Spatial-Temporal of Urban Green Space in the Tropical City of Kuching, Sarawak, Malaysia

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Abstract

Urban green space is one of the essential variables to influence urban climate. Urban green spaces offer evaporative cooling. The evaporative process is vital to mitigate the urban heat island. This paper investigates the spatial-temporal pattern changes of urban green space in the tropical city of Kuching, Malaysia, using remote sensing and GIS. To achieve the objective, this study required three steps. The first was a performed pre-processing, namely geometric correction, atmosphere correction, and radiometric correction. The next step was a retrieval of land surface temperature at the thermal band for every selected data for the year 1988, 2000, 2011, and 2019. The third step performed supervised classification for every selected data to generate a land cover map every selected year. The final step was to identify a correlation between urban greens space and LST. The results discovered spatial patterns of urban greens space significantly effects of cooling potential which the more urban green space areas encounter the stronger cooling effect of the urban heat island. The expansion of the urban areas significantly decreases urban green spaces areas. Correct spatial planning is an essential tool for improving urban green spaces infrastructure. This output can improve the knowledge planners, and policymakers understand green spaces recognized in urban areas and plan the urban green space strategically to mitigate UHI effects.

Keywords: *Urban Green Space, Spatial-Temporal, Cooling Effect, Urban Heat Effect, Remote Sensing.*

1. Introduction

In 2018, the United Nations reported that 55% of the world population was living in city areas, and this number was predicted to increase to 68% in 2050 [1]. The increase of population in urban areas significantly increases urban activities leading to various environmental and ecological problems. Albert [2] stated that urbanization development remains, separates, and destroys natural habitats, disturbs the hydrological system, and modifies energy flows and nutrients. Urbanization development without proper planning harms green space in urban areas. Urban green spaces are one of the vital components in the restoration and management of a healthy urban ecosystem [3]. The objectives of the study are to analyze the spatial patterns change of green space between 1988, 2000, 2011, and 2015 using geospatial analysis methods and to identify the major driving forces of the change of green spaces.

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2. Literature Review

The literature reviews show urban green spaces provide benefits to an individual's health and well being, namely relaxation [4-5] recreational opportunities [5-6], and connection to nature [4]. In addition, literature also shows urban green spaces are vital components of ecosystem services, namely in mitigation of urban heat effect [7], and reduction of air and noise pollution [8]. Currently, spatial-temporal analysis has become a vital tool to produce evidence for policy-makers, spatial planners, residential communities, and local governments [3]. The output of the study is to be able to provide guidelines to those who are working with landscapes to formulate proper policies and strategies, create data for spatial planning, and develop comprehensive land use plans as well as understand agents of change [5,9]. It is critical to analyze the relationship between the use of urban green spaces and factors influencing their utilization because it can deliver crucial references for green space site selection in urban planning [5,10]. The spatial-temporal analysis helps policy-makers guarantee sustainable development and know the dynamics of the changing environment [3,5]. The current discussion on the importance of the urban landscape method needs sufficient spatial data on the past and present conditions of green spaces in urban centers to continually and successfully manage the urban environment and reduce the temperature caused by the urban heat effect. Consequently, information on the spatial and temporal investigation of green spaces becomes vital to improve the urban green spaces planning in urban centers. A literature review has examined the interaction between population and urban expansion in Malaysia, but most of the researchers missed the temporal aspect and their focus varied greatly in terms of thematic area as well as spatial locations [11-14]. Besides that, the spatial pattern changes of green urban spaces and their driving forces were either not examined or were still lacking [5,15]. There are no detailed studies done to analyze the type of urban green space evolution [16]. Literature reviews stated there is still lacking the knowledge to understand the critical evaluation process which greatly impacts land surface temperature [16]. Besides that, the result planners and decision-makers did not consider the provision of green space for urban ecosystem services in their action plan [16].

3. Study area

Kuching is the capital city of the state of Sarawak, Malaysia. Civilization in Kuching began in the surrounding area of Sungai Sarawak, and thus this is the main reason why most of the development centered in this area. The region's climate is a tropical rainforest with annual precipitation of 4600 millimeters [17]. The average temperature value is between 19°C and 36°C [17]. The northeast season is from September until March and the southeast season is from May until August. The northeast season is the significant wet season at Kuching and the southeast season is dry. In 2018, the population in Kuching was 570, 407 [1]. The literature review has recommended focusing on small-medium cities with a population below 2 million [16] because according to previous literature reviews, the urban heat island effect does not occur in a small medium-size city. The urban heat island effect in the city is higher than in the rural areas. Besides Baum et al., [18] stated humans do not feel comfortable when the temperature is more than 30°C (urban heat island / hot spot). All the above characteristics of Kuching formed the primary motivation of the authors to choose Kuching as an area of study.

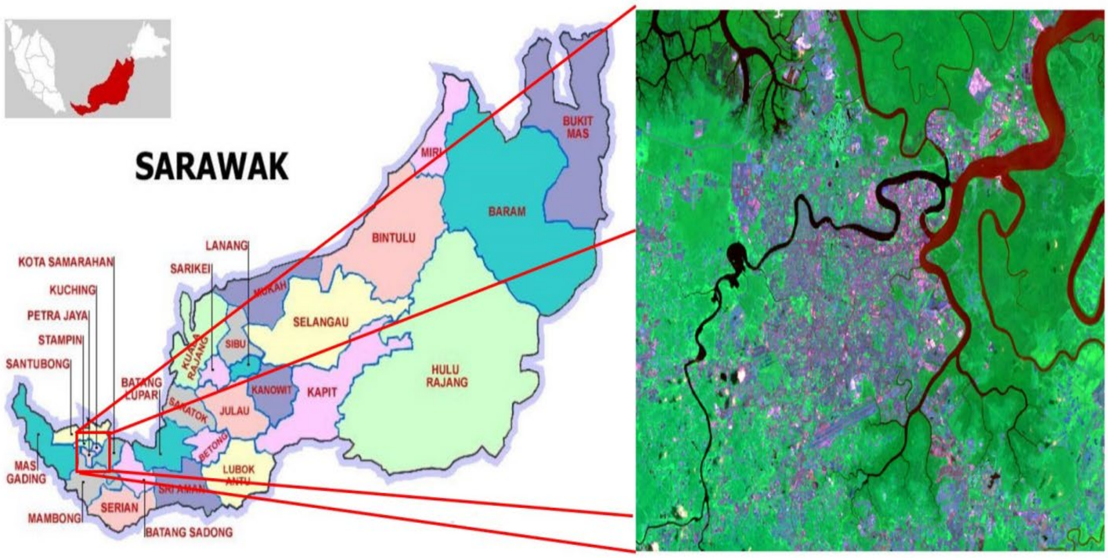

Figure 1: Location of Kuching City.

4. Methodology

The study utilized the three of Landsat 5 TM and 1 Landsat 8 OIL TIR.

Table 1: A detailed data set

Sensor	Thermal Band	Resolution Thermal band (meter)	Spatial resolution	Data Acquisition
Landsat 5	Band 6	100 resize to 30	30 meters	25 May 1988
Landsat 5	Band 6	100 resize to 30	30 meters	30 August 2000
Landsat 5	Band 6	100 resize to 30	30 meters	30 September 2011
Landsat 8	Band 10	120 resize to 30	30 meters	15 May 2019

Table 1 shows the detailed data sets that were used to achieve the objectives of this study. This study used four sets of data in 1988, 2000, 2011, and 2019. The selection of remote sensing data was only to apply to data where there was no cloud coverage because the thermal wavelength cannot penetrate the cloud. Therefore, the study did not take into account the monsoon season factor. For most of the data in the study area during the northeast monsoon (raining season), there were always clouds in the study area. This study required 4 different years of data to study the spatial pattern of land cover change for 1988, 2000, 2011, and 2019. The selected data had two resolution size pixels, namely 100 meters and 120 meters, which were resized to 30 meters per pixel.

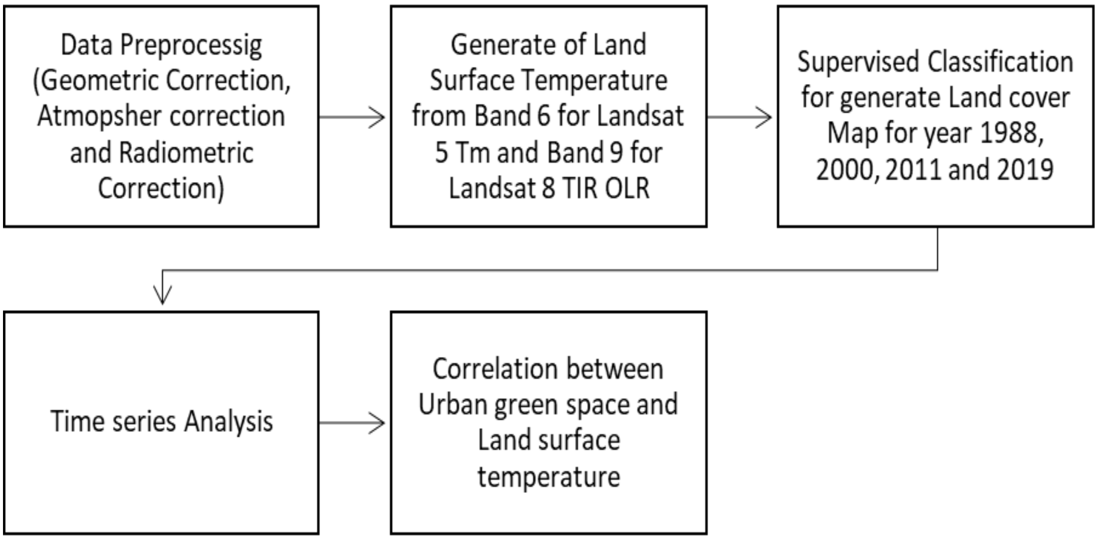

Figure 1: The flow of methodology to achieve the objective of the study.

The first step was a performed pre-processing, namely geometric correction, atmosphere correction, and radiometric correction. The next step was a retrieval of land surface temperature at thermal band every selected data for the year 1988, 2000, 2011, and 2019. The third step performed supervised classification for every selected data to generate a land cover map for every selected year. The final step was to identify the correlation between urban greens space and LST. The step of retrieving land surface temperature at Landsat 5 and Land 8 was applied based on following the steps reported by Ricky and Oliver [19]. This study was classified into four different LC categories including urban areas, vegetation, and water body using the supervised classification for the years 1988, 2000, 2011, and 2019. The results of the accuracy assessment are shown in Table 2.

Table 2: Result Accuracy Assessment

Indices	Land Cover	1988	2000	2011	2019
User Accuracy (%)	Water Body	90	97	95	97
	Urban Area	99	94	92	96
	Vegetation	95	97	96	98
Producer Accuracy (%)	Water Body	98	96	98	99
	Urban Area	94	100	99	97
	Vegetation	98	99	100	99
Overall Accuracy (%)		99	98	99	98
Kappa Coefficient (%)		98	98	98	98

The table illustrates that user and producer accuracy marks generated more than about 90% modelling accuracy for all phases. The kappa coefficient for the four-year classification was 98, 98, 98, and 98, correspondingly. Ricky and Oliver [20] and Yu et al., [22] stated the kappa coefficients greater than 0.75 indicate that classification and reference data are compatible.

4. Result and Discussion

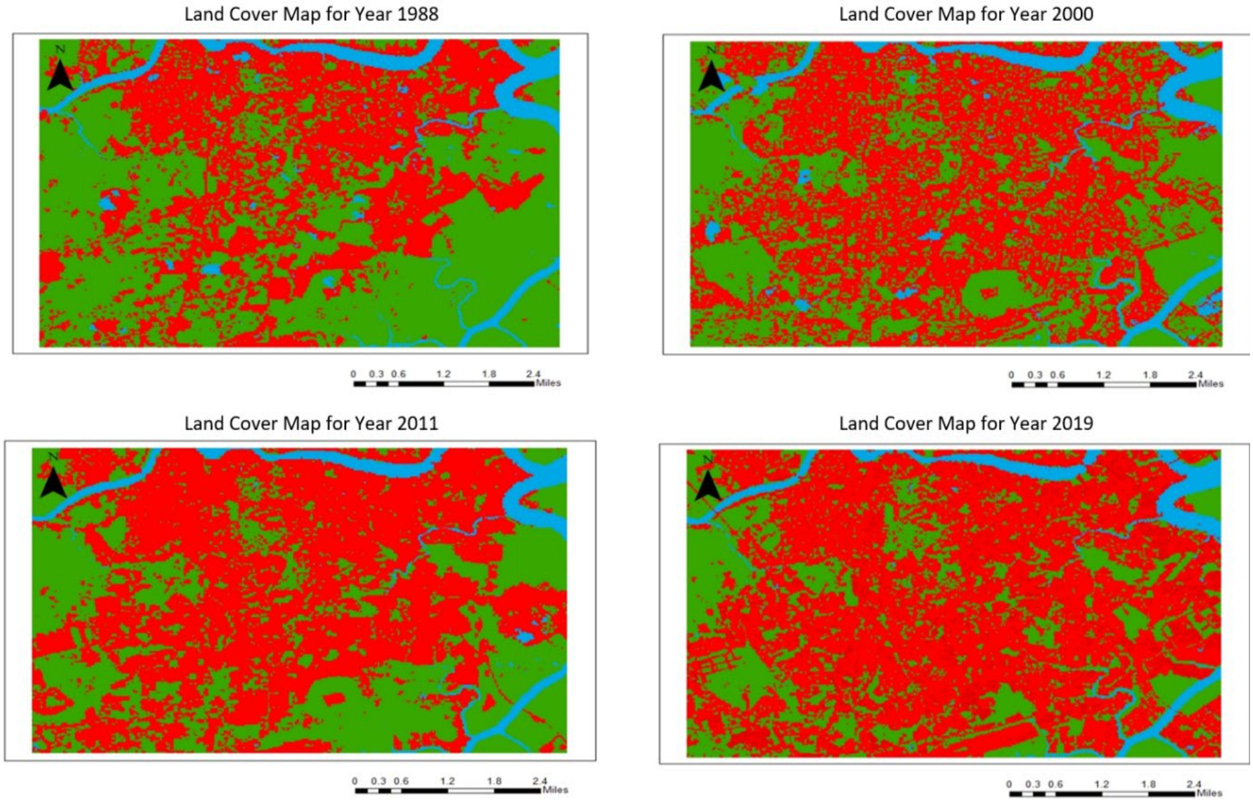

Figure 2: The Land cover map for the years 1988, 2000, 2011, and 2019.

Areas in red in Figure 2 represent urban areas, blue areas are water, and green areas are plants. The trend of area land cover change for 1988, 2000, 2011, and 2019 is represented in Figure 2. The urban areas increased in every selected year. There was an increase of 10.1 km² from 1988 to 2000, 9.2 km² from 2000 to 2011, and 8.8 km² from 2011 to 2019.

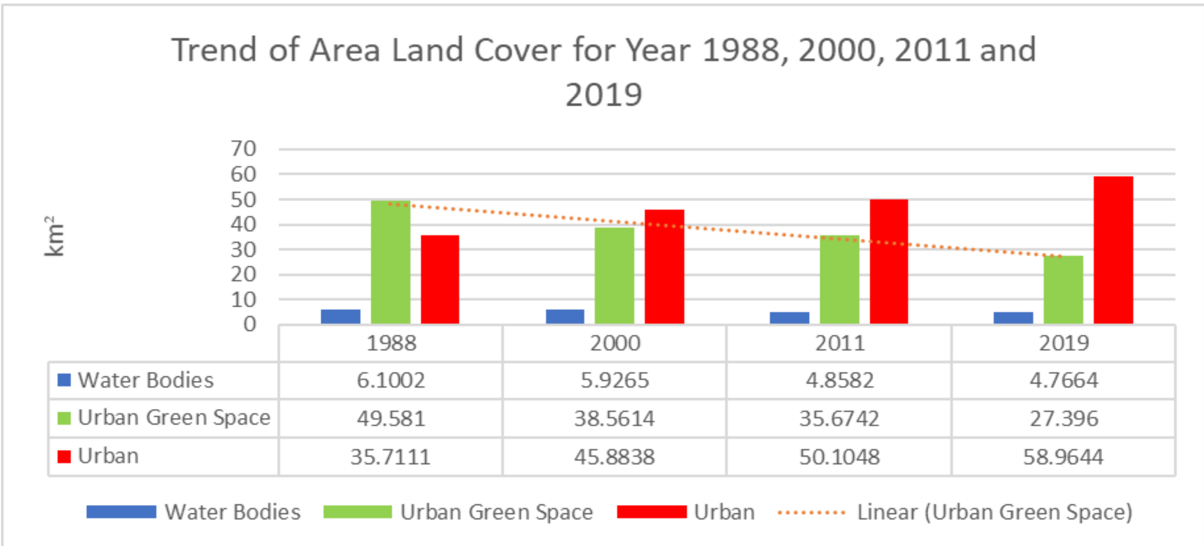

Figure 3: The trend of area land cover for 1988, 2000, 2011 and 2019

Figure 3 shows the trend of area land cover change for 1988, 2000, 2011, and 2019. The area land cover for the urban areas increased in all the selected years. However, this trend was the opposite for water bodies and urban green space areas. Most of the urban green space areas transformed into urban areas for commercial, industrial, and settlement activities. Besides that, water bodies areas reclaimed to urban areas for developing the port facilities namely Malaysia Maritime Jetty and Kuching Port.

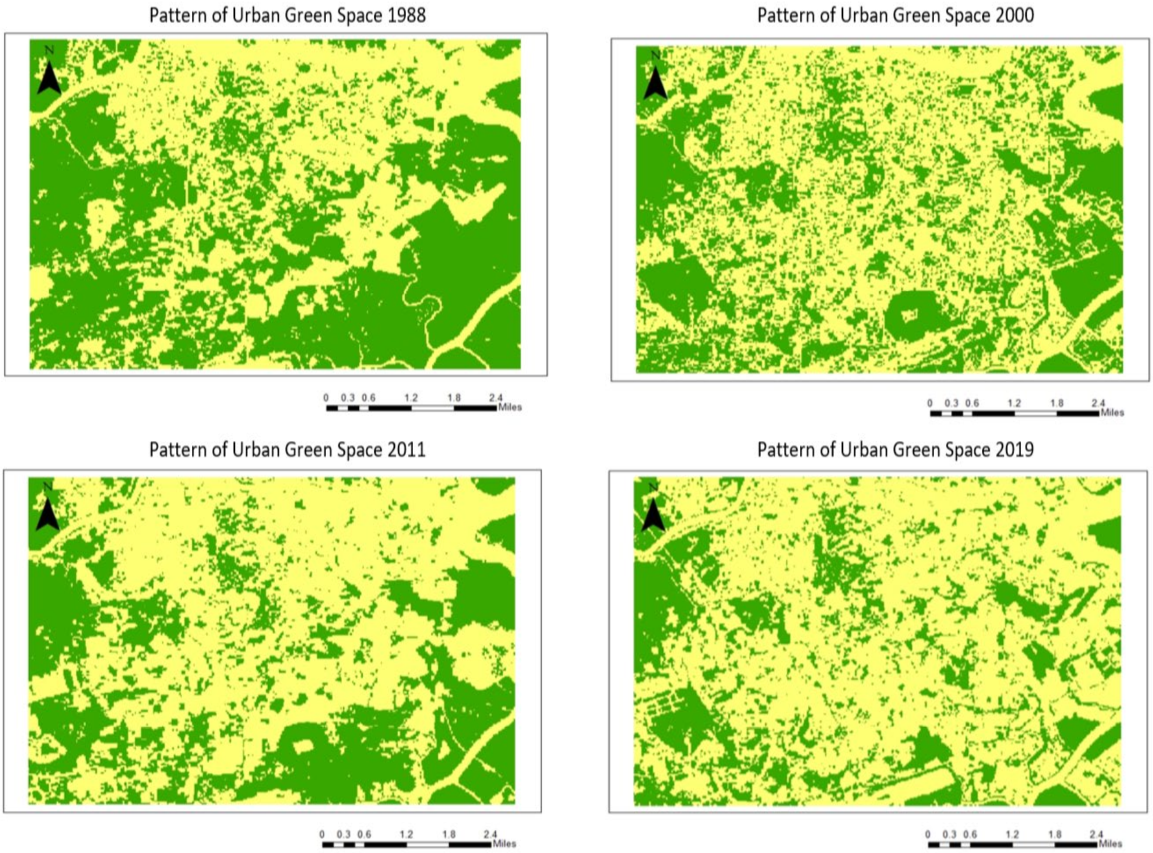

Figure 4: The pattern of urban green space for the years 1988, 2000, 2011, and 2019.

Figure 4 shows the pattern of urban green space for 1988, 2011, and 2019, whereby the yellow areas represent urban areas, and green areas represent plants. The patterns show the area of urban green space decreased in every selected year because of urbanization activities. The urbanization process, which transformation vegetation areas to build up man namely commercial areas and resident increases from the center to suburban, as shown in Figure 4. The trend of urban green spaces in 1988, 2000, 2011, and 2019 can be seen in Figure 5.

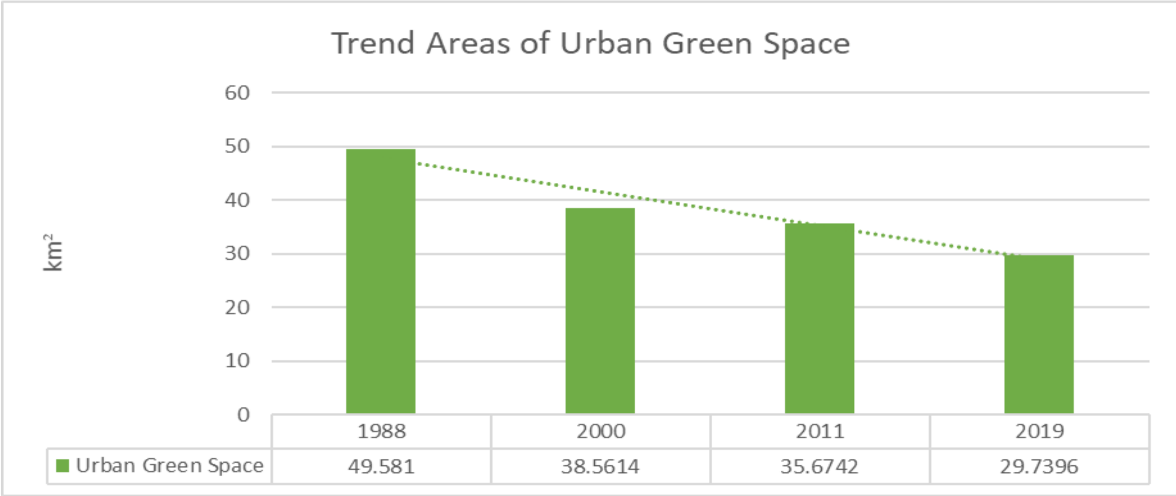

Figure 5: Trends of areas of urban green space for the years 1988, 2000, 2011, and 2019.

Figure 5 shows the trend of urban green space area in 1988, 2000, 2011, and 2019, in which the urban green space decreased by 11.02 km² between 1988 and 2000, 3.09 km² between 2000 and 2011, and 6.94 km² between 2011 and 2019.

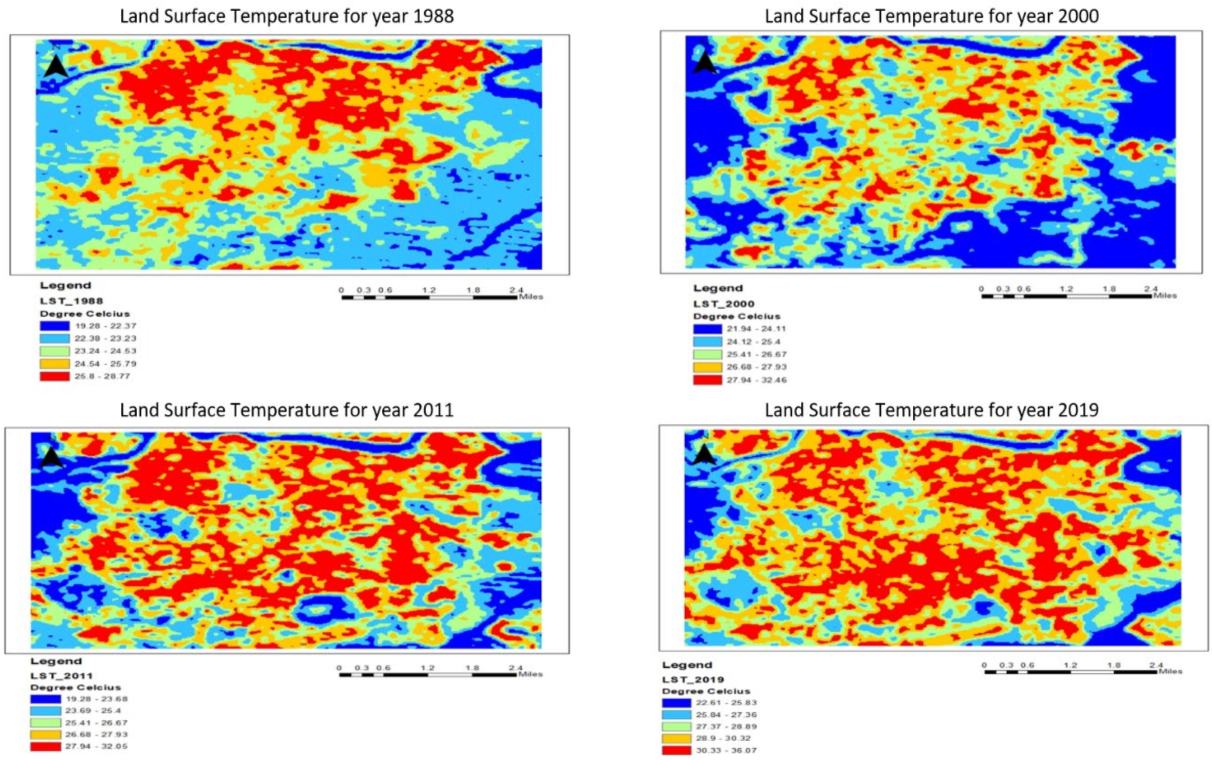

Figure 6: The Land surface temperature for the years 1988, 2000, 2011, and 2019.

Figure 6 shows that the location of hot spots increased in every selected year. The hotspot areas were the locations that have land surface temperature of more than 30°C. Baum et al. [18] developed the HUMUIDEX which humans do not feel comfortable once the temperature is higher than 30°C. The increase in the hot spot locations was because of the increase in urban areas namely Skema, Padungan, Tabuan Jaya, Riveredge, and Metro City. Besides that, the industrial areas namely Bintawa Industrial Park, Pending Industrial Park, Samajaya Industrial Park were also hot spots. The transformation areas from natural to anthropogenic heat areas factor of increase hot spots. As can be seen in Figure 6, there was no location that had the temperature of 30°C in 1988; the maximum temperature was 28.77°C. Hot spot areas began to appear in 2000, 2011, and 2019. Hotspots spread from the urban center's area to the countryside. Besides, there was a clear difference between the 1988 and 2019 maps for which the northern area of the map is dense with the red color of the LST 2019 map. The factor provides the efforts of local government provides landscapes vegetation to reduce temperatures or reduce the urban heat island.

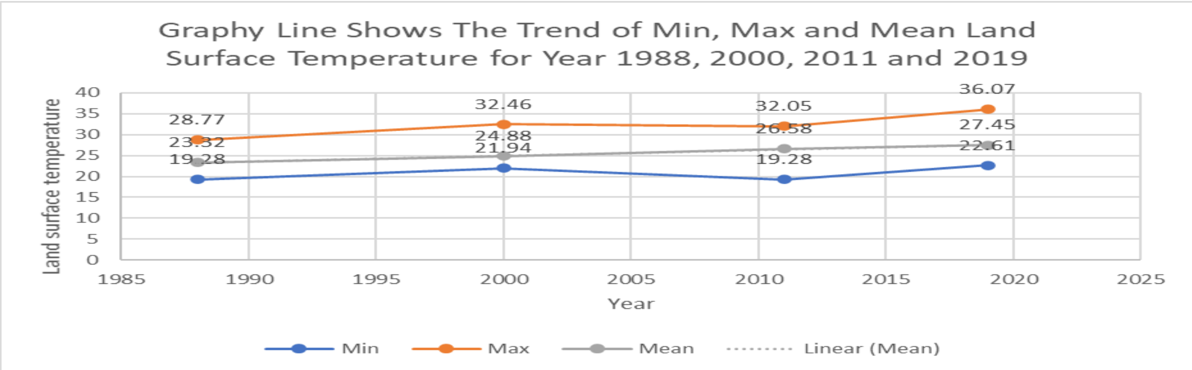

Figure 7: The min, max, and means for LST for the years 1988, 2000, 2011, and 2019.

Based on the information in Figure 7, there was an increase of 2.63°C between 1988 and 2000 and a decrease of 1.66°C between 2000 and 2011. However, following that, there was an increase of 3.33°C. The trend for the max value of LST was similar to the min value, which for 1988 and 2000, an increase of 4.51°C and a decrease of 0.36°C between 2000 and 2011, and an increase of 2.02°C between 2011 and 2019. The trend pattern for the mean value of LST continuously increased by 2.64°C between 1988 and 2000, 1.70°C between 2000 and 2011, and finally an increase of 1.07°C. The result was similar to the result reported by Cai et al. [15], Yang et al. [21], and Feyisa et al. [14]. The decrease of area urban green space at the area of study led to a significant increase of LST and reduction of human comfort [14,21,22].

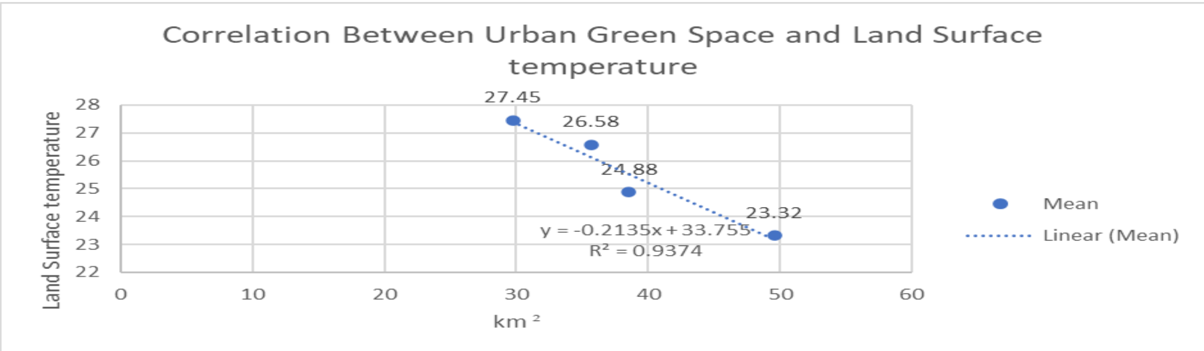

Figure 8: The correlations between urban green space and land surface temperature.

Figure 8 shows a strong negative correlation between urban green space and land surface temperatures with 0.9374 value R^2. The means the value of land surface temperature in decreases with urban green space increase. The temperature of urban green space was found to reduce 3°C for every increase of 1 km². The result of this study is similar to the results reported by Cai et al., [15]. Cai et al. [15] found that the LST will decrease by 1.65°C and 0.89°C, respectively, when the areas of the water body and vegetation increase by 10%.

5. Conclusion

The objective of this study is to examine the spatial-temporal pattern of urban green spaces in the tropical city of Kuching for the selected years of 1988, 2000, 2011 and 2019. This study found the major driving forces for the change of green spaces. The map land surface temperature showed spatial variation in the pattern of green space in 1988, 2000, 2011, and 2019, and it depends on the pattern of urbanization and urban green spaces. This study found the urban heat island effect happens in the small medium-sized city of Kuching with a population of less than one million. Besides that, the study found that urban green spaces are very important to reduce LST and urban heat effect. The study found that LST will decrease by 3°C with more areas of urban green space. This study helps to show the trend of green space changes over time and recognizes the main driving forces that contribute to the changes in green spaces. It also creates valued and standard information compulsory for decision-makers and planners to come up with proper planning for the development of green infrastructure. This study may be used as an instrument to inform ordinary citizens about the degradation and loss of urban green spaces in the case of the study area as well as in the country. This study will serve as a reference to cities and towns elsewhere, especially in the emerging towns that the destruction or loss of urban green spaces should be treated as multi-dimensional problems. Besides, the results of this study will play an essential role in inspiring the interest of other scholars, professionals, policy analysts, and other stakeholders in the planning, development, and management of green infrastructure and related studies. Based on the spatiotemporal change of urban green spaces, it may help in decisions concerning urban greening policies and urban expansion, population pressure, illegal settlement, and lack of awareness were the main driving forces. Moreover, policies and other legal frameworks relating to green space should be developed, and practically implemented to rehabilitate and improve the existing green spaces in and around the urban centers. The improvement of knowledge by the quantity of spatial variation of LST can help understand the duty of green urban spaces with the urban ecosystem in services urban heat effect mitigation for Malaysia to achieve the status as a low carbon city or smart city besides reducing the negative urban heat effect.

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