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RESEARCH ARTICLE

Hotspots of land use/land cover change around Bolgoda wetland, Sri Lanka

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Abstract: Wetlands are among the most productive ecosystems in the world. Urban wetlands are increasingly affected by population growth and developmental activities. A buffer region of 60 m from the Bolgoda lake boundary was gazetted as an Environmental Protection Area (EPA) by the Central Environmental Authority in 2009 as it is the largest freshwater wetland in Sri Lanka. This study attempts to quantify the land use changes during the period of 2001 to 2019 using GIS and to identify the 'hot spots' where a significant change in land use occurred. Land use/land cover (LULC) changed in the Bolgoda wetland area disproportionately. The greatest proportion of loss of natural area was observed in dense vegetation, where a 63.35 % decrease was apparent from 2000 to 2019. In contrast, the residential and commercial areas increased and in 2019 the change reached 49.62 % and 68.57 %, respectively. Hotspots were identified at Grama Niladhari divisions that belong to Kesbewa and Bandaragama DS divisions with the largest change in LULC. Thus, the results of the investigation provide vital information for the conservation and sustainable use of wetland resources in a rapidly expanding urban landscape.

Keywords: Geographic information system, hotspots, land use, remote sensing, wetlands.

INTRODUCTION

Wetlands are complex and highly productive ecosystems with high ecological, social, and economic values. Many wetlands are high in biodiversity and provide habitats for flora and fauna of significant ecological importance (Jinadasa *et al*., 1992; Punchihewa *et al*., 2017). These habitats are particularly important for livelihood of the communities who live in the area. For instance, fisheries and tourism are dependent on wetlands (Gachhadar *et al*., 2004). Ecosystem services provided by wetlands include absorption of pollutants, carbon sequestration, groundwater recharge, and disaster mitigation (Chmura *et al*., 2003; Chen *et al*., 2008; Ramsar Convention Secretariat, 2014). Yet human induced land use/land cover (LULC) changes affect the wetlands worldwide as well as services provided by them (Zhao *et al*., 2004; Zorrilla-Miras *et al*., 2014). Tooth *et al*. (2015) state that the wetlands provide major ecosystem services, including water and food supply, which however occur in climatically varying and moisture stressed environments that can be treated as 'hotspots.' Therefore, monitoring land use changes around wetlands is important in the conservation and management of wetlands.

Remote sensing (RS) and Geographical Information System (GIS) are increasingly being used to investigate land use changes (Rogan & Chen, 2004; Treitz & Rogan, 2004). RS and GIS are considered appropriate for wetland monitoring, especially when the extent of land considered is large. Moreover, the availability of multi-temporal images allows temporal analysis of land use changes over time (Ozesmi & Bauer, 2002).

Bolgoda wetland has gained attention of policy makers, since it is the largest fresh water wetland in

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Sri Lanka with high ecological, social and economic value (Silva *et al*., 2013). Located in the Western Province it comprises north and south lakes. In 2009, the Bolgoda lake and a buffer region of 60 meters from the lake boundary were gazetted as an Environmental Protection area (EPA) under the Gazette Notification No. 1634/23 (Central Environmental Authority, 2018). Nevertheless, it has deteriorated in both quantity and quality due to unplanned developmental activities, growth of population, and unsustainable urbanisation (Dahanayaka *et al*., 2016).

Monitoring LULC changes presents important insights for management of natural habitats and helps decision making in controlling the balance between natural and human altered landscapes (Giner & Rogan, 2012). In this context, the present study was carried out with two objectives: to quantify the land use changes during the period 2001 to 2019; and to identify the hotspots of LULC change where significant changes in land uses were apparent. The results of the investigation provide vital information for the conservation and sustainable use of wetland resources in rapidly expanding urban landscapes.

Study region

The Bolgoda lake (6°52´ and 6°39´ North latitudes and 79°52´ and 80°0´ East longitudes) and a buffer region of 2 km from the lake boundary were considered as the study region with a total area of 140 km^2 (Figure 1). The study region is located under the divisional secretariat (DS) divisions of Ratmalana, Kesbewa, Moratuwa, Panadura, Bandaragama, and Kalutara.

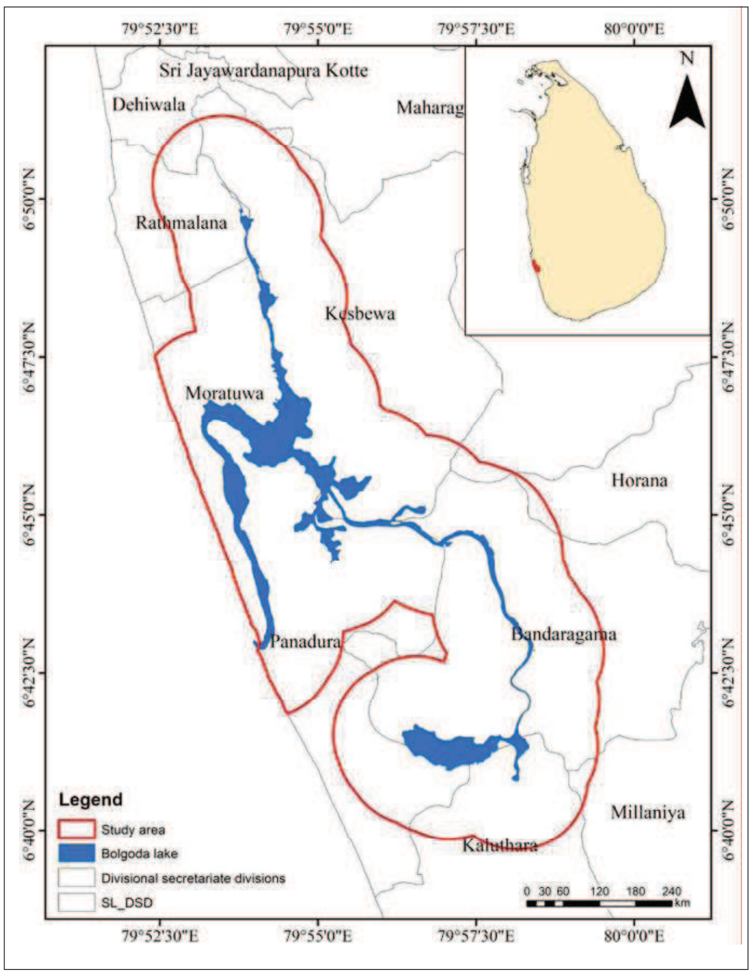

Figure 1: Location of study area

METHODOLOGY

Data collection

Landsat images corrected for surface reflectance were obtained from the United States Geological Survey (USGS) (Masek *et al*., 2006). These particular images were selected based on image availability and the presence of less than 20 % land cloud cover (Table 1).

Moreover, a rapid assessment to investigate field conditions was carried out by visiting the study area in 2018 followed by semi-structured interviews with 25 residents of the area to understand the underlying reasons for land use changes.

Image classification

Satellite images from Landsat 5 and Landsat 8 were used in LULC classification. Spectral bands of images were selected based on corresponding wavelengths of TM and OLI sensors. Six spectral bands were used in the classification: blue, green, red, NIR (Near Infrared), SWIR (Short Wave Infrared) 1, and SWIR 2. Through field observations and visual interpretations, six LULC types were identified: water body, commercial areas, residential areas, dense vegetation, sparse vegetation and bare land (Table 2).

Satellite images were classified using the supervised classification method in ArcMap version 10.5. As the first step, pixels with known land use categories were selected to prepare the training sample. These training sites for each LULC were selected based on high resolution images from Google Earth. Historical images from Google Earth were used to identify land use characteristics of the past. NDVI (Normalied Difference Vegetation Index) maps were prepared to identify the vegetation condition of each year. Training sites for vegetation classification were selected based on NDVI values. Due to the lack of high-resolution images, the same training pixels from 2005 were used for classification of the 2001 image.

The pixels of the images were then assigned to each LULC category according to statistical similarity to the training site's pixels. Classification was done based on Maximum Likelihood Classifier Algorithm.

Table 1: Details of satellite images used in the study

Year of study	Date of satellite image	Sensor
2001	2001.09.14	Landsat 5 Thematic Mapper (TM)
2005	2005.02.13	Landsat 5 Thematic Mapper (TM)
2015	2015.01.08	Landsat 8 Operational Land Imager (OLI)
2019	2019.01.03	Landsat 8 Operational Land Imager (OLI)

Table 2: Land use/land cover definition

Land use/land cover	Description
Residential	Areas with houses
Bare land	Bare soil with no vegetation or infrastructure
Water body	Bolgoda lake and other open surface water bodies
Commercial	Large buildings, industries and roads
Dense vegetation	Closely compacted vegetation with NDVI higher than 0.4 including woody trees, shrubs and cultivations
Sparse vegetation	Sparse vegetation with NDVI below 0.4 which mainly includes grass dominated wetland

Accuracy assessment

The accuracy of the classified images was determined using the confusion matrix method. The classification results were compared with testing site pixels. These testing sites were obtained using high resolution images from Google Earth. For each LULC type, 60 reference points were used. Accuracy assessment was not done for 2001 due to lack of high-resolution images.

Table 3: Overall accuracy and Kappa coefficient of classified images

Year	Overall accuracy	Kappa coefficient
2001	-	-
2005	81.85	0.78
2015	78.84	0.76
2019	86.94	0.84

Overall accuracies of all the classified images were above 75 % and the Kappa coefficients were above 0.7 as shown in Table 3. These values show the statistical agreement between the classified image and the reference data (Congalton & Green, 2002).

Identifying hotspots of land use/land cover change

To identify hotspots of LULC change from vegetation to build up region, both residential and commercial regions from 2001 and 2019 were extracted as separate layers. Then both layers were combined using the union tool in ArcMap. From the combined layer, new built up areas which appeared in 2019 were extracted again as a separate layer.

Table 4: Land use areas as percentages of the total area from 2001–2019

Land use/ land cover	2001 (%)	2005 (%)	2015 (%)	2019 (%)
Residential	35.25	36.87	52.83	52.76
Bare land	3.11	3.86	1.06	2.86
Water body	6.63	7.09	6.89	6.71
Commercial	2.90	3.83	4.81	4.90
Dense vegetation	34.09	33.04	16.20	12.50
Sparse vegetation	18.02	15.31	18.20	20.28

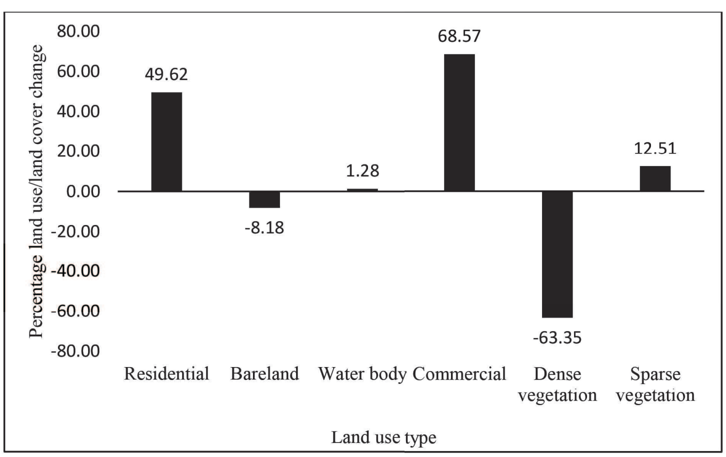

Figure 2: Percentage change in land use/land cover from 2001 to 2019

RESULTS AND DISCUSSION

Results

The area of six land use types in each year differed between the years (Table 4). Bare lands and water bodies showed relatively low percentage area change (Figures 2 and 3). Commercial land use has an increase of 68.57 %. Furthermore, residential land use areas have shown a 49.62 % increase while dense vegetation has decreased by 63.35 %. Sparse vegetation, on the other hand, was increased by 12.51 %. These results indicate that dense vegetation has transformed to sparse vegetation and in some parts, to residential and commercial land use. As a result, residential areas have become the predominant land use type and sparse vegetation has become the major vegetation type around Bolgoda lake.

A rapid field assessment revealed that utilisation of the wetland by the residents were not prominent; livestock grazing, small scale collection of leafy vegetables and freshwater fishing were the only significant signs of exploitation of wetland resources. Paddy lands in the area have been abandoned due to non-availability of labour. At present the Bolgoda wetland area has become a thriving

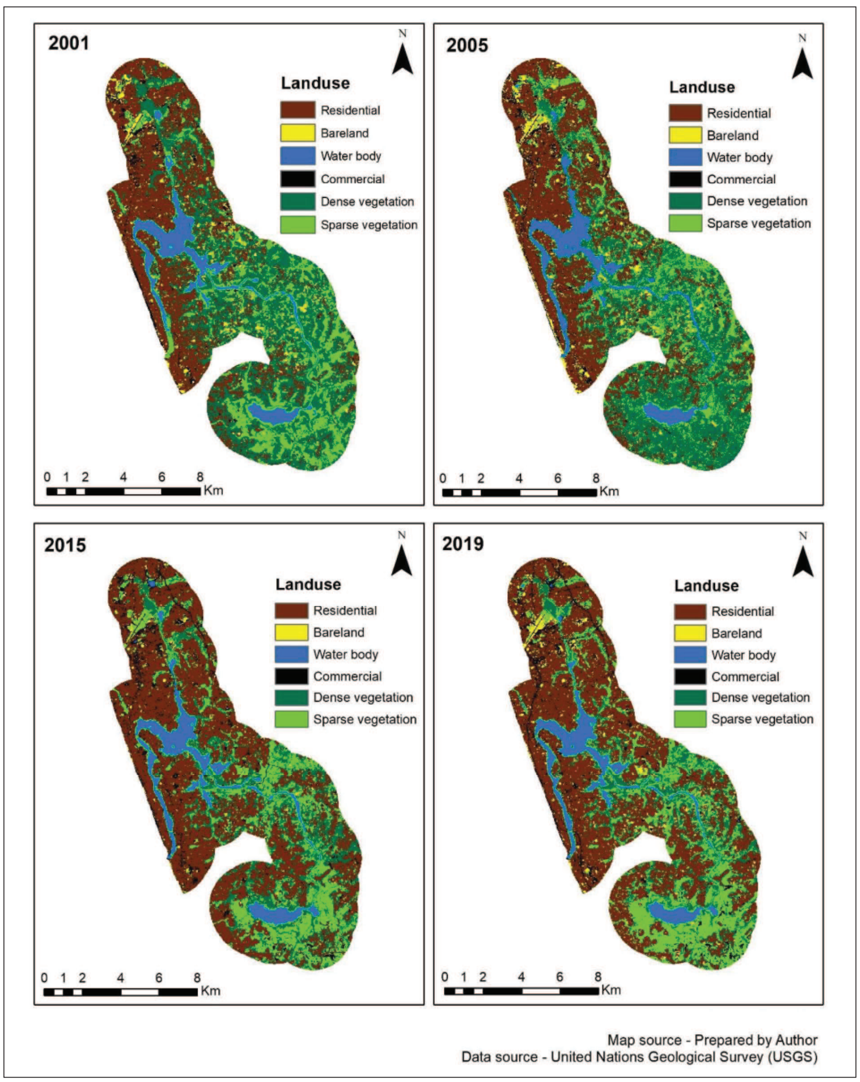

Figure 3: Land use/land cover around Bolgoda lake in 2001, 2005, 2015 and 2019

hub for tourism and recreational activities including bird watching and water sports such as rowing. Thus, the local community may have moved to alternative livelihoods such as tourism with the increasing potential of hospitality activities in semi-urban areas targeting both local and international visitors (*personal observations*). Over time, most of these paddy lands have gradually been converted to wetlands. All respondents to interviews indicated the need for conserving the wetland to provide aesthetic value, clean neighbourhood and livelihood opportunities especially in hospitality industry.

Discussion

With rapid urban development, wetlands and surrounding landscapes in many parts of the world have faced changes in LULC (Obiefuna *et al*., 2012; Zhang *et al*., 2015). For instance, various urban wetlands have undergone changes due to infrastructural development including construction of houses and buildings (Sithole & Goredema, 2013).The situation is similar around Bolgoda lake in Sri Lanka.

As expected, LULC has changed, although disproportionately, in the Bolgoda wetland area. The greatest proportion of loss of natural area was observed in dense vegetation, where a 63.35 % decrease was apparent from 2000 to 2019. Dense vegetation has been replaced by the residential and commercial areas that have increased by 49.62 % and 68.57 %, respectively. Most of the changes have occurred during the ten year period from 2005 to 2015. Studies report that during the same period urban expansion has increased by more than 30 % when compared to the period before 1985, due to population growth and increase in commercial and industrial activities in the area (Weerakoon, 2017). Another reason is that following the end of civil conflict in 2009, many economic opportunities were opened up, which facilitated growth of urban activities. As a result, the wetlands, cultivations and even home gardens have been transformed into infrastructural and commercial areas. Field observations confirmed that houses and commercial buildings including hotels and cottage industries are encroaching the natural environment. Most of such lands were owned by private owners and high land prices have encouraged people to convert their lands into other uses.

Several factors have contributed to the increase in sparse vegetation. Abandoned paddy fields have been converted to marshes over-time. On the other hand, the amount of water logging has increased in the area resulting frequent floods (Jayasinghe & Rajapakse, 2017). Thus, sparse vegetation has gradually increased, which is reflected in low NDVI values in the aerial maps. Another major finding of this study is the hotspots: Kesbewa and Bandaragama DS divisions have undergone the largest change in LULC. The reason behind this is linked to the population increase where these DS divisions showed the highest rate of population growth according to the population census in 2001 and 2012 (Department of Census and Statistics Sri Lanka, 2019). Thus, high rate of population increase may be the underlying reason for land use conversion in these regions.

Changes of natural landscapes result in many issues. As a consequence of LULC change, property values of land could be affected (Gwamna & Yusoff, 2016). On the other hand, the LULC is considered as one of the key driving factors of global change which reflects the anthropogenic impacts on the environment (Dewan *et al*., 2012). Understanding the degree of such changes over time is crucial for urban planning as well as conservation of natural habitats (Mirkatouli *et al*., 2015).

For instance, LULC changes from natural ecosystems to other land uses affect ecosystem services provided by wetlands; including hydrological functions (Zhan *et al*., 2019), carbon sequestration capacity (Xu *et al*., 2018); impairment of water quality (Houlahan & Findlay, 2004), loss of green spaces, and reduction of biodiversity. Although the LULC changes are visible, their long term and irreversible impacts often go unnoticed. Biodiversity worldwide is reported to be affected by human-induced changes in the structure of ecosystems (Sinha & Sharma, 2006). LULC change is regarded as the primary cause of global biodiversity crisis, especially due to habitat loss (Jackson & Sax, 2010). Moreover, LULC is the key culprit for global species extinction (Didham *et al*., 2012). For instance, Sri Lankan wetlands with increased pollution levels have negatively impacted amphibian fauna (Jayawardena *et al*., 2013, Priyadarshani *et al*., 2015) which is most vulnerable to environmental contaminants and have been reported to show a decline globally (Gallant *et al*., 2007).

To achieve the Sustainable Development Goals (SDGs) by 2030, healthy wetlands are essential as they provide multiple services to the local community. Goal number 6 (clean water and sanitation), goal number 11 (sustainable cities and communities), and goal number 14 (life on land) are directly related to urban wetlands. In the Colombo District, urbanisation has been identified as the main driver of wetland modification (Hettiarachchi *et al*., 2014). Especially in the Bolgoda area, increased commercialisation has been reported in previous studies (Piyadasa & Chandrasekara, 2010). In case of Bolgoda, 'hotspots of LULC change' where the ecosystem could continue to degrade, losing its potential to contribute positively to environmental health, warrant special attention. The city of Colombo has been declared as one of the first wetland cities in the world (Ramsar Convention Secretariat, 2018). In this context, proper conservation management plans for Bolgoda wetland is crucial in securing ecosystem services offered by this wetland.

CONCLUSION

The decrease of dense vegetation with an increase in residential and commercial areas was evident from 2001 to 2019 due to transformation of natural land to urban areas. Kesbewa and Bandaragama DS divisions demonstrate the highest LULC change and can be regarded as 'LULC hotspots'. As these changes could result in various environmental and socio-economic issues in future, appropriate urban planning as well as implementation of policies and regulations are essential to ensure the balance between nature and development.

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