kaja, with 365.84 ha. For the field and park, the highest is on Dangin Puri Kangin Villages, with 6.19 ha on the Ngurah Rai Stadium. The highest areas of empty/abandoned land, river borders, and moorlands are located in Peguyangan Kangin Villages with 170.41 ha. The details of land use type areas are shown in **Fig 6.**

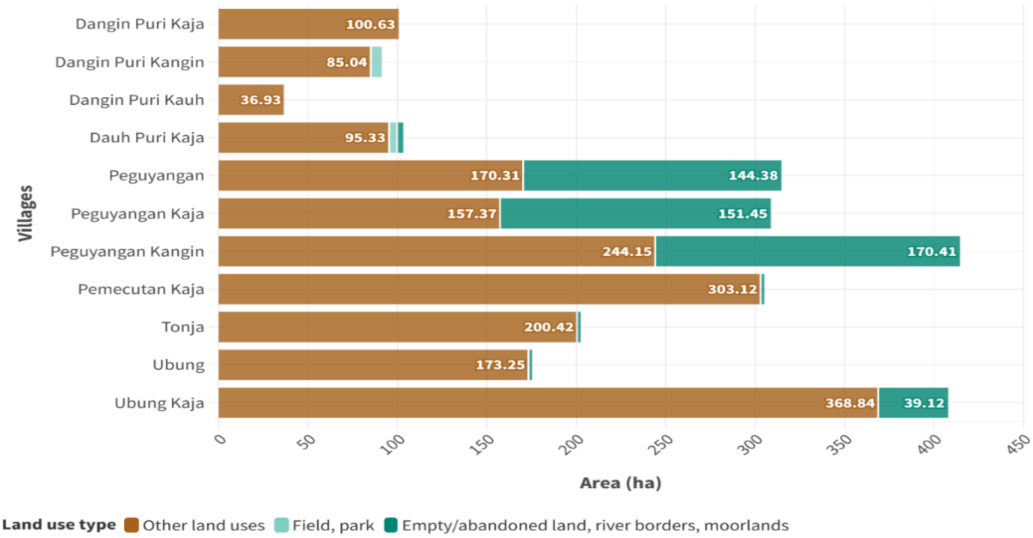

Fig. 6. The details of land use type areas.

The accessibility focuses on three kinds of functions on the road, as mentioned in section 3.2.2; the roads are buffered with 400 m-radius, as shown in Figure 5(b). The arterial roads have areas of 935.80 ha (36.25%), collector roads have areas of 489.46 ha (18.96%), and local and neighborhood road areas have 1,156.13 ha (44.79%). The largest areas designated for each road function are found in Pemecutan Kaja Villages (253.64 ha) for arterial roads, Peguyangan Villages (199.38 ha) for collector roads, and Peguyangan Kangin Villages (421.39 ha) for local and neighborhood roads. The details of accessibility areas are shown in **Fig 7.**

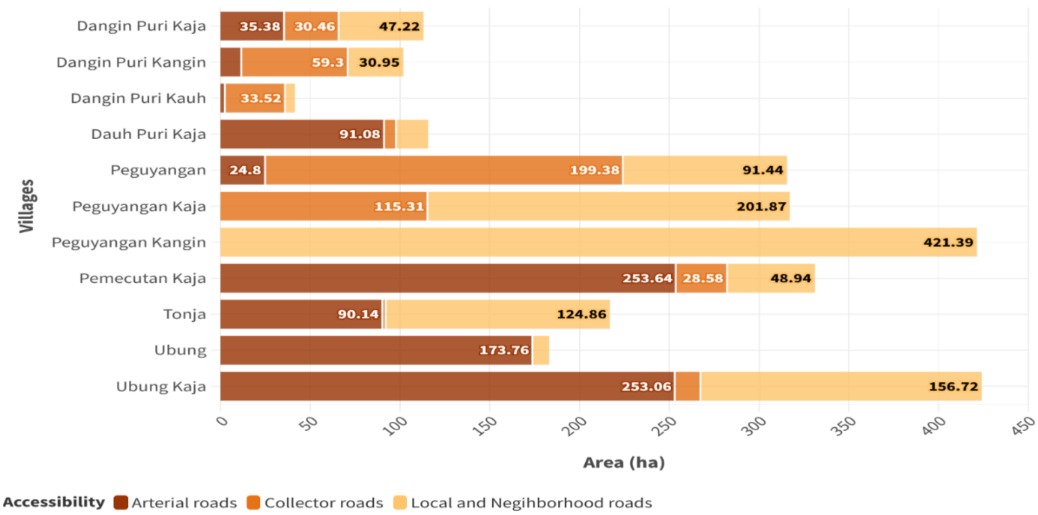

Fig 7. The details of accessibility areas.

The land use pattern is shown in Figure 5(c); it consists of three parameters, this data references are from local government information based on the Denpasar City Spatial Plan for 2021–2041 (Mayor of Denpasar City, 2021). The first parameter is the direction of cultivation areas with areas of 1,946.12 ha (79.08%), the second parameter is the direction of protected areas with areas of 27.51 ha (1.12%), and the last is the direction for urban green open space as the main function with areas 487.20 ha (19.80%). The highest areas for the direction of cultivation areas are in the Ubung Kaja Villages with 368.84 ha. While the direction for protected areas and the direction for urban green open space as the main function, both are in Peguyangan Kangin Villages with 8.70 ha and 161.71 ha, respectively. The details of that are shown in **Fig 8.**

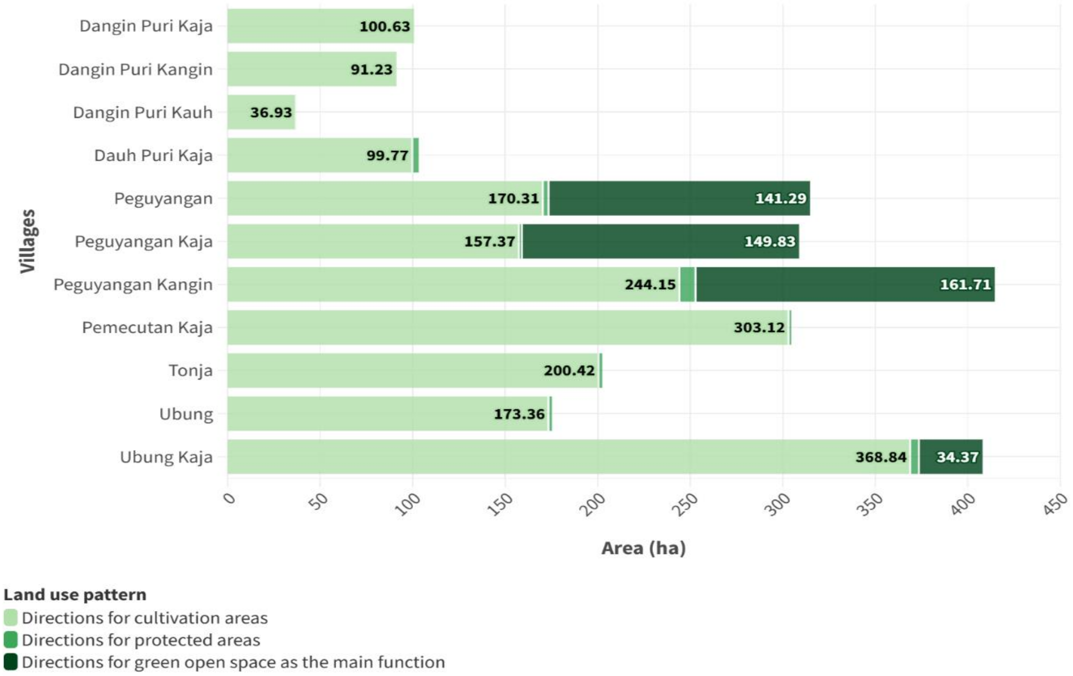

Fig. 8. The details of land use pattern areas.

The land ownership is divided into three classes, i.e., government assets, other than government assets and private land, and private land, as shown in Figure 5(d). The government asset area is 10.63 ha (0.41%), the private land area is 2,450.19 ha (93.96%), and other areas are 147.01 (5.64%). Thus, most land ownership in the North Denpasar Sub-district was owned by private. The Dangin Puri Kangin Villages is the most land owned by the government, with 6.19 ha located in the Ngurah Rai Stadium. Private land owned is in Peguyangan Kangin Villages, which is 414.56 ha, because the total area is larger compared to the other villages. The last for other ownership is located in Pemecutan Kaja Villages with 26.08 ha. The details of the land ownership area are shown in F**ig 9.**

The minimum area of urban green open space was determined by NDVI values, with calculated areas followed in Table 1 after filtering non-vegetation and low vegetation; its spatial distribution is shown in Figure 5(e). The areas with more than equal to 15,000 m² are 1,164.52 ha (93.79%), more than equal to 5,000 m² and less than 15,000 m² are 52.29 ha (4.21%), and more than equal to 250 m² and less than 5,000 m² are 24.78 ha (2.00%). On the level villages, the Peguyangan Kangin village has higher areas for more than 15,000 m² with 289.22 ha areas, for more than 5,000 m² and less than or equal to15,000 m² the Peguyangan Kaja Villages has the higher with areas 6.52 ha. At the same time, more than 250 m² and less than 5,000 m² are in Ubung Kaja Villages with 4.67 ha areas. The details of the minimum area of urban green open space are shown in **Fig 10.**

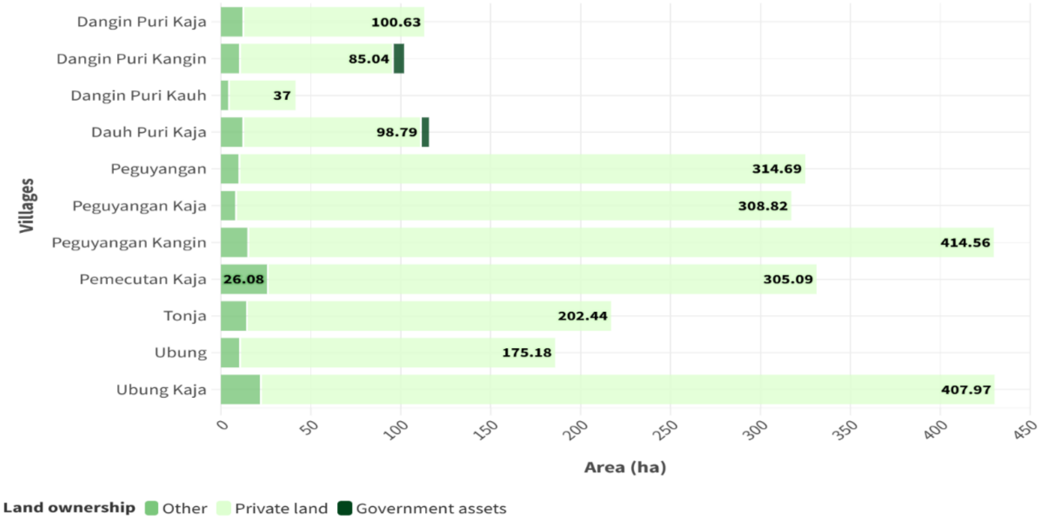

Fig. 9. The details of land ownership.

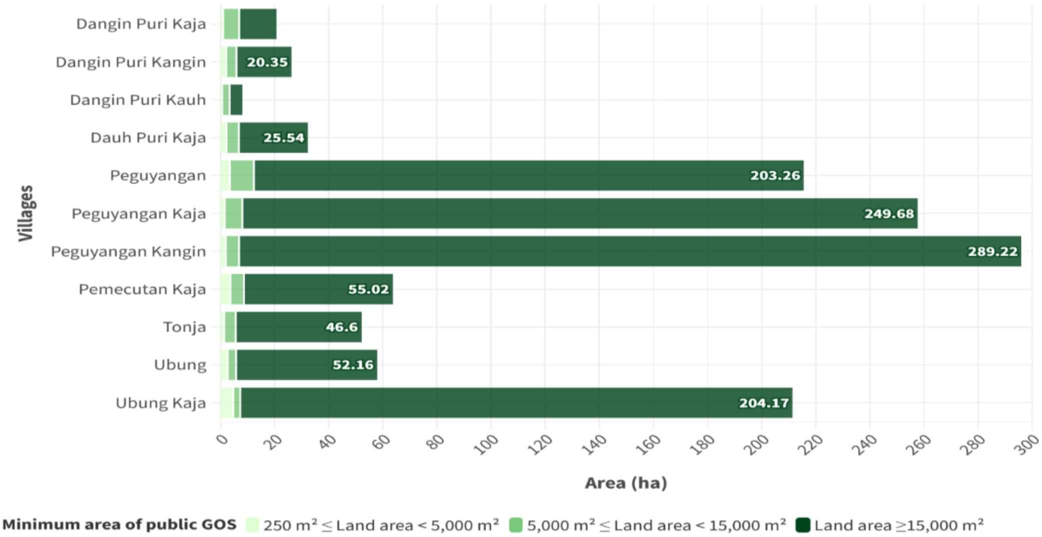

Fig. 10. The details of the minimum area of Green Open Space.

The spatial distribution of "Subak" rice fields is illustrated in Figure 5(f), revealing that rice fields measuring over 20 ha are situated in three distinct locations: Peguyangan, Peguyangan Kaja, and Peguyangan Kangin Village. Additionally, **Fig 11** provides an overview of field distribution within each village. In Peguyangan Village, there are two fields measuring 93.53 ha and 41.19 ha, respectively.

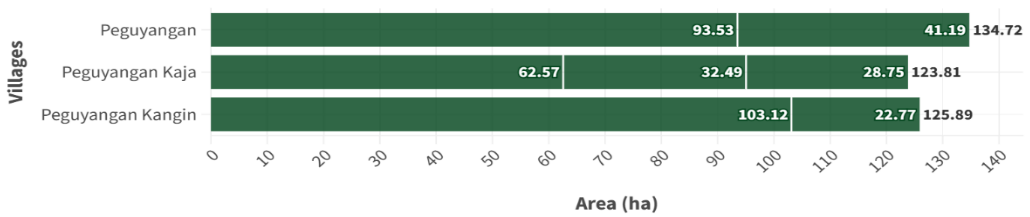

Fig. 11. Distribution of rice fields “Subak” based on villages in North Denpasar District.

Peguyangan Kaja Village boasts the largest field, encompassing three fields measuring 62.57 ha, 32.49 ha, and 28.75 ha, respectively. Finally, in Peguyangan Kangin Village, two rice fields are present, with one encompassing the largest area in the entire region at 103.12 ha, while the other measures 22.77 ha.

4.3. The potential of Green Open Space development

In order to achieve sustainable urban development and investigate the harmonious cohabitation of human activities and the biological environment, green open space planning is a crucial step. The significance of ecological land should be assessed from the viewpoints of both human demand and natural functions when determining the ecological sources of green spaces. Building green spaces encourages the sustainable growth of cities, based on the features and direction of development of the study area as of right now (Bai et al., 2022).

The importance of green open space planning in the North Denpasar Sub-district cannot be overstated, especially in the context of urban resilience. Developing green open spaces is crucial for improving the area's ability to withstand different challenges, including those brought about by climate change. This strategy promotes environmental sustainability and significantly enhances residents' quality of life by providing natural habitats and mitigating urban heat effects (Manoli et al., 2019; Zhou et al., 2019).

The result shows that the primary focus for development is on Ubung Kaja Village due to its alignment with the green open space development directions. The score of 13 is attributed to the privately owned land, which received the highest score among the evaluated areas and covers an area of 2.83 ha. The other location of development direction for other areas for urban green open space only achieved a score of 12, making it the second priority for development. The urban green open space land is located on the collector road and comprises areas between 5,000 m² and 15,000 m². The secondary development priority of urban green open space applies to all villages in North Denpasar Sub-district, but in Dangin Puri Kauh Village, the secondary priority is very limited, covering only 0.07 ha. This is because Dangin Puri Kauh Village has limited space, mostly dominated by man-made structures or built-up areas. The spatial distributions and the total areas of each priority are shown in **Fig 12** and **Fig 13**, respectively. **Fig 14** shows the satellite image of the first priority of urban green open space development.

Reviewing land ownership, government-owned land is only considered for developing second and third-priority green open spaces. Specifically, the villages of Dangin Puri Kangin and Dangin Puri Kauh fall into the second priority category. The Dauh Puri Kaja Village meets the following criteria: park, cultivation area, arterial road, and land area exceeding 15,000 m², situated in Lumintang Park. In contrast, Dauh Puri Kangin meets the following criteria: park, cultivation area, collector road, and land area exceeding 15,000 m², located in Ngurah Rai Stadium.

Considering land ownership, the community and the government need to work together to preserve potential land for open space. The government should take on the role of regulator and educate the public about their responsibility to contribute to maintaining the city's ecosystem to safeguard it. One crucial function of green open space is to serve as an important ecosystem service. Based on an analysis of the spatial pattern of the North Denpasar District, rivers and agricultural land should be the primary focus areas for future development.

Protecting the ecosystem of water areas holds the utmost importance among ecological resources. In order to protect and improve the natural environment of the water area, it is essential to maximize the value of the water area based on local conditions, as indicated by the results of the ecosystem services function analysis. Therefore, implementing intercropping in agricultural production can enhance the ecosystem services of agricultural land and uphold its ecological function and environmental value (Bai et al., 2022; Ludwig et al., 2021). This approach will establish a sustainable agricultural development model centered on biodiversity, particularly given Bali's Indigenous wisdom and cultural heritage known as "Subak", as well as Sustainable Food Crop Land Protection, which must be conserved (Presiden Republik Indonesia, 2009, 2011).

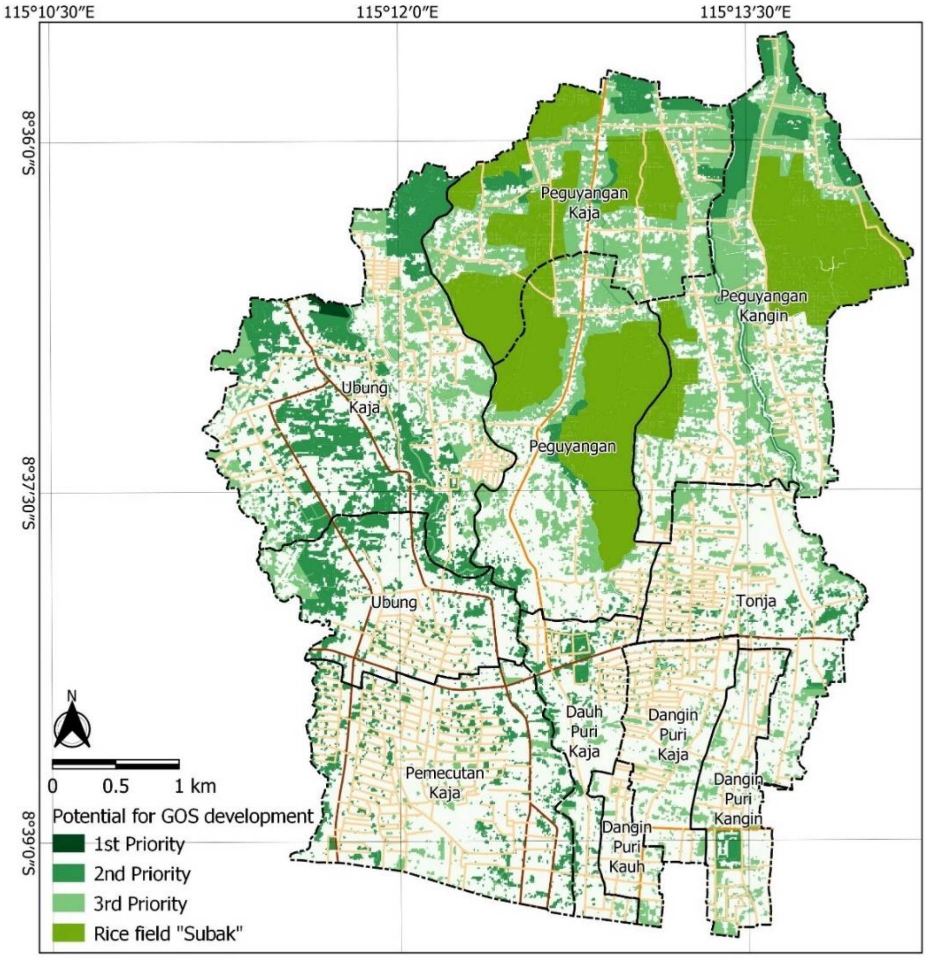

Fig. 12. The potential of Green Open Space development.

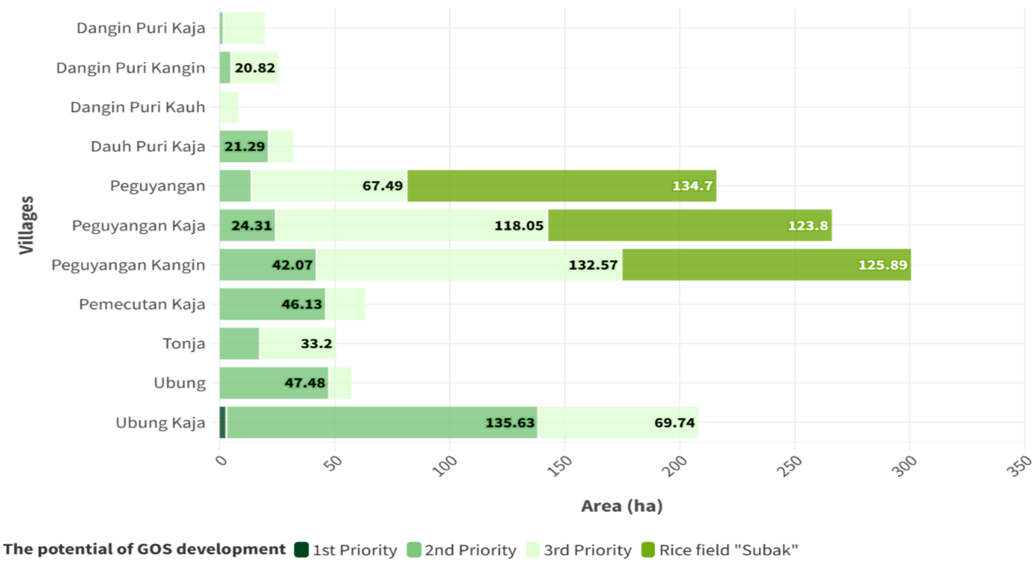

Fig. 13. The details of potential areas of Green Open Space development.

Fig. 14. the Satellite Image of the First Priority of Urban Green Open Space Development in Ubung Kaja Village.

The development of green open space in Ubung Kaja Village will complement the existence of existing green open space in Dauh Puri Kaja Village, namely Lumintang Park. Based on population density data in 2023, Lumintang Park is located in a high population density location in Dauh Puri Kaja Village and is adjacent to villages with high population density, namely Dangin Puri Kaja, Dangin Puri Kauh and Ubung.

The location of green open space development in Ubung Kaja Village is around villages with low population density, namely Peguyangan Village, Peguyangan Kaja, Peguyangan Kangin and Tonja. Although located in a location with low population density, population growth in Denpasar City allows the northern region to become increasingly dense. So the existence of a new green open space area will greatly support the existing area. Accessibility to the location of green open space development in Ubung Kaja Village is supported by national roads, making it easy to get to the location. The average distance of the development location to the existing green open space is within 2.5 kilometers, making it easy to access from and to the existing green open space. **Fig. 15** shows the location of green open space development linked to population density and accessibility.

Previous studies have used multispectral satellite imagery to determine the potential for green open spaces. The method used is using NDVI based on Landsat and Sentinel 2-A satellite imagery (Hasyim & Hernawan, 2017; Wikantiyoso, et al., 2020; Nurdin & Wijayanto, 2020). The use of green open space calculations with NDVI has the advantage of being able to avoid misclassification of other types of land use. NDVI analysis reveals the distribution of vegetation density in Malang City. The distribution of vegetation density is the basis for vegetation density in green open spaces. Temporally, Malik & Shanti (2024) conducted a mapping of changes in green open space in 2018-2022 using Sentinel 2-A satellite imagery due to the earthquake and liquefaction disaster in Palu City in 2018. Sentinel 2-A multitemporal satellite imagery can be used to monitor green open space cover and urban settlements in order to mitigate and rehabilitate land use in the future.

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Multitemporal Sentinel 2-A satellite imagery can be used to monitor green open space cover and urban settlements in order to mitigate and rehabilitate future land use. Meanwhile, this study uses NDVI and parameters to determine the potential for green open space development, namely land use, accessibility/distance from main roads, land ownership, spatial patterns and minimum area of green open space through NDVI analysis. Further research can take into account temporal aspects, population density as one of the parameters and increase the detail of the results by using satellite imagery that has more detailed spatial resolution. Using weighting to determine which parameters are more important for the development of green open space can also taken into account.

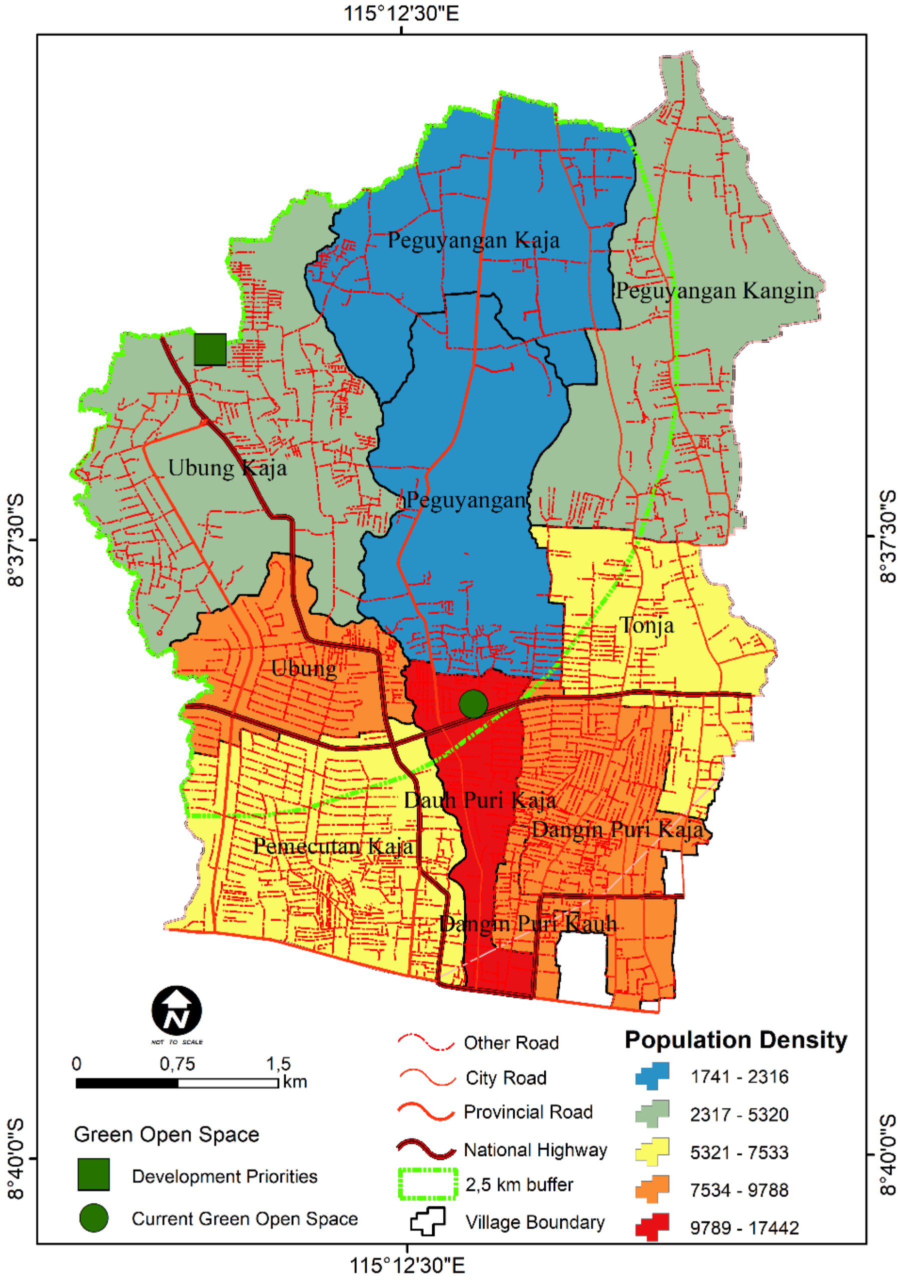

Fig. 15. The location of green open space development linked to population density and accessibility.

5. CONCLUSIONS

The study assesses the potential for creating green spaces in the North Denpasar Sub-district of Denpasar City, Bali, Indonesia. Urban planners should prioritize developing and designing green open spaces due to their numerous ecosystem benefits, including reducing the urban heat island effect, air purification, noise reduction, and carbon dioxide absorption. The analysis used Sentinel-2, which provides high-resolution mapping and tracking of global human settlements, to study vegetation areas. Examining the most recent developments is important with the rapid changes in land use across the city. The evolving trend has also led to limited interaction between residents and green open areas. The changes in cultivated land are primarily driven by urban planning and development in the area. Urban spatial planning has shifted from focusing on economic development to emphasizing capacity, quality, and sustainability. It now identifies the essential components of green open space and integrates ecological demand intensity and ecosystem function to determine the future pattern of green space.

The Ubung Kaja Village has been identified as the most compatible and prioritized location for green open space development, aligning with the specified development guidelines covering 2.83 hectares. Finally, this study will only have a significant impact if the government, as a regulator, enacts regulations concerning green open spaces and if the local community is aware of the importance of maintaining these issues. The research underlines the significance of not overlooking the government's initiatives aimed at preserving Sustainable Food Crop Land along with the local Balinese cultural heritage, particularly the "Subak" rice fields, ensuring their sustainability and maintenance.

Similar research in the future can overcome the shortcomings of this study by increasing the detail of the results by using satellite imagery that has a more detailed spatial resolution, using more parameters and using weighting to determine which parameters are more important for the development of green open space. The results of the potential of green open space in this study can be continued by analyzing green open space problems, such as land use conversion, lack of green belts, and lack of public awareness of the function of green open space. In addition, green open space management strategies, such as planning a green open space master plan, legalizing green open space regulations, and increasing community participation are also important to study.

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