



Beyond H2O

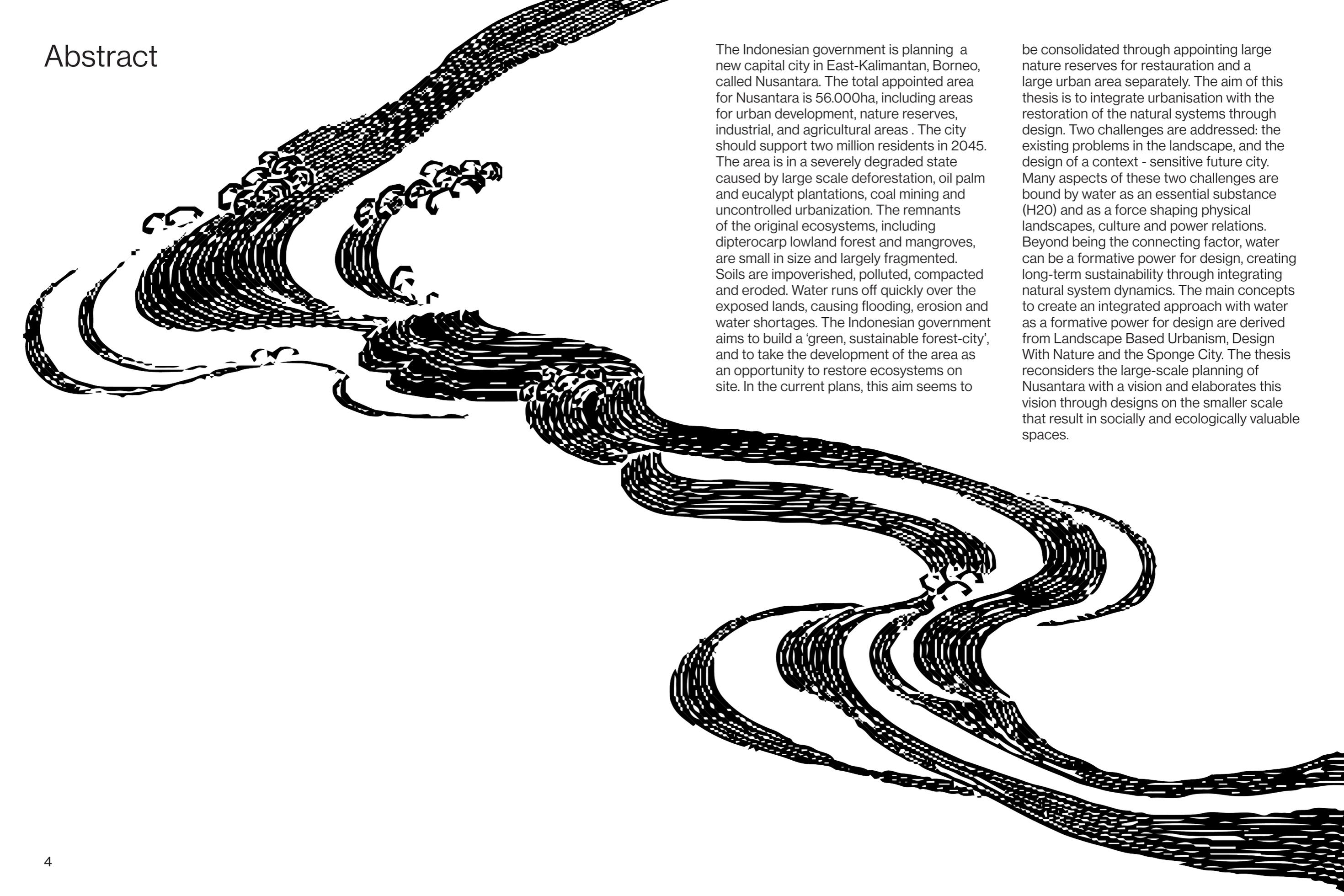
**Water-based landscape
architecture in Nusantara**

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Abstract



The Indonesian government is planning a new capital city in East-Kalimantan, Borneo, called Nusantara. The total appointed area for Nusantara is 56.000ha, including areas for urban development, nature reserves, industrial, and agricultural areas. The city should support two million residents in 2045. The area is in a severely degraded state caused by large scale deforestation, oil palm and eucalypt plantations, coal mining and uncontrolled urbanization. The remnants of the original ecosystems, including dipterocarp lowland forest and mangroves, are small in size and largely fragmented. Soils are impoverished, polluted, compacted and eroded. Water runs off quickly over the exposed lands, causing flooding, erosion and water shortages. The Indonesian government aims to build a 'green, sustainable forest-city', and to take the development of the area as an opportunity to restore ecosystems on site. In the current plans, this aim seems to

be consolidated through appointing large nature reserves for restoration and a large urban area separately. The aim of this thesis is to integrate urbanisation with the restoration of the natural systems through design. Two challenges are addressed: the existing problems in the landscape, and the design of a context - sensitive future city. Many aspects of these two challenges are bound by water as an essential substance (H₂O) and as a force shaping physical landscapes, culture and power relations. Beyond being the connecting factor, water can be a formative power for design, creating long-term sustainability through integrating natural system dynamics. The main concepts to create an integrated approach with water as a formative power for design are derived from Landscape Based Urbanism, Design With Nature and the Sponge City. The thesis reconsiders the large-scale planning of Nusantara with a vision and elaborates this vision through designs on the smaller scale that result in socially and ecologically valuable spaces.

Fascination & position

Water is a connector of all systems; cultural and natural, urban and rural, above- and underground, land and sea. This position of water in the landscape made me interested in the role it can play in understanding the connectivity of the landscape systems. Every urban or landscape designer should understand the systems within which his or her design will land, 'just as the specialists in the hospital are expected to keep an eye on the whole person' (Tjallingii 2015).

My views on Borneo, as childhood reference of 'the big wild jungle', have been drastically deromanticized; it is not anymore as pristine as it was. By some, the new capital is feared to increase negative effects of human intervention on the fragile ecosystems and indigenous people in the area through land clearing, resource extractions, water depletion, environmental pollution, etc. (Syaban & Appiah-Opoku, 2024). Many of these issues cannot be solved by landscape architecture, as they depend on political decisions and management.

However, landscape architects should be optimistic, as we design a new future. I believe that landscape architecture can play a positive role not only through developing landscape - based designs for urbanization, but also through making the complex range of challenges and opportunities in the landscape visual, contributing to discussions among specialists, planners, policy makers, civilians and designers.

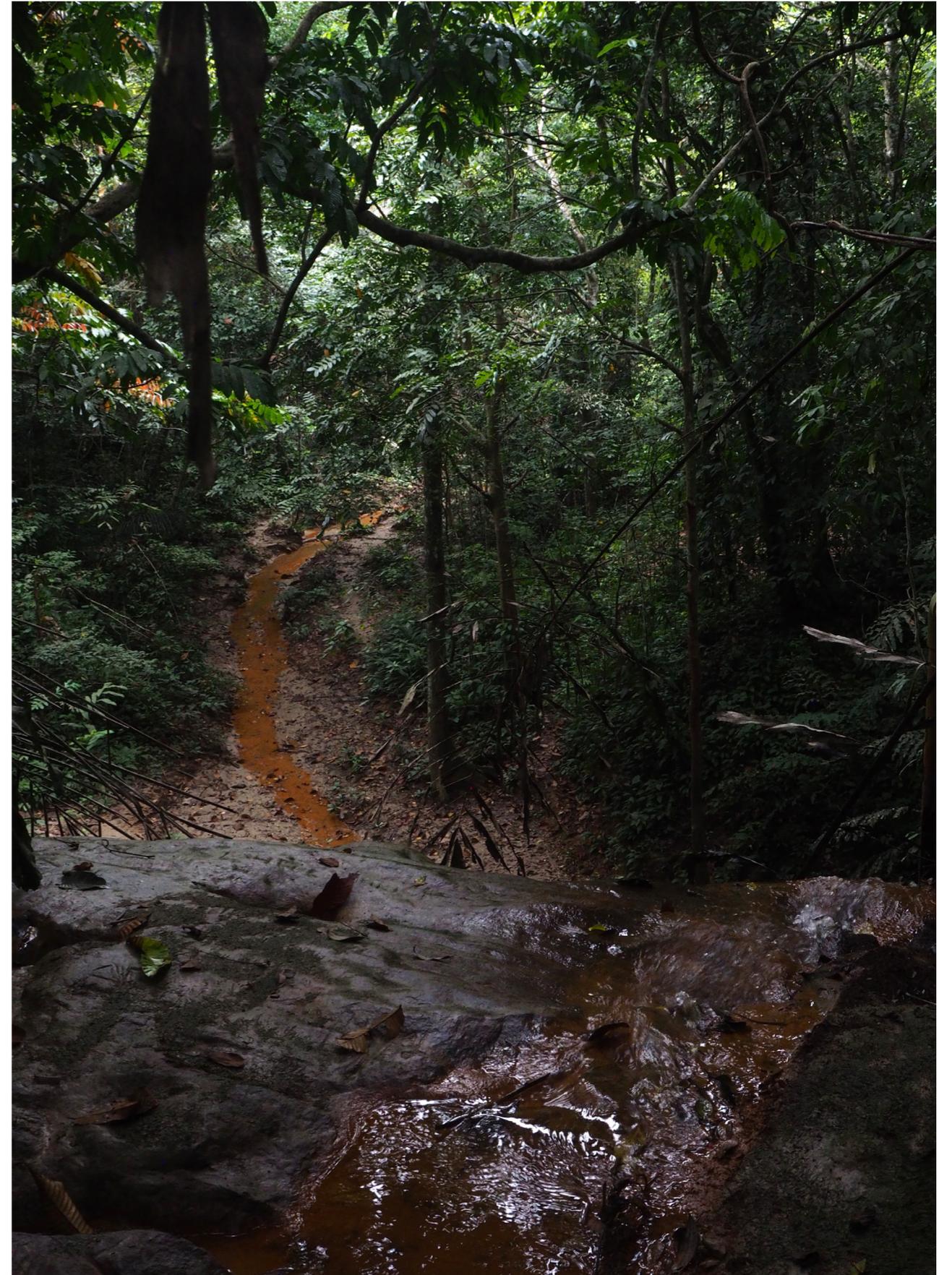


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1.

Introduction

Indonesia's need for a new capital

The story starts with Jakarta, the current capital city of Indonesia. Jakarta, located on Java Island, faces problems with overcrowding, land subsidence, flooding, and air pollution. This led the Indonesian government to the decision to build a new capital city, called Nusantara, on East – Kalimantan, Borneo (Kurniawan et al., 2021; Syaban & Appiah-Opoku, 2024). The name Nusantara refers to the Indonesian archipelago as a whole, which symbolizes the aim of the Indonesian government to increase cohesion and to create a feeling of unity between the islands (Gokkon, 2023). The movement of the capital fits in a trend of the relocation of capitals from colonial epicentres to locations that symbolize national unity and independence (Syaban & Appiah-Opoku, 2024). The idea for the creation of a new capital city in East – Kalimantan is not new; president Soekarno had already given commission for calculations that showed a nearby location as the geographical centre of the Indonesian archipelago (NOS, 2024). The central location of Nusantara is meant to support economic development throughout Indonesia, whereas it is now very much centred on the island of Java (Kurniawan et al., 2021; Syaban & Appiah-Opoku, 2024). Furthermore, the capital's new location on Borneo holds many natural resources and is located away from seismic zones and volcanoes, reducing natural disaster risk (Kurniawan et al., 2021)

The Indonesian government aims for Nusantara to become a green and sustainable 'forest city' (Adinugroho et al., 2022), that should accommodate two million people by 2045 (Gokkon, 2023). The first constructions have already started with the administrative centre, which will be inhabited by government workers and their families (Gokkon, 2023)

However the aim for Nusantara is to be a green and sustainable forest city, criticisms have risen. Beside questions about political continuity and economic feasibility, the plan is feared to increase environmental



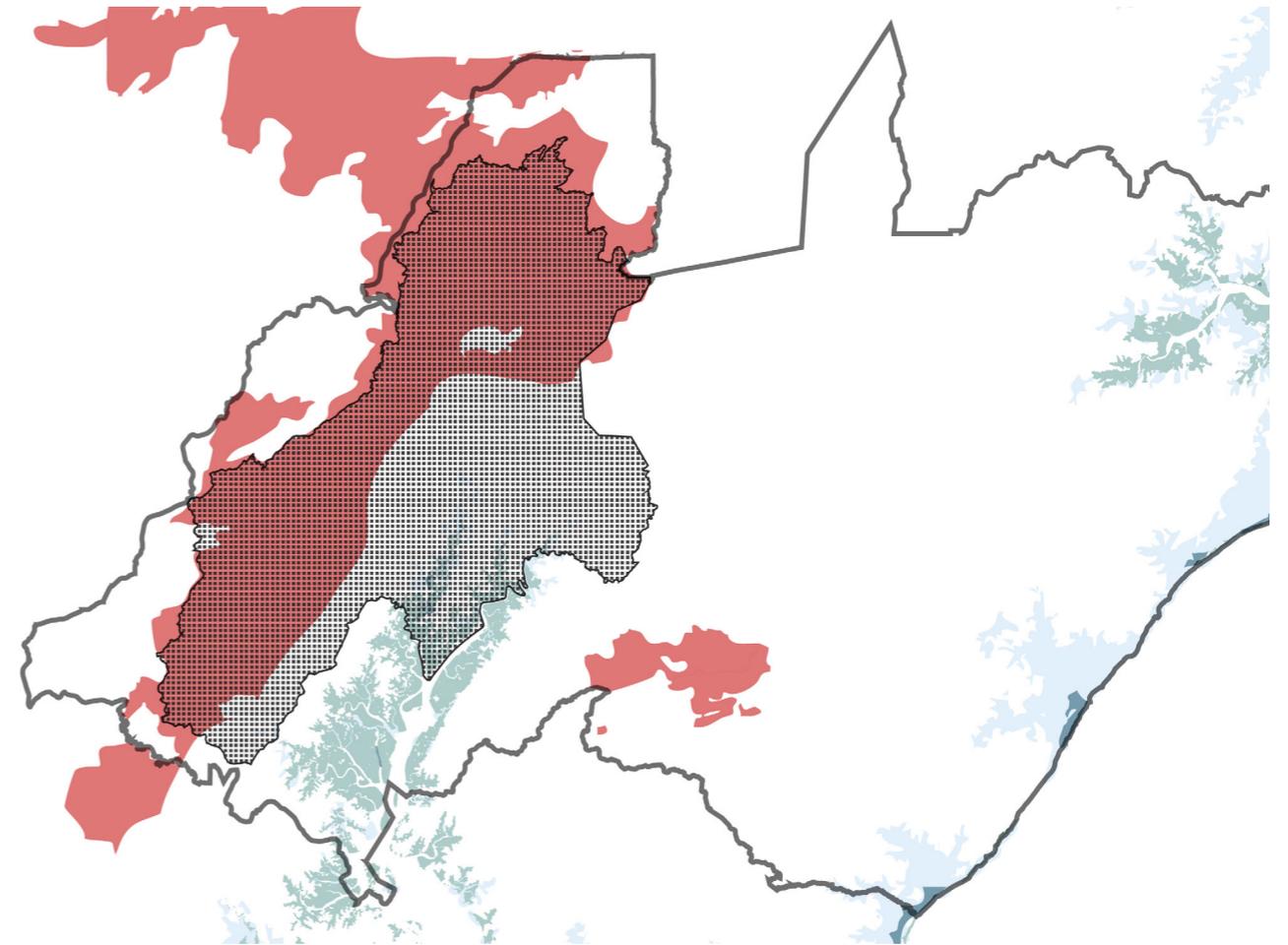
degradation, water availability and marginalization of local people. Unsustainable land management practices near the new capital may involve hydrological alteration affecting river systems and groundwater, impacting human water use and aquatic ecosystems. Environmental conflicts are a significant concern due to the area's rich biodiversity, including many endangered species. Socio – cultural conflicts are another critical aspect, since native communities with deep cultural ties to the land call the area home (Syaban & Appiah-Opoku, 2024). These impacts are seen by planned cities around the world, showing rigid master planning, a program -instead of process-oriented approach, and environmentally destructive construction work. This leads to the degradation of ecosystems, proneness to natural disasters, destruction of local livelihoods and culture, and reinforcement of existing (inequal) power structures (Kelly, 2020; Syaban & Appiah-Opoku, 2024).

The current spatial planning of Nusantara includes an urban planning area (56,000 ha) including a core government area (5,600 ha), and an expansion zone that include the rural planning areas and forest conservation areas (200,000 ha) (Said et al., 2024), (see figure...). However land slides and floodings are common in the area, the urban planning area seems to overlap with both the erosion prone upstream zones and the flooding prone downstream zones (see figure...). The National Development Planning Agency of Indonesia mentions the potential for flood disasters as a main weakness of the chosen location (Kurniawan et al., 2021). Environmental involvement of the plans can be seen in the masterplan for Nusantara biodiversity management (Nusantara Capital Authority, 2024) (see figure...). Some large areas are appointed as forest in the biodiversity management master plan; however, those plans seem to overlap with the appointed urban planning area (see figure...). The biodiversity plan was created after the master plan for the city was made (Indriyatno, 2024), suggesting that biodiversity and ecological

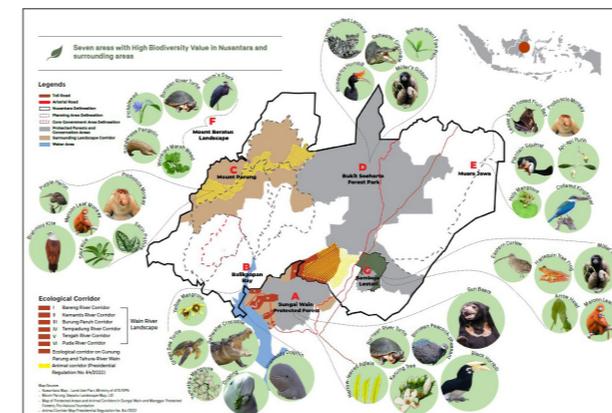
restoration is not taken as the base for the city design, as is implied with designing a 'forest city'. Looking at the available master plans, the project seems to spatially separate ecology from urbanism (Syaban & Appiah-Opoku, 2024), leading to the same old-fashioned program oriented approach for the urban zone as other cities (Tjallingii, 2015).

During the conversations with Nusantara's project leaders on the site visit, this discrepancy between visions and spatial outcomes was confirmed. The intentions for a green and biodiverse city were clear; visions concerning Design With Nature, a watershed based approach and a focus on biodiversity were often mentioned. (IKN, personal communication, February 13, 2025). However, the spatial strategies that were implied to follow from these visions seem to be lacking, both on the large and small scale.

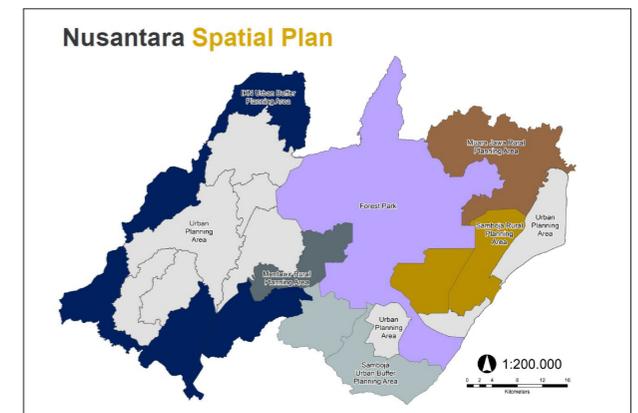
In which context is it, that these developments should be understood?



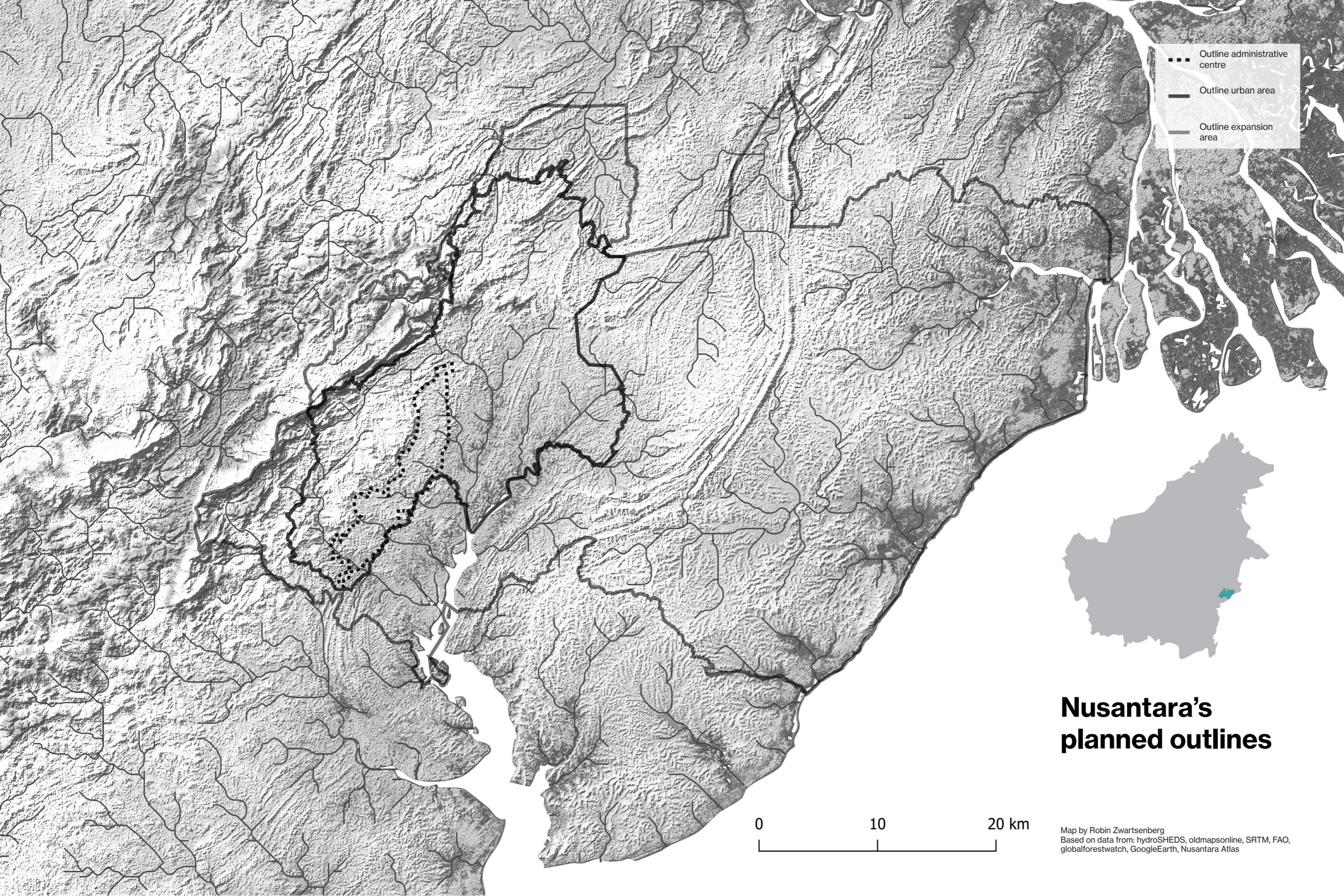
Nusantara's main urban planning zone overlaps with major wetlands downstream (blue) and areas with high flooding and erosion risk upstream (red) (Map by Robin Zwartsenberg Based on data from: hydroSHEDS, oldmaponline, SRTM, FAO, globalforestwatch, GoogleEarth, Nusantara Atlas)



Biodiversity zoning strategy for Nusantara's forest areas. Reprinted from Nusantara biodiversity management master plan - Nusantara nature positive plan, (Nusantara Capital Authority, 2024)

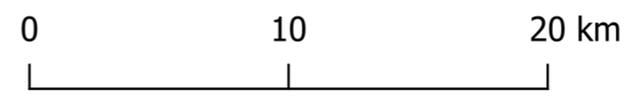


Spatial planning concept showing planning areas in Nusantara. Reprinted from Spatial plan of Nusantara Capital City: Coexistence of urban and rural areas in Nusantara spatial planning, (Amalia, M. 2023)



- Outline administrative centre
- Outline urban area
- Outline expansion area

Nusantara's planned outlines



Map by Robin Zwartsenberg
Based on data from: hydroSHEDS, oldmapsonline, SRTM, FAO, globalforestwatch, GoogleEarth, Nusantara Atlas

A short history of the site

Nusantara is situated in East Kalimantan, on the island of Borneo. Borneo, Indonesia's largest island, is home to approximately 23 million people. The island is predominantly part of Indonesia, with Malaysia and Brunei occupying smaller sections. Borneo is renowned for its enormous biological and cultural diversity. (MacKinnon, 1996). East Kalimantan has undergone extensive deforestation, with Global Forest Watch reporting a loss of 1.2 million hectares of primary forest between 2002 and 2020 – representing a substantial portion of the region's forest cover. This widespread deforestation is largely fuelled by logging and the expansion of palm oil plantations. The trend reflects Indonesia's controversial transition from forested landscapes to palm oil production – an industry that, economically significant as an export, has contributed to massive deforestation, biodiversity loss, and the displacement of indigenous communities. (Syaban & Appiah-Opoku, 2024).

The impacts of deforestation in Indonesia extend far beyond its borders. The resulting loss in biodiversity threatens global genetic diversity and thus the resilience of ecosystems and humankind. Moreover, Indonesia ranks as the world's third-largest emitter of greenhouse gases – an alarming 80% of which stem from environmental degradation, particularly deforestation. These impacts underscore the global significance of conserving Indonesia's rainforests, explains biologist Willie Smits for TED (2009).

The development site of Indonesia's new capital aligns closely with the broader historical trajectory of land use in East Kalimantan. Ecologist Smits has monitored developments in the area since conducting his initial academic research there in 1980 – at which time the site was still covered by pristine rainforest. Soon thereafter, the first logging concessions were granted to an American timber company, initiating large-scale deforestation. Following the company's departure, additional concessions were issued to other operators, many

of whom extracted timber from areas already selectively logged. As a result, only fragmented sections of forest – primarily those on steep slopes, in high-altitude zones, or in wetland areas – remained relatively intact.

Further degradation occurred due to extensive forest fires in 1998 and 2015, which destroyed large swathes of the remaining forest. Today, the landscape is dominated by monoculture plantations, primarily eucalyptus and oil palm. The eucalyptus production forest where the centre of the capital is planned, is currently in its fourth rotation cycle (Willie Smits, personal communication, April 15, 2025).

These developments have resulted in a heavily degraded landscape characterized by severe soil erosion and compaction, water pollution and increased flood risk, the loss of habitats for numerous vulnerable species, fragmented ecosystems, and significant disruptions to local livelihoods (Syaban & Appiah-Opoku, 2024).

The potential of water

As a result of the subsequent land uses, the site designated for the new capital is no longer a pristine rainforest and faces numerous challenges.

However urbanisation is traditionally perceived as an enemy of ecology (Adinugroho et al., 2022; Tjallingii, 2015), a new city is also an opportunity to improve the qualities of the landscape. This project involves two key challenges: addressing the existing environmental issues and designing a sustainable, context-sensitive urban area.

To capitalize on the opportunities offered by the landscape and avoid the mistakes made in other planned cities, a landscape-based approach can be instrumental. Landscape-based urbanism offers a framework for adaptive, sustainable, and holistic urban development by emphasizing the dynamics of natural systems (such as hydrology, topography, and ecosystems), contextual sensitivity (socially, culturally, and environmentally), and long-term sustainability and resilience to climate change (Nijhuis, 2022).

As highlighted in the literature discussing the challenges of the site and the new capital, many of these issues are water-related, underscoring the crucial role of water in the landscape system – whether in scarcity or abundance. These challenges include drought, forest fires, erosion, flooding, and ensuring a clean water supply (Kurniawan et al., 2021; Rahmawan & Eliana, 2023; Syaban & Appiah-Opoku, 2024; Wahid et al., 2024). Wahid et al. (2024), argue that in determining the location of Nusantara, geographical elements – particularly rivers, local topography, catchments, drainage basins, and sub-catchments – should play a central role in guiding the effective management of land and water resources for disaster risk reduction and sustainable development.

That water is such an essential element in the landscape, is not a surprise: water is a vital source for life and shapes physical

environments, culture and power relations. Water is fundamental to human survival and plant growth. Physical landscapes are shaped through the dynamic processes of erosion and sediment deposition, while the availability of water governs the distribution and structure of ecosystems (McHarg, 1969). Culturally, water plays a formative role in shaping cultural practices and social relationships, structuring human interactions with the environment. Above that, because the hydrological cycle and water availability are increasingly shaped by human interventions, water must be understood not only as a natural resource but also as a social and political construct that both reflects and reinforces power relations (Linton & Budds, 2014).

Water thus serves as a fundamental organizing element in both natural systems (McHarg, 1969) and anthropogenic systems, as emphasized by Linton & Budds (2014): 'Water is not merely a resource to be managed, nor just a product to be valued and consumed, but it actively shapes new geographies' (p. 174).

In this thesis, water is thus approached as such:

Water beyond H₂O; a formative power for design.

Research objective & questions

As previously outlined, both the current landscape and the envisioned future city present a range of challenges and opportunities. In response, and with a focus on utilizing water as a formative force in design, the following objective has been established:

To design a water-based landscape framework that leverages water to guide sustainable, socio-ecological urban development in Nusantara.

Explanation of used terms: 'water - based' because water is used as a formative power. 'framework' because the goal is not a fully developed design of the city, but a landscape-based structure from which the developments can proceed. 'sustainable, socio-ecological' because the goal of the design framework is to serve both humans and ecosystems on the long term.

RQ 1, understanding - What are the challenges and opportunities related to water in the current landscape system of Nusantara?

RQ 2, Design strategies and principles - Which landscape design strategies and principles are suitable to design a water-based landscape framework that leverages water to guide sustainable urban development with integrated ecology in Nusantara?

RQ 3, design - How can these design strategies and principles be implemented in the context of Nusantara over time?

RQ 4, Reflection - Which lessons can be taken from the landscape approach and the design outcome for Nusantara?

These questions will be answered with the following methods; a literature review, a site visit, GIS mapping and research through design.

Relevance

This study addresses the intersection of water, urban development, and ecological resilience in the context of Nusantara, Indonesia's newly planned capital. This research is significant for several key reasons:

Professional relevance: In the field of landscape architecture, it contributes to the advancement of landscape-based planning approaches by using a methodology in which water is positioned as a guiding spatial framework addressing global challenges such as biodiversity loss, water scarcity and urbanisation. This perspective aligns with contemporary thinking in landscape urbanism and hydro social studies, emphasizing the need for integrated, systems-oriented design strategies in urbanizing regions. This thesis serves as an example of research-driven spatial development through a landscape-based approach. The resulting strategies and principles have the potential to be adapted and applied to other similar contexts.

Practical relevance: The authorities of Nusantara have expressed an ambition to pursue an approach grounded in designing with nature and the watershed systems. However, a detailed spatial elaboration has so far been limited. This thesis offers a potential source of inspiration for the development of Nusantara by demonstrating how these ambitions can be translated into concrete spatial design strategies.

Academic relevance: The study adds to academic discourse by integrating theories of hydro social territories, landscape ecology, and resilient urbanism, demonstrating how interdisciplinary thinking can inform the shaping of future cities. Furthermore, this thesis integrates and consolidates a wide range of data sources, identifying key aspects relevant to a landscape-based approach in Nusantara. In doing so, it provides both a curated collection of essential references and a foundation for future research on the development of Nusantara.

Study limitations

One of the main limitations of this study concerns data acquisition. Landscape architecture projects inherently integrate specialized knowledge from diverse fields such as hydrology, soil science, geography, ecology, sociology, and landscape history. While this thesis draws on scientific literature, professional reports, and direct observations from site visits, certain assumptions were necessary where site-specific data were lacking. Further collaboration with local stakeholders would ensure that design interventions align with the needs, aspirations, and traditional practices of the communities. Such engagement can also facilitate the collection of more accurate and context-specific data on local water systems, native plant species, and indigenous agricultural practices, thereby enhancing the ecological and cultural relevance of the proposed strategies. Furthermore, within the design exploration phase, projections about the future development of the city were made based on informed estimations, acknowledging the inherent uncertainties of such a rapidly evolving context.

A second limitation of this study is time. This thesis includes an application of the water-based design approach, envisioned at the larger landscape scale and further elaborated at a smaller, local scale. However, the available time constrained the ability to fully develop detailed designs for all zones at the smaller scale, resulting in a focus on selected areas to illustrate the application of strategies and principles.

A third limitation is the absence of validation. Neither hydrological models nor field experiments were employed to assess water flow on site. To determine the feasibility and effectiveness of the proposed design under real-world conditions, small-scale field trials would be necessary to evaluate its performance.

Reading guide

This thesis is structured into the following chapters: methodology, analysis, design approach, design exploration, and synthesis. The methodology chapter outlines the theoretical framework, situating the water-based approach within relevant theories and clarifying the lens through which the problem statement and objective introduced earlier are addressed. After that, the methods section details how the research questions are approached and answered. The analysis chapter provides a comprehensive understanding of the site's landscape system. Based on this analysis, the design approach chapter formulates design strategies and principles that respond to the identified challenges and opportunities. These strategies and principles are then applied to the site in the design exploration chapter. Finally, the thesis concludes with a reflection on both the design outcomes and the overall research process in the discussion and conclusion chapter.



2.

Methodology

Theoretic framework

The theoretical foundation of this study brings together interdisciplinary perspectives from landscape-based urbanism, watershed ecology, urban water management, local knowledge systems, and political ecology. Together, they provide a comprehensive lens through which to understand, design, and evaluate water-based urbanism in a tropical, socio-culturally rich, and ecologically sensitive region.

Landscape-Based Urbanism

In search for an integrated approach of urbanism and ecology, Ian McHarg's work in *Design With Nature* (1969) is foundational. Traditionally, environmentalists and ecologists tend to position ecology within the realm of conservation, often framing urbanization as a threat. However, a more integrated perspective shifts this view – seeing ecology not as a set of limiting constraints, but as a foundation that offers carrying conditions for urban development. McHarg presents natural systems as both an inspiration and a practical framework for urban design. Within this approach, the water cycle becomes a central organizing principle, guiding urban development based on natural drainage systems, river networks, floodplains, wetlands, lakes, aquifers, steep terrains, and forested areas. Urban structures, should respond to and respect this inherent natural order to ensure long-term resilience, public health, and a sense of place (McHarg, 1969).

Nijhuis (2022) builds on these ideas with the concept of landscape-based urbanism. Rather than imposing urban development onto a landscape, this approach calls for a design process that emerges from the underlying ecological, hydrological, and topographical systems. Landscape is thus seen not only as context but also as infrastructure, capable of delivering ecosystem services, shaping spatial organization, and enhancing resilience. In the case of Nusantara, with its degraded yet ecologically significant site, this paradigm offers a basis for sustainable development

that aligns with natural systems rather than opposing them.

Landscape-based urbanism conceptualizes spatial frameworks, as used in thesis, as strategic tools that guide urban development by creating robust and resilient landscape structures. These adaptive frameworks serve a dual purpose: they provide a coherent long-term vision for regional development while simultaneously allowing flexibility to accommodate localized, short-term interventions (Nijhuis, 2022).

A layered understanding of the living landscape

Nijhuis (2022), presents an analytical framework that interprets the landscape as a dynamic system shaped by ongoing interactions between nature and human activity. It emphasizes a continuum of interconnected spatial scales, where insight emerges through the study of spatial, ecological, functional, and social relationships. It is structured into three interrelated layers:

1. Natural Context

This foundational layer includes topography, water systems, soil, geology, and climate, along with their ecosystems. These physical conditions evolve slowly through natural processes such as tectonics, erosion, sedimentation, and ecological succession. Rather than a static backdrop, the natural context is an active force that influences and constrains land use and development (Nijhuis, 2022).

2. Human Intervention

This layer captures the transformation of the natural environment through human activities such as infrastructure development, land reclamation, water management, and settlement. These interventions are shaped by long-term socio-economic and cultural processes, leaving sometimes big imprints

in the landscape such as parcel patterns, canals, and built structures (Nijhuis, 2022).

3. Culture, Organisation, and Politics

This layer reflects how societies conceptualize and govern landscapes, including spiritual beliefs, scientific understanding, political systems, and aesthetic ideals. These perspectives influence short- to medium-term decisions and shape both the use and perception of natural systems – for instance, the differing cultural meanings and governance of water (Nijhuis, 2022).

Watersheds as Holistic Systems

The concept of watersheds as interconnected systems offers a way to understand natural environments, emphasizing the relationships between humans, land, water, and ecosystems. In both literal and metaphorical terms, the watershed represents a boundary of interdependence, where everything within its confines functions as part of a greater whole. This framework is not only essential for environmental management and design but also for reshaping how we perceive the natural world.

Watersheds of the mind

The watershed provides boundaries in the endlessly connected natural system. This system is robbed of its wildness and natural movements by human intervention. But this is not only true for the geographical watershed. The watershed of the mind (Moretti, 2005) of people, is also tied in. Just as a physical watershed is defined by natural topography, drawing lines around hills and valleys that direct the flow of water, a watershed of the mind can be understood as the mental and conceptual boundaries that define how we perceive and engage with the environment. Humans used to be connected with their lands, whereas they live now in a mindset restricted by modern society, in a disconnection from nature, where

human activities are viewed as separate from natural processes. To reconnect humans with the land they live in, ... suggests starting with understanding the bioregion you live in. Here, the geographical watershed is a powerful entity, since it includes all the relations of the system you live in: where the water comes from and where the water goes, and how humans and nature interact. Using the geographical watershed as an entity in design can thus help the people living in it to reconnect to their natural environment and its rhythms. It furthermore encourages a mindset of stewardship, where we recognize our role in maintaining the balance of the systems we inhabit (Moretti, 2005)

The Watershed as an Organizing Framework

As one of the foundations of landscape-based urbanism, Ian McHarg (1969) approaches watersheds as natural organizing units. Watersheds are natural hydrological boundaries defined by natural topography, not political or administrative boundaries. Managing water based on these natural divisions allows for a more accurate understanding of water flow, sources, and sinks, while capturing the full water cycle (including evapotranspiration, infiltration, and groundwater recharge). McHarg advocated for ecological planning rooted in an understanding of these natural processes, where human development respects the logic of water and the natural drainage system following from the interaction of flow, soil, vegetation, and slope (McHarg, 1969). Applying this approach in Nusantara enables urban form to align with hydrology, supporting flood resilience, water supply, and ecosystem connectivity.

The watershed approach offers a comprehensive framework that encompasses both environmental and socio-economical dimensions and helps to spatially prioritize interventions and infrastructure. Its applications extend beyond water management, fostering ecological, socio-cultural, and climate-adaptive solutions

(Linton & Budds, 2014; McHarg, 1969; Sharma, 2019; Tjallingii, 2015).

A watershed includes all ecosystems – forests, wetlands, rivers, and urban areas – within its boundaries. Understanding the upstream–downstream dependencies helps in tracing pollution sources, understanding effects of land uses in other areas planning habitat preservation (McHarg, 1969).

In terms of water as a resource, watersheds help planners to balance water demands (urban, agricultural, industrial), optimize rainwater harvesting, infiltration, and storage and support long-term water security through sustainable yield management. An approach to integrate the urban water cycle – including stormwater, potable water, and wastewater – is Water Sensitive Urban Design (WSUD), providing a variety of interventions on the medium and small scale (like raingardens, permeable pavements, swales) for sustainable, water-efficient cities with minimal environmental impact (Sharma, 2019).

In terms of risk mitigation (floods, erosion, droughts), watershed management helps identify vulnerable zones – such as steep slopes, erosion-prone soils, and floodplains – and to spatially identify where to implement soil and vegetation restoration upstream and buffer zones and green infrastructure downstream (McHarg, 1969). Modern concepts like sponge cities build on this approach, regulating runoff and enhancing groundwater recharge through infiltration, and thus supporting adaptive planning under climate uncertainty by improving the management of extreme weather events (Wu et al., 2020; Yin et al., 2022).

In terms of water as socio – cultural construct, watersheds can help to understand the dependencies and interaction with humans and their environment, including water. The concept of the hydro-social cycle, views water as not just a natural element but as one embedded in social, cultural, and political relations. Elements such as water,

society, and social power are not seen as pre-existing or independent entities; instead, their identities are shaped through internal relationships, meaning they co-construct each other through interaction. It challenges purely technical or ecological approaches by highlighting how water access, control, and distribution are shaped by governance, equity, and power dynamics. This perspective ensures that the framework considers not only ecological sustainability but also social justice - particularly critical in the context of a new capital with significant political, economic, and symbolic weight (Linton & Budds, 2014).

The relationship between humans and water goes beyond its role as a mere resource. Water is both physically and culturally experienced and embodied. Its meanings are not externally imposed but arise from close, embodied interactions – through acts of ingestion and expulsion, contact, and immersion. Examining lived experiences with water reveals context-specific and non-scientific forms of knowledge. Often rooted in local and Indigenous traditions, these perspectives highlight the complexity and diversity of hydro social relationships, as well as the deep interconnection between water’s physical and spiritual dimensions – foundations that support collective identity and social cohesion within communities (Linton & Budds, 2014).

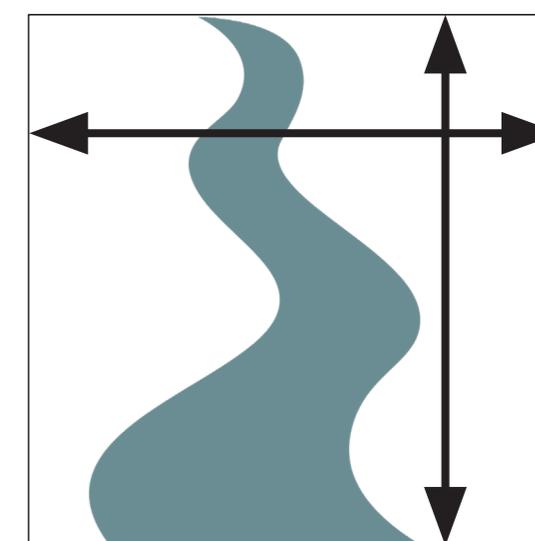
The Two Networks Strategy

To further develop the approach that positions the watershed as an organizing framework for both human activity and infrastructure, Tjallingii’s (1995) Two Networks Strategy offers an applicable and complementary perspective. The two networks strategy introduces a dual approach encompassing the water network and the infrastructural or traffic network. For this strategy, the water network based on the drainage pattern is the carrier, or the spatially organizing structure, of the slow or quiet zone. Here the focus lies on water

safety and quality, landscape, biodiversity and recreation. In addition, the traffic network is the carrier of the fast or dynamic zone. Here, environmental criteria are equally important but the emphasis of design solutions is more on technology (Tjallingii, 2015).

Central to the Two Networks Strategy in relation to water strategies are several key components: an upstream zone functioning as an infiltration area, followed by a midstream zone characterized by a network of both major and minor rivers. Equally important is the integration of water bodies that serve as storage systems – helping to mitigate peak stormwater runoff and enabling the use of wet season surpluses during dry periods. In terms of water quality, a critical concern lies in addressing downstream pollution stemming from upstream activities. Concerning water quality, the key question is how to address downstream pollution problems caused by upstream sources. For water pollution, the following applies: ‘an ounce of prevention is worth a pound of cure’ (Tjallingii, 2015).

The two networks strategy city model for medium sized cities emphasizes the edge qualities of a green structure (the slow zone)



The two networks strategy with the water network guiding for the slow zones and the traffic network for the fast zones

that penetrates into the built environment (the fast zone) as an essential characteristic. The social aspect of the slow and fast lane zoning is based on understanding that it is vital 'for a town to give people both intense activity and deep satisfying quiet' (Tjallingii, 2015).

In Nusantara, this strategy ensures that urban growth does not fragment ecological systems but rather coexists with them, enabling a multifunctional and adaptive urban landscape. It brings in the human scale, emphasizing accessibility, liveability, and social integration alongside ecological integrity.

Views on High tech and Lo Tek

Nusantara's authorities aim for the capital to be a 'smart city' incorporating many high tech features. Technology can be very helpful for creating large scale infrastructures, environmental monitoring, water treatments or the development of sustainable materials. (IKN, personal communication, February 13, 2025). Although technology is frequently promoted as a driver of sustainable development, it has often produced unintended environmental consequences. High-tech systems can foster a disconnection from the natural environment, weakening the human-nature relationship and so contributing to unsustainable patterns of resource consumption, including excessive use of energy, water, and materials. Additionally, many advanced technologies depend on resource-intensive extraction and result in significant waste generation. They may also marginalize traditional ecological knowledge and reinforce unsustainable infrastructures, occasionally serving as greenwashing mechanisms that obscure or delay the need for more systemic change (Watson, 2019).

Complementary to careful integration of high tech solutions, Local Technological Ecological Knowledge can provide practices that are often sustainably adapted to and deeply rooted in their environment. In Lo-TEK: Design by Radical Indigenism, Julia Watson

(2019) presents a compelling argument for integrating Traditional Ecological Knowledge (TEK) into modern urban planning. Indigenous systems – often developed over centuries – are low-impact, adaptive, and deeply integrated into local ecosystems. Incorporating traditional water management methods, local materials, and craft-based construction can create context-specific solutions that not only enhance sustainability but also empower local communities and preserve cultural heritage (Watson, 2019). Nijhuis (2022) also emphasizes that Traditional ecological knowledge and local expertise are essential resources for both environmental management and design. Both literally and metaphorically, they offer critical insights into timing and techniques – such as when to plant or harvest, how to prune or seed, and what should be allowed to grow or be removed.

Conclusion

Together, these theoretical lenses form an integrative foundation for the design of a water-based landscape framework in Nusantara. Design with Nature and Landscape-based urbanism provides the base for spatial logic; the watershed model offers ecological structure; the hydro-social cycle ensures that water is understood as socio-cultural construct; the two networks strategy balances ecological integrity with urban needs; the Sponge City and WSUD deliver practical design strategies; Lo-TEK brings in valuable local knowledge and cultural relevance; and. This multifaceted framework enables the development of a city that is resilient, sustainable, context-sensitive, and equitable – guided by water as both a resource and a design driver.



This section provides a detailed explanation of the methods employed to address each of the research questions.

RQ 1, understanding - What are the challenges and opportunities related to water in the current landscape system of Nusantara?

The understanding of the landscape system began with the formulation of the problem statement through a comprehensive study of news articles, reports from Nusantara's authorities, books, and scientific literature. For the subsequent analysis phase, research was more specifically directed towards addressing the objective of this thesis. In addition to the aforementioned sources, this phase incorporated the comparison of spatial data, field observations during a site visit, and conversations with local professionals.

Spatial data comparison was primarily conducted using QGIS (Geographic Information Systems). GIS is a powerful tool in landscape-based urbanism for processing, analysing, and visualising spatial data to gain deeper insights and inform the design process (Nijhuis, Landscape-Based Urbanism). In this research, various data layers – such as water bodies, land use patterns, and topography – were overlaid to better understand the landscape system and uncover the relationships between these elements. Conclusions drawn from spatial analysis were cross-validated with findings from literature.

A crucial component of the understanding phase was the site visit, undertaken with a group of four students and our supervising professor. The two-week fieldwork included visiting diverse sites, engaging with local communities, conducting interviews, taking photographs, and sketching observations. The visit was essential for gaining a nuanced, sensory understanding of the local climate, culture, and landscape dynamics. The major urban centres of Samarinda and Balikpapan offered insights into contemporary urban life

in Indonesia.

The site visits encompassed guided explorations of various ecosystems in the region, including mangrove forests, wetland rainforests, and dryland rainforests. Locations include Sungai Wain, Bukit Bankirai, Mahakam delta and Samboja Lestari. Observations also included large-scale industrial plantations (eucalyptus and oil palm), as well as small-scale agricultural systems such as coffee agroforestry and roadside farming practices.

Part of the visit was dedicated to the construction site of Nusantara, where we engaged with project leaders to discuss the planning aims, the current progress of construction, and the envisioned transformation of existing eucalyptus plantations.

Additionally, we visited the Forestry Department of Mulawarman University in Samarinda, where we shared our perspectives on the Nusantara project and exchanged knowledge with professors and students about East Kalimantan's environmental and social landscape.

Local community engagement included visits to villages, such as a Dayak village and a fisherman's village within the mangrove area. In the fisherman's village, conversations with the village head provided insights into the local challenges and opportunities.

The understanding phase remained iterative, continuing throughout the design exploration phase, with refinements and updates made as necessary during the development of the design approach and strategies.

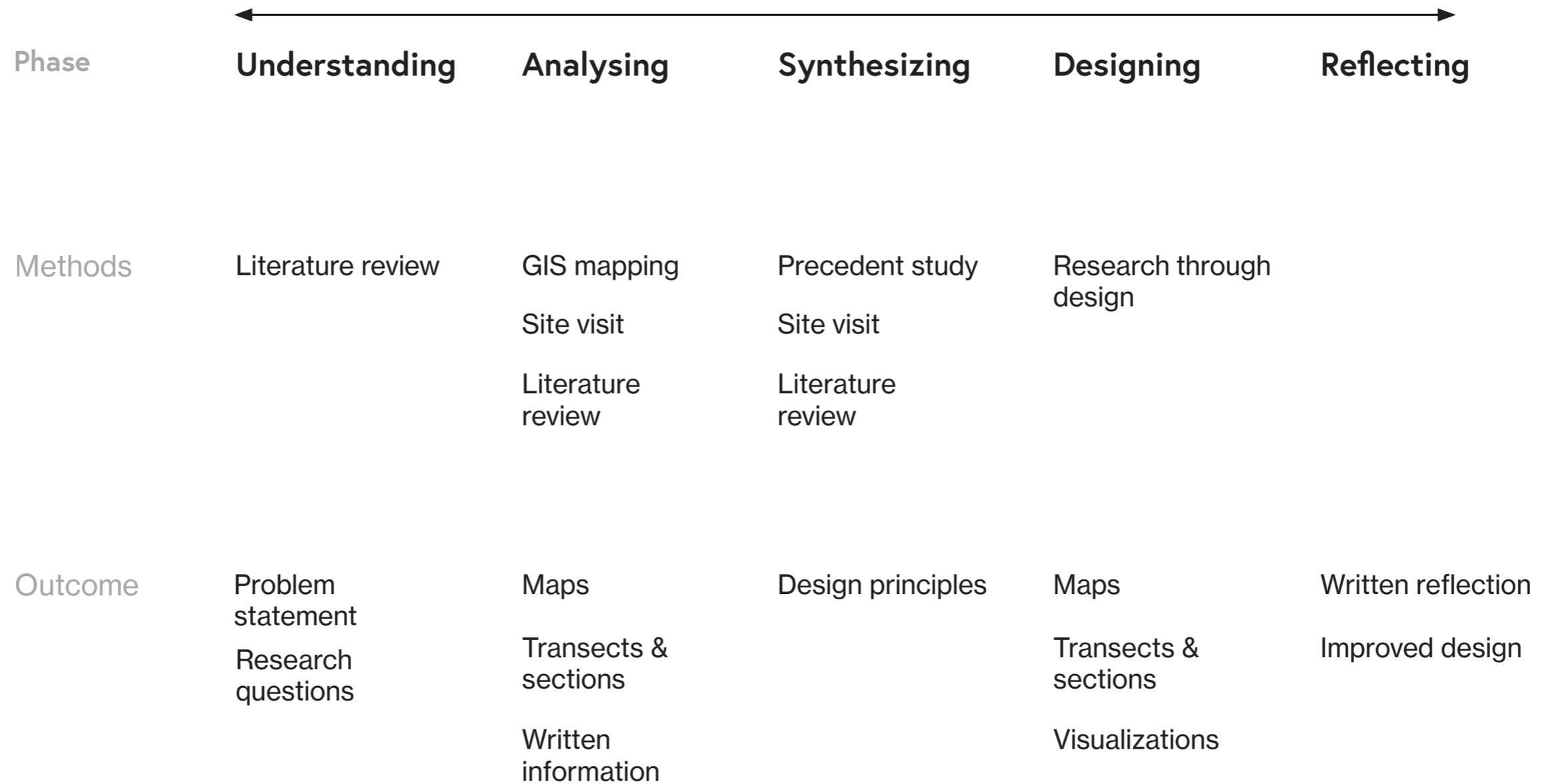
RQ 2, Design strategies and principles - Which landscape design strategies and principles are suitable to design a water-based landscape framework that leverages water to guide sustainable urban development with integrated ecology in Nusantara?

Exploring the design strategies and principles that respond to the identified challenges and opportunities within the landscape system is done in various ways. The strategies are grounded in contemporary landscape-based approaches, supported by a review of relevant literature. Design principles are informed by insights gained during the site visit, supplemented by literature on Water Sensitive Urban Design (WSUD) and Local Ecological Technological Knowledge (Lo-TEK). Additional design principles have been derived from the analysis of relevant precedent studies.

RQ 3, design - How can these design strategies and principles be implemented in the context of Nusantara over time?

To translate the design strategies and principles into a spatial and temporally responsive design, this thesis employs a research through design methodology. This approach involves iterative sketching and the development of various design outputs – including maps, sections, diagrams, and perspective drawings – across multiple scales. It is termed research through design because design decisions made at specific scales or within certain formats not only generate new insights but also inform and refine decisions at other scales and representations. The continuous interplay between different scales and media is therefore essential to the research process and the evolution of the design.

Research design





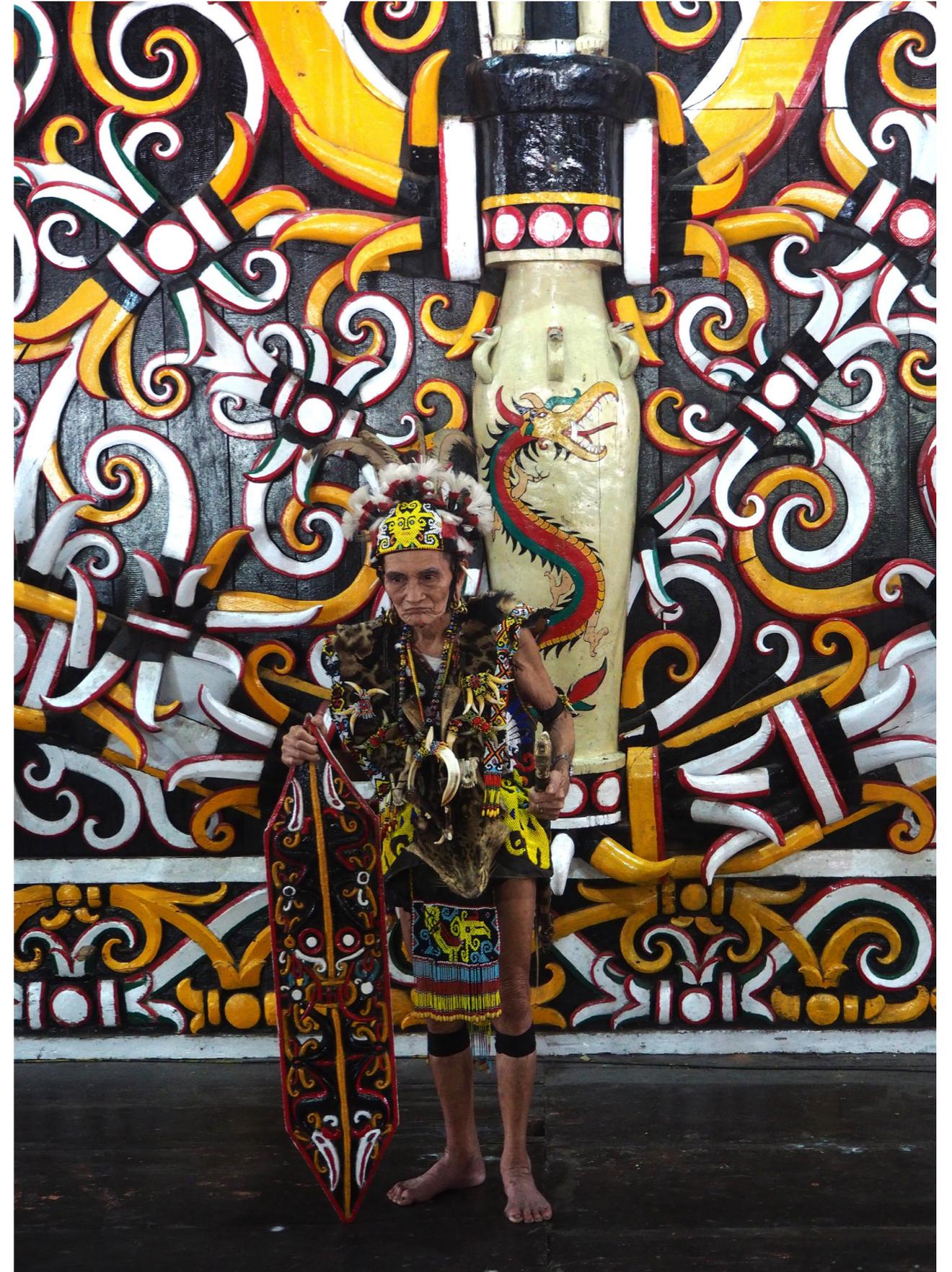
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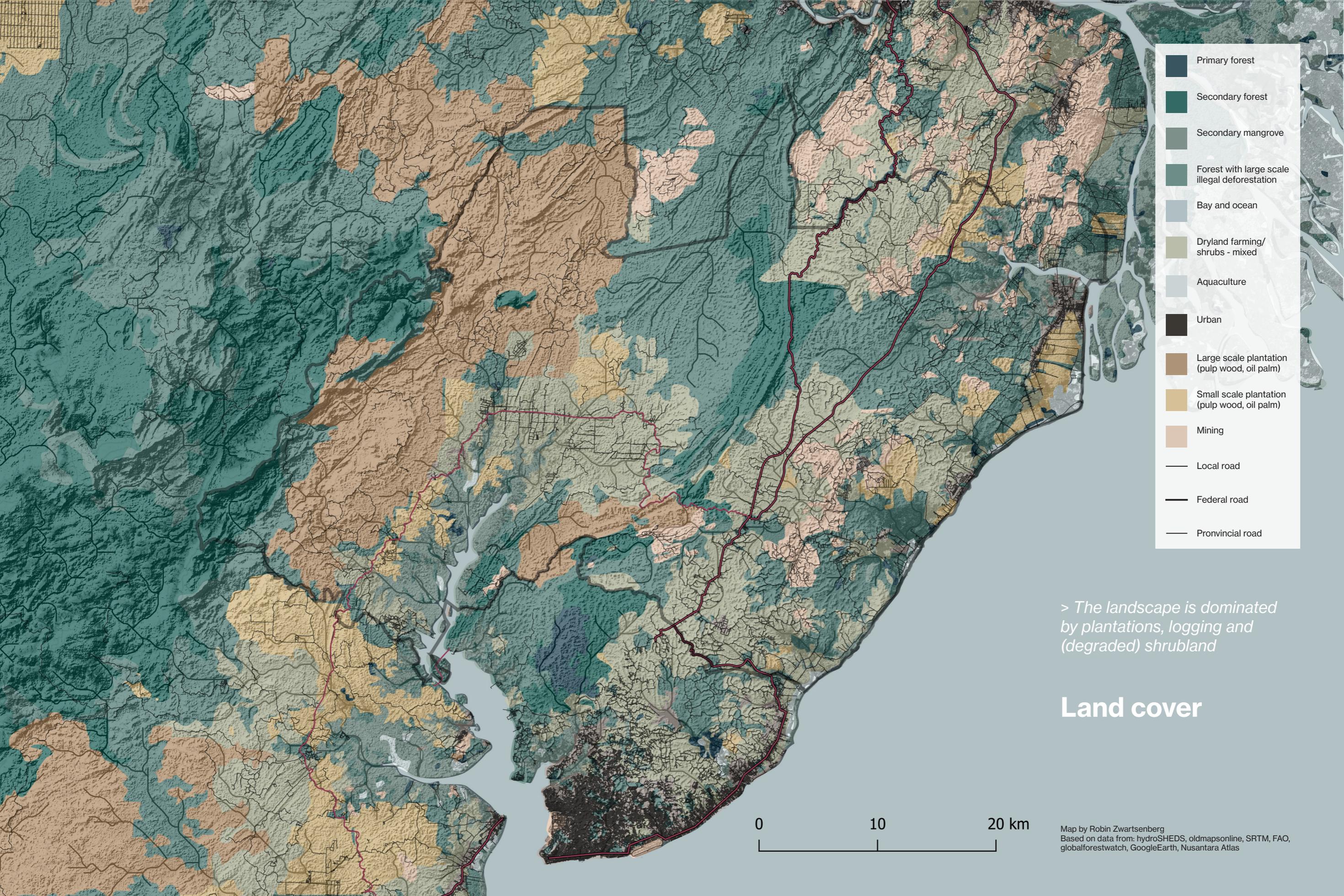
Understanding the
landscape system

Introduction

The living landscape system of Nusantara will be analysed in three chapters, based on the layer analysis proposed by Nijhuis (2022): firstly the natural context, secondly human interventions that influenced the landscape on the long term and thirdly culture and society. In each chapter, the role of water is emphasized.

The landscape of Nusantara is significantly degraded, primarily due to extensive monoculture plantations of eucalyptus and oil palm (Kurniawan et al., 2021; MacKinnon, 1996; (Nusantara Atlas, n.d.). Geographically, the site is bounded by the Makassar Strait to the east and a mountain range to the west, with Balikpapan Bay situated within its territory. The region is positioned between two major urban centres: Balikpapan to the south and Samarinda to the north.

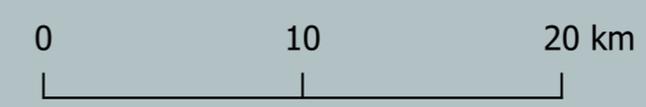




- Primary forest
- Secondary forest
- Secondary mangrove
- Forest with large scale illegal deforestation
- Bay and ocean
- Dryland farming/shrubs - mixed
- Aquaculture
- Urban
- Large scale plantation (pulp wood, oil palm)
- Small scale plantation (pulp wood, oil palm)
- Mining
- Local road
- Federal road
- Provincial road

> The landscape is dominated by plantations, logging and (degraded) shrubland

Land cover



Map by Robin Zwartsenberg
Based on data from: hydroSHEDS, oldmapsonline, SRTM, FAO, globalforestwatch, GoogleEarth, Nusantara Atlas

Natural context

This foundational layer includes climate, topography, water systems, soil and geology, along with their ecosystems. These physical conditions evolve slowly through natural processes such as tectonics, erosion, sedimentation, and ecological succession. Rather than a static backdrop, the natural context is an active force that influences and constrains land use and development (Nijhuis, 2022).

Climate

Nusantara, located in East Kalimantan on the island of Borneo, is located just above the equator and experiences a tropical rainforest climate, characterized by persistently high temperatures, humidity, and precipitation throughout the year. Mean daily temperatures typically range between 26°C and 31°C, with minimal seasonal variation and an annual average of approximately 27.5°C (MacKinnon, 1996). Relative humidity frequently exceeds 80%, intensifying latent heat flux and thermal discomfort, particularly in urbanizing regions (Pradana et al., 2025).

Annual rainfall in East Kalimantan ranges between 2,500 mm and 3,500 mm. During the West Monsoon (November to March), moist air masses originating from the Indian Ocean result in elevated precipitation levels. In contrast, the East Monsoon (May to September) brings drier continental air from Australia, leading to reduced rainfall. Despite the wet climate, high evapotranspiration rates contribute to possible water deficits during the dry season. Wind speeds typically remain low to moderate, averaging 10–20 km/h, with prevailing directions influenced by seasonal monsoonal shifts (MacKinnon, 1996).

Rainfall in this equatorial region is primarily governed by convective processes, rather than frontal systems more typical in temperate climates. Intense solar radiation throughout the day heats the land surface, causing warm, moisture-laden air near the ground to rise rapidly. As this air ascends, it

cools and condenses to form cumulonimbus clouds, frequently resulting in short-duration, high-intensity rainfall, often accompanied by thunderstorms in the late afternoon or evening. This process is locally influenced by the type of land cover, in which dense forest vegetation causes increased local rainfall, as opposed to shrub and grasslands. This is because dense forest vegetation enhances evapotranspiration and the release of chemicals into the air that accelerate cloud formation (Spracklen et al., 2012). The result is frequent, localized downpours that contribute to rapid runoff, erosion, and flash flooding, especially in low-lying or deforested areas (MacKinnon, 1996; Spracklen et al., 2012)

Rainfall and temperature are influenced by the El Niño–Southern Oscillation (ENSO) on interannual timescales. El Niño phases lead to drier conditions, water scarcity, and heightened wildfire risks (Field et al., 2009). Conversely, La Niña increases rainfall intensity and flood potential across much of the region (Ariska et al., 2024).

Topography & the hydrological cycle

The topography of the Nusantara region is characterized by an undulating landscape, bordered by a north–south oriented mountain range in the east, an interior hill ridge running parallel to it, and lower-lying alluvial and coastal plains surrounding Balikpapan Bay and the coastline.

Watersheds

These features are defining for the watersheds. This thesis regards watersheds, also referred to as catchments, as fundamental spatial units through which the interplay between topography and hydrology is examined. A watershed, also known as a drainage basin, is a natural land area where all precipitation and surface water converge to a single outlet, such as a river, lake, or ocean. It is defined by topographic boundaries – typically ridges or hills – that separate it from adjacent basins. Watersheds

function as fundamental hydrological units, influencing water quantity, quality, and flow dynamics (McHarg, 1969). In Kalimantan, high annual precipitation drives continuous water movement through the atmosphere, surface, and subsurface systems (MacKinnon, 1996). Three zones can be divided within the watershed; the upstream, midstream and downstream zone.

Upstream zones

In the upstream zones, elevated terrain and high rainfall intensity promote rapid surface runoff as well as significant infiltration, supporting both river discharge and groundwater recharge. The forested uplands act as a natural headwater zone, contributing to groundwater recharge and playing an essential role in river baseflows mid and downstream (MacKinnon, 1996).

The upstream regions in the eastern part of the area are defined by the north–south oriented mountain range (the Meratus mountains range), with elevations reaching up to approximately 1200 meters above sea level, and up to 700 meters within the Nusantara region (NASA Jet Propulsion Laboratory, 2000). This range features steep slopes, with inclinations in the Nusantara designated area reaching up to 40% (Kumalati et al., 2022). The elevated terrain acts as a natural divide, directing hydrological flow westward toward inland catchments and eastward towards Balikpapan bay and the coastal plains (Lehner et al., 2008).

The other main upstream zone is the Bukit Soeharto hill ridge, part of a broader north–south trending highland zone that defines the eastern interior of the Nusantara region. This ridge reaches elevations up to 200 meters above sea level and consists of undulating to steep terrain, with slope gradients commonly ranging from 15% to 30% (NASA Jet Propulsion Laboratory, 2000). The Bukit Soeharto hill ridge serves as a critical topographic divide that influences the direction of surface runoff, with water draining north-westward into the Mahakam River

system, south-westward into Balikpapan Bay and eastward toward coastal sub-watersheds (Lehner et al., 2008).

Midstream zones

In the midstream zones, where the topography is more undulating with elevations between 20-60 meters (NASA Jet Propulsion Laboratory, 2000), hydrological processes are dominated by subsurface flow, delayed runoff and percolation. Soil permeability and vegetative cover influence the partitioning of water between surface discharge and infiltration. In this zone, rivers start to meander (MacKinnon, 1996).

Downstream zones

The downstream zones consist of flat coastal plains and estuarine environments, gradually transitioning from the inland hills to Balikpapan Bay or the Makassar Strait. Elevations in this zone typically range from sea level to about 20 meters, with minimal relief. The coastal zone is subject to tidal influences, brackish water interactions and sediment deposition from upstream river systems. The flatness of the terrain leads to slow water movement, enhancing the risk of inundation during extreme rainfall or high tide events. Poor drainage and shallow water tables are common, making the region sensitive to saltwater intrusion, coastal erosion, and subsidence (MacKinnon, 1996).

One of the most significant coastal features in the area is Balikpapan Bay, a large semi-enclosed inlet situated on the southern part of the area. The bay acts as a natural estuarine system, receiving freshwater input from several rivers draining the uplands and midstream areas of the Kutai Basin (Lehner et al., 2008), which transport sediment and nutrients into the bay (MacKinnon, 1996). The salinity of the bay is influenced by the influx of these rivers and the tidal waves coming from the ocean, meaning that salinity rates increase downstream. The dominant flow direction of water in the bay is towards the ocean (Anwar et al., 2021). The relatively sheltered nature of the bay promotes the

accumulation of sediments and supports rich mangrove forests (MacKinnon, 1996).

Groundwater

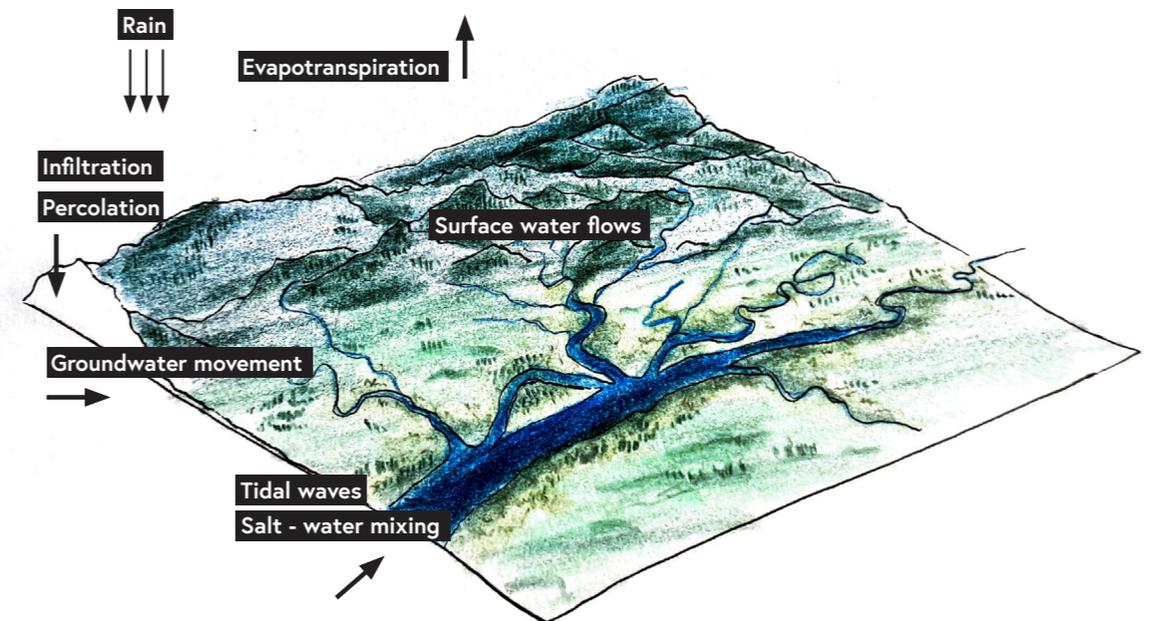
Groundwater systems in the region include both shallow aquifers and deeper fractured bedrock formations. Recharge primarily occurs through rainfall infiltration and percolation in the upland and midland areas. Forest cover in these areas enhances rainfall infiltration and regulates stream flow, acting like a sponge that slows water release and allows for steady groundwater recharge. The shallow groundwater reservoirs provide essential baseflow to surface waters and maintain hydrological stability during dry periods (MacKinnon, 1996).

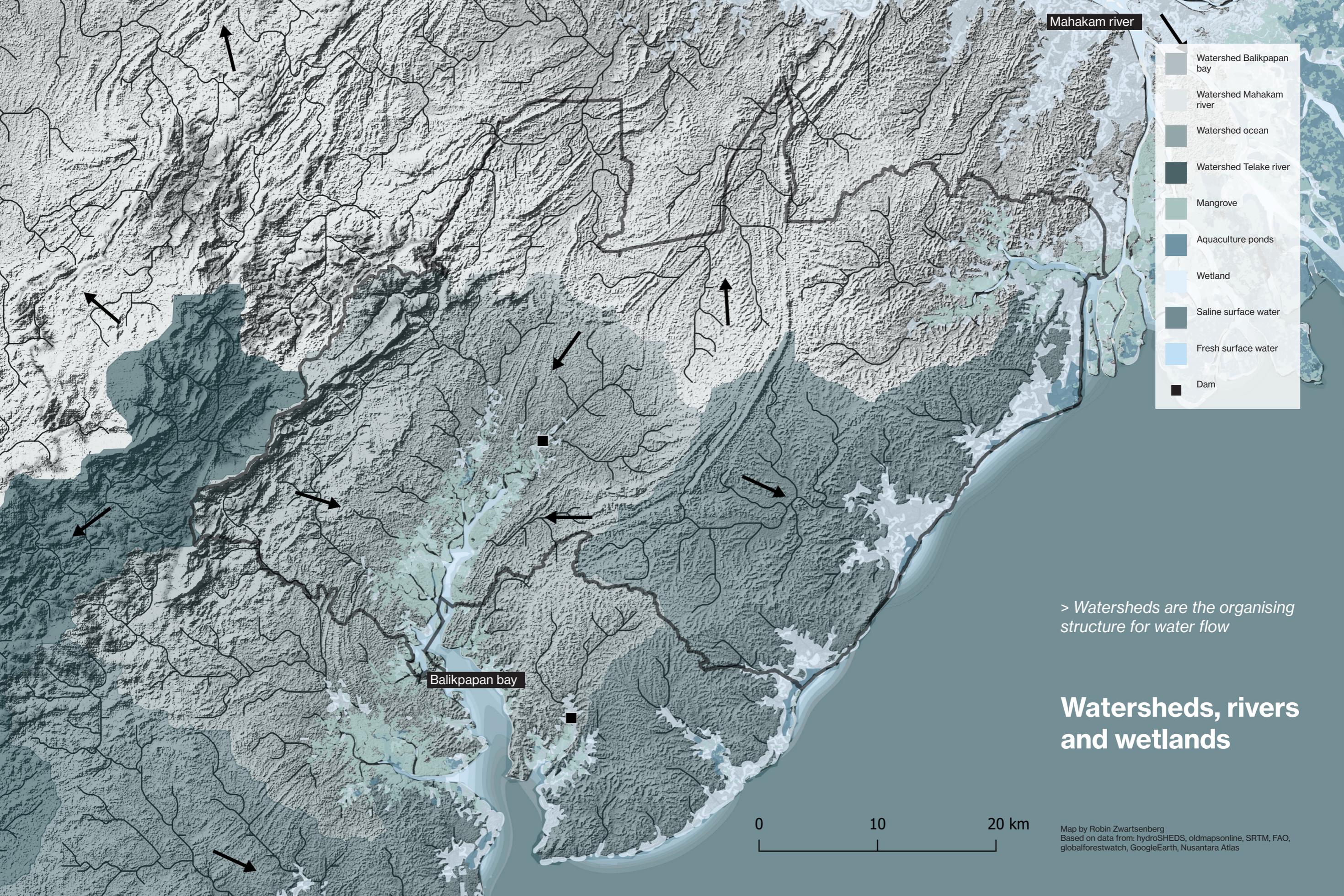
Time aspect

It is important to acknowledge that the hydrologic cycle is significantly more complex than the term "cycle" conventionally implies. The trajectory of a single water molecule within the hydrosphere encompasses a wide range of potential pathways, many of which are non-linear and subject to reversal. For instance, precipitation and surface runoff may be lost to evaporation before contributing to streamflow. (Linton & Budds, 2014). In East Kalimantan too, the hydrological cycle encompasses a range of temporal dynamics. These include the frequency and periodicity of precipitation events such as thunderstorms, which may occur almost daily; the response time of river systems to rainfall, where water levels can rise by several meters overnight; the recharge timescales of aquifers, which may span from years to centuries; and the travel time of a water parcel from headwaters to the ocean, which varies depending on the distance and flow velocity of the stream (MacKinnon, 1996).

Soils & geology

The Nusantara area is shaped by the movement of three major tectonic plates: the Eurasian, Australian, and Pacific plates. This has created a geologically active landscape with underground layers that have been bent





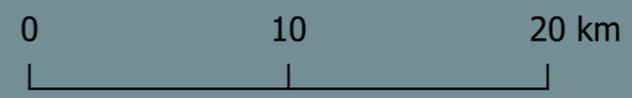
Mahakam river

- Watershed Balikpapan bay
- Watershed Mahakam river
- Watershed ocean
- Watershed Telake river
- Mangrove
- Aquaculture ponds
- Wetland
- Saline surface water
- Fresh surface water
- Dam

Balikpapan bay

> Watersheds are the organising structure for water flow

Watersheds, rivers and wetlands



Map by Robin Zwartsenberg
Based on data from: hydroSHEDS, oldmapsonline, SRTM, FAO, globalforestwatch, GoogleEarth, Nusantara Atlas

and cracked over time. These processes have caused the land to become hilly and uneven, with both gentle and steep slopes. The area is mostly made up of old sedimentary rocks which were deposited in deltaic to shallow marine environments, consist predominantly of sandstones, siltstones, and claystones. Through prolonged weathering under tropical conditions, these rocks break down, contributing to the development of Ultisols and other deeply weathered soil types. Particularly Ultisols dominate the region. Ultisols are typically acidic, low in fertility, and characterized by a high degree of leaching and low nutrient retention, which poses challenges for agriculture and vegetation recovery after land clearing (MacKinnon, 1996).

These nutrient-poor soils are very common in the region, largely due to the effects of the tropical climate. In warm and humid conditions, organic matter decomposes rapidly, and nutrients are quickly absorbed by vegetation rather than accumulating in the soil. As a result, soil fertility remains low, and the removal of vegetation significantly reduces the system's capacity to retain nutrients, further exacerbating degradation (MacKinnon, 1996).

The soils in the Nusantara Capital City (IKN) region are predominantly clay-rich, a characteristic that significantly influences their hydrological and structural behaviour. While these fine-grained soils offer high water-holding capacity and support vegetation in undisturbed forested areas, they also present challenges such as low infiltration rates, surface sealing, and crusting – especially under conditions of deforestation or compaction. These issues, compounded by steep terrain and intense rainfall, elevate the risk of surface runoff, erosion, and landslides. Despite clay's high ability to hold nutrients, prolonged weathering and leaching in the tropical climate render the soils nutrient-poor unless vegetation is maintained. Overall, the dual role of clay – as both a reservoir for moisture and a driver of

erosion and low fertility – underscores the need for nature-based planning strategies that maintain vegetative cover to stabilize soils, enhance infiltration, and sustain long-term ecosystem function (MacKinnon, 1996).

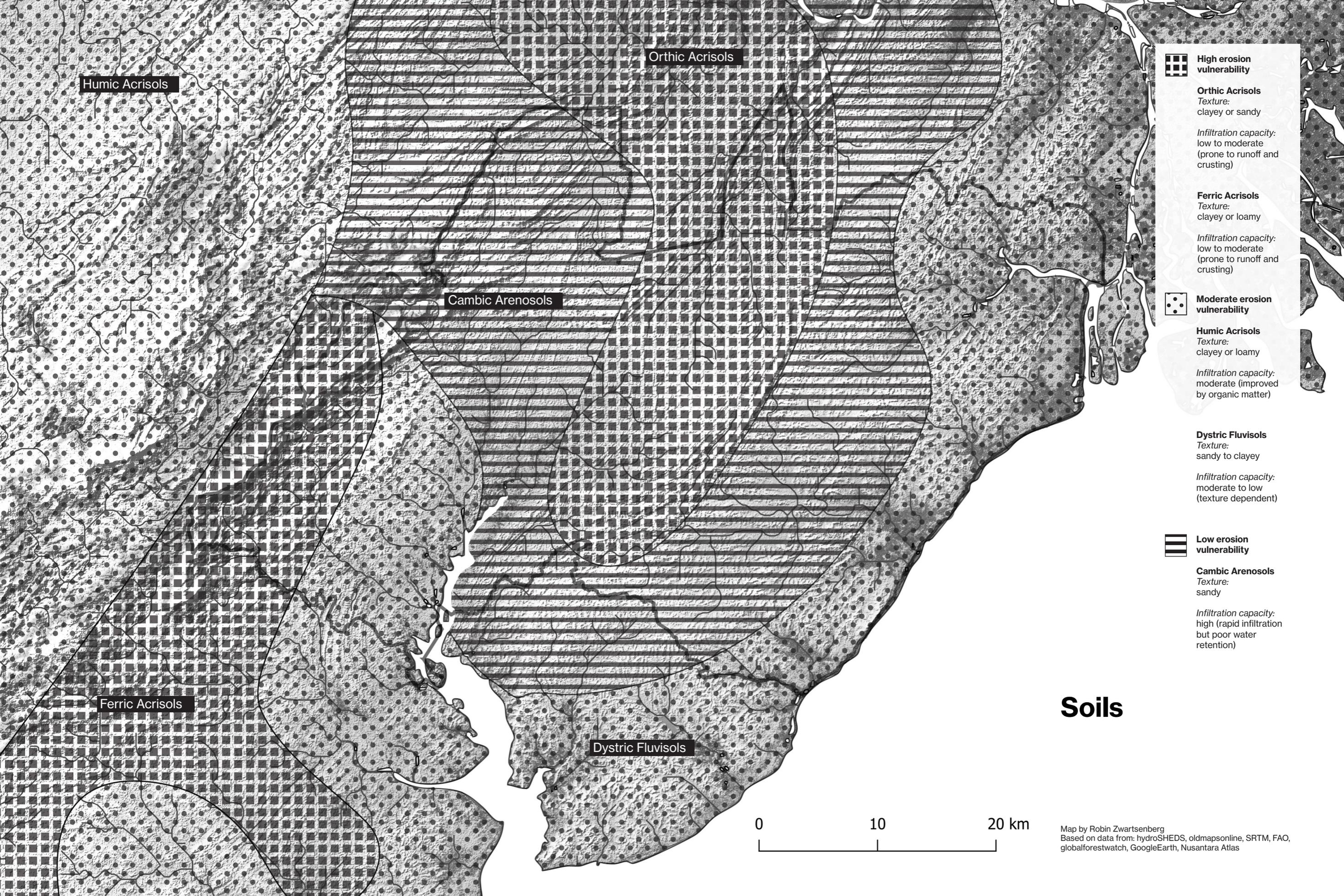
Ecosystems

Originally, a sequence of highly diverse ecosystems is found on site. From upstream to downstream, these include the dryland dipterocarp forests, periodically wet lowland forests, the mangroves, and the bay (MacKinnon, 1996)

Ecosystems surrounding the new capital area are home to 34 critically endangered species, 105 endangered species, and 301 vulnerable species. Unregulated infrastructure growth and agricultural expansion pose serious threats to species like the proboscis monkey, sun bear, and pangolin, all of which depend on intact natural habitats for survival. Changes in land use leading to deforestation, habitat fragmentation, and environmental pollution can reduce both the quality and availability of habitats, negatively impacting biodiversity and pushing vulnerable species closer to extinction. This concern is especially pressing in the development of Nusantara, where rapid progress without careful ecological consideration could further intensify these impacts (Syaban & Appiah-Opoku, 2024).

Dipterocarp forests (dryland rainforests), the dominant forest type in the upland and hilly inland areas of East Kalimantan, are characterized by tall hardwood species such as Shorea, Dipterocarpus, Dryobalanops and Hopea. Trees can reach heights of up to 60 meters, forming a multi-layered canopy structure with distinct vertical stratification; emergent, main canopy, sub-canopy, and understory layers. This structure fosters complex vertical niche. The uppermost emergent trees rise above a dense, continuous canopy, beneath which various species of palms and shade-tolerant flora thrive in the subdued light. This vertical complexity contributes to high biodiversity





Humic Acrisols

Orthotic Acrisols

Cambic Arenosols

Ferric Acrisols

Dystric Fluvisols



High erosion vulnerability

Orthotic Acrisols

Texture: clayey or sandy

Infiltration capacity: low to moderate (prone to runoff and crusting)

Ferric Acrisols

Texture: clayey or loamy

Infiltration capacity: low to moderate (prone to runoff and crusting)



Moderate erosion vulnerability

Humic Acrisols

Texture: clayey or loamy

Infiltration capacity: moderate (improved by organic matter)

Dystric Fluvisols

Texture: sandy to clayey

Infiltration capacity: moderate to low (texture dependent)



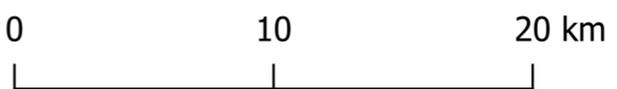
Low erosion vulnerability

Cambic Arenosols

Texture: sandy

Infiltration capacity: high (rapid infiltration but poor water retention)

Soils



Map by Robin Zwartsenberg
 Based on data from: hydroSHEDS, oldmapsonline, SRTM, FAO, globalforestwatch, GoogleEarth, Nusantara Atlas

and microclimatic regulation (MacKinnon, 1996). The canopy cover significantly moderates ground-level temperatures, often maintaining daytime conditions up to 10°C cooler than in degraded or secondary forests – a key factor influencing species distribution, such as the preference of orangutans for intact primary forest habitats (Willie Smits, personal communication, April 15, 2025). The ecological richness of dipterocarp forests makes them vital for regional biodiversity conservation and ecosystem functioning. However, they are highly sensitive to disturbance, particularly deforestation and logging, which rapidly degrade their structure and ecological integrity, making their preservation a key priority in landscape planning for the Nusantara region (MacKinnon, 1996).

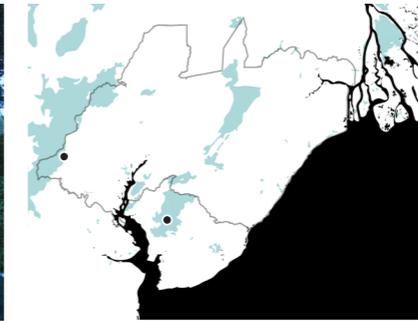
Freshwater wetland forests, typically found in floodplains and river valleys of the Nusantara region, are characterized by seasonal or permanent inundation. These ecosystems support a diverse range of fauna and flora, including amphibians, waterbirds, and aquatic plant species adapted to fluctuating water levels. Functionally, they provide crucial ecosystem services such as natural flood regulation, sediment trapping, and water purification. Their ecological role is especially important in buffering downstream areas against extreme hydrological events and maintaining water quality across the watershed (MacKinnon, 1996; Syaban & Appiah-Opoku, 2024).

Mangrove forests in the Nusantara region, particularly along the coastline and estuarine zones near Balikpapan Bay, are vital coastal ecosystems. Their spatial distribution is shaped by salinity gradients and tidal inundation patterns. A distinct gradient is observable in the mangrove vegetation, transitioning from upstream *Nypa* (*Nypa fruticans*) to downstream *Rhizophora* species. *Rhizophora apiculata* dominates closer to the sea; *Nypa* thrives further inland in brackish, low-salinity tidal zones. These forests provide essential ecological functions,

including serving as breeding grounds for marine life, buffering against coastal erosion, and acting as significant carbon sinks. However, mangroves face increasing threats from habitat loss due to urban expansion and aquaculture, pollution and disrupted freshwater flow from upstream, ecological connectivity with upstream, and excessive sedimentation resulting from inland erosion, all of which undermine their resilience and ecological function (MacKinnon, 1996).

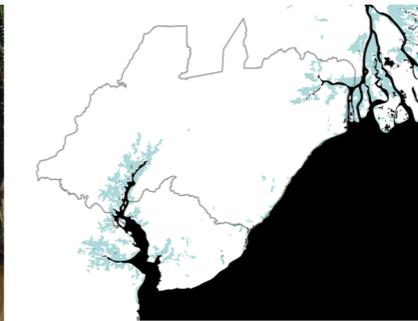
The coastal and marine ecosystems surrounding Nusantara, particularly along the Makassar Strait and within Balikpapan Bay, comprise coral reefs and seagrass beds. These ecosystems are critical for supporting fisheries and sustaining marine biodiversity. Balikpapan Bay, in particular, is recognized as a biodiversity hotspot, providing essential habitat for endangered species such as the Irrawaddy dolphin and proboscis monkey, while also supporting aquaculture and local livelihoods. These ecosystems are ecologically and economically valuable, yet remain vulnerable to coastal development and pollution pressures (MacKinnon, 1996).

Rivers play a crucial role in maintaining ecosystem integrity and supporting biodiversity, particularly through their function as ecological corridors that ensure habitat connectivity across landscapes. This connectivity enables the migration and dispersal of aquatic and terrestrial species, supporting diverse life cycles and genetic exchange. Rivers are especially vital for sustaining fish populations, many of which rely on uninterrupted flow and access to spawning and feeding grounds. Moreover, healthy river systems contribute to broader ecosystem services such as nutrient cycling, sediment transport, and flood regulation, underscoring their foundational role in both ecological and socio-economic systems (MacKinnon, 1996; Syaban & Appiah-Opoku, 2024).



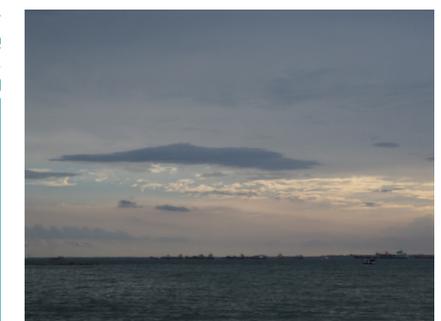
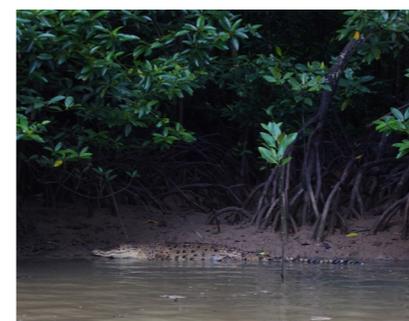
Map by Robin Zwartsenberg. Based on data from: SRTM, Nusantara Atlas

High- and lowland rainforest



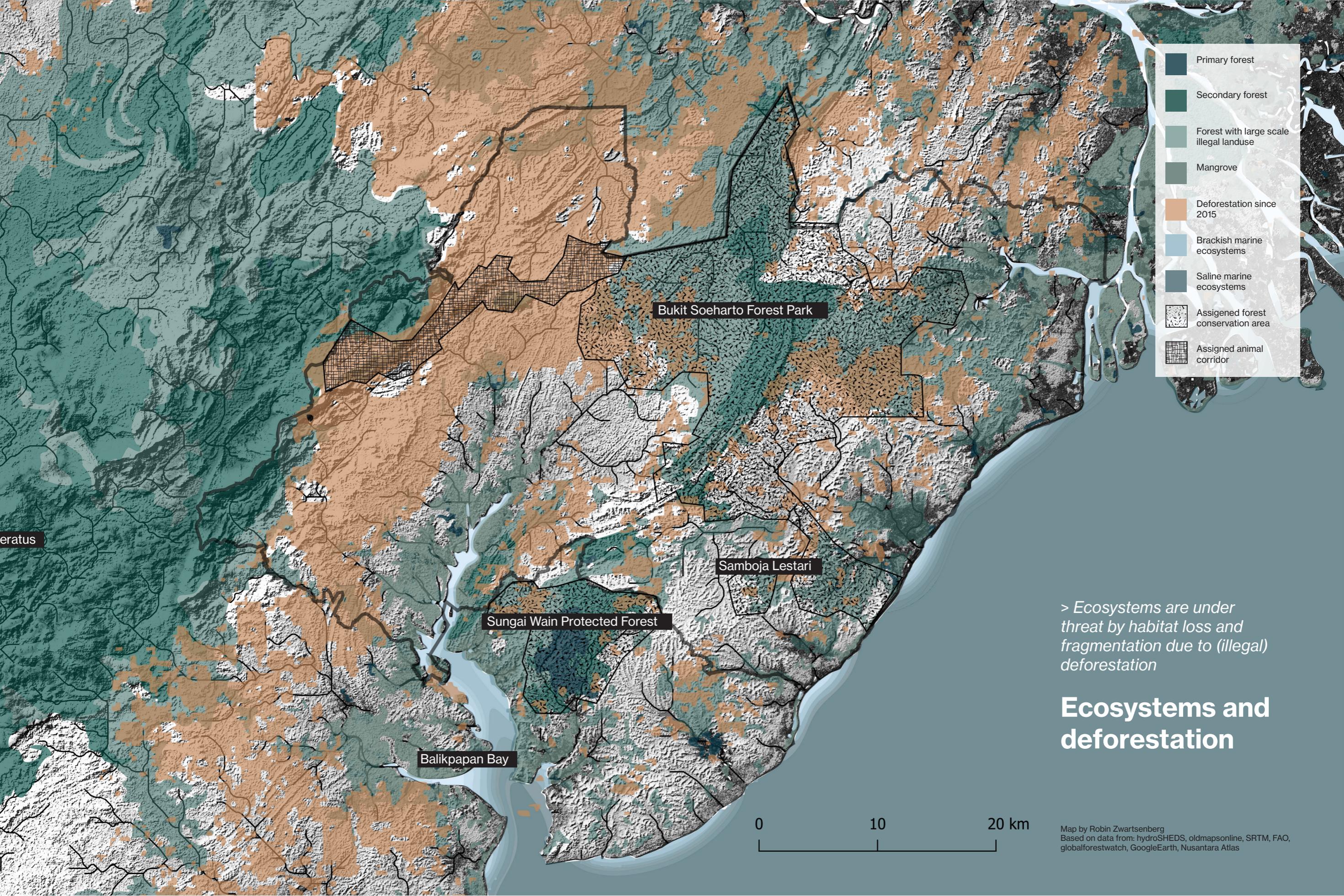
Map by Robin Zwartsenberg. Based on data from: SRTM, Nusantara Atlas

Mangroves



Map by Robin Zwartsenberg. Based on data from: SRTM, Nusantara Atlas

Coastal and marine ecosystems



- Primary forest
- Secondary forest
- Forest with large scale illegal landuse
- Mangrove
- Deforestation since 2015
- Brackish marine ecosystems
- Saline marine ecosystems
- Assigned forest conservation area
- Assigned animal corridor

eratus

Bukit Soeharto Forest Park

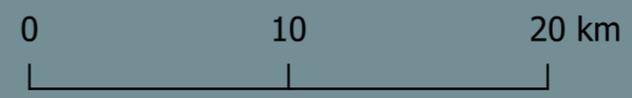
Samboja Lestari

Sungai Wain Protected Forest

Balikpapan Bay

> Ecosystems are under threat by habitat loss and fragmentation due to (illegal) deforestation

Ecosystems and deforestation



Map by Robin Zwartsenberg
Based on data from: hydroSHEDS, oldmapsonline, SRTM, FAO, globalforestwatch, GoogleEarth, Nusantara Atlas

Tree architecture

'Even suburban nature seemed aggressively lush, rampant with excessively large palms; with trees covered with ferns, ferns like fans, ferns sprouting like bullrushes in every fork of every tree' Redmond O'Hanlon, *Into the Heart of Borneo* (1985).

Indonesia's rich biodiversity is not only evident in its vast number of plant species, but also in the abundant diversity of tree architecture that define its landscapes. These varying plant forms – shaped by ecological conditions such as light, soil, and competition – create complex, multi-layered forest canopies with ever-shifting patterns of light and shadow. Towering dipterocarps dominate the emergent layer with their tall, columnar trunks and expansive crowns, while smaller trees with multi-stemmed or irregular forms fill the understory. The aesthetic value of this structural diversity is profound: enormous round leaves and diverse palm forms – some arching like roofs, others radiating outward – add visual rhythm to the forest composition. Large epiphytic ferns perch high in trees, while smaller ferns cascade down trunks like living green banners. Whirling lianas twist through the vegetation, linking trees in dynamic, sculptural patterns. This architectural variety does not only enhance ecological function – such as habitat provision, microclimate regulation, and nutrient cycling – but also offers a rich visual and spatial language. Acoustic landscapes are equally dynamic, with a continuous soundscape of primates, cicadas, and other fauna that shift in intensity and composition throughout the day and night, yet remain persistently rich and immersive. The forest here is both habitat and gallery, offering inspiration for landscape compositions rooted in the harmony and complexity of tropical forest systems (Field trip observations; MacKinnon, 1996).



Human interventions

This layer captures the transformation of the natural environment through human activities such as land reclamation, water management, infrastructure development, and settlement. These interventions are shaped by long-term socio-economic and cultural processes, leaving sometimes big imprints in the landscape (Nijhuis, 2022).

Land uses

The area has been a target of logging activities on the large scale (Global Forest Watch, n.d.) (see figure...). These logging activities have varying impacts on the landscape, depending on the soil, topography and severeness of logging (MacKinnon, 1996).

Logging

Secondary and partly logged forests in the Nusantara region represent areas previously subjected to timber extraction or land clearing, now undergoing varying degrees of natural regeneration, with varying degrees of success depending on disturbance intensity and soil conditions. This type of forest is largely represented in Bukit Soeharto (see figure of partly logged forests). While these forests typically support lower biodiversity compared to primary forests, they remain ecologically valuable as they contribute to habitat connectivity, carbon sequestration, and erosion control. They also serve as buffers or corridors around primary reserves, extending conservation value. Their transitional nature also offers significant potential for targeted reforestation or integration into agroforestry systems, particularly when supported by local ecological knowledge, thereby enhancing both ecological resilience and community livelihoods (MacKinnon, 1996).

Savanna-like and grassland areas in the Nusantara region are typically the result of prolonged disturbance, such as repeated logging, fire, or forest conversion, leading to dominance by hardy species like *Imperata cylindrica* (alang-alang grass). These



landscapes are characterized by low biodiversity, degraded soil conditions, and a high susceptibility to wildfires, especially during dry periods (MacKinnon, 1996; Steiner, 2019). While ecologically impoverished, they present opportunities for ecological restoration, reforestation, or controlled agroforestry interventions aimed at improving land productivity and reducing fire risk, as seen in Samboja Lestari (Steiner, 2019).

Logging activities leave forest soils exposed, significantly increasing their vulnerability to surface runoff and erosion. Without the stabilizing effect of tree cover, the soil lacks natural anchorage and becomes highly prone to being washed away (Wahid et al., 2024). The lack of infiltration causes dry soils, which is one of the main contributors to large scale wildfires. Local forestry specialist Willie Smits describes in his TED talk (2009) that there are ten thousands of underground coal fires in East Kalimantan. Each dry season, the cracks in the soil allow oxygen to reach the smouldering layers and cause new forest fires. Once the grasslands start burning, there is no stopping. After the fire, the ash with all nutrients goes to the sea, leaving the land with an even lower soil fertility, and it kills the corals on the coastal zones.

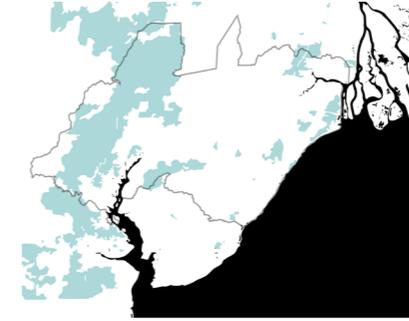
Plantations

Monoculture plantations, such as palm oil and eucalypt, have been established extensively due to the availability of relatively flat terrain and accessible road infrastructure in East Kalimantan (Kurniawan et al., 2021). These plantations have a very low value for biodiversity: the uniform planting of a single species (monoculture) reduces structural diversity (tree heights, stem diameters, vegetation layers), which in turn lowers habitat variety for insects, birds, and mammals (MacKinnon, 1996).

Eucalypt plantations in the Nusantara region are fast-growing, economically valuable monocultures. While they offer short-term benefits such as timber and pulp production, they are ecologically

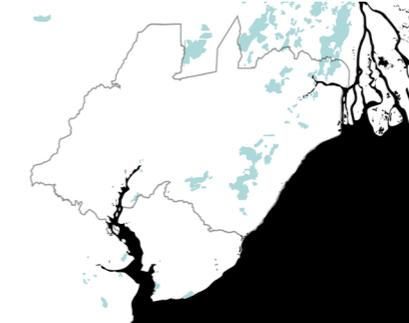
destructive, supporting little biodiversity and contributing to soil drying due to high water uptake and destruction of soil structure (MacKinnon, 1996). Their flammability also increases wildfire risk, particularly in dry conditions, explains local forestry specialist Willie Smits (personal communication, April 15, 2025). Furthermore, eucalypt trees release chemicals that can inhibit the growth of surrounding vegetation, potentially complicating reforestation efforts (Chu et al., 2014). Nevertheless, their rapid biomass accumulation and fast canopy closure make them useful in phased ecological restoration strategies, especially when combined with native species. The dense canopy helps stabilize the microclimate by lowering surface temperatures, shading the soil, and reducing evaporation – conditions favourable for the regeneration of more sensitive native plants. Acting as pioneer species, eucalypts can facilitate ecological succession by creating structural conditions for natural regeneration or targeted planting. When carefully managed through mixed-species planting or gradual replacement, they can support the transition toward more diverse and resilient forest ecosystems (Willie Smits, personal communication, April 15, 2025).

Another wide spread crop is the oil palm. Oil palm plantations exert even greater adverse impacts on hydrological processes and ecological integrity than eucalypt plantations; they are like a biological desert: almost no other species are found. These plantations have no undergrowth, caused by active removal with chemicals, soil and light conditions. Big amounts of herbicides are added to suppress weeds and undergrowth, and these chemicals will last for centuries explains local forestry specialist Willie Smits (TEDx Talks, 2011). The dense, uniform canopy of oil palm trees intercepts most of the sunlight, significantly reducing the amount of light that reaches the forest floor. This creates a dark understory environment where few pioneer species adapted to brighter conditions can grow. The oil palms strongly compete for surface water and leave little



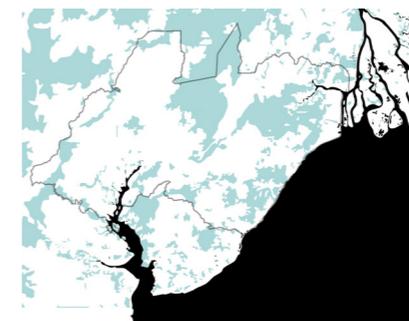
Map by Robin Zwartsenberg. Based on data from: SRTM, Nusantara Atlas

Industrial pulp wood and oil palm plantations



Map by Robin Zwartsenberg. Based on data from: SRTM, Nusantara Atlas

Coal mining



Map by Robin Zwartsenberg. Based on data from: SRTM, Nusantara Atlas

Forest with large scale illegal deforestation

water available for other plant species in the understory, inhibiting their growth. The lack of undergrowth leaves the soil exposed to surface runoff, which is increased even more due to soil compaction by machinery use. This leads to higher peak flows, erosion and sedimentation in nearby streams. Oil palm increases surface runoff twice compared to natural forests and decreases infiltration, which can lead to flash floods and reduced baseflow in rivers (MacKinnon, 1996). Big amounts of fertilizer are added to oil palm plantations, due to the natural low fertility of the tropical soils; up to 1760 kg of fertilizer is used per year per hectare (TEDx Talks, 2011). Leftover fertilizer and herbicides are transported by surface runoff and pollute rivers and water bodies downstream, harming aquatic life through eutrophication and pollution (MacKinnon, 1996).

Mining

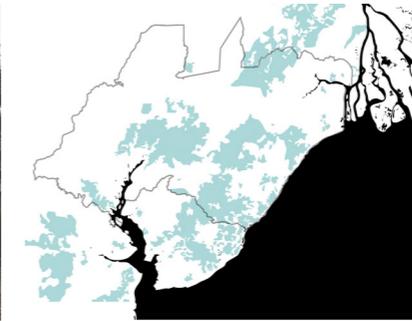
Coal mining is a significant extractive activity in the Nusantara region, contributing to severe environmental degradation. Coal mining, widespread in East Kalimantan, causes deforestation, landscape fragmentation, and heavy sedimentation of waterways due to open-pit methods and inadequate rehabilitation. Mining disrupts hydrological systems, degrades water quality, and contributes to long-term ecological imbalances (Izza et al., 2019)

Small scale agriculture and aquaculture

In addition to large-scale monoculture plantations, the region also supports small-scale agriculture. These areas are predominantly inhabited by smallholder farmers who settled there as part of a government-led transmigration program initiated already in 1938, and significantly increasing from 1950. These transmigration schemes aimed to alleviate population pressure in densely populated areas by relocating communities to less populated regions, including the Nusantara area. Transmigration lands were typically cleared for agricultural use, resulting in the conversion of forested areas into farmland. This land was

primarily used for cultivating cash crops such as oil palm and rubber, as well as subsistence crops including dry rice, maize, soybeans, cassava, and various fruits like coconut, banana, papaya, and durian. These crops are often grown in polyculture systems rather than as monocultures. While agriculture provides an essential source of livelihood for these communities, certain land management practices – particularly slash-and-burn techniques – can exacerbate environmental risks such as wildfires and soil erosion if not conducted sustainably. The landscape is spatially diverse, comprising a mosaic of open and closed areas, with farming practices typically adapted to local variations in soil quality, water availability, and topography (MacKinnon, 1996).

In the coastal and estuarine regions of Kalimantan, small-scale fisheries and aquaculture form an essential part of local livelihoods and food security. One prominent aquaculture method is tambak – manmade brackish-water ponds constructed on coastal mudflats or in tidal swamplands near mangrove areas. These systems are used to rear fish and prawns, including tiger prawns (*Penaeus monodon*), milkfish (*Chanos chanos*), tilapia, mullet, snapper, mangrove crabs (*Scylla serrata*), and others. Tambak ponds demonstrate a deep understanding of local tidal cycles and estuarine hydrology. Water flow is carefully regulated using sluice gates, allowing for regular flushing that removes waste and brings in fry and nutrients with the tides. Traditional tambak rely largely on wild larvae swept in during high tide. Tambak systems are economically and ecologically significant for local communities. They provide a diversified income and dietary protein, and support a mosaic of species, including birds like storks and egrets that feed in and around the ponds. However, there are ecological trade-offs. The conversion of mangrove forests to tambak can undermine the very productivity these systems rely on, as mangroves serve as critical nurseries and sources of detrital food (MacKinnon, 1996).



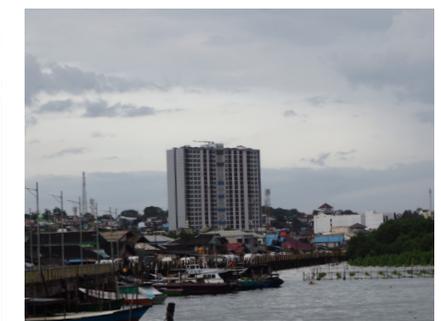
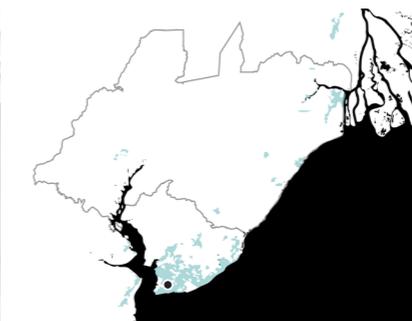
Map by Robin Zwartsenberg. Based on data from: SRTM, Nusantara Atlas

Local livelihoods - dryland agriculture (smallscale farming) in Sepaku



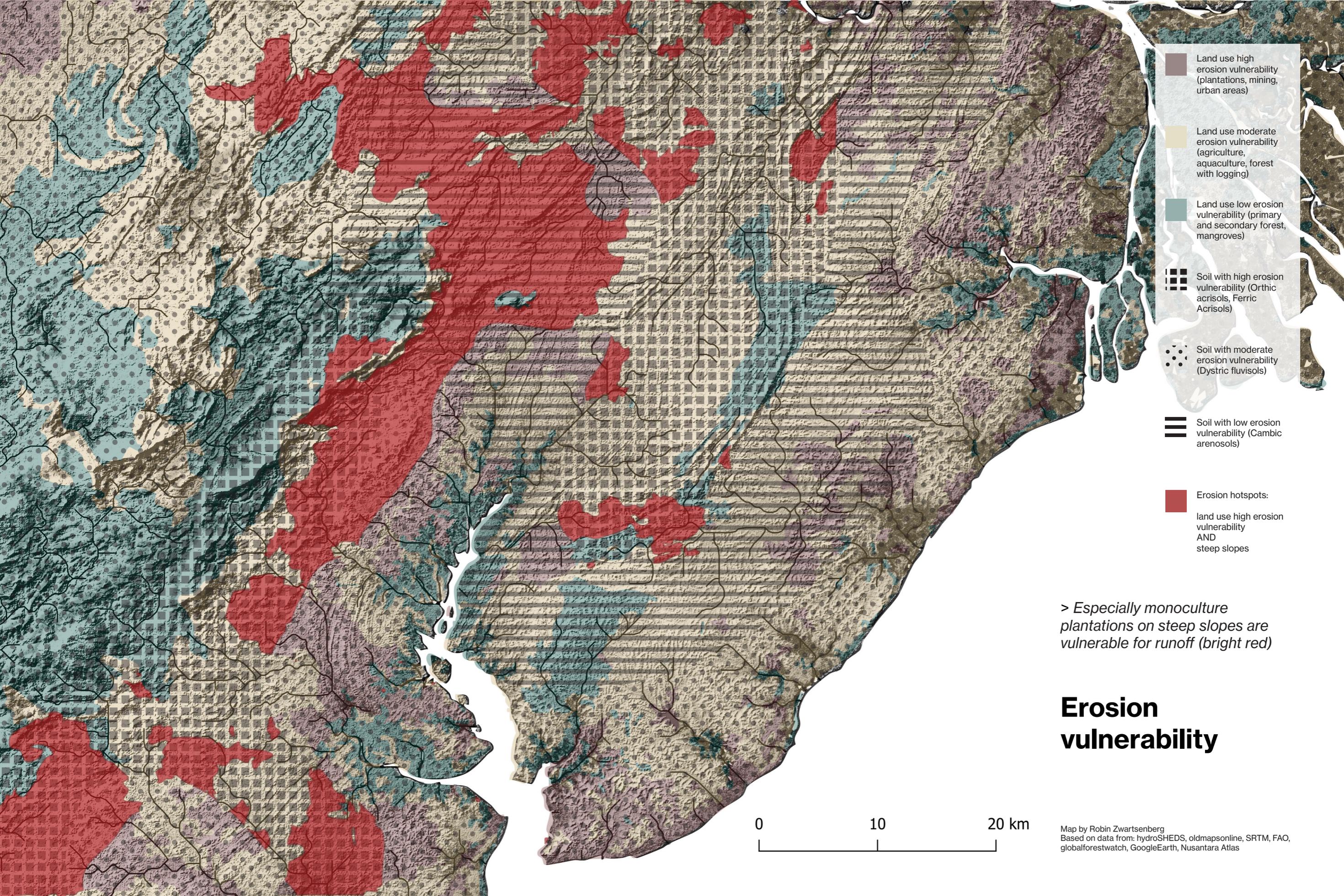
Map by Robin Zwartsenberg. Based on data from: SRTM, Nusantara Atlas

Local livelihoods - fishermen and aquaculture in Balikpapan Bay



Map by Robin Zwartsenberg. Based on data from: SRTM, Nusantara Atlas

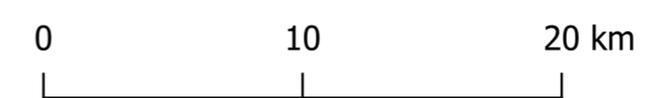
Local livelihoods - urban living



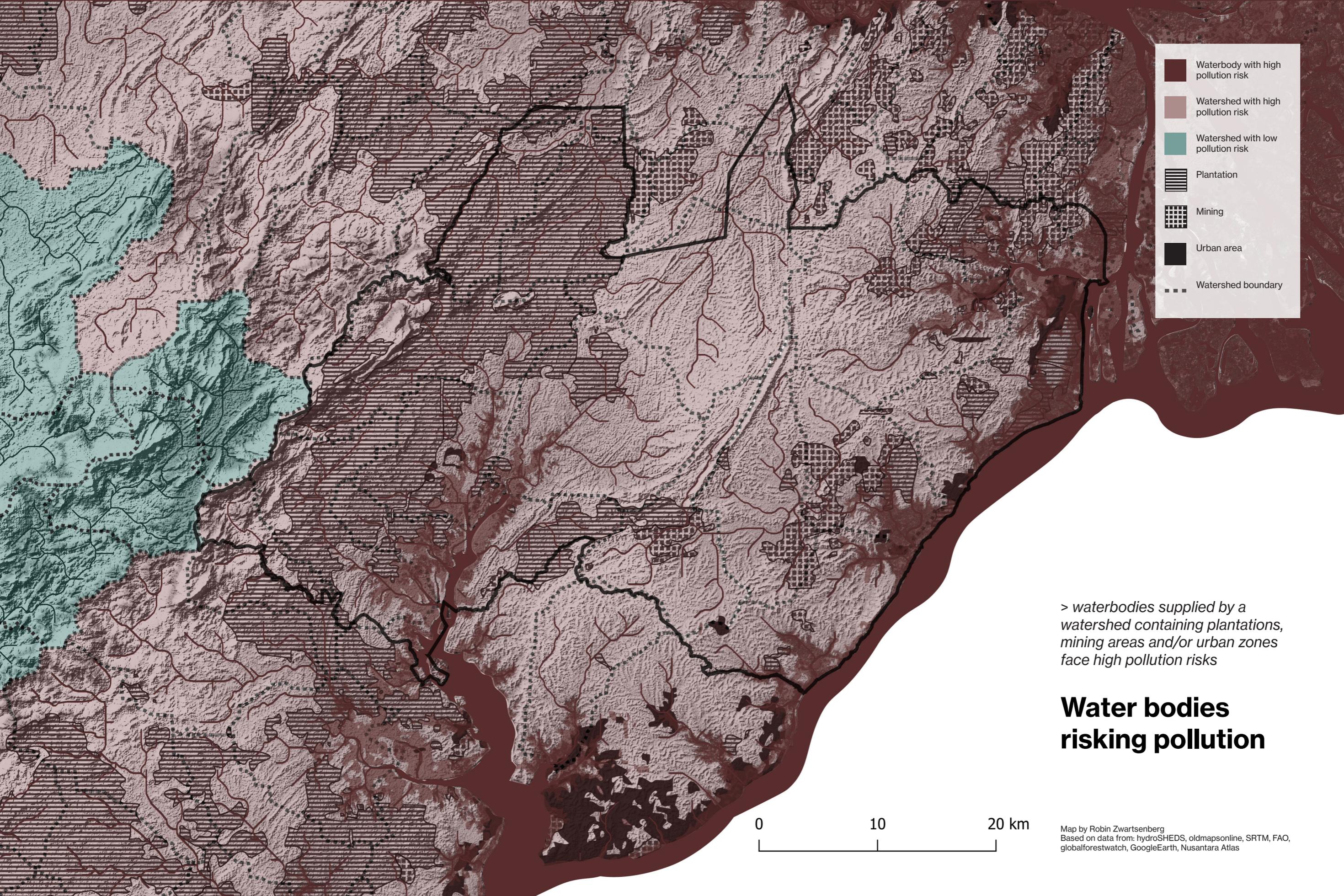
- Land use high erosion vulnerability (plantations, mining, urban areas)
- Land use moderate erosion vulnerability (agriculture, aquaculture, forest with logging)
- Land use low erosion vulnerability (primary and secondary forest, mangroves)
- Soil with high erosion vulnerability (Orthic acrisols, Ferric Acrisols)
- Soil with moderate erosion vulnerability (Dystric fluvisols)
- Soil with low erosion vulnerability (Cambic arenosols)
- Erosion hotspots:
land use high erosion vulnerability
AND
steep slopes

> Especially monoculture plantations on steep slopes are vulnerable for runoff (bright red)

Erosion vulnerability



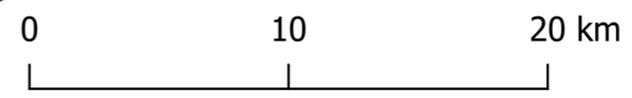
Map by Robin Zwartsenberg
Based on data from: hydroSHEDS, oldmapsonline, SRTM, FAO, globalforestwatch, GoogleEarth, Nusantara Atlas



- Waterbody with high pollution risk
- Watershed with high pollution risk
- Watershed with low pollution risk
- Plantation
- Mining
- Urban area
- Watershed boundary

> waterbodies supplied by a watershed containing plantations, mining areas and/or urban zones face high pollution risks

Water bodies risking pollution



Map by Robin Zwartsenberg
Based on data from: hydroSHEDS, oldmapsonline, SRTM, FAO, globalforestwatch, GoogleEarth, Nusantara Atlas

Water management

The hydrology of an area is a result from the historical interaction between nature and culture (Linton & Budds, 2014; Tjallingii, 2015). In this region, these impacts are primarily manifested through extensive land use changes. Widespread logging and the expansion of monoculture plantations in the Nusantara region have significantly altered the local hydrology, primarily by reducing the soil's infiltration capacity and its ability to retain moisture. This degradation increases the risk of wildfires, surface erosion, flooding, and excessive sedimentation in water bodies. Additionally, plantation activities often contribute to water pollution through the use of agrochemicals and runoff, further degrading water quality. The loss of natural forest cover also disrupts local precipitation dynamics by decreasing evapotranspiration and the availability of condensation nuclei, which can reduce local rainfall (Kurniawan et al., 2021; MacKinnon, 1996; Spracklen et al., 2012; Syaban & Appiah-Opoku, 2024).

Currently, six dams are planned to provide raw water for Nusantara, in a region beyond Nusantara's borders, up to the Mahakam river. Of these dams, one - the Sepaku Semoi Dam – is located within the urban planning zone of the city (Said et al., 2024).. Besides being constructed to secure a raw water supply, it is supposed to mitigate flood risks for both the existing Sepaku area and the planned capital (Simbolon et al., 2025).

While the dams play a strategic role in securing water provision for IKN Nusantara and surrounding areas, they also represent a significant modification of the local hydrological regime, with far-reaching ecological consequences. The construction of the reservoir alters the natural flow of the Sepaku River, disrupting downstream ecosystems by changing sediment transport, reducing flow variability, and impacting water quality and quantity. Flow variability is negatively affected through the reduction of natural seasonal flow variation, which many

aquatic species rely on for breeding, feeding, and migration. The physical barrier created by the dam fragments aquatic habitats and hinders species movement, compromising biodiversity and genetic exchange (MacKinnon, 1996).

Infrastructure

The infrastructure network in the Nusantara region reflects a layered development shaped by both historical land use and recent capital-driven expansion.

Two major roads connect Balikpapan in the south to Samarinda in the north, forming key transportation corridors in the region. The regional road traverses agricultural transmigration zones, passes through Bukit Soeharto National Park, and skirts large-scale mining sites. It is a two-lane road with considerable traffic, cutting directly through the landscape (see figure...). Another two lane road runs around Balikpapan Bay, linking the two largest villages within the Sepaku district. In these villages, residential structures are predominantly located along the main road and the network of perpendicular dirt roads that extend into the surrounding area, creating a linear settlement pattern.

A recently constructed toll road runs roughly parallel to the older regional road and the coastline, with distances between the two roads ranging from 1 to 18 kilometres, and the toll road situated approximately 15 kilometres inland from the coast (see figure...). This four-lane highway, separated by a central concrete barrier, represents a substantial infrastructural intervention with significant ecological implications, and is planned to extend towards the new city. Its scale and design create a physical barrier that impedes wildlife movement, particularly between upland and lowland ecosystems, thereby contributing to habitat fragmentation. In addition to this, another major infrastructure project is underway within the mangrove-dominated Balikpapan Bay area – a large bridge intended to connect the two sides of

the bay, approximately 20 kilometres from its mouth (Esterman, 2023).

Single-lane hardened dirt roads traverse the agricultural areas, following the natural topography and avoiding steep gradients. In upland forested areas, a network of unpaved logging roads – originally established for timber extraction – remains present (see figure...). Roads leading into wetland zones and fishing villages are aligned along higher elevation lines to minimize flooding risk. In the fishing villages themselves, paths are frequently constructed on stilts, extending from the settlement into the water to accommodate tidal conditions and maintain connectivity.

Settlements

Two main cities lie close to the future capital city. Balikpapan lies on the corner of Balikpapan bay and the open ocean. As of 2023, Balikpapan has an estimated population of approximately 740,000 resident (Wikipedia, 2025b). Balikpapan developed as a resource – extraction city for oil exploitation in the early 20th century. Balikpapan's refinery processes oil from South Kalimantan fields, and the city produces kerosene, diesel oil, gasoline, and fuel oil. The city's economic boom, fuelled by multinational oil companies, led to a significant influx of migrants and expatriates seeking employment opportunities (MacKinnon, 1996). It currently still is a company city dominated by oil industries, with significant infrastructure built to support petroleum refining, storage, and export (Wikipedia, 2025b).

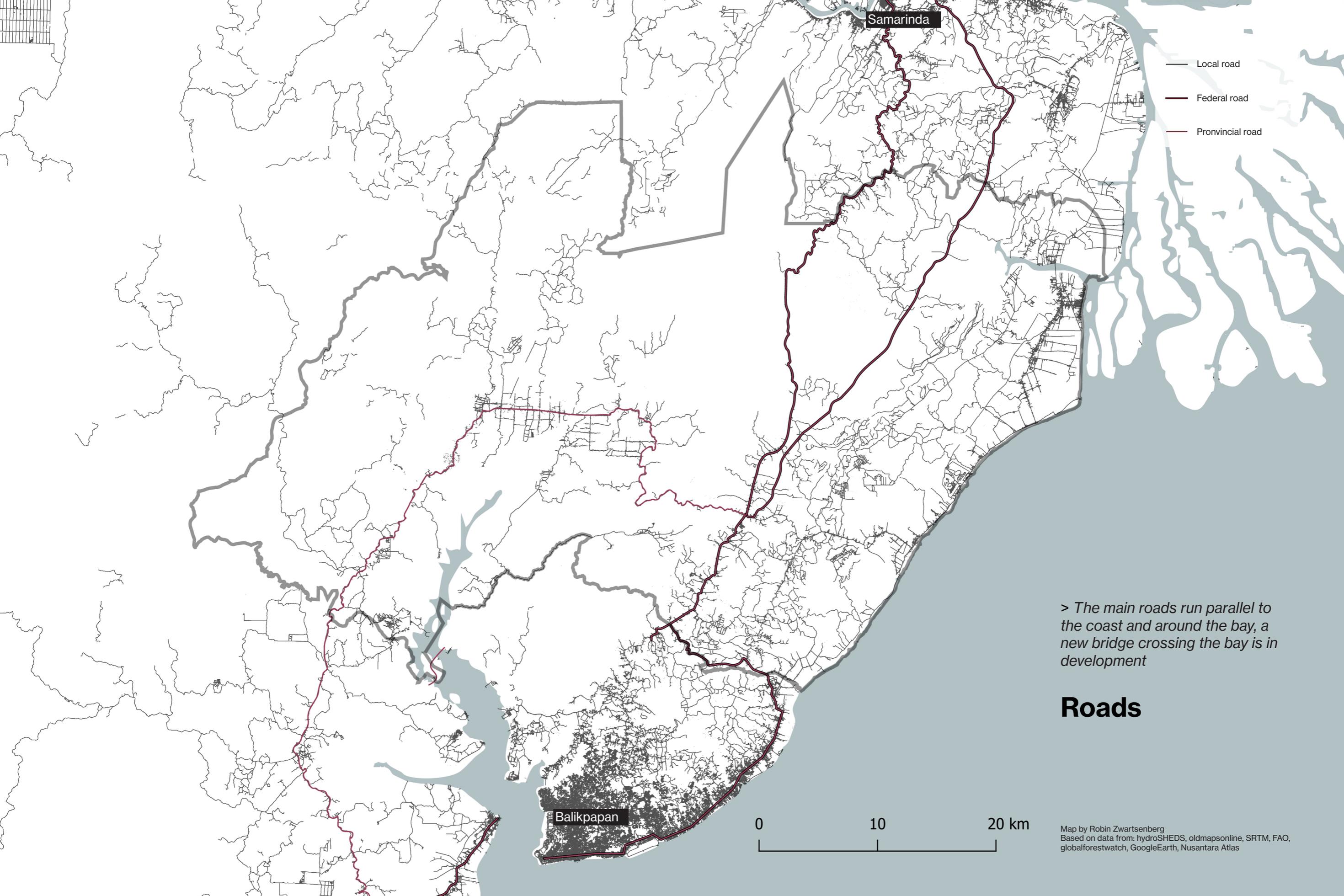
Samarinda, with a current amount of 870,000 residents, is the capital of East Kalimantan. Samarinda has its roots in indigenous settlement by the Kutai people and later migration by Bugis and Banjar communities. Situated along the Mahakam River, it developed as a strategic hub for riverine trade, transportation, and agriculture. Historically, the area was shaped by a mix of traditional and migrant influences, though the

city is often viewed as having more deeply rooted local communities than the rapidly industrialized Balikpapan (Wikipedia, 2025a; MacKinnon, 1996).

The two cities possess different characteristics; Balikpapan and Samarinda differ in their historical development, urban structures, and available services. Balikpapan's growth is rooted in industrial activities, while Samarinda's development is influenced by its riverine setting and role as a provincial capital (Wikipedia, 2025a; MacKinnon, 1996).. Together, the cities provide a broad range of industrial, cultural, economical, educational and healthcare services.

Indigenous settlements in the Nusantara region, particularly among the Dayak and Balik peoples, have traditionally been located along lowland and upland rivers throughout Kalimantan. Rivers play a central role in both the daily lives and cultural identities of local communities, serving as vital sources of fish and freshwater, as well as providing fertile land for practices such as shifting cultivation. Furthermore, rivers are critical arteries for transportation, trade, and communication, linking inland communities to downstream trade networks. These waterways thus shape not only the ecological setting of Dayak society but also their social and economic relationships, both within and between communities (MacKinnon, 1996).

Following from this, the orientation of settlements along rivers holds cultural significance among the Dayak people, who traditionally distinguish spatially between upstream and downstream directions. Upstream areas are often seen as purer, representing the origin of life, while downstream areas are linked to trade and interaction with external communities. Upstream–downstream orientations have traditionally served as important spatial reference frameworks. This hydrological axis is used alongside cardinal directions such as east–west to structure spatial understanding,



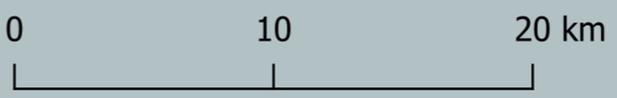
Samarinda

Balikpapan

- Local road
- Federal road
- Provincial road

> The main roads run parallel to the coast and around the bay, a new bridge crossing the bay is in development

Roads

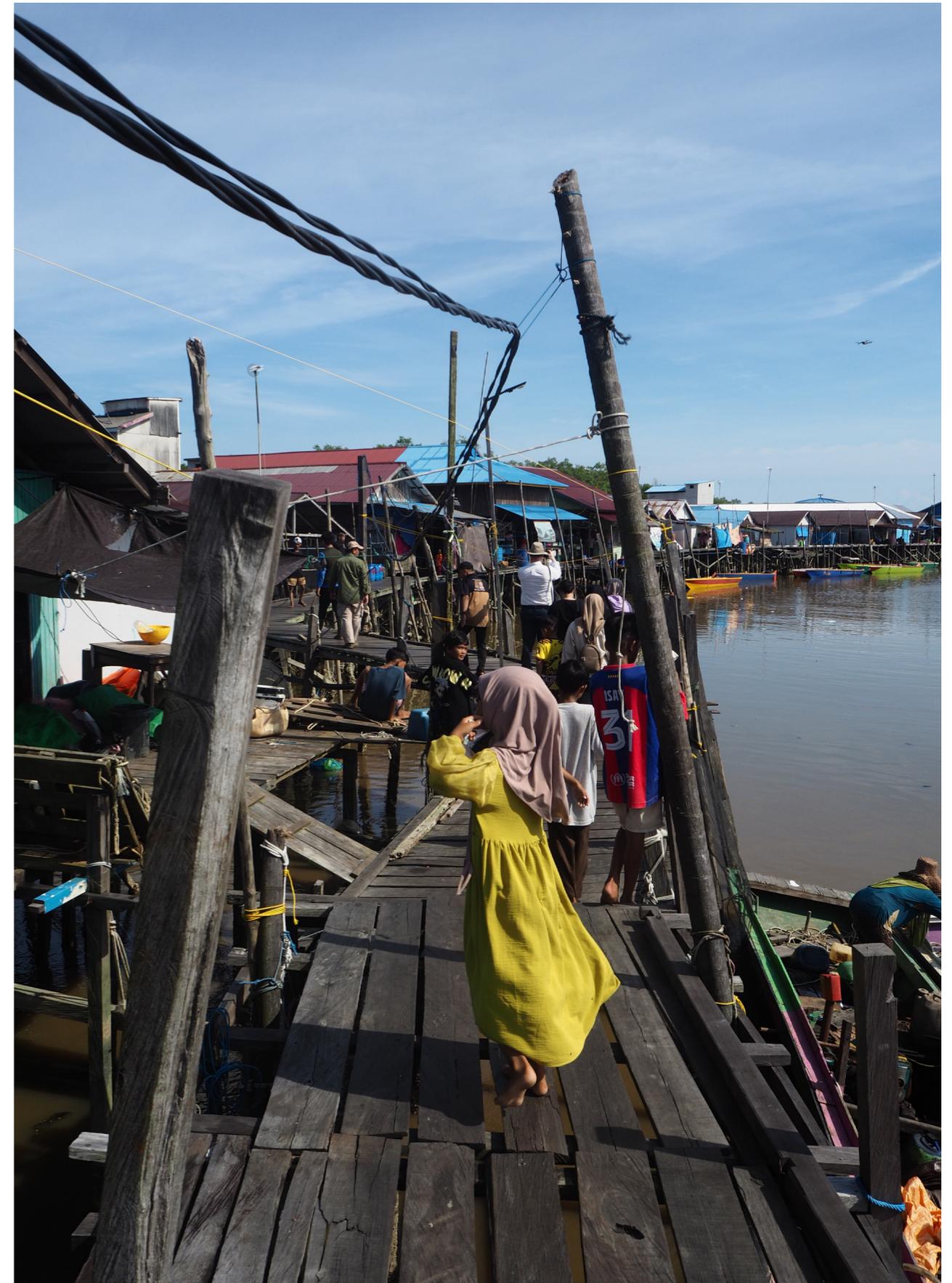


Map by Robin Zwartsenberg
Based on data from: hydroSHEDS, oldmaponline, SRTM, FAO, globalforestwatch, GoogleEarth, Nusantara Atlas

navigation, and settlement organization(Sally & Sihombing, 2023).

Indigenous communities traditionally sustain themselves through a mix of forest product collection, fishing, and ecologically sophisticated swidden agriculture. In recent decades, interactions with transmigrant populations and government resettlement initiatives have led to increasingly permanent and spatially mixed communities. Traditional livelihoods are now often complemented by small-scale farming of cash and subsistence crops, along with greater engagement in market-based activities (MacKinnon, 1996). For many Indigenous communities in Kalimantan, both rivers and land represent more than just an economic asset – it is deeply tied to their identity and way of life. As a result, changes in land use have significant implications for maintaining cultural diversity and social unity (Syaban & Appiah-Opoku, 2024).

A notable example of an Indigenous community are the Balik in Sepaku. Located in the Sepaku district, this community maintains ancestral ties to the land and relies partly on forest resources for their livelihoods. They have been actively engaged in rehabilitating customary forests to preserve their cultural heritage and sustain their environment (NUSANTARA FUND, 2025).



This layer reflects how societies conceptualize and govern landscapes, including spiritual beliefs, scientific understanding, political systems, and aesthetic ideals. These perspectives influence short- to medium-term decisions and shape both the use and perception of natural systems – for instance, the differing cultural meanings and governance of water (Nijhuis, 2022).

High - tech and Lo – TEK in the region

Both high tech and Lo – TEK (Local Traditional Ecological Knowledge) are represented in the region.

In terms of high tech, Nusantara is envisioned not merely to match other contemporary urban centres but to surpass them through its designation as a ‘smart city.’ The government aims to integrate advanced technological systems such as autonomous vehicles, artificial intelligence-based monitoring, and digital infrastructure to optimize urban management, mobility, and public services (IKN, personal communication, February 13, 2025).

In terms of Local Ecological Traditional Knowledge (Lo-TEK) in East Kalimantan, harmony with nature is fundamental to the practices of indigenous communities. Firstly, they make use of natural forests. The Dayak have deep botanical knowledge used for medicine and food (MacKinnon, 1996). When extracting forest resources, these communities typically govern forest areas through a council or a community head, who grants permission for resource use. This permission is granted based on the forest’s carrying capacity, which is assessed with consideration to seasonal changes, such as breeding seasons or drier periods, ensuring sustainable use. This governance system reflects a deep understanding of ecological balance and the need for adaptive resource management over time (Joshi et al., 2004).

Secondly, beside the resource extraction

of natural forest, the Dayak also practice agroforestry with a variety of forest garden types, tailored to the soil fertility of specific areas, which they assess by recognizing indicator species. Depending on the land’s characteristics, they would enrich the existing forest with edible species, such as fruit trees (Joshi et al., 2004).

Thirdly, the Dayak engage in shifting cultivation (slash and burn). This form of agriculture was carried out with careful consideration, as regeneration plans for the forest spanned up to 200 years, ensuring sustainable land use across multiple generations (Joshi et al., 2004). In the current landscape, slash-and-burn techniques, though once sustainable, have become unsustainable and are a significant cause of wildfires. This shift is largely due to the large-scale degradation of indigenous lands caused by industrial logging, leaving communities with limited options to sustain their livelihoods (MacKinnon, 1996)

Furthermore, communities in fishing villages also demonstrate a high degree of adaptability and ecological knowledge of their coastal environment, as seen on the site visit. Livelihood strategies commonly combine traditional fishing practices with Tambak aquaculture. Various forms of craftsmanship remain prominent, including techniques for catching fish and crabs, harvesting molluscs, net weaving, and the construction of stilt houses using local materials. Foto’s. This embodied knowledge of marine systems and material practices offers valuable insights for environmentally responsive design and presents opportunities to integrate local craftsmanship into sustainable construction approaches.

In Kalimantan, many indigenous peoples have experienced displacement due to logging, mining, plantation concessions, and urban development. These pressures have led to migration, resettlement, and increased engagement in modern livelihoods, including market-based agriculture. As

traditional lifestyles are replaced or altered, the ecological and cultural knowledge once integral to forest-based living is increasingly at risk. Much of this traditional knowledge survives primarily among elder generations, and without active efforts to preserve it, it may be lost (MacKinnon, 1996).

Architecture

Traditional architecture is often adapted to the tropical climate, utilizing locally available materials such as timber and bamboo, and incorporating natural ventilation and shading. The traditional Dayak longhouse architecture, characterized by large, steeply pitched roofs made of natural materials such as ijuk (sugar palm fibre) shingles, is primarily adapted for efficient surface runoff in high-rainfall environments. The steep angle prevents water accumulation and reduces the risk of roof leakage and material degradation. Longhouses were traditionally adjusted in size, according to the (growing) needs of the community. Spatial layouts favour openness and communal living, mirroring social cohesion and environmental adaptability (van den Heuvel, 2020).

The intense rainfall influences contemporary daily life, as observed during the site visit. Small resting houses on stilts with roofs are commonly found in both urban and rural areas, offering shelter from the rain and providing a space for community gathering. More stilted dwellings and infrastructures are often seen with fisherfolk communities living in wetlands or coastal areas, allowing for water level variations caused by tides and rainfall.

Beliefs and aesthetics

The community’s understanding of indigenous knowledge reflects a spiritual embodiment of the Creator within the water domain. The relationship between the Creator and the river or water area is mediated by a traditional leader, who is regarded as a representative of the divine. Spiritually, these

traditional figures are believed to maintain a sacred connection with the spirits inhabiting the river, playing a vital role in the renewal and continuity of life associated with water. This belief underpins the community's deep respect and reverence for the river (Sally & Sihombing, 2023).

The river holds significant value in the cosmological and spiritual worldview of the Dayak people, representing both the upper natural world and the lower realm. This duality forms a sacred and harmonious cosmos, making water – particularly rivers – central to their spiritual life. Consequently, rivers are a dominant spatial element in the organization of Dayak settlements. The Dayak community's deep connection to rivers is rooted in the belief that water is the fundamental source of life. This reverence is expressed through various traditional ceremonies and rituals that symbolically involve the river. According to Dayak customary beliefs, the location of their settlements along riverbanks reflects spiritual interpretations of river orientation: the upstream is regarded as auspicious and associated with positive meanings, while the downstream is seen as less favourable. As a result, traditional floating houses (Lanting) built along the river are consistently oriented upstream, aligned longitudinally with the river's flow (Sally & Sihombing, 2023).

Aesthetic ideals in East Kalimantan are embedded in the cultural, ecological, and spiritual fabric of local communities. These ideals often emphasize harmony with the natural environment, and are often expressed through visual arts and symbolic designs, notably in the intricate Dayak motifs that adorn homes, textiles, and ritual objects. These patterns often depict elements of the natural world – leaves, animals, flowing water – and are imbued with spiritual meaning (Darmadi, 2017; MacKinnon, 1996). Notable examples include the hornbill, revered as an omen bird, and the naga (water dragon); a mythological creature representing water, life, and protection. The naga symbolizes the deep respect for and dependence on water

systems, serving as both a spiritual guardian and an emblem of the interconnectedness between people and nature (Janowski, 2019). These motifs are not merely decorative elements but are integral to the broader cultural landscape, where aesthetic expression serves to reinforce a worldview that emphasizes the interconnectedness between humans and nature (MacKinnon, 1996).

Public space

In contemporary urban centres such as Samarinda and Balikpapan, street life is strongly shaped by food culture, as observed during the site visit. Streetside dining is prevalent, with many restaurants and food vendors operating in open-air or semi-permanent settings. Affordable meals are commonly consumed outside the home for breakfast, lunch, and dinner. During the hotter hours of the day, eating tends to take place indoors, while in the cooler evening hours, public spaces such as plazas and side streets are activated by pop-up food stalls, accompanied by music and informal social gatherings. This flexible, climate-responsive dining culture reflects a dynamic use of urban space that adapts to both environmental conditions and social rhythms.

In terms of everyday mobility, motor scooters are the most commonly used mode of transport, as observed during the site visit. They offer a cost-effective, flexible, and climate-adapted solution for navigating congested urban roads. While walking remains a practical mode of movement in rural areas, pedestrian activity is limited in urban centres due to several factors: inconsistent or poorly maintained pedestrian infrastructure, frequent exposure to poor air quality, and high daytime temperatures. These conditions collectively discourage walkability and reinforce reliance on motorized two-wheel transport in both formal and informal urban environments. However, on some locations, commercial areas feature covered walkways or galleries

along shopfronts, providing pedestrians with protection from rain and sun.

In the contemporary urban environments of Samarinda and Balikpapan, the primary water infrastructure consists of concrete drainage canals designed to expedite the removal of surface water from the city. These structures are frequently in a state of disrepair, with visible damage compromising their functionality, as observed during the site visit.

Waterfronts in these cities – both along rivers and the coastline – are generally not developed for recreational purposes, as observed during the site visit. Nonetheless, various water-related infrastructures such as dam outlets and drainage canals are informally utilized by children for swimming, with similar practices observed along less regulated village waterfronts, despite the often poor water quality. Adult swimming is less common, however, adults were observed utilizing infrastructure such as pipelines and the highway bridge as informal fishing platforms. In non-urban environments, the potential presence of crocodiles further discourages recreational water use.

Summary: challenges and opportunities of the landscape system

Water-related challenges represent one of the most pressing concerns for the development of the future capital. The prevalence of monoculture plantations and logged forests in the region has significantly increased its vulnerability to wildfires, primarily due to the soil desiccation these land uses cause, compounded by the flammability of species such as eucalyptus and oil palm. The limited infiltration capacity and low moisture retention of these soils contribute to accelerated surface runoff and heightened erosion risk. These issues are exacerbated by the region's steep terrain and episodes of high-intensity rainfall. The resulting land degradation not only impacts the immediate area but also poses significant downstream consequences. Altered hydrological flows elevate flood risks in midstream and downstream zones, while sediment-laden rivers threaten the health of downstream aquatic and coastal ecosystems.

The primary focus should be on enhancing the watershed's sponge capacity to mitigate wildfire risk, reduce erosion and flooding, and ensure consistent and clean water availability throughout the catchment. A key opportunity lies in transforming existing monoculture plantations – often described as biological deserts – into natural forest systems and urban areas designed with high permeability. Restoring forests in this context not only supports hydrological resilience but also presents significant potential for increasing regional biodiversity. Incorporating local ecological knowledge on forest restoration and natural succession processes offers a valuable pathway to ensure ecological integrity, while fostering meaningful participation and stewardship among local communities.

The undulating terrain of the area is shaped by an extensive river system, offering multiple spatial opportunities. First, a watershed-based understanding of upstream–downstream relations enables the development of a landscape framework that incorporates phasing. Construction in

flood-prone mid- and downstream zones should follow upstream interventions – such as reforestation – enhancing soil water retention. Second, aligning urban development with natural topography and drainage patterns can significantly reduce flood risks while creating linear green spaces that improve microclimate, support urban biodiversity, and provide recreational benefits. Third, the implementation of riparian forest buffers along rivers serves as a natural defence against pollution and flooding, thereby informing strategic priorities for reforestation. Since rivers connect the upstream and downstream ecosystems, they offer valuable potential for establishing ecological corridors along natural gradients; the landscape transitions from dryland dipterocarp forests in the upstream zones, to periodically inundated lowland forests in the midstream floodplains, and finally to wetlands, mangroves, and coastal ecosystems downstream.

The remaining primary and well-developed secondary forests serve as valuable seed banks, offering a strong foundation for the regeneration of new, biodiverse forest areas. Areas where these forest patches are in close proximity present strategic opportunities for establishing ecological corridors. Such corridors can facilitate species movement, enhance habitat connectivity, and support broader ecosystem restoration efforts.

The landscapes that currently sustain local livelihoods could bring opportunities to support the future higher population density. In the short term, existing green patches within small-scale agricultural areas present opportunities to create attractive, liveable neighbourhoods that blend natural and cultivated landscapes. Furthermore, local fishing villages located downstream offer unique potential for eco-tourism and recreational access to the bay. By utilizing existing roads that traverse wetland areas, these villages could become gateways to nature-based tourism, providing both cultural value and alternative income streams for local

communities.

Areas comprising mixed and logged forests present significant potential for restoration and enrichment through the incorporation of edible tree species, leveraging local indigenous knowledge of forest gardening. Agroforestry systems not only create employment opportunities and foster community engagement with the forest, but also enhance food security, promote biodiversity, and improve soil water retention.

The two nearby cities could serve as service hubs for the residents of the new capital, allowing the capital time to develop its own infrastructure and prioritize long-term sustainability. Existing roads can serve as a foundational structure for urban expansion. Rather than fragmenting the landscape, using existing roadways as development corridors helps to concentrate urban growth along already-altered zones, thereby minimizing further ecological disruption.

Local architecture offers opportunities for climate-adaptive building, such as rainwater harvesting through rooftops and constructing homes on stilts to mitigate flooding. The use of local materials and traditional building techniques has demonstrated long-term durability, while also supporting the local economy, preserving craftsmanship, and blending aesthetically with the environment. Furthermore the high daily precipitation rates, coupled with increased rainfall due to climate change, present a valuable opportunity for local rainwater harvesting to meet drinking water needs in the urban environment.

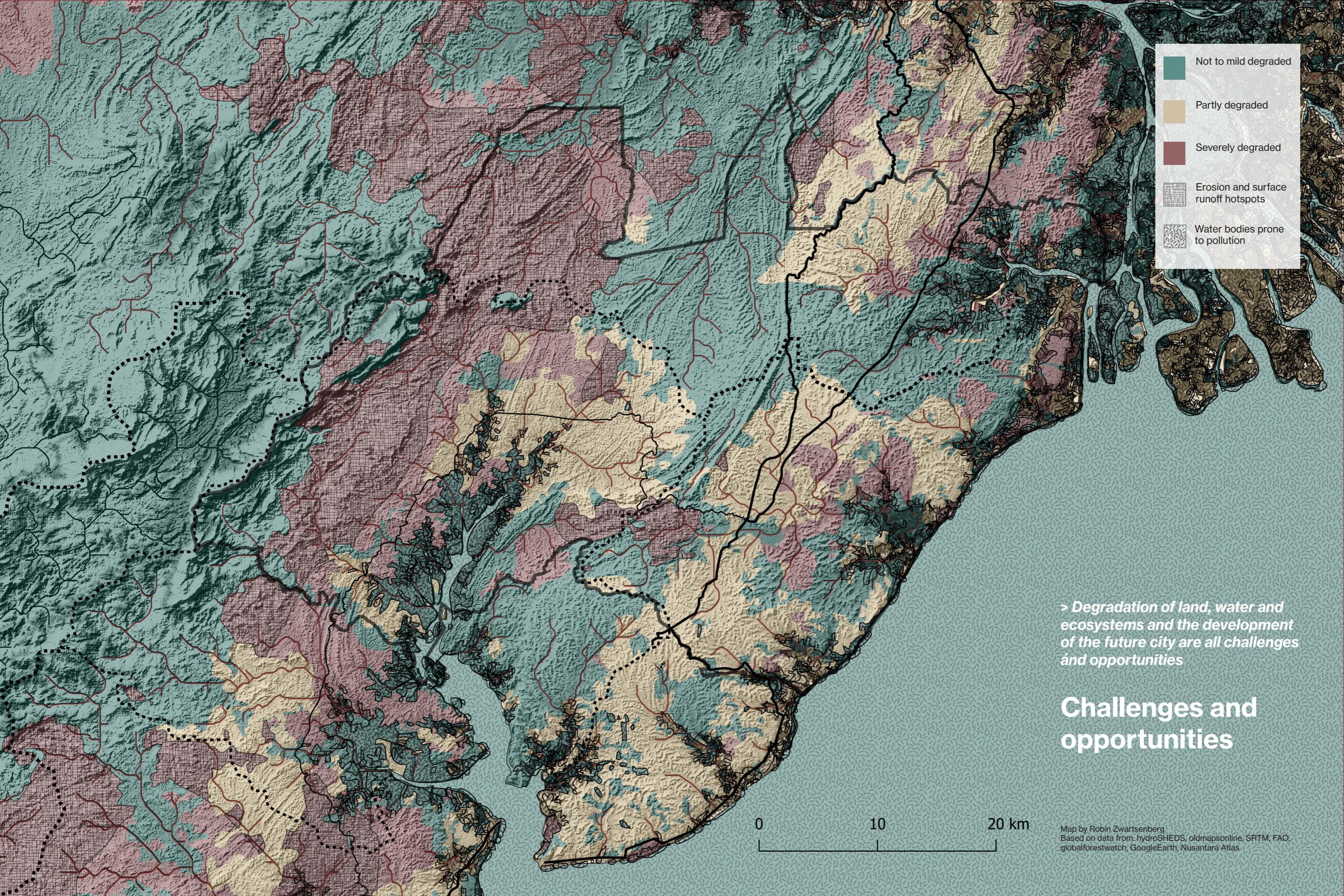
Indonesia's vibrant street culture presents a valuable opportunity to cultivate dynamic and culturally resonant public spaces. The prevalence of flexible, mobile food stalls and pop-up restaurants – particularly active in the evenings – can quickly bring life and a sense of place to urban environments.

The commonly seen elevated resting platforms offer shelter from sudden tropical

downpours, creating climate-adaptive public spaces that can also function as informal communal gathering points. These structures could be inspired by Dayak longhouses, honouring local Indigenous culture while incorporating their traditional adaptability—allowing the longhouse to be extended in response to the evolving needs of the community.

Last but not least, the warm, humid climate and the high diversity of local tree species—with their varied forms and architectures—offer significant potential to integrate lush, visually rich green spaces into the built environment.

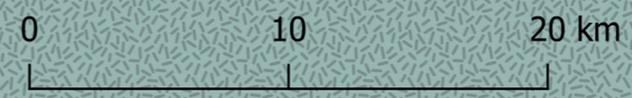




- Not to mild degraded
- Partly degraded
- Severely degraded
- Erosion and surface runoff hotspots
- Water bodies prone to pollution

> *Degradation of land, water and ecosystems and the development of the future city are all challenges and opportunities*

Challenges and opportunities



Map by Robin Zwartsenberg
Based on data from: hydroSHEDS, oldmapsonline, SRTM, FAO, globalforestwatch, GoogleEarth, Nusantara Atlas



4.

Design strategies and toolbox

Introduction

This chapter presents the strategic design approaches formulated in response to the challenges and opportunities outlined in the preceding analysis, and is guided by the watershed approach and the two networks strategy. These strategic design approaches are underpinned by a toolbox of design principles that guide their implementation.



The watershed approach & the two networks strategy

The design approach is fundamentally based on a watershed-oriented perspective. The analysis revealed that many of the region's challenges – such as flooding, erosion, landslides, and dry, fire-prone soils – are primarily linked to rapid surface runoff and insufficient infiltration.

The main objective of this approach is thus to restore the sponge capacity across the landscape, enhancing water infiltration and minimizing surface runoff. This approach will increase water availability for vegetation, improve baseflow in rivers, and facilitate groundwater recharge. Reduced surface runoff will also mitigate local erosion and alleviate downstream flooding (Yin et al., 2022). Additionally, the enhanced groundwater recharge may contribute to the future water supply of the city.

The analysis highlighted that different zones within the watershed exhibit distinct characteristics and varying degrees of land-use suitability.

In the upstream region, characterized primarily by steep slopes, surface runoff presents significant challenges. Consequently, reforestation is prioritized in this zone to mitigate local impacts and to reduce downstream risks such as erosion and flooding.

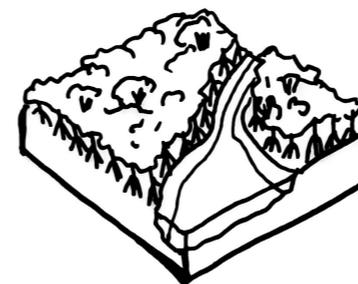
The midstream region, with its more gently undulating terrain, is identified as the most suitable area for urban development. This area is hydrologically shaped by meandering river systems.

In the downstream region, the focus is on the conservation of wetlands. These areas are ecologically valuable due to their rich biodiversity, are unsuitable for construction, and serve a critical function as natural water retention zones.

Preserving the natural hydrology of the landscape lays the foundation for a green-blue infrastructure framework, which must

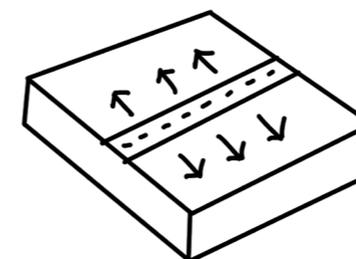
be thoughtfully integrated into the structure of the future city. To achieve this, specific design principles for the integration of green-blue and grey infrastructure are developed, ensuring ecological function, urban resilience, and spatial coherence. These integration are based on the concept of fast and slow zones by Tjallingi (2015)

The design toolbox is structured into three categories: the slow zone, the fast zone, and the zone that facilitates integration between the two.



Using rivers, drainage patterns and infiltration zones as carrier for the slow zone

In the slow zone, water functions as the carrying network. This network encompasses natural drainage patterns, rivers, floodplains, infiltration zones, steep slopes, and valleys. The focus in this zone is on maintaining water quality and quantity, preserving biodiversity, and supporting low-impact human activities.



Traffic network as base for urban expansion

Conversely, in the fast zone, transportation networks serve as the dominant structuring framework. The accessibility provided by

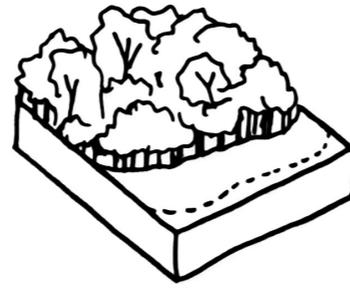
these networks supports the demands of a modern urban environment, including high-density development and commercial functions.

The strength of this dual-network strategy lies in the synergy between the fast and slow zones, enabling the development of a sustainable and liveable urban landscape.

The social aspect of the fast and the slow zonation is based on understanding “..how vital it is for a town to give people both intense activity and deep and satisfying quiet” (Alexander et al., 1977).



Slow zone toolbox



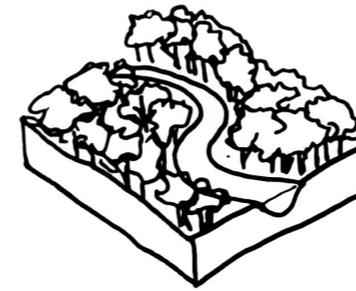
Protection of remaining forest in headwaters

The upland forests serve as the headwaters of the watershed and play a critical role in regulating streamflow. In Borneo, these forested uplands contribute significantly to hydrological stability – providing approximately half of river discharge during storm events and sustaining nearly twice the flow during drought periods when compared to deforested upland areas (MacKinnon, 1996).



Leaving room for the river and floodplains

When rivers are allowed sufficient space to meander and access their natural floodplains, the risk of flooding is significantly reduced (MacKinnon, 1996).



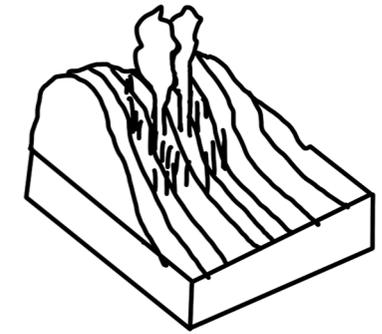
Implementing riparian buffers

Rivers serve as accumulation points for water within a watershed. Establishing riparian buffers along riverbanks plays a critical role in stabilizing water levels and filtering pollutants from surface runoff. In addition, meanders and vegetated riverbanks are vital for maintaining riverine ecological integrity. Riparian buffers also function as ecological corridors, facilitating connectivity between upstream and downstream habitats (MacKinnon, 1996). Beyond their hydrological and ecological benefits, broad riparian zones can serve as foundational elements in a green-blue infrastructure network, shaping a resilient and ecologically integrated future urban form.



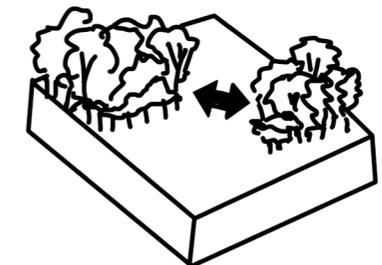
Preservation of wetlands

Wetlands function as natural water retention and storage areas within the watershed, enhancing water quality through filtration and infiltration processes, while also supporting exceptionally high levels of biodiversity (MacKinnon, 1996).



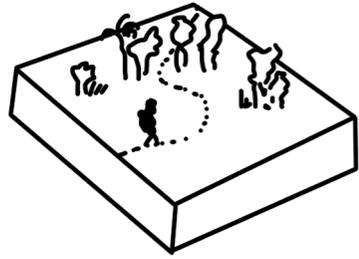
Vegetating steep slopes

Steep slopes play a significant role in landscape hydrology, as they tend to accelerate surface runoff, leading to erosion and limiting water infiltration. Due to their sensitivity to water dynamics, these areas are considered vulnerable and are best managed through reforestation. Maintaining forest cover on steep slopes helps stabilize the soil, reduce the speed and volume of surface runoff, and enhance water infiltration (MacKinnon, 1996).



Connection of ecosystems through creating corridors

Basing natural areas on the components of the natural hydrological system establishes vital connections between upstream and downstream habitats, promoting ecological continuity and landscape integrity (MacKinnon, 1996). To enhance these ecological functions, such hydrological linkages will be further developed and reinforced, supporting ecosystem resilience.



Facilities for low impact recreation

The slow zone offers potential for low-impact recreational activities, including trails, boardwalks, bridges, and observation areas that allow for public engagement while preserving the ecological integrity of the area. These features are intended to foster appreciation and connection with the landscape without causing harm to the sensitive environments within the slow zone.

Precedent study: Samboja Lestari

The Samboja Lestari reforestation project is located East-Kalimantan, Borneo, within the borders of the expansion zone of Nusantara. Initiated by Willie Smits and his Borneo Orangutan Survival Foundation, the project aims to demonstrate the possibility to restore a severely degraded area into a healthy rainforest while contributing to the local economy. (Steiner et al. 2019). Like more than half of the Kalimantan rainforest, the rainforest in Samboja has been cut down in the 20th century. Since then, the area became dry and fire-prone, and forest fires caused by El Nino, slash and burn techniques and underground coal fires teased the area annually. In 2002, Samboja was facing poverty, huge crime rates, severe floodings, water shortages, depleted soils, a low life expectancy, droughts, failing crops and an extinction of animal and plant life, leaving only Alang – Alang (*Imperata cylindrica*) grasslands. With annual fires being the biggest problem, a 100m wide ring of fire-resistant sugar palms was planted around the boundary of the 2,000 hectare Samboja Lestari property, creating a natural fire break. Beside fire resistant, the sugar palms (*Arenga pinnata*) are also flood resistant, can

grow on steep slopes, have deep rooting systems (up to 12m), are not invasive and can provide a stable daily income for local people, since the sugary liquid can be used for both food and biofuel without harvesting essential organs of the tree. The plots with sugar palms were divided within the local community. Involvement of local people both economically and in management is crucial for success, explains Smits (TED, 2009). A row of densely planted Salak palms (*Salacca zalacca*) formed an additional fence with its long sharp thorns, keeping the orangutans in and invaders out. Within the boundaries of the natural fences, the restoration of the land began with planting fast-growing, nitrogen-fixing pioneer species (like *Acacia mangium* and *paraserianthes*), to shade away the fire-prone grassland and restore both soil structure and microclimate. Agricultural crops like beans, pineapples, teak, rubber, coffee, bananas, papayas, chocolate, nutmeg, mango, bamboo, fodder trees, vanilla, wild fig and durian were planted between trees in an agroforestry system, fertilizing the soil, yielding early income for locals and speeding up ecosystem regeneration. Fungi and compost from local materials were added to improve the soil. After a while, a high diversity of indigenous rainforest species were planted and given space to establish before harvesting the *Acacia* trees for timber after eight years. Now, 1,200 tree species, 137 bird species and 9 primate species are present in the area, while providing 3000 local people with income. The temperature in the reforested zone has gone down by 3-5 degrees Celsius, the air humidity has gone up by 10%, cloud cover by 11,5%, and rainfall by 25%. The significant increase in rainfall has largely increased drinking water availability for nearby city Balikpapan, showing the project's impact beyond her boundaries (Steiner et al. 2019; TED, 2009).

Conclusions and tools from the Samboja Lestari case study:

The case study demonstrates that forest restoration on degraded lands – resulting from extensive logging and palm oil

cultivation – is indeed achievable. Through ecological restoration efforts, the soil's sponge capacity can be regenerated, enhancing groundwater recharge and even contributing to increased local rainfall. The restored landscape develops into a secondary forest with significant ecological value, while simultaneously mitigating fire-prone dry grasslands and reducing surface runoff. Moreover, the case highlights the viability of an integrated system that combines ecological restoration with local knowledge and community-driven economic investment through agroforestry practices.

Design tools derived from this case study include using forest regeneration through accelerated natural succession and the use of agroforestry.



Forest regeneration through accelerated succession

The reforestation approach is based on mimicking natural succession through phased planting, guided by local ecological knowledge.

The Benuaq people view their shifting cultivation system as a form of cyclical land use, with forest regeneration occurring in five distinct phases: young scrub, old scrub, young secondary forest, old secondary forest, and eventually, primary forest. The full regeneration process may span 100 to 200 years, depending on soil fertility, microclimate, and past disturbance (Joshi et al., 2004).

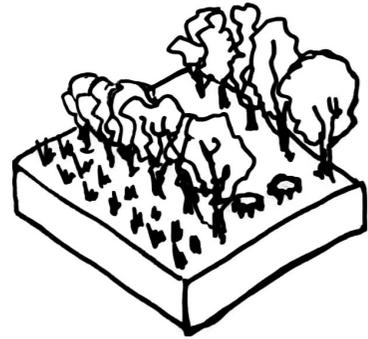
Initial regrowth (young scrub or *kurat uraq*) emerges within 1–3 years, dominated by grasses, herbs, shrubs, and pioneer trees. This transitions to old scrub (*kurat tuha*) within 2–5 years, marked by denser vegetation and saplings. By 3–10 years, young secondary forest (*kurat batang muda*) forms, featuring larger pioneer trees and partial canopy closure. In nutrient-poor soils, this phase may be delayed up to 15 years (Joshi et al., 2004).

The old secondary forest phase (*kurat batang tuha*) typically develops after 9–15 years, characterized by over 80% canopy cover and increasing presence of valuable hardwoods such as *meranti* and *kayu ulin*. This phase may persist for over a century before the forest is considered primary again (*hutan bengkar*). The Benuaq often wait until this fourth stage is reached before re-clearing for cultivation (Joshi et al., 2004).

This process can be accelerated by human intervention. Then the initial phase focuses on establishing pioneer species such as *sungkai* (*Peronema canescens*) and nitrogen-fixing leguminous trees like *Acacia mangium*, supported by soil enrichment using biochar and compost. These pioneer species suppress invasive weeds, restore soil structure and moisture retention, enhance fertility, and create a favorable microclimate for the eventual introduction of native rainforest species. During this phase, active management – including weeding and human-assisted seed dispersal – is essential. In the subsequent phase, native rainforest species (e.g., ...) are introduced, along with symbiotic fungi necessary for their development. As the forest matures, management requirements decrease, as the regenerating rainforest begins to support its own ecological processes, including natural seed dispersal by wildlife (Joshi et al., 2004; Steiner, 2019).

Design principles grounded in natural regeneration should emphasize the development of land-use systems that mirror natural successional processes,

progressing from pioneer species to mature forest ecosystems over extended periods. To effectively guide land-use decisions, ecological regeneration must be defined and monitored through distinct, observable phases – such as changes in canopy cover indicating transitions from early scrub to secondary forest – providing a structured framework for assessing and supporting long-term ecosystem recovery.



Agroforestry

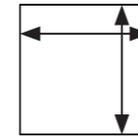
According to local forest specialist Willie Smits, the Dayak man made food forest 'Lembo' is one of the most productive systems you can find in east Kalimantan (TEDx Talks, 2011).

Simpukng (or lembo) are traditional family-owned forest gardens integral to the Benuaq resource management system. Typically established on former swidden fields (umag), these agroforestry plots contain a mix of cultivated fruit trees, Tanyut (honey trees), and other useful plant species. Visually, simpukng often resemble the surrounding fallow forest, with indistinct and dynamic boundaries that blend into the regenerating landscape (Joshi et al., 2004).

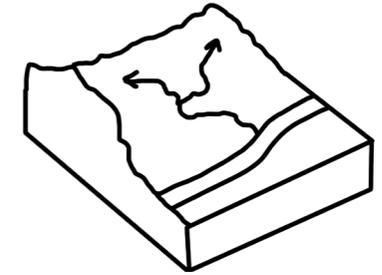
While ownership is recognized, simpukng are generally accessed more freely during mast fruiting years, when usufruct rights allow community members to consume fruit on-site. However, harvesting for commercial purposes from another person's simpukng is not permitted. Commonly cultivated species include jackfruit (nangka), langsung, rambutan,

durian, mango (mangga), coconut (kelapa), candlenut (kemiri), and coffee (Joshi et al., 2004).

Design principles for cultivated landscapes should aim to emulate the structure and composition of natural forests by establishing agroforestry systems that incorporate mixed species, layered canopies, and irregular boundaries, allowing them to blend naturally with fallow or secondary forests. These systems should prioritize productive perennial species, such as fruit tree gardens, to support long-term ecological regeneration while providing sustained yields. A diverse array of species – encompassing fruit, spice, and nectar-producing plants – should be cultivated to meet food, economic, cultural, and ecological needs, enhancing system resilience, supporting pollination, ensuring food security, and promoting biodiversity. Additionally, landscape design must acknowledge and respect informal land tenure arrangements, enabling communities to regulate land use and stewardship according to local norms and practices.

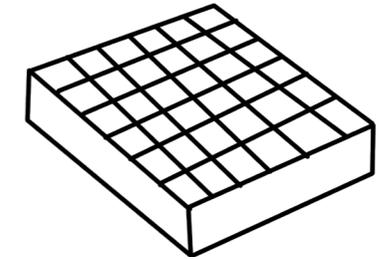


Fast zone toolbox



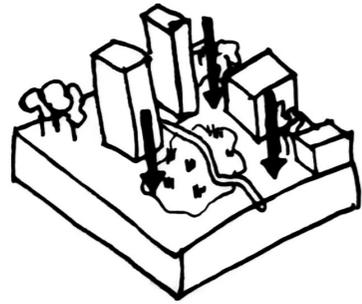
use existing roads where possible

For a sustainable and context-sensitive design approach, existing road infrastructure – including highways, bridges, and logging roads – will be utilized wherever feasible, minimizing environmental disturbance and reducing the need for new construction.



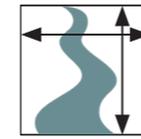
100x100m grid for walkability and human scale

To promote walkability within urban zones, a 100m x 100m grid will be facilitating pedestrian movement and supporting the development of accessible, human-scaled public spaces that encourage social interaction and active mobility.

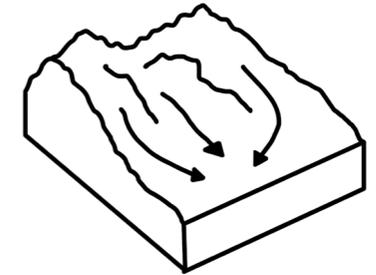


Permeable urban zones

The permeability of urban areas is primarily supported by vegetation-rich green spaces integrated into the urban fabric. According to Pradana et al. (2025), green space in tropical regions such as Indonesia is recommended to enhance the local microclimate. This vegetative cover also contributes significantly to urban permeability, facilitating infiltration and reducing surface runoff.

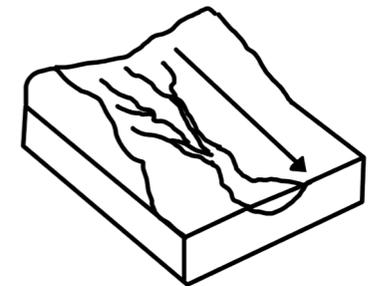


Integration toolbox



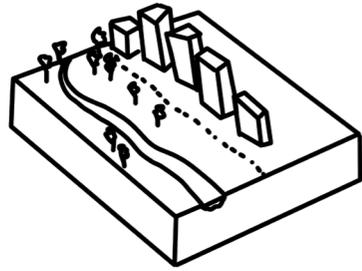
Natural drainage pattern as bioswales in urban zone

Bioswales are engineered landscape elements designed to manage stormwater runoff by mimicking natural hydrological processes. Typically consisting of gently sloped, vegetated channels, bioswales slow down water flow, promote infiltration, and filter pollutants through a combination of soil, vegetation, and microbial activity. They are integrated into urban infrastructure as a strategy to reduce surface runoff, mitigate flooding, and improve water quality. Site bioswales in low-lying areas and existing drainage lines; intercept and treat runoff where it naturally accumulates. (Sharma, 2019).



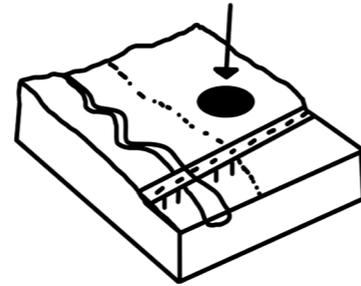
Orienting the city based on upstream downstream axis

The upstream-downstream axis will serve as a primary orientation framework within the city, guiding both spatial organization and movement. Riparian buffer zones will align with this natural hydrological flow, and urban road networks will also be designed to follow this axis, reinforcing orientation, enhancing connectivity, and embedding landscape logic into the structure of the urban environment.



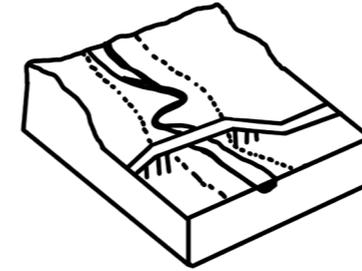
High contrast edge between fast zone and slow zone

A high-contrast edge will emerge between the dense urban zone and the adjacent natural slow zone, creating a dynamic interface where urban life meets wilderness. This edge offers residents immediate access to both the services and amenities of the city and the recreational and restorative benefits of a nearby natural area, fostering a unique coexistence of built and ecological environments.



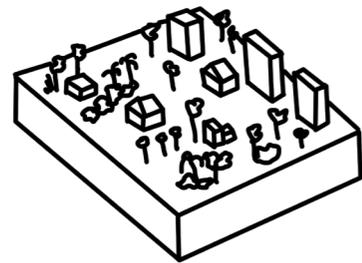
Urban nodes close to crossing fast and slow zone

Urban nodes will emerge at locations with high accessibility provided by the traffic network, strategically positioned near the water network that forms the structural framework of the city. This spatial relationship ensures a livable urban environment by combining efficient connectivity with proximity to natural elements, supporting both functional mobility and environmental quality.



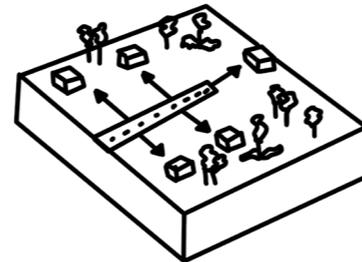
Bridges to cross the greenblue corridors

Green-blue corridors within the slow zones will be crossed using carefully placed bridges to maintain and reinforce the continuity of these ecological pathways. By allowing uninterrupted flow of water, wildlife, and vegetation beneath, the bridges support habitat connectivity while enabling human access without fragmenting the natural systems.



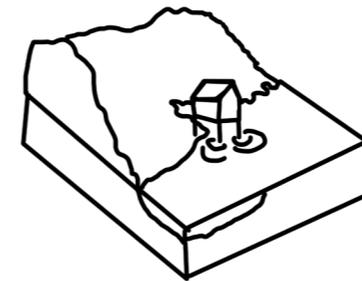
Gradient edge between slow zone and fast zone

Gradient edges between the fast urban zone and the slow natural zone will accommodate transitional functions such as agroforestry, urban agriculture, and light industry. These zones serve as buffers that soften the contrast between urban and natural areas, while supporting multifunctional land use that contributes to food production, economic activity, and ecological resilience.



Access from the inside, landscape outside

Accessibility to urban zones will be organized from within, ensuring that buildings along the edges are oriented toward and integrated with the surrounding landscape. This inward-facing access strategy allows edge structures to maintain a direct visual and spatial relationship with natural surroundings, enhancing the quality of the urban-nature interface.



Low - density housing adapted to the local landscape

Low-density housing will be sensitively adapted to the local landscape conditions, ensuring minimal environmental impact and strong contextual integration. This may include elevated structures on poles in wetland areas to accommodate fluctuating water levels, or terraced housing designs that follow the contours of steep hillsides in upland zones, allowing for stable construction while preserving natural landforms.



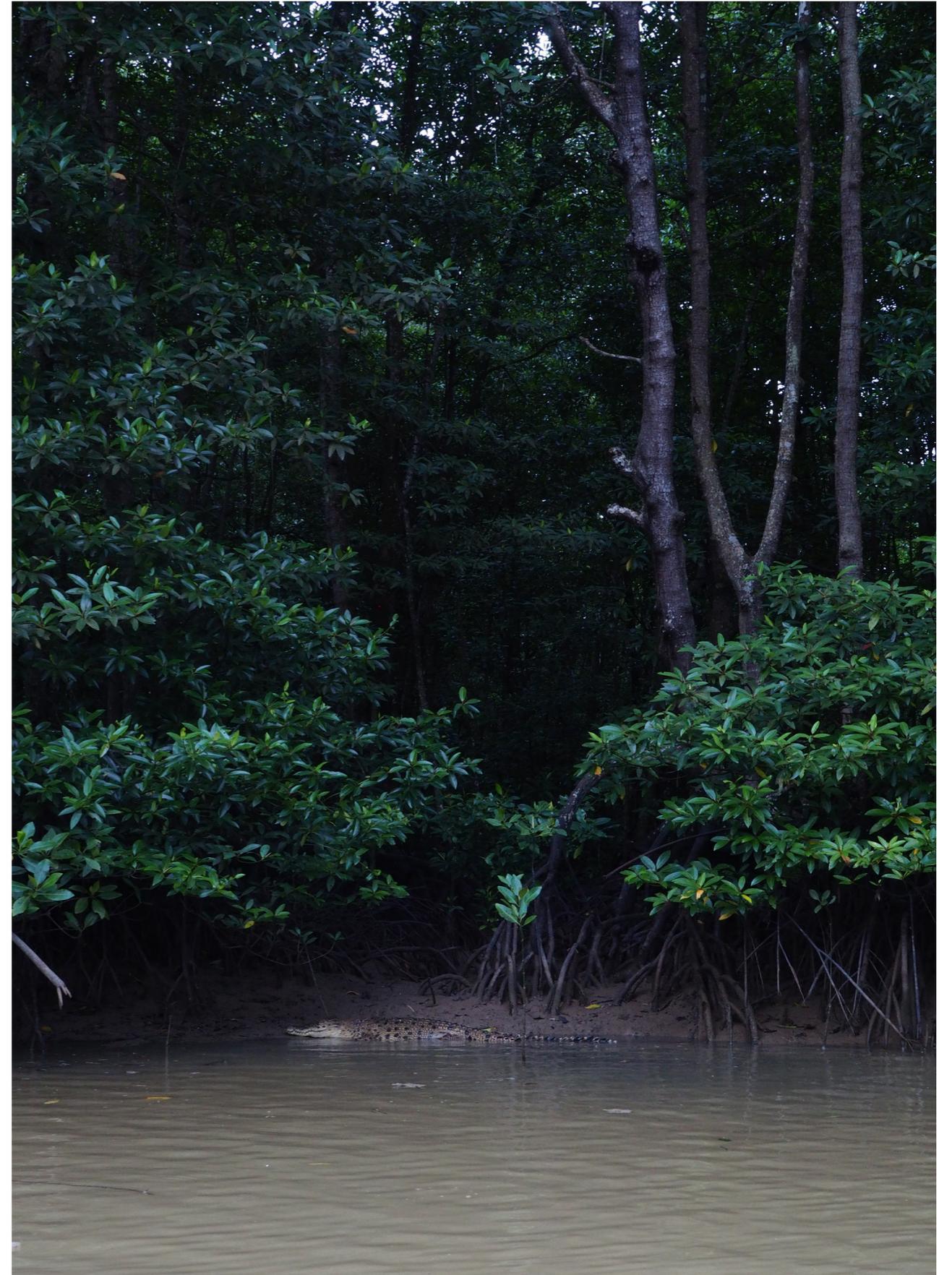
5.

Design exploration

Introduction

An important insight drawn from design with nature is the concept of living in balance with the natural environment – emphasizing that humans have a responsibility not only to use natural resources but also to actively support their renewal (McHarg, 1969). This design embodies that principle by restoring hydrological systems, re-establishing ecological connectivity, and facilitating forest regeneration, while allowing long-term ecological processes – potentially unfolding over centuries – to take place.

Water functions as a central organizing element across large (L), medium (M), and small (S) spatial scales, integrated through the dual-network strategy of fast and slow zones. At the large scale, a regional water-based landscape framework is established, enhancing natural hydrological processes, ecological connectivity, and the development of green-blue (slow) infrastructure to guide future urban growth. At the medium scale, urban zones are strategically allocated based on their infiltration potential and proximity to both green-blue networks (slow zones) and rapid transit corridors (fast zones). At the small scale, water shapes urban liveability by informing the design of the built environment in alignment with local drainage patterns and by articulating well-defined transitions between fast and slow zones.



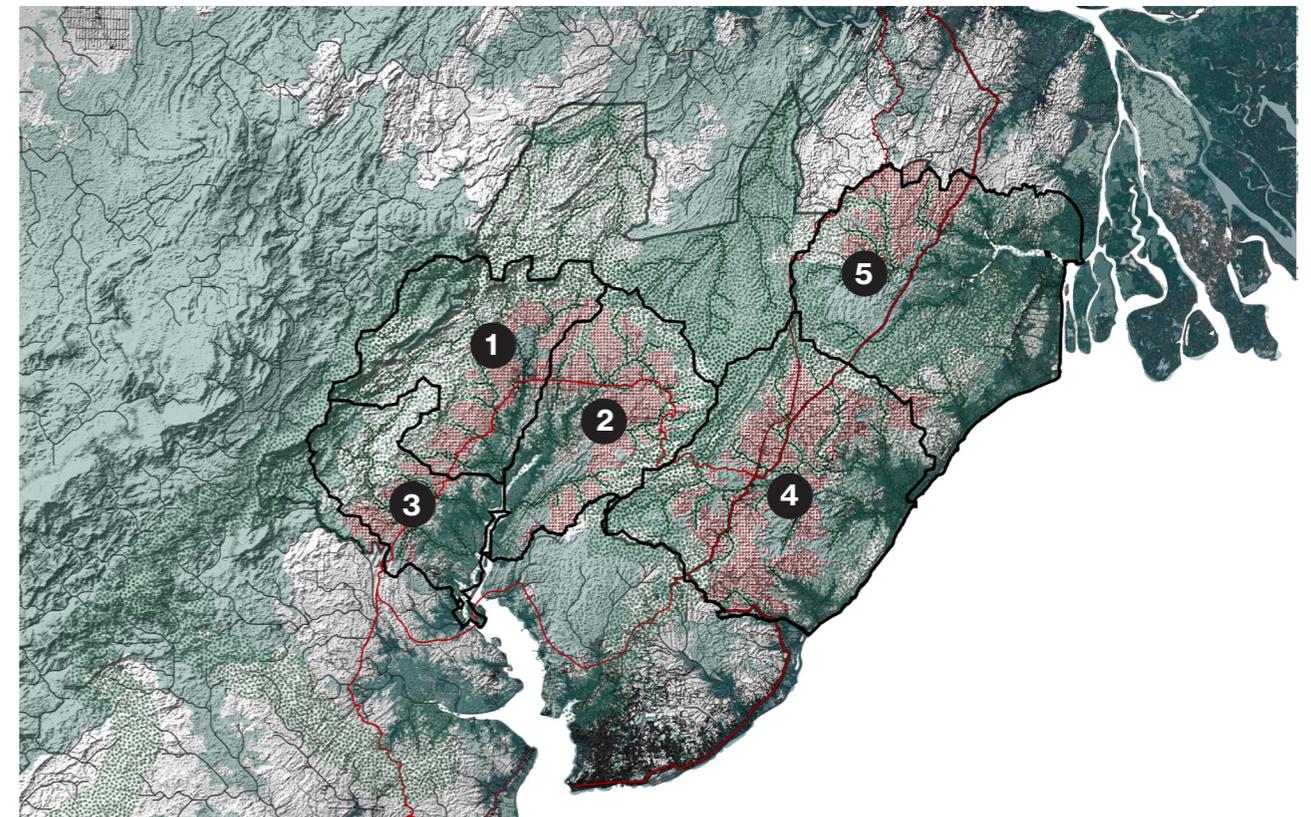
Large scale

Nusantara is envisioned to accommodate a population of two million people. As highlighted in the preceding analysis, many of the city's anticipated challenges are water-related. Addressing these challenges requires a comprehensive understanding of watershed dynamics. As noted by Wahid et al. (2024), considering catchment areas in urban planning for Nusantara enhances the ability to assess and mitigate the potential impacts of natural hazards such as soil erosion, landslides, and flooding. To mitigate flood risks in the midstream zone – where the urban core will be located – it is crucial to first enhance the upstream area's water retention capacity. This can be achieved through reforestation efforts, including the restoration of natural forests or the implementation of agroforestry systems.

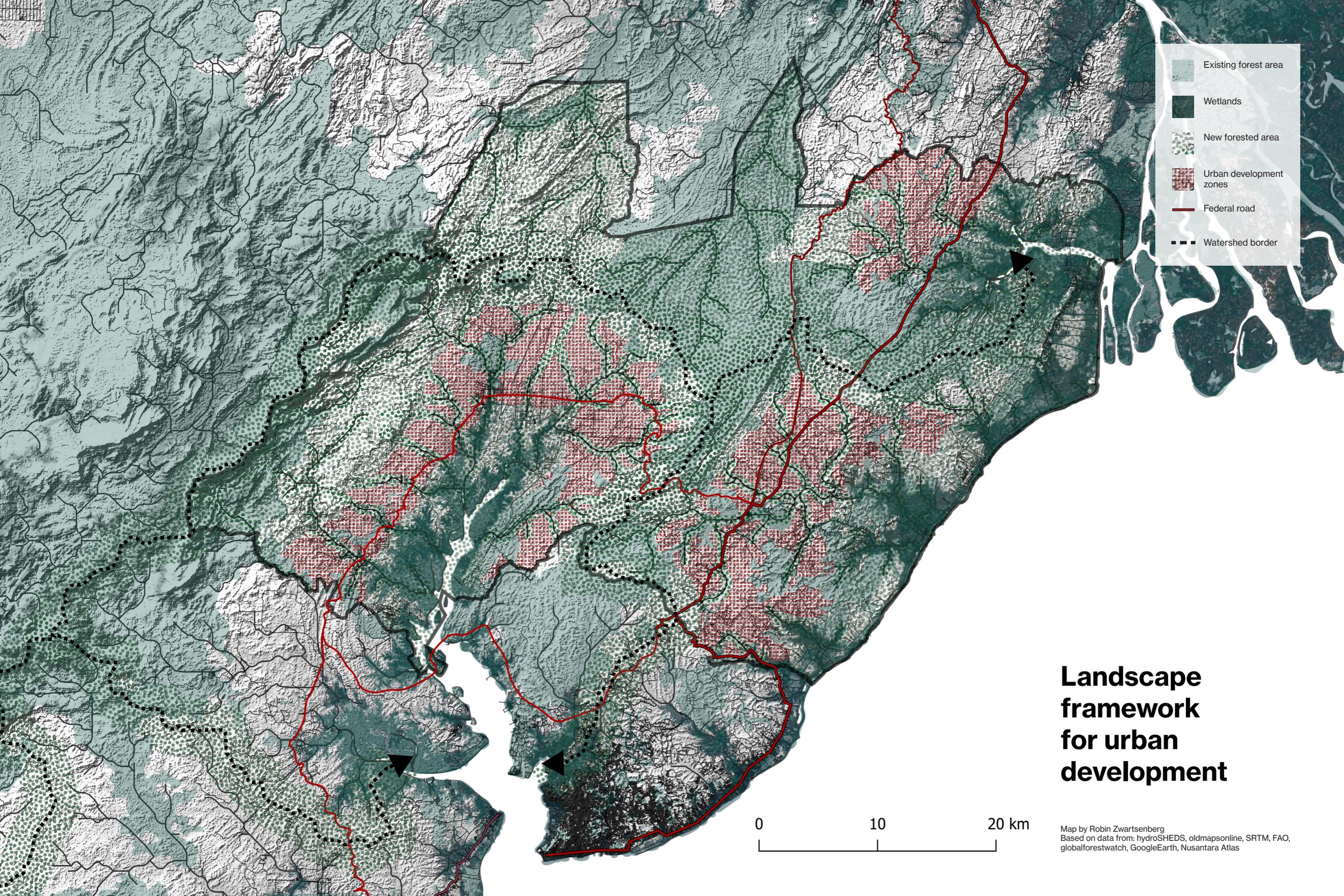
At the large (L) scale, water structures the foundational landscape framework. The primary objective is to preserve natural hydrological systems while establishing a coherent network of slow zones to support the future urban environment. This is achieved through the designation of a principal infiltration zone in upstream and steep terrain, which serves to recharge groundwater, mitigate erosion, reduce soil desiccation, and prevent downstream flooding. This zone also reconnects fragmented ecosystems, thereby strengthening regional ecological continuity. In the downstream areas, wetlands – critical for both wetland and coastal ecosystems – are preserved due to their ecological sensitivity and unsuitability for urban development. Between these upstream and downstream areas, riparian buffer zones are introduced in midstream regions. These buffers decelerate surface runoff, filter pollutants before they reach the river, and provide space for natural river fluctuations and floodplain dynamics. In addition, they support the restoration of riparian ecosystems and function as ecological corridors linking the upper and lower catchment zones.

The areas delineated by this resilient landscape framework serve as the initial priority zones for urban development. Establishing the green-blue infrastructure from the outset is essential, as it safeguards the hydrological integrity and ecological connectivity of the entire region. Urban expansion should proceed in clearly defined phases, allowing the city to adapt progressively to actual population growth and evolving spatial needs. The phasing can be organized by watersheds. This strategy ensures that upstream areas, which directly influence midstream urban zones, are developed either prior to or in parallel with urban expansion. As the city grows, this watershed-based framework can be systematically applied to subsequent catchments.

Within the designated expansion boundaries of Nusantara, five distinct watersheds have been identified – three larger and two smaller catchments. Based on the available developable land defined by the proposed landscape framework, the larger watersheds should ideally accommodate approximately 500,000 residents, while the smaller ones should support up to 250,000 each. Collectively, these capacities would align with the city's target population of two million. Urban development has already commenced in one of these catchments, the Sepaku watershed. Consequently, the medium (M) scale design strategy will focus on the Sepaku watershed, which is ideally planned to accommodate 500,000 inhabitants.



Watershed - based phasing



- Existing forest area
- Wetlands
- New forested area
- Urban development zones
- Federal road
- Watershed border

Landscape framework for urban development

0 10 20 km

Map by Robin Zwartsenberg
Based on data from: hydroSHEDS, oldmaponline, SRTM, FAO, globalforestwatch, GoogleEarth, Nusantara Atlas

Medium scale

At the medium scale (M scale), the Sepaku watershed is considered. Both the upstream and downstream areas are excluded from urban development to prioritize ecological preservation. In the upstream region, remaining patches of natural forest will be conserved, and degraded areas will undergo reforestation through natural forest regeneration and the implementation of agroforestry systems. This zone will also accommodate limited low-density habitation, composed of small communities situated along existing logging roads, who will be actively involved in forest stewardship. In the downstream area, the primary emphasis is on wetland conservation. Similarly, low-density settlements are maintained to support existing fishing communities and small stilted-house villages, which are located in accordance with existing access roads into the wetlands.

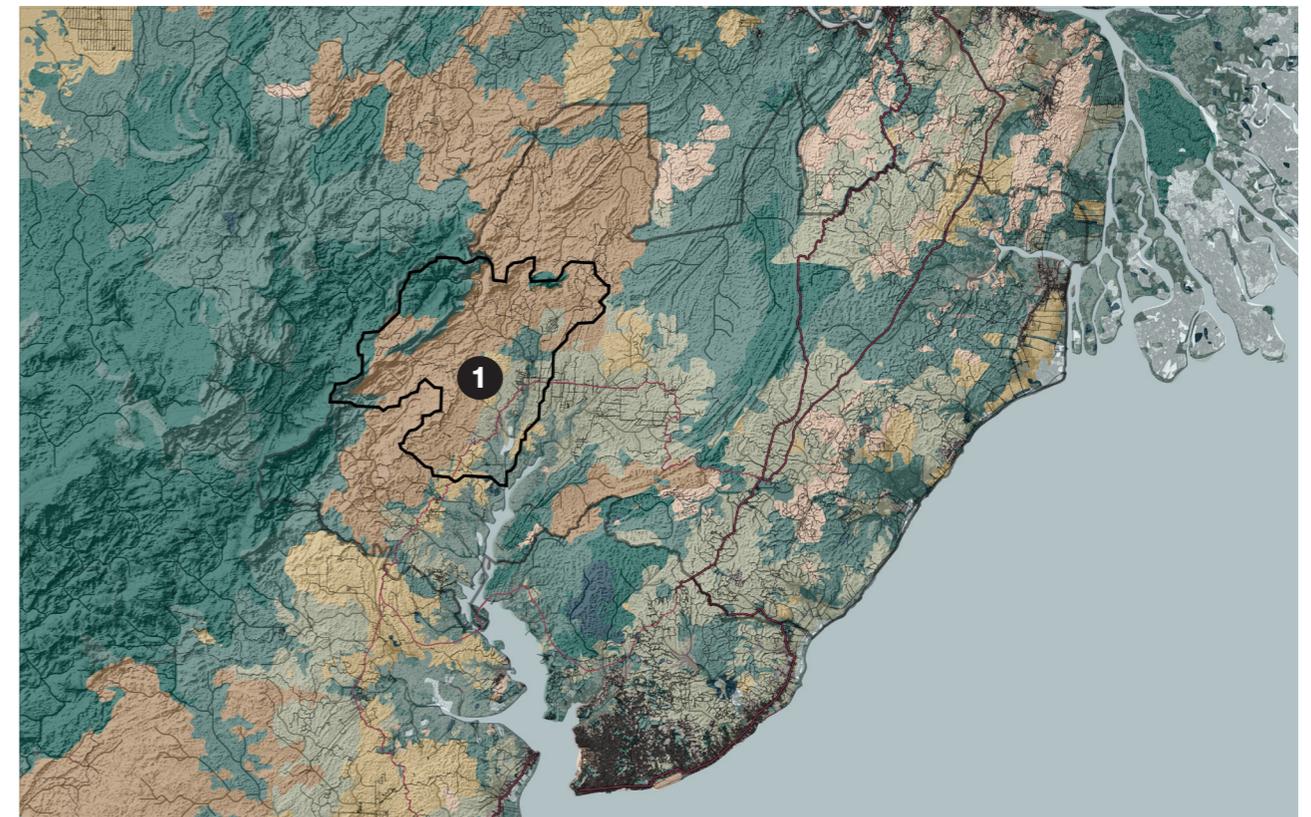
The midstream zone of the Sepaku watershed is designated for urban development, with residential densities distributed according to the spatial logic of the fast and slow zones. The slow zones are structured by the landscape framework defined at the large scale, while the fast zone aligns with the main road, offering accessibility and essential services. Together, these zones form extended linear edges that support a high-quality living environment. Consequently, the highest residential densities (indicated in dark red) are located along the interface between the main road and the downstream wetland area. Riparian buffers also generate desirable edge conditions, leading to a continuation of high-density housing along these buffers in the upstream direction, with density gradually decreasing further from the road. The central portion of each district is characterized by lower residential density and functions as an infiltration and groundwater recharge zone. Positioned furthest from both rivers and wetlands, this area effectively represents an upstream zone at a more localized scale. Between the high- and low-density zones lies a band of medium-density development.

This creates two principal edge typologies: a hard edge, where high-density urban fabric borders the riparian and wetland zones; and a soft edge, where mid-density development transitions into lower-density, ecologically functional areas that support infiltration and ecosystem services.

In the midstream zone, spatial orientation is guided by two primary axes: the upstream-downstream axis, defined by the rivers and riparian corridors, and the axis defined by the main road. Logical urban nodes emerge at the intersections of these axes, serving as central points for city life. These nodes are designated as primary urban centers, accommodating public buildings, shops, and essential services. To ensure their visibility and identity within the broader urban fabric, each node will feature a distinctive landmark – such as a high-rise building – making them recognizable from various parts of the city.

Within the midstream zone, three distinct residential density types are defined. Based on the spatial distribution illustrated in the example district, the watershed has the potential to accommodate approximately 500,000 inhabitants. This projection is derived from the following density categories:

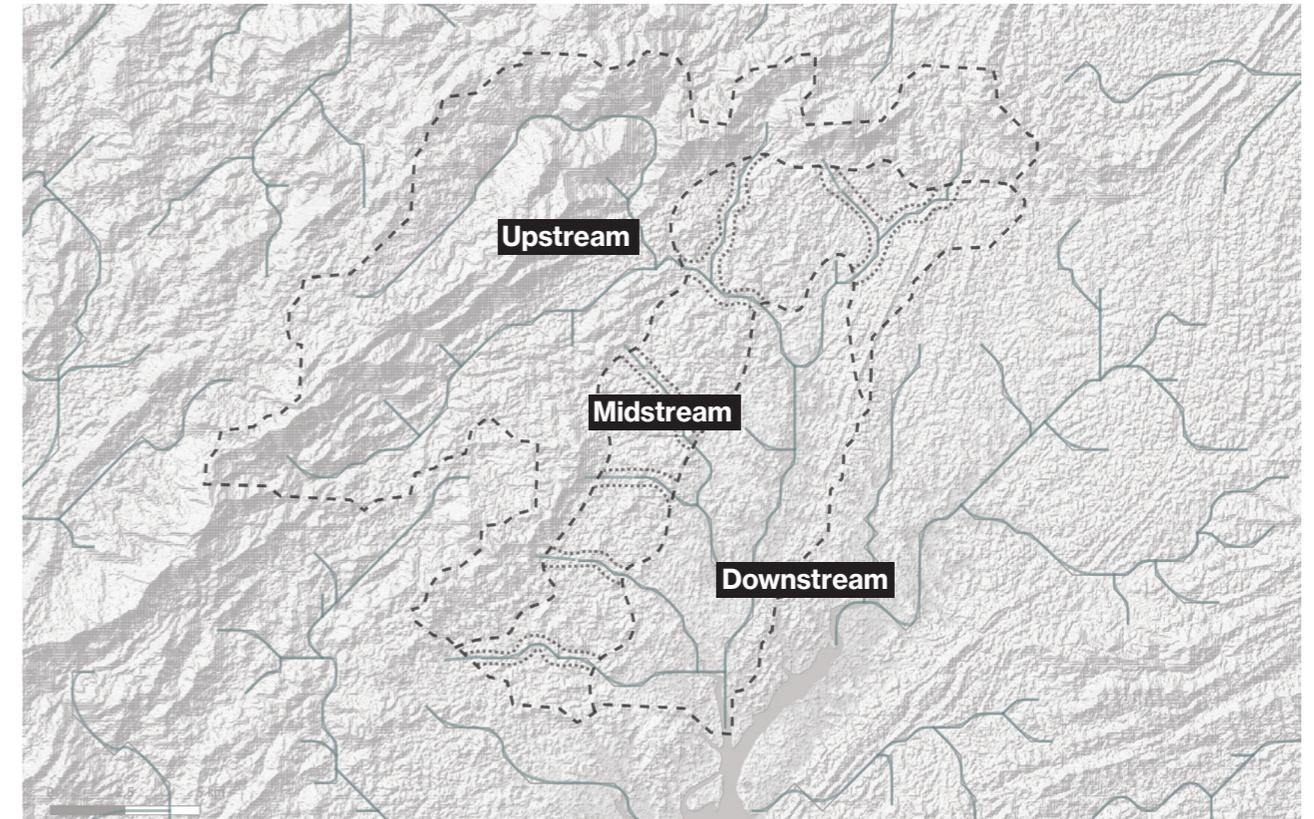
High Density: average of 140 persons per hectare. This is the highest density category, located in close proximity to the fast zone and forming a hard edge with adjacent slow zones, such as the downstream wetlands and riparian buffers. Plots in this zone are relatively small and feature a mix of high-rise and mid-rise buildings. The urban fabric includes a combination of semi-private and public green spaces, as well as accessible public areas designed to support vibrant street culture, including food stalls and informal social gatherings.



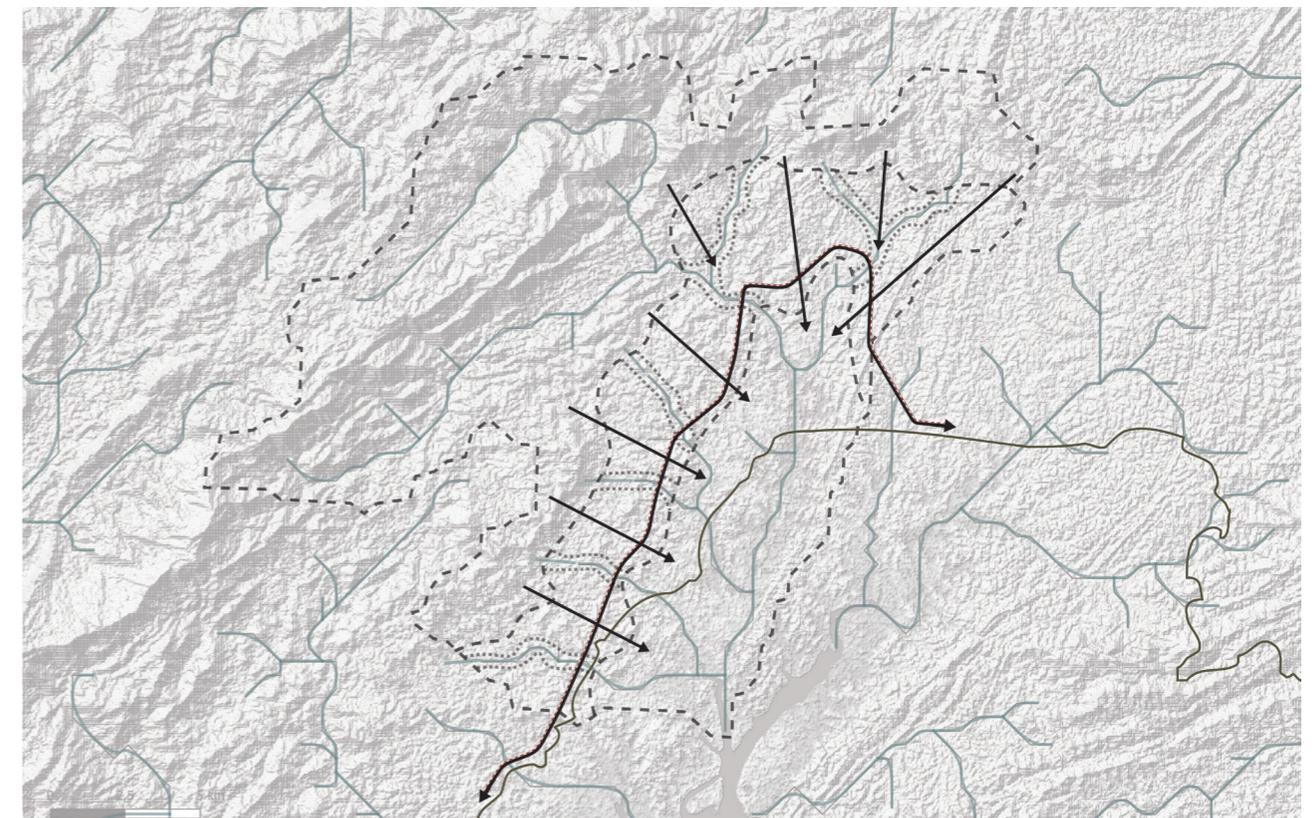
Sepaku watershed

Mid Density: average of 80 persons per hectare. This density level features fewer high-rise buildings and emphasizes integration with the surrounding landscape. Building configurations are designed to foster community development, with layouts that encourage interaction among residents while maintaining access to green space and ecological corridors. The spatial structure supports a balance between privacy and communal living, enhancing both social cohesion and environmental quality. This zone supports agriculture, like agroforestry.

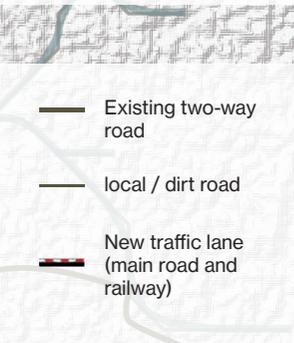
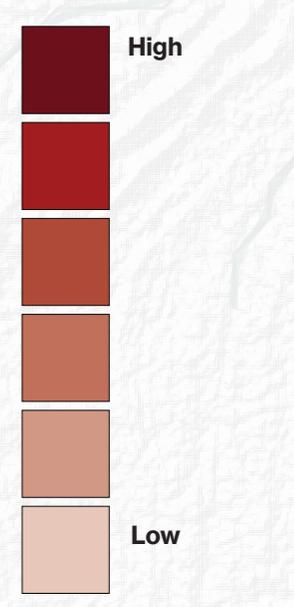
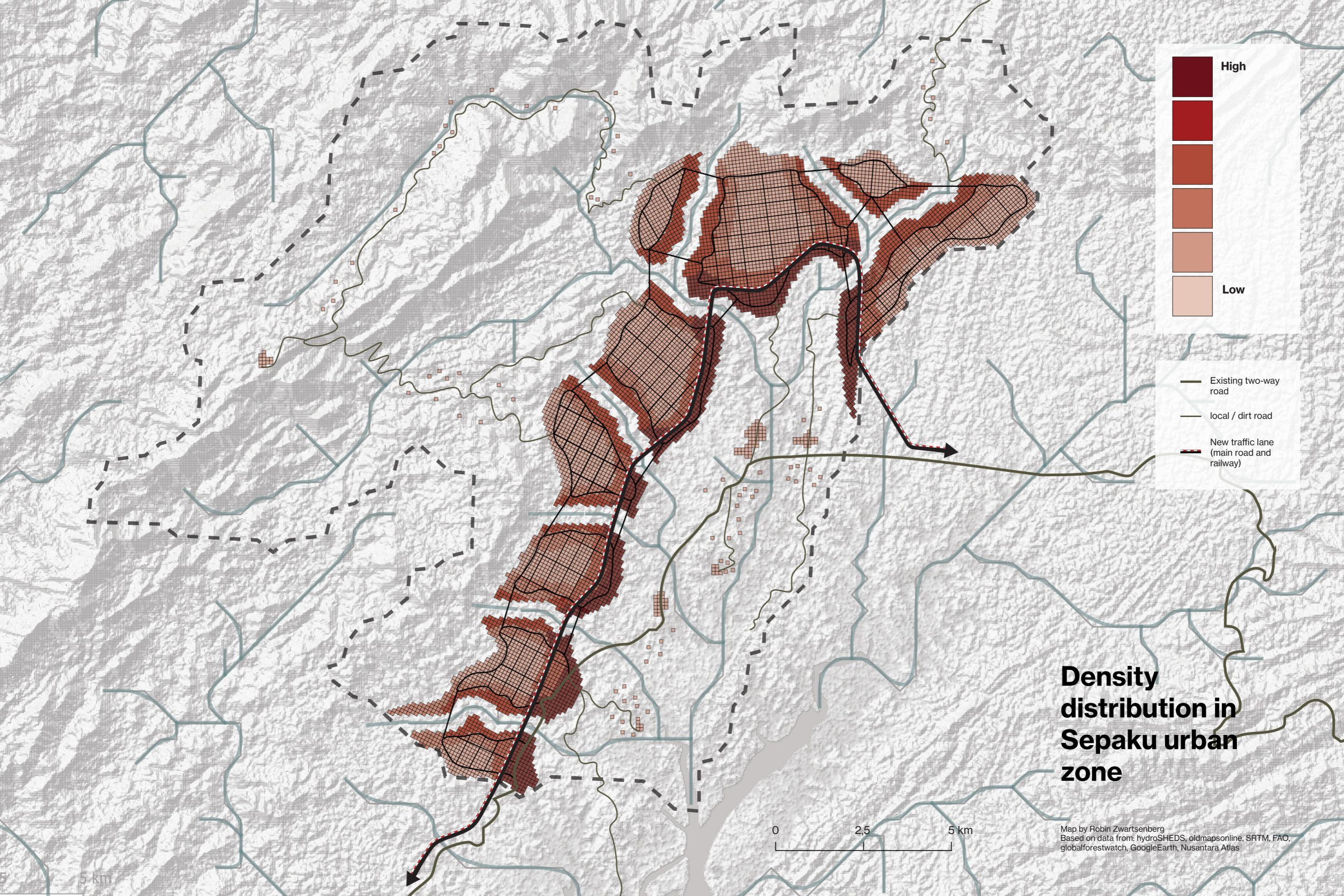
Low Density: average 10 persons per hectare. This density category is located in the central part of the midstream urban zone, where residential plots are dispersed along existing logging roads and include agroforestry plots. Similar low-density living arrangements are also found in the upstream and downstream areas, beyond the main urban development zone, where small communities are situated within natural forest or wetland environments, promoting a harmonious coexistence with the surrounding ecosystems.



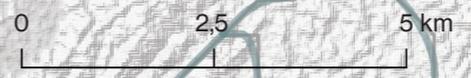
The L scale landscape framework forms the base for the M scale.



The upstream - downstream axis and main road form the base for the urban pattern.



Density distribution in Sepaku urban zone



Map by Robin Zwartsenberg
Based on data from: hydroSHEDS, oldmapsonline, SRTM, FAO, globalforestwatch, GoogleEarth, Nusantara Atlas

5 km

Small scale

The S scale is a zoom in of the hard edge between the fast zone and the slow zone from the two networks strategy. It shows how the urban infrastructure is adapted to water. It was emphasized by Syaban & Appiah-Opoku (2024) that long-term sustainability in Nusantara can be achieved by adapting urban infrastructure to withstand the impacts of climate change. Strategies such as implementing water-permeable surfaces and establishing flood mitigation zones are key in enabling the city to better manage projected increases in rainfall and flooding.

In the exploration of the S scale, the natural drainage pattern was taken as the base for the slow zone, while the main road was taken as the base for the fast zone. Water plays a key role in spatial organization by responding to the site's topography and natural drainage patterns. The road network – primarily intended for pedestrians but accessible to vehicles when necessary – is based on a rectangular grid but adapts flexibly to the natural contours and drainage flows. Steep slopes are deliberately left undeveloped in terms of building and retained as forested areas to reduce the risk of surface runoff and erosion. The design integrates continuous linear bioswales through the built environment, functioning as a primary drainage corridor that extends to the wetland. This bioswale is accompanied by a pedestrian pathway, forming a multifunctional green infrastructure corridor that accommodates water flow, human movement, and ecological connectivity.

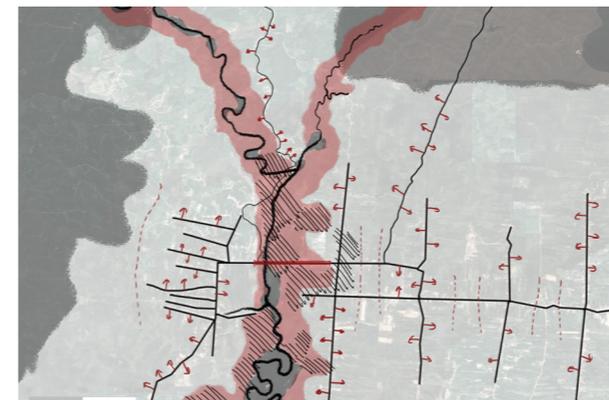
Furthermore, water shapes social spatial organization is through the experiential qualities of the zones it defines. This is achieved by pedestrian paths and park structures through the large bioswales, an elevated walkway extending into the wetland, and a boulevard that traces the boundary between the fast-paced urban area and the slower, ecologically focused wetland zone. Together, these elements create a publicly accessible and aesthetically engaging environment.

The masterplan map illustrates the various shades of green integrated into the design, each representing a distinct type of vegetated space. It includes the riparian ecosystem located within and along the riverbanks, the evolving wetland forest anticipated to develop over time in the low-lying floodplain, and the urban green corridors that weave through the built environment. These corridors maintain a wild, natural character while incorporating pedestrian paths for accessibility. Additionally, the map highlights a central park and green public spaces within the urban area, featuring small retention ponds and bioswales that contribute to stormwater management and enhance ecological function.

Research through design

The sketch below is based on an initial interpretation of the two-networks strategy, where the river zone was extended with riparian buffers and floodplains, and urban development was initiated along existing road infrastructure.

However, the existing main road – located near downstream wetlands – frequently floods, as identified in the analysis. The perpendicular roads are unpaved and primarily used as dirt tracks, which raises concerns about their suitability as a foundation for large-scale urban development. The new design for S scale follows more directly from the designs on the L and S scale.

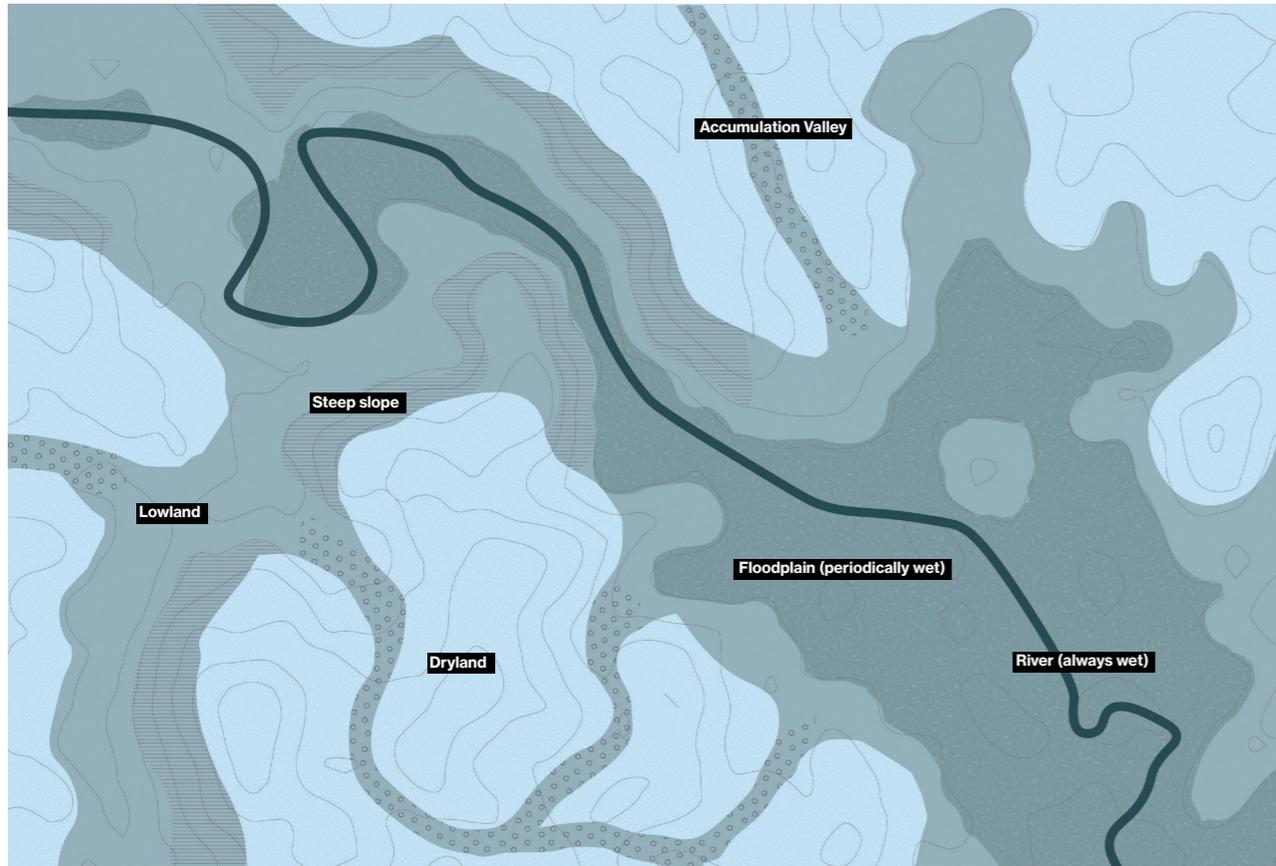




- Wetland forest
- Dryland forest
- Pedestrian zone
- Buildings
- Ring road
- Permeable single road

**Masterplan
hard edge
fast - slow
zone**

0 100 200m



Water on the small scale

This map illustrates the elements of the site's natural hydrology, which together form the carrying network that guides the spatial organization of the slow zone in the area.

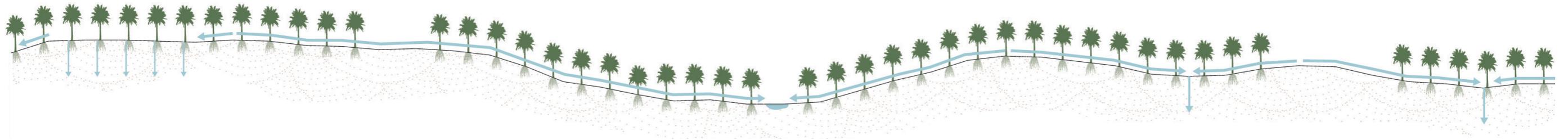
Culture on the small scale

This map illustrates the cultural layer of the design, highlighting how spatial organization supports both mobility and social life. The fast zone is structured around a ring road and a network of secondary roads, ensuring efficient access and connectivity. The compact arrangement of building blocks promotes walkability, with short distances making the area well-suited for pedestrians. In the Indonesian context, where public street space holds significant cultural importance, generous green public spaces are integrated between the building blocks to create shaded, comfortable areas that support social interaction and a favorable microclimate. A larger central park provides additional communal space. Meanwhile, the riparian buffer zone – maintained as a 'wild' area – caters to recreation through a network of partially elevated pedestrian paths, small bridges crossing the river, and a watchtower offering distant views.



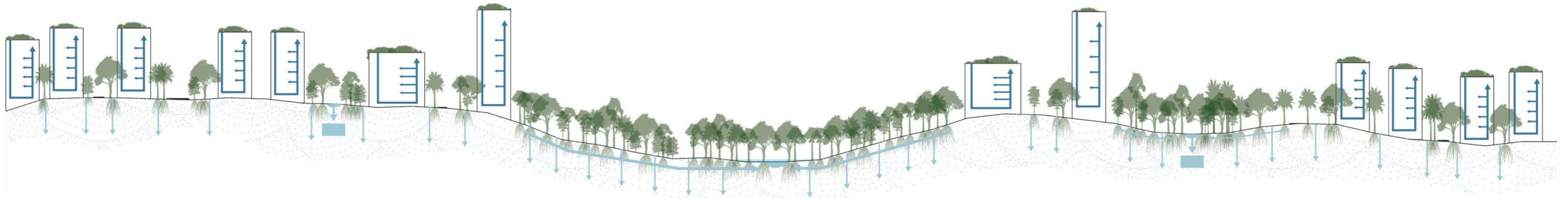
Section of current landscape

In its current state, the site is largely dominated by oil palm plantations and open, degraded land. This land cover contributes to high surface runoff, which in turn leads to soil erosion, water pollution, reduced soil moisture retention, and increased flooding during peak rainfall events.



Section of design

In the design, urbanization is closely integrated with reforestation to restore ecological balance and enhance water management. Rainwater is harvested on green roofs, where it is locally treated to provide potable water for residents. Reforestation within the riparian buffer zone significantly increases the landscape's infiltration capacity, helping to reduce erosion, filter runoff, and contribute to the river's baseflow. Between buildings, small depressions are shaped into bioswales that naturally filter stormwater as it flows through vegetation and soil layers. This water is then directed to underground storage tanks, supplying non-potable water for local uses such as irrigation, thereby reducing pressure on freshwater resources.



Urban islands shaped by water

The green-blue corridors, shaped by the river, its floodplains, and the natural drainage patterns of the local topography, establish a foundational framework for the urban fabric. These corridors guide the spatial organization of the city, integrating hydrological and ecological systems into urban planning.



Regenerating forest

The acceleration of vegetation succession within the slow zone in the masterplan – formerly mainly small palm oil plantations and degraded lands – will be informed by local ecological knowledge. However, full ecological restoration of the site is expected to require a long-term timescale, potentially extending from 100 to 200 years.

Based on the case study of Samboja Lestari, selective tree removal is undertaken to allow sufficient light penetration for newly introduced vegetation in the initial phase. However, not all existing trees are cleared; those located along contour lines are retained to maintain soil integrity and minimize surface runoff and erosion. Open areas are replanted with pioneer and nitrogen-fixing species to improve soil structure and replenish nutrient content, in alignment with local ecological restoration practices. In Samboja Lestari, drought-tolerant species like sungkai (*Peronema canescens*) and leguminous trees such as *Acacia mangium* were established in the first phase. Tree planting is complemented by soil enhancement techniques involving the application of biochar and compost. In wetter zones, fast-growing bamboo is introduced, serving as an effective natural filter for pollutants.

In the second phase, approximately eight years after the initial planting, the pioneer species have created water and soil conditions to provide for rainforest species. At this stage, the remaining oil palms can be gradually removed, following the same pioneer planting approach used in the first phase. In areas transitioning into the second phase, native rainforest species are introduced beneath the established pioneer canopy, alongside selected agroforestry crops. Successful progression of this phase depends on the inoculation of appropriate mycorrhizal fungi and careful management practices, including consistent weeding and assisted seed dispersal. These interventions are crucial due to the absence of native

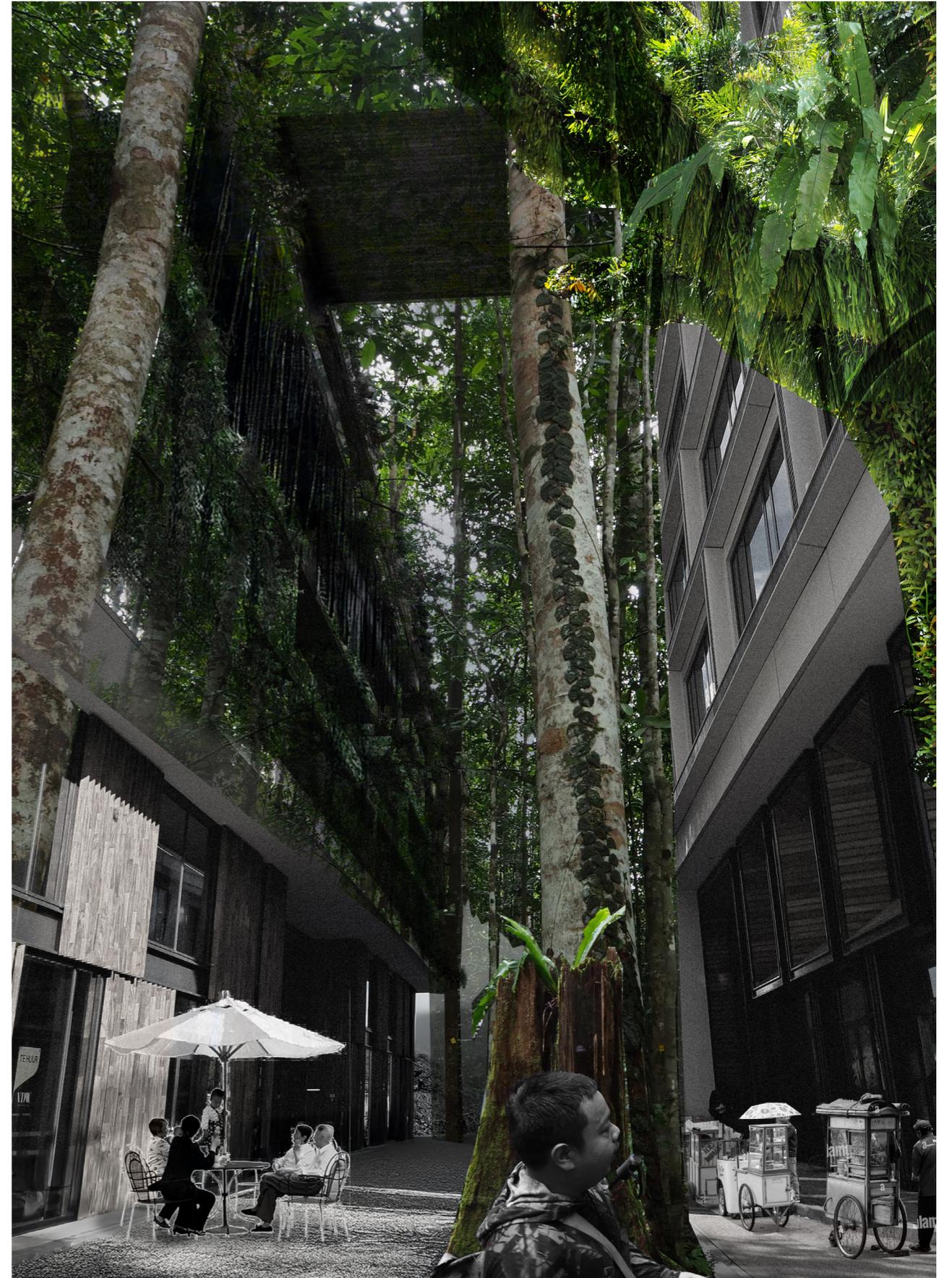
fauna from nearby rainforests, which would otherwise facilitate natural seed distribution.

After several years, the pioneer species will naturally decline and phase out. In the final stage – projected to occur after approximately 200 years – a mature secondary rainforest, enriched with agroforestry elements, will have developed. This restored forest is expected to approach the ecological quality of reference sites such as Sungai Wain (as showed on the right). This forest is also a secondary forest, meaning that it has regrown after severe logging and disturbance. The forest structure will include a mosaic of both open and closed canopy areas. Strategic integration of fruit-bearing trees and recreational pathways will help attract visitors from adjacent urban or transitional zones into the wetland forest, fostering ecological connectivity and public engagement.



Forest city

The green corridors created by the water network creates the conditions for the forest to be interwoven between buildings, blending wild and urban elements together. This integration fosters a comfortable microclimate, enhances water permeability, and supports biodiversity, while offering residents direct contact with nature within the urban fabric.



The hard edge

Some parts of the edge between the high density fast zone and the low density slow zone are reinforced by a boulevard, where the lush vegetation will rise high once the forest has reached full maturity.. This boulevard makes the edge between the urban and the wild explicit and provides space for local street food culture and a nice walk.





6.

Synthesis

Introduction

The objective of this thesis was: 'To design a water-based landscape framework that leverages water to guide sustainable, socio-ecological urban development in Nusantara.'

In the discussion, the chapter evaluates the extent to which the design outcomes fulfilled the research objective and assesses the effectiveness of the methodology in supporting this objective, concluding with a reflection on personal development achieved throughout the thesis process.

In the conclusion part, this chapter presents the conclusions drawn from each research question, demonstrating how they collectively support the overarching objective.



Discussion

Impact of design outcomes

A key takeaway design with nature is the principle of living in harmony with the natural environment – recognizing that humans should not only take from nature but also contribute to its regeneration. The design reflects this philosophy by restoring natural hydrological systems, reconnecting fragmented ecosystems, and supporting forest recovery through accelerated reforestation while allowing sufficient time – potentially spanning centuries – for full ecological regeneration. While a city of two million inhabitants poses significant threats to the environment, ecosystems have demonstrated resilience; with careful stewardship, they may continue to thrive alongside urban growth. However, the harmony achieved through design remains vulnerable to risks such as rapid development, poor management, or unregulated resource extraction.

At the large scale, the proposed framework provides a solid foundation for restoring the area's hydrological system. The phasing strategy, organized by individual watersheds, aligns with the natural hydrological processes and targets problems throughout the watershed that are originated upstream. However, this phased approach should not be taken too literally; the green-blue framework – critical for groundwater recharge and sustaining a healthy hydrology – will work at its best when implemented comprehensively across the entire region from the outset. Ecologically, a watershed-by-watershed implementation is insufficient, as ecological connections transcend watershed boundaries and interconnect the wider landscape. Socially, the initial urban development zones are located on monoculture plantation land, allowing upstream and downstream villages to maintain their livelihoods and decrease water - induced hazards. Future urban expansion into adjacent watersheds, particularly midstream zones with existing villages and small-scale agriculture, may lead

to social tensions. Overall, the framework shows potential for large-scale positive impact throughout the watershed by reducing natural hazards such as flooding and fire, while enhancing water availability through groundwater recharge and supporting local livelihoods.

At the medium scale, the hydrological system established at the large scale is further developed through a living density distribution that corresponds to the permeability of each urban typology. The density distribution of the proposed city addresses the required residential capacity but risks imposing certain building densities onto the landscape, necessitating careful small-scale design to ensure compatibility with hydrological, ecological, and social contexts. Ecologically, this scale enhances the framework by introducing a biodiverse agroforestry system in the central zone, which is connected to surrounding areas via green fingers aligned with the natural drainage network. Infrastructure planning ensures that roads cross riparian buffers using bridges, though this approach may result in higher construction costs. Socially, the medium scale introduces districts with varying densities and integrates the fast and slow zone concept; however, the design lacks a clear strategy for fostering social cohesion within and between these districts.

At the small scale, water functions as the primary organizing element, integrated with the fast and slow zone concept. The green-blue framework established at the medium scale continues to play a central role, both hydrologically and socially. Within the urban fabric, bioswales are strategically placed in water accumulation areas, serving both as functional drainage and as potential urban green spaces or parks. Socially, the water-based layout creates opportunities for public spaces that support Indonesian street culture and foster community development. Ecologically, wetlands and riparian buffers are reserved for low-impact recreational use, allowing natural ecosystems to evolve

over time. The inclusion of agroforestry and bioswales within the urban environment further promotes biodiversity. This demonstrates that water-based design can simultaneously support ecological resilience and vibrant social spaces.

While the design outcome is specific – particularly given the unbuilt status of the city and the scale of the watershed – it offers broader applicability in key areas. The slow zone of the two networks strategy, which positions the water system as the primary structuring element, provides scalable design concepts that support hydrological restoration and ecological connectivity. These principles could be adapted for both the development of new urban areas and the retrofitting of existing cities situated within watersheds of comparable size and possessing similar topographic characteristics. Furthermore, the integration of the slow and fast zones, especially through the creation of diverse edge conditions, presents a flexible framework that could be applied in a wide range of urban and landscape contexts.

While the design at all scales is logically derived from the preceding analysis, the small-scale interventions could have been further developed to more explicitly address the human experience. Greater attention to how individuals interact with these spaces would have enhanced the design's social and spatial depth.

The human dimension introduces both significant challenges and valuable opportunities for the implementation of the design. Existing local landscapes – such as small-scale agricultural zones and traditional fishing villages – can complicate integration with expanding urban development; however, they also offer potential for sustainable, low-density urban expansion and the promotion of eco-tourism. Establishing connections between the new urban development and the adjacent existing city presents logistical and infrastructural difficulties, yet it also opens possibilities for creating complementary

urban centers that can serve as functional service hubs for the surrounding region. The fluctuating water levels in wetland areas pose design and planning challenges, but they also provide an opportunity to incorporate vernacular elevated architectural forms adapted to such conditions. Furthermore, while the informal nature of Indonesian street life and culinary culture may conflict with formal urban frameworks, it simultaneously offers the potential to foster dynamic, culturally rich urban environments that reflect local identity and enhance social vibrancy.

The proposed design framework adopts a top-down approach, which is essential for establishing a consistent and comprehensive regional structure. However, it simultaneously accommodates flexible, bottom-up infill, allowing for context-specific adaptations. For example, this flexibility enables the integration of existing agricultural land within the slow zones without necessitating its conversion into strictly protected natural areas. Moreover, the framework allows for the continued presence of village communities, particularly in the upstream and downstream regions, supporting social continuity alongside ecological and infrastructural development.

The proposed design outcome diverges from the current plans for Nusantara in different ways. Firstly, it adopts a comprehensive watershed-based approach, wherein ecological and hydrological restoration – particularly upstream reforestation – is initiated prior to urban development, thereby establishing a resilient environmental foundation. Secondly, the design is guided by an overarching landscape framework that prioritizes biodiversity at the regional scale. This framework ensures ecological objectives are embedded throughout the development process without relying on a rigid masterplan, thereby allowing for flexible and adaptive urban infill. Thirdly, the concept of a forest city is realized without compromising urban functionality, services, or accessibility. In this design, proximity to ‘wild forest’ is consistently maintained, reinforcing the forest city ideal by

integrating nature as an everyday presence within the urban experience.

Furthermore, the current plans for Nusantara have a very high focus on high tech. High-tech solutions can play a valuable role in advancing sustainable urban design for Nusantara, particularly in areas such as water treatment, the development of eco-corridor infrastructures, permeable urban surfaces, and rainwater harvesting systems. However, their application should align with a systemic understanding of the landscape – one that views urban environments as integrated with natural systems rather than in opposition to them. Therefore, the most promising path forward may lie in a thoughtful integration of high-tech and systematic approaches, where technological innovation supports rather than replaces the principle of living in harmony with nature. This design proposes the systematic part of this puzzle.

Methodology

The research-through-design approach yielded several insights. The act of drawing itself proved to be an essential tool for spatial understanding; it enabled the identification and refinement of spatial relationships that would not have emerged through abstract analysis alone. Thus, drawing was not merely a representation tool, but a critical part of the design thinking and problem-solving process.

Considering this research-through-design methodology, it may have been valuable to complement the outcome, which followed from the large scale, with a design exploration that started at the small scale. Specifically, starting from a design in which maximizing sponge capacity on the small scale is the primary objective could offer insights into how such a model might inform or reshape larger-scale urban strategies.

To strengthen the research-through-design methodology, a potential improvement would have been to produce a *greater number* of drawings – including plans, sections,

and perspectives – throughout the design process, rather than attempting to resolve all ideas conceptually in advance. An increased number of drawings would have helped uncover both potential design solutions and unforeseen challenges, enriching the development and refinement of the proposal.

The watershed was proposed as the fundamental design unit to guide and structure the urban development process. This approach supports an understanding of hydrological relationships between upstream and downstream zones. However, a limitation of this method lies in its limited consideration of the interconnections between adjacent watersheds – particularly in terms of social, cultural, and ecological relationships that extend beyond hydrological boundaries.

The application of the two-networks strategy proved effective in mediating between fast and slow zones, offering a valuable framework for establishing favourable living conditions at the medium and small scale. The two networks strategy has demonstrated a capacity for diverse interpretations, which contributes to its flexibility and adaptability across different contexts. However, this versatility also necessitates a clear and critical definition of both the fast and slow zones, along with their corresponding design principles, to ensure consistent and effective application.

This thesis also sought to incorporate local indigenous knowledge to develop context-specific design principles. While literature and case studies related to reforestation and agroforestry provided valuable insights, the approach would have been significantly strengthened by direct engagement with local communities. On-site collaboration could have yielded site-specific knowledge regarding indicator species, species selection throughout the regeneration process, and traditional management practices, also concerning water management – information essential for developing truly grounded and ecologically responsive design strategies.

Recommendations for future research

This research offers a foundation that could be further developed and enriched through collaboration with landscape architects, urbanists, architects, ecologists, and other relevant specialists.

Further exploration by a landscape architect could focus on small-scale spatial development across various parts of the city, with particular attention to the characteristics of different zones and transitional edges.

The medium- and small-scale designs could be enhanced through the expertise of an urbanist, who could optimize density by exploring how high-rise buildings can be strategically positioned and integrated within the urban fabric.

The plans could also be further developed with architectural input, focusing on green roofs and facades to reduce surface runoff, while selecting architectural forms and materials that harmonize with the landscape. Incorporating local crafts, such as elevated houses and pathways, and using regional materials in the design would enhance context sensitivity and promote sustainability through climate adaptation.

For a plan to be implementable, each area – particularly within the built environment – requires thorough research into local topography, soil conditions, vegetation, site history, and ecology. Additionally, exploring how spaces evolve over time through both natural and human processes can further contribute to enhancing long-term sustainability in urban design.

Although the design addresses key landscape issues and envisions a future urban development strategy, it lacks a concrete solution for long-term water availability for the city. However local rainwater harvesting is touched upon and the replenishment of groundwater is addressed – which has potential for future extraction

if managed sustainably – no water supply strategy is proposed. Future work should include a detailed water supply strategy that accounts for both quantity and quality over time. Also, future research should further explore integrated water management systems, including flood control, wastewater treatment, and water recycling strategies, to support the development of a more comprehensive and resilient urban water management framework. The research could be strengthened through the implementation of small-scale pilot projects, allowing for real-world testing of water management strategies and ecological restoration techniques. Such practical applications would generate more concrete data and support the refinement of design approaches.



Conclusion

The conclusion chapter summarizes the key takeaways. The first question addresses the problem statement and analysis chapter, the second focuses on the methodology and design strategies chapter, the third examines the design exploration chapter, and the final question pertains to the discussion.

RQ 1 – Understanding

What are the challenges and opportunities related to water in the current landscape system of Nusantara?

A key finding is that water-related challenges in Nusantara are crucial to the region. These issues are mainly caused by a lack of water infiltration and exacerbate drought, wildfire risk, erosion, flooding, landslides, and water pollution. The region's steep terrain and intense rainfall further intensify surface runoff problems. However, the high water inputs also present an opportunity, as they create favourable conditions for rapid vegetation growth and groundwater recharge when the sponge capacity is enhanced. The vast expanses occupied by monoculture palm oil and eucalypt plantations have contributed significantly to land degradation, water resource depletion, and ecological imbalance, highlighting the urgent need for sustainable management and rehabilitation strategies. Although the region's rivers are currently associated with pollution and recurrent flooding, they also present potential avenues for ecological mitigation and landscape restoration. Additionally, the fragmentation of previously intact ecosystems poses a major threat due to habitat loss; however, the remaining patches may serve as critical nodes for ecological connectivity and act as seed sources to support broader restoration efforts.

RQ 2 - Design theories and tools

Which landscape design strategies and principles are suitable to design a water-based landscape framework that leverages water to guide sustainable urban

development with integrated ecology in Nusantara?

The primary strategy to address the challenges found in the analysis is to enhance the soil infiltration and water retention capacity (the sponge capacity) across the watershed, with a particular focus on upstream areas, where many surface runoff issues originate.

The primary approach to enhancing the watershed's sponge capacity in conjunction with urban development is the implementation of the two-networks strategy. This strategy is supported by three distinct design toolkits, each corresponding to a specific spatial zone: the slow zone, the fast zone, and their integration. In the slow zone, the water network is the carrier, with design principles focused on improving water quality and quantity, supporting biodiversity, and accommodating low-impact human activities. In contrast, the fast zone, the traffic network is the carrier, addressing the functional demands of contemporary urban life. The integration of these two networks provides a set of design guidelines aimed at fostering a water-sensitive, biodiverse, and liveable urban environment.

In the slow zone, design principles for reforestation are informed by natural succession processes and agroforestry practices, drawing from indigenous ecological knowledge. In more densely urbanized areas, the emphasis shifts toward maintaining high surface permeability. This is achieved through the implementation of strategies such as bioswales, permeable pavements, and other green infrastructure solutions that enhance water infiltration and support ecological function within the urban fabric.

RQ 3 – Design exploration

How can these design strategies and principles be implemented in the context of Nusantara over time?

The key discoveries at the L scale highlight that a robust framework for hydrological integrity can be established by integrating upstream headwaters, a midstream river network, and downstream wetlands. This framework is valuable both ecologically and socially. Ecologically, connecting the forest zones in the upstream areas creates large, continuous ecological corridors. The midstream river network forms the foundation for a finer web of ecological corridors, linking upstream and downstream ecosystems through the natural flow of water. In the downstream areas, wetlands are preserved as retention zones while also providing significant ecological value. Socially, the framework supports a network of slow zones essential for the development of a liveable city.

The key findings at the M scale revealed that by manipulating densities in combination with the slow green-blue zones provided by the large-scale framework, it is possible to accommodate the population targets set by Nusantara authorities, while also creating long edges between the slow and fast zones, a diverse range of living environments, and sufficient infiltration capacity to align with natural hydrology. Another discovery was the use of the upstream-downstream axis, derived from indigenous landscape logic, as an orientation framework for the city, which can be complemented by a road network running perpendicular to this axis.

The main findings at the S scale indicate that, also at this level, water-based design can create socially and ecologically sustainable spaces. The local topography dictates the distribution between built and non-built environments: steep slopes are reserved for forested areas, low-lying regions are designated for wetland development that can double as recreational parks, while milder and higher terrain accommodates urban infrastructure such as roads and buildings. Reforesting local drainage patterns as bioswales could further enhance the green infrastructure woven throughout the urban

fabric. The transitional edge where the slow and fast zones converge presents valuable opportunities for public interaction with nature. This interface can be strategically activated through the development of public spaces that not only facilitate ecological connectivity but also accommodate elements of Indonesian street and food culture, thereby fostering culturally resonant and socially vibrant environments.

RQ 4 – Reflection

Which lessons can be taken from the landscape approach and the design outcome for Nusantara?

The design outcome that made use of water as a formative principle effectively addressed the issues identified in the analysis, including flooding, erosion, and water quality. This systematic approach begins early in the design process, restoring the natural hydrology of the system and fostering sustainable urban development throughout scales. The proposed watershed-based phasing is effective hydrologically but presents social and ecological challenges that extend beyond individual watershed boundaries. Small-scale design demonstrates that water-based planning can facilitate the creation of socially and ecologically sustainable spaces. The proposed design framework adopts a top-down approach, which is necessary for establishing a consistent regional plan, but allows for flexible infill with context – specific and bottom – up designs. The design concepts throughout the scales could be replicable in another context, if the watersheds and topographic characteristics in this context are similar to the context of this design.

The design outcome differs from the current design of Nusantara in different ways; firstly, it addresses the main problems on site at its origin (upstream) through a phasing strategy, where the current design started with the urban zone without addressing the upstream

regions simultaneously. Secondly, the overarching landscape framework prioritizes hydrological and ecological integrity on the large scale over time, where the current design is focused on the urban program in the first place. Thirdly, the proximity to ‘wild’ forest is consistently maintained in this design, reinforcing the forest city ideal, where the current design does integrate trees but not ‘forest’ in the urban design.

The design outcome tackles many of the challenges on site and offers a socio-ecological framework for the city. Further research and design could include further elaboration on the small scale and a water – supply strategy for the city.

The research-through-design methodology revealed the value of complementing large-scale planning with small-scale explorations. The iterative drawing process was crucial for uncovering spatial relationships and refining the urban fabric. The two-networks strategy effectively mediated between fast and slow systems, particularly at the medium and small scales. While the thesis incorporated indigenous knowledge through literature, its contextual relevance would have been greatly enhanced by direct engagement with local communities.

Throughout this thesis process, I developed skills in balancing independent work, seeking feedback, and managing tasks. I learned to increasingly trust my intuition, and gained a deeper understanding of the landscape architect’s role in foreign cultures, recognizing both the importance of local knowledge and the designer’s ability to foster systemic change through design - thinking and a holistic approach to the landscape.





7.

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