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Heath forest identification using remote sensing in the surrounding area of the new capital city of Indonesia

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Abstract. The construction of Indonesia's new capital city, Nusantara, is envisioned as a forest city that heavily relies on biodiversity. One of the forest ecosystem types surrounding the Nusantara landscape is the heath forest ecosystem, also known as Kerangas. Heath forest is a rare and extreme habitat, thriving in nutrient-poor environments characterized by low pH, quartz sand soil, and podsol soil. However, there is still a lack of knowledge regarding the heath forest in East Kalimantan, particularly in the Nusantara region. This research aims to map the location and characteristics of the heath forest in the surrounding area of Nusantara, specifically in Penajam Paser Utara Regency and Kutai Kartanegara Regency, East Kalimantan. The creation of a tentative heath forest map requires four parameters: elevation, soil texture, NDVI, and a land cover map. Landsat 9 imagery was employed to conduct unsupervised classification and generate a land cover map. The Normalized Difference Vegetation Index (NDVI) was also applied as an image transformation. The parameters were then overlaid using Geographic Information System (GIS) with a binary model. The results indicate that the heath forest covers an area of 56,646 hectares, representing 23% of the total Nusantara area, while the non-heath forest covers 194,610 hectares. The heath forest tentative map aligns with the RePPProT (Regional Physical Planning Project for Transmigration) land system map. Kerangas forests exhibit unique vegetation types, characterized by stunted trees, shrubs, and various epiphytes. Due to the nutrient-poor soil conditions, the vegetation in heath forests is typically sparse and of low height.

1. Introduction

The construction of Indonesia's new capital city, known as Nusantara, has generated significant controversy due to its potential negative impact. The development of Nusantara has raised significant concerns regarding the environment [1,2]. The ecological consequences associated with the development of Nusantara may include the disruption of biodiversity, water scarcity, depletion of carbon stocks in the forests, degradation of the regional landscape, and increased waste pollution [3]. Nevertheless, to address economic inequality in Indonesia, the development of Nusantara must proceed. To ensure its success, the development of Nusantara must adhere to the principles of forest city and priority environmental consideration [3].

The area of Nusantara is encompassed by crucial ecosystems and protected areas [3]. Among these is the heath forest ecosystem, also known as Kerangas, which is notable for its ability to thrive in nutrient-poor soil, low pH, quartz sand soil, and podzol soil [4–6]. These unique conditions render

heath forests highly susceptible to disturbances and make their recovery after degradation challenging [5,7]. Unfortunately, the existence of the heath forest ecosystem is under threat due to changes in land cover resulting from forest fires, conversion to rubber and oil palm plantations, mining activities, illegal logging, and regional development. [4,7,8].

Further study of the heath forest ecosystem is necessary. The heath ecosystem possesses not only potential medicinal vegetation but also plays a crucial role in the environment and forest communities [9,10]. Ecologically, certain vegetation within the ecosystem serves as natural insect pest control and acts as a carbon dioxide (CO_2) gas absorber [11].

However, there remains a lack of knowledge regarding the heath forest in East Kalimantan, particularly in the Nusantara region. Intensive research on heath forests has been conducted in countries like Malaysia [12,13] and Brunei Darussalam [14,15]. Therefore, it is imperative to acquire up-to-date information on the heath forests within the Nusantara area. To effectively implement the concept of a forest city in Nusantara, modern technologies such as remote sensing and geographic information systems (GIS) can be utilized to gather current data and information on the region, including the location and characteristics of the heath forest.

2. Method

2.1. Study area

The research was conducted in the national strategic area (*Kawasan Strategis Nasional* or KSN) surrounding Nusantara, which includes portions of Penajam Paser Utara Regency and Kutai Kartanegara Regency in East Kalimantan (Figure 1). The KSN of Nusantara is also a part of the Sundaland Heath Forest. Sundaland heath forests, also known as Kerangas forests, are a distinct type of tropical forest ecosystem found in the Sundaland region of Southeast Asia. Sundaland encompasses areas in Indonesia, Malaysia, Brunei, and Singapore. These forests thrive in nutrient-poor, sandy soils and are characterized by their unique vegetation and ecological features. However, the Sundaland heath forests now face significant threats from human activities, including logging, conversion to agriculture (particularly for palm oil plantations), mining, and urbanization. These activities result in habitat loss, fragmentation, and degradation, posing a severe risk to the delicate balance of this exceptional ecosystem.

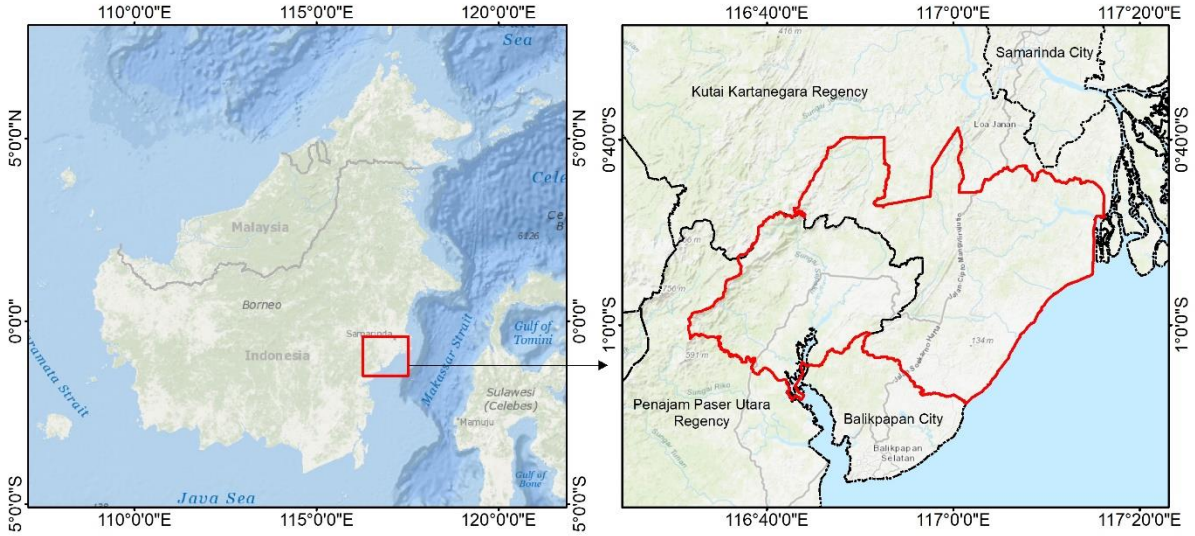

Figure 1. Research location

2.2. Data collection

We employ remote sensing data to generate a preliminary heath forest map. Cloud coverage is considered in the selection of remote-sensing images. Landsat 9 was chosen due to its medium spatial resolution and low cloud coverage. Furthermore, we collected additional data, including elevation information from SRTM and soil texture and soil pH data from zenodo.org. The specific data utilized is presented in Table 1.

Table 1. The data required for generating a tentative heath forest map.

No	Data	Date	Spatial resolution	Source
1.	Landsat 9 Path/Row 116/061	26 April 2022	30 m	https://earthexplorer.usgs.gov/
2.	Landsat 9 Path/Row 117/061	19 May 2022	30 m	https://earthexplorer.usgs.gov/
3.	SRTM	23 Sept 2014	30 m	https://earthexplorer.usgs.gov/
4.	Soil Texture Class (USDA System) for depth 30 cm	Update until 01 January 2018	250 m	https://zenodo.org/record/2525817
5.	Soil pH in H_2O for depth 30 cm	Update until 01 January 2018	250 m	https://zenodo.org/record/2525664

2.3. Remote sensing data processing

Landsat 9 images were corrected to Surface Reflectance (SR) using Semi-Automatic Classification Plugin in QGIS. Then, the Normalized Difference Vegetation Index (NDVI) was calculated as the ratio between the red (R) and near-infrared (NIR) values [16] using the equation:

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

NIR is band 5 and Red is band 4 for Landsat 9.

The subsequent step involved performing an unsupervised classification using the ISO Cluster Classification method in ArcGIS. This unsupervised classification is based on selected classes that represent different land cover types [17], including bare land, built-up areas, water bodies, mangroves, and vegetation with low, moderate, and high density.

2.4. Heath forest tentative map

There are five essential parameters required: elevation, soil texture, NDVI, land cover, and soil pH in H_2O, to create a tentative heath forest map. Elevation information was derived from the SRTM image, while the soil texture and soil pH map were acquired from zenodo.org. The NDVI and land cover maps were generated through image processing of Landsat 9 data.

Table 2. Binary raster code for each parameter

No	Parameters	Description	Raster code	Source
1.	Elevation	Elevation >300 meters	0	[18]
		Elevation ≤ 300 meters	1	
2.	Soil texture	Clay, clay loam, loam	0	[19]
		Sandy clay, sandy clay loam, sandy loam	1	
3.	NDVI	NDVI value ≤ 0	0	[20]
		NDVI value > 0	1	
4.	Landcover	Bare land, built-up area, water body, mangrove	0	[7]
		vegetation	1	
5.	Soil pH in H_2O	Soil pH >5	0	[21]
		Soil pH <5	1	

To generate a preliminary heath forest map, a binary method was employed using Geographic Information System (GIS). This approach is based on the research conducted by Pourghasemi [22], which identifies areas prone to forest fires. The method has also been utilized in multi-criteria decision analysis within forest-dominated landscapes [23]. The parameters were prepared and converted into a binary raster, with a code of 0 indicating the absence and 1 indicating the presence of the heath forest (Table 2).

Furthermore, a raster calculator was used to overlay each parameter using a multiplication formula for each attribute value with the following equation:

$$\text{Heath forest tentative map} = \text{Elevation} \times \text{Soil texture} \times \text{NDVI} \times \text{Landcover} \times \text{Soil} \quad (2)$$

3. Results and Discussions

3.1. Heath forest tentative map

The data needed to establish the heath forest tentative map can be seen in Figure 2. The digital elevation model (DEM) derived from the SRTM image is depicted in Figure 2.a. The national strategic area (KSN) of the Nusantara exhibits elevations of up to 605 meters above sea level. The region predominantly features flat and sloping terrain, with a few hilly areas situated in the western part of the Nusantara. Overall, the topography of the Nusantara area is suitable for the presence of heath forest, which typically thrives in lowland areas with consistently moist climates [5]. According to Maimunah [24], heath forests on Borneo are mainly located between lowland peat-swamp forests and the hilly Dipterocarp Forest. In Sebulu, Kutai Kartanegara Regency, heath forest clusters are found on flatland, even in areas where the surrounding dipterocarp forest terrain is hilly [18].

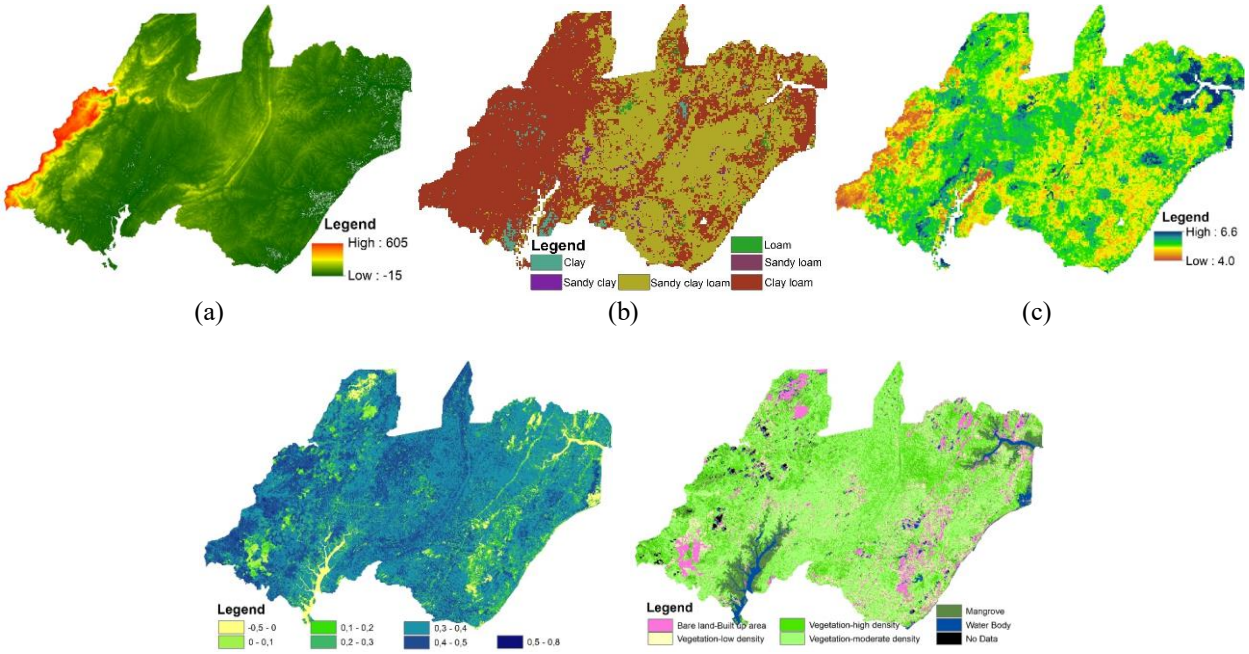

Figure 2. The input data required for generating the heath forest indication map includes the following parameters: (a) elevation, (b) soil texture, (c) soil pH in H_2O, (d) NDVI, and (e) land cover.

Figure 2b. displays the soil texture in the Nusantara area at a depth of 30 cm, obtained from zenodo.org. Within the study area, six soil texture types, classified according to USDA classification, can be identified: clay, sandy clay, clay loam, sandy clay loam, loam, and sandy loam. The geological composition of the Samboja area in Kutai Kartanegara Regency is part of the Balikpapan Formation,

which consists of quartzite sandstone, silt claystone, shale with marl intercalations, limestone, and coal [25]. In Wanariset Samboja, the dominant soil types are Hapludults and Dystropepets, with soil textures ranging from sandy to sandy clay loam and sandy to sandy loam [26]. Being part of central Sundaland, Borneo is characterized by sandy soils, giving rise to swamp and heath forests [27]. Heath forests, located between lowland and swamp forests, are distinguished by the prevalence of sandy and shallow peat layers [24].

The soil pH at a depth of 30cm in the study area ranges from 4.2 to 6.6, as shown in Figure 2.c. According to Batjes [28], the soil pH (H_2O) characterization can be classified into very strongly and strongly acid ($4.0 < pH \leq 5.5$), as well as moderately acid, slightly acid, and neutral ($5.5 < pH \leq 7.3$). In specific heath habitats, the podzol soil type is commonly found, exhibiting a pH range of 4.4 to 6.1 within the 0-30cm depth [28]. The soil pH in heath forests can vary due to distinct ecosystem characteristics and underlying geology, but these forests are typically associated with acidic soils. Typically, the pH of such soils falls within the range of moderately acidic to strongly acidic [14,21].

NDVI and land cover maps were generated through the processing of Landsat 9 images. The NDVI values within the study area range from -0.478 to 0.837. As depicted in Figure 2.d, higher NDVI values are observed in hilly relief areas compared to flat relief areas near the coastal regions. NDVI serves as an estimate of "greenness" by analyzing satellite imagery. It also serves as an indicator of vegetation health and ecosystem degradation. Decreased NDVI values reflect degraded vegetation within the ecosystem. [29].

The unsupervised classification of multispectral images resulted in the identification of seven land cover classes: bare land-built-up area, water body, mangrove, vegetation-low density, vegetation-moderate density, vegetation-high density, and no data (Figure 2.e). Mangrove and water bodies exhibit distinct spectral reflection patterns, allowing for easy differentiation from other objects [30,31]. However, bare land and built-up areas exhibit similar spectral reflection patterns [32], resulting in their classification as a single class. The "no data" class corresponds to areas covered by clouds and cloud shadows. The land cover map highlights several activities that involve land clearing, such as mining, road construction, and settlements.

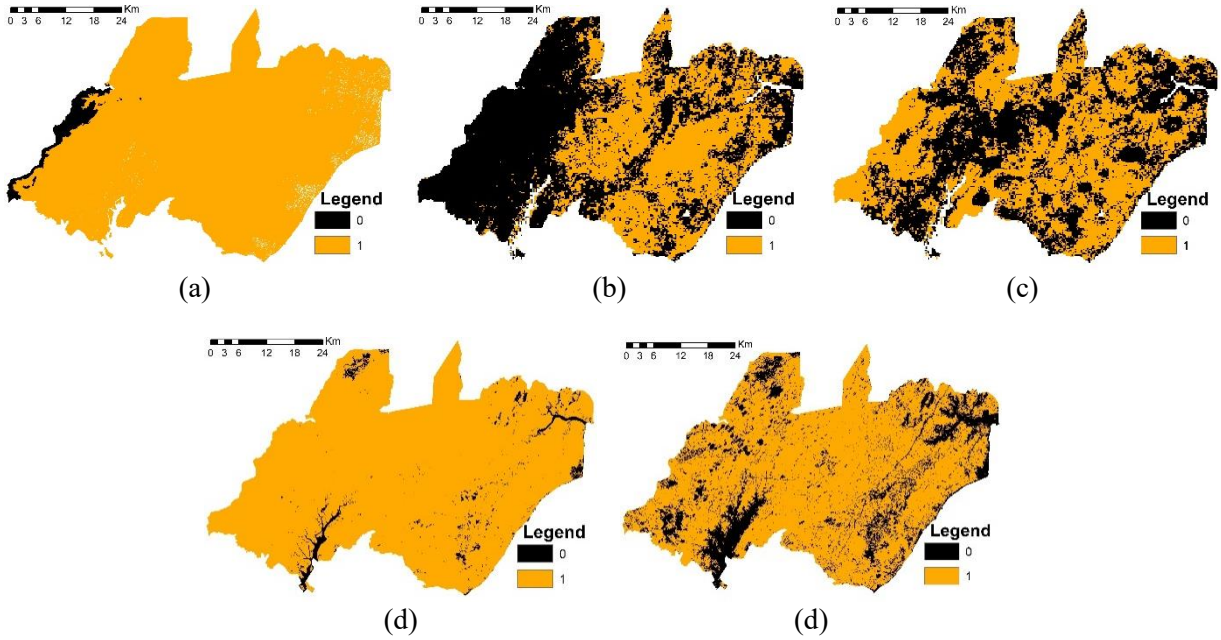

Figure 3. Raster binary code for each parameter, (a) elevation, (b) soil texture, (c) soil pH in H_2O, (d) NDVI, and (e) land cover

The data was transformed into binary codes, representing two classes: a value of 0 indicating no indication of heath forest (depicted in black), and a value of 1 indicating the presence of heath forest (depicted in orange) (Figure 3). By analyzing the elevation data (Figure 3.a) and soil texture (Figure 3.b), it can be observed that the western part of Nusantara is not suitable as a heath forest habitat. Unlike soil texture, suitable and unsuitable soil pH for heath habitats is distributed across the entire Nusantara area (Figure 3.c). Furthermore, the NDVI data (Figure 3.d) displays zero values near the coastal area and scattered in other locations. The binary representation of the land cover (Figure 3.e) clarifies that the presence of mangroves near the coastal area excludes the possibility of heath forest habitat.

The maps illustrating the potential heath forest areas resulting from GIS analysis can be observed in Figure 4. This composite map combines data from band 6 (short wavelength infrared or SWIR), band 5 (near infra-red or NIR), and band 4 (red). Vegetation is depicted in green color. Based on the calculations, the identified heath forest region covers 56,646 hectares, which corresponds to 23% of the total Nusantara area. Conversely, non-heath forest areas span 194,610 hectares. The heath forest indication primarily occurs within the central portion of the Nusantara boundary and extends to the flat terrain sections.

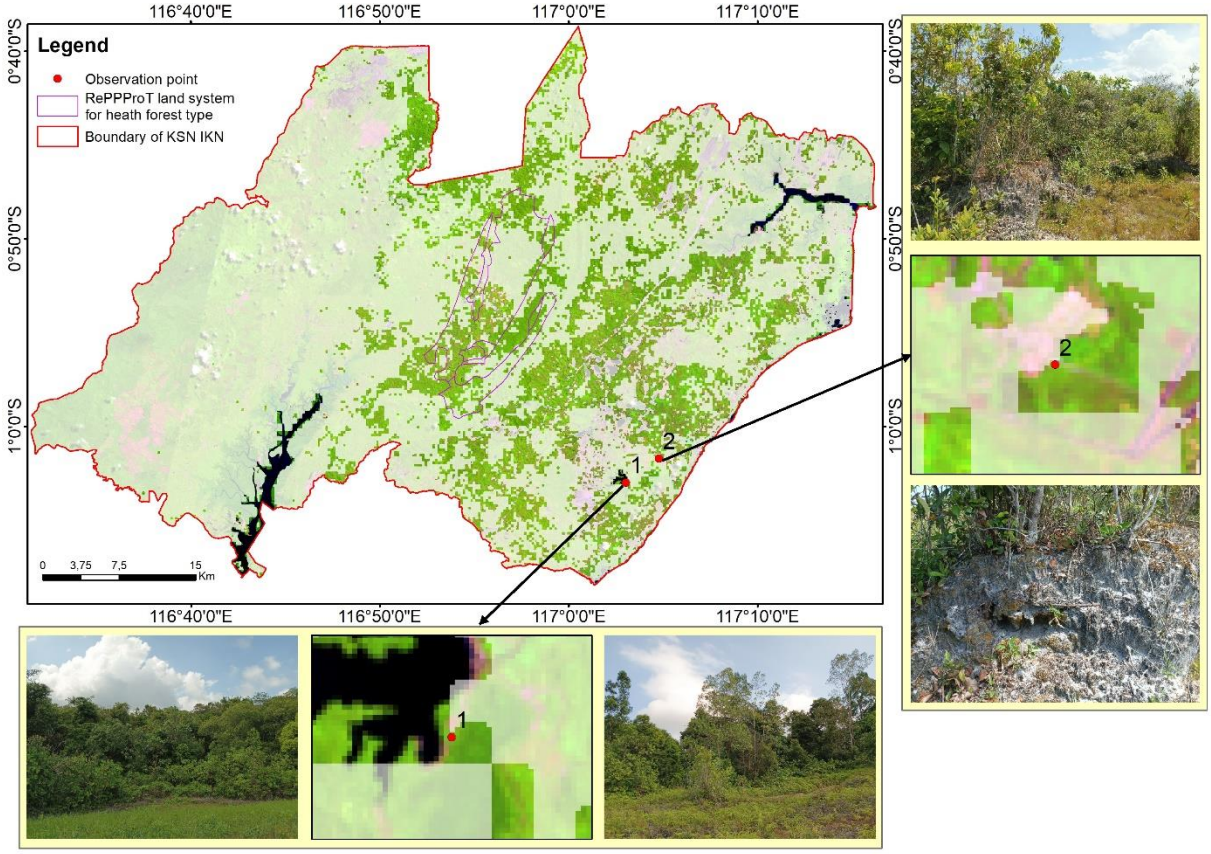

Figure 4. Distribution of heath forest indication

The preliminary heath forest map was further overlaid with the RePPProT (Regional Physical Planning Project for Transmigration) land system map. This allowed for the identification of specific ecosystem types, such as kerangas, as indicated in the RePPProT Land System Map [33]. In Figure 4, the heath ecosystem type is highlighted with a purple line. The land system maps provide key characteristics of the heath ecosystem, including an elevation range of 0-500 meters (lowland area), slope range of 0-5 degrees, and landforms consisting of mountainous sandstone cuestas with dissected dipslopes.

The observation of heath forest was conducted in two locations. The selection of observation sites was informed by the research findings of Riswan [19,34] on Gunung Pasir, Samboja and Rujehan [35] in the Samboja Reservoir. The first location near Samboja reservoir exhibits characteristics of a heath habitat, including sandy soil and moderate to high-density vegetation. The second location is near Wonotiro sub-district office called "Gunung Pasir". In Gunung Pasir, the vegetation is dominantly composed of shrubs, with a low to moderate vegetation density, and most of the area has a sandy soil texture. Oktavia [7] reported that there are three habitat types of vegetation composition and structure in East Belitung, namely grassland (padang), secondary heath forest (bebak) and primary heath forest (rimba). Similarly, the vegetation composition and structure of the Kerangas forest in Sebulu referred to as Padang due to its dominance of shrub and short tree species [36]. The two locations might be classified as padang and bebak structures.

3.2. Vegetation characteristics

During our fieldwork, we were able to directly observe several plant species, including *Nepenthes gracilis*, *Rhodomyrtus tomentosa,* and *Melastoma malabathricum* (Figure 5). *Nepenthes gracilis*, in particular, serves as an indicator of low soil nutrients, often found in areas with high sand quartz content [37–39]. Kerangas is one of the habitats where *Nepenthes gracilis* can be found [37,40]. This species is commonly encountered in disturbed forest areas across Kalimantan, Sumatra, Sulawesi, and Peninsular Malaysia [41]. It has also been documented in former tin mining sites [7]. Despite its relatively easy accessibility, *Nepenthes gracilis* is listed under Appendix II of the Convention on International Trade in Endangered Species (CITES) [42].

(a) (b) (c)

Figure 5. Species of vegetation founded in the field (a) *Nepenthes gracilis* (b) *Rhodomyrtus tomentosa* (c) *Melastoma malabathricum*

Rhodomyrtus tomentosa is a flowering plant belonging to the Myrtaceae family, and it is widely distributed throughout Southeast Asia [10,43]. Local communities, including the Chinese, Vietnamese, and Dayak, regard this plant as a remedy for diarrhea [43]. *Rhodomyrtus tomentosa* demonstrates remarkable adaptability to sandy soils, making it a valuable choice for rehabilitating former tin mining sites in Bangka Belitung [44]. Additionally, it is commonly employed as a plant species to prevent erosion [45]. During our observations, we also encountered *Melastoma malabathricum* close to *Rhodomyrtus tomentosa. Melastoma malabathricum*, a shrub-like invasive species [46], is known to dominate open areas and disturbed sections within heath forest areas in Belitung, functioning as a pioneer species [7].

Rhodomyrtus tomentosa and *Melastoma malabathricum* are shrub or small tree species. These characteristics align with the vegetation composition of Kerangas in Belitung, where the dominant plant family is Myrtaceae, consisting of woody plants that do not grow tall [7,39]. This observation is

consistent with the vegetation composition found in the Kersik Luway Nature Reserve [10]. Both *Rhodomyrtus tomentosa* and *Melastoma malabathricum* can be found in disturbed Kerangas forests [36], similar to *Nepenthes gracilis*.

Similar to many other forest areas, the Kerangas forest area in the new capital city has also faced disturbances. During our observations, we noted the presence of community-owned oil palm plantations in the first location near Samboja reservoir. Furthermore, the Gunung Pasir area is designated as a Type C quarry mining site, specifically for sand extraction. Notably, this area has been documented as a research site for studying vegetation succession in Kerangas forests following forest fires [19]. The ongoing land clearing activities in both locations serve as indications of the significant population growth in the area. This is evident from the increasing number of residential and office building developments in the Gunung Pasir area.

4. Conclusion

Biodiversity plays a vital role in the development of Indonesia's new capital city, which is designed as a forest city. The Kerangas ecosystem, also known as heath forests, is a unique type of tropical forest found in the vicinity of the IKN. It possesses distinct characteristics that set it apart from other forest types. Remote sensing technology enables the identification of locations classified as heath forests. Five parameters are employed to gather information about the kerangas habitat, which include elevation, soil texture, soil pH, NDVI, and land cover. The heath forest area covers 23% of the IKN region and is predominantly distributed in areas with flat terrain. The vegetation within Kerangas forests has adapted to the challenging conditions of nutrient-deficient soils. Notable plant species found in the heath area include *Nepenthes gracilis*, *Rhodomyrtus tomentosa*, and *Melastoma malabathricum*. Unfortunately, the heath ecosystem faces significant threats from human activities, particularly the conversion of land for palm oil plantations and urbanization. To enhance future research efforts, it is recommended to incorporate additional comprehensive parameters for determining heath forest habitats. These parameters could include factors such as soil types, land use, mining concessions, distribution of plantations, and other relevant variables.

References

[1] Mutaqin D J, Muslim M B and Rahayu N H 2021 Analisis Konsep Forest City dalam Rencana Pembangunan Ibu Kota Negara *Bappenas Work. Pap.* **4** 13–29
[2] Ichwan M, Reskiani U and Makmur A 2022 Green Economy: Bentuk Pengoptimalan Konsep Forest City dalam Rencana Pembangunan Ibu Kota Negara *J. Legis.* 115–25
[3] Rahayu N H 2022 Safeguard Lingkungan “kota dunia untuk semua” *STANDAR Better Stand. Better Living* **1** 52–6
[4] Onrizal O, Kusmana C, Saharjo B H, Handayani I P and Kato T 2005 Species composition and structure of ex-burned heath forest in Danau Sentarum National Park, West Kalimantan *Biodiversitas J. Biol. Divers.* **6** 263–5
[5] Hilwan I 2015 Biophysical Characteristic in Various Conditions of Heath Forest in East Belitung Residence, Province of Bangka Belitung Islands Karakteristik Biofisik Pada Berbagai Kondisi Hutan Kerangas Di Kabupaten Belitung Timur, Provinsi Kepulauan Bangka Belitung *J. Silvikultur Trop.* **6** 59–65
[6] Sellan G, Thompson J, Majalap N and Brearley F Q 2019 Soil characteristics influence species composition and forest structure differentially among tree size classes in a Bornean heath forest *Plant Soil*
[7] Oktavia D, Pratiwi S D, Munawaroh S, Hikmat A and Hilwan I 2021 Floristic composition and species diversity in three habitat types of heath forest in belitung island, Indonesia *Biodiversitas* **22** 5555–63
[8] Sunardi and Mansur M 2021 Abundance, associations and habitat threats of Nepenthes bicalcarata Hook.f. in Mandor Nature Reserve, West Kalimantan *Bul. Kebun Raya* **24** 66–75
[9] Puspaningtyas D M and Fatimah E 1999 Inventory of orchid species at Kersik Luway Nature

Reserve, East Kalimantan *Bul. Kebun Raya Indones.* **9** 18–25
[10] Hartini S 2007 Keragaman Flora dari Monumen Alam Kersik Luway, Kalimantan Timur *Biodiversitas* **8** 67–72
[11] Mansur M 2017 Potency of CO2 Absorption of Lowland Pitcher Plants (Nepenthes spp.) *Ber. Biol.* **16**
[12] Syuharni A W, Hakeem K R, Faridah-Hanum I, Alias M S and Ozturk M 2014 Ecology of the coastal heath forest flora - A case study from Terengganu, Malaysia *Emirates J. Food Agric.* **26** 1114–23
[13] Sellan G, Thompson J, Majalap N, Robert R and Brearley F Q 2020 Impact of soil nitrogen availability and pH on tropical heath forest organic matter decomposition and decomposer activity *Pedobiologia (Jena).* **80** 150645
[14] Din H, Metali F and Sukri R S 2015 Tree diversity and community composition of the tutong white sands, Brunei darussalam: A rare tropical heath forest ecosystem *Int. J. Ecol.* **2015**
[15] Tuah W H, Udayanga K T, Jaafar S M and Sukri R S 2020 Post-fire impacts on tree diversity in coastal heath forests of Brunei Darussalam *Sci. Bruneiana* **19**
[16] USGS 2022 Landsat Normalized Difference Vegetation Index | U.S. Geological Survey *Landsat Mission.*
[17] Lemenkova P 2021 ISO Cluster classifier by ArcGIS for unsupervised classification of the Landsat TM image of Reykjavík *Bull. Nat. Sci. Res.* **11** 29–37
[18] Kartawinata K 1980 A note on Kerangas (heath) forest at Sebulu, East Kalimantan *Reinwardtia* **9** 377–479
[19] Riswan S and Kartawinata K 1991 Species Strategy in Early Stage of Secondary Succession Associated with Soil Properties Status in a Lowland Mixed Dipterocarp Forest and Kerangas Forest in East Kalimantan *Tropics* **1** 13–34
[20] Jeevalakshmi D, Reddy S N and Manikiam B 2016 Land cover classification based on NDVI using LANDSAT8 time series: A case study Tirupati region *Int. Conf. Commun. Signal Process. ICCSP 2016* **560056** 1332–5
[21] Oktavia D, Setiadi Y and Hilwan I 2015 The Comparison of Soil Properties in Heath Forest and Post-tin Mined Land: Basic for Ecosystem Restoration *Procedia Environ. Sci.* **28** 124–31
[22] Pourghasemi H R 2016 GIS-based forest fire susceptibility mapping in Iran: a comparison between evidential belief function and binary logistic regression models *Scand. J. For. Res.* **31** 80–98
[23] Greene R, Luther J E, Devillers R and Eddy B 2010 An approach to GIS-based multiple criteria decision analysis that integrates exploration and evaluation phases: Case study in a forest-dominated landscape *For. Ecol. Manage.* **260** 2102–14
[24] Maimunah S, Capilla B R, Armadiyanto and Harrison M E 2019 Tree diversity and forest composition of a Bornean heath forest, Indonesia *IOP Conf. Ser. Earth Environ. Sci.* **270**
[25] Zakaria Z, Dipatunggoro G and Haryanto E T 2007 Karakteristik Tanah Lempung Lapukan Formasi Balikpapan Di Samboja, Kalimantan Timur *Bull. Sci. Contrib.* **5** 209
[26] Mulyadi M and Arruan D 2019 Kajian Penilaian Kesuburan Tanah Tegakan Dipterocarpaceae dan Non Dipterocarpaceae di Wanariset Samboja, Kalimantan Timur *J. Agroekoteknologi Trop. Lembab* **2** 79
[27] Raes N, Cannon C H, Hijmans R J, Piessens T, Saw L G, Van Welzen P C and Ferry Slik J W 2014 Historical distribution of Sundaland's Dipterocarp rainforests at Quaternary glacial maxima *Proc. Natl. Acad. Sci. U. S. A.* **111** 16790–5
[28] Batjes N 1995 *A global data set of soil pH properties* vol 27
[29] Meneses-Tovar C L 2011 NDVI as indicator of degradation *Unasylva* **62** 39–46
[30] Kuenzer C, Bluemel A, Gebhardt S, Quoc T V and Dech S 2011 Remote sensing of mangrove ecosystems: A review *Remote Sens.* **3** 878–928
[31] Kamal M and Phinn S 2011 Hyperspectral data for mangrove species mapping: A comparison of pixel-based and object-based approach *Remote Sens.* **3** 2222–42

[32] As-syakur A R, Adnyana I W S, Arthana I W and Nuarsa I W 2012 Enhanced built-UP and bareness index (EBBI) for mapping built-up and bare land in an urban area *Remote Sens.* **4** 2957–70
[33] Sulistioadi Y B, Rustam, Wahyudi D, Mulyadi R, Sari U K, Setiawati, Jufriansyah and Nasir M 2017 *Identifikasi Kawasan Bernilai Konservasi Tinggi (KBKT/HCV) pada Skala Bentang Lahan di Provinsi Kalimantan Timur* vol 1
[34] Riswan S 1985 Nitrogen Content of Topsoil in Lowland Tropical Forest in East Kalimantan (Indonesia), Before and After Clear-Cutting and Burning *Rein* **10** 131–8
[35] Rujehan and Matius P 2018 Potential and management strategy of floral biodiversity in the coastal areas in East Kalimantan, Indonesia *Biodiversitas* **19** 1130–7
[36] MacKinnon K, Hatta G, Halim H and Mangalik A 1997 *The Ecology of Kalimantan (Volume 3)*
[37] Mansur M 2013 Tinjauan Tentang Nepenthes (Nepenthaceae) Di Indonesia *Ber. Biol.* **12** 1–7
[38] Kissinger, Rina M N P, Zuhud E A M, Latifah K D and Iskandar Z S 2015 Analisis Fungsi Nepenthes gracilis Korth. Terhadap Lingkungan Hutan Kerangas *J. Hutan Trop.* **3** 61–6
[39] Robiansyah, Hidayati N A and Santi R 2018 Keanekaragaman dan komposisi vegetasi penyusun habitat Nepenthes di hutan Kerangas Dusun Tuing, Kabupaten Bangka *Pros Sem Nas Masy Biodiv Indon* **4** 254–260
[40] Mansur M, Brearley F and Haq J R 2020 Diversity, abundance and ethnobotany of Nepenthes in Mandor Nature Reserve, West Kalimantan, Indonesia *Planta Carniv. J.*
[41] Adam J H, Wilcock C C and Swaine M D 1992 The ecology and distribution of Bornean Nepenthes *Garden* **5** 13–25
[42] UNEP-WCMC 2021 *Checklist of CITES Species* (Geneva, Switzerland-Cambridge,United Kingdom)
[43] Vo T S and Ngo D H 2019 The health beneficial properties of rhodomyrtus tomentosa as potential functional food *Biomolecules* **9** 1–16
[44] Fadhillah M, Nadila D and Febriyani M 2011 *Potensi Karamunting (Rhodomyrtus tomentosa) Sebagai Tumbuhan Lokal Dalam Perbaikan dan Pemanfaatan Lahan Bekas Tambang Timah di Bangka Belitung* (Bogor)
[45] Halim A and Normaniza O 2015 The effects of plant density of Melastoma malabathricum on the erosion rate of slope soil at different slope orientations *Int. J. Sediment Res.* **30** 131–41
[46] Master J, Qayim I, Setiadi D and Santoso N 2020 Autecology of melastoma malabathricum, an invasive species in the way Kambas National park, Indonesia *Biodiversitas* **21** 2303–10