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RESEARCH ARTICLE

Changes in the ecological system of coastal areas of Bantul and Kulon Progo Regencies

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Abstract. Coastal areas are classified as highly vulnerable because they are always tied to changes in the global aquatic environment. The ecosystem dynamics are increasingly complicated and complex as a result of interactions with other systems on land. This phenomenon is very visible in the coastal areas of Bantul Regency and Kulon Progo Regency. We use Sentinel-2 satellite image interpretation in the period 2013-2022 as a historical record of land use change, and then explore it with Niklas Luhmann's social system theory to understand how communities and government mean the ecological system represented by activities in coastal areas. The results showed that the community and the Government massively changed the original ecosystem of pes-caprae with the dominant afforestation of shrimp cypress. For the community, afforestation is assumed to support production agriculture, from subsistence agriculture. For the government, afforestation is a misconception about reforestation and protecting vital infrastructure such as Yogyakarta International Airport. The main capital for change is technology and its knowledge, and economic capital obtained from production. The economic capital obtained is used for social transformation, including eliminating the stigma of poor, uninformed, and inferior coastal communities. The results achieved change the meaning of land from previously only to support daily livelihoods to production factors that have very high economic and social value. Any attempt to change the establishment of the social and economic system will be met with strong resistance from the community. Under these conditions, the sustainability discourse that we are developing is to build an institutionalized knowledge system, which is carried out repeatedly and continuously, which is important for the community to understand because its dynamics will continue to develop in the future.

Key words:
coastal;interpenetration; ecology; social; development

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1. Introduction

The successful development measures associated with macroeconomic growth adopted by the Government (Sartika et al., 2015), was continually criticized due to negative externalities frequently experienced by developing countries such as Indonesia. This was caused by the excessive exploitation of natural resources, including an imbalance with environmental improvements (Kuspradono, 2003). According to Akbar et al., (2017), development does not pay attention to the sustainability of natural resources and environmental carrying capacity.

The impact on the environment or ecological system is imbedded in regulatory and institutional problems, determined and reflected in the enactment of policies (Purwanto, 2019). Furthermore, the implementation process becomes increasingly complicated because development affects several parties, each with different purposes and objectives (de Sardan, 2005). This dissimilarity was reflected in the intentions of the actors, with some searching for a living, while others mobilized as well as managed large material and symbolic resources.

Understanding the meaning of development in modern society must also look at communication that builds social systems (Luhmann, 1996), both by the community as a social system, and by the Government in the form of a development policy system. A more basic construction of thought, the social system and development policy system carry out selective reconstruction of the environment which is seen as something too complex (Luhmann, 1993). For example, coastal areas are only seen as potential land for tourism, while mountainous areas are agricultural only. This selective reconstruction means creating the risk of eliminating many other parts to avoid complexity. In fact, living systems at various levels, experiencing various kinds of interaction processes, produce different behaviors, so that to describe and understand the ecological process is very difficult (Maurer, 2009).

Properly, humans are part of the ecological system of their environment, but in modern human history, exploitation and destructive acts against nature have been demonstrated (Ewert et al., 2014). Economics do the separation, in addition of reproducing social systems, and place natural environment as externality, especially for rare and high valu natural resources. Similarly, it's often so in development policy system, with its mandate to successfully the development also simplifies the risk of impacts on the environment.

In general, (Odum, 1964), once stated that the evolution of understanding about ecology has greatly influenced by human population explosion. Human population growth continuously demands new spaces that eventually open up previously sterile areas, or areas whose ecological systems are formed solely by the relationship between biotic factors and their physical environment. Ecological systems are constantly creating new ecosystems when humans begin to intervene in natural life-support systems or even attempt to exert control them, opening up opportunities for new flows of energy and matter.

Additionally, negative externalities tend to become increasingly complicated in coastal areas. (Nicholls et al., 2007), stated that this led to the phrase low-lying areas. Coastal threats are always associated with global environmental changes categorizing such areas as increasingly vulnerable (Hamid et al., 2019; Rumahorbo et al., 2023; Ramieri et al., 2011; Oloyede et al., 2022; Šimac et al., 2023), due to the interconnection with riverine areas. The vulnerability was greatly influenced by attributes associated with coastal areas, as an entity that needed to be either protected or exploited, including the numerous actions adopted to support the transformation of social and development system. The attributes attached will also influence the types of actions towards the coastal area.

The relationship between the applied ecological models reflects how the social and development policy system interpret coastal areas, alongside the associated attributes. Several previous research was conducted on sustainable initiatives (Yáñez-Arancibia et al., 2013; Glaeser et al., 2009; André et al., 2021; Hafsaridewi et al., 2018), in the form of natural coastal protection using artificial infrastructure, or a combination of natural and man-made models (Powell et al., 2019).

Exploring how the social system and development policy system interpret the ecological system of coastal areas is crucial, as it helps identify the drivers of change in these regions, as observed in the coastal areas of Bantul Regency and Kulon Progo Regency. The morphology of their coastal areas is very similar, and based on initial observations, many parts of their original ecosystems have already undergone significant changes. These changes have the potential to bring about various consequences in the future, as according to (Widianto & Damen, 2014), these areas are actually highly vulnerable to multiple disasters such as tsunamis, high waves, and coastal erosion-accretion. Socially, although the sandy lands in the coastal areas of both regencies are considered marginal, the production of horticultural commodities is relatively high

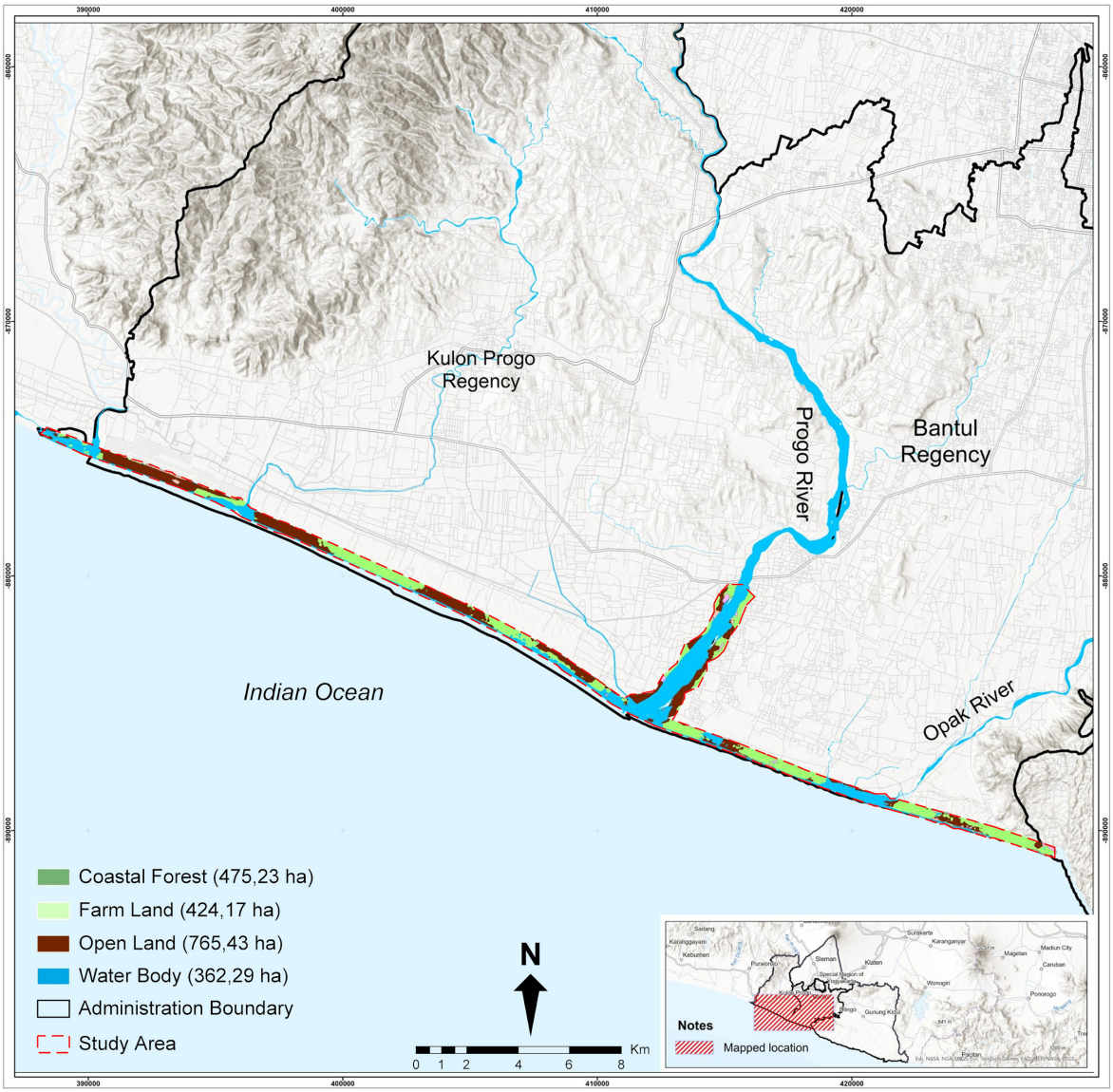

Figure 1. Land cover classification in Bantul and Kulon Progo Regencies, DI Yogyakarta Year 2022

(Subejo et al., 2019). Subejo et al. further note that many of the actors involved are university graduates who are quite familiar utilizing information from the internet, subsequently modernizing their agricultural techniques with appropriate technology. Therefore, it is important to explore how the community and the government interpret the ecological system, as this will help explain the dynamics of the ecological system, which is essentially only a resultant.

2. Methods

The research location administratively covers coastal areas of Bantul and Kulon Progo regencies, Yogyakarta Province. The distance between the two regencies is 47.86 km, while areas of the boundary studied is 400 meters wide from coastline, equivalent to 2,023.78 hectares. Furthermore, it is geographical located at coordinates 110.125580, -8.019456 and 110.346680, -7.862362.

Ecological data collection was carried out by examining land use trends based on satellite imagery obtained from 2013 to 2022. The method of analysis uses guided digital classification (Karra et al., 2021), distinguishing it into four types of land use, namely open land, agriculture, coastal forests, and water bodies. Reconfirmation was also carried out by observing the physical environment of coastal areas.

Data collection on the dynamics of the ecological system was conducted by analyzing land use trends based on Sentinel-2 satellite imagery for the period of year 2013-2022. Field verification was carried out at 48 points along the coastal areas of both regencies. The analysis of satellite imagery and field verification used supervised digital classification, following (Karra et al., 2021), and categorized the land into four types: open land, farmland, coastal forest, and water bodies. The dynamics of land use were used to understand the background and how the ecological system of the coastal areas has changed, which underlies the decisions made by the community and the government to alter it.

Data and information regarding the chronology, background, and how the social system and development policies meaning the coastal areas—manifested in the treatment or exploitation of its ecological system—were collected through observations of social, economic, and developmental phenomena. The results of these observations were confirmed through three group discussions, which were further validated through semi-structured in-depth interviews using purposive sampling. A total of 75 informants were interviewed, including 42 community leaders, 9 academics and researchers, 23 government bureaucrats, and 2 representatives from non-governmental organizations.

Data analysis was conducted by examining the dynamics of capital ownership, referencing (Bourdieu, 1986), which includes economic capital, social capital, cultural capital, and symbolic capital. These forms of capital serve as tools and resources utilized by the community (social system) and development initiatives by the Government (development policies) to transform the ecological systems of coastal areas. Furthermore, the ownership of capital becomes an analytical tool to understand the meaning behind the ecological systems of coastal areas, which forms the foundational framework of thought for both the community and the Government in positioning and managing coastal resources.

The collected field data and information were enriched and/or reinforced by tracing secondary data and information from various relevant reports. These reports pertained to coastal morphology, ecosystem development, and conflicts between the community and the government over coastal land. Triangulation during the research process helped establish facts that explain the phenomena of the dynamics of interaction between the ecological system and the social and development policy systems. This analysis was conducted repeatedly throughout the research period, providing insights into how communication shapes the interpretation and autopoiesis of these systems.

3. Result and Discussion

Changes in ecological system due to the dominance of social system and development policies

The morphology of the coastal areas of Bantul and Kulon Progo Regencies is characterized by black sand formations that create undulating dunes. The resilience and vulnerability of the ecological systems in these coastal areas are naturally influenced by the supply of sand from Mount Merapi (Mustafa & Yudhicara, 2007), which flows through the Progo and Opak Rivers. However, over the past decade, there has been a significant increase in sand mining activities in the upstream areas around Mount Merapi, extending to the downstream areas and the estuaries of the Progo and Opak Rivers. These activities have the potential to directly impact the morphology of the coastal areas in both regencies.

The loose texture of the sand, high sunlight intensity, elevated air and soil temperatures, high salinity levels, and strong sea winds are key factors contributing to environmental stress. The original ecosystem is dominated by the *pes-caprae* formation, primarily consisting of shrubs (Djuwanto et al., 2006). Only a few plant species naturally thrive in this environment, including the siwalan palm (*Borassus flabellifer*), ketapang (*Terminalia catappa*), keben (*Barringtonia asiatica*), waru (*Hibiscus tiliaceus*), and coconut (*Cocos nucifera*). In the lower strata, the dominant shrubs that can survive include *Spinifex littoreus*, *Ipomoea pes-caprae*, *Calotropis gigantea*, *Crotalaria tridax*, and *Physalis* sp. Among the taller shrubs resembling trees is the pandan (*Pandanus tectorius*).

The environmental stress that developed made the sandy lands in the past unsuitable for productive cultivation, leading to only a few communities willing to settle in the coastal areas. Economic activities were limited, primarily subsistence farming and very basic fishing, which were the skills mastered by the local population. This situation caused them to become a group of impoverished, low-educated, and marginalized people, earning them the negatively stigmatized label as *wong cubung*. Some residents who could not endure the environmental stress and the stagnant, low-economic system chose to migrate or become seasonal migrants who only returned home occasionally.

This stagnation in the social system prompted some residents to attempt transforming the productivity of the sandy coastal agricultural lands. They suspected that the strong winds and high salinity levels caused crops to die or, if they survived, to yield low productivity. This reasoning led to experimental afforestation efforts in the mid-1990s around Goa Cemara Beach in Bantul Regency, using waru and acacia trees, which ultimately failed. Subsequently, trials using cemara udang (*Casuarina equisetifolia*) in the late 1990s at Samas Beach, also in Bantul Regency, proved successful. This success was later replicated in other coastal areas and continues to this day. Around the estuaries of the Opak, Progo, and Bogowonto Rivers, afforestation efforts focused on establishing mangrove

ecosystems with Rhizophora and Avicennia, which are actually introduced species.

The success of *Casuarina equisetifolia* afforestation, as wind barrier and wind blocker gusts and air salinity, is believed by the community to have implications for increasing agricultural productivity. It's combined continue advancing the knowledge and the use of technology, particularly in irrigation and fertilization. The dry and highly permeable sandy soil is addressed through irrigation technology using water pumps, drip systems, or sprinklers. Meanwhile, for fertilization, farmers combine the use of organic and synthetic materials for plants nutrient. These achievements have transformed the agricultural system from subsistence farming to production farming, directly improving the household economies of the farmers. The information shared among farmers in these two regencies represents a form of social capital that is common in Indonesia. Over time, the production system has also contributed to the growth of coastal and beach tourism in both regencies, with the established ecological system of *Casuarina equisetifolia* forest serving as a foundational asset. The tourism industry complements the coastal agricultural production system, and it is highly likely to encourage the emergence of other economic production ventures.

The *Casuarina equisetifolia* afforestation has transformed the coastal areas from barren, dry, and low-productivity sandy lands into regions with diverse and growing economic activities. This development has been supported by the government through infrastructure projects such as the South Coast Road of Java Island (Jalur Jalan Lintas Selatan/ JJLS), Kretek 2 Bridge, Tanjung Adikarto Port, and Yogyakarta International Airport, along with its airport rail link. Future projections include the construction of a toll road connecting Semarang and Solo in Central Java Province and Srandakan 2 Bridge, complementing the existing infrastructure. While some of these infrastructure projects are aimed at supporting the current economic activities in the coastal areas, others reflect the central government's broader vision, such as enhancing inter-regional connectivity, improving the mobility of goods, and facilitating faster population movement.

The development of the agricultural production system and tourism, along with supporting businesses such as trade and hospitality, occurring simultaneously with government-led infrastructure projects, reflects a shift in the perspectives of the social system and development policies toward the coastal areas. To understand the dynamics of the coastal regions in both regencies, we conducted an analysis of land use over the past 10 years to observe how both systems have reacted to the current state of the coastal areas. This analysis can also serve as a basis for projecting future trends.

Land use classification was divided into four categories: open land, agricultural land, coastal forest, and water bodies (Figure 2). Open land represents remaining shrublands, grasslands, or *pes-caprae* ecosystems, while agricultural land includes areas used for seasonal crop cultivation and plantations. Coastal forest illustrates the *Casuarina equisetifolia* and mangrove ecosystems, and water bodies encompass coastal areas, river systems, and a small portion of shrimp ponds.

The transformation of the original *pes-caprae* coastal ecosystem began with the continuous expansion of coastal forests. During the period 2013-2022, the area of coastal forests increased by 128.2%, from 208.26 hectares to 475.23 hectares (see Figure 2). The dominant species planted were *Casuarina equisetifolia* along the coast and mangroves at the estuaries of the Opak, Progo, and Bogowonto Rivers. In 2019, the coastal forest area decreased due to the construction of Yogyakarta International Airport (YIA), but it later expanded again through afforestation efforts by Balai Pengelolaan Daerah Aliran Sungai (BP-DAS) in Yogyakarta. The goal was to reduce the potential impact of wind carrying fine sand, which could damage aircraft engines. The species planted included *Casuarina equisetifolia*, keben (*Barringtonia asiatica*), ketapang (*Terminalia catappa*), nyamplung (*Calophyllum inophyllum*), waru (*Hibiscus tiliaceus*), and pandan (*Pandanus tectorius*).

Meanwhile, open land areas decreased by 12.7%, from 876.9 hectares to 765.43 hectares. These open lands primarily included road infrastructure, the YIA runway area, and settlements. The reduction in open land was mainly due to conversion into agricultural land and coastal forests. Another portion was converted during the construction of NYIA in Kulon Progo Regency, which later rebounded after the airport became operational.

Agricultural land experienced a significant decline of 32.9% over the 10-year period, from 632.39 hectares to 424.17 hectares. This reduction was largely due to the conversion

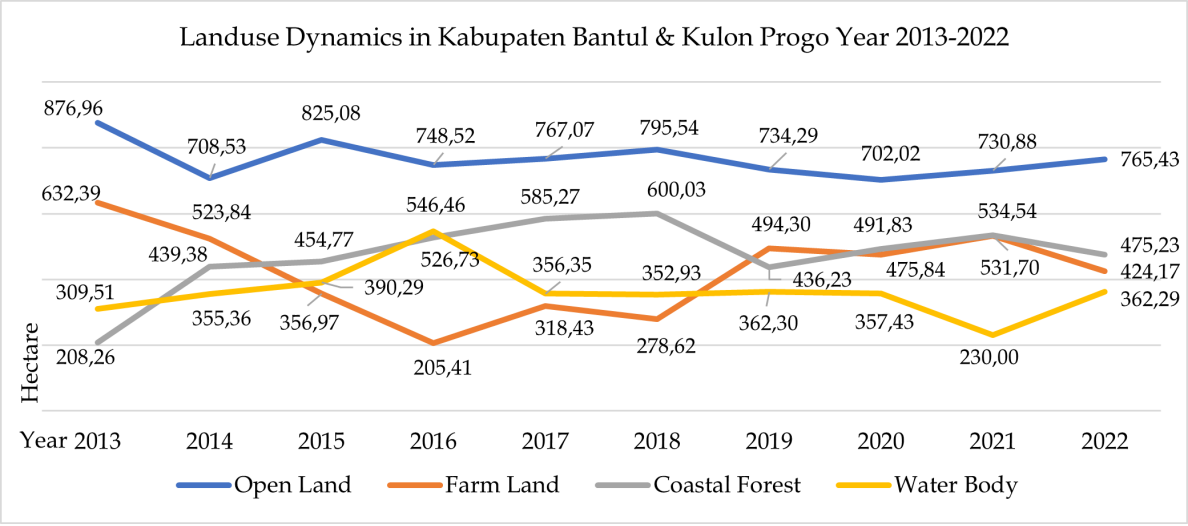

Figure 2. Land use trends in coastal areas of Bantul and Kulon Progo regencies 2013 - 2022

of agricultural land for the construction of YIA and the Jogja Magasa Iron sand mining concession in Kulon Progo Regency. This conversion prompted communities to adapt by utilizing open lands as replacements for lost agricultural areas. Simultaneously, in the eastern part of Bantul Regency, which was not directly affected by the airport construction, the growth of coastal forests blocking sea winds encouraged communities to adapt by using sand dunes for agriculture. In the central and western parts, previously unproductive lands gradually began to be used for farming.

Changes in agricultural land were also driven by the boom in vaname shrimp farming, which began in 2010, peaked in 2014, and was largely abandoned by 2016 due to losses. This trend is reflected in the increase in water bodies, which later declined until 2021. The increase in water bodies also included river erosion and coastal abrasion, which expanded from 309.51 hectares in 2013 to 362.29 hectares in 2022, a 17.1% increase. The most extensive erosion occurred at the Progo River estuary, where sand mining caused the loss of agricultural land. These findings align with reports by (Wahyuningsih et al., 2016) and (Cahyono et al., 2017), which noted that abrasion had eroded coastal areas in both regencies by 2.9 to 219.5 meters.

The land-use changes trend year 2013 to 2022 into coastal forests, agricultural land, and infrastructure indicates an interpenetration by social systems and development policies into the ecological systems of coastal areas, which had already undergone significant changes prior to this period. The interpenetration of these two systems has transformed the coastal landscape, whose morphology consists of sand dunes formed by wind. This also includes the formation of barchan sand dunes on the eastern side of Bantul Regency, the largest unique ecosystem in Southeast Asia. Afforestation with *Casuarina equisetifolia* has obstructed the wind flow that carries fine sand particles, which are essential for dune formation. Afforestation has also reduced the microclimate, triggering the growth of understory plants, as well as rodent and lepidopteran species.

The interpenetration by the social system has only been applied to the ecological system, transforming the original *pes-caprae* ecosystem into coastal forests and agricultural land. This change aims to support the reproduction of the socio-economic system, shifting from subsistence livelihoods to production-based livelihoods in the form of primary agricultural activities, tourism, and other economic ventures. Meanwhile, the interpenetration by development policy systems intersects with both ecological and social systems. Its intersection with the ecological system involves infrastructure development, which is politically almost impossible to restore to its original ecological state. Its intersection with the social system has led to open conflicts, such as during the designation of iron sand mining areas and the construction of Yogyakarta International Airport (YIA). Established social systems based on agricultural livelihoods suddenly had to confront government interests, justified in the name of development to pursue economic growth.

Another interpenetration, which has actually hidding laten conflicts, has also been carried out by the Central Government. Around the river estuary, the Ministry of Environment and Forestry (KLHK) has designated 435.3 hectares of mangrove forest as an Essential Ecosystem Area (KEE). Similarly, the Ministry of Marine Affairs and Fisheries (KKP) has designated 695.89 hectares of shrimp pine forest in Bantul Regency as a Marine Conservation Area (KKP). Another note is the failure of the operation of Tanjung Adikarto Port, which during its construction process ignored the ecological system, resulting in its failure being evident from the very beginning of its inauguration.

The interpenetration by the social system and development policies will continue to drive dynamic changes in land use, fueled by evolving technology and knowledge. Existing community economic activities are likely to expand in the future. Similarly, the government's plans for an aerotropolis (airport city), connected by Srandakan 2 Bridge and toll roads to Semarang and Solo, will further shape development. These ongoing and future developments are based on the Spatial and Regional Planning framework and the regional development paradigm in 2012 encapsulated in the slogan *Among Tani Dagang Layar*, which positions coastal and beach areas as economic growth centers focused on agriculture and capture fisheries (Setiadi, 2018).

Use of technology and changes in the meaning of coastal areas

The agricultural production model by the community and infrastructure development by the government in Bantul Regency and Kulon Progo Regency have dramatically and will continue to transform the ecological systems of their coastal areas. The initial initiative started by the community was later followed by the government through infrastructure development, which not only supports the growth of the coastal region but also aims to achieve development goals. These efforts have altered the constellation of economic capital ownership, including cash, savings, and liquid assets, which then became tools for social transformation and development.

The initial catalyst for change was the exploration of knowledge and technology (objectified cultural capital), which is easily accessible on the internet. The community, many of whom are graduates, primarily focused on acquiring knowledge about irrigation and fertilization techniques. The use of technology is determined by the capacity of capital ownership, where greater economic capital enables the adoption of more modern technologies to boost agricultural productivity.

Simultaneously, the government, through political lobbying channels, made decisions to develop the coastal area to drive economic growth. These decisions were supported by supervisory bodies consisting of practitioners and academics, who utilized knowledge of sandland construction as technical justification. The smooth progress of development was backed by increasing government budgets every year.

Knowledge and technology leap for coastal land management by the community and government directly increased productivity, accumulating economic capital in various forms. For the community, the increase in economic capital strengthened social capital, positioning them as equals with other societal groups and gradually erasing the stigma of being associated with the lower strata, often referred to as *wong cubung*. The community also formed agricultural and tourism professional organizations to protect and maintain the social and economic capital they had achieved. These organizations became platforms to resist disruptions or threats, such as the planned iron sand mining by PT Jogja Magasa Iron between 2006-2013 and the construction of Yogyakarta International Airport (YIA) between 2018-2019. The organizations adopted the cultural slogan "farm or die."

The ecological system of the coastal areas in the two regencies, as a result of the interpenetration of social systems and development policy systems, reflects a significant shift in meaning, as noted by (Luhmann, 1996). This shift places economic capital and the stability of social capital in a position that tends to negate the original ecological system. The change in meaning, initiated by afforestation, as referenced by (Sunarto, 2014), appears to embody the concept of biocentrism on the surface but is actually more anthropocentric. Afforestation is essentially land engineering that turns it into a production factor to accumulate economic capital.

The meaning of land varies across different phases, as noted by (Bruckmeier, 2016) and (Abdoellah, 2020), and is determined by the use of technology. In the initial introduction phase, the meaning was limited to supporting resilience or self-sufficiency in meeting basic needs. For coastal communities, this meant subsistence farming, while for the government, it involved roads as basic infrastructure connecting regions. At this stage, the reproduction of the system was relatively slow. Proposals for changes to the ecological system were met with low resistance, such as reducing the area of afforested land to preserve the original ecosystem or the natural formation of sand dunes.

The meaning of coastal land continued to strengthen and expand as more technologies were introduced, enhancing the stability of economic and social capital acquisition and development. Within the social system, the formation of organizations marked a redefinition of land as a complex issue tied to identity, as argued by (Raby, 2019). Farming communities also view land as the primary resource for livelihood, as noted by (Syahyuti, 2001), making it both a social asset and a capital asset, as highlighted by (Dewi & Salim, 2020). Ultimately, any threat to the land is seen as a direct challenge that will be resisted both physically and politically.

Economic growth and reinterpretation of coastal areas

The use of technology, along with the collective knowledge of coastal area management by the community (social system) and the government (development policy system), has dramatically transformed the ecological systems of the coastal areas in both districts. The native *pes-caprae* ecosystem has largely been replaced by various new ecosystem types resulting from productive economic activities. This change has introduced a new measure of success in area management, namely economic growth and capital accumulation. According to the social system, the indicator of this success is the shift from subsistence farming to production-based agriculture, alongside the emergence of other business units. For the government, the indicators include increased human and goods traffic, as well as economic transactions.

These findings align with the modern anthropocentric perspective, which, according to (Purwanto, 2019), measures development success through productivity growth and investment. This perspective tends to negate or disregard other considerations deemed incompatible. For the community, achieving economic growth has proven to strengthen social capital, positioning them as equals to other societal groups and gradually erasing the stigma of being associated with the lower strata, often referred to as *wong cubung*. For the government, this change also serves as a benchmark for the success of development plans that have transformed low-productivity land into areas with high economic transaction volumes.

Ironically, at the moment when the economic interests revered by both systems converge, they do not strengthen productivity but instead lead to clashes. For instance, there was manifest conflict between the community and the government over the plan for iron sand mining by PT Jogja Magasa Iron from 2006 to 2013 and the construction of YIA Airport from 2018 to 2019. The conflict escalated as the community formed an organization called *Paguyuban Petani Lahan Pasir* (PPLP), while the government employed state power instruments such as the police and other law enforcement agencies. The slogan used by PPLP was "farm or die," while the government justified its actions in the name of order and the success of development plans.

Historical records of conflicts between communities and the government over coastal areas have revealed their true nature when economic growth and capital accumulation are used as measures of success. Interpretation of land solely as a factor of production has proven to shape both parties into mere *homo economicus*. This interpretation has triggered the most brutal survival instincts, solely to maintain the accumulated capital. Furthermore, the ongoing and continuously evolving processes, which create reciprocal relationships and new dynamics, completely disregard the ecological system. The complex, temporal, and autopoietic nature of social reality will continue to evolve in tandem with the knowledge and dependence on technology in daily life.

Referring to (Luhmann, 1996), the resultant interpenetration, as a product of changed interpretations, represents a trade-off with the previously well-established ecological system over a very long period. The social and development policy systems have created differentiation in land functions and social structures, which will continue to occur because these systems possess the financial power, knowledge, technology, and infrastructure to accelerate them. At this point, the preferred choices of the social and development policy systems have reached a stage where correction is extremely difficult. This reinterpretation is even directed to support broader economic growth, not limited to coastal areas alone.

The paradox of the reinterpretation of coastal areas

The economic growth resulting from ecological system engineering is an achievement that has created comfort zone for social systems and development policies. For coastal communities, this achievement becomes a means of transforming the social system, placing them on equal footing with other societal groups while opening up further opportunities. For the government, it shapes a new direction for development policies based on infrastructure. Historical records and these achievements merge to form a future orientation perceived as better: economic growth.

Yet, the aligned focus on economic growth has previously placed the two systems in conflict, showing both are reluctant to reorient their perspectives toward coastal areas. They only view every piece of land as a production factor that has been mastered and must be preserved, which then leads both systems to completely ignore the ecological system changes. The government paradox which consistently emphasizes environmental factors as a consideration in every development.

The primal paradox lies in the fatal misjudgment of both society and the government, who adopt the slogan of greening the coast that alter the original pes-caprae ecosystem—deemed unproductive—through afforestation, which is

considered capable of serving as a barrier against tsunami waves potentially triggered by a megathrust earthquake south of Java. Actions grossly overlooks the natural characteristics of sand dunes as a stronger barrier, as reported by (Khotimah, 2006) and (Triatmadja & Warniyati, 2021). Furthermore, (BNPB, 2023) reports an increasing vulnerability of the physical environment in coastal areas due to rising sea levels, large waves, strong winds, and routine annual estuary flooding. Moreover, sand dunes themselves are a native ecosystem designated as a strategically important environmental area under laws, government regulations, and regional regulations. The paradox stems from the error of interpreting the coastal environment merely as a physical object rather than a collection of resources requiring study before development is undertaken.

The paradox is also starkly evident in the stalled Tanjung Adikarto port project due to a lack of understanding of the ecological system. This failure has raised questions from many parties despite the massive budget allocated for its construction. Some groups have even mocked the wasteful development. And so the construction of the Bogowonto River jetty to protect the NYIA Airport environment from flooding cost nearly 700 billion. This substantial cost has sparked numerous questions regarding its economic viability.

The paradox and irony are simultaneously apparent in the conflict that once occurred between society and the government, both of whom fundamentally aimed to achieve economic growth. Ideally, a shared goal should only require finding common ground. However, with both parties desiring to dominate control over coastal land, what transpired was an antagonistic positioning of the two.

The irony becomes even more evident when the government, increasingly aware of the mistakes in its afforestation policies, proposes corrections by reducing the area of coastal forests, only to face rejection from a society whose livelihoods from tourism have become established. This rejection emerged around the Parangkusumo sand dune area, with concerns that it would reduce comfort and, consequently, visitor numbers. Yet, the government, with its resources and authority to rectify the situation, has not utilized them as it did during the construction of YIA Airport and the granting of iron sand mining concessions.

Ultimately, altering the ecological system to pursue economic growth as a tool for transforming social systems and development policies once again proves paradoxical in the process of achieving its goals. This paradox sharpens further, as (Tualeka, 2017) notes that the phenomenon of differing interests creates substantial and direct contestation. Moreover, the government often positions development (measured by economic growth) as a justifying reason, which, according to (Usboko, 2016), has the potential to create actual conflict groups and potential conflict groups.

The fundamental issue is that the complexity of the coastal ecological system, with all its resources, has not been fully defined by the social system and the development policy system. A reduction in understanding occurs, which inevitably poses risks to the ecological system and, in turn, impacts the social system and the development policy system itself. The potential risks create vulnerabilities, as evidenced by the historical trajectory of past conflicts. The slogan "farm or die" represents a latent problem that could resurface at any time with varying intensity. The history of resistance between the two systems will always remain a dark chapter.

What is the future of the ecological system of coastal areas in Bantul and Kulon Progo Regencies?

The changes in the ecological system of the coastal areas of the two regencies are relevant to the views of (von Bertalanfy, 1968), (Marín, 1997), and (Nagelkerken, 2009), which discuss the existence of complex spatiotemporal interactions among various systems. The complexity of these situations, as referred to by (Taylor, 2005), can be observed in the increasing chaos and lack of clear boundaries, as what happens in one system continuously affects the others. Between these interpenetrating systems, they meld together and create ceaseless changes. Therefore, we must not view changes in the ecological system rigidly; rather, we must openly see them as the resultant of the interpenetration of other systems.

The overexploitation of the coastal areas of Bantul and Kulon Progo Regencies necessitates a reinterpretation of the ecological system within its constellation with the social system and the development policy system. This reinterpretation must be continuously reproduced to reduce uncertainty regarding complexity, unpredictability, the distribution of benefits from growth, and its sustainability. The strategy, as per (Glaeser et al., 2009), involves developing a knowledge system by the social system and the development policy system. The goal is to build a shared understanding of the value and function of the coastal ecological system by the other two systems.

The implementation mechanism involves conducting continuous interdisciplinary research or observations by the social system and the development policy system. Both systems must also agree on the subjects and objects of coastal area management, thereby establishing a shared interpretive synthesis and progressive synthesis. Lastly, both systems must develop adaptive capacity and transformability through discussions and knowledge-sharing about the dynamics of the ecological system, social system, and development policy system. The aim is for the social and development policy systems to understand the detailed development of the ecological system.

Operationally, this can be achieved by forming joint institutions between the social system at the grassroots level (community) and the development policy system, represented by local government. The governance of these institutions will eliminate antagonistic situations between systems, particularly between the social system and the development policy system. The institution serves as a platform for joint discussions on development plans and coastal area management.

The established institution becomes the midpoint where the interests of the systems in the coastal area converge. This convergence of interests ensures that the systems share the best knowledge, the best methods, and/or the best technologies used to manage the coastal ecological system as the primary support for the other two systems. The impact not only strengthens the resilience and reduces the vulnerability of the coastal ecological system but also minimizes complexity and uncertainty in the future. Thus, institutional governance becomes the embodiment of a policy knowledge system containing legal rules and norms for managing the coastal area. This model can continue to evolve, remaining flexible and adapting to the adaptive capacity and transformation of the three systems in the coastal area.

4. Conclusion

In conclusion, changes in the ecological system were characterized by a complex situation because the outcomes had

interpenetrating symptoms of the other system. Therefore, an understanding of coastal ecological system should be detailed, avoiding reduction and the materialization of risks related to complexity, uncertainty, and sustainability. The reinterpretation of ecological system should be accompanied by the continuous reproduction of institutionalized knowledge.

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References

Abdoellah, Oekan S. (2020). *Dari ekologi manusia ke ekologi politik*. Gramedia Pustaka Utama.

Akbar, Aji Ali, Junun Sartohadi, Tjut Sugandawaty Djohan, & Su Ritohardoyo. (2017). Erosi pantai, ekosistem hutan bakau dan adaptasi masyarakat terhadap bencana kerusakan pantai di negara tropis. *Jurnal Ilmu Lingkungan*, *15*(1), 1–10.

André, Laure Vaitiare, Simon Van Wynsberge, Mireille Chinain, & Serge Andréfouët. (2021). An appraisal of systematic conservation planning for Pacific Ocean tropical islands coastal environments. *Marine Pollution Bulletin*, *165*, 1–20.

BNPB. (2023). *Inarisk Badan Nasional Penanggulangan Bencana*. Https://Inarisk.Bnpb.Go.Id/Dashboard_sumut/Index.Html.

Bourdieu, Pierre. (1986). The form of capital. In JG Richardson (Ed.), *Handbook of Theory and Research for the Sociology of Education* (pp. 15–29). Greenwood Press.

Bruckmeier, Karl. (2016). *Social-ecological transformation: Reconnecting society and nature*. Palgrave Macmillan.

Cahyono, Hendrik, Theresia Retno Wulan, Musrifah, & Edwin Maulana. (2017). Analisis perubahan garis pantai dengan menggunakan data citra landsat di pesisir Kabupaten Kulonprogo. *Bunga Rampai Kepesisiran Dan Kemaritiman Jawa Tengah*, 1–12.

de Sardan, Jean-Pierre Olivier. (2005). Chapter 1. Introduction: The three approaches in the anthropology of development. In *Anthropology and Development: Understanding Contemporary Social Change* (pp. 1–16). Bloombury Publishing.

Dewi, Ni Luh Gede Maytha Puspa, & M Nazir Salim. (2020). *Berakhir di Temon: Perdebatan panjang pengadaan tanah untuk [New] Yogyakarta International Airport (YIA)*. STPN Press.

Djuwanto, Suyitno, Sudarsono, & Ratnawati. (2006). Karakteristik Vegetasi Di Kawasan Pantai Samas Bantul Daerah Istimewa Yogyakarta. *Seminar Nasional MIPA 2006*, 46–55.

Ewert, Alan W, Denise Mitten, & Jillisa Overholt. (2014). *Natural Environments and Human Health*. CABI.

Glaeser, Bernhard, Karl Bruckmeier, Marion Glaser, & Gesche Krause. (2009). Chapter Eigth. Social-ecological systems analysis in coastal and marine areas: A path toward integration of interdiciplinary knowledge. In Begosi PL (Ed.), *Current Trends in Human Ecology* (pp. 183–203). Cambridge Scholars Publishing.

Hafsaridewi, Rani, Benny Khairuddin, Jotham Ninef, Ati Rahadiati, & Hasan Eldin Adimu. (2018). Pendekatan sistem sosial-ekologi dalam pengelolaan wilayah pesisir secara terpadu. *"Marina" Sosial Ekonomi Kelautan Dan Perikanan*, *4*(2), 61–74.

Hamid, AIA, AHM Din, N Yusof, NM Abdullah, AH Omar, & MFA Khanan. (2019). Coastal vulnerability index development: A review. In A. A. Rahman (Ed.), *6th International Conference on Geomatics and Geospatial Technology (GGT 2019)* (pp. 229–235). International Society for Photogrammetry and Remote Sensing (ISPRS).

Karra, Krishna, Caitlin Kontgis, Zoe Statman-Weil, Joseph C. Mazzariello, Mark Mathis, & Steven P. Brumby. (2021). Global land use / land cover with Sentinel 2 and deep learning. *IGARSS 2021 - 2021 IEEE International Geoscience and Remote Sensing Symposium*, 4704–4707.

Khotimah Hidayat Chusnul. (2006). Kelestarian gumuk pasir Pantai Parangtritis sebagai penghalang (barrier) alami gelombang pasang dan tsunami. *Geomedia*, *4*, 81–92.

Kuspradono, B. (2003). Kritik terhadap konsep pembangunan ekonomi "neoliberal." *Kinerja*, *7*(1), 1–12.

Luhmann, Niklas. (1993). Ecological communication: Copping with the unknown. *System Practice*, *6*(5), 527–539.

Luhmann, Niklas. (1996). *Social system*. Stanford University Press.

Marín, Victor H. (1997). General System Theory and the Ecosystem Concept. *Bulletin of the Ecological Society of America*, *78*(1), 102–104.

Maurer, Brian A. (2009). Ecological complexity. In R Meyers (Ed.), *Encyclopedia of complexity and systems science* (pp. 2697–2711). Springer.

Mustafa, M. Akrom & Yudhicara. (2007). Karakteristik pantai dan resiko tsunami di kawasan pantai selatan Yogyakarta. *Jurnal Geologi Kelautan*, *5*(3), 159–167.

Nagelkerken, Ivan. (2009). Introduction. In I. Nagelkerken (Ed.), *Ecological connectivity among tropical coastal ecosystems* (pp. 1–6). Springer.

Nicholls, Robert J., Poh Poh Wong, Virginia Burkett, Jorge Codignotto, John Hay, Roger McLean, Sachooda Ragoonaden, & Colin D. Woodroffe. (2007). *Coastal systems and low-lying areas. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds.* (pp. 315–356). Cambridge University Press.

Odum, Eugene P. (1964). The new ecology. *BioScience*, *14*(7), 14–16.

Oloyede, Mary O., Akan B. Williams, Godwin O. Ode, & Nsikak U. Benson. (2022). Coastal vulnerability assessment: A case study of the Nigerian coastline. *Sustainability*, *14*(2097), 1–21.

Powell, Emily J., Megan C. Tyrrell, Andrew Milliken, John M. Tirpak, & Michelle D. Staudinger. (2019). A review of coastal management approaches to support the integration of ecological and human community planning for climate change. *Journal of Coastal Conservation*, *23*, 1–18.

Purwanto, Erwan Agus. (2019). Kebijakan publik yang agile dan inovatif dalam memenangkan persaingan di era VUCA (volatile, uncertain, complex and ambiguous). In *Pidato pengukuhan jabatan guru besar Ilmu Kebijakan Publik pada Fakultas Ilmu Sosial dan Ilmu Politik*. Universitas Gadjah Mada.

Raby, Megan. (2019). "Slash-and-burn ecology": Field science as land use. *History of Science. Special Issue: Shared Ground: Between Environmental History and History of Science*, *57*(4), 441–468.

Ramieri, Emiliano, Andrew Hartley, Andrea Barbanti, Filipe Duarte Santos, Ana Gomes, Mikael Hilden, Pasi Laihonen, Natasha Marinova, & Monia Santini. (2011). *Methods for assessing coastal vulnerability to climate change*. European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation. European Environment Agency.

Rumahorbo, Basa T., Maklon Warpur, Rosye H.R. Tanjung, & Baigo Hamuna. (2023). Spatial Analysis of Coastal Vulnerability Index to Sea Level Rise in Biak Numfor Regency (Indonesia). *Journal of Ecological Engineering*, *24*(3), 113–125.

Sartika, Ika, Gatiningsih, & Wirman Syafri Sailiwa. (2015). *Teori pembangunan dan implikasinya di Indonesia*. Pustaka Rahmat.

Setiadi, Amos (2018). Konsep "Among Tani Dagang Layar" tata ruang wilayah DIY dan pembangunan kawasan wisata bahari. In S. Patabang (Ed.), *Seminar Nasional Riset dan Teknologi Terapan 8* (pp. 43–52). Fakultas Teknik Universitas Katolik Atma Jaya.

Šimac, Zaviša, Nina Lonˇcar, & Sanja Faivre. (2023). Overview of coastal vulnerability indices with reference to physical characteristics of the Croatian coast of Istria. *Hydrology*, *10*(14), 1–20.

Subejo, Dyah Woro Untari, Ratih Ineke Wati, & Gagar Mewasdinta. (2019). Modernization of agriculture and use of information and communication tehnologies by farmers in coastal Yogyakarta. *Indonesian Journal of Geography*, *51*(3), 332–345.

Sunarto. (2014). Geomorfologi dan kontribusinya dalam pelestarian pesisir bergumuk pasir aeolian dari ancaman bencana agrogenik dan urbanogenik. In *Pidato Pengukuhan Jabatan Guru Besar pada Fakultas Geografi*. Universitas Gadjah Mada.

Syahyuti. (2001). Pengaruh politik agraria terhadap perubahan pola penguasaan tanah dan struktur pedesaan di Indonesia. *Forum Penelitian Agro Ekonomi*, *19*(1), 21–32.

Taylor, Peter. (2005). Unruly complexity: Ecology, interpretation, engagement. In *Curriculum and Instruction Faculty Publication Series*. University of Massachusetts Boston.

Triatmadja, Radianta & Warniyati. (2021). Catatan tentang perencanaan tembok laut untuk mitigasi bencana tsunami. *Media Komunikasi Teknik Sipil*, *27*(1), 29–40.

Tualeka, M Wahid Nur. (2017). Teori konflik sosiologi klasik dan modern. *Jurnal Al-Hikmah*, *3*(1), 32–48.

Usboko, Ignasius. (2016). Role players analysis dalam konflik pengelolaan sumber daya alam: Studi kasus konflik pertambangan mangan di Kabupaten Timor Tengah Selatan, Provinsi Nusa Tenggara Timur tahun 2010-2011. *Politika*, *7*(1), 1–21.

von Bertalanfy, Ludwig. (1968). *General system theory: Foundations, development, applications*. George Braziller.

Wahyuningsih, Dwi Sri, Mega Dharma Putra, Th. Retno Wulan, Anggara Setyabawana Putra, Edwin Maulana, & Farid Ibrahim. (2016). Mitigasi bencana erosi kepesisiran di Pantai Kuwaru dan Samas, Kabupaten Bantul, Daerah Istimewa Yogyakarta. In Priyono, A. N. Anna, A. A. Sigit, Y. Priyana, & C. Amin (Eds.), *Upaya Pengurangan Risiko Bencana Terkait Perubahan Iklim. Seminar Nasional Geografi UMS 2016*. Muhammadiyah University Press.

Widianto, Arief & Michiel Damen. (2014). Determination of coastal belt in the disaster prone area: A case study in the coastal area of Bantul Regency, Yogyakarta, Indonesia. *Indonesia Journal of Geography*, *46*(2), 125–137.

Yáñez-Arancibia, Alejandro, John W. Day, & Enrique Reyes. (2013). Understanding the coastal ecosystem-based management approach in the Gulf of Mexico. *Journal of Coastal Research. Special Issue*, *63*, 243–261.