RESEARCH PAPER

TRANSFORMED WETLANDS AND URBAN RESILIENCE: A CASE STUDY FROM BELLANWILA – ATTIDIYA WETLAND SANCTUARY, SRI LANKA

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ABSTRACT. Urbanization is a major issue that threatens natural habitats. However, carefully planned anthropogenic activities give the opportunity to transform urban natural habitats to offer new services to cities. In this study, we assessed the impact of land-use conversions on the spatial status of Bellanwila - Attidiya wetland sanctuary in the Colombo district, Sri Lanka. The Bellanwila - Attidiya wetland provides many ecosystem services but is highly vulnerable to the rapid land use and land cover changes that comes with urbanization. Multi-temporal remote sensing images were analyzed for the years 2005, 2009, and 2015 to study the changes in land use/land cover features of the wetland. The social perception of the ecosystem services was assessed by conducting semi-structured interviews with the residents. During the study period, parts of the wetland had been transformed into residential areas (10.1%) and open water systems (8.6%). Urban expansion and the construction of a storm water management system were found to be the main causes for these changes. The community perception revealed that the wetland has deteriorated, and that the ecosystem services had been altered due to the land use/land cover changes. The anthropogenic transformation of part of the wetland into a flood retention area and the addition of infrastructure for recreational purposes have added value to the wetland complex and therefore opportunities for new ecosystem services have emerged. Our findings shed light on the need for inclusive urban planning mainstreaming community perceptions. It also highlights the benefits of transforming urban spaces into anthropogenic landscapes that blends with nature to offer ecosystem services and enhance community resilience.

KEYWORDS: wetlands, ecosystem services, land use change, community perception, GIS

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INTRODUCTION

Wetlands represent important natural capital that delivers many Ecosystem Services (ES) including provisioning, regulating, supporting, and cultural services (Millennium ecosystem assessment 2005). Yet, these ecosystems have been threatened throughout the world due to different human-induced activities such as fragmentation, pollution, overexploitation, and urbanization. Land Use/Land Cover (LULC) changes are identified as the main driver that affects the degradation of wetlands (Gagné and Fahrig 2007; Jurn et al. 2018). Dynamics in physical, chemical, and biological features that are associated with the wetland ecosystems can affect the proper functioning of the system while disrupting the services it offers to the community (Ehrenfeld 2000; Zhan et al. 2020). For instance, alterations in land use associated with wetlands can result in fluctuations in biodiversity profile, hydrology, and connectivity of habitats which led to changes in the benefits obtained from the wetland ecosystems (Yurek et al. 2016; Roy-Basu et al. 2020).

Urban wetlands have been identified as one of the most threatened ecosystem types in the world due to their intensive interaction with the surrounding landscape which is dominated by humans (Ehrenfeld 2000). As they are the intersections between wetlands and municipal landscapes, these fragile ecosystems are affected by many anthropogenic activities in different degrees (Khatri and Tyagi 2014). This may lead to a decline in the degree of the ES derived from the wetland and it could affect human well-being (Millennium ecosystem assessment 2003). On the other hand, urban wetlands provide several habitats for different groups of flora and fauna while maintaining comparatively high biodiversity as species have been restricted to these areas due to habitat fragmentation and urbanization, and degradation of the quality of the wetland systems may adversely affect their survival.

The benefits obtained from wetlands are influenced by the perceptions of people based on the location, beliefs, values, cultural and socioeconomic status of the landscape (Willock et al. 1999; Urgenson et al. 2013; Hein et al. 2006;

Cowling et al. 2008). Especially, communities that are living close to the ecosystems such as rain forests, wetlands have a higher appreciation regarding the ES-derived from the natural systems (Sodhi et al. 2010; Abram et al. 2014; Muhamad et al. 2014) Therefore, investigations on urban wetlands with the surrounding human-dominated landscape are essential to understand the patterns and processes associated with the ecosystem and the benefits they offer to communities (McInnes 2014). However, there are limited studies that focus on ES derived from urban wetlands to the communities. Therefore, consideration of the community perception is needed as it is important to understand the attitudes of urban dwellers on the benefits they receive from these habitats, in the view of management and conservation of wetlands (Grimm et al. 2000; Alberti et al. 2003).

The present study focuses on Bellanwila – Attidiya Wetland Sanctuary, which is known as one of the most significant wetlands located in a major urban agglomerate in South Asia (Hettiarachchi et al. 2014). The sanctuary is in the wet zone which, together with the Western Ghats in India, is considered as one of the 34 global biodiversity hotspots (Mittermeier et al. 2004). This Sanctuary is listed under the highly-threatened wetlands in the Colombo district and declared as a protected area by the Department of Wildlife Conservation Sri Lanka (Kotagama and Bambaradeniya 2006). BirdLife International has declared this wetland as an Important Bird and Biodiversity Area (IBA) in 2004 (Karunarathna et al. 2010).

According to the National Wetland Directory of Sri Lanka (2006), Bellanwila – Aththidiya wetland system maintains high biodiversity. *Nymphaea* spp., *Syzygium* spp. and *Pandanus* spp., and several species of grasses including *Cynodon dactylon* and sedges including *Fimbristylis* spp., *Eleocharis* spp. have been recorded as the noteworthy flora in the wetland (IUCN and CEA 2006).

Considering the fauna, previous studies have been reported 77 species of butterflies, 37 species of dragonflies with 5 nationally threatened species, 15 species of nationally threatened and endemic amphibians, 30 species of reptiles, 27 species of reptiles, and 33 species of freshwater fish species in the study site (Nanayakkara 1998; Goonethilake et al. 2001; Maduranga 2005). As reported in the various studies the most dominant vertebrate group in the Bellanwila – attidiya area is birds including both resident and migratory species (Karunarathne et al. 2010). The vegetation type and the aquatic areas create suitable habitats for a variety of birds such as herons, egrets, cormorants, kingfishers, pelicans, etc. as this area is an important breeding habitat of native birds, as well as for the migratory birds and it is also a preferred feeding and resting habitat of several species. This site has been used by several species of rare winter migrants including globally threatened *Pelecanus philippensis* (IUCN and CEA 2006; Karunarathne et al. 2010). Further, uncommon waterbird species such as *Rallus striatus, Porzana fusca, Gallicrex cinerea, Phalacrocorax carbo, Rostratula benghalensis* have been recorded in the study area (IUCN and CEA 2006).

In the past few decades, urban expansion, and other associated LULC changes such as landfilling for development, land clearing, flood control systems, etc. have resulted in severe pressure on the Bellanwila – Attidiya Wetland Sanctuary as well as the ES it served (Flower et al. 2019). Yet, studies on LULC changes through integrating remote sensing tools with the perceptions of local communities concerning urban wetlands are lacking. Therefore, this kind of study can provide useful insights regarding the requirement for the success of participatory approaches to the management of urban wetlands. In this context, the present study was carried out to investigate the changes in LULC of Bellanvila – Attidiya Wetland Sanctuary, from 2005 to 2015. The study also attempts to understand the perception of residents of the area on land-use changes and the ES they obtain from the wetland.

MATERIALS AND METHODS

Study site

Bellanvila-Attidiya Wetland, bearing IUCN status as a sanctuary, which is located at 6° 52′ 0″ N and 79° 52′ 0″ E to 6° 48′ 0″ N and 79° 56′ 0″ E within the Kesbewa Divisional Secretariat Division (DSD), a local administrative division in Colombo District in Western Province, Sri Lanka (Fig. 1.a). The study area consists of an extent of 372 ha within the Kesbewa DSD which carries a high population (244,062) in the district. This study has been conducted based on five "Grama Niladari Divisions (GND)" which are subunits of local administrative divisions within the Colombo district (Fig. 1.b).

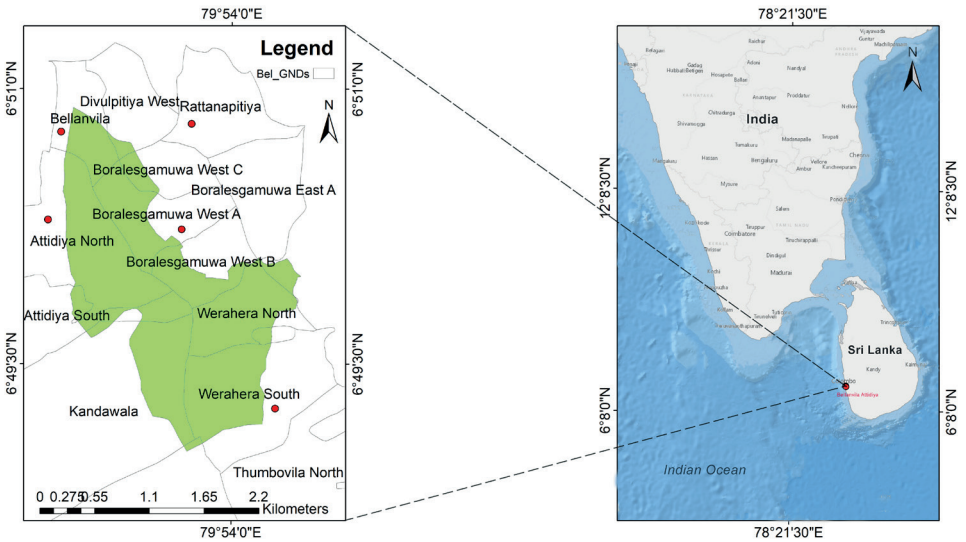

Fig. 1. Map of the study site, (a) local administrative divisions covering the study site in Colombo District in Western Province, and the GNDs in which the study has been conducted denoted by red dots. (b) Location of the study area in the Sri Lanka

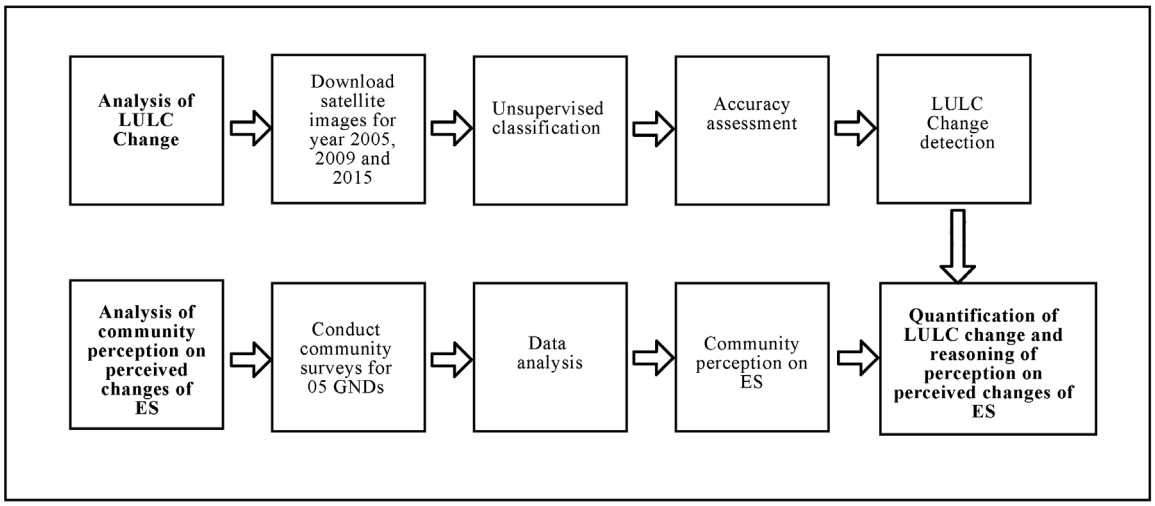

Fig. 2. Summary of methods used to analyze LULC change and community perception on perceived changes of ES

Analysis of LULC change

Multi-temporal satellite images for the years 2005, 2009, and 2015 were downloaded from the Earth Explorer USGS website (https://earthexplorer.usgs.gov/) to assess the LULC Changes (Reis, 2008). A collection of land images from Landsat 4-5 TM (dated 13/02/2005, path 141, row 55) Landsat 4-5 TM (dated 08/02/2009, path 141, row 55), and Landsat 8 OLI/TIRS (dated 08/01/2015, path 142, row 54) were used to generate the study maps. The cloud cover for the downloaded satellite images was selected at 10% or less. The composite band images were prepared for the downloaded satellite images and the masking tool in the ArcGIS (Version 10.3) software was used to extract the study area. The unsupervised classification method was utilized to identify the temporal LULC changes for the study area (Lillesand et al. 1998; Dewan & Yamaguchi 2008; Karnieli and Rozenstein 2011). Five LULC types were defined for this study and presented in Table 1. Different band combinations for the images were used for the identification of different LULC categories during the classification process (NASA 2011). The features of the LULC classification on the images were verified using Google earth pro software during this study. The change detection method was used, and changes were calculated in percentage for the analysis of the transformation of land categories into other categories (Dewan & Yamaguchi 2008).

Analysis of community perception on perceived changes of ES

A social survey was carried out using a semi-structured interview based on a questionnaire focusing on the community perception of the wetland. The people who have been living in the Bellanwila- Attidiya wetland sanctuary area since on or before 2005 were interviewed. Questions in the questionnaire were designed to collect data on the community perception of perceived changes of the ES derived from the wetland. The questions were designed as multiple-choice questions where the residents had to choose the most suitable answer which described their perception. The survey data were analyzed by using the statistical package of social sciences (SPSS 20.0) software and the Minitab 17.0 statistical software and RStudio (Version 21.0).

RESULTS

Analysis of LULC change

The LULC change analysis for the period 2005–2015 revealed that open areas and settlements have increased while thick vegetation, soft vegetation, and water bodies have decreased (Table 2 and 3; Fig. 3). According to the data analysis, human settlements have been increased by 31.12% while open water areas have been increased by 4.07% between 2005–2009 (Table 2). These values show a significant increase comparing the other LULC classes. From 2009 to 2015, the highest LULC change was recorded for the human settlements (30.37%) and it has been decreased compared to LULC in 2005–2009 (Table 3). The second highest LULC change has been recorded in open water areas (5.65%) and it has been significantly increased compared to the LULC changes in 2009–2015. The major reason for the conversion of the wetland area into open water areas is the flood management scheme that has been implemented in this area.

According to the LULC map, the pattern of urban pressure on the wetland demonstrates three distinct models (Fig. 3). However, the intensity of land use alterations in association with urban transformation and stormwater management program that was carried out during 2005–2009 was restricted to the perimeter of the wetland boundary. In contrast, during the period 2009–

Table 1. LULC class types identified in the Bellanwila – Attidiya wetland sanctuary

LULC class	Description
Water bodies	Areas covered with water bodies
Settlement	Residential areas and areas with infrastructure
Wetland soft vegetation	Marshlands with bushes, grass, or waterly plants
Thick vegetation	Areas with thick vegetation cover
Open areas	Open land areas

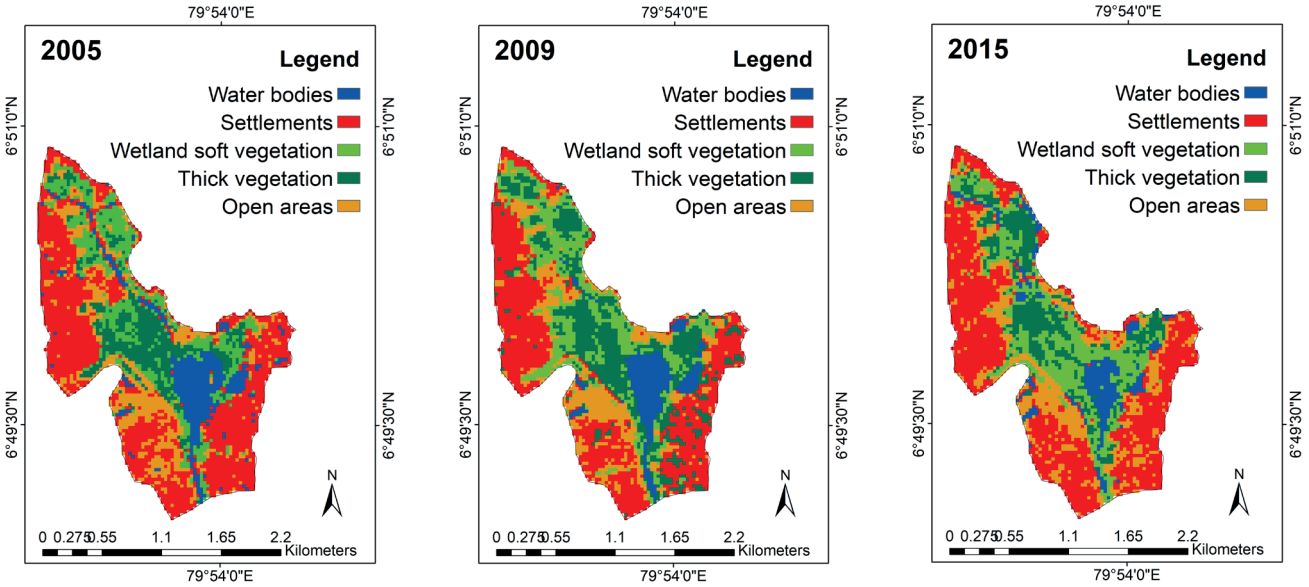

Fig. 3. Human-induce LULC conversions in the Bellanwila – Attidiya Wetland Sanctuary for the period (a) 2005 (b) 2009 (c) 2015

Table 2. LULC conversions between 2005–2009

2009										
2005	Row Labels	Open area		Settlement		Soft vegetation		Thick vegetation		Water bodies	
		ha	%	ha	%	ha	%	ha	%	ha	%
	Open area	33.75	8.88%	15.47	4.07%	12.20	3.21%	3.43	0.90%	0.26	0.07%
	Settlement	20.79	5.47%	118.29	31.12%	7.19	1.89%	15.36	4.04%	2.47	0.65%
	Soft vegetation	3.70	0.97%	1.83	0.48%	25.39	6.68%	29.78	7.84%	1.15	0.30%
	Thick vegetation	2.03	0.53%	0.18	0.05%	17.96	4.73%	26.57	6.99%	0.50	0.13%
	Water bodies	0.15	0.04%	0.96	0.25%	6.69	1.76%	7.21	1.90%	26.75	7.04%
	Grand Total	60.42	15.90%	136.73	35.97%	69.43	18.27%	82.35	21.67%	31.13	8.19%

ha – hectare

Table 3. LULC conversions between 2009–2015

2015										
2009	Row Labels	Open area		Settlement		Soft vegetation		Thick vegetation		Water bodies	
		ha	%	ha	%	ha	%	ha	%	ha	%
	Open area	30.98	8.14%	21.51	5.65%	3.49	0.92%	1.67	0.44%	2.83	0.74%
	Settlement	18.27	4.80%	115.55	30.37%	1.53	0.40%	0.38	0.10%	1.45	0.38%
	Soft vegetation	12.24	3.22%	5.85	1.54%	29.48	7.75%	17.62	4.63%	4.20	1.10%
	Thick vegetation	6.95	1.83%	11.01	2.89%	29.49	7.75%	31.87	8.38%	2.97	0.78%
	Water bodies	2.02	0.53%	1.90	0.50%	7.40	1.95%	1.35	0.36%	18.43	4.84%
	Grand Total	70.46	18.52%	155.82	40.96%	71.40	18.77%	52.89	13.90%	29.87	7.85%

ha – hectare

2015, the conversions have moved into the core areas of the wetland indicating the severity of pressure on land.

Analysis of community perception on perceived changes ES

The community survey was carried out focusing on five GNDs of Kesbewa DSD, i.e., Bellanwila, Boralesgamuwa West A, Rattanapitiya, Attidiya North, and Werahara South. Fifty-seven residents between the age of 20-90 years old have been interviewed for this study. There were 46% of females and 54% of males in the study group and the majority (99.95%) were permanent residents in this area. Perceptions of the residents reflect their experiences on land-use changes, causes, and ES they derive from the wetland (Fig. 4).

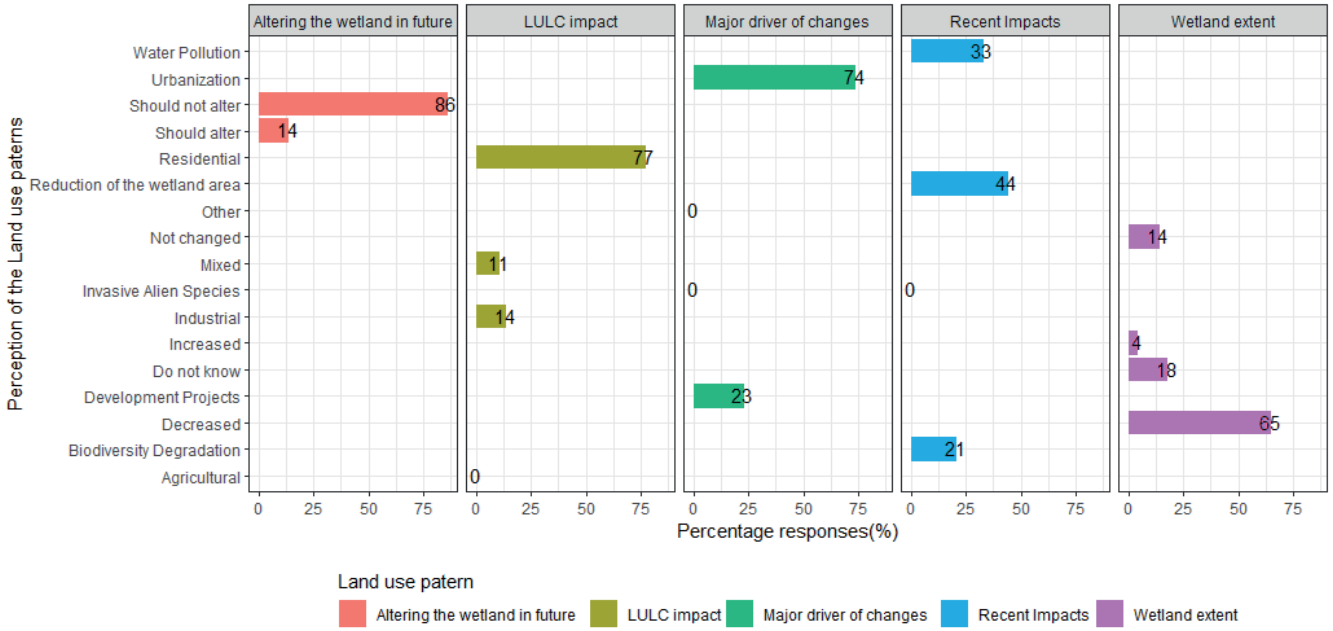

Fig. 4. Summary of the respondent's perception of land–use patterns

Although this ecosystem is a sanctuary, some human-induced activities that would not harm the environment are allowed by the law. While a series of questions were presented to the respondents, significant findings concerning the changes in ES are presented below.

Question 1: What happened to the extent of the wetland area during the past decade?

Sixty-five percent of respondents stated that the extent of wetland areas has been significantly decreased during the past decade.

Question 2: What is the major reason for the reduction of the extent of the wetland area?

According to 77% of the residents, the expansion of the residential areas was identified as the major reason for the reduction of the extent of the wetland. In contrast, 14% of the residents believe that the wetland area is reducing due to the increasing industrial activities in the vicinity.

Question 3: In your opinion, what is the most recent major damage to the wetland?

The reduction of the wetland area was identified as the major damage that happened in the recent past as indicated by 43.86% of the residents, while 33% of them believe that it is the degradation of the quality of the water due to the pollution. Moreover, 74% of the residents believe that urbanization is the major driver of wetland pattern and process change while 23% of the residents are under the opinion that it is the development projects that were taken place in the area.

Question 4: What happened to the ES-derived from the wetland over the past 10 years?

According to the results of the community survey, ten years ago more than 56% of the residents have at least obtained a single provisioning service including water or food from the wetland. In contrast, 84% of the respondents are obtaining none of the provisioning services as in the previous times. (Fig. 5). Nearly half of the respondents believe that water was clean ten years ago compared to now indicating water pollution in the wetland area. Interestingly, 14 % of residents believe that services related to recreation have been increased compared with the recent past due to the alternation of sanctuary landscapes.

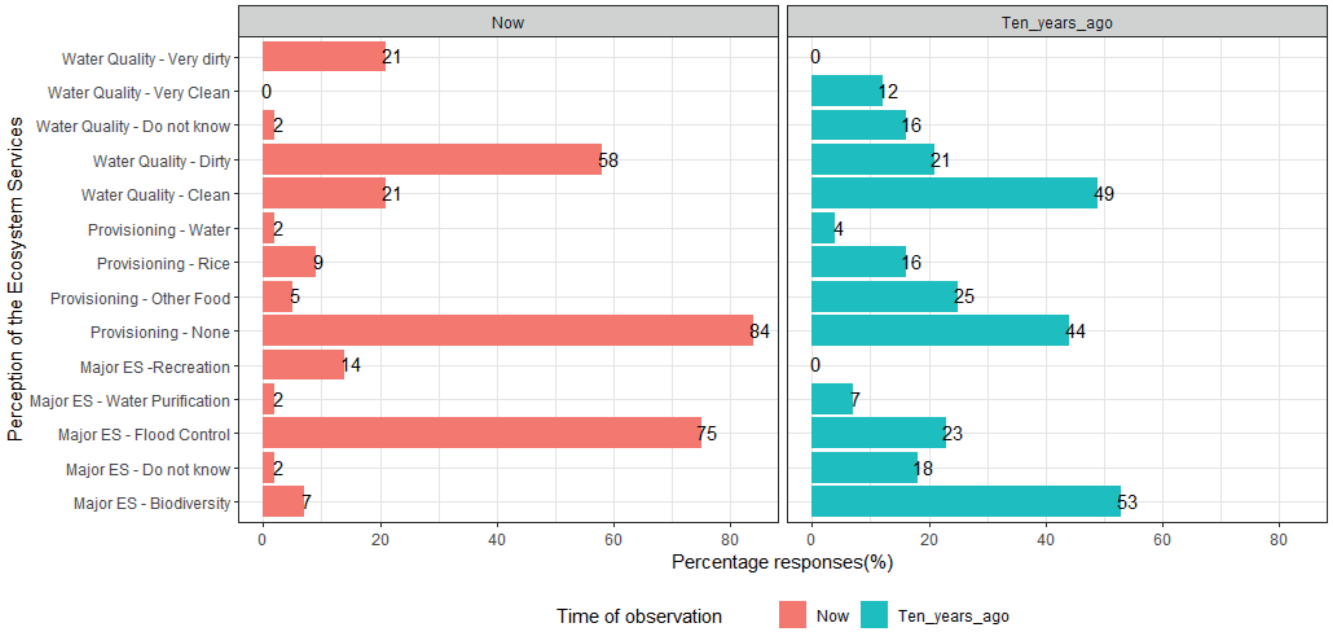

Fig. 5. Percentage responses of the identified ES provided 10 years ago and the present (n = 57)

DISCUSSION

Understanding the link between ES (Ecosystem Services) and human wellbeing is becoming a major research area worldwide as it recognizes the benefits people gain from nature which supports achieving sustainable development goals (Karki et al. 2018). Against this backdrop, this study presents an overview of LULC change in the Bellanwila – Attidiya wetland sanctuary, Sri Lanka between 2005 to 2015 and the perceptions of the local community on the provisioning of several ES by the sanctuary.

The ESs are indispensable to the well-being of people everywhere on the globe because it is essential in assuring the sustainable livelihood of the community (Islam et al. 2015). In the recent past, the anthropogenic transformation of natural ecosystems has been increasingly evident which either contributes to enhancing or reducing the ESs these habitats provide. For instance, transforming a wetland into a rice field will affect the natural water balance of the habitat, yet it may enhance food security. Urban areas are one of the most dynamic landscapes with ever-increasing human activities (Ricaurte et al. 2017). In many parts of the world, the changes in land use have not restricted only to the city area but gradually encroaching the suburbs as well as remaining natural habitats (Bengtsson et al. 2003; McDonagh 2007).

A wide array of problems emerge as anthropogenic activities rise in urban areas affecting ecosystems. In particular, rapid urbanization has been recognized as a key contributor to the degradation of ecosystem quality. The LULC changes have been identified as one of the main drivers of changes in different ecosystems and their services worldwide (Gaglio et al. 2015; Wang et al. 2015; Karki et al. 2018). Unplanned changes and unsustainable land-use practices in urban areas create significant impacts on natural ecosystems which affects the multi-functionality of these habitats (Seto et al. 2010; Zorrilla-Miras et al. 2014). Sri Lanka has been undergoing rapid urbanization over the past few decades resulting in alterations and changes in the ecosystems in time and space. For instance, the built-up area in Colombo, the capital city, has undergone a seven-fold increase from 1995 to 2017 (UN-HABITAT 2018). Similarly, there has been a significant reduction in green spaces in Colombo during the recent past (Li and Pussella 2017).

Results of the present study reveal a significant change in LULC in the study area. During the study period, areas that were covered with thick and wetland vegetation in and around the wetland sanctuary have been transformed into settlements and open water areas. The percentage transformation of the wetland to residential areas was10.1% and open water systems was 8.6%. Nearly 77% of the residents thought that the expansion of the residential areas was the foremost reason for the reduction of the wetland area. They were not aware of the actual extent of the transformation of open water areas. The major cause for the increase of open areas is the stormwater management program, the Weres River Project, which has been established to avoid flash floods, inundation, and damage to the land. This project is a part of a large wetland and canal network in Colombo flood mitigation. Under this flood management program, some areas of the wetland were dredged to remove sediments and to increase water holding capacity, and new connections were made to link isolated ponds. The area around the sanctuary is rapidly transforming into an urban landscape with high human density and commercial capacity. Thus, new or improved infrastructures are needed to avert the adverse impacts of floods. As expected, the floodwater retention capacity of the wetland has been increased due to these transformations and development under the Weres river project.

Less than half of the communities interviewed (43.86%) believe that the reduction of the wetland is the major damage that happened in the recent past. In contrast, 33% of them believe that the pollution of water is the major damage. Also, it's worth noting that half of the respondents believe that the water was clean ten years ago than today. Wetland has been providing ESs to fulfill community needs: more than half of the respondents indicated that wetland provided food items and water in the past. A majority (84%) of the respondents stated that they do not obtain any provisioning services from the wetland when compared to the previous time.

On the other hand, even though some ESs have been diminished due to the loss of natural wetlands as mentioned by the communities, new opportunities have emerged. According to the results of the analysis of the community perception regarding the changes of perceived ES, people have experienced a significant loss of ES such as provisioning services including food and water from the wetland system while gaining increased cultural services such as wetland parks and walkways. Some parts of the areas surrounding eh wetland sanctuary have been developed as walking pathways and serve as a recreational area for different entertaining activities. It is important to note that at least only a comparatively low proportion (14 %) interviewed, believe that services related to recreation have been increased compared to the past. However, the majority of the people have understood the increase of regulatory service of the wetland as a flood-controlling area compared to the past 10 years, but the perception of the biodiversity has been notably declined.

In this regard, understanding the impacts of LULC change is essential for mitigating the consequences of human-environment interactions (Hasan et al. 2020), and these changes should be accurately quantified to understand the impacts of the changes on the ecosystems as well as the community well-being. The results of the present study reveal that although the natural habitats were affected depriving the ES to the community due to different intensities of LULC changes, the new developments could contribute to enhancing urban resilience to floods as well as offering opportunities for physical well-being. Few studies have so far highlighted the community perception on the transformation of urban natural habitats to anthropogenic land or waterscapes. As inadequate information and knowledge limit good urban governance, city planners need to take proper steps to conserve and restore urban natural habitats to establish ESs, while taking careful consideration of community views.

CONCLUSION

The present research attempts to examine changes in LULC and the impacts of urban expansion on Bellanvila – Attidiya wetland sanctuary. This wetland is situated in a rapidly expanding urban area, yet delivered many services to the residents for decades. The results reveal that during the period 2005 to 2015, the sanctuary and the adjacent areas have undergone a rapid change in LULC. Most prominent changes are reflected in built up areas which has increased in size by expanding into the wetland marshy areas replacing vegetation. However, the open water area of the wetland has increased. The thick vegetation has decreased

in extent from 21.67% to 13.90%. The alternation of natural wetland results in changes in ecosystem services it offers to the residents. For instance, more than 80% of residents have indicated that the wetland currently does not offer any provisioning services it provided 20 years ago.

However, the transformation of a part of wetland into a storm water management pond and subsequent infrastructural development have provided new services in the recent past. Residents believe that opportunities for leisure and recreational activities that are being currently provided by the wetland contribute positively to urban resilience and community wellbeing. Our findings offer new insights into urban management and indicate the benefits of transforming urban spaces into landscapes that blend with nature and reduce developmental pressure. Our study highlights the essential need to pay attention to community views in effective and inclusive urban planning.

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