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Spatio-temporal Analysis of Urban Growth Pattern and Relevant Environmental Consequences: A Case Study of Kandy City and Surrounding Area

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Abstract

The earth's natural landscape changes over time and spatially, and it also influences the creation of various environmental issues. Urbanization is inevitably one of the most important development indicators and is a rapidly growing dynamic process. Especially the cities in the hill country of Sri Lanka are also facing the adverse effects of rapid urbanization due to their economic and social significance. This study examines the spatiotemporal pattern of urbanization and the relevant environmental consequences in Kandy City, Sri Lanka, from 1994 to 2021. The data required for this research were obtained from both primary and secondary and analyzed using GIS techniques and Statistical Analysis methods. Land Use/Land Cover (LULC) classification was made using a pixel-oriented supervised classification method and examined the temporal pattern of urban land changes across two-time intervals (1994–2007, 2007-2021, and 1994–2021). Variations in urbanization patterns were analyzed from 250 m to 250 m using a Multiple Ring Buffer. A ground-level study was conducted to verify the accuracy of the information obtained from the mapped data, and data were obtained from a questionnaire and

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interviews with a randomly selected 100 people living near the city of Kandy. The Pearson Correlation Analysis and descriptive statistic methods were used to illustrate the relationship between variables. The results showed that the area under Impervious Surface during the 27 years from 1994 to 2021 increased by 35.23 Km^2, while the forest cover decreased by 52.78 Km^2. The annual growth rate of the Impervious Surface can be identified as 1.30 km^2 per year from 1994 to 2021, and the forest cover has lost 1.95 km^2 per year. Depicts a positive correlation between urbanization and other variables, such as environmental pollution, climate change, waste disposal, and resource availability. Thus, the study identified a rapid increase in land area and a rapid decline in forest cover due to the growing informal urban pattern. Therefore, this research confirms that it is required to focus on sustainable urban development to address the current environmental, social and economic crisis.

Keywords: Kandy City; Urban Growth, LULC Changes; Multiple Ring Buffer; Sustainable Urban Development

Introduction

Understanding the entire earth's surface makes it possible to identify various changes in the current land use pattern spatially and temporarily. Humans have considered the earth their habitat for about a million years, which is considered a very short period, and humans, as well as other species, have lived as part of nature itself. As a result of prolonging the human life span, human beings have been able to transcend environmental boundaries and fulfil their infinite needs. As a result, the land has undergone various changes over time and changes in environmental factors.

According to the United Nations World Population Prospects (UNWPP), "urbanization is a complex socio-economic process that transforms the built environment, converting formerly rural into urban settlements, while also shifting the spatial distribution of a population from rural to urban areas. It includes changes in dominant occupations, lifestyle, culture, and behavior, thus altering urban and rural areas' demographic and social structure (United Nations, 2018). In 1920, the urban population comprised 14% of the World and reached 25% in 1950 (Weber & Puissant, 2003). In 1990, only 15% of the World's population lived in cities, while in the 20th century, this picture was fully transformed, with half the population of the World estimated to live in cities (Michael, Annez, & Buckley, 2009). Currently, 50% (3.3 billion) of the World's population lives in urban areas (United Nations, 2008). Whether in developed or developing countries, the widespread growth of urbanization is making pursuing prosperous and sustainable cities problematic. As a city grows, it will need to develop more land for public infrastructure (roads, water, and utilities), housing, and industrial and commercial use due to increasing population concentration and economic activity. Therefore, urbanization can be considered as an observable transformation of the spatial pattern of land use and land covers, such as the transformation of agricultural and forest land use into a built-up area or the gradual transformation of the rural landscape into an urban form.

During the past decades, Kandy City, Sri Lanka's last kingdom and the country's "heartbeat" in South Asia, has experienced rapid urban growth. However, due to new development projects and other human activities, the natural system is in a critical condition today. The rapid growth of Kandy City has created several environmental problems throughout the area that arise from widespread urban poverty, slum growth, high energy consumption, urban waste problem, increasing vehicular air pollution, and mismanagement of limited resources. In addition, valuable urban green cover spaces and agricultural land have also been affected due to land-use changes (JICA, 2018). This impedes the 11th goal of the sustainable development goals of Smart & Sustainable City. Therefore, spatial analysis is fundamental to understanding urban growth and Remote Sensing (RS), and Geographical Information System (GIS) techniques provide exceptional opportunities to analyze growth patterns and changes in the city.

In this context, this study aims to study the spatiotemporal analysis of -growth patterns and the relevant environmental consequences in the Kandy urban area from 1994, 2007 to 2021 and to identify and analyze the Land Use Land Cover (LULC) changes in the Kandy city and surrounding area by using remote sensing and GIS techniques and statistical analysis methods. The findings of this study can be used as essential information to improve the sustainability of future urban planning in Kandy.

Materials and Methods

Study Area

Kandy District has 20 Divisional Secretariat Divisions and 1188 Grama Niladhari Divisions (GND). Several Divisional Secretariat Divisions (DSD) from the city Centre are very important because it is an area where large-scale development projects have been and are being implemented recently. Kandy is roughly 500 meters above sea level, surrounded by mountains and hills, and has a pleasant temperature. The "Sacred City of Kandy," which includes the Temple of the Tooth Relic, is a UNESCO World Heritage Site. It has a tropical climate characterized by high rainfall and high temperatures. The dry period is from January to April. The average daytime ambient temperature is in the range of 28–32 °C, and relative daytime humidity is in the range of 63–83% (Dissanayake, Morimoto, & Ranagalage, 2019). Kandy experiences a monsoon rainfall distribution, with a long-term mean (2085 mm) and monthly rainfall of approximately 52–398 mm (Ranagalage, et al., 2018). The population of the Kandy district increased gradually from 1,048,317 in 1981 and 1,279,028 in 2001 to 1,375,382 in 2012, with an average growth rate of approximately 0.66% between 2001 and 2012. The daily transient population was approximately 100,000 in 2011. In this study, the researcher selected a 15 × 15 km geographical grid as the study area with a 7.5-km radius from the city Centre (latitude 7.293118°, longitude 80.635050°) covering 225 km^2, bounded by 7.225320° to 7.360850° latitude and 80.567086° to 80.703099° longitude. Also, the study area covers 12 Divisional Secretariat Divisions in the Kandy District.

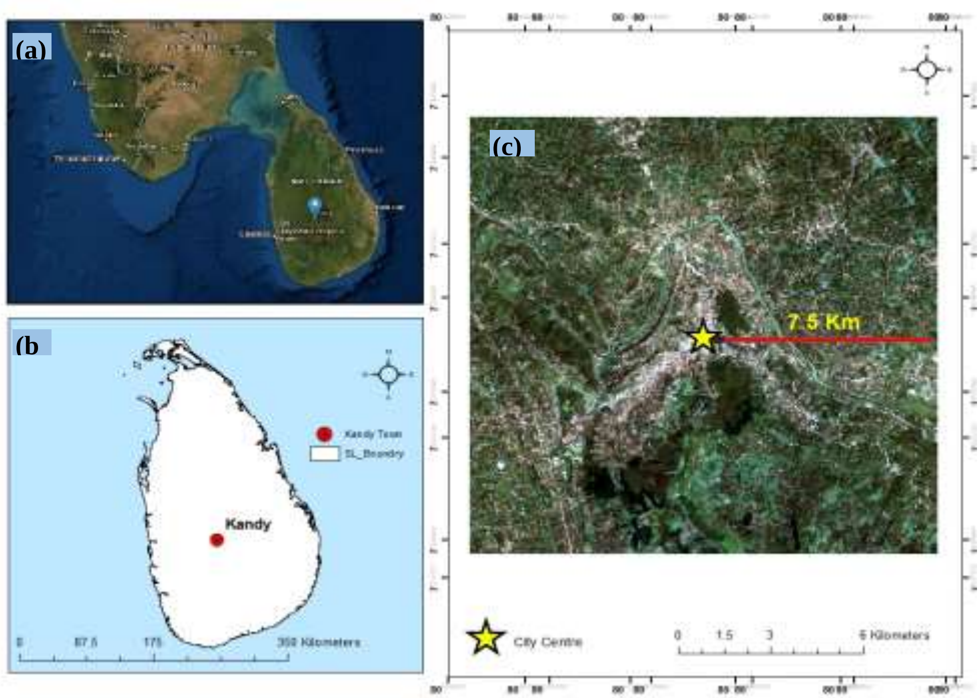

Figure 01: (a) Location of Sri Lanka in South Asia, (b) Location of the Kandy in Sri Lanka,) (c) The study area is represented by ‘ Landsat-8 image with a true-colour

Datasets and Data Preprocessing

The data required for this research were obtained from both primary and secondary. The researcher used Landsat Level 1, radiometrically calibrated and atmospherically corrected data from the United States Geological Survey (USGS). Landsat images were used to map the Land-use/Cover of the Selected Kandy area for three-time points, i.e., 1994, 2007, and 2021. These images, with a spatial resolution of 30 m, include a Landsat-5 image acquired on 14 January 1994, a Landsat-5 image acquired on 02 January 2007, and a Landsat-8 image acquired on 08 January 2021. Various methods were adopted in the data selection stage to generate quality and reliable outputs. These are; selecting cloud-free images and pre-geo-rectification using Universal Transverse Mercator (UTM) zone 44 north projection.

Table 01: Metadata of Landsat Images (1994-2007-2021)

Metadata of Landsat images			
Sensor	Landsat 5 TM	Landsat 5 TM	Landsat 8 OLI/TIRS
Landsat Sensor ID	LT05_L1TP_141055_19940114_20170115_01_T1	LT05_L1TP_141055_20070102_20161117_01_T1	LC08_L1TP_141055_20210108_20210307_01_T1
Date	14-Jan-94	2-Jan-07	8-Jan-21
Spatial Resolution	30m*30m		
Time	04:15:19 - 04:07:32 a.m.	04:48:43 - 04:46:52 a.m.	04:54:09 - 04:54:12 a.m.

1994 – Landsat 5 2007 – Landsat 5 2021 – Landsat 8

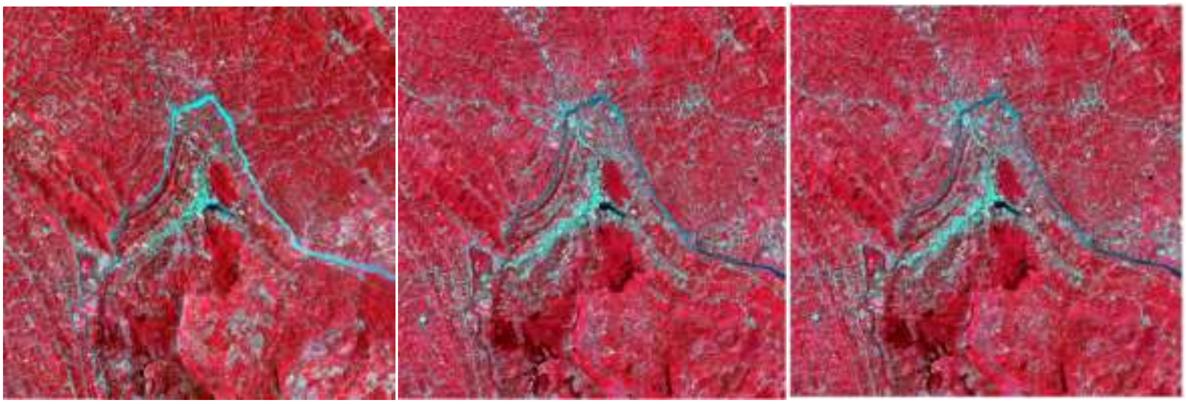

Figure 02: Landsat Images represent the study area (Color Infrared (CIR)

Primary data were used to verify the accuracy and reliability of the data obtained from the maps of this research. A questionnaire and interview methodology were used to obtain the data. Data collection was done based on two main objectives. Those are;

a. To study the impact of urban growth on the environment (questionnaire & interview),

b. To study the accuracy of the facts confirmed by the maps.

To study the impact of urban growth on the environment, independent variables and dependent variables were created in the questionnaire, and data were collected accordingly.

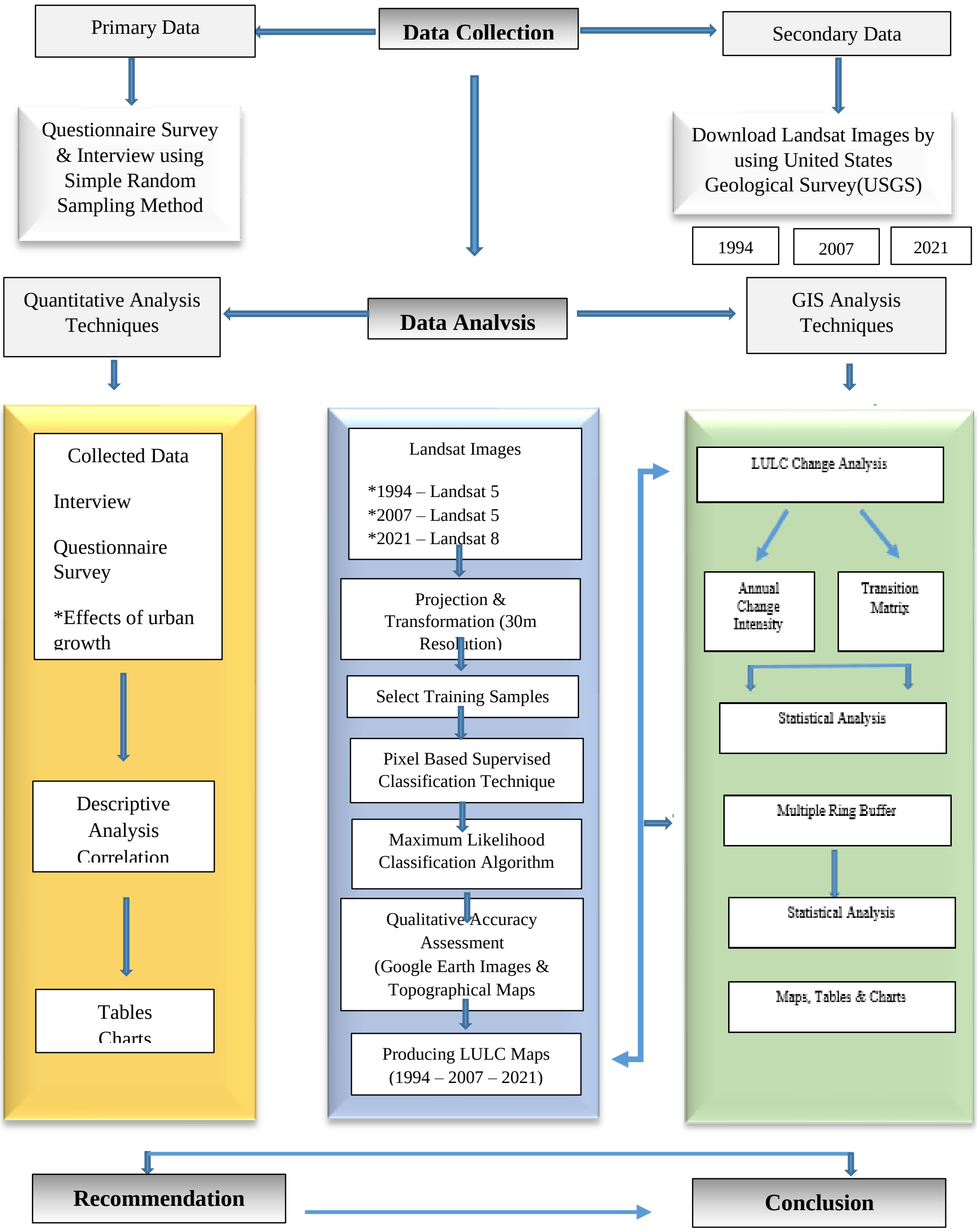

Figure 03: Workflow of the study

A hundred residents of the identified urbanized areas of Kandy, such as Rajawatta, deiyannewela, Ampitiya, Katugastota, and Tennekumbura were randomly selected based on the maps. Soft and hard copy versions of the questionnaire were distributed among the sample.

Table 02: Sample Size and Selection of Samples

Primary Data Collection Method	Sample	Sample Size	Sample Selection Method
Questionnaire Survey Unstructured Interviews	Residents o Rajawatta o Katugastota o Ampitiya o Deiyannewela o Thennekumbura	100	Simple Random Sample Method

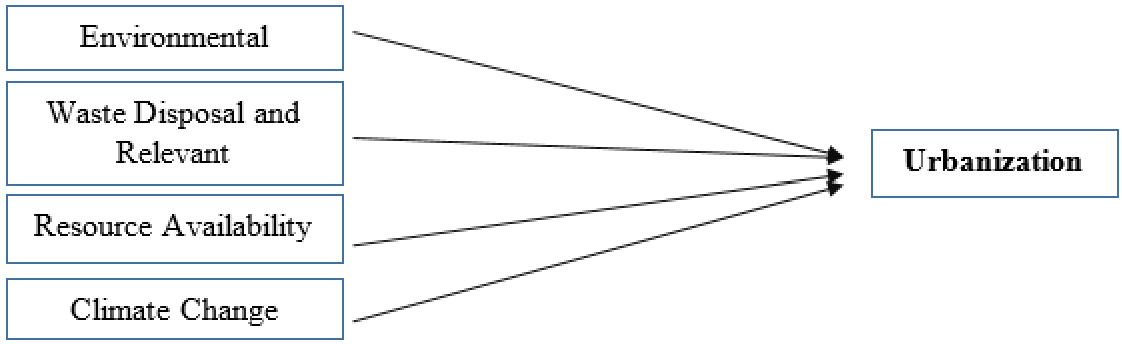

Figure 04: Independent variable and dependent variables used in the questionnaire (Conceptual Framework)

1.1.Land-use/cover (LULC) Classification

The researcher used the pixel-based supervised classification technique employing the maximum likelihood classification algorithm to analyze 1994, 2007 and 2021 Landsat images. This technique involved three main steps; (i) training sites/sample preparation (total 1200), (ii) signature development (iii) Classification. The classification was conducted to extract the four LULC types, as shown in the below table.

Table 03: Description of land-use/land-cover (LULC) classes with respective codes

ID	LULC	Code	Description
1	Impervious Surface	IS	Areas with a very high urban proportion, including the central business district, and commercial, industrial, and residential lands.
2	Forest Cover	FC	Areas with a high vegetation fraction, including dense and less dense forests with evergreen trees.
3	Cropland	CL	Agricultural lands, including paddy, tea, and other farmlands.
4	Water body	WB	Areas covered by water, including rivers, tanks, and ponds.

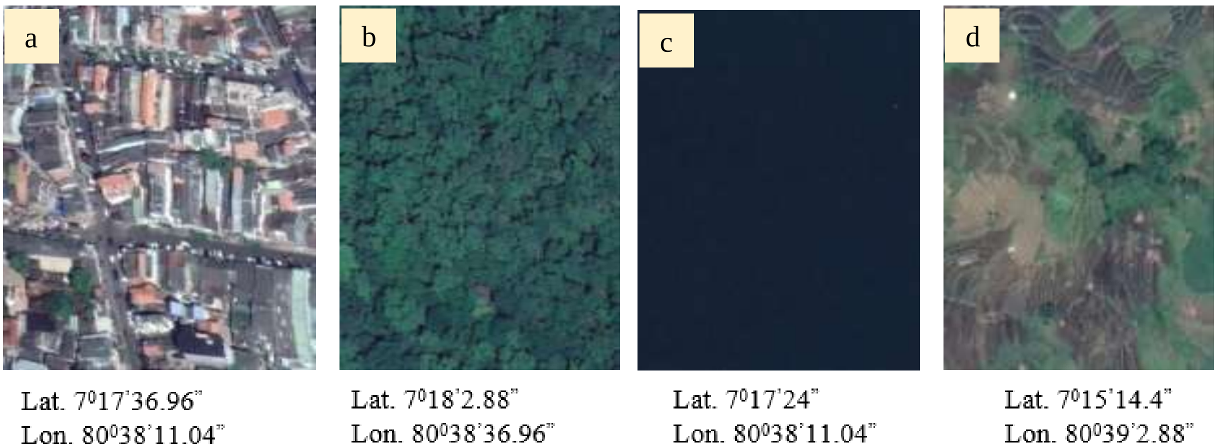

Figure 05: (a) Impervious Surface, (b) Forest cover, (c) Water body, (d) Cropland

Accuracy Assessment

The accuracy assessment was performed to determine the accuracy of the LULC information and was obtained from Landsat data. A layered random sampling method was selected to cover all LULC types, generating 120 points each year. Subsequently, in 1994, 2007, and 2021, Google Earth historical images were used as reference data for accuracy assessment.

Table 04: Accuracy assessment of LULC types.

	LULU	**1994**	**2007**	**2021**
User accuracy (%)	IS	100	93.3	100
	FC	90.63	100	100
	CL	96.43	76.7	90
	WB	100	100	100
Producer accuracy (%)	IS	100	100	96.77
	FC	96.67	100	100
	CL	90	81.08	93.75
	WB	100	100	100
Overall accuracy (%)		96.7	92.5	97.5
Kappa Coefficient		95.62	90.19	94.77

Area Calculation

Classified 1994, 2007 and 2021 maps are in raster format and represent pixel-like terrain. So in doing the calculations, the grid was converted to kilometers.

Equation 1:

$$\text{Area (Sq. Km)} = \text{No. of Grid} / 0.0009$$

LCLC Change Calculation

The maps were categorized separately, and the existing changes in land-use patterns from year to year were studied. Changes in impervious surface, forest cover, croplands and water bodies were studied from 1994 to 2007 (13 years). In this way, changes in land use patterns during 2007–2021 (14 years) and 1994–2021 (27 years) were analyzed.

Equation 2: 1994 vs. 2007 LCLC Changes = (2007 – 1994)

2007 vs. 2021 LULC Changes = (2021 – 2007)

1994 vs. 2021 LULC Changes = (1994 – 2021)

The following formula was used to calculate the annual changes in each land use pattern.

Equation 3:

$$\text{Annual LULC Change} = \frac{\text{LCLC Change}}{\text{No. of years (Ex; 2007-1994 = 13)}}$$

Transition Matrix

Each year's land use/cover change patterns should be compared to identify which land use category is transferred to the other land use category. (to create transition). For this, the Combine tool of the ArcGIS 10.4 software was used (Spatial Analysis Tool – Local – Combine). This method can represent the transitions in the selected period under each land use/cover category. It is then analyzed using the pivot table in Excel software, and all data has been translated into sq. kilometers. Using ArcGIS 10.4 software, gain maps, lost maps, and no change maps were created.

Multiple Ring Buffer

The Multiple Ring Buffer tool generates several buffers at a set distance. Accordingly, 250 m, 500 m, 750 m, 1000 m, 1250 m, 1500 m, 1750 m, 2000 m, 2250 m, 2500 m, 2750 m, 3000 m, 3250 m, 3500 m, 3750 m, 4000 m, 4250 m, 4500 m, 4750 m, 5000 m, 5250 m, 5500 m, 5750 m, 6000 m, 6250 m, 6500 m, 6750 m, 7000 m, 7250 m, and 7500 m distances were designed and studied from the clock tower as the Centre point in the Kandy city area selected as the study area. The spatial changes that have taken place in urbanization can be identified in terms of individual distances.

Statistical Analysis Methods

The research methodology plays a unique role in achieving the research objectives, and as an essential step in the research methodology, it is possible to check the significance between the independent and dependent variables. That is, to study the extent to which the results obtained by research using the scientific method of the independent and dependent variables have influenced the change in the independent variable. Although geological research is based on spatial information and phenomena, statistical calculations are widely used to identify the relationship between this spatial information. The 'Pearson Correlation Analysis method and the Descriptive Statistic method' can be identified as analytical methods used in statistics to represent the relationship between variables. This method was used as a statistical method to identify the relationship between calculated indicators using remote sensing techniques in identifying geo-environmental changes in research.

Results and Discussion

Identification of land use & land-cover changes in Kandy City and the surrounding area

The Kandy area is of paramount importance compared to other cities, so the sustainability of its sensitive ecosystem is essential. In making a comparative analysis of this, it is important to pay close attention to the major changes that have taken place in the pattern of land use in the years 1994, 2007, and 2021.

Table 05: LCLC areas in 1994,2007 and 2021 with Km^2

Category	**ID**	**1994**	**2007**	**2021**
Impervious Surface	IS	5.3	18.5	40.5
Forest Cover	FC	130.3	98.4	77.6
Croplands	CL	87.8	105.6	104.4
Water body	WB	2.3	2.4	2.5
Total		225.7	225.0	225.0

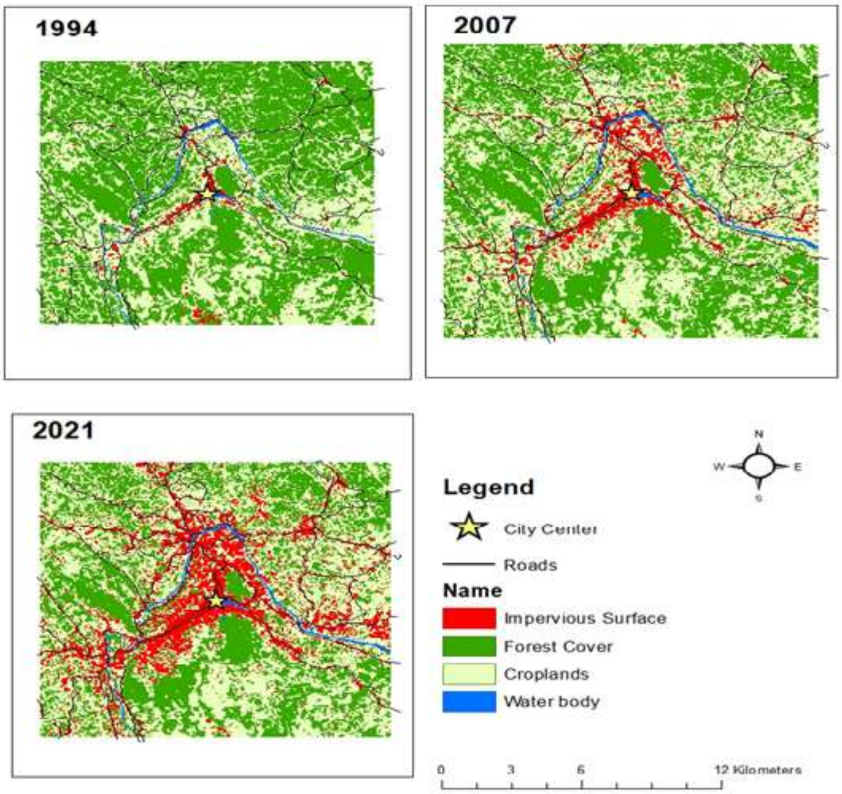

Figure 06: Land-use / Land cover Change in 1994, 2007 and 2021

In 1994, when the land use patterns of the study area were identified, most of the croplands (CL) were spread in the area's central, eastern and southwestern parts. Statistically, it covers an area of about 87.8 km^2. A more protected forest area can be identified than croplands in 1994. It covers an area of about 130.3 km^2. Especially in areas like Watapuluwa West, Yatihalagala, Boowelikada, Uda peradeniya, Maligathenna, Pussathenna, etc., the forest cover (FC) was high. This area's impervious surface (IS) is mainly in the city Centre. A linear urbanization pattern can be identified along roads such as Kandy city, Mahaiyawa, Deiyannewela, Mulgampola, Welata, Katukele, Katugastota, etc. In addition, IS in other areas can be identified as normal usual. A small area of about 5.3 Km^2 has been identified as an IS area. Regarding water sources, the Mahaweli River, its tributaries, Nuwara-Wewa and other water sources are spread over a distance of about 2.3 Km^2. Especially in 1994, the Kandy area did not show many urban features besides the city Centre.

In 2007, a large area of land was used for croplands (Agricultural lands) in identifying the land use patterns of the study area. That is, about 105.6 Km^2. This revealed that most of the land had been used for human activities. Croplands are more prevalent in the mapped area's eastern, southwestern, and central parts. Forests are also scattered throughout the area. That is an area of 98.4 Km^2. Preserved areas such as Udawattekele and Hanthana sites are protected. Also, the Impervious surface area in 2007 has grown rapidly and is growing at about 18.5 Km^2. Accordingly, with the rapid decline in the percentage of forests, the number of impervious surfaces and croplands has increased.

An analytical study of the land use patterns scattered throughout the area by 2021 in the 21st century confirms that more land area has been used for agriculture. That is an area of 104.4 Km^2. The human impact will increase rapidly by 2021. The rapid growth of the population, as well as the need to meet current needs, represents the spread of urbanization throughout the region by 2021. The impervious surface is spread over a large area of about 40.5 Km^2. By 2021, an evolving pattern of informal urbanization can be seen near roads and throughout the region.

Annual Change Intensity of 1994 – 2007, 2007 – 2021, and 1994 – 2021

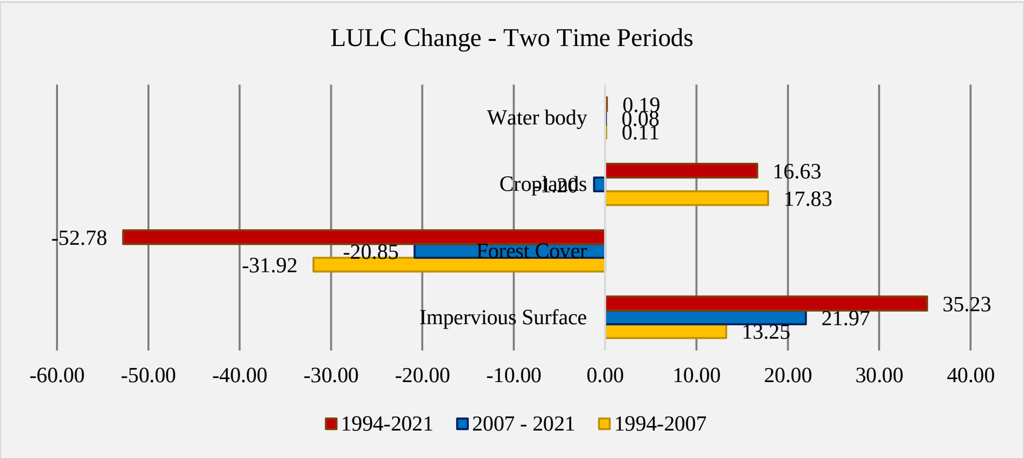

Figure 07: Land-use Land Cover Change - Two-Time Intervals

Table 06: Comparative study of the LULC change

LULC Type	ID	1994-2007	2007 - 2021	1994-2021
Impervious Surface	IS	13.25	21.97	35.23
Forest Cover	FC	-31.92	-20.85	-52.78
Croplands	CL	17.83	-1.20	16.63
Water body	WB	0.11	0.08	0.19

During the first period (1994 – 2007), that is, over 13 years, 13.25 Km^2 of impervious surface (IS) was added to the total land area to identify the land use pattern of the area. The Croplands (CL) adds up to 17.83 Km^2 of total land area. It can identify a growing state of urbanization. The total area of forest cover (FC) has decreased by 31.92 Km^2. This significant reduction confirms the impact on the environment of urban growth. The second period, 2007 to 2001, saw more urban sprawl over the 14 years than in the first period. That is 21.97 Km^2 of the total land area under IS, an increase of 8.72 Km2 over the previous period. Especially during 2007-2021, we lost 20.85 Km2 of forest cover during these fourteen years compared to the total land area of 21.97 Km^2. The area under cultivation increased from 17.83 Km^2 in the previous year to 1.20 Km^2 in the second period. Considering the total urban growth during the third period, 27 years from 1994 to 2021, we have lost a vast area of 52.78 Km^2 of forest cover.

Table 07: Annual LULC Change Calculation

LULC Types	ID	1994-2007	2007 - 2021	1994-2021
Impervious Surface	IS	1.02	1.57	1.30
Forest Cover	FC	-1.46	-1.49	-1.95
Croplands	CL	1.37	-0.09	0.62
Waterbody	WB	0.01	0.01	0.01

This calculation represents the reduction and the increase in annual forest cover, impervious surface, water resources, and croplands over selected periods. During the period of thirteen years from 1994 to 2007, 1.02 Km^2 of land was created annually over the entire land area in Kandy. That is, there has been a gradual development of physical resources. Also, an area of 1.46 Km^2 of forest cover is lost annually. It has a considerable impact on the ecosystem. When new construction occurs on road development buildings, etc., the forest cover for those projects is removed. Also, from 1994 to 2007, an area of 1.37

Km^2 was added to the total area annually. From 2007 to 2021, the forest cover decreased by 1.49 Km^{2,} and the cultivated area decreased by 0.09 Km^2 annually.

However, there has been a rapid increase in the area of construction, which is estimated to be 1.57 Km^2. During the 27 years from 1994 to 2021, 1.30 Km^2 was added annually, and the forest cover decreased by 1.95 Km^2.

Transferring of land uses during the corresponding periods

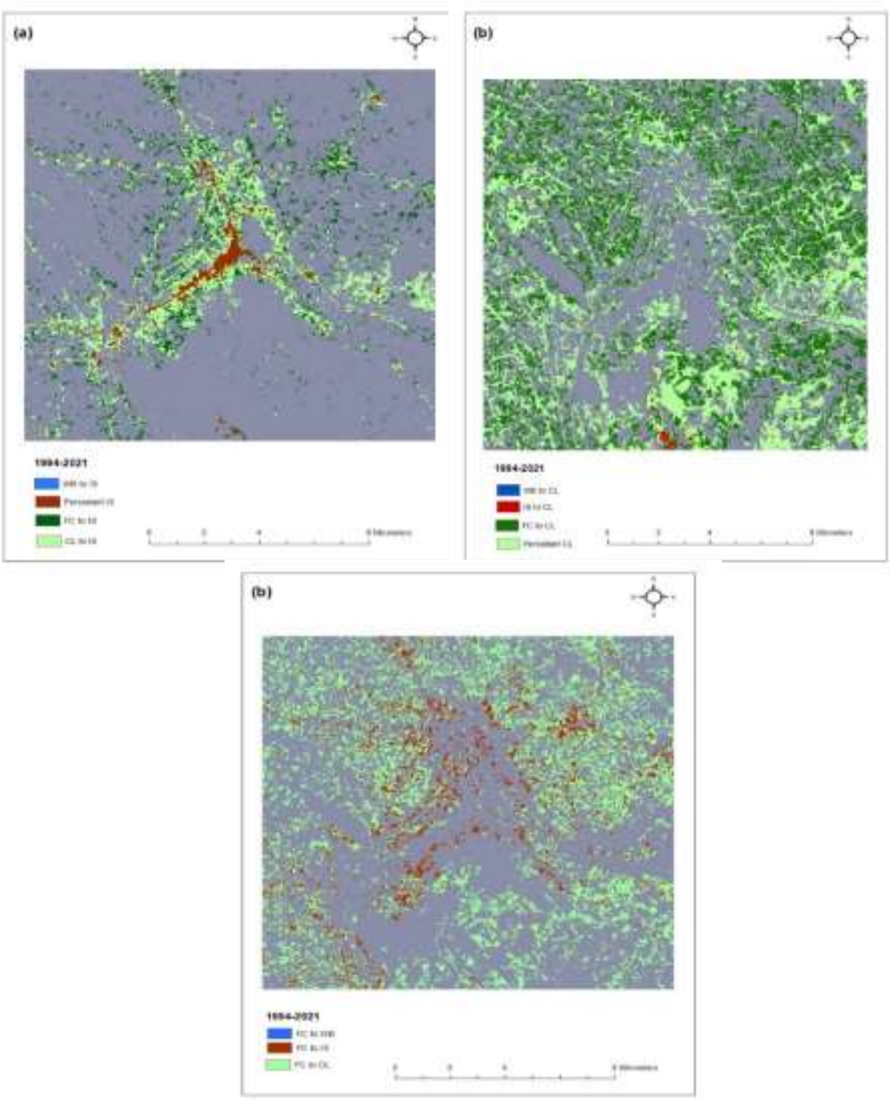

Figure 08: (a) Impervious Surface Gain Map, (b) Croplands Gain Map, (c) Forest Lost Map

During 1994-2021, a large area of forest cover, i.e. about 14.03 $Km^{2,}$ was transferred into IS. In particular, a significant amount of forest cover remains in this area, as responsible agencies such as the Environment Authority of Sri Lanka, the Ministry of Wildlife, and the Central Environmental Authority protect ecologically sensitive areas as protected areas (Dunumadalawa Forest Reserve, Udawattakele Sanctuary, Campbell's Lane Forest Reserve). However, it can be seen that there is much construction around these sensitive areas. From 1994 to 2021, 22.03 Km^2 of forest cover was transferred into Cropland. Also, 21.34 Km^2 of croplands have been converted into IS.

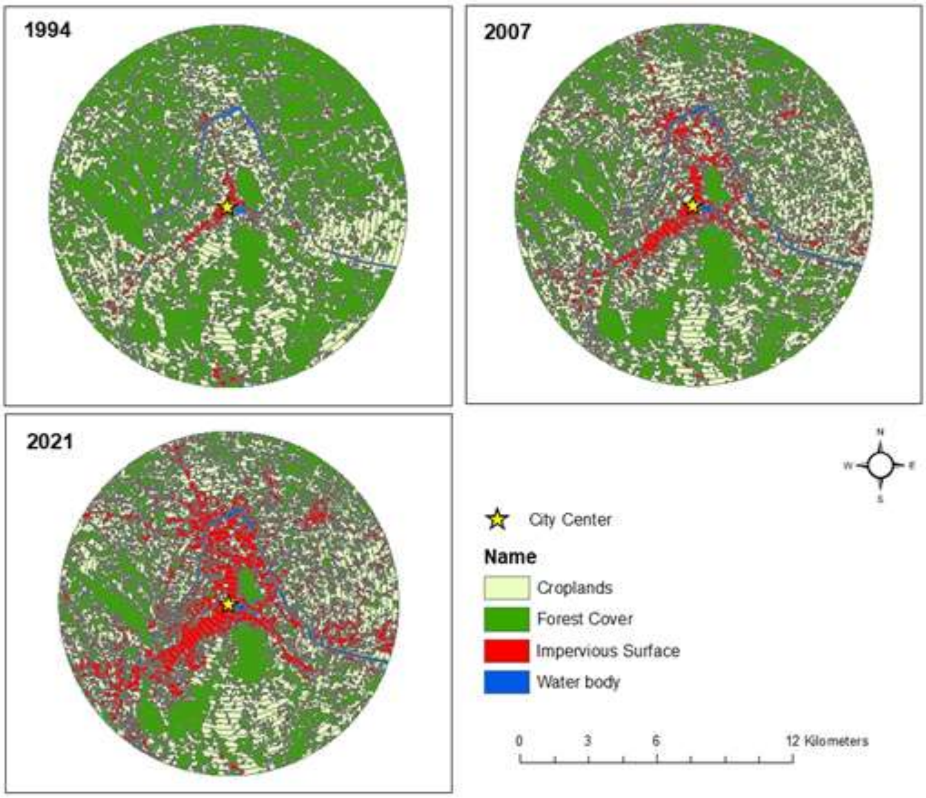

Figure 09: Identification of urban growth Pattern by 250 m by 250 m Using Multiple Ring Buffer

Table 08: Land-use Land cover by 250 m by 250 m in 1994

	LULC ID	250 m	1000 m	3000 m	5000 m	7500 m
1994 (%)	Crop Lands	4.46	40.04	41.71	40.03	34.58
	Forest Cover	0.01	39.68	52.93	58.50	63.81
	Impervious Surface	95.53	18.08	2.77	0.85	1.22
	Waterbody	0.00	2.19	2.59	0.63	0.39

The spatial distribution of urbanization over 1994, 2007, and 2021 confirms the distinction of 250 m from the city Centre.

- With the rapid growth of urbanization, a rapid increase in land under IS can be seen.
  Example: In 1994, 18.08% of the land area was IS within 1,000 m of the city Centre. By 2007, that figure had grown to 45.04%; by 2021, it was 65.50%, up 36.96% from 1994.
- With the growth of urbanization, forest cover is declining rapidly.
  Example: In 1994, forest cover within 1,000 m of the city Centre was 39.68 %. However, by 2007, that figure had fallen further to 23.94 %, and by 2021 it had dropped to 20.94 %.
- In the early days of urbanization, it stretched between 250 m and 500 m, but today it has expanded to 7500 m.
  Example: The area of IS, 7500 m from the city Centre in 1994 was 1.22 %; in 2007, it had increased slightly to 3.87 %. However, by 2001, the area under IS had grown rapidly to 11.16 % at 7,500 m.
- With the growth of urbanization, human beings have become more and more focused on land use (Croplands) in the Kandy area.
  Example: At a distance of 7500 m, in 1994, the croplands were identified as 34.58 %. That land area has grown to 46.75 % by 2021.
- By 2021, the Kandy area shows a pattern of informal rapid urban growth compared to 1994.

The objective of this statistical analysis was the identification of the environmental consequences of urbanization. As per the methodology, the sample size of the research is 100. This information was obtained from the people of Deiyannewela, Thannekubura, Ampitiya, Rajawatta, and Katugastota targeting the urban community. The researcher was able to distribute 60 printed copies to the community. The remaining 40 responses were collected through an online survey. After filtering all the data, 14 responses were rejected for various reasons like sample responses, missing mandatory data, etc. The response rate for the data collected via the printed questionnaire was 100%, while the response rate for the online questionnaire was 23.9%.

Table 09: Survey Sample

Sample	Population	Received	Expected	Rejected	Achievement
Urban Area	Deiyannewela, Thannekubura, Ampitiya, Rajawatta, Katugastota	Online (54)	40	14	100%
		Hard copy (60)	60	0	100%

(a.) Correlation Analysis

A Pearson correlation analysis was conducted among Environmental Pollution, Waste Disposal, Resource Availability, Climate Change, and Urbanization. Cohen's standard was used to evaluate the strength of the relationships (Cohen, 1988). According to the confirmed data, urban growth and waste generation represent a positive correlation. That is, the questionnaire asked whether eco-friendly methods are being used to dispose of waste due to the informality of urbanization, and it was found that more than 90% of people dispose of garbage in an environmentally friendly manner. Most city-dwellers dispose of solid waste on poles, nearby water sources, or on both sides of roads. Also, more than 95% of the waste is discharged into the drainage system, directly affecting pollution.

Moreover, when asked if people living in suburban areas have access to fresh air, more than 75% said no. More than 90% of the respondents said that animals such as rats, cockroaches, and mosquitoes are endangered in the confirmed areas of urbanization. Thus there is a positive correlation of 0.114581738 between urbanization and waste disposal.

Table 10: Correlation Analysis

	Urbanization	*Waste Disposal and the Relavant Consequences*	*Resource Availability*	*Environmental Pollution*	*Climate Change*
Urbanization	1				
Waste Disposal and the Relavant Consequences	0.114581738	1			
Resource Availability	0.128132043	0.212441077	1		
Environmental Pollution	0.140990353	0.109477744	-0.26563607	1	
Climate Change	0.19125521	0.102733312	0.271206107	0.100128859	1

Map data showed that urban growth is causing extensive deforestation. Appropriate questions were put to the public to substantiate those points and the facts were confirmed. Accordingly, in a rural environment, nearby water sources are widely used for drinking water. But 100% said that the water sources that people living in the suburbs ask for were never used for drinking victory. It confirms the nature of informal urbanization. More than 88 % said the air around them was not fresh. Air pollution in the urbanized areas of Kandy has peaked due to factors such as heavy traffic, factories, and garbage. It is also influenced by location and can be verified based on data provided by the public. Also, a major feature of urbanization is the lack of space for cultivation or other activities. Accordingly, it was stated that more than 79% did not have enough space. Also, it is not less than five meters from the house where more than 95% of the people live. Accordingly, it can be identified that there is a positive correlation between urbanization and the adequacy of resources and it is numerically shown as 0.128132045.

It also identified a positive correlation between urbanization and environmental pollution. It can be identified as 0.140990353 if expressed numerically. That is, there are frequent noises in urban areas, such as vehicle noises and factory emissions. Data showed that areas, where more than 80% of the population live, are noisy. Soil erosion and soil degradation are also common in these areas and directly contribute to pollution. Accordingly, 76% of the respondents stated that they do not use sustainable landscaping methods. They also asked if there were any illegal constructions in the areas where they live in the 21st century as compared to the twentieth century, where more than 58% said there were illegal constructions. But 42% said it was not so. This is due to the fact that there are no unauthorized constructions on government lands (Rajawatta), and in the vicinity of resorts (Deiyannewela), people living in these areas from birth, and so on.

The final was observed to be the relationship between climate change and urbanization. According to the data obtained, these variables represent a positive correlation between the two, i.e. 0.19125521. In providing the questionnaire, most people who lived in these areas for about ten to twenty years provided data, and about 92 % of them stated that changes in rainfall patterns were observed compared to the twentieth century. Also, high temperatures are a hallmark of urbanization, with 99% claiming to see a significant change in temperature patterns. More than 87% said there was a lack of forest cover. It has also been suggested that many people are affected by natural disasters such as floods and landslides, and most do not. Thus, climate change is confirming the urbanization of this area.

(a.) Descriptive Statistics

The descriptive analysis explores the significance of the selected variable towards the dependent variable. As per the analysis carried out by the researcher, it is possible to state that the variables selected for the study are significantly positive and dependable.

Table 11: Summary Statistics Table for Interval and Ratio Variables

Variable	Mean	SE	Median	SD	SV	Kurtosis	Skewness	Sum	Min	Max
Urbanization	4.55	0.037	4.666	0.374	0.14	0.512	-0.886	455	3.333	5
Waste Disposal	3.056	0.046	3	0.46	0.211	0.196	-0.023	305.6	1.8	4
Resource Availability	2.737	0.06	3	0.601	0.361	0.227	-1.197	273.75	1.25	3.25
En Pollution	1.713	0.04	1.833	0.402	0.161	-1.201	-0.169	171.332	1	2.333
Climate Change	4.146	0.048	4	0.489	0.239	-0.383	0.124	414.6	2.8	5

Conclusion

This research is based on the spatiotemporal patterns of urbanization in 1994, 2007, and 2021. At present, it is possible to identify how LULC changes are taking place in almost every region of the World, and this study is based on the selected area of the Kandy region. The researcher used Landsat Level 1, radiometrically calibrated and atmospherically corrected data from the United States Geological Survey (USGS). A questionnaire and interview methodology were used to obtain the data. GIS & RS techniques and Statistical Analysis Strategies are data analysis methods. The results analysis illustrates the rapid spread of urbanization. The area under IS was 5.3 Km^2 in 1994, increasing rapidly to 18.5 Km^2 in 2007 and 40.5 Km^2 in 2021.

In comparison, forest cover was 130.3 Km^2 in 1994, declining to 98.4 Km^2 in 2007 and 77.6 Km^2 by 2021. Also, in the 27 years from 1994 to 2021, we lost 52.78 Km^2 coverage, which can be identified as a severe environmental threat. When studying the annual distribution of urbanization, we lost 1.46 Km^2 of forest cover from the total land area, while 1.02 Km^2 of IS per year between 1994 and 2007 was added to the total land area. From 2007 to 2021, 1.57 Km^2 of land was added to the total land area, and 1.49 km2 of forest cover was removed. Also, from 1994 to 2001, 1.30 Km^2 of IS was added annually to the total land area, while 1.95 Km^2 of forest cover was removed from the total land area. Thus, the growth of urban spatial expansion will have a direct negative impact on a sensitive ecosystem such as Kandy. That is, it can be assumed that this area has a high level of environmental pollution. The ground-level analysis helped confirm that it's accurate and false and that there is a positive correlation between each variable. It was confirmed that the garbage crisis, a significant problem of urbanization, actually exists in this study area. They also found that rainfall and climate change were more severe in the 21st century than in the 20th. Preliminary data also confirm that environmental crises caused by growing urbanization, such as noise pollution, air pollution, soil erosion, unauthorized construction, resource scarcity, disasters, shanties, and overpopulation, are prevalent in the area. Therefore, this research confirms that it is necessary to focus on sustainable urban development to remedy the current environmental, social, and economic crisis, and appropriate remedies have been suggested for it.

Recommendations

According to the final analysis results obtained from the research, it is clear that the environmental factor has changed during the selected period in the selected Kandy area. An optimal climate and environment must be created for the organisms to live in an area. Accordingly, the involvement of all parties in creating a conducive environment in any area is essential. Several sustainable proposals, such as; the proper establishment of city boundaries, creating strong, sustainable, secure urban governance and developing the resilience of the people, using renewable energy sources, promoting ISO 045001 Energy Management System, focusing on organic farming, and facilitating, the establishment of natural processes like Land Management Techniques, Agro-Forestry, Land Restoration, Urban/Smart Agriculture, and Green vertical farms and, improve the sustainable transport systems can be made for this and its effectiveness will be available to all living beings, in the long run, short term, and medium-term.

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