Multi Spectral Satellite Data to Investigate Land Expansion and Related Micro Climate Change as Threats to the Environment

M Hanif, B G Putra, K Nizam H Rahman and A Y Nofrizal
Department of Geography, Padang State University, Padang 25132, Indonesia
hanifl2jhenif@gmail.com

Abstract. Technology development of satellite earth observation offers multi-spectral data, variations sensitivity of satellite sensors are very useful to detect existing conditions by using the remote sensing algorithm to extract the land cover and the phenomenon that has occurred. Ecosystems have bound tolerance to nature condition and organisms have adaptation limit to climate change. Method used in this study was the extraction of land cover by applying multi spectral analysis as Maximum Likelihood, object base image analysis, (LST) land surface temperature, and also the formula Threat of Land Expansion (TLE) to the environment. Result showed that multispectral and time series analysis gave the increasing dynamic of land expansion, especially for forest high density, which areas ranged from 29098.73 ha in 2000 to 19216.7 ha in 2018. The surface temperature increase was ± 2.8°C in eighteen years. The temperature dynamic represented the micro climate changes, has followed stream of land expansion. TLE represented zone threats of land expansion to natural ecosystems. It was found that threat zone because land expansion. The area of high threat vale 0.4 around central human activity was a built up area.

Keywords: satellite data, ecosystem, land expansion, climate change.

1. Introduction
Surface temperatures have an indirect, but significant, influence to air temperatures, especially in the canopy layer, which is closest to the surface. For example, parks and vegetation areas, which typically have cooler surface temperatures, contribute to cooler air temperatures. Dense, built-up areas, on the other hand, typically lead to warmer air temperatures. Because air mixes within the atmosphere, though, the relationship between surface and air temperatures is not constant, and air temperatures typically vary less than surface temperatures across an affected area, therefore urban heat islands and global climate change (global warming) are often similar. For example, some communities may experience longer growing seasons due to either or both phenomenon. Urban heat islands and global climate change can both also increase demand of energy, particularly summertime air conditioning demand, and associated air pollution and greenhouse gas emissions, depending on the electric system power fuel mix [1].

The context study of expanding it is cycle, where land use influence temperatures and climate changes of urban, natural environment and harmonious nature ecosystem like natural forests. Basically, natural land cover is target for expansion, where this area productive in economy context. The various types of nature land cover have wealth, there are in the land that has not involving human activity. The process of expanding land it give impact to supply carbon, emission to air temperatures, as beginning for the micro climate changes, and then it will be surplus to global warming. While the land use change also
give the impact to biodiversity, changing population biodiversity, and increasing air temperature, and pressing morphology and physiological adaptation of animal and vegetation, it also will make a barrier for animal migration in seasons. Therefore, land expansion will continually increase, if that happens will be basic of disasters. It can damage natural sustainability such as erratic weather, drought and meteorological disasters because the control of the air voltage has changed from the original land covers.

Several publications appeared that use aerial and satellite remote sensing data to study the change of urban environment due to the dynamic increase of population. The assessment was carried out in this study by considering the current study of a significant advancement [2]. Remote sensing and GIS assessments are proved to be useful tools for spatial and temporal patterns mapping of urban surface temperature [3, 4]. The purpose of the research is to investigate the influence of land expansion to micro climate change, and to analysis threat of land expansion to environment, it following the targets (SDGs) sustainable development goals point 13 is climate action, and point 15 is life on land. The case study is Padang city, a capital city of West Sumatra Province, Indonesia. The region is one of the central developments, in order to support the progress of regional development. For maintaining the sustainability of environment, not all of lands could be developed to support human necessary there should be a limit (ecological tolerant). If land development is carried out it will contribute to changes and increases in micro climate air temperature and threat to environmental conditions, both biodiversity.

2. Material and Method

2.1. Material
In this study, we used Landsat TM5 and OLI8 images of 2000, 2010, and 2018 data from USGS, at the map scale 1: 100,000. Administration and infrastructure map were obtained from BAPPEDA regional planning, development agency. Terrain data by using DEM was obtained from BIG geospatial information agency Indonesia.

2.2. Method

2.2.1. Multi Spectral Analysis for Land Expansion
In this study we used a multi-spectral image analysis model, namely Maximum Likelihood spectral, based image classification, after which it was combined with image classification based on OBIA objects base image [5], to improve images classification results. Multi spectral image classification Maximum Likelihood is known as a well-established image classification statistical model in grouping pixels for land cover identification [6]. As a parametric classifier, the algorithm relies on one each training sample being represented by a Gaussian probability density function, completely described by the mean vector and variance-covariance matrix, using all available spectral bands. These parameters, it possible to compute the statistical probability of a pixel vector being a member of each spectral class [7].

2.2.2. Micro Climate Change
Analysis of micro climate changes is carried out using data from multi spectral satellite, namely thermal band. By using thermal waves, we can identify the condition of the land surface temperature, from the multi spectral satellite data recording information on the surface of the earth. In this analysis, we use the Land surface temperature (LST), which represents the surface temperature of the land surface in response to the object's response. There are several steps taken to analyse terrestrial surface temperature, which are spectral values to radians, change radians to degrees of temperature to kelvin, and change the temperature of Kelvin to a degree of Celsius. TOA to Radiance, in the process we must transform top of atmospheric data, known as TOA, which is reflected radiance. At this stage, we will change the digital number (DN) of the TIRS Landsat OLI band image to radiance data, the formula is [8]:

TOA to radiance:

\[ LA = ML Qcal + AL \]  

(1)

Radiance to temperature:
\[ T = \frac{K2}{\ln\left(\frac{K1}{L\lambda} + 1\right)} \] 

(2)

Where,

- **T**: Temperature (K)
- **L\lambda**: TOA Spectral radiance (Watts/(m^2 * srad*µm))
- **K1** and **K2**: Constant band 10 or band 11

Final process \((T – 273)\) to convert degree from Kelvin to celcius.

2.2.3. **TLE Threat of land expansion to environment**

The environmental threat in this case, where we used spatial approach with (GIS) Geography Information System, the technology to be implemented from an aspect that it is an area that will be a land expansion threat to the environment. This threat will be calculated from parametric model data that is linked to land expansion, and it will be performed based on the weight and indicator of driving factor. We use an approach with analysis of delivery data that encourage changes in land cover, as a form of land expansion.

3. **Results and Discussion**

3.1. **Land cover and Temperature change**

We use data from multi-spectral satellite technology to investigate land expansion. Several experts of the satellite system data explained that the more satellite waves used than it will be able to distinguish more detailed object variations. Results of multi-spectral classification, the Maximum Likelihood is statistical model, showed that variation and distribution of land cover, which is an indication of the land cover expansion. There was category of land expansion on land cover types that are affected by human activities. It was not involving natural land cover. Natural land cover types, such as forests, and some other types will be further processed as a threat to land expansion in natural ecosystems.

![Figure 1. Land cover changes](image)

The results of multi spectral image as land cover map were exported to GIS technology to calculate the land cover area as shown in figure 1. We have compiled chart of the land cover area variations in study time by looking at the largest variant of land expansion. This land expansion tends to move from the central area of the city, and it spreads along the road and some infrastructure. East hills boundary, with pattern of land expansion that follows the physical pattern of the road.
The bar chart in figure 2 reveals the land cover change because land expansion. Overall, there was a significant difference in the land cover from 2010 to 2018. There was a decrease in land cover changes for forest high density and increase for built up. Forest high density in one decade decreased from 29098.733 ha in 2000 to 25001.7 ha in 2010 and to 19216.7 ha in 2018. The Built-up increased from 5109.78 ha in 2000 to 6394.84 ha in 2010, and to 8956.42 ha in 2018. Plantation area increased dramatically from 3734.79 ha in 2000 to 7931.879 ha in 2010 and to 8636.82 ha in 2018.

The land expansion occurs in some natural land cover and it is threat for ecosystem. They are transformed to serve human necessary. The human activity on the land gives impact as degradation of vegetation spread. When there is loss of vegetation area, then it will disturb air in urban area. The vegetation can influence the micro climate as cooler for air temperature. The impact of land expansion is the most significant because it made loss biodiversity. There were fluctuated changes of some kind of land cover such as forest middle density, grass, and paddy. The land use change brings number of changing in climate pattern. Excessive deforestation leads to decrease in precipitation level and increase in surface temperature on global scale, thus it changes whole global climatic model as forest-covered surfaces are a special form of vegetated surfaces [9].

The band thermal of Landsat it use-full to take information land surface temperature. Result of extraction data has shown in figure 3. Landsat satellite has records of surface object as responses of spectral by pixel value, it is representation temperature object. From this research has found from many years, there was a significant change. The color index of the map represents the area between low to high temperature. From the map has represented the zone of summit maximum temperatures on the land. The zone is namely urban heat island. In one decade, the urban heat island zone was concentrated near coastal, but it is difference in eight years latters. The island spreads around all of lands, especially at every place where the people carry out expansion to develop residential or change the natural area to other function such as plantations, agricultural, etc.
The graphic in figure 4 reveals how the surface temperature changes in eighteen years. Overall, there was gradual temperature increase of 2.8°C from 2000 to 2018. We can observe the distribution of surface temperature variants from many years. The maximum surface temperature was made zone around built up area in 2000, and follow the built-up area changes in 2010 and 2018. The maximum surface temperature was widespread around area, where human activities were taken place. This represents the changing conditions of the micro-environment, which is one of the climate aspects of the air temperature, and the surface temperature of the land was very close to the conditions of the land cover variation. The surface temperature increase relatively then spread on area, following land cover changes because impact land expansion.

Urban surfaces are characterized by large roughness elements, wide-spread sealed areas, reduced moisture availability at the surface, and increased possibilities for heat storage. This leads to higher turbulence intensities in the UBL and to stronger sensible heat fluxes from the urban surface [10]. Deforestation and vegetation lost are habitat fragmentation, which occurs when parts of a habitat in a local environment, in which an organism is usually found, become separated from one another because landscape changes, such as road constructions, and the developed land. Our understanding of how climate change will impact natural terrestrial ecosystems and the goods and services is required [11].
In this study at Padang City, the natural habitat was degraded because of deforestation for timber and land expansion for agriculture, paddy field and un-irrigation agriculture. The unproductive areas can be developed to be residential and public facilities as generally we know as built-up. There was a supply of carbon emission and air warming. The disappearance of forest land cover by conversion to plantation, settlement, agriculture and to the needs of other sectors has changed the climate pattern. [12] Human has change ecosystems more rapidly and extensively than in any comparable period of time in human history, to meet rapidly growing demands for food, fresh water, timber, fibre, and fuel. The because of biodiversity loss can be broadly grouped into five categories: habitat loss, fragmentation or change; over exploitation of species; pollution; the spread of invasive species; and climate change, all of which have their origins in human demands placed on the biosphere.

In our research, we found that because of the degradation of vegetation in Padang City, we lost many natural ecosystem areas with the vegetation cover as natural forest to be plantation or agriculture. Some locations with little vegetation have changed into built up areas (urban), resulted in increase of air of temperature. [13] This vegetation loss meant a loss of cooling in urban areas. Indeed, vegetation plays an essential role in preventing the build-up of heat through the process of evapotranspiration and shading of the ground and buildings. During the natural process of evapotranspiration of water vapor, the ambient air is cooled, releasing part of its heat to allow evaporation. Vegetation also contributes to effective control of air quality in cities.

3.2. Threat of Micro Climate change to Environmental,
The fact that smog, which is composed of fine particulate matter and tropospheric ozone, is formed during the reaction between the sun’s rays, heat and pollutants nitrogen oxides (NOx) and volatile organic compounds (VOCs) [14, 15]. Measures that have been used to approximate adaptive capacity are the ecosystems diversity, the plasticity of a species, the mobility of individual organisms, including dispersal mechanisms, or the existence of climate gradients [16]. In our research, we found the trend of land surface warming by the years. There was a gradual increase every year. The summit warming of urban heat island was made at the central zone on built-up area. The temperature was gradually dropped away from crowded built-up area and spread out from central. When micro climate change continually, it will be a threat and disturbed circle in environment, such as drying on land surface, depression of soil moisture to physic and chemistry process for vegetation growth. Phenomenon of urban heat island will be a threat to environment such as, the increase of surface temperature, and will finally affect the degradation of air quality by supporting the emission of carbon dioxide (CO2), dust, and smoke to the atmosphere. In this research the maximum temperature increase was 2.85 °C.

In the longer term, outlying populations of wet forest species in dry areas, and vice versa, on edaphically or topographically extreme sites, the impacts of climate change on regional biodiversity can be mitigated only by the protection of large tracts of minimally disturbed forest that are continuous over both altitudinal and rainfall gradients. Existing protected areas are insufficient, so this will require both the rehabilitation of damaged forests and the reforestation of degraded areas [17].

The species, such as vegetation and other biota, have a tolerant and limit temperature for germination. The temperature close to air moist serves as the first media to support vegetation germination to grow. In the future, if the micro climate changes increase every year, and the human do not control and mitigate toward increase of micro temperature, then the climate change will destroy some unique species, or number of species. It is a circle threat of land expansion to micro climate change, and climate to environment.

3.3. Threat of Land Expansion to Environment,
Threat of land expansion to environment (TLE) is approach to measure threat land expansion to general aspect in environment. The environment we mean including vegetation, habitat in ecology landscape, biodiversity, air condition. In this case Padang City is tropical zone and variant geomorphology. We developing and apply the formulation using GIS. We using indicators where adaptation as driving factors that drive land expansion and resistance factor. The considerations we use from several researchers' studies of land cover changes, conditions of distance from roads, distance from residential,
land cover existing, and morphological in region. We not considering TLE can do apply in other region with difference geographical characteristic.

There more available driving factor each other to be threat to environment. The contribution of climate change to future extinctions depends on how quickly species can respond to change [18]. Fragmentation of vegetation makes it difficult for species to move within a habitat, and poses a major challenge for species requiring large tracts of land. The land expansion had press and change the land cover type and causing loss of land cover nature vegetation, where it really had a strong position to control micro climate. When the vegetation decreased, then the micro climate also increased, it made the micro climate change [19]. Vegetation is an important factor affecting the ecological balance, especially in ecologically fragile areas, ecology connectivity to protect biodiversity and human [20].

**Table 1. Indicator and weight TLE**

| Land cover          | Weight | Geomorphology    | Weight | Distance from residential | Weight | Distance from road | Weight |
|---------------------|--------|------------------|--------|---------------------------|--------|-------------------|--------|
| Forest high density | 0.1    | Plain            | 2      | 100                       | 2      | 100               | 2      |
| Forest low density  | 0.1    | Slop slightly    | 1.8    | 300                       | 1.2    | 200               | 1.8    |
| Built-up            | 2      | Middle aslant    | 1.1    | 800                       | 0.8    | 300               | 1.4    |
| Bare land           | 1      | Aslant           | 0.5    | 1500                      | 0.5    | 500               | 1.2    |
| Mangrove            | 0.1    | Steeply, cliff   | 0.1    | < 3000                    | 0.1    | 700               | 1      |
| Grass               | 0.1    |                  |        |                           |        | 1000              | 0.8    |
| Plantation          | 1.2    |                  |        |                           |        | 1500              | 0.6    |
| Paddy field         | 1.5    |                  |        |                           |        | 2000              | 0.4    |
| Agricultural        | 1.5    |                  |        |                           |        | 3000              | 0.2    |
| Mixed grass         | 0.1    |                  |        |                           |        | < 4500            | 0.1    |

In this research we using indicator such us distances from road and residential, it have high influence to land expansion. It adopted by principle from many researches using existing land use, distance from road and residential as driving factors, it forward for land use changes. There are also indicators of threats to environment and biodiversity where when land cover changes to residential the vegetation and habitat will disappear and increasing emission to air temperature. In other case when land cover changes to plantation or agricultural area, the vegetation as habitat in environment will change to be fragmentation and corridor in landscape ecology. It meaning the energy of vegetation on the land to control environment and air condition will drop gradually.

Geomorphology is resisting indicator for land expansion, because not all geomorphology characters suitable to develop for human necessary, specific for resident, paddy area, and plantation. It reason we adopted geomorphology as resistance for threat of land expansion to environment, the natural geomorphology can protected environment by the limitation in suitability to development. The threats analysis will obtain from weight sum all indicator and then it must be divided to 4 to get final value analysis. The result of threat land expansion to ecosystem will represented environmental damage, the threat as habitat loss of biodiversity. Where the high value it represent the invulnerable ecosystem from the threat of land expansion and low value it represent the environment in high threat because land expansion.
From figure 5, the map representing variation and distribution threat land expansion to environment. Colour index as quantitative value to represent distribution of threat. The colour index showed that the area between natural and unnatural ecosystems is the location that receives the highest threat. The increase in purple colour by the value 2 is referred to very high invulnerable ecosystem, that mean threat to environment is low. The colour cyan by the value 0.4 represented the area with a high threat. The factors inhibited the land expansion is geomorphological conditions and accessibility. Geomorphological conditions by fraudulent slope help reduce the threat to ecosystem conditions from land expansion.

4. Conclusion
Increase in the built-up area for years has degraded natural ecosystems. Thermal temperature data was gradually increasing following the land expansion, which shows an increase in microclimate because of the amount of vegetation degradation. There is a strong connection in environmental cycle between land cover changes because of expansion in activities, giving effect to air temperature, and land expansion and climate changes can also be threats to ecosystems and habitats.

Acknowledgements
Special appreciation for research team, and also for members of Community of Geospatial Science and Technology, Padang. Besides of this, authors sincerely honors all referees and appreciates their comments and suggestions that significantly improve this paper.
References

[1] Wong E, Hogan K, Rosenberg J, Denny A 2015 Reducing Urban Heat Islands: Compendium of Strategies. Environmental Protection Agency’s Office of Atmospheric Programs U.S.

[2] Roth M, Oke T R, Emery W J 1989 Satellite-derived urban heat islands from three coastal cities and the utilization of such data in urban climatology. International Journal of Remote Sensing vol 10, 1699–1720.

[3] Nichol J 2005 Remote Sensing of Urban Heat Island By Day and Night. Photogrammetric Engineering & Remote Sensing Vol 71, 613–621. DOI: 10.14358/pers.71.5.613

[4] Orsolya G, Tobak Z, van Leeuwen B 2016 Satellite Based Analysis Of Surface Urban Heat Island Intensity. Journal of Environmental Geography Vol 9 (1–2), 23–30.

[5] Hanif M and Nofrizal A Y 2017 Application Multi Vegetation Index to Mapping Mangroves Distibution Coastal Environment Northeast Province of Aceh. Sumatera Journal Disaster Geography and Geography Education. SJDGGE, Vol 1.

[7] Weng Q 2011 Advances in Environmental Remote Sensing, Sensor, Algotihma and Applications. Indiana State Univeristy. ISBN: 978-1- 4200-9181-6.

[8] http://landsat.usgs.gov/Landsat8_Using_Product.php

[9] Velasco E, Márquez C, Bueno E and Bernabé R M 2007 Vertical distribution of ozone and VOCs in the low boundary layer of Mexico City. Atmos Chem Phys Discuss. Vol 7: 12751–12779

[10] Smith A M S 2014 Remote sensing the vulnerability of vegetation in natural terrestrial ecosystems. Journal Remote Sensing of Environment. Vol 154. 322–337.

[11] Eimeis S 2011 Surface Based Remote Sensing of Atmospheric Boundary Layer. Journal Springer. Dordrecht Heidelberg London New York.

[12] WWF 2012 Ecological Footprint Report Africa Green Infrastructure For Africa’s Ecological Security. The African Development Bank and WWF – the World Wide Fund for Nature. ISBN 978-2-940443-39-0.

[13] Mesev V, Gorte B and Paul L A 2001 Remote Sensing and Urban Analysis. First published 2001 by Taylor & Francis 11 New Fetter Lane, London EC4P 4EE.

[14] Akbari H, Berhe A and Levinson R 2006 Cool Color Roofing Materials. California Energy Commission, Berkeley, CA,73 p.

[15] Eike L, Catherine M 2013 Ecosystem Vulnerability to Climate Change, a Literature Review. World Agroforestry Center.

[16] Salomon T, Aubert C 2004 La fraîcheur sans clim. Terre Vivante, Paris, 160 p.

[17] Corlett R 2010 Global Climate Change and Biodiversity. University of East Anglia, Norwich, UK.

[18] Mccarty J P 2001 Ecology Consequence of Recent Climate Change. Journal Conservation Biology Page. Vol 15 No. 2 April.

[19] Noonan-Mooney K 2018 How are people affecting biodiversity. Ladybird, Julia Kresse

[20] Kang H, Li X and Zang J 2015 GIS Analysis of Changes in Ecological Vulnerability Using a SPCA Model in the Loess Plateau of Northern Shaanxi, China. International Journal Environment. Res. Public Health Vol 12, 4292-4305