

Evaluation of Various Vegetation Indices for Multispectral Satellite Images

L.Gowri, K.R.Manjula

Abstract: Vegetation indices play a predominant role in the field of Remote processing systems which assimilate vital multispectral images. The digital numbers identify the spectral information in one or more spectral bands. It focuses mainly on two or more spectral regions and obtains different types of surfaces like vegetation, built-up, bare soil and water area. Different types of vegetation can be studied and analyzed using LANDSAT images. In this paper, comparison has been made on ten major vegetation indices such as RVI, DVI, NDVI, TNDVI, NDWI, MNDWI, NDBI, UI, SAVI, and NDMI using different spectral bands and different features are detected and extracted with the help of ArcGIS and MATLAB tools. This study reveals better classification accuracy.

Keywords: NDVI, NDBI, Landsat5, SAVI, UI

I. INTRODUCTION

Remote sensing is a technique to acquire the information about land and ocean. It is used to observe an object's shape, texture, pattern, size and physical characteristics of an object. The spectral reflectance properties are measured with the help of the electromagnetic spectrum. Spectral variations are the changes of reflection or emission of objects. Several spectral vegetation indices are derived from remotely sensed data, which is useful to monitor the Earth's vegetation [6] swath. The vegetation indices are used to represent an algebraic combination of spectral reflectance. The signature characteristics are calculated using statistical methods. Landsat5 Thematic Mapper (TM) was a low earth orbit satellite and launched on first March 1984 to collect earth surface images. The satellite images collected in seven spectral bands with 30 and 120 meters spatial resolutions. The band 1 to band 5 and band 7 have 30 meters resolution and band 6 is a thermal band with 120 meters spatial resolution, but it is resampled with 30 meters. The satellite swath width is 185km and coordinate system is UTM zone 44 and worldwide reference system-2. This paper is aimed to compare different vegetation indices and extract different types of features from the satellite images. Types of vegetations are classified into many numbers of ways: based on the range of spectral bands or based on slope value [4] or based on distance or based on visible and invisible region comparison. First, we focused vegetation area and no vegetation area. For finding this, we used the following indices RVI, DVI, NDVI, and TNDVI.

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L.Gowri, School of Computing SASTRA Deemed University, Thanjavur, Tamil Nadu, India.

Dr.K.R.Manjula, School of Computing SASTRA Deemed University, Thanjavur, Tamil Nadu, India.

The RVI is used only the ratio of visible and invisible band. The DVI is helpful for finding the differences between visible and invisible bands, but we could not get normalized value. So we move to NDVI [5], which is useful for finding different type features present in the image. This NDVI consider equal preferences of features. The TNDVI highly focus vegetation features. The land areas cover either water content or soil content. The NDWI [2] and MNDWI [2] are used for finding presence of water content in the image. The land use changes generally obtain with the help of residential or non-residential. For identifying this, we used a Normalised Difference Built-up Index (NDBI) [3] and Urban Index (UI) [7]

II. STUDY AREA

We used Landsat5 (TM) images from USGS earth explorer [10]. The acquired image data is 32-bit radiometric resolution with GeoTiff format. It consists of 7 bands with the spatial resolution of 30 meters. Location of the study area: Thanjavur is the city of Tamil Nadu state in the south Indian. The city is placed in Cauvery delta zone, and it is one of the agriculture centres' of Tamil Nadu. This district is located at 10.08°N 79.16°E in Central Tamil Nadu. The Thanjavur district covering area is 36.33 km² approximately 14.03 square miles.

Table I: Landsat5 (TM) Satellite Data details

Image No.	Path	Row	Date of image acquisition
1	142	52	19-05-2008
2	142	53	03-05-2008
3	143	52	26-05-2008
4	143	53	10-05-2008

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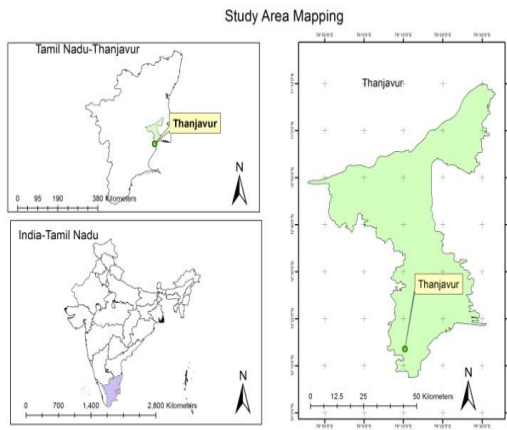


Fig. 1: Study Area - Thanjavur Region

III. METHODOLOGY

A. Satellite image data Pre-processing

In this study, we used the Thanjavur district image, which is used to identify the political boundary of the district. Thanjavur district satellite image is not a single path and row image. It has four different combinations of path and row images. After collecting all images from the USGS earth explorer, we need to apply radiometric correction and atmospheric correction separately for all bands with respective images (path and row). The processed images are ready to process different types of indices. These images contain information about vegetation, soil, build-up and water areas. Before calculating indices, it requires two steps of pre-processing the image. The first step of pre-processing is the radiometric correction. To improve spectral radiance, the digital brightness values need to be calibrated. It helps to normalize spectral values among wave bands. The purpose of radiometric pre-processing is reducing the radiometric noise or error present in the image. The DN (Digital Number) values are converted into radiance, and those radiance values should be converted into reflectance values using the standard equation [8]. The DN to Spectral Radiance conversion:

$$SR_{\lambda} = \frac{SR_{MAX\lambda} - SR_{MIN\lambda}}{Q_{MAX} + Q_{MIN}} * (DN - 1) + SR_{MIN\lambda} \quad (1)$$

Where, SR_{λ} is the cell value radiance. The $SR_{MAX\lambda}$ is the spectral radiance that is scaled to Q_{MAX} . $SR_{MIN\lambda}$ is the spectral radiance that is scaled to Q_{MIN} . Q_{MIN} is the minimum quantized calibrated pixel value, the typical value is 1. Q_{MAX} is the maximum quantized calibrated pixel value; the typical value is 255. DN is the band specific digital number. $SR_{MAX\lambda}$, $SR_{MIN\lambda}$, Q_{MIN} , Q_{MAX} and DN values can be found in the metadata file. Next step is converting from spectral radiance to Top of Atmospheric (TOA) spectral reflectance [9]

$$TOA = \frac{\pi * SR_{\lambda} * d^2}{ESUN_{\lambda} - COS(V)_S} \quad (2)$$

Where TOA is the planetary reflection, the value of π is 3.14, d is Earth Sun distance in astronomical, $ESUN_{\lambda}$ mean solar exoatmospheric spectral irradiance which is available in USGS exoatmospheric spectral site. $COS(V)_S$ is solar zenith angle in degrees. The d and v values can be found in the metadata file. Second step of pre-processing is atmospheric correction. Due to presence of scattering or absorption effect in atmosphere, the surface characteristics are modified. Dark Object Subtraction (DOS) is the simple method and often used for image atmospheric correction. Identify the minimum DN value with the help of histogram of image and subtract this minimum value from all pixels of wave bands. The purpose of atmospheric correction is reducing atmospheric disturbance.

B. Study Area Subset and Feature Extraction

After pre-processing the images, we need to locate the exact location of the study area. This is two steps of the process shown in Fig.2. The first step is mosaic all the path and row images using ArcGIS tool. Download Thanjavur District shapes file from the internet and subset this shape file into the mosaic image then study area could be obtained. The second step is feature extraction which is used for extracting different type features form different indices.

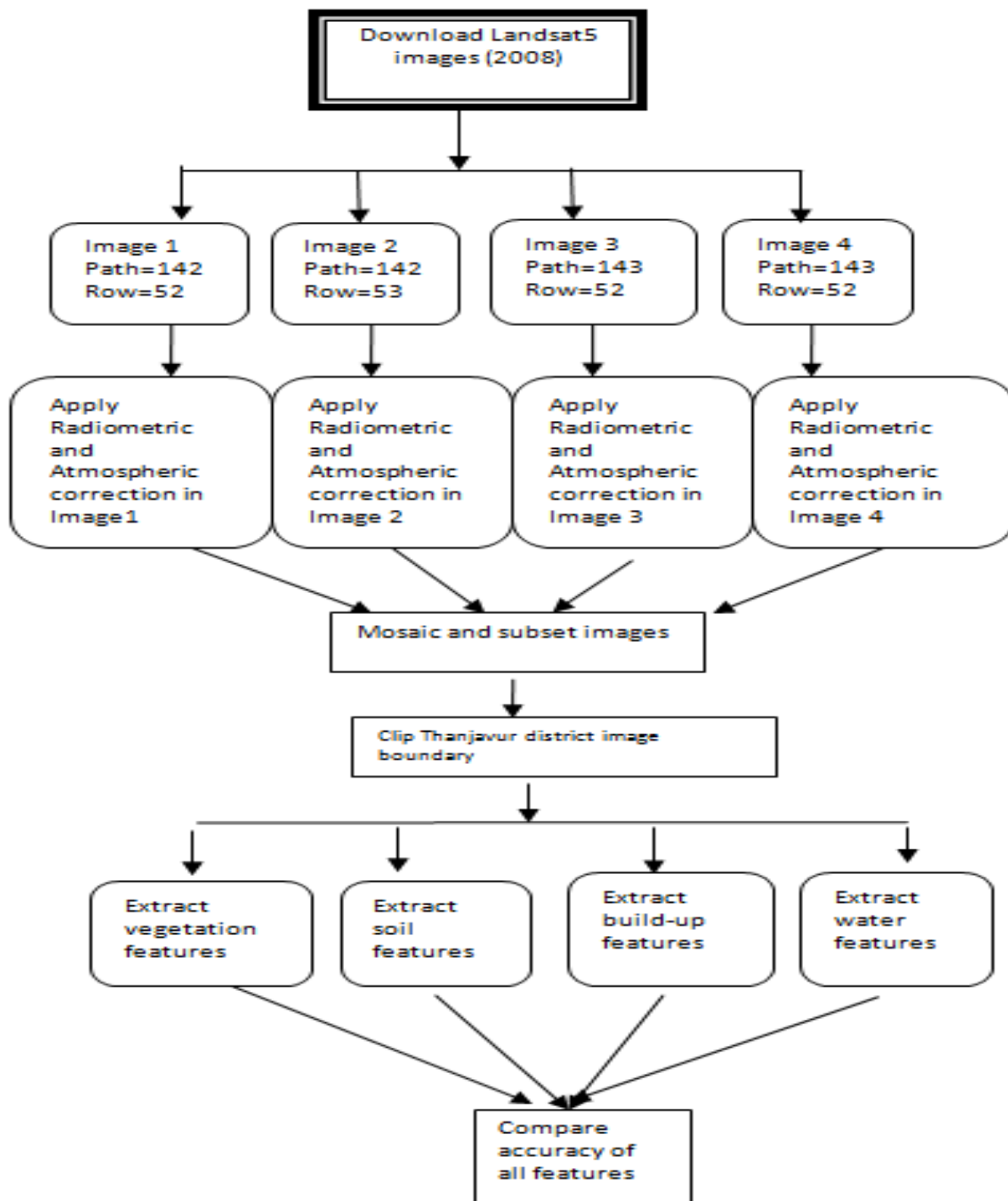


Fig.2: Flow Diagram for methodology

c. Vegetation Feature Extraction

The study area should be broadly classified into vegetation and non-vegetation areas. In this extraction we are focusing only the vegetation area. Based on the presence of chlorophyll content, the vegetation areas have been properly identified. Generally Normalized Difference Vegetation Index (NDVI) has the range of -1 to +1. The values lie between -1 and 0 there is no vegetation and the values lie between 0.1 and 1 has vegetation portions. This range of values is very useful to categories as dense, medium and sparse area of vegetation. For identifying strength of

vegetation, we used Difference Vegetation Index (DVI), Ratio Vegetation Index (RVI) and Transformed Normalized Difference Vegetation Index (TNDVI). The simple or ratio vegetation index is used to differencing green vegetation from soil type of background reflectance. High chlorophyll content or healthy vegetations are highly reflected in the range of infrared spectrum region. Low chlorophyll or no chlorophyll contents are reflected in the range of red region. This reflection difference between TM_{RED} and TM_{NIR} is useful for separating vegetation and no vegetation

area clearly. The range of RVI is 0 to infinity.

$$RVI = \frac{TM_{RED}}{TM_{NIR}} \quad (3)$$

The range of ratio values are lies between 0 and 1.0 that should be considered as vegetation while the ratio values greater than 1 to some extent is taken as no vegetation area. The main problem is divisible by zero. When pixel value is 0 in the TM_{RED} spectrum then will assign infinity as ratio value. Remove this problem, to compute Normalized Difference Vegetation Index (NDVI). First try with Difference Vegetation Index (DVI), which is used for distinguished between TM_{NIR} and TM_{RED} spectrum band

$$DVI = TM_{NIR} - TM_{RED} \quad (4)$$

The equation 4 is used to find only minimum number of difference between TM_{NIR} and TM_{RED} band reflectance. The ranges of values are less than 0 indicate no vegetation and the ranges of values are greater than 0 indicate vegetation. The zero values are indicating soil type. This is not useful for finding dense vegetation indices. So we need to move NDVI method. This is useful for finding different type of vegetation like sparse or dense.

$$NDVI = \frac{TM_{NIR} - TM_{RED}}{TM_{NIR} + TM_{RED}} \quad (5)$$

NDVI is used to measure the healthy and unhealthy vegetation area. The range of values are lies between -1 and 1. If the values have low spectral reflectance in TM_{RED} band and high spectral reflectance in TM_{NIR} band, this will give positive values and different range of vegetation area. If the values have high spectral reflectance in TM_{RED} band and low spectral reflectance in TM_{NIR} band, this will give negative values and no vegetation area like water content.

$$TNDVI = \sqrt{NDVI + 0.5} \quad (6)$$

D. Water Feature Extraction

Normalized Difference Water Index is used to extract water bodies from the satellite images. TM_{SWIR} spectral value is used to detect water bodies and moisture content of the image. TM_{NIR} is to used find dry content, but not for water content. So the water features are display in positive values and soil or vegetation features are suppressed into negative or zero values. So we called this index is independent of vegetation index.

$$NDWI = \frac{TM_{NIR} - TM_{SWIR1}}{TM_{NIR} + TM_{SWIR1}} \quad (7)$$

This NDWI is used only invisible spectrum range of values to find out water content of the image. To maximize this water content reflection, we use combination of visible and invisible spectrum ranges. The green band wavelength is used to identify the increased level of water content reflection of the image. Because of absorbing, the TM_{NIR} wavelength reflection is low. So we used TM_{SWIR2} and TM_{GREEN} wavelength.

$$MNDWI = \frac{TM_{GREEN} - TM_{SWIR2}}{TM_{GREEN} + TM_{SWIR2}} \quad (8)$$

For eliminating presence of soil feature and vegetation feature, it should use TM_{GREEN} and TM_{SWIR2} reflection bands and also enhance the presence of water features than the NDWI index.

E. Build-up Feature Extraction

Normalized Difference Build-up index is used to obtain the features of built-up and no built-up area. The range of reflection is minus one to plus one. The positive values are projected highly built-up area and negative values are not built-up area.

$$NDBI = \frac{TM_{SWIR1} - TM_{NIR}}{TM_{SWIR1} + TM_{NIR}} \quad (9)$$

The Urban Index is useful for finding exact level of urban area and non urban area. $UI = \frac{TM_{SWIR2} - TM_{NIR}}{TM_{SWIR2} + TM_{NIR}}$ (10)

F. Soil Feature Extraction

$$SAVI = \frac{TM_{NIR} - TM_{RED} * (1+L)}{TM_{NIR} + TM_{RED} + L} \quad (11)$$

The calculation of SAVI [6] is similar to the NDVI but it requires additional value of L. The L is soil brightness correction factor. The range of L value is lies between 0 and 1. If the value of L=0 then easily we identified healthy vegetation. The value of L=1 then there is no green vegetation. Actually L=0.5 works well in the most of situations. The moisture level index also used for finding soil content of image.

$$NDMI = \frac{TM_{RED} - TM_{NIR}}{TM_{RED} + TM_{NIR}} \quad (12)$$

IV. RESULTS AND DISCUSSION

The Ten vegetation indices (RVI, DVI, NDVI, TNDVI, NDWI, MNDWI, NDBI, UI, SAVI, NDMI) are used our study. These outputs are shown in figure 3. The RVI is used to find out variation present in visible and invisible region. This index is useful for broad categorization. Next DVI is commonly used all images for fixing the categories of features. But this also very less usage of find exact type of features. The NDVI is the best index to find out vegetation features and also most widely used index. But the index focused vegetation and no vegetation features equally. So we moved to TNDVI index, which is the best index to extract clear vegetation features from the images. The NDBI and UI indices are useful for finding built-up and no built-up area. The UI is the best index to extract better built-up features. The NDWI and MNDWI are used to figure out presence of water content in the image. The MNDWI is the good index for extract water features. The SAVI and NDMI are suited for finding soil background information. The NDMI is the best index to identify the soil and moisture content present in the image.

Finally, compare all these ten indices with respect to features and no features. The feature areas are further classified into sparse, medium and dense. This is shown in

the figure 4. The no feature area cover 42%, the sparse area cover 26%, the medium area cover 22% and the dense area cover only 10% of the image.

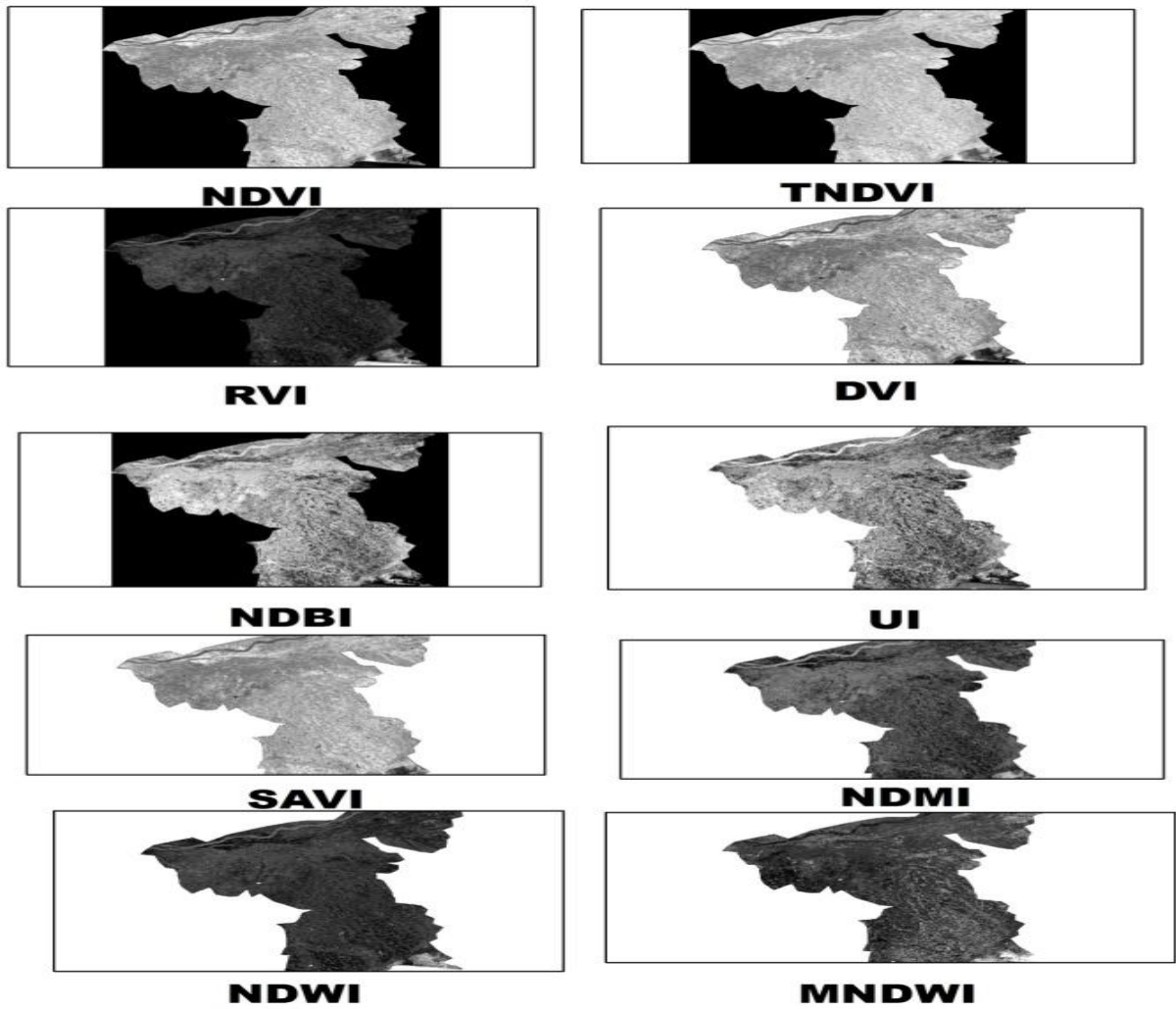


Fig.3: Results of Indices

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Table II: Comparison Of Different Indices

VEGETATION INDICES	FEATURE TYPE	FEATURE NAME	PIXEL COUNT	% OF AREA	MIN	MAX	MEAN	STD
RVI	No Vegetation		2433718	21.90	0.0000	0.0525	0.0291	0.0134
	Vegetation	Sparse	2007915	18.07	0.0525	0.1171	0.0800	0.0182
	Vegetation	Medium	888809	8.00	0.1171	0.2181	0.1529	0.0266
	Vegetation	Dense	146851	1.32	0.2181	0.9998	0.2802	0.0726
DVI	No Vegetation		8721175	78.49	0.0000	0.0096	0.0008	0.0022
	Vegetation	Sparse	2594157	23.35	0.0096	0.0308	0.0189	0.0060
	Vegetation	Medium	1315516	11.84	0.0308	0.0637	0.0429	0.0089
	Vegetation	Dense	290158	2.61	0.0637	0.2692	0.0835	0.0205
NDVI	No Vegetation		8775024	78.98	0.0000	0.0168	0.0015	0.0039
	Vegetation	Sparse	2492278	22.43	0.0168	0.0521	0.0324	0.0100
	Vegetation	Medium	1311788	11.81	0.0521	0.1026	0.0717	0.0138
	Vegetation	Dense	341915	3.08	0.1026	0.4247	0.1320	0.0301
TNDVI	No Vegetation		2402091	21.62	0.0000	0.0250	0.0137	0.0064
	Vegetation	Sparse	1918645	17.27	0.0250	0.0545	0.0378	0.0083
	Vegetation	Medium	944562	8.50	0.0545	0.0972	0.0707	0.0116
	Vegetation	Dense	211995	1.91	0.0972	0.3704	0.1227	0.0277
NDWI	No Water		2339848	21.06	0.0000	0.0515	0.0275	0.0132
	Water	Sparse	1714784	15.43	0.0515	0.1070	0.0764	0.0158
	Water	Medium	1046745	9.42	0.1070	0.1803	0.1376	0.0206
	Water	Dense	396625	3.57	0.1803	0.5004	0.2221	0.0367
MNDVI	No Water		2594256	23.35	0.0000	0.0580	0.0307	0.0147
	Water	Sparse	1760759	15.85	0.0580	0.1236	0.0864	0.0186
	Water	Medium	888634	8.00	0.1236	0.2163	0.1598	0.0255
	Water	Dense	254353	2.29	0.2163	0.7975	0.2721	0.0535
NDBI	No Built-up		2327765	20.95	0.0000	0.0515	0.0275	0.0132
	Built-up	Sparse	1752571	15.77	0.0515	0.1090	0.0772	0.0164
	Built-up	Medium	1016348	9.15	0.1090	0.1823	0.1396	0.0205
	Built-up	Dense	380609	3.43	0.1823	0.5004	0.2238	0.0365
UI	No Built-up		2318393	20.87	0.0000	0.0667	0.0358	0.0172
	Built-up	Sparse	1738440	15.65	0.0667	0.1370	0.0984	0.0201
	Built-up	Medium	1056488	9.51	0.1370	0.2318	0.1759	0.0264
	Built-up	Dense	363972	3.28	0.2318	0.8884	0.2863	0.0489
SAVI	No Soil		8828705	79.46	0.0000	0.0175	0.0016	0.0041
	Soil	Sparse	2545748	22.91	0.0175	0.0544	0.0337	0.0104
	Soil	Medium	1274412	11.47	0.0544	0.1105	0.0752	0.0151
	Soil	Dense	272141	2.45	0.1105	0.4472	0.1445	0.0361
NDMI	No Moisture		2428075	21.85	0.0000	0.0459	0.0246	0.0119
	Moisture	Sparse	1872576	16.85	0.0459	0.0987	0.0690	0.0150
	Moisture	Medium	949763	8.55	0.0987	0.1721	0.1273	0.0201
	Moisture	Dense	247588	2.23	0.1722	0.5766	0.2160	0.0454

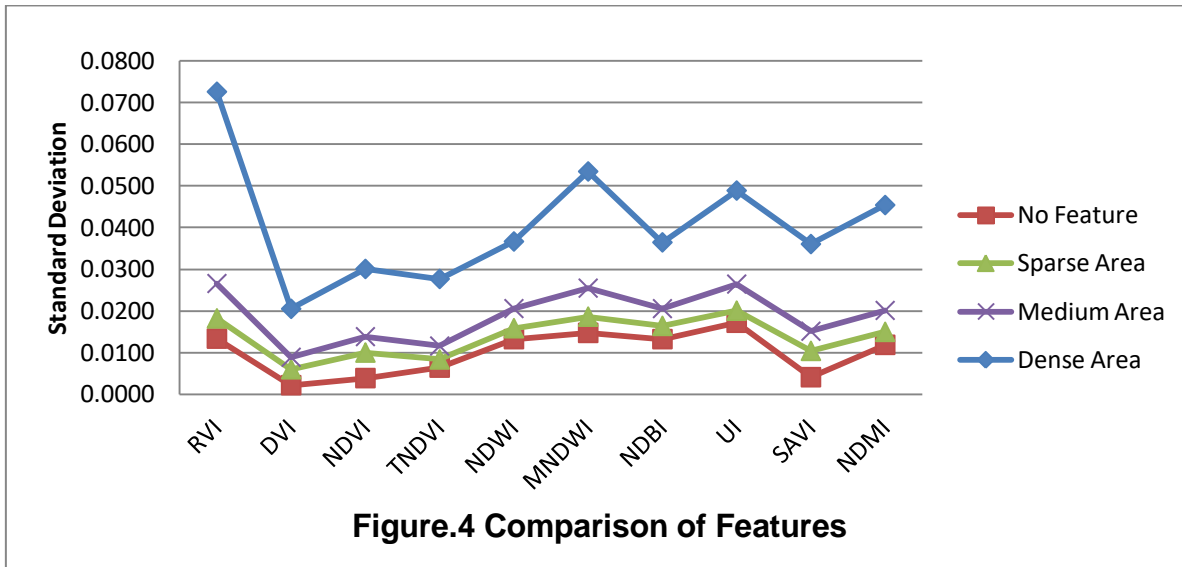


Figure.4 Comparison of Features

V. CONCLUSION

This study utilizes ten major vegetation indices and reveals different perceptions in extracting various features of multispectral satellite images. RVI, DVI, NDVI, and TNDVI are used to classify vegetation and non-vegetation features, in which TNDVI out performs in extracting better features. NDWI and MNDWI are used to extract water features of the images, where MNDWI produces better result. NDBI and UI are used to extract built-up features. Even though NDBI extracts all type of features UI is the good index in finding relevant built-up features from the image. Finally, SAVI and NDMI are utilized to find out soil type features. Among these indices NDMI performs well in extracting the suitable features. In future, we add a greater number of indices and perform many comparisons to improve the classification accuracy of multispectral satellite images.

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