

# Forest Reserves in Urban Landscape: Case of Udawattakele and Dunumadalawa Forest Patches in Kandy, Sri Lanka



Lalitha Dissanayake and Nilukshi Perera

**Abstract** Urban forests play a significant role in urban space since their provision of ecosystem services. The study focuses on two urban forests in Kandy City, Sri Lanka: Udawattakele and Dunumadalawa. The aims are to identify the current status of the ecosystem services and the main challenges in maintaining two urban forest patches. We used field surveys, observations, and interviews to identify changes in forests and services. Reduction of forest and species changes were studied using Google maps and image analysis. The city's forest cover decreased from 64 to 48.9% in 20 years. As a result, the water level in Kandy Lake decreased, followed by the rapid development of the urban heat island effect, species degradation, and spread of diseases. Unbalanced increment of fauna species negatively influenced food supply level. Urban forests impact local weather by reduction of land surface temperature, air pollution, and air purification. Moreover, examined forest patches help to supply purified water to Kandy City. The decrease in urban forest patches makes the city more vulnerable. Thus, re-plantation, proper boundary demarcation, and adopting appropriate management strategies represent current city needs.

**Keywords** Urban forest · Ecosystem services · Udawattakele · Dunumadalawa · Sri Lanka

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## 1 Introduction

### *1.1 Urbanization, Urban Ecosystem Services, and the Role of Urban Forests*

In the contemporary world, urbanization is heading toward new concepts. These include urban nature, urban ecosystem services and disservices, quality of life (Sieber and Pons 2015), urban green and blue infrastructure, Millennium Ecosystem Assessment (MEAB), etc. Urban areas are characterized by high population densities and a network of non-natural, built-up infrastructure (Sanders 1984). Urban ecosystem services are defined as the benefits people obtain from ecosystems (MEAB 2005). Urban ecosystem services are provided by different green spaces including urban forests, parks, cemeteries, gardens, and yards and others, and blue spaces including streams, lakes ponds, etc. (Elmqvist et al. 2015). Urban forests can be defined as the forests or forest-like vegetation in and around urban environments that appear in different compositions (Patarkalashvili 2017). Urban forests play a major role in urban space since they provide a large portion of ecosystem services to the urban areas. They provide four categories of ecosystem services (TEEB 2011):

- Provisioning: providing material or energy outputs such as food, water, raw materials, and other resources
- Regulating: maintaining the quality of air and soil, providing flood and disease control or pollinating crops, etc.
- Cultural: non-material benefits that people obtain from the ecosystems including aesthetic inspiration, cultural identity, sense of home, and spiritual experience related to the natural environment (MEAB 2005)
- Supporting or habitat services: ecosystem services that are necessary for the maintenance of all other ecosystem services such as biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat (Hassan et al. 2005).
- This study focuses on two urban forest patches: Udawattakele and Dunumadalawa in Kandy City, Sri Lanka, which are classified under green space. They play a major role in reducing urban heat and air pollution, the sequestration of carbon dioxide, supporting water demand in the city, filtering water, and providing large diversity of animals and plants.

### *1.2 Aim*

The aim of this study is to identify the current status of two urban forest patches in Kandy City (Sri Lanka), Udawattakele and Dunumadalawa. This includes the ecosystem services provided, provisioning, regulating, supporting, and cultural services. We also aim to identify the major challenges in maintaining urban forest patches.

## 2 Methodology

### 2.1 Study Area

#### Kandy City

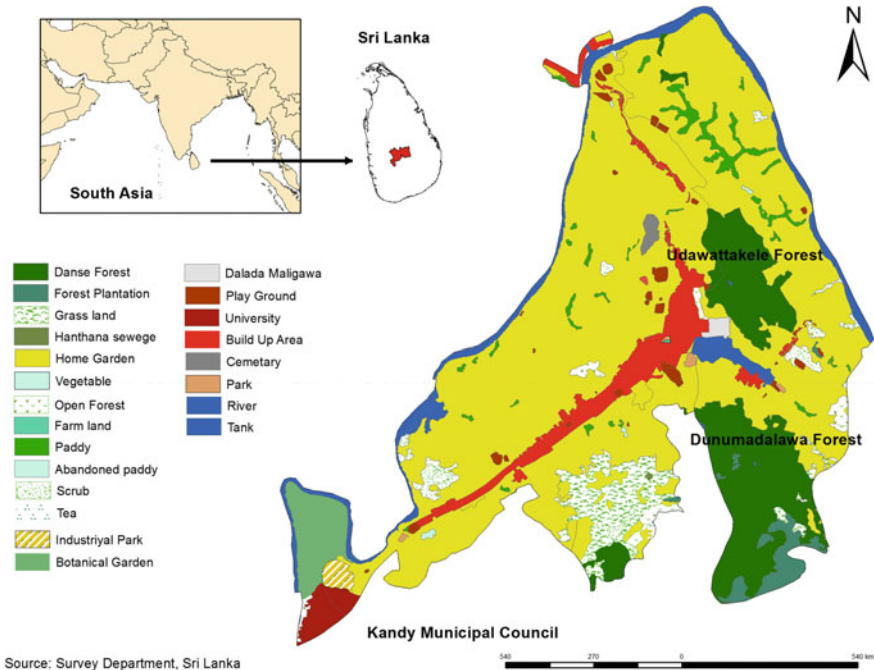
The study is based on two forest patches situated in Kandy City, which is located within the Central Highlands of Sri Lanka under Gangawatakoralya Divisional Secretariat Division (DSD). Kandy City is an important source of various ecosystem services and one of the hotspots of biodiversity on a global scale (Breuste and Dissanayake 2013). Kandy City has played a major role as a cultural, commercial, and administrative and transport center in the mountainous country for the last 600 years since its establishment as the capital of the Kandyan Kingdom in the fifteenth century (Uduporuwa and Manawadu 2017).

It has a great religious value as Temple of the Tooth Relic is situated there, and UNESCO declared it as a world heritage site in 1988. It covers an area of 28.53 km<sup>2</sup>, and as of 2012, the population of Kandy district is 1,375,382, where 158,561 of population is concentrated in Kandy Four Gravets and Gangawatakoralya, the divisional secretariats of and near Kandy City. The city is located in a valley bottom in between mountain ranges including Hanthana, Kadugannawa, and Knuckles mountain range. River Mahaweli bounds it from North, East, and West. When entering the city, Balana, Balakaduwa, Galagedara, Ginigathena, and Hunnasgiri passes are met. Figure 1 shows the Udawattakele and Dunumadalawa forest patches located within the Kandy Municipal Council.

#### Udawattakele

Udawattakele is located in the eastern part of the city. It is within walking distance of the center of Kandy town (Nyanatusita and Dissanayake 2013). This forest has existed since the Kingdom era, and it was proclaimed as a Crown Forest Reserve in 1885 and as a wildlife sanctuary in 1938. At present, it covers an area of 1.04 km<sup>2</sup>. Udawattakele consists of secondary formation of flora where approximately 460 plant species can be found. Plant species consist of 135 tree and shrub species and 11 lianas. Also, there are 58 indigenous tree species (7 endemic), 61 indigenous shrub and small tree species (7 endemic), 31 indigenous herbs (3 endemic) including 12 orchids, and 57 indigenous lianas, creepers, and vines (4 endemic) (Nyanatusita and Dissanayake 2013).

Udawattakele forest is also a famous bird watching site, and both local and foreign people visit regularly for bird watching. Here, approximately 80 bird species, 32 butterfly species (Chandrika 2016), and 9 endemic land snails, mammals, reptiles, amphibians, and snakes (Nyanatusita and Dissanayake 2013) can be seen. A rare lizard was found at this forest called "Hump nosed lizard" (*Lyriocephalus scutatus*) according to the list of insects prepared by Dr. Mrs. Thelma T. P. Gunawardena (Karunaratna 1986).



**Fig. 1** Map showing the two urban forest patches: Udawattakele and Dunumadalawa within Kandy City. Design by Lalitha Dissanayake and Nilukshi Perera

### Dunumadalawa

Also known as Walker state or “Waraka watta,” Dunumadalawa is situated on the edge of the Hanthana mountain range in the southern side of the city. This is a semi-isolated mid-country wet zone forest (Hettiarachchi and Wijesundara 2017). It covers an area of 4.8 km<sup>2</sup> and is a secondary growth forest since the site has been used earlier for tea and cocoa plantations. At present, few primary forest patches are remaining in the forest reserve (Hettiarachchi and Wijesundara 2017).

Dunumadalawa was an active estate until the early 1900s. Then, it was released from plantation use such as tea, coffee, and cocoa and allowed to naturally regenerate, with some active reforestation of native plant species since 2000 (Kittle et al. 2014). Vegetation cover consists of a canopy layer and subcanopy layer of mixed plant species with native plants. The forest is characterized by grasslands, pine plantations, and woody areas. When it comes to fauna species, the forest consists of 13 endemic bird species and 29 endemic sub-species (Hettiarachchi and Wijesundara 2017). This forest is important to the Kandy City since it serves as a catchment area to provide water to Kandy.

## 2.2 Data Collection

### Ecosystem Services

A review on secondary data from research papers, books, online articles, and newsletters was carried out in order to collect data about ecosystem services, including provisioning, regulation, supporting, and cultural. Moreover, field surveys and observations were done within the two urban forest patches to collect data about damages to fauna and flora species, identifying specific animal trails between forest reserves and urban space, vegetation types, and areas where invasive species spread. Stakeholder interviews were done with randomly selected dwellers within the buffer area to collect data about status and degradation of ecosystem services provided by the two forests including food provisioning, and threats for native fauna and flora species (i.e., monkeys and pigs).

### Challenges

Challenges of the urban forest patches were considered mainly by Google map analysis to identify the reduction of the forest area (reason: small scale encroachment); image analysis to figure out the degradation of native species and massive increment of invasive species; field survey to identify increment of invasive species; and observation and stakeholder interviews to figure out the encroachment by surrounding dwellers, several threats they faced by fauna species (i.e., monkeys and pigs) and degradation of native species according to them. Secondary data sources were used to identify the major challenges and solutions that were taken by the government.

## 3 Results

### 3.1 Ecosystem Services

#### Provisioning

Provisioning of food and water can be specifically identified within the two urban forest patches. The map analysis, field observation, and stakeholder interviews reveal that originating streams from Udawattakele forest reserve directly provide water for paddy lands within the city limits and indirectly supply water for many other different purposes such as usage for home gardens. This was further evidence that the streams fed paddy fields in Natha Devala and paddy fields in palace below Lewella Road and in Dumbara Valley (Karunaratna 1986).

Dunumadalawa forest also acts as a catchment to provide water to Dunumadala Tank which was built in 1865 (Ministry of Megapolis and Western Development 2016) and Roseneath Tank, both of which supply water to Kandy City (Dharmasena et al. 2001). The study reveals that originating streams from Dunumadalawa forest

reserve directly provide water to fulfill the water requirement of Kandy Municipal Council area. Mainly, water supply from Dunumadalawa catchment is used for drinking purposes. Water for Kandy Middle Stream as known as *Meda Ela* is supplied from this catchment, and most of the people from low-income households, those who live along the stream, use this water for fishery industry, laundry services, etc., to generate their income. Thus, Dunumadalawa forest improves their livelihood by providing water. Dunumadalawa water treatment system is one of the main water supply systems along with Getambe Water Treatment plant and Greater Kandy Water Supply System. Dunumadalawa water plant was established in 1963, and it is sourced by Dunumadalawa Tank. This plant is used to supply safe drinking water to Kandy City. This impacts on reducing water borne health issues, thus improving livelihood opportunities (Ministry of Megapolis and Western Development 2016). Moreover, these forests help to control urban flooding.

In addition, food is provided for animals that live in the forest reserve. Providing food is one of the most important provisioning services for fauna species within the forest. In Udawattakele mainly various bird species, butterflies, mammals, reptiles, etc., are the fauna species that depend on the food provided by the forest.

### Regulating

Dunumadalawa and Udawattakele forest reserves regulate mainly the urban heat within the city limit. Urban heat is higher within the built-up area and lower within vegetation cover. The stakeholder interviews revealed that nearly 50 years ago Kandy and the surrounding landscape had a very cold atmosphere. As a dweller stated, most of the time during the year they had to wear warm cloths to prevent getting cold. Nowadays, in urban premises the situation is totally different and many people try to reach buildings with air conditioners. According to the field survey, the forested area and surrounding places have low heat with a smooth weather. This situation changes in built-up areas such as near Kandy City Center where temperatures are higher. Thus, the two urban forest patches act as cooling machines to reduce the urban heat and to provide a suitable weather condition.

According to recent researches, air in Kandy is three times more polluted than in Colombo (Illeperuma and Abeyrathne 2006). Main reasons for the air pollution include the fact that the road network is not enough to control the traffic congestion, the air is circulated within the city due to its topography, and polluting domestic and industrial activities. Udawattakele and Dunumadalawa forest patches absorb air pollutants such as Sulfur Dioxide (SO<sub>2</sub>), Nitrogen Dioxide (NO<sub>2</sub>), and Particulate Matter (PM10). These pollutants are higher in the Good Shed area (Premasiri et al. 2012), where a large number of vehicles is concentrated. But the amount of air pollutants is lower within the dense vegetation cover. As an example, this amount is lower in Kandy Wales Park which is an urban park with various plant species. Therefore, these two dense forests contribute to regulating the air by absorbing air pollutants and filtering the air. Table 1 shows Sulfur Dioxide, Nitrogen Dioxide, and Particulate Matter concentration in 5 locations within Kandy City.

The two forest patches located within the city help to purify the water supplies to urban space. Biochemical Oxygen Demand (BOD), Total Nitrogen (as N), Total

**Table 1** Concentration of sulfur dioxide, nitrogen dioxide, and particulate matter in 5 locations (Premasiri et al. 2012)

Location	Concentration of air pollutants $\mu\text{g}/\text{m}^3$		
	Sulfur Dioxide ( $\text{SO}_2$ )	Nitrogen Dioxide ( $\text{NO}_2$ )	Particulate Matter (PM10)
Tennis court	24	23	56
Trinity College	31	36	65
Wales Park	19	23	30
Tooth Temple	20	24	42
Good Shed	54	51	89

Suspended Solid (TSS), and Temperature parameters impact water pollution. Amount of BOD and Total Nitrogen in Kandy Meda Ela changes from place to place. These amounts are within the tolerance limits near forest patches while they exceed tolerance limits in urban and other impervious space. Tolerance limit of BOD is less than 5 mg/l but this limit is exceeded in Meda Ela as of 2014, where during rainy season 11.7 mg/l is shown in the beginning of the stream. However, this amount is reduced to 11.4 mg/l in the middle reach since a stream from Dunumadalawa forest connects to Meda Ela in the middle reach (Dissanayake 2014). This trend can be seen in the concentration of Total Nitrogen. The tolerance limit of N is 2–6 mg/l, and in the beginning of the stream, it shows 6.6 mg/l, and in the lower parts, it shows an amount as high as 16.9. In the middle reach, however, it only shows 1.9 mg/l (Dissanayake 2014).

## Supporting

Udawattakele and Dunumadalawa forest reserves maintain nutrient cycles to feed fauna and flora species that live in the forest areas. Moreover, these forest patches serve as a habitat to fauna and flora species within the urban space.

Therefore, various types of fauna and flora species, especially endemic species, can be seen within the forest cover.

Udawattakele contains a great variety of native and endemic shrub and small tree species, many with medicinal and economical value such as betel nut palm (*Areca concinna*), wild pepper (*Piper zeylanica*), and wild cardamom (*Amomum graminifolium* & *Amomum echinospermum*) (Nyanatusita and Dissanayake 2013). Bird species include brown-capped babbler (*Pellorneum fuscocapillus*), Ceylon shikra (*Accipiter badius badius*), and crested serpent eagle (*Spilornis cheela spilogaster*). Moreover, it is the home for high variety of mammals, reptiles, and butterfly species.

Dunumadalawa forest consists of different types of habitats such as woody areas, grasslands, and pine plantations (Hettiarachchi and Wijesundara 2017). Jackfruit and mango trees are dominant here, and canopy and subcanopy layers consist of mixed plant species. A high concentration of fauna species can be seen, and total endemism of fauna species is 41.6% (Hettiarachchi and Wijesundara 2017). The two urban forest patches provide supporting services to all these flora and fauna species.

Even though air pollution is high in Kandy City, air quality is balanced by producing atmospheric oxygen from the two forest patches. However, the production of atmospheric oxygen decreases with the decrement of the forest covers. Along with that, air quality also decreases over time.

### **Cultural**

The two urban forest patches, especially Udawattakele, provide various cultural ecosystem services since they have a long history of thousands of years. Until the nineteenth century, Udawattakele remained a forbidden forest reserved only for the royal family. Thus, it was named as “*Tahanchi Kale*” (Forbidden Forest). This forest was strictly protected by Kandyan kings and used by queens who bathed in the pond and used the forest as a pleasure garden. Also, it was used as a defense to escape whenever invaders attacked the city (Karunaratna 1986).

It is reported that Senkada Brahmin who lived in a cave in Udawattakele brought a Bodhi Tree plant and planted it in the present site of Natha Devalaya. This forest was inhabited by Buddhist monks who practiced meditation. It contains three Buddhist forest monasteries, i.e., Forest Hermitage, Senanayakaramaya, and Tapovanaya, and three cave dwellings for Buddhist monks, i.e., Cittavisuddhi-lena, Maitri-lena, and Senkadandagala-lena. During the British era, an Anglican church was built here to establish a school (Karunaratna 1986).

After nineteenth century, with the British rule, the land of the Udawattakele was used for different purposes, and thus, the total forest cover had decreased. The land near the Temple of the Tooth was used to build the Kandy Garrison Cemetery. Moreover, coffee plantations, town expansions, houses, coffee gardens, etc., were built within the forest area. The forest was also used as a source of wood supply for fuel. Various paths which were built during British rule can be seen within the forest reserve, such as Lady Horton’s Drive and Lady McCarthy’s Drive. With the time, British rulers understood the importance of the forest and declared it as a forest reserve. Udawattakele is one of the first forests to be proclaimed as a forest reserve in Sri Lanka (Karunaratna 1986).

Even today, Udawattakele provides cultural services such as recreational values since it is one of the major tourist destinations in Kandy City. Even though air pollution becomes a huge problem within the area, still Kandy is one of the most important tourist destinations because the two forest patches balance the cultural values of the city. Both local and foreign visitors come to the forest especially for bird watching. School and university students regularly visit the forest and the Nature Education Center for educational purposes. Scientists and university students have used the forest for carrying out research on trees and animals (Nyanatusita and Dissanayake 2013). Tourist attraction is improved by providing cycle services, establishing suitable places to rest, establishing circuit bungalows, etc.

Dunumadalawa forest reserve consists of secondary growth forest since it had been used as tea and cocoa plantation before. This was an active estate until the early twentieth century (Hettiarachchi and Wijesundara 2017). This forest is not open for public to visit since it is a strict nature reserve. Therefore, recreational activities are



not provided by the forest reserve, but it acts as a major urban forest which provides many other cultural services including scenic beauty.

### 3.2 Challenges for Ecosystem Services

#### Provisioning

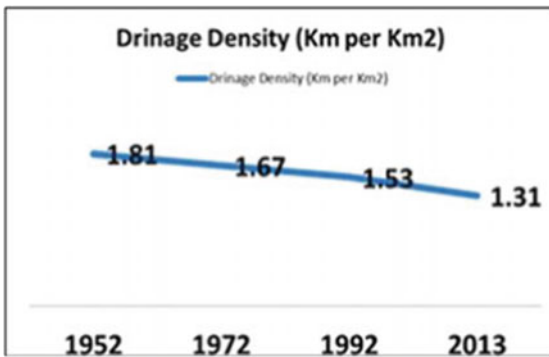
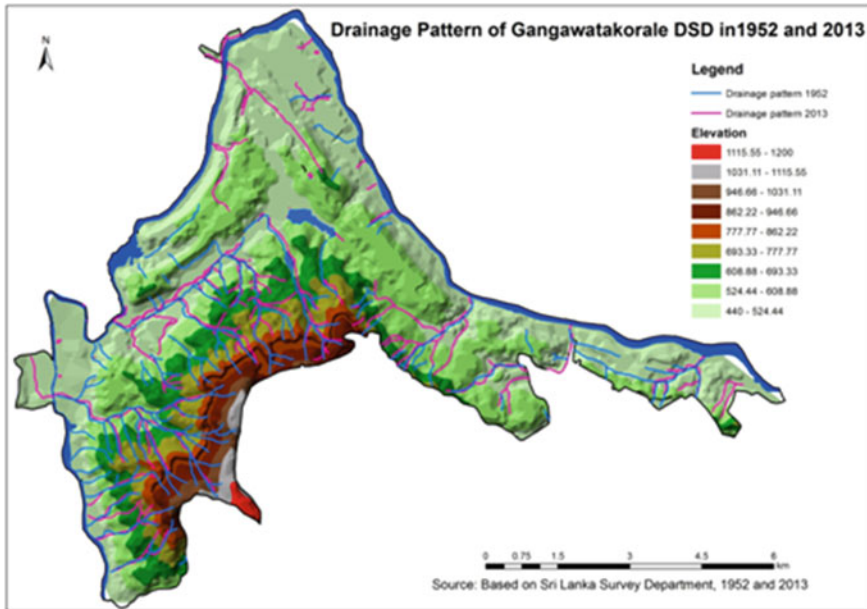
The pattern of decreasing water levels in the Kandy Lake and streams has occurred with the decrement of forest cover. According to the dwellers who live near the forest patches, vegetation cover has decreased in small scale during past decades due to increment of built-up areas. Forest cover of the Kandy City is decreased from 25,875 ha (64%) to 19,563.9 ha (48.9%) within 20 years (1996–2017). Impervious surface has been increased from 911.3 ha to 7474.6 ha during the same period of time. Based on map analysis and field survey, the drainage density of streams that are fed by Dunumadalawa catchment shows a decreasing trend over time. Streams that supply water to Kandy Middle Lake or *Meda Ela*—namely Siyambalange Kumbure Ela, Hal Oya, Meda Kumbure Dola, Ellewela Ela, and Dunumadalawa Ela—show a gradual decrement of drainage density. Thus, it is clear that these streams will be dried up over time due to lack of water. Below Fig. 2 shows the drainage pattern of Gangawatakorale DSD and decreasing trend of drainage density in Meda Ela from 1952 to 2013. As shown in Fig. 2, most of the streams vanished during this time period. Also, new streams were generated in some areas. Increase of impervious land is one of the major reasons impacting on decrement of streams within city limits.

Decreasing pattern of food supply occurs also in the two forest patches with the unbalanced increment of fauna species. Especially monkey and pig populations are rapidly increasing; thus, food supply is not sufficient to feed all animals who live in the forest. Hence, most of the fauna species come to the urban space during daytime seeking food and go back to the forest during nighttime.

#### Regulating

One of the most important challenges for regulating services is the rapid increment of the urban heat within the city. Urban heat increases with the increase of impervious land. Surface temperature differences have occurred with the increase of impervious surfaces and the decrease in forested areas in the city. In 1996, average land surface temperature was 25.2 °C, and it increased during past 2 decades where in 2017 average land surface temperature was 27.4 °C (Rangalage et al 2018). With the increment of surface temperature, some flora and fauna species are degraded. As people who live in surrounding areas said, some fauna and flora species have vanished since they could not adapt to the increasing temperature.

These two forest patches control waterborne diseases (e.g., cholera and typhoid), airborne diseases (e.g., lung cancer and influenza), and diseases caused by urban heat (e.g., heat cramps and heatstroke) by regulating the water supply, air quality,



Total length of the stream decrease around 12–15 km (from 1952 to 2013)

**Fig. 2** a Map showing the drainage pattern of Gangawatakorale DSD in 1952 and 2013. Design by Lalitha Dissanayake and Nilukshi Perera, b Graph showing the decreasing pattern of drainage density in Kandy Meda Ela from 1952 to 2013 (Dissanayake 2016)

and urban heat. But with the quantitative and qualitative degradation of the forest cover, significant diseases have occurred. Majority of people who live within the city limits suffer from coughing, lung diseases, allergies, etc. According to the recent researches, severe coughing, known as “*Kandy kassa*,” is one of the significant health issues. It is a cough that lasts more than a week or a month (Gamage 2017) and is caused by smoke released by the vehicles. Increased number of heart patients and respiratory diseases among young and old people are also the health issues due to air pollution (Siribaddana et al. 2010).

## Supporting

Maintenance of the nutrient cycles becomes a problem due to a lack of food within the forest areas. Thus, fauna species come out of the forest seeking food. This negatively impacts on surrounding dwellers since these fauna species damage their properties, steal food, etc. Also, some of the fauna species visit urban space on a daily basis. Some of the regular routes of these species, especially monkeys and pigs, were identified by observation. Therefore, daily mobility of fauna species was identified.

## Cultural

Tourists and local people who visit Udawattakele forest reserve may harm the cultural values of the forest by polluting the forest area, damaging ancient places, damaging native flora and fauna species, supplying unnecessary food to fauna species (specially to monkeys), etc. According to the observation, some flora species are damaged by the visitors by trampling, scratching, and bark damage.

## 4 Discussion

Over the last 550 years (since the beginning of Kandyan Kingdom in 1499), virgin forested landscape converted into urbanized landscape. Earlier nearly 25 km<sup>2</sup> of the area was covered by forest but at present it is reduced to approximately 6 km<sup>2</sup>. Likewise, over 50 years' forest cover has been reduced globally due to human activities including rapidly growing demands for food, fresh water, timber, fiber, and fuel (MEAB 2005). With the reduction of forest cover, ecosystem services provided by the forests also are reduced over time.

The remaining two urban forest patches give enormous services to the entire landscape and its organisms. More than 500 fauna species who live in Udawattakele and Dunumadalawa forests depend on food provided by the forest cover, and more than 150,000 people living in Kandy City depend on water supply from the forest patches. This is proved by various researches and, as Holdren and Ehrlich (1974) state, in addition to providing goods, ecosystem services support life through generation and preservation of soils and renewal of their fertility, pollination of crops and natural vegetation, and cycling and movement of nutrients.

The remaining forest patches help to control the urban heat and control the air pollution to some extent. Urban forests impacts on local weather and helps to reduce Land Surface Temperature. Forest patches control urban heat by limiting moisture loss and reducing surface temperature. As argued in some researches, a 10% increase in tree canopy cover may result in a 3–4 °C decrease in temperature (Gill et al. 2007).

This research evidenced differences of concentration of air pollutants in some locations within the urban area. A smaller amount of air pollutants is concentrated within vegetative cover such as Wales Park while higher amount of air pollutants is concentrated within urban space. Therefore, these forest patches definitely contribute to reducing the air pollution by absorbing air pollutants. According to

recent researches, urban forests provide ecosystem services such as air purification, global climate regulation, urban temperature regulation, noise reduction, runoff mitigation, and recreational opportunities, as well as ecosystem disservices, such as air quality problems, allergies, and damages to infrastructure (Escobedo et al. 2011; Gómez-Baggethun and Barton 2013).

The two forest patches help to supply purified water to Kandy City. The beginning part of the Kandy Meda Ela represents high levels of pollution (BOD, DO, Total N). The middle reach of the stream represents low levels of water pollution compared with the beginning reach. The reason is that one substream originating from Dunumadalawa forest brings clean water and connects with the main stream, thus controlling the pollution levels of water. It is clearly evidenced by this research.

Udawattakele and Dunumadalawa provide habitats for various fauna species including endemic species. Also, many types of flora species (most of them are native) can be seen within the vegetation area. Since these two urban forest patches are the remaining areas for survival of many flora and fauna species within an urbanized and impervious space, providing habitats can be considered as one of the most important ecosystem services. Since most of the native and endemic species live within the forest patches, it is clear that these forests contain huge biodiversity within a small area. According to MEAB (2005), ecosystems are spatially and temporally explicit units that include all living organisms, the abiotic environment, and the interactions between the two in a given location (MEAB 2005).

Production of atmospheric oxygen is one of the ecosystem services provided by forests. Amazon Forest, which covers 5.4 million km<sup>2</sup>, produces 20% of the planet's atmosphere (Science alert 2019). Likewise, production of oxygen by forests helps regulate the air quality and to improve the living conditions of human and other organisms within city limits.

Udawattakele has had a cultural value from the beginning, which it has differed during different time periods. Before the kingdom era, it had a religious value while during the kingdom era it was used only by royal elites. It had many recreational values during the British era since many specific locations such as Garrison Cemetery and various paths were added. At present, it serves as a famous tourist destination. Dunumadalawa forest also provides cultural values since it covers a relatively large area within the urban space. Cultural values are essential for Kandy City since it is stressed by increasing population and urbanization. The importance of cultural values provided by urban forests is identified by other researches. As Botkin and Beveridge (1997) suggest, vegetation is essential to achieving the quality of life that creates a great city and that makes it possible for people to live a reasonable life within an urban environment.

Udawattakele and Dunumadalawa forest reserves have faced several issues or challenges for decades. As observation campaigns, field surveys and stakeholder interviews reveal the main reasons behind those issues which are as follows:

- **Population pressure and political involvement.** The topography of Kandy is not favorable for high population growth since it is situated in the bottom of a valley. Thus, growing population pressures the two urban forest patches located within the

city limits. Also, political involvement impacts the decrement of forest cover with the growing human needs. However, it can be said that this situation has changed since these forests are protected as a sanctuary and a strict nature reserve.

- Encroachment of peripheral area. At the beginning, the forest boundary of Udawattakele was originally the Kandy Lake, the whole length of Trincomalee Street up to the Watapuluwa ferry on one side and on the other side, Malabar Street, then down Lewella road to the Lewella ferry and on the fourth side, the Mahaveli River. The forest covered over 4.05 km<sup>2</sup> during the Kingdom era, and then, it reduced to 1.52 km<sup>2</sup> during British rule and at present it only covers 1.04 km<sup>2</sup> (Karunaratna 1986). This extent is stable since the forest was declared a sanctuary in 1938. However, due to encroachment of peripheral areas and land grabbing, forest cover has been reduced during the past decades. This encroachment is done by dwellers who live in surrounding areas. Moreover, people illegally enter the forest area to collect fuel wood and other resources. This leads to degradation of resources. Forest Department takes actions to control these illegal encroachments and entrances by making fences around the forest reserve and by demarcating the boundary. But still it is not successful due to lack of trained officers in the department. Small scale encroachment can be seen also in Dunumadalawa forest reserve. Proper boundary demarcation is also needed here.
- Growing population of fauna species. Especially population of monkeys and pigs has been growing within the Udawattakele. Due to lack of food sources in the forest area and easy access to food in surrounding areas, monkeys and pigs go to urban space for food during daytime and go back to the forest at night on a daily basis. Thus, forest reserve has been used only as shading rather than a habitat by them. Since they have easy access to food, annual population is increasing and this may jeopardize the sustainability of the forest reserve. Also, these fauna species damage the surrounding urban space by stealing food, damaging properties, digging holes in the ground, frightening foreigners and locals, etc. Thus, proper management actions are needed in order to ensure the sustainability of the forest reserve.
- Increment of invasive species. Forest Department has been involved in trying to prevent illegal hunting, wood cutting, and encroachment in Udawattakele but the greatest threat is the fast growth of invasive, exotic tree, shrub, and creeper species (Nyanatusita and Dissanayake 2013). These species replace native flora species and negatively impact on animals that depend on them, since invasive species do not provide any nourishment to native animal and flora species. Most of the invasive plants were introduced by British administrators in order to gain economic benefits from them. In Udawattakele, Peru balsam (*Myroxylon balsamum*), is the most aggressively spreading invasive tree, and therefore the most in need of control. This is widely used in perfumes, shampoos, and medicines (Nyanatusita and Dissanayake 2013). The devil's ivy or golden pothos (*Epipremnum aureum*) is the second major threat since it completely covers several hectares of the forest floor and tree trunks, leaving no space for other vegetation and young trees. Mahogany (*Swietenia macrophylla*), Ecuador laurel or salmwood (*Cordia alliodora*), hard milkwood (*Havari nuga*) (*Alstonia macrophylla*),

Panama rubber (*Castilla elastica*), coffee shrubs (*Coffea robusta*), glow vine (*Saritaeta magnifica*), Bengal trumpet (*Thunbergia grandiflora*), star apple tree (*Chrysophyllum cainito*), African tulip tree (*Spathodea campanulata*), rusty pittosporum (*Pittosporum ferrugineum*), Philippine evergreen (*Aglaoneama communatum*), maidenhair fern (*Adiantum pulverulentum*), etc., are the other invasive species that were introduced to the forest and now became a threat (Nyanatusita and Dissanayake 2013). Forest areas between the Temple of the Tooth, the Forest Department at the western entrance, and the slopes northeast of the royal pond are the areas most severely degraded due to invasive species. Even though Forest Department addresses the rapid growth of invasive species within the forest, it does not have a proper management plan to destroy these creepers and upgrade the status of native species.

In Udawattakele, the remaining area where native flora species exist has a rich biodiversity including numerous fauna species. Udawattakele contains native and endemic shrub and small tree species that have economic and medicinal values. These species include endemic wild betel nut palm (*Areca concinna*), orangeberry (*Dysoxylum ficiforme*), fragrant orange jessamine (*Murraya paniculata*), wild pepper (*Piper zeylanica*), and herbs such as wild cardamom (*Amomum graminifolium*). Native trees within the forest area are kitul palm (*Caryota urens*), cinnamon (*Cinnamomum verum*), longan (*Dimocarpus longan*), soapnut (*Sapindus emarginatus*), and endemic ceylon paper mulberry (*Broussonetia zeylanica*). Moreover, the canopy layer consists of native trees such as blackboard tree (*Alstonia scholaris*), wal-munamal (*Aphananthe cuspidata*), wal del (*Artocarpus nobilis*), red silk-cotton (*Bombax ceiba*), and Indian mahogany (*Chukrasia tabularis*) (Nyanatusita and Dissanayake 2013). Udawattakele consists of various fauna species such as mammals including wild boar (*Sus scrofa cristatus*), muntjac deer (*Cervus muntjak*), Indian porcupine (*Hystrix indica*), the Sri Lankan spotted chevrotain (*Moschiola meminna*), and Indian pangolin (*Manis crassicaudata*); reptiles including green pit viper (*Trimeresurus trigonocephalus*), Sri Lanka cat snake (*Boiga ceylonensis*), and banded kukri (*Oligodon arnensis*); birds including brown-capped babbler (*Pellorneum fuscicapillus*), ceylon shikra (*Accipiter badius badius*), and crested serpent eagle (*Spilornis cheela spilogaster*), butterflies, and fireflies (Nyanatusita and Dissanayake 2013). These fauna and flora species are currently being threatened, and a proper management plan is needed in order to conserve them.

Invasive species are dominant in some areas of the Dunumadalawa forest reserve. Here canopy and subcanopy are characterized by mixed plant species including native species. Understory of the forest is covered primarily by invasive species such as yakada maran (*Myroxylon balsamum*), large-leaf mahogany (*Sweetinia macrophylla*), and ceylon almond (*Canarium zeylanicum*). Because of these invasive plant species, unmanaged tea, cocoa, and coffee plants have been destroyed (Kittle et al. 2014).

## 5 Conclusions

This study was done to identify ecosystem services provided by the urban forest patches and the challenges for the forests. Reduction of urban forest patches makes the city more vulnerable to urban heat, air quality changes, and water quality changes. Thus, implementation of re-plantation programs is needed in order to increase urban green space and to increase urban ecosystem services. Especially re-plantation of native flora species is a contemporary need since native species are degraded due to rapid growth of invasive species. Implementation of a proper management system within the forest reserves is needed in order to reduce encroachment. Also, proper boundary demarcation is a contemporary need. A useful management plan should be implemented to control and balance the growth of specific fauna species (especially monkeys and pigs). Distribution of invasive flora species should be controlled in order to maintain nutrient cycles and save native flora and fauna species. Since most of the people do not identify the values of forest covers, awareness programs should be held at school level, university level, and community level.

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