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ANALYSIS OF LAND SURFACE TEMPERATURE VARIABILITY OVER THE INDUSTRIAL ZONE DURING THE LOCKDOWN PERIOD OF COVID-19 PANDEMICS BY USING SATELLITE REMOTE SENSING AND GIS

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ABSTRACT

Rapid industrialization one of the concerns that lead to climate change in the current world. With the advancement of industrialization declining vegetation cover inversely proportional to the raise of built-up areas. Export processing zones (EPZ) are playing a vital part in the economy of any country and usually associate with some environmental issues. Due to COVID 19 pandemic, the Sri Lankan government declared a lockdown period from 20th March to 11th May 2020 and the EPZ zones have not functioned during that time. Therefore, the present study concentrates to examine the land surface temperature variation during the lockdown period and the normal working time in Seethawaka EPZ. The long-time record of remote sensing satellite images was beneficial in time series analysis. Consequently, the Landsat 8 satellite images were used for the research, and the processing was accomplished in the ArcMap 10.5 software environment by using the temperature extraction method defined by the NASA and United States Geological Survey. Rendering to the study that reveals there is considerable temperature variation during lockdown time and the normal working day. As an outcome of the study, its illustrations a decrease in the temperature during the non-working day than the normal working day. Further, it shows mean temperature increase concerning the NDVI ranges throughout the working day than the non-working day which indicates the effect to the air temperature upsurges due to the working condition. In conclusion, it highlights the requirement of careful environmental monitoring over the area for conservation and temperature control. Although that we might not proceed with development devoid of proper industrialization, it is vital to revenue necessary actions for the sustainability of these zones. Hence, continuous measuring of climatological parameters over these areas, making green walls in between buildings, using eco-friendly building materials were the possible actions that could take as solutions.

KEYWORDS: *Covid-19, Epz, Remote Sensing, Temperature, UHI,*

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1. INTRODUCTION

The quantity of export processing zones (EPZs) has been expanded in developing countries in recent years (Cling, Razafindrakoto and Roubaud, 2005). These EPZ plays a vital role in the economic expansion in developing countries (Shah and Rivera, 2007). Though, EPZs are basically isolated from the internal economy, and useful for developing countries to collaborate with foreign investors freely by obeying the rule and regulations of the country (Jayanthakumaran, 2003).

Even though the EPZs are vital in the economy it may be a threat to nature due to the misuse of the environment and can lead negative impact on nature (Cling, Razafindrakoto and Roubaud, 2005). Several environmental problems can be highlighted in these EPZs such as temperature increases, air, and water pollution, collection of solid hazardous trashes, noise radiation, soil infection, and chemical. Sometimes these problems are not associated with a single industry, and it is due to the whole zone. Environment and biodiversity defeat, reduction of water reserves, and terrain disruptions can be highlighted as the major issues in concern. Although, on the other hand when all these industries together it will be important for providing facilities, reduction of transport cost, to increase the collaboration between organizations and etc. Further, the population growth of the EPZ could be identified as the foremost secondary challenge of these areas which could lead to various associated complications with the environment (Shah and Rivera, 2007).

Under this investigation, it is supposed to analyze the land surface temperature difference of the EPZ on normal working days and non-working days. Due to the COVID-19 pandemic, the Sri Lankan government declared a lockdown period from 20th March to 11th May and all these zones were not occupying in that period. This brought an advantage for this study since it is difficult to find the non-working days for these EPZs. As a consequence of the tough to access EPZ in the lockdown phase the remote sensing provides the best platform to analyze such scenarios remotely makes this study flexible than manual data collection.

The development of satellite technology enhances the remote sensing analysis in various ways and the monitoring of Land Surface Temperature (LST) highlighted as one of the important phases (Weng, Lu and Schubring, 2004). The Thermal infrared (TIR) remote sensing consents for the compilation, assessment, and modeling of ecological factors. The TIR remote sensing crucial in measuring LST which is the foremost concerning factor in ecological related approaches, for instance, global warming or Urban Heat Islands (UHI) analysis (Taylor and Kim, 2007). The long-time record and the free availability of Landsat satellite image provide the best tools to assess environmental related problems (Feizizadeh and Blaschke, 2012) and the thermal bands of Landsat 8 satellite provide the best platform for examining the LST variations efficiently and effectively.

2. METHODOLOGY

Study Area

Analyzing the temperature variations requires collecting the data of the industrial zone. Hence due to the availability of the satellite data during the lockdown time the Seethawaka EPZ zone (6.9599° N, 80.2067° E) was selected.

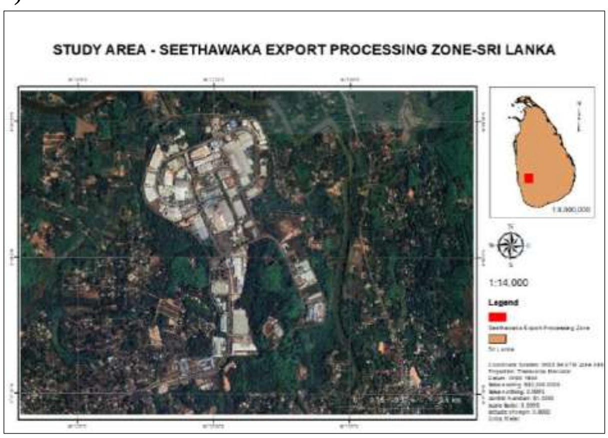

Figure 1 The study area under the investigation, Seethawaka Export Processing Zone-Sri Lanka (6.9599° N, 80.2067° E). Coordinate System: WGS 84 UTM Zone 44N Source: Google earth Image

Seethawaka EPZ was established in 1999 and it is the only zone located in Colombo District which is 47 Km away from Colombo. Approximately 431 acres of the area encompassed and around 21,500 number of people employed in Seethawaka EPZ (Karunaratnen and Abayasekara, 2013). There are currently 27 enterprises in commercial operation at the Seethawaka zone that are involved in the manufacture of Apparel & Accessories, Glove Products & Rubber Products, Fabric, Chemical & mineral, Printing, and food processing. Buildings, roads, and barren lands are the primary land use and land cover types in the study area, and further, the surrounding area covers with a vegetative zone.

Data used

The Landsat program is the longest-running innovativeness for the acquisition of satellite imagery of Earth. It delivers a greater platform to remote sensing applications in a medium resolution scale. In this study Landsat-8 data (U.S. Geological Survey, 2019) used as the main data source which were downloaded from U.S. Geological Survey (USGS) using Earth Explorer. The thermal band basically utilized for the temperature extraction and the Near Infrared (NIR) and Red bands were occupied for the correction over the images through Normalized Difference vegetation Index (NDVI) (http://earthexplorer.usgs.gov).

Table 1: Data used for the analysis *Weather Source: https://www.accuweather.com/*

Time Period	**Date**	**Time**	**Weather**
Before the Lockdown	2020-02-23	04:53:55.5011040	Sunny
During the Lockdown	2020-04-11	04:53:33.1560590	Sunny

The Workflow of Investigation

The whole workflow of the study based on Landsat data processing and statistical analysis in an ArcGIS environment. Under the investigation, two Landsat images that obtain Before the Lockdown (Normal Working Day) and During the Lockdown (Non-Working Day) were processed and analyzed. The overall approach of the study can be described as follows.

Landsat Thermal Band Analysis

The preprocessing of data is a crucial step in the remote sensing analytical workflow. Therefore, firstly the images were corrected from geometrically and radiometrically. Then conversion from DN to radiance and sun angle correction was performed over the images, respectively(U.S. Geological Survey, 2019).

The phases of the analysis described as follows.

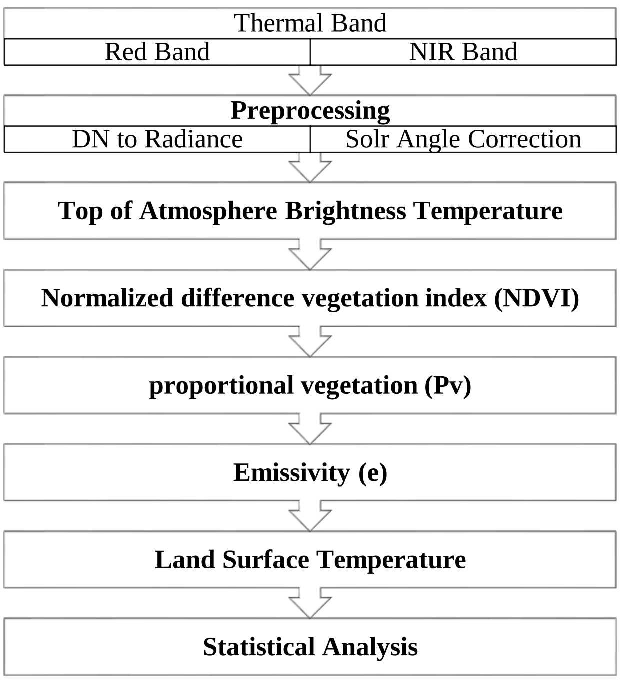

Figure 2 The overall approach of the experimental analysis

OLI and TIRS at Sensor Spectral Radiance

Images were processed in units of absolute radiance using 32-bit floating-point calculations (Young *et al.*, 2017). These values were converted to 16-bit integer values in the finished Level 1 product. Then converted to spectral radiance using the radiance scaling factors provided in the metadata file of the image (U.S. Geological Survey, 2019):

DN to radiance conversion.

$L\lambda = ML * Qcal + AL$ -----------(1)

Where:

- $L\lambda$ = Spectral radiance (W/(m2 * sr * µm))
- ML = Radiance multiplicative scaling factor for the band (RADIANCE_MULT_BAND_n from the metadata)
- AL = Radiance additive scaling factor for the band (RADIANCE_ADD_BAND_n from the metadata)
- Qcal = Level 1-pixel value in DN 5

Correction for solar elevation angle(Pλ)

$P\lambda = L\lambda$ /Sin (Sun Elevation) ------------------(2)

Where:

$L\lambda$ = Spectral radiance (W/(m2 * sr * µm)) ------(3)

TIRS Top of Atmosphere Brightness Temperature

The top of atmosphere brightness temperature is a measurement of the radiance of the Thermal Infrared radiation drifting upward from the top of the atmosphere to the satellite, expressed in units of the temperature. Subsequently the top of Atmosphere Brightness Temperature was obtained by using following equation(U.S. Geological Survey, 2019).

$T=K2/\ln (K1/L\lambda + 1)$ -----------------------(4)

Where:

- T = Top of atmosphere brightness temperature (K)
- $L\lambda$ = TOA spectral radiance (Watts/ (m2 * srad * µm))
- K1 = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the thermal band number)
- K2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the thermal band number)

The resulted temperature value in kelvin and it will be converted to degree by using following equation.

Conversion of degree kelvin into Fahrenheit (TF)

$TF=T-273.15$ -----------------(5)

Where:

- T = Top of atmosphere brightness temperature (K)

Computing the Normalized difference vegetation index (NDVI)

NDVI introduced Tucker in 1979 as an index of vegetation wellbeing and thickness. The NDVI is a simple vegetation index that widely used for vegetation related analysis and in various aspects (Singh, Roy and Kogan, 2003) by using NIR and RED are the reflectance in the close to infrared and red groups. NDVI varies from -1 to +1 and a decent marker of green biomass, leaf region index, and examples of creation. Landsat noticeable and close infrared groups were utilized for ascertaining the NDVI. The significance of assessing the NDVI is fundamental since the measure of vegetation (Li, 2011) present is a significant factor and NDVI can be utilized to induce general vegetation condition. NDVI has become an essential indicator for mapping changes in vegetation spread and investigating natural effects.

$NDVI= (NIR-RED)/ (NIR+RED)$ ---------------(6)

Where:

- NIR= Near Infrared Band
- RED= Red Band

Then the Proportional vegetation was calculated by using the maximum and minimum of NDVI result images in each year.

Proportional vegetation (Pv)

This Pv gives the estimation of area under each land cover type(U.S. Geological Survey, 2019).

Pv= ((NDVI-NDVImin)/ (NDVImax-NDVImin)) 2 -------(7)

Emissivity (e)

Then e calculated by using the previous resulted Pv value of each image(U.S. Geological Survey, 2019).

Emissivity

e = 0.004*(Pv) + 0.986 -------------------(8)

Land Surface Temperature

Finally, the top of atmosphere brightness temperature was converted to Land Surface Temperature (LST) via following equation by utilizing previously calculated emissivity value(U.S. Geological Survey, 2019).

LST can be retrieved using the equation

LST=BT/ (1+W*(BT/P) *ln (e)) ------------------(9)

Where,

- BT= satellite brightness temperature
- W=wavelength of emitted radiance
- P= 14380
- P= h*c/s
- h= Plank's constant (6.626 x 10-34)
- s= Boltzmann constant (1.38 x 10-23 J/K)
- c=Velocity of light (3 x 108 m/s).

Source of the calculation: (U.S. Geological Survey, 2019).

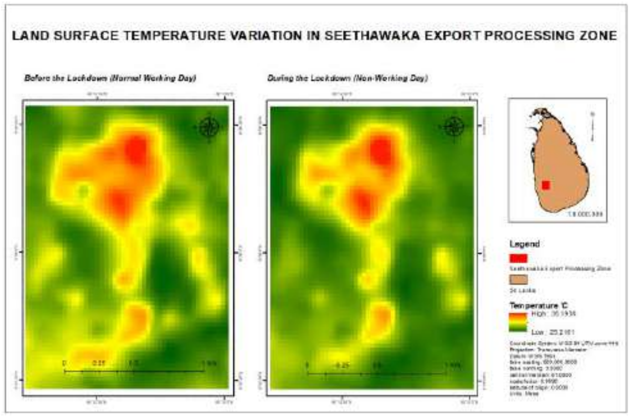

Figure 3 The Land surface temperature variation in Seethawaka EPZ Before the Lockdown (Normal Working Day) and During the Lockdown (Non-Working Day). Coordinate System: WGS 84 UTM Zone 44N. Source: Landsat 8 Satellite Images

3. RESULTS

The variation of temperature before and after the lockdown could be identified as a key finding of the study. The resulted maps show comparative difference of temperature during the two periods as in figure 3. It demonstrates the fluctuation of temperature in Seethawaka EPZ during the normal working day and the lockdown time indicating the fact that during the working day temperature has risen than the non-working day. This reveals when all the factories were occupied there is a considerable amount of temperature upsurge in the study area. This may be due to factory carbon dioxide emission, fuel consumption, the material of the building, the layout of EPZ, population around and their anthropogenic activities etc.

NDVI is well-known indices in vegetation mapping and evaluation. The investigation highlighted the fluctuation of NDVI value in two different periods with the LULC category. As the temperature variation, the NDVI also highlights the low NDVI for the building and bare earth while rich NDVI value for the vegetation areas. The NDVI indicates the differences between the vegetation cover over the area during the two periods. The highest NDVI values indicate rich vegetation covers and the smallest NDVI values denote the built-up areas.

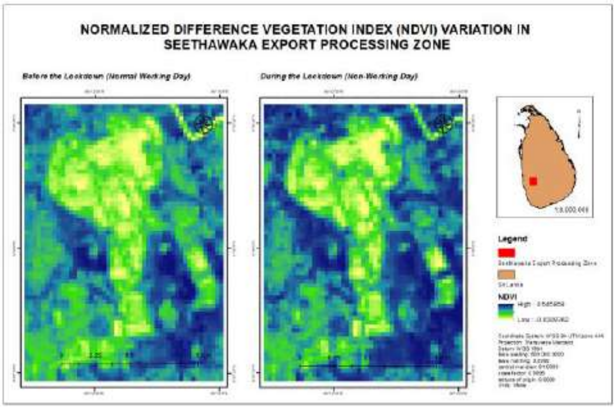

Figure 4 The NDVI maps of the Seethawaka EPZ Before the Lockdown (Normal Working Day) and During the Lockdown (Non-Working Day) lockdown
Coordinate System: WGS 84 UTM Zone 44N
Source: Landsat 8 Satellite Images

Bigger NDVI values show that the land surface was secured with thick solid vegetation, while negative qualities demonstrate the nearness of mists, a day off, or a brilliant non-vegetated surface (Chen *et al.*, 2006). Hence the above NDVI map of before and after lockdown shows the condition of the land use land cover (LULC) classes since the NDVI analysis is a good indicator of measuring the condition of the vegetation and land.

The LULC forms have strongly correlated with the variation of thermal radiation, for example, the industrial locations and heavy urban regions were warmest, and forest and vegetated areas were coolest (Xian and Crane, 2006). Then the LULC classes of the Seethawaka EPZ were identified and collected the point sample for the analysis from the Google Earth images. Then, extracted the temperature of each LULC type in the ArcGIS environment from the resulted satellite images. The following figure 5 describes the variation of the temperature of different LULC during the two periods.

The percentage of mean temperate variation in each LULC class shown in the following table.

Table 2 The mean temperatures of each LULC in before and after the lockdown

LULC Type	Mean Temperature		Precentage of Difference
	Before Lockdown	During Lockdown	
Building	32.80	32.27	1.60%
Bare earth	29.23	28.31	3.13%
Vegitation	25.86	25.22	2.47%
Water	25.84	25.30	2.09%

Following Figure 5 describe the detail explanation of the above figure, the temperature variation regard to the land use land cover type on the ground.

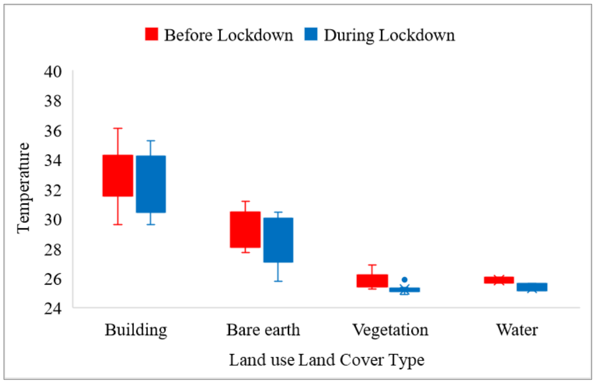

Figure 5 Temperature difference in each LULC in Two periods

Then examined the distinct between NDVI values in the two time periods for each LULC category of the study area in order to identify the comparative variation. Further, it designates less fluctuation of NDVI values in manmade features against the comparatively high variation in natural features respect to the temperature fluctuation.

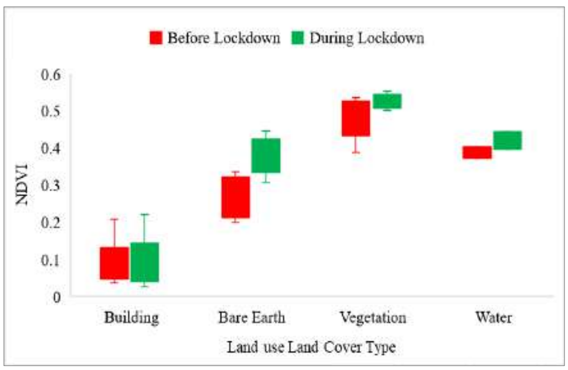

Figure 6 NDVI difference in each LULC in Two periods

4. DISCUSSION

Rendering to the study, it shows the fluctuation of temperature in Seethawaka EPZ during the normal working day and the lockdown time. This indicates when all the factories were occupied there is a considerable amount of temperature upsurge in the study area. This may be due to factory carbon dioxide emission, fuel consumption, the material of the building, the layout of EPZ and etc.

And furthered this study indicate that different LULC types have associated temperature class which varies with the feature type, texture pattern, contamination and etc. In addition, it shows the less amount of temperature variation in Building areas related to other areas even in the lockdown time as the same fluctuation of NDVI values. Further, it highlights the importance of the building materials and the layout of the zone for temperature conservation.

LST and NDVI two variables that contain interrelationship among each. Then perform correlation analysis among the LST and NDVI to examine the interrelationship between the variables. The resulted graph indicates the positive correlation between the LST and NDVI during the two times.

(a) **(b)**

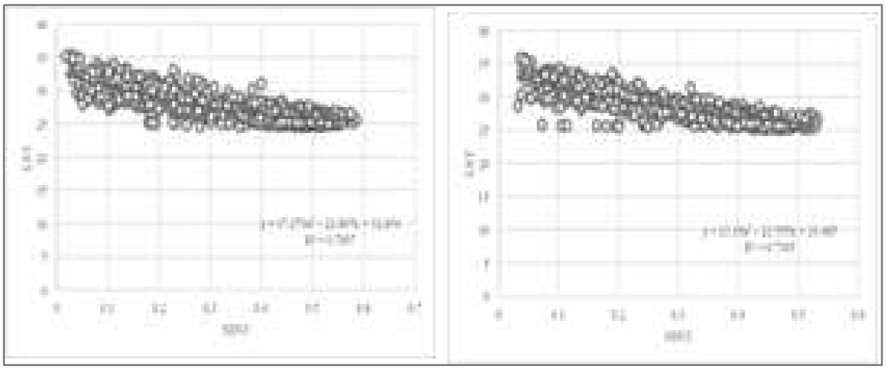

Figure 7 Correlation analysis among the LST and NDVI in two time periods (a) (Normal Working Day) (b) During the Lockdown (Non-Working Day)

NDVI is utilized not just for the exact depiction of land spread, vegetation grouping and vegetation phenology, but on the other hand, is utilized adequately for observing precipitation and drought, assessing crop development conditions and harvest yields and etc. (Singh, Roy and Kogan, 2003). NDVI is well-known indices in vegetation mapping and evaluation. The investigation highlighted the fluctuation of NDVI value in two different time periods with the LULC category. As the temperature variation, the NDVI also highlights the low NDVI for the building and bare earth while rich NDVI value for the vegetation areas. Further, it designates less fluctuation of NDVI values in manmade feature against the comparatively high variation in natural feature same as the temperature fluctuation.

Then examine the fluctuation of temperature respect to the NDVI ranges during the two times. For both instances, the mean temperature values of the same NDVI range have been varied. Comparatively, low-temperature values could be observed at the non-working day than the working day as per the following Table.

Table 3:Mean Temperature fluctuation respect to the NDVI ranges

NDVI Range	Mean Temperature	
	During Lockdown	Normal Day
0.0-0.1	31.28	31.94
0.1-0.2	29.79	30.58
0.2-0.3	28.34	28.86
0.3-0.4	26.86	27.53
0.4-0.5	26.08	26.52
0.5-0.6	25.64	26.19

The LULC forms have strongly correlated with the variation of thermal radiation, for example, the industrial locations and heavy urban regions were warmest, and forest and vegetated areas were coolest (Xian and Crane, 2006).

Then the LULC classes of the Seethawaka EPZ were identified and collected the point sample for the analysis from the Google Earth images. then, extracted the temperature of each LULC type in the ArcGIS environment from the resulted satellite images. Then the following.

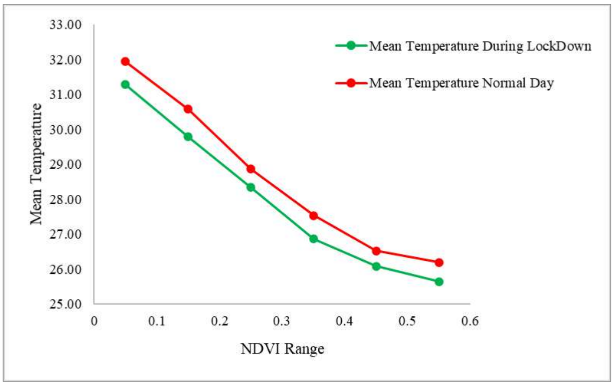

Figure 8 NDVI ranges and respective Mean temperature decreasing in normal working day and non-working day

And furthered this study indicate that different LULC types have associated temperature class which varies with the feature type, texture pattern, contamination, etc. In addition, it shows the less amount of temperature variation in Building areas related to other areas even in the lockdown time as the same fluctuation of NDVI values. Further, it highlights the importance of the building materials and the layout of the zone for temperature conservation.

5. CONCLUSION

Freely available medium-resolution Landsat images were beneficial in time series analysis remotely. This study highlights the importance of remote access to the data in such pandemic times since the manual data collection was high risk.

Further, this study shows the percentage of variation of temperature during the working and non-working time of the industrial area. The UHI could be identified as the foremost swelling issue due to the temperature rises of an area because of the building coverage and the industrial process. It concludes when the industry gets occupied there is considerable temperature fluctuation comparatively. Hence all the environmental authorities should focus to maintain the conservation of the environment in such industrial zones while balancing the temperature fluctuation. Since the temperature increases directly affect to the lively hood of the people animals and finally nature. Therefore, any industrial area should maintain a green area ratio among the built-up area, and the vegetation cover and the green wall in between the buildings also vital. These strategies should come as a policy development of the country. In addition, this study revel even the industrial area does not occupy the temperature variation of manmade features against the natural features were low. Hence the occupying of the EPZ is not only the factor that affects the temperature increase. Therefore, we have to consider the building materials, the layout of the EPZ, height, and shape of the buildings and etc. for consideration.

More or less these EPZs are vital in the economy, and we cannot neglect them. As a developing nation, we should go with industrial development unless being a developed nation would only be a dream. Hence, we need proper development for the country while maintaining production. Therefore, the process of development should be sustainable and eco-friendly which cater to the current requirement of the country. After All, the reduction of temperature during the lockdown time in EPZ gives us a silent message that the earth gets recovered during the COVID 19 time.

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