Estimation of Greenfield Changes in Kerala using NDVI on Landsat Data

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ABSTRACT

Vegetation Greenness have significant importance over the life on the planet Earth. The greater the vegetation area the more healthy the existence of this planet. Thus the measurement of Greenfield changes has its remarkable role. Here comes the relevance of Normalized Difference Vegetation Index (NDVI). It calculates the greenness on per-pixel basis as the normalized difference between the red and near infrared bands from a satellite image. Landsat data which is an open source data set provided by NASA are used for calculating NDVI. Kerala State of India is chosen as the region of interest. NDVI of Kerala for ten years were calculated and plotted for further evaluation. For detailed evaluation each year data were analyzed as thick, medium, scarce vegetation and graphs are plotted accordingly. From this study it is evident that the greenness value is slightly increasing for the study area which cope with the current studies of NASA that leaf area of India and China show slight increase. For the completion of the work regression algorithm is used for the prediction of next ten years vegetation changes.

INTRODUCTION

Remote sensing using satellite images has gained popular attention due to its versatility and accuracy. This is very useful for processing large geographical area of interest. Greenfield estimation is one of the most popular applications of remote sensing. NDVI is the most common technique used for this purpose.

By taking the ratio of red and near infrared bands from a remotely-sensed image, an index of vegetation greenness can be defined. NDVI which stands for Normalized Difference Vegetation Index is an indicator of vegetation greenness. It is computed from the difference between the reflectance of the near-infrared and the red bands. The value of NDVI come in between -1 and +1. But the values within -1 to 0 were not considered here since it have no significance with the vegetation greenness. Thick, medium, scarce vegetation are evaluated using the NDVI values which comes within 0 to +1.

Landsat data which is an open source provided by NASA are used for calculating NDVI. Landsat-8 is the eighth satellite in the Landsat series which is launched by United States Geological Survey (USGS) and NASA. It uses Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) as the two-sensor payload for the acquisition of image data for nine shortwave bands and two long wave thermal bands. Landsat 8 data is available only from the year 2013, so this work depends on the Landsat 7 data for the early years.

The main objective of this paper is to develop a systematic study of the greenfield changes of the Kerala state of India for the last ten years. The graphical analysis of the data shows that there is an increase in the green-area. This work also tried to predict the changes for upcoming years.

RELATED WORKS

Normalized Difference Vegetation Index (NDVI) based estimation for harvest yield calculation was proposed by Authors, Jing Huang et al. [1]. A correlation analysis based technique of crop yield was used by them and they processed the MODIS-NDVI data in order to find the best timing for booting, flowering, and ripening of the crops. For comparatively small regions the system works well. Another group of authors [2] particularly studies the after effects especially the the vegetation destruction of the earthquake in Wenchuan. For that, MODIS NDVI data is analysed for a short duration of 8 days in a small area and then it is extended to a larger area. In another paper [3], the authors mainly focus on land cover change. They used an Extended Kalman Filter to determine per-pixel change of NDVI time-series satellite data. 89% accuracy is claimed for the change detection.

An enhanced technique on TIMESAT algorithm was developed by authors, Bin Tan et al. [4] for extracting phenology of vegetation metrics. The ancillary information, land surface temperature and snow-cover flag were incorporated in order to improve the TIMESAT algorithm. For the validation the study depends on the ground data according to the experience of the data collectors. The authors Liying Geng et al. [5] tried to reconstruct the high resolution NDVI time series data. They developed a compound technique with eight techniques to avoid the noise. They used the de-noising algorithms to detect noisy data, and for replacing the noisy data by the medians of the de-noised values. These eight way compound algorithm helps effectively to avoid the drawback of individual techniques. The authors William S. Mcinnes et al. [6] differentiated the cultivated land from the native grassland by an effective mapping job. To separate the two classes of vegetation, Normalized Difference Vegetation Index technique is used with MODIS data. The inspiration for them was the fact that the spring green up rates observed at pixel level may be different for different types of plants. This technique found seventy three percentage of overall accuracy.

Mapping of impervious land cover was done by the authors Joseph Knight and Margaret Voth [7]. A multi-temporal technique used to process NDVI MODIS data. They used the sequential maximum angle convex cone and linear spectral un-mixing (LSU) for analysing the data. The MOD13A1-NDVI data of the state of Haryana, India was analysed Vandana Tomar et al. [8] in order to estimate the crop yield. They assessed the average pixel reflectance of a 3*3 spatial window at the regional level of the NDVI layer, to understand the linear regressive relationship. They suggests the evaluation of the correlation between the vegetation index, final crop yield and major nutrients for the maximum efficiency level of the use of fertilizers in a particular area. Yonglin Shen et al. [9] developed the relationship between crop progress stages of corn and fractal dimension of satellite data. For measuring the roughness of corn fields during the flowering and harvesting stages, theory of fractals is used. Also an automated compound smoother, which can reduce the noise of the NDVI time series data was developed by the authors Zhenyu Jin and Bing Xu [10]. This fast and nonlinear method is named as RMMEH, and it has the advantage that the automatic working of the system without the intervention of an expert.

STUDY AREA AND DATA-SET

Study Area

The State of Kerala is one of the most vegetated area in India. The main reason for the greenery is its position as a narrow strip of land that is sandwiched between the Western Ghat Mountains on the East, and the Arabian Sea on the West. There are two rainy seasons for this region, so this area got plenty of rain and its the main cause of the greenness of this land. Here the humidity is high and the atmosphere contains water molecules which provide life for the green leafs. This work concentrated on those parts of Kerala State (Figure 3.1) which lies between 9.06576 0 - 11.15816 0 N and 75.60695 0 - 77.68718 0 E covering approximately an area of 15285 km 2 .
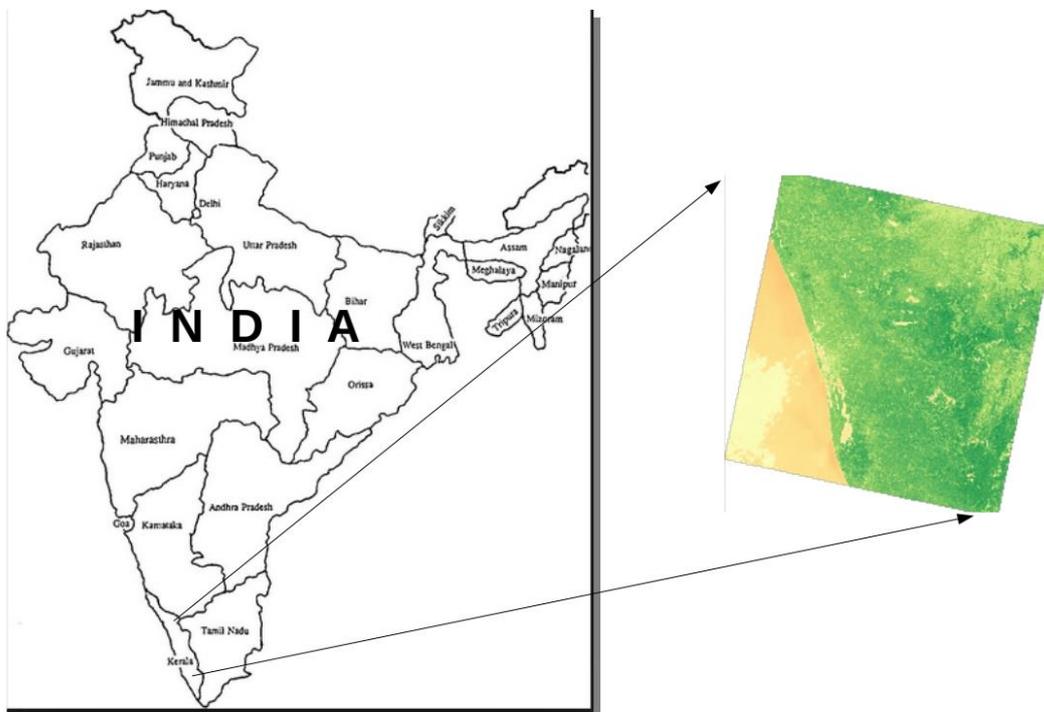

Fig. 1 Study Area

Data-set

For calculating the Normalized Difference Vegetation Index, the primary requirements are the visible red and the infrared values. For the value of these here the raster images are processed. Infrared and visible red bands are available in almost all the satellite images. For this the official satellite sites which provide free and trustable data source are useful.

The data-set used in this work is downloaded from the United States Geological Survey (USGS) official site, which provide free and open-sourced raster data-set of area of this study. This site provides various kinds of information about the universe mainly collected from the

satellites. The user interface by Earth Explorer (EE) is a tool for searching, finding, and ordering the data and it is from the USGS site. EE provides the surfing for the images from the satellites and other remote sensing devices with its graphical user interface. This study uses those informationfrom the Landsat satellite series, especially the raster images from Landsat8 and Landsat7.

For downloading those data items from the site initially specify the area, and then the time duration must given as the next input in the search criteria. Then the data sets Landsat collection 1 level 1 may be selected and from there Landsat 8 OLI/TIRS C1 level 1 is specified. Her the OLI stands for Operational Land Imager. Thermal Infrared Sensor is the full form for TIRS. These two sensor payload used for the acquisition of raster data for all the bands. Image set contains shortwave bands, nine in number and two thermal long wave bands. Moving towards the result set, the specified folder can be downloaded as .tar.gz file. This folder includes eleven band data and one band quality files in .TIF format, and two .txt format files named as angle coefficient file, and metadata file. Form the eleven band data-set Bands Three (Green), Four (Visible Red) and Five (Infrared) are inputted to the system.

For the data sets of time period before 2014, Landsat 7 ETM+ C1 level 1 data must be chosen. Here ETM+ stands for Enhanced Thematic Mapper Plus.There the .tar.gz includes eight band data and one band quality files in .TIF format, and three .txt format files named as ground control point file, angle coefficient file, and metadata file. Here form the eight band data-set Bands Two, Three and Four are selected which stands for Green, Red, and Near Infrared respectively which also are used for this work.

SYSTEM DESIGN

The proposed system in figure 4.2 takes Raster data of near infrared band and visible red band as input, then it is preprocessed for the NDVI calculation. Preprocessing involves the normalization, cropping, reflectance correction, etc. Then the NDVI is calculated and plotted in histogram and pi-chart forms. With the ten years data a detailed evaluation of the vegetation growth studied. Finally the NDVI values are compared with the rainfall history of Kerala using linear regression algorithm for prediction.

Input:
• Raster image data of visible red band and near infrared band.

Output:
• NDVI of the Kerala region for ten years.
• Pi chart plotting of the results.
• Histogram plotting and evaluation.
• Comparison and prediction results.

```
              ┌─────────────────────────┐
              │   Input Raster Images    │
              └─────────────────────────┘
                 │                  │
                 ▼                  ▼
          ┌──────────┐        ┌──────────────┐
          │ Red Band │        │ InfraRed Band│
          └──────────┘        └──────────────┘
                 │                  │
                 ▼                  ▼
          ┌──────────────┐   ┌──────────────┐
          │ Normalization│   │ Normalization│
          └──────────────┘   └──────────────┘
                 │                  │
                 ▼                  ▼
          ┌──────────────┐   ┌──────────────┐
          │Cropping Image│   │Cropping Image│
          └──────────────┘   └──────────────┘
                 │                  │
                 ▼                  ▼
          ┌──────────────┐   ┌──────────────┐
          │ Reflectance  │   │ Reflectance  │
          │ Correction   │   │ Correction   │
          └──────────────┘   └──────────────┘
                 │                  │
                 └────────┬─────────┘
                          ▼
                 ┌──────────────────┐
                 │ NDVI Calculation │
                 └──────────────────┘
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                          ▼
                    ┌──────────┐
                    │  Result  │
                    └──────────┘
                     │        │
                     ▼        ▼
              ┌─────────┐ ┌──────────┐
              │  Pi -   │ │ Plotting │
              │ Chart   │ │Histogram │
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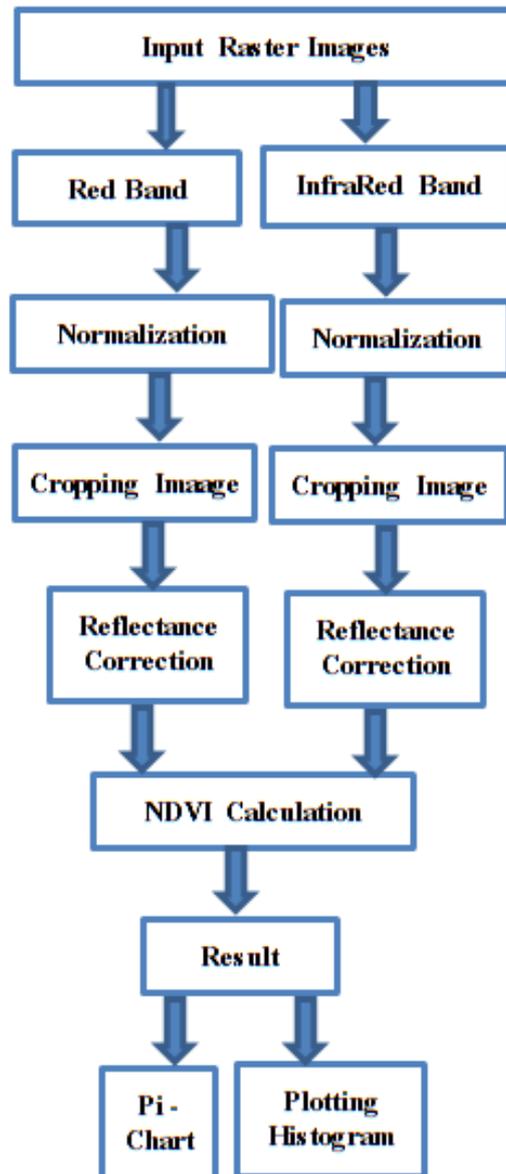
Fig.2 Block Diagram of the Proposed Model

This project includes six modules.
Modules:
1). Collecting the input raster images from the USGS site, and input it into the working model.
2). Normalization of the raster input.
3). Cropping the raster images of selecting the area of interest.
4). Calculating reflectance and correction of it for the Landsat images.
5). Calculating NDVI and plotting the results in different formats like pi chart and histogram for further evaluation.
6). Comparison and prediction using the rainfall history of Kerala.

In the first module the input data form the USGS site is give to the system in the forms of band data of visible red and infrared. These two images are in the form of raster data. the

system reads them using its numpy array. The second module includes the normalization of the numpy arrays into scale 0.0 - 1.0, of the raster input. For this the minimum and maximum values from the given array items are picked up and each array item is then normalized accordingly by deleting the array smallest value, and dividing it with difference of array minimum value and maximum value. This normalized value is used for the plotting of the False positive image or Color-infrared (CIR) imagery. In the third module, the cropping the raster images of selecting the area of interest. The red and infrared band information contains some black areas which should be avoided before the NDVI calculation, otherwise it may affect the accuracy of the study. This non-significant regions having the value equal to zero, which means black regions were cropped out.

Reflectance correction of the Landsat images included in the fourth module. TOA which stands for Top of Atmosphere Reflactence is that measure which having no unit, estimates the radiation reflected ratio of the surface's incident solar radiation. This count value is calculated from spectral radiance of satellite applying the solar spectral irradiance means on the solar elevation angle. Reflectance correction according to the sun elevation and the reflectance add and multi band correction information. For this the study includes this module which process the data with the above mentioned values. The fifth module includes the NDVI calculation applying the popular equation, NDVI = (Near Infrared - Red) / (Near Infrared + Red), for this vegetation indexing. The key idea behind this formula is that the green leaves absorbs the visible red light and the reflect back the near infrared waves. The values of NDVI ranges from -1 to 1, which the values near -1 signifies water and those near 1 representing thick and healthy vegetation. Each year data is processed on by one, and stored. For the further evaluation each year data is processed and plotted the results in the formats of histogram and pi-chart. In the sixth module, the prediction can be carried out in terms of the availability of rain in the study area from the NDVI information and the raining history of this region using the linear regression algorithm.

SYSTEM IMPLEMENTATION

Landsat satellite images are used for the NDVI calculation in this system. The Raster images are given to the system and then it undergone some preprocessing steps such as cropping, normalization, and reflectance correction etc. The NDVI is calculated from the corrected data and is plotted in different formats in order to forward them for further evaluation. Linear regression algorithm is also used for some prediction steps.

Specifying the Input

The primary input to the system is a comma separated value (csv) file (Figure 3).

YEAR	SUN_ELEVATION	SCENE_ID	RED_RMB	RED_RAB	NIR_RMB	NIR_RAB	SAT_INFO
2010	47.81222611	LE07_L1TP_144053_20100123_20161215_01_T1	0.0012407	-0.011219	0.0027545	-0.017247	L7
2011	54.55864699	LE07_L1TP_144053_20111110_20161205_01_T1	0.0012562	-0.01136	0.0027889	-0.017463	L7
2012	51.7900256	LE07_L1TP_144053_20120214_20161203_01_T1	0.0012486	-0.011291	0.0027721	-0.017358	L7
2013	49.76886017	LE07_L1TP_144053_20130131_20161126_01_T1	0.0012431	-0.011241	0.0027599	-0.017281	L7
2014	52.60455674	LC08_L1TP_144053_20140211_20170425_01_T1	2E-05	-0.1	2E-05	-0.1	L8
2015	48.37053742	LC08_L1TP_144053_20150113_20170414_01_T1	2E-05	-0.1	2E-05	-0.1	L8
2016	48.57002801	LC08_L1TP_144053_20160116_20170405_01_T1	2E-05	-0.1	2E-05	-0.1	L8
2017	48.81700125	LC08_L1TP_144053_20170118_20170311_01_T1	2E-05	-0.1	2E-05	-0.1	L8
2018	49.07532098	LC08_L1TP_144053_20180121_20180206_01_T1	2E-05	-0.1	2E-05	-0.1	L8
2019	49.37574384	LC08_L1TP_144053_20190124_20190205_01_T1	2E-05	-0.1	2E-05	-0.1	L8

Fig. 3 Input csv File

From the above given csv file the system gets almost all the input information. First column signifies the year, then next is the sun elevation given in the particular data set. The third column signifies the actual set of input here it is given as the folder name, which contains the raster images of red and near infrared bands. Next for column contains the reflectance correction values and the last column gives the satellite information whether it is Landsat8 or Landsat7.

Normalization and False Colouring

For reproducing the near infrared band information in a visible format it is necessary to colour the infrared image, which is called as Colour Infrared (CIR) Imagery or False Positive Imagery. Here the initial steps are some normalization process which includes finding the minimum and maximum values with in the array and normalize the whole array values on the basis of minimum and maximum values difference.

Top of Atmosphere Reflectance

Reflectance Correction needed for those images from the Landsat. TOA which stands for Top of Atmosphere Reflactence is that measure which having no unit, estimates the radiation reflected ratio of the surface's incident solar radiation. This count value is calculated from spectral radiance of satellite applying the solar spectral irradiance means on the solar elevation angle. First, TOA reflectance remunerates the different counts for the solar irradiance evolving from spectral band dissimilarities. Second, it removes the sine effect of individual solar elevation angle because of the time alteration between acqusition of data.

Calculation of Reflectance

The formula issued by the USGS for transforming scaled Digital Numbers [17], which are quantized and calibrated for representing multi spectral image data collected by Landsat satellites, is uesd here for claculating the reflectance. This is an easy equation having no much complicated terms. The formula for TOA Reflectance is : reflectance band = (REFLECTANCE MULT BAND * band value) + REFLECTANCE ADD BAND [18]. This conversion formulas uses values such as REFLECTANCE MULT BAND and REFLECTANCE ADD BAND kept in the meta data set with each image, often an supporting information file having the description of file name.met or file name MTL.txt. REFLECTANCE MULT BAND is a one time multiplier for reflectance correction of value to be applicable with each input band. 0.00002 is its default value for the Landsat 8 and that for the Landsat 7 it must be collected from the file name MTL.txt metadata file. In the similar way REFLECTANCE ADD BAND is the addictive correction value for reflectance to be applicable with each input band. -0.1 is the default value, and it can be varied for each image.

Reflectance Correction

Reflactance correction is for removing the sine effect of the sun elevation angle due to the change in time of acquisition of data. This must be corrected properly before it is given to the

system since it may create mistakes in the estimation of NDVI. TOA reflectance can be corrected for the sun angle by the formula, band = (reflectance band / sin (SUN ELEVATION)) SUN ELEVATION is that count which signifies elevation of sun above the horizon at the (in degrees) above the horizon at the collection time of the image. In most case this value for Landsat 8 and Landsat 7 images are given with in their parent folder having the identification name SUN ELEVATION with in the metadata file. This value is give to the system through the csv input file. Before applying it in to the formula the sun elevation value must be converted from degree to radon.

NDVI Calculation

Normalized Difference Vegetation Index is that powerful vegetation greenness measure that calculated from the satellite image which contains the bands of visible red and near-infrared. It is calculated by comparing the reflected near-infrared band (NIR) to reflected visible red band (RED), applying the simply formula, NDVI = (Near Infrared - Red) / (Near Infrared + Red) The key idea behind this formula is that the green leaves absorbs the visible red light and the reflect back to the near infrared waves.

RESULTS AND DISCUSSION

Normalized Difference Vegetation Index is calculated by the system for each raster input. Per pixel NDVI values are binned in for separating them into Water, Cloud, Bare ground, Scarce vegetation, Medium vegetation, and Thick vegetation. From all of these the total NDVI is calculated and the percentage is given as the NDVI for that particular input raster data. The result is displayed in different format by the system, such as graphs, pi-chart, and histogram. Each years' data is analysed individually and collectively with in the system.

Analysis of Result from Individual Input

Each input is given to the system one by one and each one produces its on contribution to the final result. Every individual input creates a set output contributions, that contains the representation of each input in human visible format, CIR representation, NDVI chart, histogram, and pi-charts. The analysis of the individual output is necessary before all the results are analysed collectively. Each individual year input gives its own significant results to the whole system. Thus the initial search is to understand them individually by taking some of them as examples.

Here in Figure 4, represents the case of the input of the year 2019. That figure narrates the representation of input visible red band and near infrared band in the first row. But they were not that much clear to the normal vision. It is necessary to colour them accordingly in order to present them for normal vision. A false positive imagery is used to colour the infrared image. Then the result is plotted as CIR image. After calculating the NDVI, the system plots the NDVI image which
scales the colour range according to the NDVI value for each pixel it represents in the diagram. The colour ranges from green to red as each pixels NDVI value ranges from +1 to -1. The full green area shown in the picture signifies the thick vegetation, light green represents medium vegetation and so on.
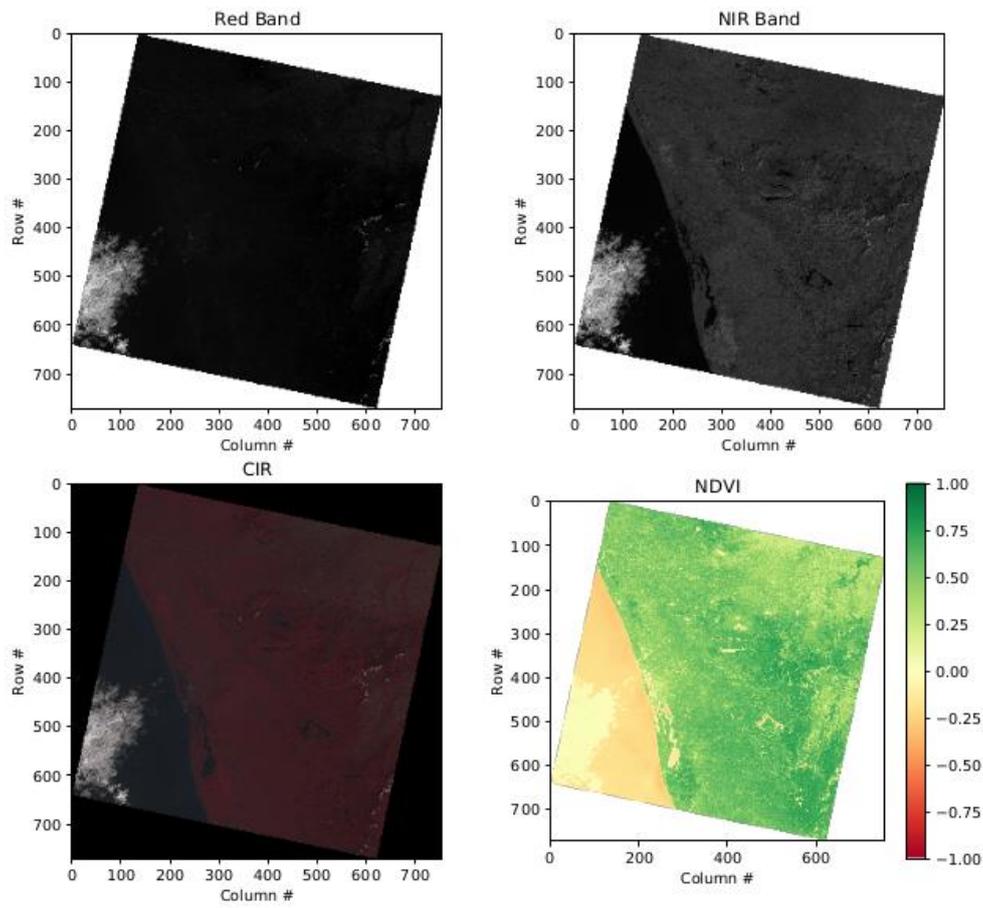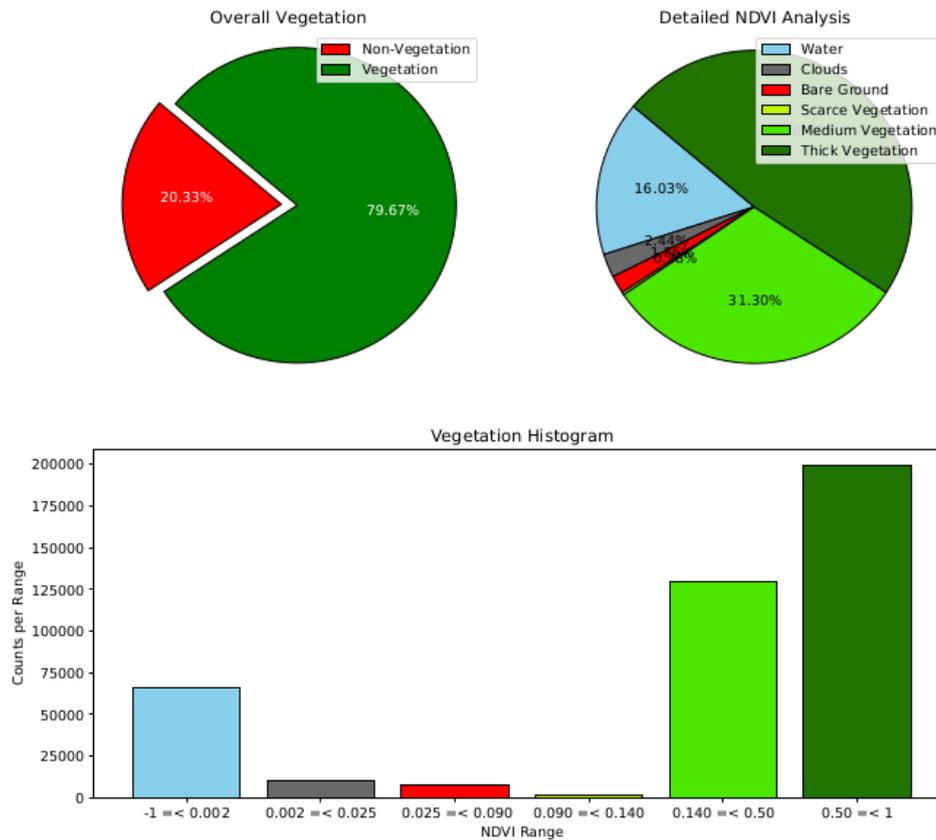
Fig. 4 Results Derived for Year 2019 (1)

Fig. 5 Results Derived for Year 2019

Figure 4 shows the NDVI results in different formats like pi-chart and histogram plotting. The first figure gives the over all narration of the vegetation area in the input image. From this its clear that there is 79.67 percentage of area, which is given as green represents the vegetated land in the input region. This total includes the scarce, medium, and thick vegetation. The red portion of in the figure of 20.33 percentage, signifies the area of non-vegetation that may be water, cloud, or bare ground. This is all about the overall vegetation representation. For the detailed NDVI analysis the system needs classification of the NDVI values. There are six separate bin arranged for classifying the NDVI values ranges from -1 to +1. The bin for Water is set in between -1 to 0.002, and that for Cloud falls between 0.002 and 0.025. Then the Bare Ground is separated form the other vegetation area with the bin which collects all the values from 0.025 to 0.090. The Scarce Vegetation which collected values between 0.090 and 0.140 is the next bin. Medium Vegetation is also having the bin between 0.140 and 0.5. Finally the Thick Vegetation bin as the values from 0.5 to +1. This separate analysis is given in the second part of the Figure 5.

Ten Year Result Analysis

After evaluating all the individual reault sets the system move towards the collective evaluation of all the input raster images. For the NDVI study of the region Kerala State here includes the analysis of the ten year results. Those ten years data were considered together and try to interpret them collectively.

Year	Water	Clouds	Bare Ground	Scarce Vegetation	Medium Vegetation	Thick Vegetation	Non-NDVI	NDVI
2010	23.29	0.1	0.26	0.31	23.41	52.63	23.65	76.95
2011	21.2	0.15	0.4	0.37	12.91	64.97	21.75	77.25
2012	21.82	0.07	0.26	0.41	25.27	52.16	22.15	77.84
2013	21.3	0.1	1.15	2.21	34.86	40.39	22.55	77.46
2014	21.01	0.18	0.35	0.24	32.33	45.9	21.54	78.47
2015	21.43	0.09	1.43	0.79	18.11	58.15	22.95	77.05
2016	20.95	0.15	0.6	0.47	19.98	57.85	21.7	78.3
2017	21.5	0.04	0.25	0.34	24.76	53.11	21.79	78.21
2018	20.67	0.16	0.59	0.45	27.82	50.29	21.42	78.56
2019	16.03	2.44	1.86	0.28	31.3	48.08	20.33	79.66

Fig. 6 Result for Ten Years Data

From the resulting csv file (Figure 6) its clear that the NDVI is in a progressing manner for the region of study. In the initial stage, in 2010, the total NDVI percentage was 76.95. then there is a slight increase accordingly up to the year 2014, then some decrease, there is increase in the next year. While analysing the whole data from 2010 to 2019 there is gradual progress in the overall percentage of NDVI of the give area of interest.

The results can also be displayed in the bar chart format (Figure 6.4). From its evaluation it is clear that there is a progress of minimum two percentage with in ten years of time period. This increase in the leaf area is some what similar to the recent studies of NASA which says that there is some increase in the vegetation areas for countries like India and China.
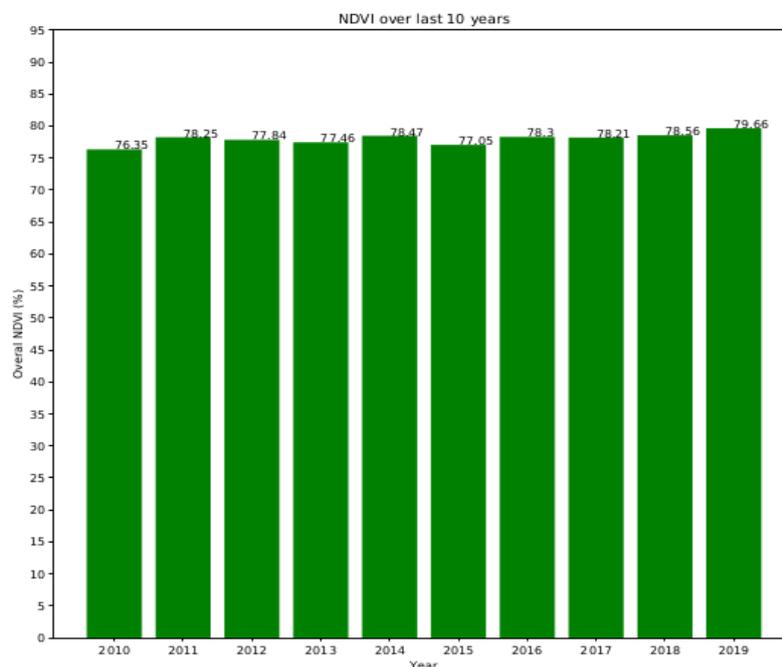

Fig. 7 : NDVI over Last Ten Years

Comparison and Prediction with the Rainfall History

For the completion of this study the system add some interesting comparisons and a try for prediction using the linear regression algorithm. Rainfall must be a factor behind the greenery of the region of interest. There for the correlative analysis of the NDVI with rainfall history may lead to some more conclusions and predictions. This rainfall history data set and the NDVI calculation results form the year 2000 are given to the system for linear regression. the Figure 8 explains our conclusion that there is an increase in the NDVI percentage value for the selected area. Figure 9 shows the result from the linear regression program that gives the values for the prediction coefficients. For finding the rainfall measure for the year 2018 we can use the prediction coefficient values in the prediction formula $y = p0 + p1 * x$. Here $p0 = 1121.61$ and $p1 = 21.87$. The calculated NDVI percentage value for the year 2018, that is $x = 78.56$. Then applying all these value into the equation gives, rainfall $= 1121.61 + 21.87 * 78.56 = 2839.72$. This result is almost similar to the rainfall history for the year 2018 available locally.

CONCLUSION

These works mainly focus on the NDVI estimation for the State of Kerala in order to determine the Greenfield changes using the Landsat data. First of all, the raster images form Landsat data were pre-processed by the system and produces the NDVI in per pixel manner. Each years data were treated separately to create the results in different formats like histogram, pi-chart etc. Then the system treats ten years results collectively to find the changes in the NDVI during these years. With the Landsat data-set from 2010 to 2019 there the finding is that there is a slight increase in the overall NDVI percentage for the region of Kerala. This finding is similar to the NASA's latest study that there is increase in vegetation area in India and China. Finally for the completion of the work there is a comparative study with the rainfall history of Kerala and try to predict the rainfall readings for recent year. The proposed new NDVI calculation method from the Landsat data is more efficient method than the MODIS data. The analysis shows that the proposed method works well than the other similar vegetation indexes.
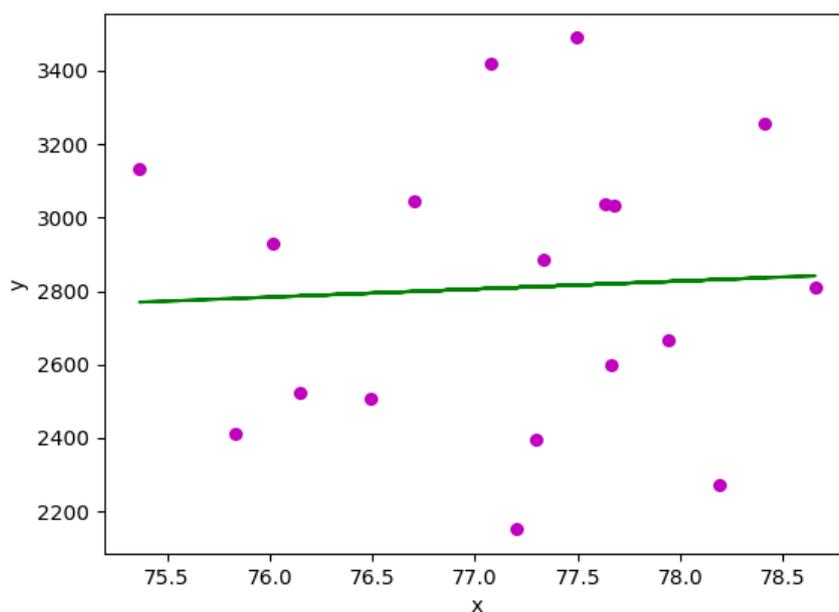

Fig. 8 : NDVI vs Rainfall Data

```
     year  rainfall      ndvi
0    2000    2412.6   75.830000
1    2001    2931.1   76.016667
2    2002    2507.4   76.490000
3    2003    2394.9   77.295000
4    2004    2886.1   77.335000
5    2005    3031.1   77.675000
6    2006    3420.6   77.080000
7    2007    3489.6   77.495000
8    2008    2524.5   76.146667
9    2009    2810.6   78.656667
10   2010    3131.8   75.366667
11   2011    3035.1   77.636667
12   2012    2151.1   77.200000
13   2013    3255.4   78.413333
14   2014    3046.4   76.707500
15   2015    2600.6   77.665000
16   2016    2270.9   78.190000
17   2017    2664.9   77.940000
False
[-0.7525616315901453, -2.16956145208
Estimated coefficients:
b_0 = 1121.60685048
b_1 = 21.866618853
```

Fig. 9 : Linear Regression Results

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