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The cover image shows older people climbing Via Raffaele Morghen's stairs in Naples (Source: TeMA Journal Editorial Staff).

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Land use changes of coastal wetlands using remote sensing. A case study of Muthurajawela & Anawilundawa wetlands, Sri Lanka

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Abstract

Wetlands are confronting significant threats arising from human activities, particularly anthropogenic influences. The alteration of land use and land cover in and around wetlands serves as a clear indicator of the escalating human pressure on these ecosystems. This study employs Geographical Information System (GIS) and Remote Sensing to conduct a spatiotemporal analysis, comparing land use changes in both an urban wetland (Muthurajawela) and a peri-urban wetland (Anawilundawa) and their respective buffer areas in Sri Lanka. The study reveals noteworthy transformations in the extent of water bodies, thick vegetation, other vegetation, settlements, and open areas during the period from 2000 to 2021. The observed changes are particularly profound in the urban wetland. In the Muthurajawela wetland, the core habitat characterized by open water experienced significant conversions into settlements and infrastructure, resulting in an 81% reduction from 2000 to 2010 and a 30% reduction from 2010 to 2021. Similarly, water bodies in the Anawilundawa wetland reduced in size by 12% from 2000 to 2010 and 16% from 2010 to 2021. The results highlight the urban wetland's more substantial transformation from natural areas to anthropogenic areas, necessitating immediate remedial and restoration action. Given this context, it is imperative to delve further into the trajectories, causes, and drivers of land use changes. This deeper investigation is crucial for developing effective wetland management strategies that support sustainability, environmental stability, and the continued functioning of ecosystems.

Keywords

Land use; Land cover; Geographical information system; Wetland; Anawilundawa; Muthurajawela

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1. Introduction

Wetlands are among the most valuable, productive, and threatened natural habitats in the world (Barbier, 2013); however, the global loss of wetlands is estimated to be between 64% to 71% over the 20th century (Gardner et al., 2015). Despite this large historical reduction, wetlands still face significant threats mainly due to anthropogenic activities, which continue to exert pressure on these sensitive landscapes.

Coastal wetlands act as an intermediate zone between marine and terrestrial ecosystems, offering a wide array of Ecosystem Services (ES) (Lopes et al., 2022). However, human influence and natural causes contribute to changes in the wetland landscape and the ES delivered by the wetlands (Gayani et al., 2022), and neglecting the full value of the ES provided by the wetlands can further contribute to the degradation of coastal wetlands (Kotagama & Bambaradeniya, 2006; Ustaoglu & Aydinoglu, 2019).

Temporal changes in Land Use Land Cover (LULC) are associated with alterations in the way land is utilized, such as the expansion of urban landscapes, infrastructure development, changes in water bodies, and vegetation cover (Anand & Oniam, 2020). These changes play a significant role in the functionality of coastal wetlands and their buffer areas by altering the hydrology of the area, nutrient cycles, and habitats. Consequently, these changes can further impact biodiversity (Yousaf et al., 2021), ES, and the resilience of the wetlands and their buffer areas. Therefore, understanding the relationship between LULC changes and coastal wetland dynamics is crucial for effective conservation measures in these areas.

It is unsurprising that population growth is a key driving force for land-use land-cover (LULC) changes in coastal areas (Ranagalage et al., 2021). Furthermore, it has been observed that the wetland landscapes most vulnerable to the process of urbanization are wetlands in urban and peri-urban areas (Zucaro & Morosini, 2018), in part due to their proximity to urban areas and the socio-economic opportunity costs the land represents. In this vein, Sri Lanka is not an exception (Athukorala et al., 2021; Hettiarachchi et al., 2014). Sri Lanka is a large island in the Indian Ocean with a coastline of 1340 km and has a significant area of coastal wetlands. Moreover, there is a rapid process of urbanization in coastal areas of Sri Lanka (Senevirathna et al., 2018) that poses a significant threat to Sri Lankan wetlands due to the growth of informal housing, infrastructure development, and poverty creating multiple opportunities to overexploit and degrade wetlands (Vithana et al., 2022). Several studies in Sri Lanka have analyzed the spatial patterns of LULC changes in wetlands; however, there is a gap in detailed investigations on temporal changes in LULC in Anawilundawa and Muthurajawela wetland areas.

The current study seeks to assess the extent to which two prominent urban and peri-urban coastal wetlands in Sri Lanka have transformed into different land uses between 2000 and 2021. This study analyzes and compares the LULC changes in two wetlands using Geographical Information Systems (GIS) and Remote Sensing (RS). The study areas are confined to the Muthurajawela and Anawilundawa wetland and buffer area. The Muthurajawela wetland is a noted nature sanctuary and is in an urban area of the Gampaha district, which is 15 km away from the capital city, Colombo and in close proximity to the main international airport and the main port of Sri Lanka. In contrast, the Anawilundawa wetland, which is a coastal sanctuary, is situated 102 km away from Colombo and is relatively more insulated from development pressures.

2. Study area

The study area is confined to the Anawilundawa wetland, including its 5km buffer zone area (AW) and Muthurajawela wetland, along with its 5 km buffer zone area (MW). To better understand the surroundings of these wetlands, 1 km zones have been established from the wetland boundaries. These zones are identified as zone a, zone b, zone c, zone d, zone e, zone f and zone g, among these the innermost zone being marked as zone a. The Anawilundawa wetland falls within zones a and b, while the Muthurajawela wetland is located within zone a of its corresponding study area (Fig.1).

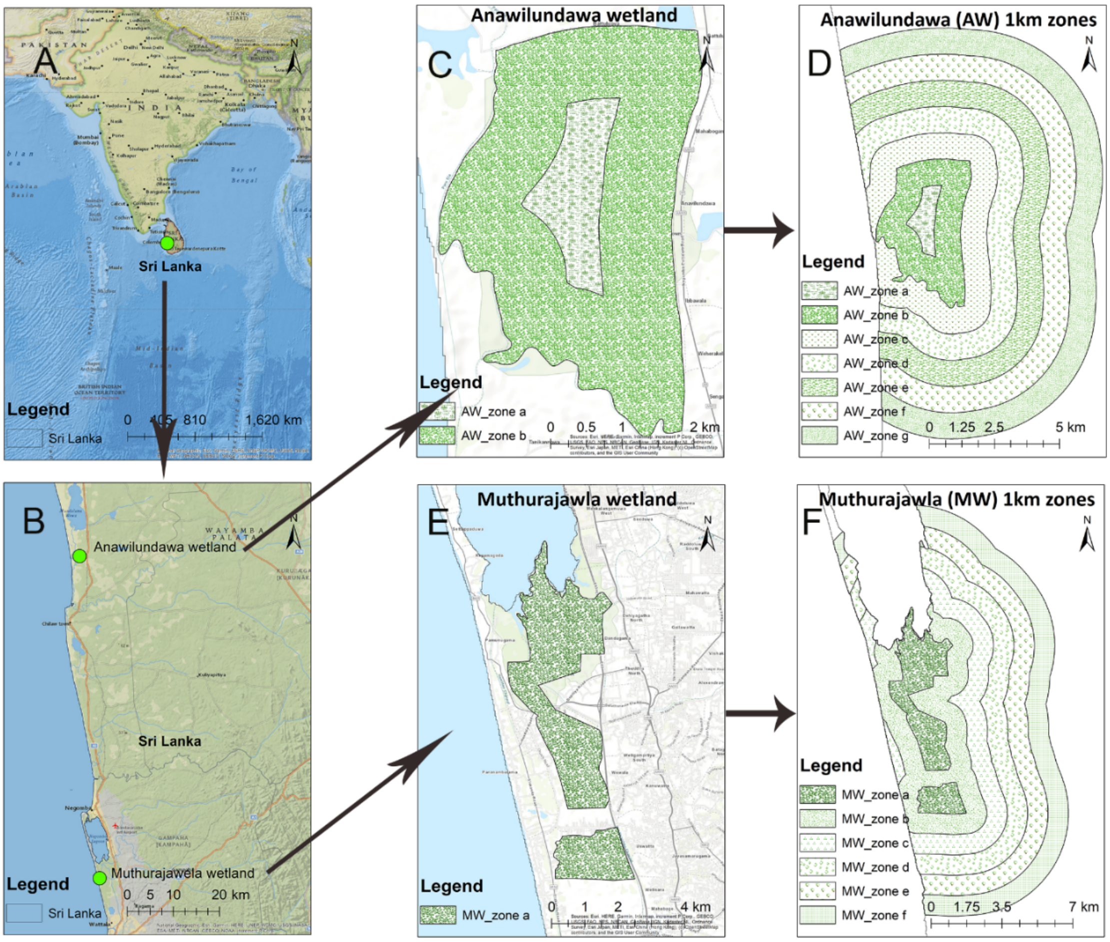

Fig.1 Study area (A) Geographical location of Sri Lanka, (B) Location of Anawilundawa wetland and Muthurajawela wetland, (C) Anawilundawa wetland, (D) Anawilundawa 1km zones, (E) Muthurajawela wetland, (F) Muthurajawela 1km zones

The Muthurajawela wetland is the largest coastal peat bog in Sri Lanka (Dahanayake et al., 2022; Vithana et al., 2022) and it is located (7° 6' 11.10" N, 79° 51' 41.85" E) between the Negombo lagoon to the north, the Kelani River to the south, and spreading inland up to Ragama and Peliyagoda in the Gampaha district. The wetland covers 6,232 ha and forms a costal wetland ecosystem together with the Negombo lagoon. The government of Sri Lanka (GOSL) has declared 1,777 ha of the wetland as a sanctuary (PA1) in July 1996 and governed under the Department of Wildlife Conservation (DWC). In 2006 another protected (PA2) area of 162 ha was designated by a Government Gazettee notification (Central Environmental Authority, 2023). The biodiversity rich wetland receives average annual rainfall around 2,000-2,500mm during the southwest monsoon season (Bambaradeniya et al., 2002). The Muthurajawela marsh receives fresh water from lower Attanagalu Oya and lower Kelani River (Central Environmental Authority and Euroconsult, 1994; IUCN Sri Lanka and Central Environmental Authority, 2006; Greater Colombo Economic Commission and Euroconsult, 1991).

The Anawilundawa wetland, designated as Ramsar site No. 1078 in 2001 and established as a wildlife sanctuary in 1997. This wetland is located (7° 42' 14.30" N, 79° 49' 1.55" E) near the western coast in the Arachchikattuwa Divisional Secretariat Division within the Puttalam District of Sri Lanka. Covering an extensive area of 1,371 hectares, it is under the administration of the Department of Wildlife Conservation (DWC). The wetland experiences a moderately hot and dry climate, with a mean annual temperature of approximately 26°C and an average annual rainfall ranging from 1,000-1,500mm. The primary rainy season occurs during October and November, aligning with the North-East monsoon season (CEA, 2006).

Anawilundawa wetland is characterized by a network of seven shallow ancient cascading tanks: Pinkattiya, Wellawala, Maradansole, Irakka-wela (Ihala Wewa), Anawilundawa tank, Suruwila tank, and Maiyawa tank. Additionally, it encompasses traditional paddy fields and marshland areas, sustaining approximately 412 hectares of traditional paddy fields. The primary water sources for the tank system include surface runoff water from the Rathabala Oya basin and spill water from the Katupotha tank (CEA, 2006).

3. Materials and Methods

3.1 Land use land cover classification and satellite data

The time points of year 2000, 2010 and 2021 were selected for the study, and the Land Use Land Cover classifications were based on satellite data from year 1997 to 2021. The study utilized 30m resolution satellite data from Landsat 5 TM (LS5) and Landsat 8 OLI (LS8), and the images were obtained from United States Geological Survey (USGS) image collection. The Google Earth Engine was used to download the median images and Individual bands were downloaded separately and composite was created for the analysis (Hussain et al., 2022; Liu et al., 2020; Ranagalage et al., 2021).

The satellite images were classified using supervised classification method with the Maximum Likelihood Classifier in Arc Map 10.8. The images were classified into five categories: Water body, thick vegetation, other vegetation, settlements, and open areas and different band combinations used for the image classification is provided in Tab.2.

3.2 The normalized difference vegetation index (NDVI)

NDVI is widely used as an indicator to analyze the vegetation and the biomass of an area using multi spectral satellite images. The NDVI value ranges from -1 to +1, and calculated in Equation (1) Where NIR = Near Infra-Red Band; R = Red Band of the satellite images (Mugendi et al., 2020).

$$NDVI = (NIR-R) / (NIR+R) \tag{1}$$

LULC category	**Description**	**LS5 / Selection**	**LS8 / Selection**
Water body	Areas covered with water	Band 4:3:2	Band 5:4:3
Thick vegetation	Thick green vegetation area	NDVI >= 0.7	NDVI >= 0.7
Other vegetation	Grass lands, wetland soft vegetation, bushes	Band 5:4:3 and 0.1<NDVI<0.7	Band 6:5:4 and 0.1<NDVI<0.7
Settlements	Impervious surfaces including residential, industrial and transport utility	Band 7:5:3	Band 7:6:4
Open area	Areas with open lands, sandy areas	Band 3:2:1	Band 4:3:2

Tab.2 Band combinations used for the image classification

3.3 Assessment of land use land cover changes

After the image classification, LULC maps for the study period were developed. There were 1km zones were created from the wetland boundary, covering 5km of the land area together with inside of the wetland, and the classified image was clipped to each zone and the change detection analysis was performed for year 2000-2010 and 2011-2021.

3.4 Assessment of land use change dynamics

The Land Use Dynamic Degree method was used to evaluate the quantitative changes of rates of the LULC type of the study areas, and two folded approach i.e. Single Land Use Dynamic Degree (SLUDD) and Integrated Land Use Dynamic Degree (ILUDD). SLUDD indicates the rate of changes in the LULC categories for the study period. The ILUDD estimates the overall change of rate of the LULC (all land categories) for the study interval (Degefu et al., 2021; Gong et al., 2017; Quan et al., 2006).

$$SLUDD = (LA_{i,t2} - LA_{it1})/LA_{it1} * \frac{1}{T} * 100\% \tag{2}$$

$$ILUDD = \left(\sum_{i=1}^{n} \Delta LA_{i-j} / \sum_{i}^{n} LA_{it}\right) * \frac{1}{T} * 100\% \tag{3}$$

Where LA_{it2} and LA_{it1} are area of land use type at time *t1* and *t2*, $\Delta LA_{i\text{-}j}$ is the land use type transformation from type i to j (where i≠ j), n is the number of land use types in the study area and T is the study period.
Annual increase (AI) and annual growth rate (AGR)
AI is settlement expansion rate of the same wetland and its zone areas during different time intervals, the AGR measures the comparison of the settlement areas of the different wetlands and its zone areas (Degefu et al., 2021; Meng et al., 2020).

Annual Increase $$AI = (A_{end} - A_{start})\ /d \tag{4}$$

Annual Growth Rate $$AGR = 100\% \times \left[(A_{end}/A_{start})^{1/d} - 1\right] \tag{5}$$

Where A_{start} and A_{end} are the settlement land area at the beginning and end of the time intervals respectively, and *d* is the study's time period.

3.5 Accuracy assessment

The accuracy assessment was carried out to determine the accuracy of the LULC categories and there were 300 random points (60 sample points from each LULC class) were created for each study period, equally covering all the LULC categories. The Google Earth Pro time series historical images and topo maps from the Survey Department of Sri Lanka (2023) were used as reference data. Thereafter, confusion matrix was created, overall accuracy, user accuracy, producer accuracy and the Kappa coefficient was computed (Degefu et al., 2021; Samin et al., 2023; Twisa & Buchroithner, 2019).

4. Results

Assessment of spatial distribution of the LULC in the study areas in AW (a-c) and MW (d-f), including the identified 1km zones for the time points of year 2000, 2010 and 2021 are shown in Following Fig.2.

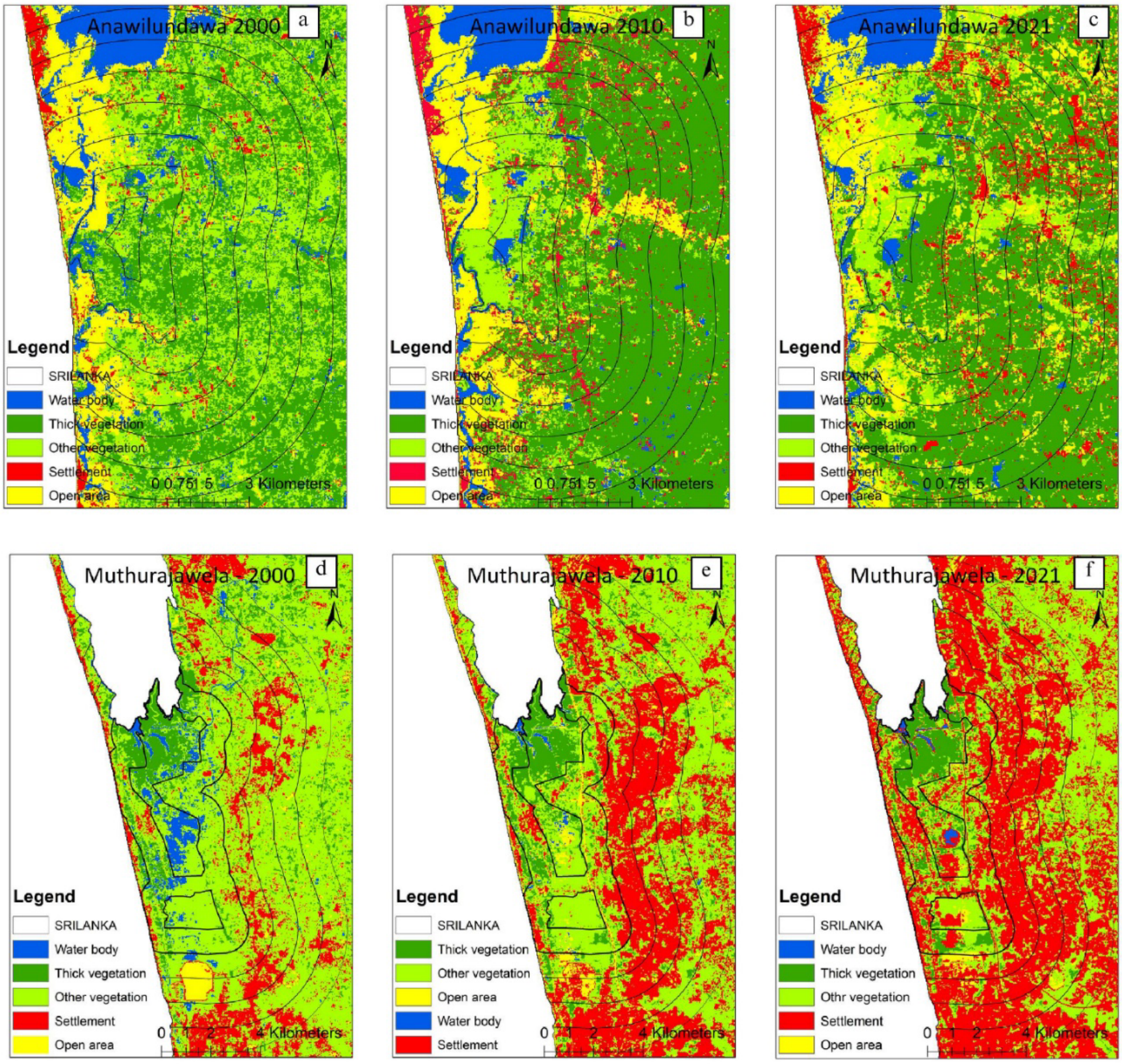

Fig.2 Spatial distribution of the LULC in Anawilundawa and Muthurajawela wetlands: (a) Anawilundawa 2000, (b) Anawilundawa 2010, (c) Anawilundawa 2021, (d) Muthurajawela 2000, (e) Muthurajawela 2010, (f) Muthurajawela 2021 (date of acquisition of the satellite data: 17/12/2022)

4.1 LULC changes in AW and MW

Water Body: Water bodies constitute a key component of wetland landscapes, encompassing rivers, streams, and waterlogged areas.

Anawilundawa (AW): In the AW study area, the total water body coverage was 12 km² in 2000, 11 km² in 2010, and 9 km² in 2021. Notably, the reconstruction of the Daduru Oya irrigation tank in 2014 enhanced regular water supply, deviating from the previous reliance on seasonal rainfall. Despite this improvement, the water bodies continued to diminish, with an annual reduction of 0.1 km² between 2000 and 2010. The decreasing trend suggests a potential acceleration, possibly influenced by reduced community reliance on free-standing water bodies.

Analyzing subzones reveals variations. Zone b experienced the highest water body conversion to other land use/land cover (LULC) categories (7.31%), while zone e showed the lowest (2.55%) from 2000 to 2010. During the second interval (2010 to 2021), zone a witnessed the highest transformation of water bodies to other LULC (7.85%), and zone g exhibited the lowest (2.07%).

Muthurajawela (MW): In the MW study area, water bodies measured 6.9 km² in 2000, reduced to 1.3 km² in 2010, and further to 0.9 km² in 2021, indicating an 87% loss. This substantial reduction diminishes MW's potential as a nature-based solution for urban flooding. Zone a recorded the highest water body conversion to other LULC categories (19.61%) from 2000 to 2010, while zones d and f showed the lowest (0.88%). In the second interval (2010 to 2021), zone a again exhibited the highest conversion (1.64%), and zone e displayed the lowest (0.12%).

Thick Vegetation: Thick vegetation, characterized by dense foliage with high Normalized Difference Vegetation Index (NDVI) values, faced anthropogenic threats. In the AW, thick vegetation covered 45 km² in 2000, increased to 64 km² in 2010, and decreased to 61 km² in 2021. Zone a in the AW experienced the highest conversion of thick vegetation to other LULC categories (37.09%) from 2000 to 2010, and zone f displayed the highest (20.79%) from 2010 to 2021. In the MW, thick vegetation measured 14 km² in 2000, increased to 15 km² in 2010, and decreased to 11 km² in 2021.

Other Vegetation: AW's total other vegetation extent was 47 km² in 2000, 18 km² in 2010, and 20 km² in 2021. Zone e in the AW experienced the highest transformation of other vegetation to other LULC categories (36.59%) from 2000 to 2010, and zone a displayed the highest (31.04%) from 2010 to 2021. In the MW, other vegetation covered 90 km² in 2000, decreased to 58 km² in 2010, and further to 46 km² in 2021.

Settlements: Settlement areas, including human habitats and infrastructure, expanded in both AW and MW. In the AW study area, settlements covered 4.03 km² in 2000, increased to 10.24 km² in 2010, and 11.17 km² in 2021. Zone e exhibited the highest settlement conversion to other LULC (2.8%) from 2000 to 2010, and zone d displayed the highest (8.7%) from 2010 to 2021. In the MW, settlements measured 21.84 km² in 2000, increased to 52.86 km² in 2010, and further to 73.51 km² in 2021.

Open Area: The total extent of open areas in the AW was 16.90 km² in 2000, increasing to 22.19 km² in 2010, and 23.43 km² in 2021. Zone c experienced the highest transformation of open areas to other LULC (4.41%) from 2000 to 2010, and zone c also showed the highest (12.18%) from 2010 to 2021. In the MW, open areas measured 2.87 km² in 2000, increased to 7.41 km² in 2010, and decreased to 3.84 km² in 2021.

Temporal Dynamics - Single Land Use Dynamic Degree (SLUDD) and Integrated Land Use Dynamic Degree (ILUDD): AW exhibited positive SLUDD values for water bodies, thick vegetation, and other vegetation. In contrast, MW showed negative SLUDD values for water bodies, indicating continuous decrease. ILUDD for both study areas averaged 2% in the first interval (2000 to 2010) and 1.74% in the second interval (2010 to 2021). The highest ILUDD for AW occurred in zone b (2%), and for MW, it was in zone b (2%) in the second interval.

	Zone a		**Zone b**		**Zone c**		**Zone d**		**Zone e**		**Zone f**		**Zone g**	
Anawilundawa	2000-2010	2010-2021	2000-2010	2010-2021	2000-2010	2010-2021	2000-2010	2010-2021	2000-2010	2010-2021	2000-2010	2010-2021	2000-2010	2010-2021
Waterbody	0.324	-0.101	-0.417	-0.217	-0.437	-0.351	-0.142	-0.274	-0.035	-0.300	-0.222	-0.146	-0.487	-0.295
Thick veg	-0.608	0.498	-2.178	2.976	1.361	1.143	2.509	-0.200	5.266	-1.299	5.655	-3.217	7.088	-2.949
Other veg	0.286	-0.503	1.981	-2.562	-3.362	0.441	-4.787	1.451	-6.874	1.309	-7.954	1.646	-8.459	0.782
Settlement	0.012	-0.013	0.377	-0.222	1.293	-0.574	1.020	-0.284	0.991	0.301	1.481	0.711	1.032	1.012
Open area	-0.013	0.119	0.237	0.025	1.145	-0.657	1.400	-0.693	0.652	-0.010	1.039	1.006	0.827	1.450
Muthurajawela														
Waterbody	-2.734	-0.009	-1.726	-0.197	-0.479	-0.075	-0.191	-0.027	-0.271	-0.024	-0.216	-0.054		
Thick veg	1.650	-0.066	0.790	-1.283	-0.165	-0.735	0.012	-0.433	-0.320	-0.530	-0.601	-0.773		
Other veg	-0.071	-1.777	-4.442	-3.368	-7.350	-1.910	-8.151	-1.284	-7.299	-2.052	-4.008	-2.470		
Settlement	0.159	2.516	3.875	5.886	7.266	3.302	8.169	2.392	7.259	2.961	4.291	3.586		
Open area	0.996	-0.664	1.502	-1.037	0.729	-0.582	0.161	-0.648	0.630	-0.356	0.534	-0.289		

Tab.3 Anawilundawa and Muthurajawela LULC Change area, 2000 to 2010 and 2010 to 2021 in km²

Annual Increase (AI) and Annual Growth Rate (AGR) of Settlements: AW's highest AI occurred in zone f (0.14) from 2000 to 2010, and MW's highest AI was 0.74 in zone d from 2000 to 2021. AW recorded the highest AGR in zone f (11.437) from 2000 to 2010, and MW's highest AGR was within the wetland (30.86) in the same period. For the second interval, AW's highest AGR was 3.94 in zone g, and MW's highest AGR was 28.32 in zone a.

The detailed analysis provides insights into the changing dynamics of water bodies, vegetation, settlements, and open areas in the Anawilundawa and Muthurajawela wetland areas over two distinct time intervals.

The LULC dynamics change (%) for AW and MW for both study periods is shown in Fig.3. Below and the LULC change from one category to another category for AW and MW for both study periods is shown in Tab.3 and Fig.4.

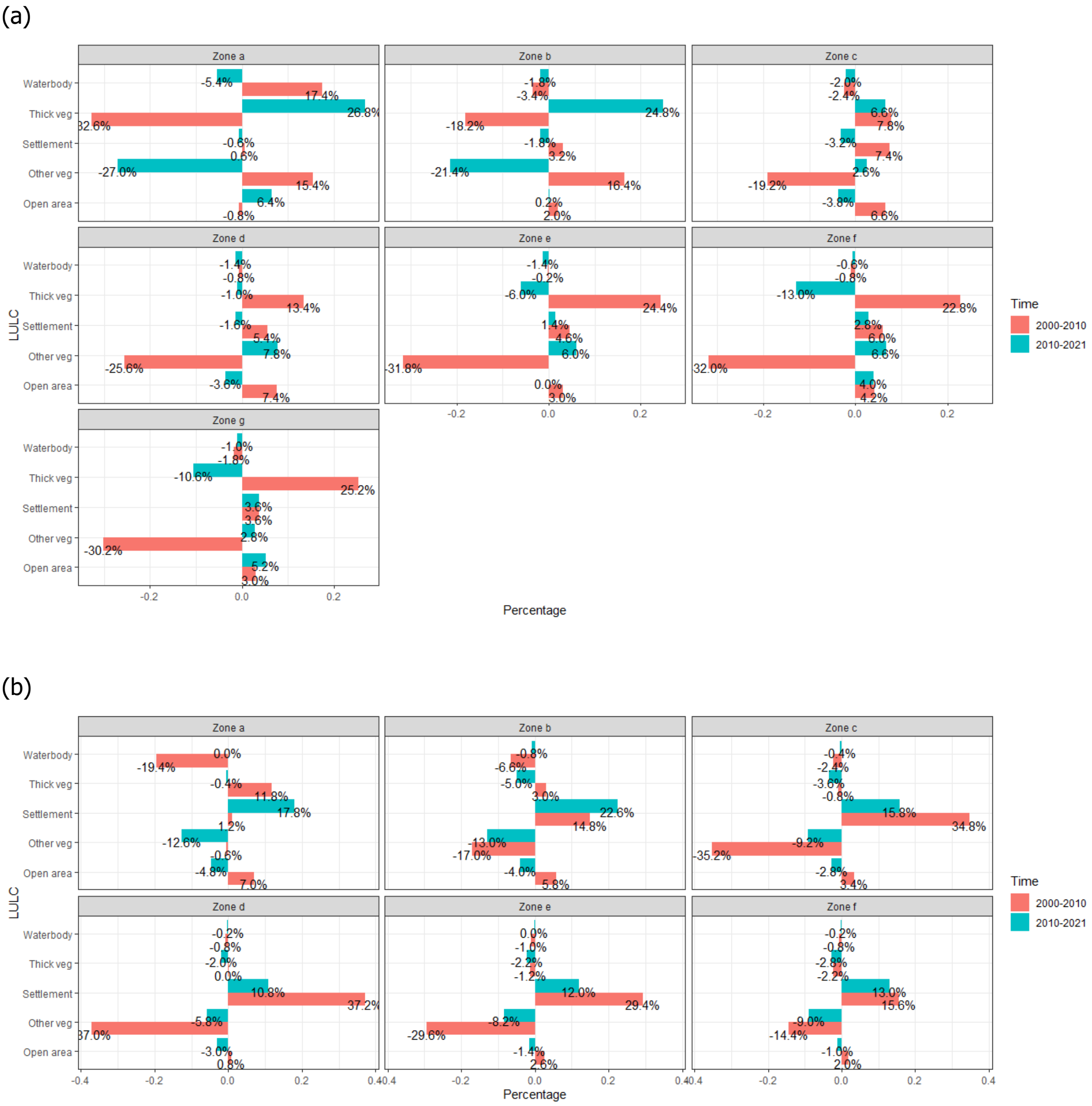

Fig.3 LULC change dynamics for study period, (a) LULC change for the Anawilundawa zone a,b,c,d,e,f and g (% change area) and (b) LULC change for the Muthurajawela zone a,b,c,d,e and f (% change area)

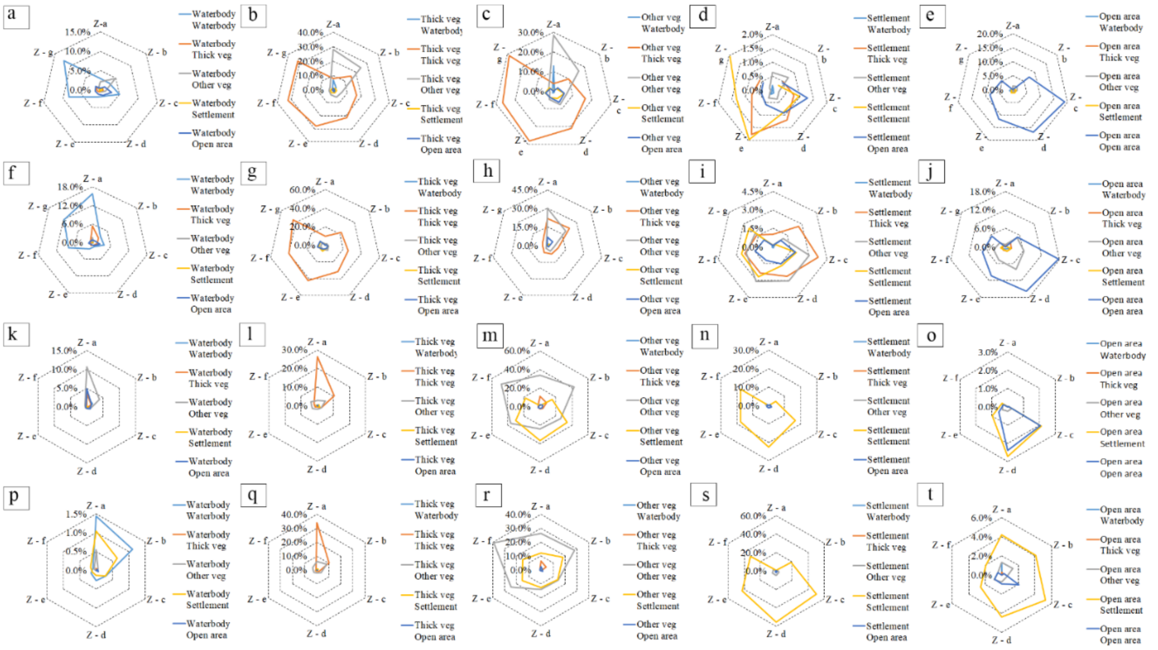

Fig.4 LULC changes from one category to other category, row 1: AW(2000-2010); (a)AW Waterbody to other, (b)AW Thick veg to other, (c)AW Other veg to other, (d)AW settlement to other, (e)AW Open area to other. row 2: AW(2010-2021); (f)AW Waterbody to other, (g)AW Thick veg to other, (h)AW Other veg to other, (i)AW settlement to other, (j)AW Open area to other. row 3: MW(2000-2010); (k)MW Waterbody to other, (l)MW Thick veg to other, (m)MW Other veg to other, (n)MW settlement to other, (o)MW Open area to other. row 4: MW(2010-2021); (p)MW Waterbody to other, (q)MW Thick veg to other, (r)MW Other veg to other, (s)MW settlement to other, (t)MW Open area to other

4.4 Accuracy assessment

Accuracy assessment is used to evaluate the performance of the image classification, and used to identify the errors in the classified image and improve the quality of the classification results. The kappa coefficient values for the each study area and the period remains above 80% and derived as acceptable accuracy for the classified LULC images (refer Tab.4).

Study area	**Anawilundawa wetland (AW)**						**Muthurajawela wetland (MW)**					
Year	2000		2010		2021		2000		2010		2021	
LULC category	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)
Water body	86.7	96.3	85.0	91.1	95.0	91.9	95.0	91.9	93.3	81.2	95.0	98.3
Thick vegetation	85.0	78.5	91.7	78.6	90.0	79.4	86.7	89.7	85.0	81.0	88.3	79.1
Other vegetation	81.7	69.0	85.0	67.1	81.7	73.1	76.7	79.3	91.7	80.9	80.0	70.6
Settlements	81.7	92.5	65.0	97.5	75.0	91.8	90.0	85.7	85.0	94.4	85.0	86.4
Open area	91.7	96.5	93.3	96.6	78.3	87.0	86.7	88.1	73.3	95.7	78.3	97.9
Overall Accuracy	85.3		84.0		84.0		87.0		85.7		85.3	
Kappa	81.7		80.0		80.0		83.8		82.1		81.7	

Tab.4 Accuracy assessment for the Aawilundawa and Muthurajawela study areas. UA: User accuracy, PA: Producer accuracy

5. Discussion

Conducting a cross-scale comparison is invaluable for gaining a comprehensive insight into whether significant transformations have occurred in the two wetlands under consideration and, if so, the nature and extent of the Land Use and Land Cover (LULC) changes across diverse categories. This analytical approach allows for a nuanced understanding of the alterations in the landscape and ecosystem, offering crucial information for decision-makers, particularly urban and environmental planners in Sri Lanka.

The outcomes of this analysis hold significant implications for the decision-making processes related to the planning and management of both urban and environmental aspects in Sri Lanka. Given the country's rich diversity of wetlands, especially those located in coastal and urban areas, the findings provide a broader context for comprehending the dynamic interplay between human activities and ecological systems. By examining the LULC changes in these wetlands, the study contributes to the knowledge base essential for informed decision-making.

Despite the fact that both wetland sites are subject to partial or full regulation under environmental protection laws, the results of this study serve to illuminate the effectiveness of the existing legal frameworks. This insight is pivotal for evaluating the impact and efficacy of regulatory measures in place, ultimately guiding policymakers and environmental authorities in refining and enhancing the legal tools and conservation strategies employed to safeguard these ecologically vital areas.

5.1 Comparison of two coastal wetlands

Both Anawilundawa and Muthurajawela wetlands have experienced notable Land Use and Land Cover (LULC) changes, with a pronounced reduction in water bodies being the most significant transformation. Anawilundawa witnessed a loss of 12% and 16% of its water bodies during the periods 2000 to 2010 and 2010 to 2021, respectively. In contrast, Muthurajawela faced a substantial decline of 81% and 20% in water bodies during the corresponding intervals. Simultaneously, both study areas saw an expansion of settlements, with Anawilundawa experiencing a growth of 154% and then 9%, while Muthurajawela exhibited a 142% increase in the first time interval followed by a 39% gain in the second time interval.

Noteworthy is the high Annual Growth Rate (AGR) observed for settlements in both study areas during the first time interval. Anawilundawa recorded the highest AGR of 11% in Zone f and the lowest at 5% in Zone a. In contrast, Muthurajawela exhibited an even more substantial expansion of settlements, with the highest recorded AGR reaching 31%, maintaining its prominence even in the second time interval. The settlement conversion rate in Anawilundawa was comparatively lower than in Muthurajawela. The most prominent LULC changes occurred in Zones d, e, f, and g, situated away from the wetland area.

Community consultations revealed that elderly residents in local areas have a strong emotional attachment to the wetland and its ecosystem services from their early days. However, poverty and resource scarcity have compelled communities to exploit the wetland, reflecting a common scenario in developing countries (Ballut-Dajud et al., 2022).

5.2 Impacts of urbanization and other drivers of the LULC changes in the coastal wetland landscapes

The degradation of Asian wetlands poses a significant challenge, influenced by various factors such as unsustainable practices and political interference (Graham et al., 2021), along with the impact of high population and economic development, leading to the transformation of wetland ecosystems (Taylor et al., 2021). Notably, environmental stressors like land reclamation, pollution, and excessive use of biological resources have contributed to the decline of coastal wetlands in China, the United States of America, Argentina, Portugal, and North Africa (Newton et al., 2020; El Mahrad et al., 2020; Lin & Yu, 2018; Zilio et al., 2013). Additionally, several studies have emphasized that the expansion of infrastructure, roads, development projects, industrial facilities, agriculture, and aquaculture activities globally has significantly contributed to the conversion of coastal wetlands into alternative land use categories (Rojas et al., 2019; Sousa et al., 2020).

In Sri Lanka, wetlands face an increasing threat from urbanization (Athapaththu & Wickramasinghe, 2020; Dahanayake et al., 2022). The Gampaha district, where the Muthurajawela Wetland (MW) is situated, holds the second-largest district population, comprising 11% of the nation's total population, with a growing trend (Department of Census and Statistics, 2012). Community consultations have revealed that political influence and land demand have driven illegal encroachment and unauthorized agricultural land expansion in the MW. In contrast, the Attanagalu Oya Wetland (AW) is located farther from core urban centers, situated in a district with approximately 4% of the national population, exhibiting slower growth and lower population density in 2012 (Department of Census and Statistics, 2012). Compared to the MW, the AW is less urbanized, and the highest Annual Increase (AI) for the AW is recorded in Zone f (0.135) and Zone g (0.092) between 2000 to 2010 and 2010 to 2020. In contrast, many zones in the MW experienced higher AI.

LULC changes in the MW are further exacerbated by regular high floodwaters from the Dandugam Oya and the Hamilton Canal. Unplanned settlements and the development of permanent structures can obstruct the wetland drainage system, leading to prolonged retention (Manawadu and Wijerathna, 2021; Siriwardhana et al., 2020).

5.3 Sustainability, wetlands and societies and policy planning dynamics

Government of Sri Lanka (GOSL) policies related to infrastructure and economic development projects, such as the establishment of an Industrial Zone in the Kerawalapitiya area, the development and operation of the Dikovita Sea Port, Petroleum Oil Terminal Facility, power plants including Kerawalapitya-Yugadanawi (300MW), and two Municipal Solid Waste (MSW) Power Plants (11.5 MW and 10 MW), Katunayake International Airport, metal crushers, asphalt plants, tourist resorts, Katunayake Industrial Zone, and garbage dumping sites within close proximity to the wetland, are anticipated to have adverse effects on the Muthurajawela wetland area. Significantly, past incidents, such as oil leakages from the main distribution pipeline in 2015 near the Muthurajawela wetland area, underscore the environmental risks associated with these projects. Similar incidents of oil leakages impacting coastal wetlands, such as the Deepwater Horizon explosion event in the northern Gulf of Mexico in 2010 and along the Panamanian coast in 1986, led to the imposition of new policies as mitigation measures (Balogun et al., 2020; Mendelssohn et al., 2012).

Furthermore, the conservation of wetlands necessitates the introduction of new policies, tools, and mechanisms. Additionally, attention is required for the implementation of sufficient compensation programs, flexible scheme designs, information-based strategies, and awareness and enforcement measures (Graversgaard et al., 2021; Marambanyika & Beckedahl, 2016). Consequently, effective government policies on wetland conservation, combined with implementation and execution by relevant authorities and local governments, will be crucial for the protection of wetlands in the future (Dinç & Gül, 2021; Pilogallo et al., 2019; Spidalieri 2020).

Community-based stewardship plays a vital role in collaborative efforts to monitor and maintain the health of the Wetland Ecosystem, addressing threats to the wetland. Regular discussions and workshops in conservation areas are essential, campaigning for the values, threats, trends, biodiversity, and overall significance of ecosystems. Additionally, exploring carbon credit markets and biodiversity offset markets for wetlands can provide incentives and tangible economic benefits, encouraging people to protect and enhance ecosystem services, thereby promoting the protection and restoration of wetlands (UNEP, 2022).

6. Conclusion

This study conducts a comprehensive analysis and comparison of land use transformations in two coastal wetlands in Sri Lanka, namely Muthurajawela (an urban wetland) and Anawilundawa (a peri-urban wetland). The findings reveal significant changes in land use and land cover (LULC) patterns, particularly in the extent of water bodies, thick vegetation, other vegetation, settlements, and open areas, spanning a two-decade period. Both study areas experienced a decline in water bodies over the specified timeframe, with Muthurajawela exhibiting the most substantial LULC changes. Notably, Muthurajawela showcased a pronounced transformation of other LULC categories into settlement areas with houses and infrastructure, while in Anawilundawa, the LULC changes were observed in areas adjacent to water bodies. These results underscore the imperative of prioritizing conservation efforts for urban wetlands, necessitating enhanced management tools such as policies, regulations, and collaborative initiatives with local residents.

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