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CHANGE ANALYSIS OF INDICES (NDWI, NDVI,NDBI) FOR MAWLAMYINE CITY AREA USING GOOGLE EARTH ENGINE

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Abstract

Until last year, most of the scholars in Geography face many problems to get fine resolution satellite images, to have small knowledge for geo-spatial techniques and difficult the use of GIS analysis as professional. To overcome the above said limitations, Google Earth Engine (GEE) can be able to get a lot of satellite images easily, easy access to data, online platform with scientific algorithms, computational power and etc. This research is analyzedusing GEE platform for temporal and spatial change of urban area which is based on satellite imagery from Landsat 5and Landsat 8 Top of Atmosphere (TOA) as inputs for Mawlamyine City, Mon State. The analysis of indices: normalized difference vegetation index (NDVI), normalized difference water index (NDWI) and normalized difference built-up index (NDBI) produce fine-quality of vegetation, water and built-up values. Although the dataset can facilitate these three indices in any platform, this paper highlight its potential use in GEE for temporal scale analysis of the urbanization process. The main aim is to evaluate the extracted values from three indices that can be applied to GEE platform for urban area analysis. The results show that the reflected values of vegetation, water and built-up in Mawlamyine City during the three time periods (1997, 2007 and 2017). This process requires reliable and comprehensive checked with field survey data for build up to validate of these products. Actually the result of built-up area comprises with the mixture of built up and bare land. It can also be reclassified with the positive and negative Digital Numbers (DNs) for built-up and bare areas. Thermal Infrared Sensor(TIRS) can only classify as an indicator to separate built-up from non-built-up areas (bare land) but this paper cannot calculated this processes to preparing for further study.

Key Words: Google Earth Engine, TOA, NDVI, NDWI, NDBI, algorithms, built up, bare land

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Introduction

Understanding the spatial distribution and growth of urban areas is essential for urban planning and resource management, and one of the basic activities required for this purpose is mapping the built-up areas (Bertrand-Krajewski, Barraud, and Chocat, 2000).Google Earth Engine is a cloud based geospatial remote sensing processing platform, complete with an extensive public data catalog (www.adpc.net). Another factor is that the encroachment of people living in slums and squatters are forced to the extended urban area. The often rapid urban expansion also makes the task of a timely and accurate mapping of urban built-up areas quite difficult (Small, 2003; Perepechko *et al*., 2005; Lein, 2006). Acceleration rates of population growth and expansion of urban areas in the most countries focus on economic development, activities and transportation accessibility. The rapid urbanization is caused by population growth as well as by people migrating from rural areas to towns in search of a better life. Establishing industrial zone in 2002 was also one of the factors that attracted immigrants from nearby towns and other places in southern Myanmar to Mawlamyine City. Therefore, population increases noticeably in this city as well as results from economic growth and job opportunities.

GEE can restore multi-temporal images without involving ancillary data and benefit from products already available in GEE. It also provides a cloud-based platform to access and seamlessly process large amount of freely available satellite imagery. Hence, it provides a set of the state of the art classifiers for pixel-based classification. Though these methods are well-documented in the literature, there were no previous studies to compare all these methods for classification. Only fine resolution imagery (30m spatial resolution) has been utilized to derive urban built up area extent. While enhancing the spatial characteristics, resolution merging methods should preserve the equally useful spectral properties of original multispectral data.

Each method has its own set of advantages and limitations; however, indices have a certain edge over other classification methods in terms of time needed to generate results. A variety of indices have been developed for the extraction of features of interest from satellite imagery. It can explore efficiency of using the GEE platform when classifying multi-temporal satellite imagery for built up area with a larger scale (e.g., town level), time duration (e.g., 1997, 2007 and 2017) and multiple sensors (e.g., Landsat-5 and Landsat-8 TOA).The normalized difference vegetation index (NDVI) is the most commonly used for the extraction of vegetation. Other indices include the normalized difference water index (NDWI) and normalized difference built-up index (NDBI) for water and built-up area extraction, respectively. These three indicate that spectral indices can be safely applied to resolution-merged imagery if the resolution ratio between the merged bands is small. The calculations of these indices are based on the specific properties of the features of interest in terms of strong absorption or reflection in different spectral bands of multispectral imagery (Jensen, 2006). However, such mapping is still challenging due to spatial, spectral and temporal variability in built-up areas for the study area.

Aim and Objectives

The main aim is to explore efficiency of using the Google Earth Engine platform when using normalized difference indices for Urban Area with spatial, spectral and temporal analysis. The objectives of this study comprise: (1) to learn about Google Earth Engine data structures and methods, functions, and algorithms(2) to compare spectral responses of the three indices within three decadal periods and (3) to evaluate the extracted values from indices for urban area analysis.

Study Area

Mawlamyine City is located at latitude 16º29' N and longitude 97^0 38' E. Covering an area of around 106.79sq-km (41.23sq-miles)with the ranges of surface elevation from5.5 meters to 61 meters above mean sea level. It is characterized as a flat terrain. It was the administrative headquarters of the Tanintharyi pan-handle part of the country. The city became the capital of Mon State in 1974. The city occupies the left bank of the Thanlwin River where it branches off into the Gulf of Mottama. The Yankin Ridge is steeper than the surrounding area of study area. The long axis is about 11.3 kilometers from north to south. Originally the urban area was on the west of the central ridge but at present urban expanded to the east and south of the range. The low central Yankin Ridge and the scenic coastline with Bilugyun Island on the west give a beautiful natural setting to the city. The surface is not flat but is a rolling topography. At present, the shape of urban area in Mawlamyine City is nearly compact shape. Thanlwin, Attaran and Gyaing are the three important rivers for Mawlamyine City. The Attaran and Gyaing join the Thanlwin in north and northeast. The Thanlwin branches off into two and empties into the sea from "Darebauk('&,fayguf)" River in the south and Mawlamyine River in the south which is 45.1 kilometers apart as the crow flies. The location of study area in Mon State is shown in Figure1.

Before 1826, Mawlamyine, one of the riverside towns, has about 2500 residents on the alluvial plain locating the junction of Thanlwin River and Attaran River. After 1989, the State Law and Order Restoration Council faces the problem of increasing population and migrating people from rural area. It had renovated and expanded the cities to meet the required standard of a progressing nation. Thus, new urban areas of Mawlamyine were also established in urban-rural fringe areas. The urban areas were extended only in the eastern and southern parts because western boundary of Mawlamyine City is Thanlwin River and Central part in higher Yankin Ridge. Therefore, urban area extension can be found eastern and southern part(Myint Thida, Myo Myo Khine, Khin Maung Zaw, 2011).

In 1993, the total population of the city was 239,683. The city has a total population of around 289,388with about 87.7% residing inurban and the rest in peri-urban and rural areas (Census Report Volume 3-J (Mon), 2014). The city is administratively divided into twenty-one in 1993 and gradually increased into twenty-nine wards in 2017.For the purpose of this research, these areas were selected as they extracted areas having built-up densities with the periods of 1997, 2007 and 2017.

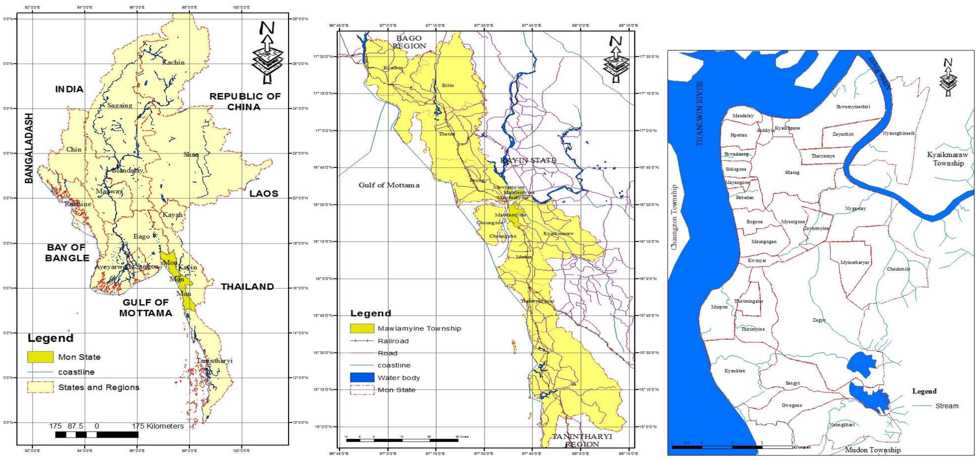


Figure1: Location of the Mawlamyine City, Mon State and Myanmar
Source: Myanmar Information Management Unit 2014

Methodology

Mawlamyine City image collection referred to a set of Google Earth Engine. It is a cloud based geospatial remote sensing processing platform, complete with an extensive public data catalog. It is available via a web-based Application Program Interface (API) called the Code Editor. In this study, Landsat satellites images from Landsat Thematic Mapper (TM)and Operational Land Imager (OLI)are used to interpret features analysis. The proposed method for extraction of spectral indices areas using GEE comprised four major steps: preprocessing of satellite data, image enhancement through resolution merging, calculation and extraction of three spectral indices and change areas assessment.

(a) Preprocessing of Satellite Data

In the study, classification of imagery is performed at per-pixel basis. Multiple imagery collection techniques are constructed a java script in GEE. One way to create a Feature Collection is to provide the constructor with a list of features for region of interest (roi). The features do not need to have the same geometry type or the same properties.

```
// Get a collection.
var L8_collection = ee.ImageCollection('LANDSAT/LC8_L1T_TOA');
var l5_collection = ee.ImageCollection('LANDSAT/LT5_L1T_TOA');
```

And then, collections more than 500 images is needed to be filtered for the region of interest (roi) (path: 131, row: 49) before printing. Earth Engine provides a variety of convenience methods for filtering image collections. To decrease an impact of atmosphere to the image quality conversion from the TOA reflectance to the surface reflectance (SR) has been done using the Simplified Model for Atmospheric Correction. In order to avoid the influence of cloud, most of images are acquired from February to April within 1997, 2007 and 2017. The World Geodetic System of 1984 (WGS84) wasset as coordinate systems.

```
var temporalFiltered = spatialFiltered.filterDate('2017-03-15','2017-04-15');
```

Then, the Mawlamyine City called as region of interest (roi) in GEE was created a rectangle feature geometry on java script and defined area.

```
// Make a list of Features.
 varroi= ee.Geometry.Rectangle([97.59,16.53,97.67,16.38])
```

This research uses two multispectral satellite imageries: Landsat-5 Thematic Mapper (TM) imagery and Landsat-8 Top of Atmosphere (TOA) imagery of Mawlamyine City which are acquired and mainly used to analyze urban expansion in City (Table-1). These images are resampled to 30 m resolution, and all reflective bands are applied in image classification excluding the thermal band. Landsat-7 Enhanced Thematic Mapper Plus (ETM+) has caused a problem by failure of the Scan Line Corrector (SLC).

Table 1: Two Multispectral Satellites and Acquired Date

Name of Satellite	Acquired Date	Resolution (meters)	Path/Row and specification
Landsat-5 (TM)	From 01-02-1997 To 31-04-1997	30/120 thermal (7 Spectral Bands)	LANDSAT/LT5-L1T/ LT51310491997112BKT01
Landsat-5 (TM)	From 01-02-2007 To 30-04-2007	30/120 thermal (7 Spectral Bands)	LANDSAT/LT5-L1T/ LT51310492007108BKT00
Landsat-8(TOA)	From 15-3-2017 To 15-4-2017	30/100 thermal (11Spectral Bands)	LANDSAT/LC8-L1T-TOA/ LC81310492017119LGN00

http://landsat.usgs.gov/tools_specialViewer

(b) Image Enhancement through Resolution Merging

Enhancement are used to make it easier for visual interpretation and understanding on imagery. For scoring Landsat pixels by their relative cloudiness, Earth Engine provides a rudimentary cloud scoring algorithm in the method. To create a median value image from a collection of the multi band, the names of the reducer has been appended to the band names. At the study location in the output image with each year, the pixel value is the median of all unmasked pixels in the input imagery. `Median ()` is a convenience method for the calculation:

```
//reduce to median value per pixel
var median_1997 = toa_1997_noCloud.median();
var median_2007 = toa_2007_noCloud.median();
var median_2017 = toa_2017_noCloud.median();
```

Figure 2(A) and (B) illustrate the difference between spatially enhanced image and median filter to reduce noise image, respectively, at a sample location in the study area. Image enhancement is the process of adjusting digital images so that the result are more suitable for display or further image analysis.

A. LANDSAT/LC8-L1T-TOA/ LC81310492017119LGN00

B. LANDSAT/LC8-L1T-TOA- Median

Figure 2: Landsat-8 TOA False Colour Composite (A) spatially enhanced image and (B) Median filterimage of Mawlayine Area

After enhanced images, the images are displayed with the default visualization: first three bands map to RGB and stretched to [0, 1] since the bands are float data type. To render the image as true colour composite, Earth Engine is displayed both the Landsat 5 bands B3, B2 and B1and the Landsat 8 bands B4, B3 and B2 band combination for R, G, and B. In contrast, false colour composite for land cover extraction, GEE is create the Landsat 5 bands B4, B7 and B3and the Landsat 8 bands B5, B7 and B4 for RGB, respectively. Specify which bands to use with the `bands` property of the `visParams` objects applied the scrip. Learn more about Landsat band combinations for visualization at this reference.

```
//add True and False Color Composite for Annual Median Reflectance
layers
Map.addLayer(median_1997,
{ min:0.05, max: 0.4, bands: ['B3, B2, B1']}, 'median_2007');
{ min:0.05, max: 0.4, bands: ['B4, B7, B3']}, 'median_2017');
```

The result of true and false colour composite were showed in Figure 3 for visualization analysis. Note that this code assigns the object of visualization parameters to a variable for possible future use.

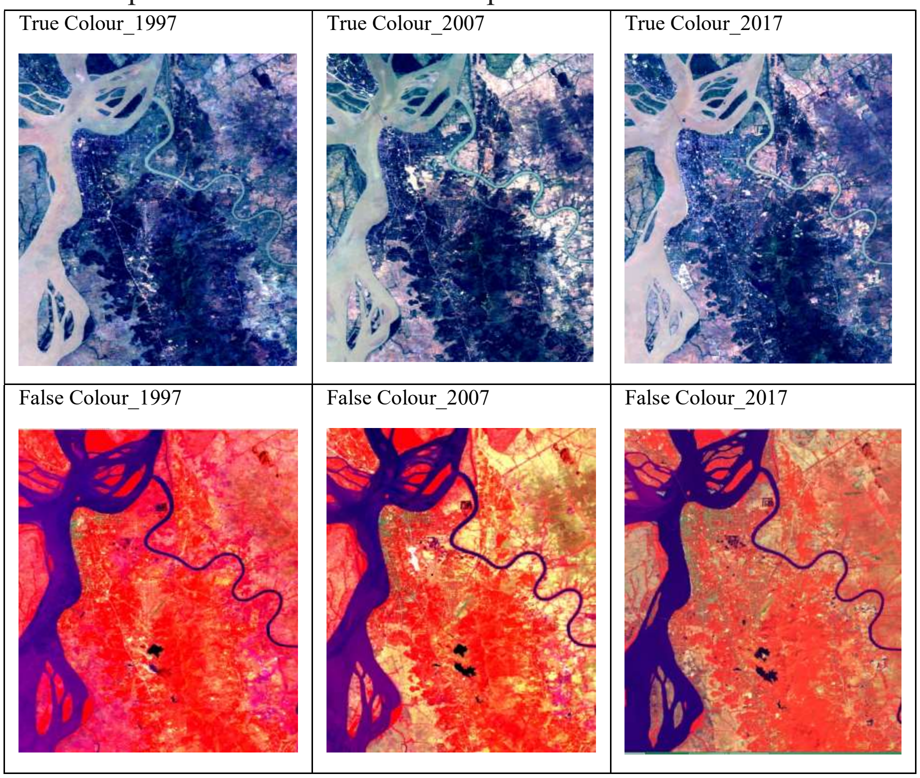


Figure 3: True and False Colour Composite for Mawlamyine City (1997, 2007 and 2017)

(https://code.earthengine.google.com)

(c) Calculation and Extraction of Three Spectral Indices

To extract three spectral indices: multispectral bands are calculated for Mawlamyine City. The positive values of NDBI, NDWI and NDVI represented built-up areas, water and vegetation, respectively. The methodology comprises three arithmetic computations or GEE algorithm. Vegetation reflects light in the near-infrared (NIR) part of the electromagnetic spectrum and absorbs light in the red part. NDVI uses this to create a single value roughly reflecting the photosynthetic activity occurring at a pixel. This results in a number between 1 and -1, where pixels with high photosynthetic activity have a high NDVI. This image was obtained using Equation (1)

$$NDVI = \frac{TOA\ Band\ 4 - TOA\ Band\ 3}{TOA\ Band\ 4 + TOA\ Band\ 3} \text{ (OR) } NDVI = \frac{TOA\ Band\ 5 - TOA\ Band\ 4}{TOA\ Band\ 5 + TOA\ Band\ 4} \quad \text{---- (1)}$$

To write Java script,

```
// NDVI calculation
varndvi_97= median_1997.normalizedDifference(['B4','B3']).rename('nd_97');
var ndvi_07 = median_2007.normalizedDifference(['B4','B3']).rename('nd_07');
var ndvi_17 = median_2017.normalizedDifference(['B5','B4']).rename('nd_17');
```

Second, the NDWI to delineate open water features was calculate Equation (2). Water uses in conjunction with vegetated cover (green) to access context of apparent change area.

$$\text{NDW}I = \frac{TOA\ Band\ 2 - TOA\ Band\ 4}{TOA\ Band\ 2 + TOA\ Band\ 4} \text{ (OR) } NDWI = \frac{TOA\ Band\ 3 - TOA\ Band\ 5}{TOA\ Band\ 3 + TOA\ Band\ 5} \text{-----(2)}$$

```
// NDWI calculation
var ndwi_97 = median_1997.normalizedDifference(['B2','B4']).rename('nd_97');
var ndwi_07 = median_2007.normalizedDifference(['B2','B4']).rename('nd_07');
var ndwi_17 = median_2017.normalizedDifference(['B3','B5']).rename('nd_17');
```

Thirdly, Built-up is typically a higher reflectance in the shortwave-IR, compared to NIR. Based on the high reflectance in the 1.55–1.75 µm and their low reflectance in the 0.76–0.90 µm wavelength range, NDBI was computed using Equation (3)

$$\text{NDB}I = \frac{TOA\ Band\ 5 - TOA\ Band\ 4}{TOA\ Band\ 5 + TOA\ Band\ 4} \text{ (OR) } NDBI = \frac{TOA\ Band\ 6 - TOA\ Band\ 5}{TOA\ Band\ 6 + TOA\ Band\ 5} \text{------(3)}$$

```
// NDBI calculation // builtup index
var ndbi_97 = median_1997.normalizedDifference(['B5','B4']).rename('nd_97');
var ndbi_07 = median_2007.normalizedDifference(['B5','B4']).rename('nd_07');
var ndbi_17 = median_2017.normalizedDifference(['B6','B5']).rename('nd_17');
```

(d) Change Areas Assessment

The performance of the proposed spatial indices extraction method in Mawlamyine City was tested through accuracy assessment at 30 point locations (pixels) using a stratified random sampling technique. Three strata, vegetation, water and built-up including non-built-up were formed and taken from each of them based on their proportion in the output image. And also checked with the Google Earth 2017 population/household data from 2014 census data, field survey and some literature reviews. These difference data were compared to assess their efficiency in terms of segregating built-up areas from other land uses. Different areas were visually examined by change detection method in detail.

Results and Discussion

GEE platform offers powerful capabilities in handling large volumes of remote sensing imagery that a set of classificational gorithms to be used for spatial analysis purposes. In order to deal with irregular observation and missing values due to clouds-based and shadows, a compositing approach was applied. Also, using the JavaScript APIs, it is possible to fill missing values of Landsat images. Spectral responses of built-up areas including bare land, vegetation and water areas were examined in Landsat multispectral bands. All three types had a unique signature in optical bands which indicated that they can be segregated from their respective indices. The analysis of indices is the function of the visible bands of multispectral data and the near infrared bands. Likewise, there are other indices using different spectral bands that may be calculated to allow more efficient interpretation of features. The overall spatial distribution of vegetation, water and built-up including bare land areas obtained from the NDVI, NDWI and NDBI indices using Google Earth Engine data are shown in Figure 4.

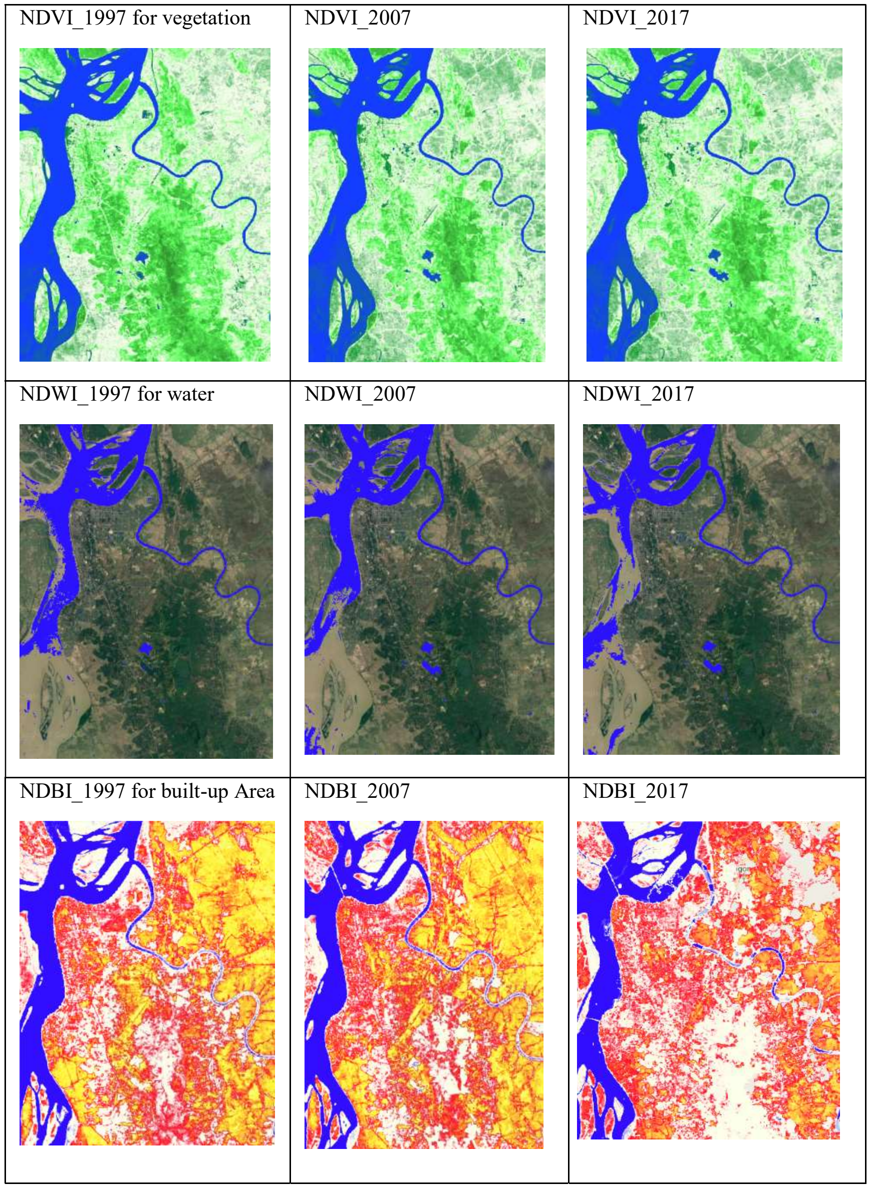
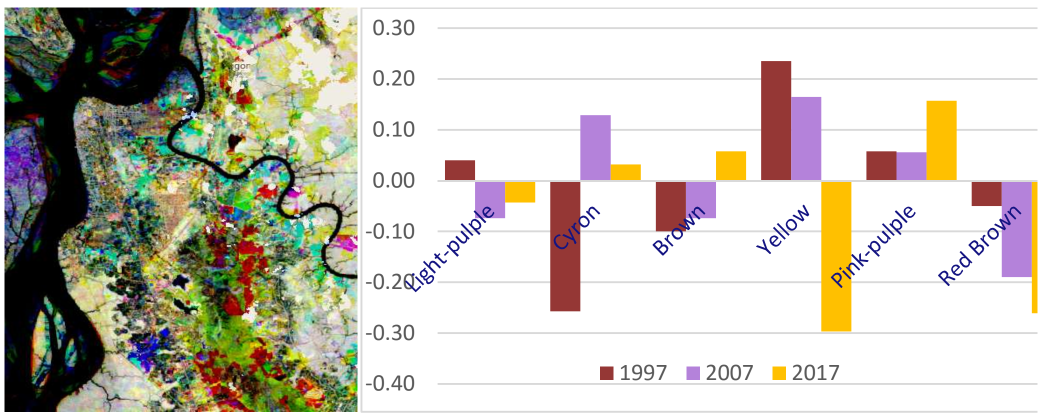


Figure 4: Comparative of NDVI, NDWI and NDBI indices

The Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Normalized Difference Built-up Index (NDBI) are selected in this study to compares for three periods. Mawlamyine city consists of urban built-up land features, water bodies and water courses imbedded in vegetation. Another relevant finding was the difference between temperatures of the three land-cover types. NDVI has been determined that the changing vegetated areas give a very simple and fast interpretation of Landsat satellite data. It expresses the relation between red visible light (from 0.4 to 0.7 μm) (which is typically absorbed by a plant's chlorophyll) and near-infrared wavelength (from 0.7 to 1.1 μm)(which is scattered by the leaf's mesophyll structure).The values of NDVI (0.2 to 0.5) represent shrub and grassland if high value (0.6 to 0.9)also indicate tropical rainforest. Negative value correspond to water, value close to zero (-0.1 to 0.1)correspond to barren areas of rock or sand. Figure 4shows that the changing vegetated areas using three decadal period. Dense vegetation cover can be found over the Yankin range and its surrounding area in 1997 but some areas near the waterfront area and the southern part are a change to thinly vegetated area in 2007. During 2017, the eastern and southeastern part of study area is becoming vegetated areas which may be replanted near the new Kimmonchom and Shwe Nattaung reservoirs for soil conservation.

Another interesting finding was found that NDWI can supply the extracting water as non-built-up area. NDWI is sensitive to atmospheric effects than NDVI. The Attaran and Gyaing join the Thanlwin in north and northeast. After the construction of Thanlwin Bridge (Mawlamyine) in 2004, the drainage pattern was changed from DarePauk, in the north and Kyaikkame in the south. The positive values of NDWI represent water content while the range between (-1) and (0) represent bright surface with no vegetation or water content. Thanlwin estuary, being two distributaries Darebauk in the north and Mawlammyine River in the south, flows entering into the gulf of Moattama. During 1997, Darebauk(N) and Mawlammyine (S) drainage pattern were same with developing fishery resources. After the construction of Thanlwin Bridge in 2007 which crosses at the center point of the distributaries, had created high sediment accumulation in the Darebauk. This effect on Mawlammyine River may be changed to the alteration of the water course. After construction of embankment along the strand road and Chaungzone Bridge in 2007, Mawlammyine River drainage system begins to flow retarding and course changing of this area.

Besides, vegetation and water were very well separated from built-up areas indicating that both NDVI and NDWI were correctly processed. NDBI was able to extract built-up areas with reasonable accuracy when applied to Landsat data. Thus, the reason for the high commission error may be attributed to spectral mixing of built-up areas with land-cover types other than transportation or vegetation or water. Figure 4presents the three changing of built up areas: built-up (red) and bare land (yellow) are mixed in 1997, built-up land are dense along the transportation rivers and roads in 2007 and bare land can be found scarcely in the study area in 2017. Actually higher temperature readings of built-up areas in the thermal bands can be used as an aiding factor to separate built-up areas from vegetation and water. This paper cannot separate urban area purely from mixture of bare land or non-built up areas but this calculation may be used for further study.



https://code.earthengine.google.com

Figure 5: Changes Areas of spatial, spectral and temporal in Mawlamyine City

Band combination of three spectral indices: (NDVI), (NDWI) and (NDBI) pixels value is calculated for accuracy assessment of changing patterns. The changing detective values also indicate a clear separation in spectral responses. As illustrated in Figure 5,change area of three spectral indices pixels value with seven colour tones show built-up areas, whereas light purple show urban areas since 1997and pink and grey purple tones are urban areas as the downtown of Mawlamyine City. And also light brown tone in urban area is interrupting the transport construction with concretes' reflectance. Cyan and light blue among the urban area which was the bare land until 1997has been changed the new urban extension areas since 2007. Densely vegetated areas appear dark and light green in this image, whereas vegetation and a few areas with less dense vegetation are shown in bright tones. Near the vegetation green area can be found urban area with dark purple again which is existing with the less transportation road since 1997. Yellow mixture with the built up with transportation road and bare land since 1997.A very clear separation between vegetation and other land-cover types is evident in this output. Water is shown as black pixels in this image, whereas other land-cover types are depicted in the tones of grey and light brown. Areas with dense vegetation appeared-brown whereas atmospheric cloud intervention.

The result of change areas' image values is verified with the Google Earth 2017, population/ household data from 2014 census data, field survey data in April, 2017 and historical recorded data. Figure 6 shows the three changes of urban area according to the urban development plan. These factors are the focus of economic development, activities and transportation accessibility. It increased to 53,107 persons in 1881, to 102,777 in 1953 and to 203,214 in 1973. According to the census data, the population of Mawlamyine City was 219,961 persons in 1983 and it increased to 289,388persons in 2014. During 1959-1960, squatter huts were moved out to wards such as Shwemyinethiri and Thirimyine wards. To meet the basic need for growing population in Mawlamyine City, urban area extension had been conducted and people are created and allocated new urban wards. In 1971, the administrative authorities put forward the "Greater Mawlamyine Project" with an aim to expand the town to the east of Yankin Ridge. And downtown urban areas have been established on the eastern and western side of the Yankin Ridge. In 2015, seven new wards was established due to accelerate rates of population growth in this area and upgraded from former rural village to urban areas. Urban area extension has been found in southeastern and southern part of Mawlamyine City. The verification for ground survey check for urban area growth is major requirement for regional development planning in Mawlamyine City.

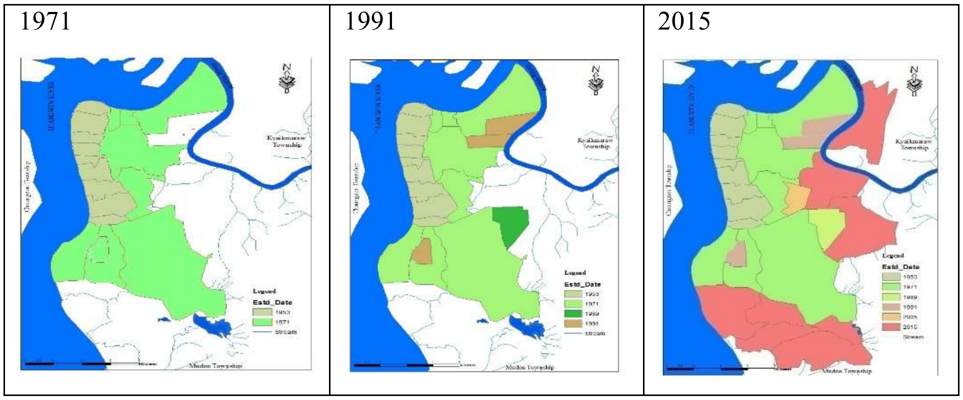


Figure 6: Urban Expansion of Mawlamyine City
Source: Township Administrated Office, 2016

Conclusion

Most of the cities are facing urbanization as more and more people are migrating to urban areas. In order to have a proper control on urbanization, it is necessary for an urban planner to have accurate information on current landuse practices and should able to know how landuse changes over the years. The basic foundation of indices discussed above is the spectral response of vegetation, water and built up areas in different bands of Landsat-5and Landsat-8 TOA data. In the present study, Mawlamyine City is explained not only for the temporal and spatial changes within the three decadal periods (1997, 2007 and 2017) but also for the spectral differences between spectral wavelength ranges of the bands for the three indices (NDVI, NDWI and NDBI). Therefore, this study is proposed for extracting built-up areas using NDBI, for vegetation using NDVI and for water using NDWI.

The output image was later segmented into a binary image (1 and 0) using an optimal threshold value. Actually the built-up areas can be reclassified with the positive for built-up and bare areas. Another important characteristic suggests that temperature can be used as an indicator to separate built-up from non-built-up areas (bare land) but this paper cannot calculated here to preparing for further study. Until the last decades, the researchers in education sector faces the many difficulties to get lower resolution image with low cost, impossible to get the latest image, very expensive to get latest high resolution satellite image and how to mosaic and clip to facilitate onscreen digitizing using GIS software. The use of GEE consequently helped in capturing the variance and comprehending a broader range of useful dataif you got good facilitated internet access.

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မော်လမြိုင်မြို့နယ် ဒေသဆိုင်ရာအချက်အလက်များ (၂၀၁၆)၊ မြို့နယ်အထွေထွေအုပ်ချုပ်ရေးဦးစီးဌာန၊ မော်လမြိုင်မြို့။

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