Land use and land cover changes and Avifauna: an empirical analysis of loss of agricultural wetlands and its impact on avian species in suburban areas

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Abstract: Much has been written both in global and local level on rice cultivation, rice production and associated problems, the impact of land-use changes, biodiversity in rice fields. Yet, an area that has received little attention in the Sri Lankan context, is the avifaunal species utilizing rice fields. As a consequence of rapid urbanization, the extent of rice fields is decreasing year by year. The study followed various methods to collect primary data and used secondary data in support of findings, to achieve the objectives of the study. Figures of avifauna, figures of land use and land cover changes, figures of population growth changes were used for the study. Normalized Difference Vegetation Index, Shannon-Wiener diversity index and Equitability index used to analyse the data by objective. Mapping techniques in Arc GIS used along with descriptive and inferential statistical analysis. A total of 13320 avian species have enumerated for a period of six months in 2019 while the number of species has significantly reduced by 4994, compared to the avian data reported for the year 2009. Loss of rice field extent and overall land cover changes highly significant where the population growth and urbanization have increased. Among the species identified waterbirds and waders were dominant. *Ardea alba*, *Ardea cinerea*, *Ardea intermedia*, *Ardeola grayii* and *Bubulcus ibis* were dominant waterbirds utilized rice fields in the study area. A weighty decrease of bird species counts reported to the projected population data for the year 2022. Therefore, the future vulnerability of avifaunal species utilizing rice fields has to be concerned with this rapid land use and land cover changes.

Keywords: *Land use and land cover, Rice fields, Suburbanization, Waterbirds and waders*

I. Introduction

Natural wetlands are in decline worldwide as a consequence of rapid population growth. Among the primary factors in the loss of wetlands is attendant land-use changes, increased urbanization and conversion of open space to agriculture in particular. It is estimated that over 50 per cent of the wetlands worldwide have been lost since 1900 (Finlayson & Davidson., 1999). This loss occurred mostly in the northern latitudes during the 50 years of the 20th century (Helen & Katharine, 2002). Most of the wetlands in Asia have declined. This is also true in Sri Lanka. Especially, Colombo district which is the main city as well as the developed city in the country. The urban filtration process has been gradually moving towards the interior of the district creating suburban areas. Among them, Maharagama, Kesbewa, Battaramulla, Kaduwela, Homagama are significant with a high rate of suburbanization. All the emerging suburbs are found in the wet climate zone of the country.

The only aseasonal ever wet region in the whole of South Asia is the well-known southwestern region of Sri Lanka (Ashton & Gunatilleke, 1987; Gunatilleke, et al., 2005) where received the highest average rainfall in the country. This wet zone of Sri Lanka along with the Western Ghats of India is designated as one of the world's biodiversity hotspots (Brookes, et al., 2002; Myers, et al., 2000). The majority of the endemic species are found in the wet zone where most of the rice fields are belong to rainfed lowland and flood-prone areas. Being the 'Granary of the East' Sri Lanka is renowned for rice (*Oryza sativa*) cultivation since the reign of Great King Parakramabahu in the Polonnaruwa dynasty. Rice fields are temporary aquatic habitats consists of both wet and predictable dry phases. As an agronomically managed temporary man-made wetland ecosystem two physically and morphologically distinct habitats can be identified. They are rectangular or similar shaped flooded fields and levees (Bambaradeniya, et al., 2004). Though rice production has many forms, most rice is grown under flooded conditions which have both wet and dry cycle. Rice fields are generally simple habitats with low heterogeneity, dominant by single plant species with uniform water levels and fluctuate on the similar scheduled pattern as well as with predictable disturbance patterns. Rice fields are man-made ecosystems rich in biodiversity that sustain not only human beings but a diverse assemblage of fauna and flora that have made rice fields their niches. A study carried out by the International Union for Conservation of Nature (IUCN) in 1999 has reported a total of 250 species associate in rice field ecosystems which represent about 40 per cent inland native vertebrate species in Sri Lanka. Also, 133 species of native birds found 30 species of winter migratory birds also documented by this study implying the biological significance of rice field ecosystems. Among

the avifaunal families utilizing rice fields, Cinconnidae, Ardeidae, Charadridae, Scolopacidae, Rallidae and Muscicapidae were dominant (Bambaradeniya, et al., 2004). This shows numerous avifaunal species have been documented to occur in rice fields. Among them, the most common groups of species utilizing rice fields are waterfowls; whistling ducks, geese, swans, ducks, shorebirds; plovers, sandpipers, gulls, terns, long-legged wading birds; herons, egrets, bitterns, ibises, stork, and gruiforms; cranes, rails, crakes, coots, gallinules. Thus agricultural wetlands provide a precious and wide array of habitats for various species such as avifauna, herpetofauna, insects, amphibians, and mammals. The studies carried out by different researchers have identified rice fields as multi-benefited wetlands for birds (Basavarajappa, 2006; Violetta, 2010; Fasola & Ruiz, 1996; Pierluissi, 2006; Stafford, et al., 2010). Though rice fields are utilized by birds, as a habitat, rice is a double-edged sword for waterbird conservation. This is because the creation of rice fields often contributes to wetland losses (Cho, 2007), however, once wetlands have been exhausted in a region, rice fields are possible providers of best habitat that remains. Nevertheless, waterbird populations are declining worldwide (Hansen, et al., 2015; Wang, et al., 2017). According to the Wetland International (2012), the decline is particularly at an alarming rate and 50 per cent of known species populations in Asia found to be declined. Waterbirds, an important component of agricultural wetland ecosystems, are sensitive to dynamics in the wetland. As a consequence, these species either disperse or aggregate in response to such changes (Brandolin & & Blendinger, 2016; Henry & & Cumming, 2016). However, the dramatic increase in urbanization has directly threatened the persistence of wetlands in urban areas. The cultivated paddy lands in Colombo district was 14.87 per cent in 2009 and it had declined to 12.71 per cent in 2013. The abandonment, as well as filling of paddy land, has greatly influenced this decline (Herath, 2016).

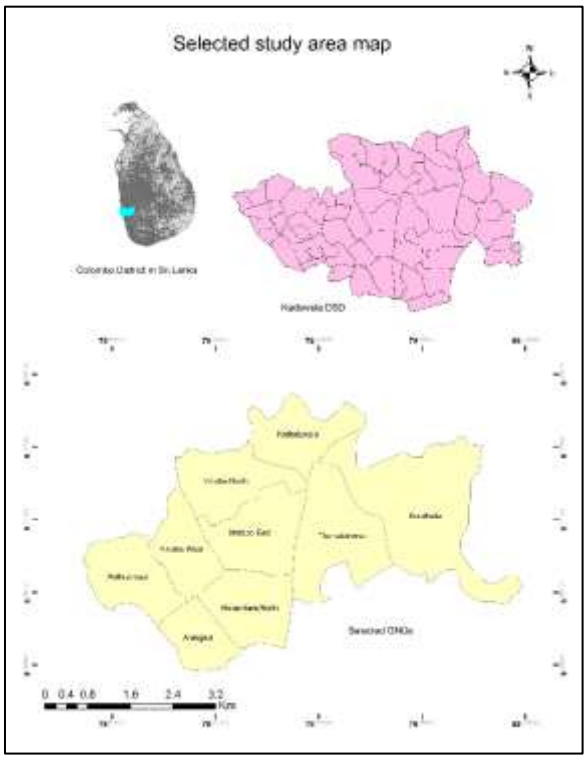

Figure 1. Study area
Source: Produced by the author, 2019

Kaduwela which is the study area of this study is an expanding suburb of 88 km^2 areas where the population increased ten times from 1971 to 2001 (Ranaweera & Ratnayake, 2017). It was 161247 people distributed in 2001 which increased up to 191687 in 2012 in Kaduwela division where the housing changes identified as 10214 (Saparamadu, et al., 2018). The land use of Kaduwela dramatically changed due to the rapid change of rural area into the urban area surrounding the Sri Jayawardenapura Kotte. The main cause of rapid change of the land use in Kaduwela is land-use changes and high rate of suburbanization. The built-up area has increased from 8.6 to 22.9 in 1975 and 2016 respectively. The paddy lands are decreasing rapidly while the built-up area expanded 165 per cent of rate. This rate of loss of paddy lands which are considered as wetlands may have a direct impact on habitats.

Over the past century, researchers have documented the importance of rice fields for waterbirds and their temporal and spatial distribution, foraging, breeding. However, there is a gap in the researches carried out to find out the relationship between Land Use and Land Cover changes particularly in rice field extent and bird species, Sri Lanka in particular. In this respect, this study aimed to detect the land use and land cover changes and study its impact on avian species diversity and abundance in Kaduwela Divisional Secretariat Division (DSD) (Fig1). To obtain the objective of the study, the following sub-objectives were achieved,

- Detect land use and land cover change and changes in rice field extent
- Assess bird composition, diversity and abundance
- Analyse the relationship of land use and land cover; rice fields, in particular, and bird species

II. Methodology

The study depends on both primary and secondary data which were used to detect the impacts of land use and land cover changes on birds. Primary data obtained applying several methods as per the objectives. The primary data obtained through a bird survey carried out in rice fields located in purposively selected ten Grama Niladari Divisions (GND) in Kaduwela DSD. The GND selection was based on the loss of paddy fields where mostly deteriorated agricultural wetlands selected. Bird survey carried out using Point Count Method (PCM). Accordingly, five-point counts were placed in each site with a 50meter radius. PCs were performed in the morning from 5.30 to 8.30 and in the evening from 4.00 to 7.00 from November 2018 to May 2019. The time taken for sampling each site was 15 minutes. Bird observations were made using binoculars while bird guides of Wijerathne and Kotagama were used to verify the species. Unpublished bird survey data for the year 2009 also used which has followed the same methodology to detect the changes of bird utilization of rice fields. Percentages were calculated for bird composition by species, by family and by genera. The diversity of bird species calculated using the Shannon-Wiener diversity index.

$$\mathrm{H}= -\sum Pi \ln(Pi) - 1$$

The value of the 'H' is range from 1 to 5. Higher the value of H higher in diversity and lower the value of H lower the diversity. The equitability (EH) of Shannon index can be calculated by,

$$EH\ {}^{1}\!/_{4}\ \ H = Hmax\ {}^{1}\!/_{4}\ H - \ln S$$

Shannon's equitability (EH) can be calculated by, where (EH) is evenness, H is Shannon 's diversity index and H max is the maximum value of H. Value of (EH) range between 0 to 1. Evenness is one means complete evenness.

Impact of land use and land cover changes detected via satellite images. Landsat ETM+ (2000 and 2018) were obtained from the United States Geological Survey website to detect the land cover and land-use changes in Kaduwela DS Division. To provide a clear picture on the pressure of land use and land cover changes towards Kaduwela DSD, Colombo and Kolonnawa DSDs also mapped for land use and land cover changes and used literary evidence to compare the accuracy of findings. Image processing and GIS approaches were implemented to achieve the overall objective of the study. Normalized Difference Vegetation Index (NDVI) used to identify the land cover and land-use changes in the study area and values were calculated using the index given below. The NDVI values are varying from -1 to +1. Non-vegetation areas are demarcated with low NDVI values and high-density vegetation areas identified with high positive NDVI values. A zero means no vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves.

$$\mathrm{NDVI} = (\mathrm{NIR} - \mathrm{RED})/(\mathrm{NID} + \mathrm{RED})$$

Rice field decline was detected by digitizing satellite imagery and verified during the bird survey. This decline was detected for 2010 and 2019. The area calculated through Arc GIS and detect the loss of rice fields in the study area.

In support of the study, population pressure and loss of natural wetlands studied. Population pressure studied using population data as secondary data obtained from the Census Department in Sri Lanka for the year 2001 and 2012 and population densities were calculated, consequently identified the spatial distribution and projected the population growth rate by 2022 to find out the future vulnerability of birds utilizing rice field. Loss of natural wetlands studied by screen digitizing of wetlands in Kaduwela DSD for the year 2010 and 2017 with the same method.

The correlation between bird count and population as well as rice fields and population were calculated to detect the impact of suburbanization on birds in rice fields. Density maps and other relevant maps have produced using Arc GIS mapping techniques.

III. Results and Discussion

The study area has consisted of three regions; Battaramulla, Athurugiriya and Kaduwela. Kaduwela is a junction settlement developed progressively connecting Colombo with 'A' class roads as well as expressways. The road network creates a beneficial relationship between other towns. The urban filtration has been transferred the busiest components of Colombo primacy towards the country. As a consequence, these areas have been facilitated with government institutions, infrastructure, schools, and many other services. Not only services, but halve of the city population also migrated to these areas due to the high location rent at the city centre. According to the Department of Census statistics in 2001, the Kaduwela population was 209,741. It was 9054 of population recorded Kaduwela in 1971 and this has increased up to 60641 within 30 year period (1971-2001). Athurugiriya and Battaramulla population also increased

by four times for these 30 years while Kaduwela reached ten times, a dramatic increase in population (Fig2). Gradually, Battaramulla, Kaduwela areas became urban centres, but, still are suburban areas[1]. This suburbanization, the high demand for land and residencies parallel to the development has led to change the land use and land cover of the study area.

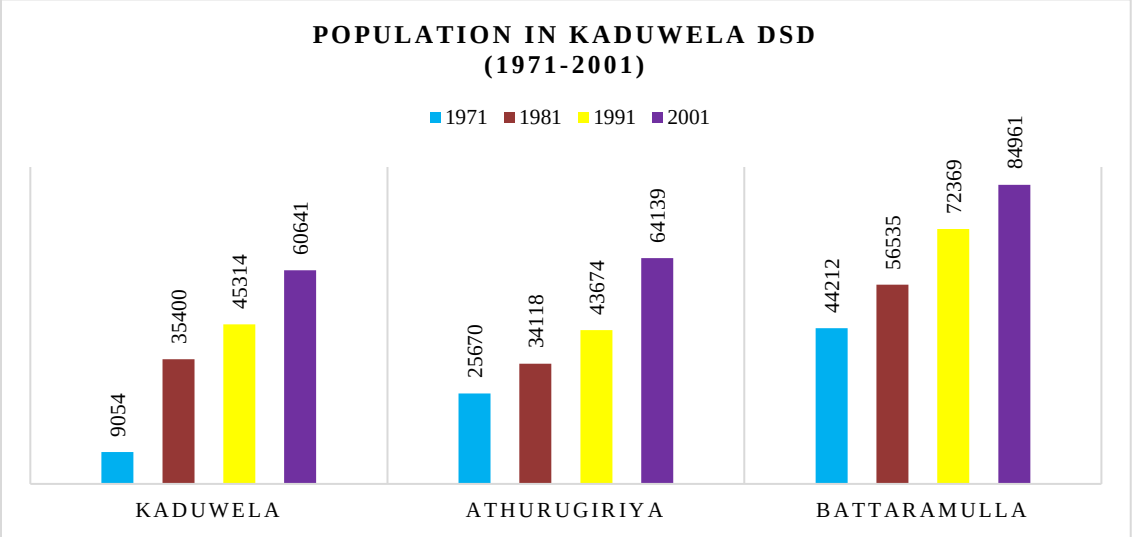

Figure 2.Administrative division wise population in Kaduwela DSD
Source: based on Department of Census population data, 1971-2001

As a result, the residential area obtained 61.1 per cent of the total extent of 8772hectare in 2005. The paddy field extent was 1233 hectare (14 per cent) and the marshy land covered 2.3 per cent (200 hectares) of the total land (Table 01). In 1998 the residential area land use was 52 per cent in Kaduwela (Ranaweera & Ratnayake, 2017).

Table 1. Land use in Kaduwela - 2005

Land-use type	Extent (ha)	Percentage
Residential	5356.4	61.1
Commercial	351	4.0
Industrial	171.0	1.9
Government and semi-government	163.0	1.9
Paddy Fields	1233.0	14
Marshy lands	200	2.3

Source: Urban Development Authority, 2005

[1] The outer, socially homogeneous, mainly residential or dormitory part of a continuously built-up area, town, or city, distinguished from the inner area by a lower housing density and characterized by a high level of commuting to central locations in the inner area.

The land cover has significantly reduced from 2000 to 2018 in Kaduwela DSD. The green coverage obtained a value less than 0.8 (0.7) where the moderate to lower density of green leaves reported. In contrast, the results of NDVI show the land cover in Colombo has increased by little and filtered its pressure towards Kaduwela DSD which is also proved by NDVI calculations done in other studies (UDA,n.d). The green coverage has reduced and the built-up area has gradually increased due to the urban sprawl (Fig3). The land cover alteration is precisely clear when analysing the population distribution and population density too.

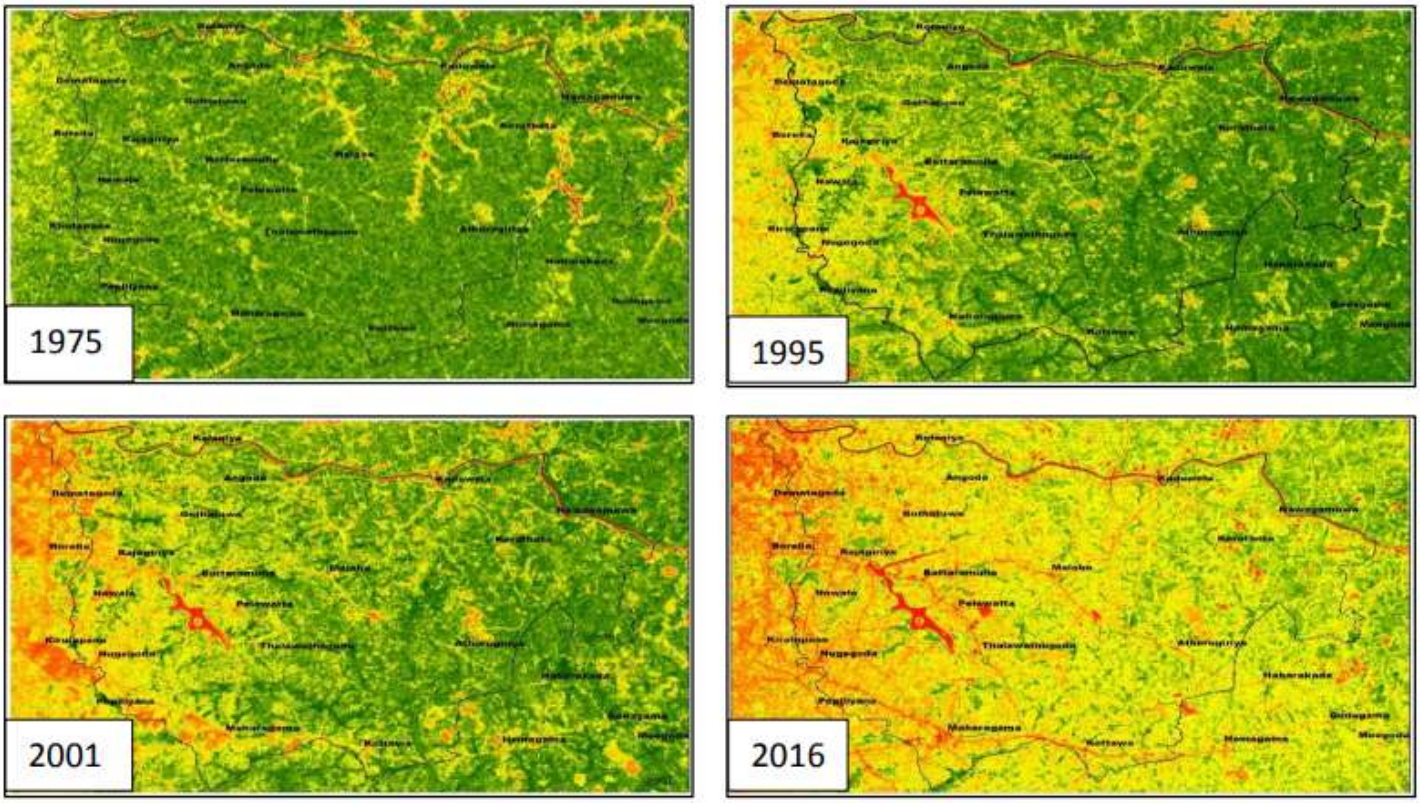

Figure 3. Land cover changes since 1975
Source: UDA, n.d

When considering land use and land cover marshy lands gained much attention, since the marshy lands are one of the best habitats of avian species has also reduced in the area. The changing rate of marshy lands (Fig4) in 2005-2010, 2010-2015 and 2015-2017 is 16.93 per cent, 13.98 per cent and 164.66 per cent respectively. Overall 28.12 per cent of marshlands were reduced from 2005 to 2017 in Kaduwela DSD. The rice field extent has reduced largely (Fig5) in the area from 1975 to 2016 by about 41.6 per cent (Table02) which are too important habitats for avian species. When considering the marshlands in the selected GNDs 1.552957km^2 of marshy lands in 2010 and 1.695371km^2 in 2017, indicating an increase of marshlands while decreasing some rice field extents.

Table 2. Paddy land extent changes

Type	1975-1980	1980-1997	1997-2016	1975-2016
Rice fields	-21.76	-10.91	-16.24	-41.6
Built-up area	69.64	12.91	38.48	165.23

Source: (Ranaweera & Ratnayake, 2017)

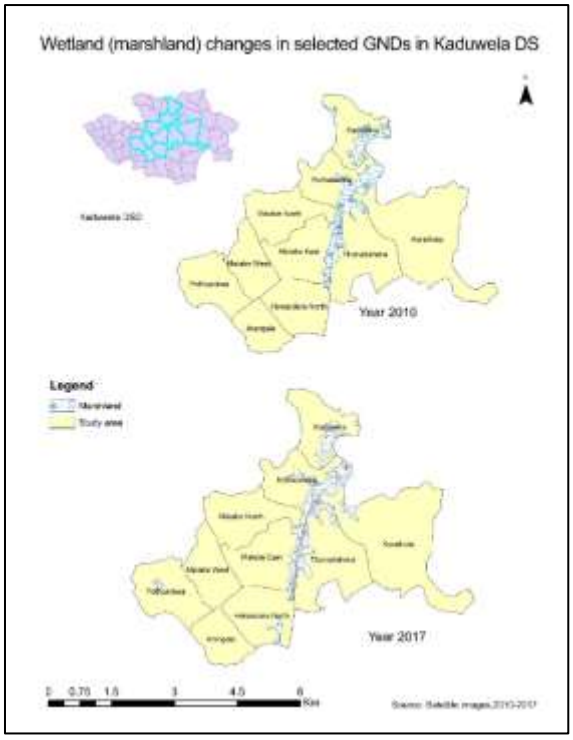

Figure 4.Marshland changes in selected GNDs

Source: Produced by the author, 2019

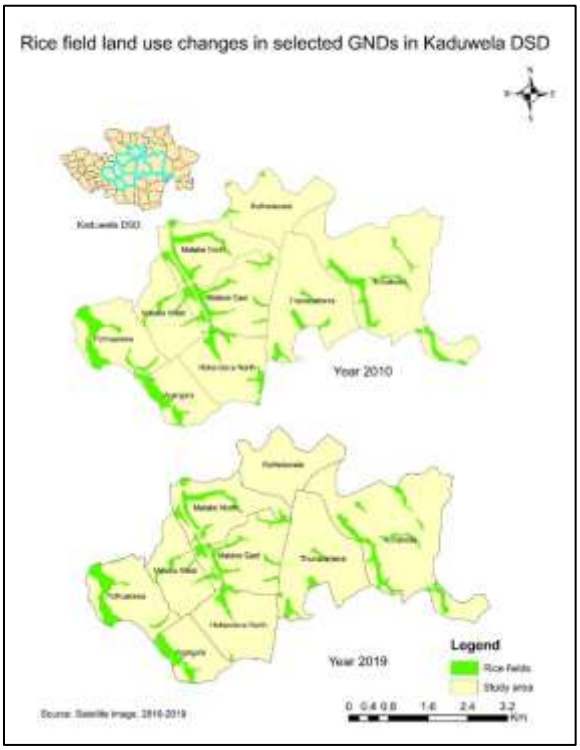

Figure 5. Rice field land use in selected GNDs

Source: Produced by the author, 2019

Since one of the objectives of the study focused on avifauna utilizing rice field ecosystems, the researcher paid special attention to the land-use change of rice fields. This has shown that rice field extent has reduced and most of the rice fields were abandoned after 2010 due to various reasons. Accordingly, the biodiversity in agricultural wetlands declined. This is significant for bird species and various arthropod species utilizing agricultural wetlands, rice fields in particular.

Sri Lanka is a part of the South Asian biogeographical region, defined as Afghanistan, Pakistan, India including the Andaman and Nicobar Islands, Nepal, Bhutan, Bangladesh, the Maldives and Chagos archipelago, form only a small part of the Oriental Region, however, is home to some 1300 species of birds; approximately 13 per cent of the world's bird species (Rasmussen & and Anderton, 2012). Among them, 143 bird species are endemic to the South Asian region. The avian species richness in this region depends on several factors. The altitudinal variation, variability in climate and associated vegetation diversity, and its geographical location within the major Central Migrant flyway are among them. Also, this region is close to two other biogeographic provinces; Palearctic and Afrotropical, which has resulted in species from these two regions extending their ranges into the South Asian region. Most of the species in this region are Oriental species, in other words, Indo-Malayan species, typified by minivets and ioras; some are Palearctic species, including accentors and small number originate in Africa and these include creepers (Wijesundara, et al., 2017). Sri Lanka is home to 459 bird species belonging to 22 orders. Of these 216 are residents and 219 are migrants. 15 occur only as highly scarce migrants and 99 only as vagrants; a total of 113 (Wijeyeratne, 2017). The majority of migrant species arrive in the country from northern latitudes. A large number of migrant species are waterbirds (Warakagoda & Sirivardana, 2006).

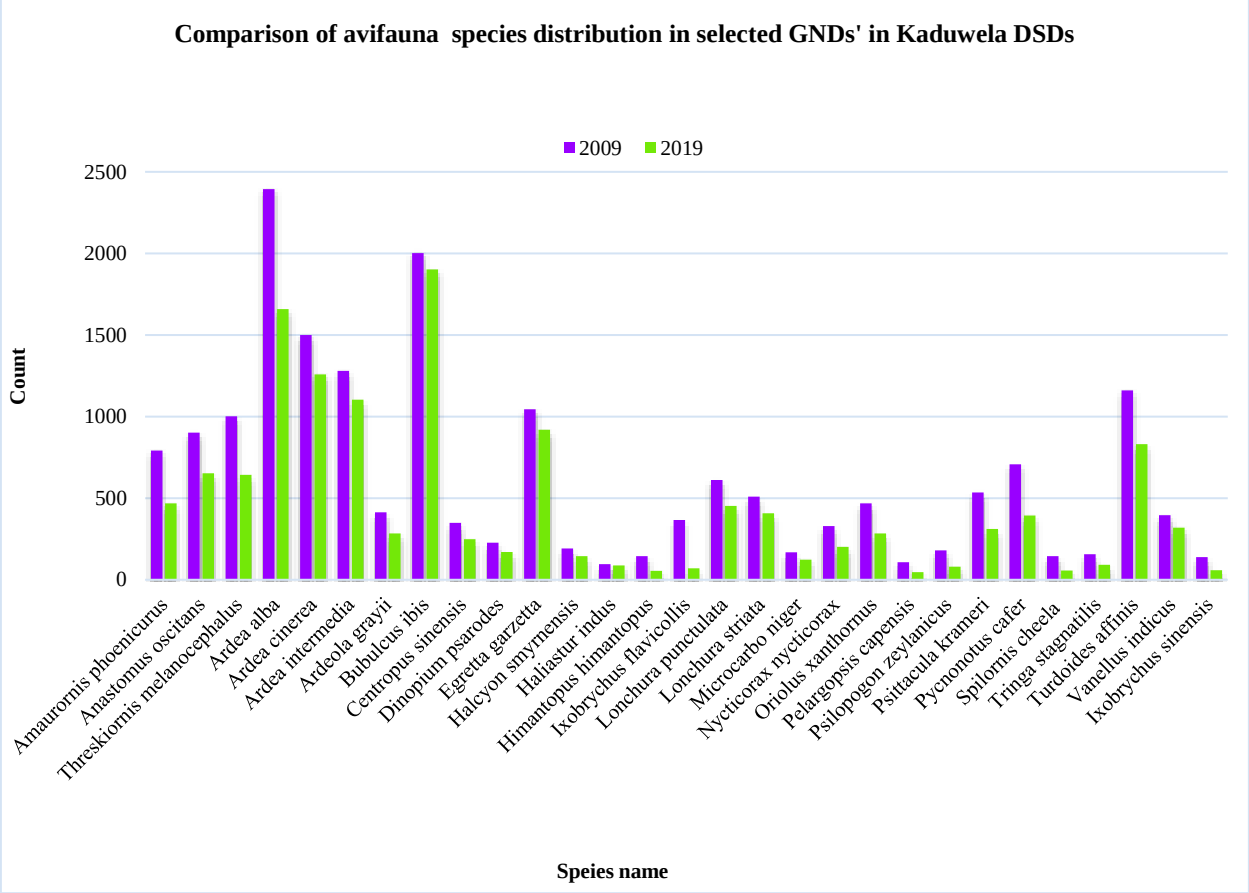

Figure 6. Avifauna species distribution
Source: Produced by the author, 2019

A total of 13320 bird species have enumerated belonging to 18 families and 24 genera during the study period. Most of them are waterbird and wader species while very few are terrestrial bird species. Waterbirds were found only within the paddy are the majority. Waterbirds and waders were dominant in both 2009 and 2019. A total of 67.26 per cent of enumerated birds were waterbirds in both years while the same number of species belongs to the waders including another 6.80 per cent. *Ardea alba*, *Ardea cinerea*, *Ardea intermedia*, *Ardeola grayii* and *Bubulcus ibis* were dominant water birds utilized rice fields in the study area (Fig6). *Anastomus oscitans* and *Threskiornis melanocephalus* were utilized paddy fields significantly after precipitation. The minority terrestrial birds reported only on levees in the paddy fields. The highest number of birds reported for the study period from Malabe-East (20%) and

the least number from Kothalawala and Thunadahena (3%). According to the 2009 bird survey data, a total of 18314 of bird species had enumerated. The highest bird count had reported in Malabe-East (21%) while the least from Kothalawala (2%).

When considering the islandwide status of the bird species majority were common residents (CR) both in 2009 and 2019, about 11612 and 8788 individual species respectively. The area was a suitable habitat for migrant species too, however, the number of common migrants (CM) has reduced by 26. 32 per cent from 2009 to 2019. The avian diversity ranges between 2.3 and 3.07 where the specie abundance ranges between 0.01 and 0.7, along with an extreme case reporting 1.5. Typical values of species diversity are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon index increases as both the richness and the evenness of the community increase. Hence, the avian diversity in the study area is to predict as in moderate to high status.

Both land use and land cover and avian species composition and species arrival have dramatically reduced in the study area. As another supporting evidence, the population distribution and the density in these selected GNDs indicate that there is a significant relationship between population and number of individual bird species recorded. The population has increased rapidly where Korathota reported the highest for the year 2001 and 2012 as 6842 and 9274 respectively. The least population reported from Thunadahena in 2001 and Kaduwela in 2012 as 2659 and 4287 respectively (Table03). Accordingly, the number of bird individual species also reduced. Malabe-east and Malabe-north presented the heaviest decline of bird species in 2019 where the population increased by 1956 and 2036 respectively. Not only has the population, when compared the paddy land extent with the number of enumerated bird species there is a significant reduction in the bird count.

Table 3. The population of selected GNDs in 2001 and 2012 and avian diversity 2009 and 2019

GND name	Population		Number of individual bird species	
	2001	2012	2009	2019
Arangala	4175	5506	1680	1560
Hokandara north	5057	6166	1700	960
Kaduwela*	3988	4150	-	-
Korathota	6842	9274	3200	2520
Kothalawala	4564	6061	420	360
Malabe east	3963	5919	3758	2688
Malabe north	5653	7689	3200	2400
Malabe west	5050	5170	1260	672
Pothuarawa	5864	7391	2200	1728
Thunadahena	2659	4359	896	432

*no birds recorded as there are no rice fields after 2005

Source: Population data-Population census, 2001 and 2012 and Avian diversity-analysed primary data, 2019

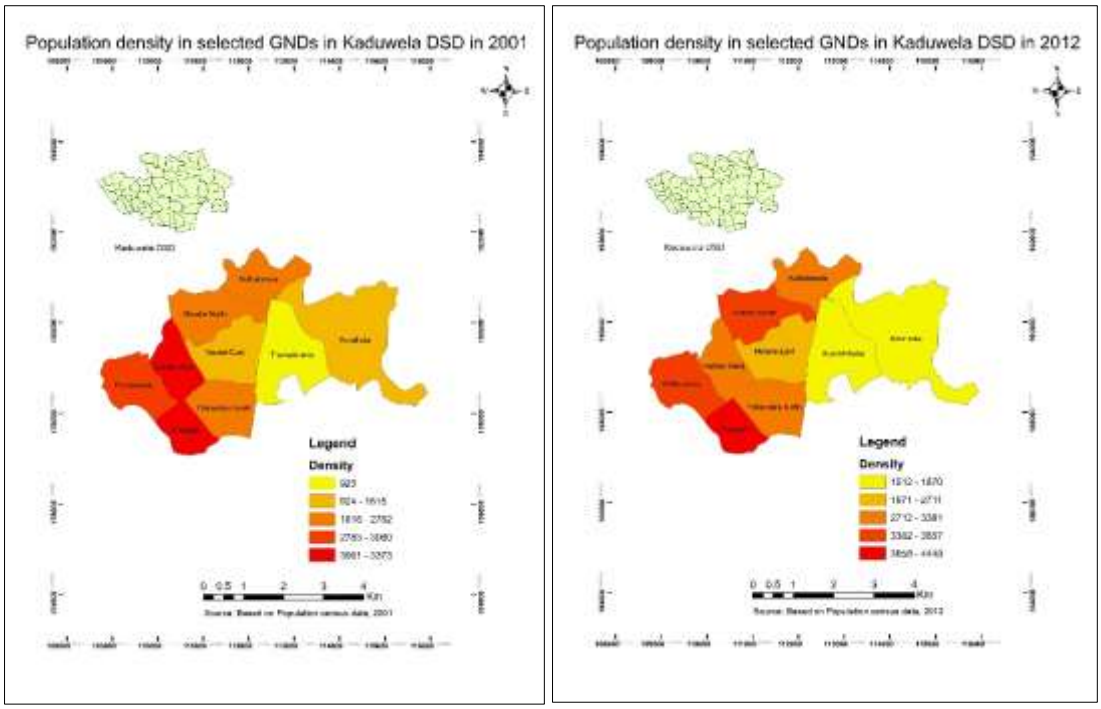

Figure 7. The population density in 2001-2012

Source: Based on population census data produced by the author

When considering population density in the selected GNDs, the highest reported from Arangala where the bird count is in its moderate status in 2009. The population density in 2012 has increased by the number than in 2001(Fig7). Every GND displayed a reduction in the number of avian species utilizes rice fields. It was revealed that the extent of paddy has reduced from 1975 to 2019 about 41 Km^2 to 23. 9 Km^2 which is also proved by the literature (Ranaweera and Rathnayake, 2017). The correlation between bird count and population shows a negative relationship in 2001 (0.486) while in 2012 (0.523) demonstrating a bit positive relationship. According to the bird count in 2019 a significant positive relationship revealed (0.805) for the projected population in 2022, indicating the population growth has a positive contribution to avifauna reduction since the population growth alter the land cover and land use of the area.

IV. Conclusion

It was revealed that the most vulnerable group of avian species utilize rice fields were waterbirds and waders. Thus it is important to study further to obtain more information on waterbird and waders use of rice field or agricultural wetlands to determine whether they function as their main habitat or alternative habitat or primary foraging sites as agricultural wetlands continue to decrease in extent and its quality due to population growth and urbanization in this area. Being an important indicator of the ecological condition and productivity of wetland ecosystems, and are one of the key attributes of the biodiversity of wetlands waterbirds are a really important group of species. Approximately 164 species of waterbirds belonging to 23 families have identified in the country. More species recorded in the area and the findings of the study reveal that this area is important for waterbirds and waders. However, if the current rate of land use and land cover change continues or doubled within a few years the extent of agricultural wetlands will decline resulting loss of habitat and biodiversity, avifauna in particular.

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