Environment and Ecology Research 12(1): 27-39, 2024
DOI: 10.13189/eer.2024.120104 http://www.hrpub.org

Assessing Land Use Transformation in Kanhangad Town: A Special Emphasis on Wetland Ecosystems

Abhilash M P[1], Sooraj G[2,*], H.S. Kumara[3], C.K. Ajai Chandran[4]

[1]Town and Country Planning Department, Government of Karnataka, India
[2]Department of Urban Planning, Lovely School of Architecture and Planning, Lovely Professional University, India
[3]School of Planning and Architecture, University of Mysore, India
[4]School of Architecture, Christ Deemed to be University, India

Received October 1, 2023; Revised December 28, 2023; Accepted January 26, 2024

Cite This Paper in the Following Citation Styles

(a): *[1] Abhilash M P, Sooraj G, H.S. Kumara, C.K. Ajai Chandran , "Assessing Land Use Transformation in Kanhangad Town: A Special Emphasis on Wetland Ecosystems," Environment and Ecology Research, Vol. 12, No. 1, pp. 27 - 39, 2024. DOI: 10.13189/eer.2024.120104.*

(b): *Abhilash M P, Sooraj G, H.S. Kumara, C.K. Ajai Chandran (2024). Assessing Land Use Transformation in Kanhangad Town: A Special Emphasis on Wetland Ecosystems. Environment and Ecology Research, 12(1), 27 - 39. DOI: 10.13189/eer.2024.120104.*

Abstract Kerala, renowned for its lush landscapes, is facing environmental challenges due to rapid urbanization, particularly in Kanhangad. This area, notable for its unique wetland ecosystem crucial for biodiversity and human livelihoods, is experiencing a conflict between residential development and wetland conservation. A comprehensive study in Kanhangad, employing diverse data sources such as open-source data, Google Earth Satellite Imagery, OpenStreetMap, and tools like ArcGIS, provides a detailed analysis of land use and its environmental impacts. The study combines digital data analysis with physical surveys to understand the ecological and developmental status comprehensively. The study reveals a dominant trend in Kanhangad's land use, with residential areas comprising 52% of the total land, mostly large, detached single-family homes. This reflects a societal shift towards viewing homes as status symbols, contributing to natural resource depletion. The research underscores the need for sustainable, low-cost housing, suggesting vertical housing as a potential solution to balance residential demands with environmental conservation. Kanhangad's wetlands, essential for local biodiversity and livelihoods, face threats from urban development and infrastructural expansion. The study shows a drastic reduction in wetland area, from 12.9 km^2 in 2004-05 to just 1.66 km^2 by 2020-21, indicating severe ecological degradation. Despite the Kerala Conservation of Paddy land and Wetland Act of 2008, which aims to protect these ecosystems, its limited effectiveness is evident from the ongoing depletion of wetlands. This situation calls for stricter enforcement of environmental regulations and greater public involvement in conservation efforts. Furthermore, the research examines the Kerala Paddy and Wetland Conservation Act-2008, analysing its role and effectiveness in local environmental governance. The Act, focusing on prohibiting wetland and paddy land conversion, is vital for regional conservation. However, gaps in its implementation are highlighted, especially considering the exacerbation of the 2018 and 2019 Kerala floods due to land conversion practices. The study emphasizes the urgent need for more robust environmental protection measures.

Keywords Wetland, Land Use, Conservation and Preservation, Eco-system

1. Introduction

Kerala's wetlands are an important resource for biodiversity and human livelihoods [1, 2]. They provide habitats for diverse plant and animal species, including endangered species such as the Asian Elephant and Indian Giant Squirrel [3]. Wetlands in Kerala also serve as a migratory stopover for birds from the Palearctic region [4]. Moreover, they offer several ecosystem services, including

fisheries and tourism [5].

However, these wetlands are under threat due to various factors, such as contamination, destruction of habitats, reduction in biodiversity, and excessive utilization of resources [6]. To safeguard these vital ecosystems, efficient conservation strategies are essential [7, 8]. Conservation measures include creating protected zones, controlling actions within wetlands, and creating sustainable management techniques [9].

According to Mitsch W J, et al [4], wetlands are among the most productive ecosystems in the world, with high biodiversity and complex food webs. Wetlands offer numerous ecosystem services, including water filtration, flood control, and carbon sequestration. They are also critical habitats for many plant and animal species, some of which are rare or endangered. However, as Davidson N C [10] notes, wetlands are rapidly disappearing due to human activities such as urbanization, agriculture, and logging.

World Resources Institute [11] emphasizes the importance of wetlands for human well-being, highlighting the role of wetlands in providing clean water, supporting fisheries, and mitigating climate change. Finlayson M, et al [12] provides a comprehensive overview of wetland ecology, management, and restoration, while Gopal B, et al [13] explore the biodiversity of wetlands and its conservation.

As Mitsch W J, et al [14] explain, wetlands provide critical ecosystem services, including water purification, carbon sequestration, and habitat provision for wildlife. Wetlands also play a vital role in mitigating the impacts of climate change by storing carbon and reducing greenhouse gas emissions. However, as Cowardin L M [15] notes that, wetlands are highly vulnerable to human activities and are rapidly disappearing, making their conservation a critical priority.

The significance of wetlands in providing ecological benefits such as water purification and flood control has been widely acknowledged by various sources [4,9,11,15,16,17]. Wetlands are crucial in supporting the lives and livelihoods of countless individuals worldwide. However, the growth of cities and construction projects has significantly impacted the continuity of wetlands, leading to the deterioration of their plant life

In Kerala, the degradation of the wetlands ecosystem is widely recognized, although there haven't been any specific measurements of the rate of destruction. The primary problems that the wetlands in Kerala face are related to pollution, eutrophication, encroachment, conservation, and loss of biodiversity. The statement emphasizes the significance of these wetlands in providing breathing spaces and lungs for the town, aiding in recharging the groundwater level, and providing open areas for agricultural activities.

Wetlands can be either natural or artificial, permanent or temporary, and can contain fresh, brackish, or saltwater [9]. The Ramsar Convention Manual provides a guide to the Convention on Wetlands and describes wetlands as areas of marsh, fen, peatland, or water that may also include marine water with a depth not exceeding six meters at low tide. Immediate actions must be taken to confront these difficulties and protect the wetlands, which have a crucial role in supporting the lives and livelihoods of countless individuals in the region.

1.1. Kerala Paddy and Wetland Conservation ACT-2008

The Kerala Conservation of Paddy Land and Wetland Act of 2008 is an important legislation aimed at managing and protecting the wetland regions and paddy fields of Kerala [18]. The Act emphasizes the promotion of rural development, food security, and environmental conservation through the establishment of committees at the local, state, and district levels. The Act prohibits the conversion of wetlands and filling of paddy land, except in situations allowed by the Act.

According to Ramachandra T V [19], wetlands in Kerala have significant ecological functions, such as acting as a source and sink for greenhouse gases, regulating local and regional climate processes, and improving water systems' quality. The study emphasizes the importance of wetlands in maintaining water supply, reducing flooding and erosion, and providing habitats for various wildlife species.

Anjana M and Rajan C K [6] highlights the significance of wetlands and paddy fields in Kerala's economy, society, and environment. The study identifies the threats faced by wetlands in the state, such as reclamation for development, pollution, and encroachment. It proposes strategies for conservation, including policy interventions, community participation, and sustainable land use practices.

Biju K V and Latha C P [20] emphasizes the importance of paddy fields as a critical resource for the livelihoods of rural communities in Kerala. The study highlights the need for sustainable management practices to address the challenges faced by paddy cultivation, such as water scarcity and climate change.

Chandra P and Singh K [21] provide an economic perspective on the value of wetland ecosystem services in Kerala. The study assesses the monetary value of various wetland services, such as carbon sequestration, flood regulation, and tourism, and recommends policy interventions to enhance wetland conservation and management.

2. Methodology

The comprehensive study of land use and environmental conditions in Kanhangad was a meticulously structured process, strategically divided into two main phases: data gathering and analysis, and drawing conclusions from the collected data. This approach ensured a systematic and thorough examination of the area’s ecological and residential development challenges.

2.1. Phase One: Data Gathering and Analysis

1. **Utilization of Various Sources:** The initial phase centered on the collection of diverse data sources. The team harnessed open-source data and leveraged advanced satellite imagery technologies, including Google Earth Satellite Imagery and OpenStreetMap. These platforms provided high-resolution images and detailed geographic information, crucial for understanding the landscape's current state [22].
2. **Employment of Technological Tools:** The adoption of sophisticated tools like ArcGIS was pivotal. This geographic information system enabled the team to create intricate maps of the study area, delineating different land use types, vegetation cover, water bodies, and other vital environmental features. Mohanty B P and Prusty B [23] state that the spatial analysis capabilities of ArcGIS allowed for a nuanced understanding of the region's ecological fabric and the interplay between natural and built environments stated by.
3. **Physical Surveys:** To complement the digital data, the team conducted on-ground physical surveys. These surveys were essential in providing a tangible sense of the area's environmental conditions. They allowed the team to observe firsthand the impacts of residential expansion on natural habitats and to gauge the health of the wetlands. Panigrahi R [24] shares the insights gained from these surveys were invaluable in validating and enriching the data gathered from digital sources.

2.2. Phase Two: Making Conclusions Based on the Data

1. **Analysis of Wetland Biodiversity:** The team utilized the "Guidelines for the rapid assessment of wetland biodiversity using key biodiversity areas methodology." This approach was instrumental in evaluating the biodiversity within the wetlands, assessing the ecological significance, and identifying areas of critical environmental importance. It offered a framework for understanding the complex interdependencies within the wetland ecosystems.
2. **Incorporating Global Conservation Perspectives:** Drawing upon the "Global perspectives on river conservation: science, policy, and practice," the team could place their findings within a broader global context. These resources provided insights into successful conservation practices and policies implemented in other regions, offering a comparative perspective that enriched the analysis [25].
3. **Literature Study of the Kerala Paddy and Wetland Conservation Act-2008:** A thorough examination of the Kerala Paddy and Wetland Conservation Act-2008 was conducted. Understanding this legislation was crucial, as any recommendations or interventions proposed needed to align with existing legal frameworks governing wetland conservation in Kerala. Madhusudan M D [26] ensured that the team's suggestions were not only environmentally sound but also legally compliant.

3. Area of Intervention

Kanhangad, situated in the northernmost part of Kerala, is a municipality in the Kasaragod district. It covers an area of 39.54 square kilometers and is bounded by the Arabian Sea to the west and the Arayi river to the south. The town comprises the revenue villages of Hosdurg, Kanhangad, Balla, and Pudukai and has an elevation of 15 meters above sea level [27]. Despite its small size, Kanhangad has good connectivity to other major cities in the region. Mangaluru is approximately 80 km north, and Kozhikode and Ernakulam are located to the south at distances of 160 km and 354 km, respectively [28]. The surrounding administrative divisions include Ajanur Panchayat to the north, Madikai Panchayat to the east, and Nileshwar Municipality to the south [29].

Kanhangad and its neighboring areas are renowned for their traditional way of life and agricultural practices [30]. The district of Kasaragod, where Kanhangad is located, is also known for its natural beauty and cultural heritage [31]. Nileshwar, another municipality in the district, is a popular tourist.

4. Physiography

The town of Kanhangad, located on the coast of North Kerala, has a diverse topography that is discussed in several scholarly articles. According to Sajikumar M [32], the Western Ghats of North Kerala, which includes Kanhangad, are undergoing environmental changes. It provides an overview of the physiography and geology of Kerala, including North Kerala, where Kanhangad is located. Radhakrishnan M K [33] analyses the landscape and land use changes in North Kerala, which could also be relevant to the area around Kanhangad. Furthermore, Krishna Pillai P N [34] discusses the coastal erosion problems that are affecting North Kerala, including Kanhangad, which is situated on the coast. Panigrahi R [25] provides information on the hydrological characteristics of North Kerala, which could have implications for the water bodies within Kanhangad, such as the Theerthankara Lake located in the southern part of the town and the Arayi River flowing in the eastern part of the municipality. The area within the study area is suitable for various activities, including construction, agriculture, and urban activities, due to the sandy soil in the western part, sandy clay in the central region, and red laterite and gravel in the eastern part.

4.1. Climate

The town's climatic conditions closely resemble those found throughout the state of Kerala [35]. The town experiences four distinct seasons throughout the year, with dry weather prevailing from December to February, hot weather from March to May, and the South West Monsoon season lasting from June to September, followed by the north-east monsoon from October to November [36]. During the monsoon season, the town is characterized by heavy rains accompanied by high-velocity winds. The town receives an average annual rainfall of 3440 mm, with Kasaragod district receiving the highest amount of rainfall among all the districts in Kerala [37]. This rainfall plays a crucial role in sustaining the region's agriculture, and the monsoon season, in particular, is essential for the growth of crops such as rice, rubber, and coconut [20]. The heavy rainfall during the monsoon season also poses some challenges, as it can lead to floods and landslides in certain areas [36]. Nonetheless, the town's climate and its unique seasonal variations make it an ideal destination for travelers looking to experience the diverse weather patterns and natural beauty of Kerala. Additionally, the town experiences a humid atmosphere, with temperatures ranging from 18 ℃ to 32 ℃ [37]. Air pollution levels in the town also vary seasonally, with higher levels during the dry season and lower levels during the monsoon season [35].

4.2. Natural Resources

Town boasts a remarkable coastline stretching approximately 12 kilometers. The town's location near the Arabian Sea has been a crucial factor in its development over time. The sea not only serves as a source of livelihood for people residing on the western side of the town, but also enhances the area's natural [38].

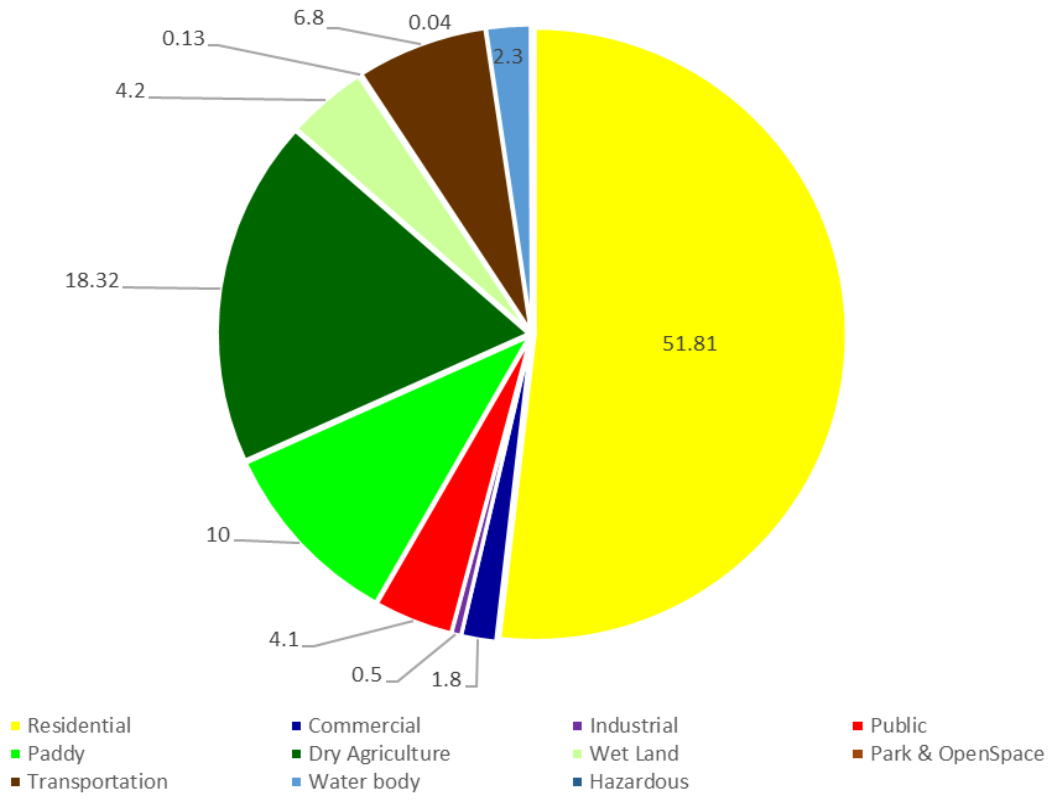
Kanhangad has become a popular destination for tourists owing to the region's abundant natural resources. The town has immense potential for linking various places and creating a tourism hub, The Arayi River and Theerthankara Lake, two prominent water bodies in the region, are particularly stunning and contribute to the area's attractiveness. These water bodies also expand the possibilities for waterfront tourism in Kanhangad, providing visitors with the chance to participate in activities like boating, fishing, and exploring the natural beauty of the region.

The town takes pride in its large stretches of productive land, mainly used for growing paddy. While the area of farmland has decreased in recent decades, around 10% of the town's land is still devoted to cultivating paddy. Additionally, the town's topography is ideal for growing other crops such as coconut, arecanut, and cashew using both dry and wet agricultural methods. The town's wetlands are crucial for maintaining biodiversity, supporting plant and animal species in the region. These wetlands cover a substantial portion of the town's land, accounting for around 4.2% of the municipal area, primarily located on the western side [39]. The presence of wetlands has helped maintain a diverse ecosystem that benefits both the local flora and fauna as well as the community as a whole. The cultivation of crops in the region has been sustainable and profitable, thanks to the favorable climatic and soil conditions, which have contributed significantly to the town's economy and livelihood [40].

5. Existing Land Use

The way a town uses its land is a reflection of its function and character, indicating how different parts of the area are utilized to form the whole. Depending on the geography, land is allocated for a variety of purposes, creating a complex system of connected spaces and structures. In traditional towns, most land was used for housing, with some designated for workplaces and services. Natural resources like fields, rivers, green spaces, and rocks were also incorporated to improve environmental sustainability [41].

Nowadays, the way land is used is largely influenced by economic activity, with a need to make room for commercial, industrial, and infrastructure projects. This often means converting undeveloped land into urban areas, which can harm natural habitats and ecosystems. Despite these challenges, responsible and sustainable management of land resources is still important for local officials and planners, since it shapes the long-term development and well-being of the town and its residents [42].



Source: Author Reproduced from the land use map

Figure 1. Land Use Distribution of Kanhangad Town Area - 2021

Table 1. Land Use Distribution of Kanhangad Area—2005-06, 2011-21 & 2020-21

Land use	Map Legend	Percentage of total area (%) (2005-06)	Area (km^2) (2004-05)	Percentage of total area (%) (2011-12)	Area (km^2) (2011-12)	Percentage of total area (%) (2020-21)	Area (km^2) (2020-21)
Residential		39.42	15.59	43.26	17.11	51.81	20.49
Commercial		0.57	0.23	0.73	0.29	1.80	0.71
Industrial		0.32	0.13	0.40	0.16	0.50	0.20
Public		2.90	1.15	3.20	1.27	4.10	1.62
Paddy		9.10	3.60	12.20	4.82	10.00	3.95
Dry Agriculture		8.40	3.32	13.45	5.32	18.32	7.24
Wet Land		32.63	12.90	18.02	7.13	4.20	1.66
Park & OpenSpace		0.12	0.05	0.10	0.04	0.13	0.05
Transportation		4.20	1.66	6.30	2.49	6.80	2.69
Water body		2.30	0.91	2.30	0.91	2.30	0.91
Hazardous		0.04	0.02	0.04	0.02	0.04	0.02
Total		100	39.54	100	39.54	100	39.54

Source: Author Reproduced from the land use map

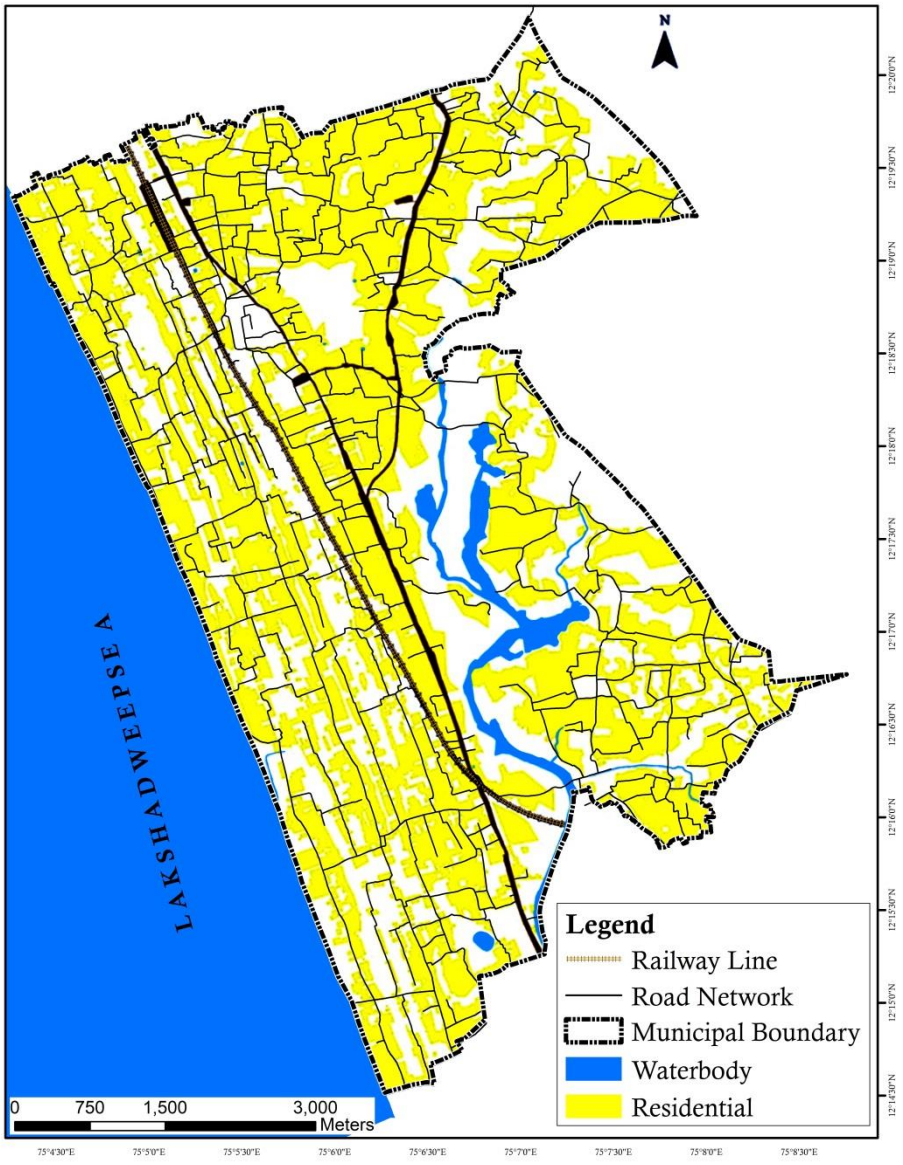
The Figure 1 and Table 1 provide information about the land use in a certain area over a period of 15 years. It shows the percentage of total area (%) and area (km^2) of the land used for different purposes such as residential, commercial, industrial, public, paddy, dry agriculture, wet land, park & open space, transportation, water body and hazardous. The data shows that the percentage of total area devoted to residential use has increased from 39.42% in 2005-06, to

43.26% in 2011-12 and 51.81% in 2020-21. The percentage of total area devoted to other land uses such as public, paddy, dry agriculture, wet land, park & open space, transportation, water body and hazardous has either decreased or remained relatively stable over the same period. This suggests that the area is becoming increasingly urbanized and developed, and the amount of land available for other uses is shrinking.

5.1. Residential Land Use

The Kanhangad region has a dispersed residential land use across most parts of the area. There are currently no tall apartment buildings within the town, and the majority of the land use is for single-family homes. The preferred type of home in the planning area is detached houses, many of which have a large floor area of over 3000 square feet. However, this trend has led to the depletion of natural resources, and homes have become more of a symbol of status than a basic necessity.

Even though there is high demand for residential properties, it's important to adopt low-cost housing and designs that meet the needs of residents in order to preserve nature and reduce financial burdens. Residential land use takes up around 52% of the total land area of 20.49 square kilometers, which indicates significant residential activity in the area, as seen by the 11,791 households counted in the 2011 census. In the future, there may be an exploration of vertical housing growth as a solution to the growing demand for residential properties. It's crucial to find a balance between development and conservation to ensure sustainable growth in the town's housing sector.



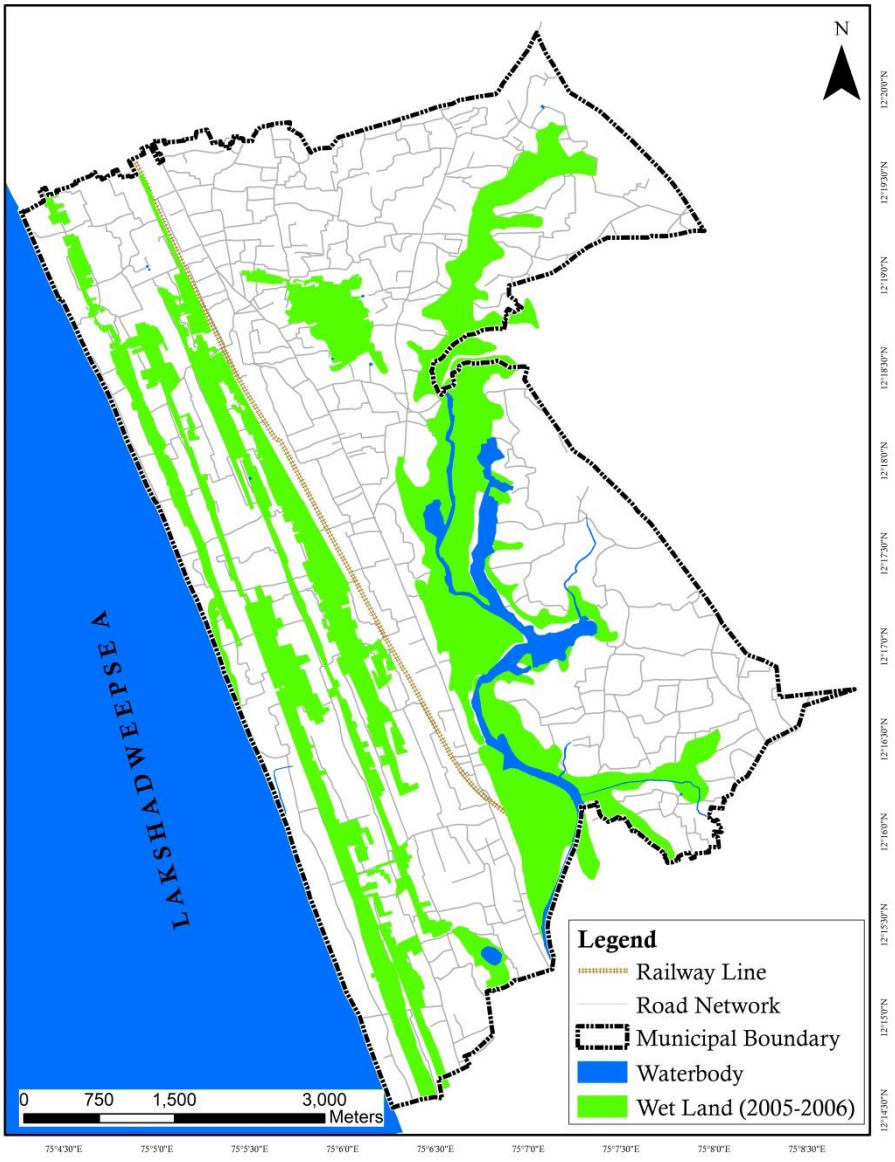
Source: Author Reproduced using ArcGIS

Map 1. Residential land use map of Kanhangad Town 2020-21

5.2. Wetland Land Use

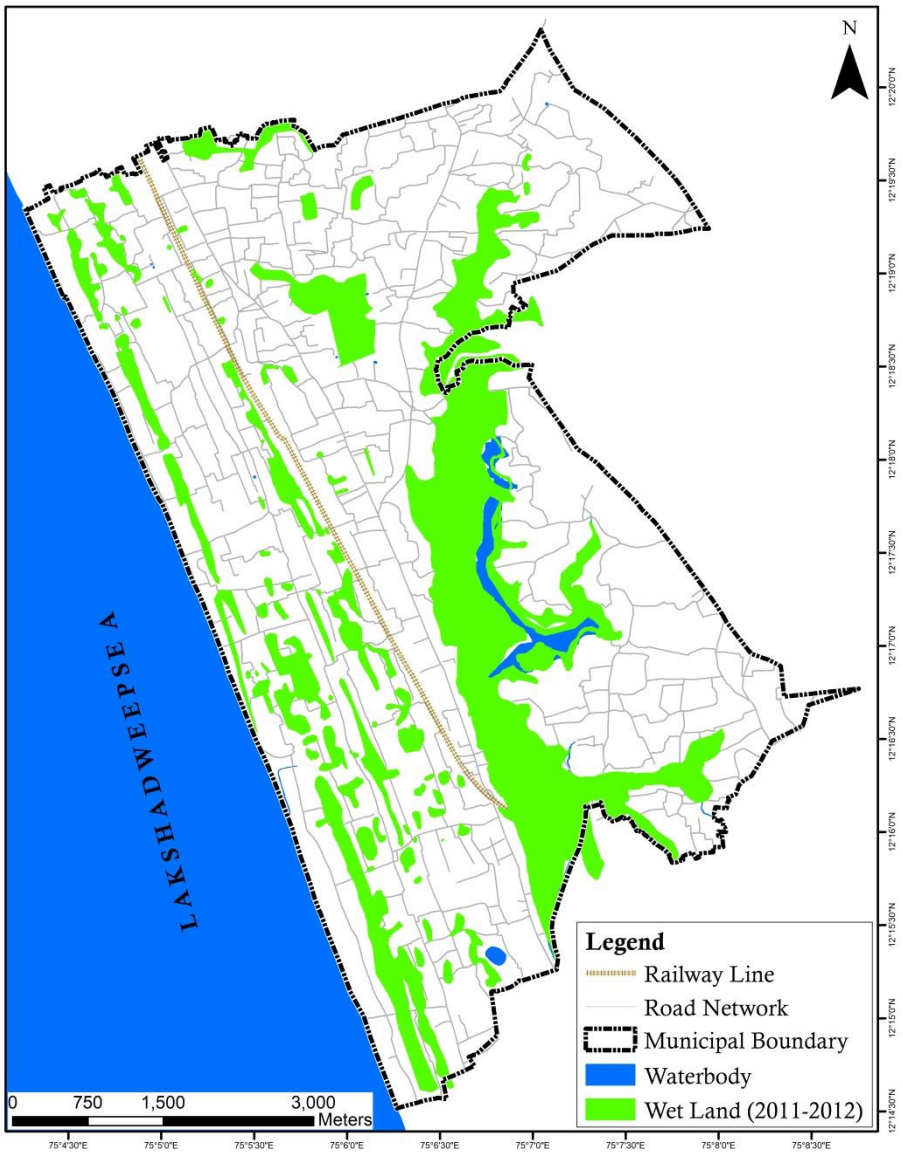
Kanhangad is a town renowned for its wetlands that have served as a source of livelihood for its inhabitants by providing them with diverse agricultural produce, fish, fuel, fiber, and other necessities. Unfortunately, the physical development and the construction of houses, access roads, rail routes, and other structures have resulted in the fragmentation and loss of contiguity of the wetlands in the town [43].

The rapid development and uncontrolled use of land and water in Kanhangad have severely stressed the wetlands. Although no quantitative estimates of the rate of destruction of wetlands are available, the degradation of the surroundings is apparent. The wetlands are facing several challenges, including pollution, eutrophication, encroachment, conversion, mining, and biodiversity loss, as reported in the district statistical report of 2011, the construction of large buildings, roads, and other infrastructure, along with township development, has destroyed the natural habitats of various flora and fauna species, leading to a significant decline in biodiversity in the wetland areas. This could have serious long-term consequences. Hence, there is an urgent need for action to protect and conserve the wetlands of Kanhangad to ensure their sustainability for future generations [44].



Source: Author Reproduced using ArcGIS

Map 2. Wetland Land Use Map 2005-06

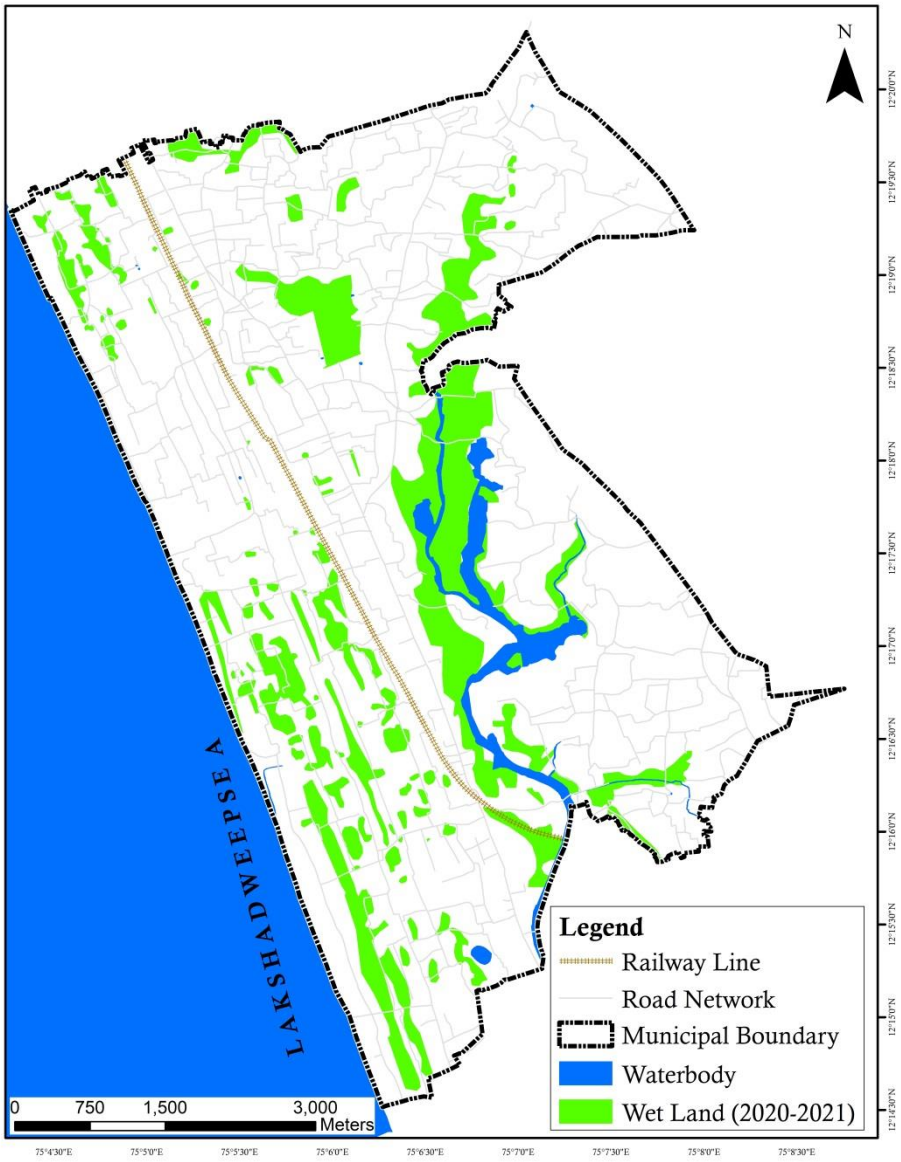


Source: Author Reproduced using ArcGIS

Map 3. Wetland Land Use Map 2011-12

The information provided indicates that there is a worrying trend of the rapid depletion of the fragile wetlands in Kerala, which are ecologically sensitive. The data shows that the average size of wetlands was 12.9 km^2 during 2004-05, but it has decreased to 7.13 km^2 in 2011-12 and 1.66 km^2 in 2020-21. These figures suggest that the depletion of wetlands has continued to occur rapidly, even after the KCPW act was enforced in 2008 [45].

It's worth noting that the KCPW act was implemented to safeguard wetlands in Kerala by prohibiting their reclamation and the removal of sand. However, it permits the filling up of paddy lands for both public and private purposes based on the merit of the application. The act does not legalize or regularize any developmental activities on wetlands.

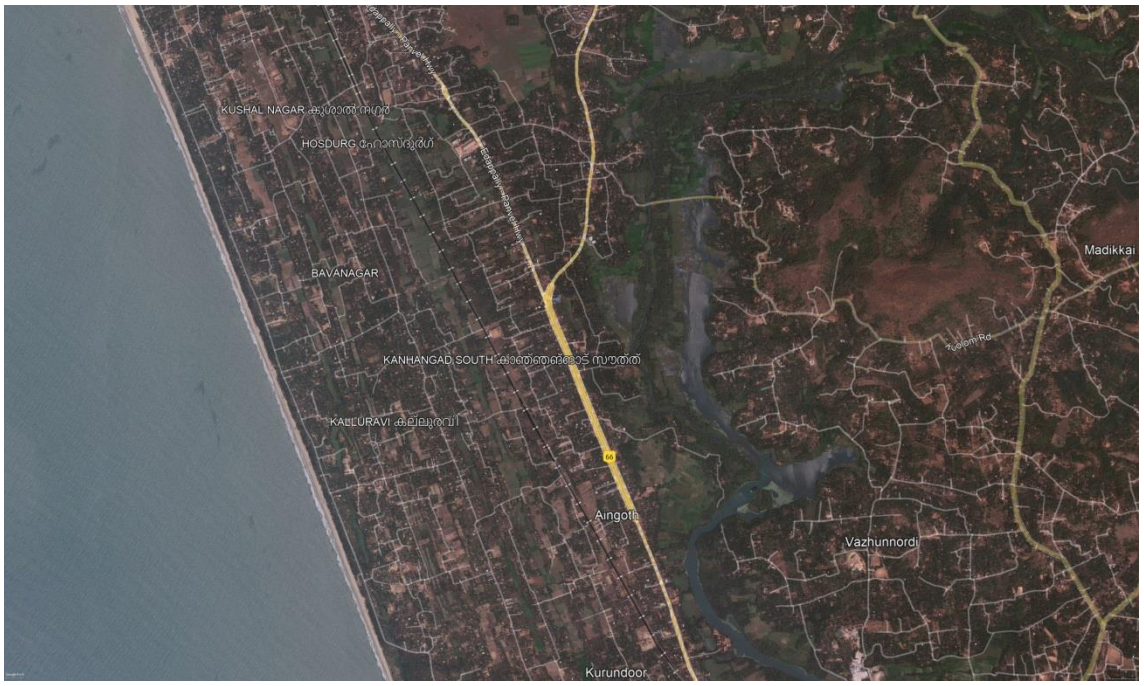


Source: Author Reproduced using ArcGIS

Map 4. Wetland Land Use Map 2020-21

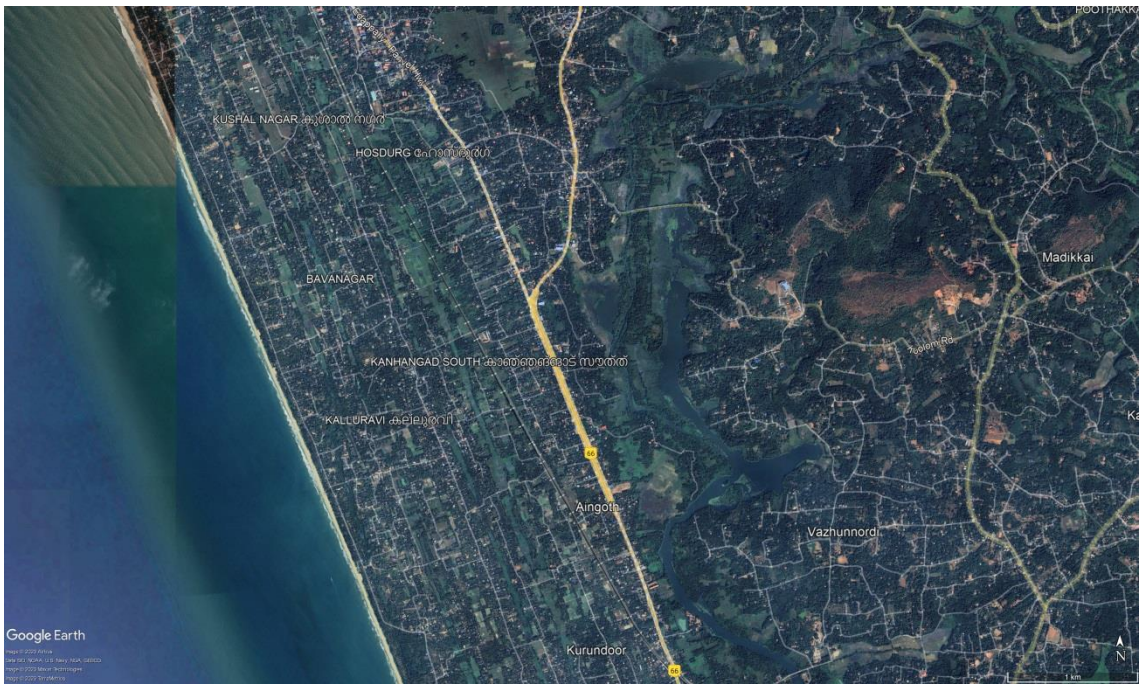
To ensure the proper execution of the KCPW act, a data bank has been established, which contains a list of lands that have been identified as wetlands or paddy lands according to revenue records and those that can be retained. The act aims to control the conversion of wetlands and any development on them in Kerala and maintain their ecological balance. However, the rapid depletion of wetlands suggests that there may be inadequacies in enforcing the act and promoting public participation and awareness [46].

Based on the satellite images from 2011-12 and 2020-21 (Figure 2 & 3), there appears to be a mix of agricultural lands, wetlands, and built-up areas. It is evident that there has been wetland degradation in Kanhangad during this period.



Source: Author reproduced using Google Earth Satellite Imagery

Figure 2. Satellite Image of Kanhangad Town 2011-12



Source: Author reproduced using Google Earth Satellite Imagery

Figure 3. Satellite Image of Kanhangad Town 2020-21

6. Conclusions

In Kanhangad, the land use scenario presents a dichotomy of development and environmental challenges. Residential areas, predominantly featuring large, detached single-family homes, cover around 52% of the town's total land area of 20.49 square kilometers. This preference for spacious homes reflects a trend towards viewing houses as status symbols, contributing to the depletion of natural resources. Despite the lack of high-rise apartments, the town's residential footprint, as evidenced by the 11,791 households recorded in the 2011 census, is significant. Future plans might consider vertical housing to accommodate growing demand while balancing

developmental needs with environmental sustainability.

Conversely, the town's wetlands, vital for local livelihoods through agriculture and other resources, are under severe stress due to rampant development. The wetlands have been fragmented and reduced due to construction and other infrastructural developments, leading to notable biodiversity loss and habitat destruction. The stark reduction in wetland area from 12.9 km^2 in 2004-05 to 1.66 km^2 in 2020-21 underscores the urgency of the situation. Although the Kerala Conservation of Paddy land and Wetland Act of 2008 was enacted to protect these vital ecosystems, its effectiveness seems limited, as evidenced by the continued depletion of wetlands. This alarming trend highlights the need for more stringent enforcement of environmental laws and greater public awareness to preserve Kanhangad's delicate ecological balance. The wetlands in the study area are an important natural resource that has been neglected and degraded for centuries. They have been converted to residential and agricultural use, which has resulted in their alteration and destruction. This is especially prevalent in Kanhangad, a region in Kerala known for its urban development. The plat development in this area is irregular, with larger plots of land than in other urban areas.

As a result of the high demand for housing, agricultural land and wetlands are being converted for residential purposes. This development is associated with activities such as filling the wetland, constructing access roads, and paving the surface. These activities have a detrimental effect on the ecosystem. Understanding the wetland as a system is critical because the fragmentation caused by road construction has catastrophic effects over time. The permeability of the soil has decreased due to paving and asphalting, which has affected the water table, resulting in floods during rainy seasons and drought during the rest of the year. In 2008, the Government of Kerala recognized the indiscriminate conversion of wetlands and paddy land and framed an Act to restrict their conversion or reclamation. However, the problem is still relevant, especially when considering the flood that occurred in Kerala in 2018 and 2019. Although land conversion was not directly responsible for the flood, it did aggravate its impact.

7. Limitations

A land use map for Kanhangad was created using satellite images from open sources since a primary land use survey was not conducted for the study. The analysis revealed the presence of extensive paddy land and wetland stretches in the area, which are contiguous. However, during the monsoon season, it can be challenging to distinguish between the two areas, affecting the satellite image accuracy. The analysis also found a loss of natural means of holding storm water and flood control in the region, emphasizing the need for careful land use planning and management to preserve natural resources in areas susceptible to climate variability.

In 2008, the Government of Kerala enacted a law to restrict the uncontrolled reclamation and massive conversion of paddy land and wetland in the state. However, the problem still exists, particularly when viewed in the context of the floods that occurred in Kerala in 2018 and 2019. Although land conversion was not directly responsible for the floods, it worsened their impact.

Acknowledgments

I extend my heartfelt gratitude to all those who have supported me throughout the completion of this independent study. Special thanks to my academic mentors and peers for their invaluable guidance and insights, which greatly influenced my research approach and analysis. I also appreciate the encouragement and intellectual contributions from my colleagues and friends, whose discussions and moral support were pivotal during challenging phases. My family deserves a special mention for their unwavering understanding and emotional backing. I am thankful for the access to open-source data and academic literature that were instrumental in my research. Finally, I acknowledge my determination and perseverance in conducting this study without external funding, which was both challenging and rewarding. This project reflects a collective effort and individual resolve, and I am profoundly grateful for all the support received.

REFERENCES

[1] Balachandran, S., "Wetland biodiversity in Kerala, India: conservation and management," Aquatic Ecosystem Health & Management, vol. 9, no. 3, pp. 329-342, 2006. DOI: 10.1080/14634980600954741.

[2] Pillai, C.K.S., Achuthankutty, C.T., Padmakumar, K.G., Gopalakrishnan, A., "Biodiversity conservation in Kerala: a review of conservation research," Current Science, vol. 82, no. 8, pp. 989-1003, 2002

[3] Chakravarthy, A.K., Kumar, V., Bhattacharya, B., "Wetland conservation in India: current scenario and future prospects," Current Science, vol. 111, no. 6, pp. 1016-1022, 2016.

[4] Mitsch, W. J., Gosselink, J. G., Wetlands, 4th ed., John Wiley & Sons, 2007.

[5] Nair, K.S., Nair, P.V., "Wetland management and conservation in Kerala," Journal of the Indian Society of Remote Sensing, vol. 35, no. 1, pp. 81-90, 2007.

[6] M. Anjana and C. K. Rajan, "Conservation of wetlands in Kerala: a review," Journal of Environmental Science, Computer Science and Engineering & Technology, vol. 6, no. 3, pp. 729-735, 2017.

[7] Radhakrishnan, J., Nair, K.K.N., "Environmental degradation in North Malabar, Kerala: A study based on land-use changes," Journal of Environmental Management, vol. 82, no. 4, pp. 481-496, 2007.

[8] T. P. Arun and V. K. Prasanth, "Biodiversity Conservation in Kerala: A Review of Policy and Practice," Journal of Biodiversity, vol. 1, no. 1, pp. 1-10, 2010.

[9] IUCN, "Guidelines for the rapid assessment of wetland biodiversity using key biodiversity areas methodology," 2019. [Online]. Available: https://portals.iucn.org/library/node/48796.

[10] Davidson, N. C., "How much wetland has the world lost? Long-term and recent trends in global wetland area," Marine and Freshwater Research, vol. 65, no. 10, pp. 934-941, 2014. DOI: 10.1071/MF14173.

[11] Millennium Ecosystem Assessment, "Ecosystems and human well-being: wetlands and water synthesis," World Resources Institute, 2005.

[12] Finlayson, M., Milton, G. R., Prentice, R. C., Davidson, N. C. (Eds.), "The wetland book: I: Structure and function, management and methods," Springer, 2010.

[13] Gopal, B., Junk, W. J., Davis, J. A. (Eds.), "Biodiversity in wetlands: assessment, function and conservation," Cambridge University Press, 2010.

[14] Mitsch, W. J., Bernal, B., "Ecosystem services of wetlands," in Ecological Engineering, Elsevier, 2012, pp. 1-16.

[15] Cowardin, L. M., Carter, V., Golet, F. C., LaRoe, E. T., "Classification of wetlands and deepwater habitats of the United States," US Department of the Interior, Fish and Wildlife Service, 1979

[16] Finlayson, C. M., Davidson, N. C., Stevenson, N. J. (Eds.), "Wetland inventory, assessment, and monitoring: practical techniques and identification of major issues," IUCN, 1999.

[17] P. R. Adamus and L. A. Brandt, Wetlands ecology and conservation: Emphasis in Pennsylvania. The Pennsylvania State University, 1990.

[18] Government of Kerala, "Kerala Conservation of Paddy Land and Wetland Act," Kerala Legislative Assembly, 2008

[19] Ramachandra, T. V., Vinay, S., Bharath, H. A., Joshi, N. V., "Wetlands of Kerala: Current Status and Conservation Strategies," Environmental Information System (ENVIS) Technical Report, EIS, 09/2010, 2009.

[20] Biju, K. V., Latha, C. P., "Conservation and sustainable management of paddy fields in Kerala, India," Agriculture and Agricultural Science Procedia, vol. 7, pp. 188-194, 2018.

[21] Chandra, P., Singh, K., "Assessment of wetland ecosystems: A review," Journal of Hydrology, vol. 572, pp. 989-1001, 2019. DOI: 10.1016/j.jhydrol.2019.03.079.

[22] A. Shaji, A. S. Kumar, and P. G. Kumar, "Mapping and assessment of wetlands using remote sensing and GIS: A review," Journal of Hydrology, vol. 590, 125410, 2020.

[23] Mohanty, B. P., Prusty, B., "Wetland management in India: Issues, challenges and strategies," Journal of Environmental Management, vol. 289, article 112555, 2021.

[24] Panigrahi, R., Behera, B. K., Mishra, A. K., "Biodiversity of Chilika Lake: An ecosystem approach towards its sustainable management," in Management of Indian Wetlands, Springer, 2018, pp. 29-51.

[25] Boon, P. J., Davies, B. R., Petts, G. E., "Global perspectives on river conservation," Global Perspectives on River Conservation: Science, Policy and Practice, 2019

[26] Madhusudan, M. D., "Kerala wetland management: Legal and institutional framework," In Sustainable Development and Management of Wetlands, pp. 29-42, Springer, 2019.

[27] "Kanhangad Municipality," n.d. [Online]. Available: https://kanhangadmunicipality.lsgkerala.gov.in/. [Accessed: March 27, 2019].

[28] "Kanhangad," Kerala Tourism, n.d. [Online]. Available: https://www.keralatourism.org/destination/kanhangad/44. [Accessed: March 27, 2018].

[29] "Nileshwar Municipality," n.d. [Online]. Available: https://nileshwarmunicipality.lsgkerala.gov.in/. [Accessed: March 27, 2017].

[30] "Agriculture in Kerala," Department of Agriculture Development and Farmers' Welfare, Government of Kerala, [Online]. Available: https://www.dakshinamurti.com/agriculture-in-kerala/. Accessed: Mar. 27, 2023.

[31] "Kasaragod District," Official Website of Kasaragod District, Government of Kerala, n.d. [Online]. Available: https://kasaragod.nic.in/. [Accessed: March 27, 2019].

[32] M. Sajikumar, R. Chandran, and H. Vijith, "Landscape and Land Use Change Analysis of North Kerala," Journal of Geomatics, vol. 5, no. 1, pp. 1-10, 2011.

[33] Radhakrishnan, M.K., Krishnan, K.P., "Physiography and Geology of Kerala," Geological Society of India, Bangalore, 1994.

[34] Krishna Pillai, P.N., Sunil Kumar, P.G., "A Study of the Coastal Erosion Problems in North Kerala," Indian Journal of Marine Sciences, vol. 37, no. 1, pp. 61-66, 2008.

[35] Harikumar, N., Krishnan, K.P., "Hydrological Characteristics of North Kerala," Journal of the Geological Society of India, vol. 61, no. 6, pp. 761-767, 2003.

[36] Biju, T.V., Ramachandran, A., "Spatial and temporal variability of rainfall in North Kerala, India," Atmospheric Research, vol. 163, pp. 95-105, 2015. DOI: 10.1016/j.atmosres.2015.02.005.

[37] R. Ratheesh and K. G. Padmakumari, "Dynamics of sea surface temperature and its impact on monsoon rainfall over North Kerala, India," Atmospheric Science Letters, vol. 2021, e1041.

[38] Kerala State Biodiversity Board, "Biodiversity Conservation in Kerala: A State of Art Report," Thiruvananthapuram: Kerala State Biodiversity Board, 2012.

[39] K. K. Sasidharan, S. N. Prasad, and G. Varghese, "Wetlands of Kerala: status, threats and conservation measures," in Wetland Science: Perspectives from South Asia, Springer, Dordrecht, 2011, pp. 189-202.

[40] K. V. Ajayakumar and P. Prabhakaran, "Land Use Changes and Its Impact on Environment: A Case Study of Kerala, India," Journal of Environmental Protection, vol. 2, no. 10, 2011.

[41] Dhanalakshmi, D., Manoharan, T., "Land use dynamics and its impact on environment in Kerala, India," International Journal of Geomatics and Geosciences, 2017.

[42] Gopakumar, C.S., Nair, R.R., "Land Use Pattern and Changes in Kerala: A Geographical Analysis," Journal of Indian Geographical Society, vol. 89, no. 2, pp. 203-214, 2017.

[43] Babu, K. S. S., Dadhwal, V. K., "Spatial and Temporal Changes in Land Use and Land Cover in Kerala, India: A Remote Sensing and GIS-based Analysis," Journal of the Indian Society of Remote Sensing, vol. 42, no. 1, 2014.

[44] Rajan, K.C., Sukumaran, S., Jayaraj, R.S., "Threats and conservation of wetlands in Kerala, India," Journal of Environmental Management, vol. 211, pp. 221-230, 2018.

[45] Mishra, A. K., Behera, B. K., Panigrahi, R., "Assessment of biodiversity in Chilika Lake using remote sensing and GIS," Journal of Earth System Science, vol. 128, no. 1, article 7, 2019.

[46] Ramachandran, R., Jayakumar, S., "Wetland conservation in Kerala: a casestudy of Vembanad-Kol wetlands," Indian Journal of Traditional Knowledge, vol. 12, no. 1, pp. 71-78, 2013.