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Land use and Land Cover Characteristics using Bhuvan and MODIS Satellite Data

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Abstract: ***Understanding vegetation characteristics is essential for watershed modeling, like in the prediction of streamflow and evapotranspiration (AET) estimation. So, the present study was taken to analyze the Land use/Land cover characteristics in a Sub-humid tropical river basin which is originating in the forested part of Western Ghats mountain ranges using the Moderate Resolution Imaging Spectroradiometer (MODIS) and Bhuvan satellite data as inputs for the algorithm. All the fourteen LU/LC characteristics present in the Hemavathi basin (5427 km^2) were analyzed in the basin using satellite data which is located in Karnataka, India. Land Surface Reflectance (LSR) and Land Surface Temperature (LST) were the two data products used as input to map the pixel-wise variations in albedo, the fraction of vegetation (FV) and Land Surface Temperature (LST). It was found from the rainfall data that the year 2019 experienced higher rainfall than the average and 2012 very low rainfall than the normal. Parameters considered in this study Albedo, LST and FV are susceptible to wetness and temperature conditions. Variations in albedo and LST were similar in that both values in the summer of 2019 and 2012 are high than winter due to the high temperature and less wetness from all the LU/LC classes. Similarly, FV variations show opposite trends that values in the summer of 2019 and 2012 are low than in winter, which is due to the high temperature and less wetness. The results and discussions show that significant realistic variations in albedo, LST and FV with respect to all LU/LC classes. All the LU/LC classes characteristics in this study show significant variations with respect to wetness and temperature conditions, so the methodology proposed in this study can be used in regional monitoring of LU/LC classes in a convenient and cost-effective manner.***

Keywords: ***LU/LC characteristics, MODIS, land surface temperature, land surface reflectance, fraction of vegetation, albedo.***

I. INTRODUCTION

It is crucial to understand the LU/LC characteristics of the study area for modeling the river basin. In order to analyze the characteristics, many studies have shown that MODIS data provides information for LU/LC classes in a convenient and cost-effective manner. Different kinds of characteristics in LU/LC classes have been derived from MODIS Land Surface Temperature (LST) and Land Surface Temperature (LSR) data. Accurate estimation of LST is important for watershed and environmental studies. LST is an important parameter for a wide variety of climatic, hydrological and ecological studies which is a good indicator of the energy balance at the Earth's surface [12, 15, 17]. LST is inferred from thermal emission of the earth's surface and average effective radiative temperature of various LU/LC classes. LST is controlling the upward terrestrial radiation and consequently controls the sensible and latent heat flux exchange. Fraction of the incident sunlight that the surface reflects is known as surface albedo. The important parameter which is influencing the earth climate is the incident solar radiation reflected in all directions by the land surface [3, 6, 9]. The energy absorbed by the surfaces raises the surface temperature, evaporating water and melts ice. Overall, it can be said that it is very important for energizing the turbulent heat exchange between the surface and the lower layer of the atmosphere. Fraction of ground covered by vegetation in a pixel is proposed by [1, 2] is estimated from MODIS LSR product is the main index and having great significance for both ecology and society. The applications of FV including soil erosion risk assessment, climate and hydrological modeling and weather forecasting[5, 7, 11, 18]. Using a linear spectral unmixing approach for estimation of FV, many remote sensing studies are done. But most of the time, due to its simplicity, rationality and feasibility in practical applications, linear approaches are used [13, 16]. Now from recent decades, it has become a base foundation for global, regional climate and hydrological models [4]. Now it can be accepted that satellite remote sensing technology is recognized to map regional to mesoscale patterns in an economically feasible manner. So, the main objective of this study was to estimate and analyze the variations in albedo, LST and FV for all the LU/LC classes in between extremely dry and wet years and seasons in a Sub-humid tropical river basin using the MODIS and Bhuvan satellite data.

II. STUDY AREA

The Hemavathi is one of the important tributaries to join the river Kaveri on its northern bank. It rises in Ballalara-Yanadurga in the Mudigere taluk of Chikmagalur district in the Western Ghats. The river basin lies between North latitudes 13º22′30″ to 12º35′15″ and East longitudes 75º31′30″ to 76º39′45″. After traversing a length of 245 km, the Hemavathi river joins the river Cauvery in the water spread of Krishnarajasagar reservoir near Akkihebbal. The Hemavathi basin extends over an area of 5427 km^2.

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The annual rainfall varies from a maximum of 2165 mm to a minimum of 1042 mm with an average annual rainfall of 1530 mm from 2019 to 2012. The year 2012 experienced 1042 mm, which is less than average rainfall and high LST compared to the year 2019 received 2165 mm rainfall with less LST.

The economy of the basin is primarily dependent on plantation and agriculture, which is the chief occupation of the people. The catchment area is a typical example of a monsoon type of climate. The summer season extends from March to May. The rainy season extends from June to October very heavy rainstorms are experienced in the rainy season. November to February are winter months. Severe cold is experienced during these months. The area under study is a hilly catchment with a steep to moderate slope. The slope is very high in the upper reaches and reduces gradually in the lower reaches. The general elevation of the basin ranges from 748 m to 1853 m above mean sea level. The entire basin may be classified as hilly lands, moderately sloping and low lands (valley lands).

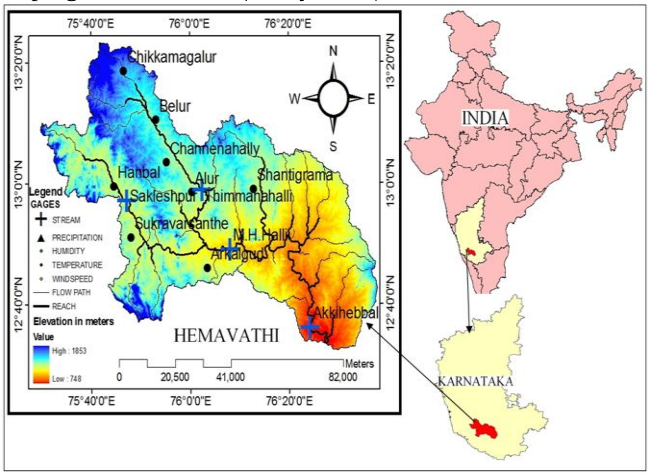


Figure 1: Location and topography of the Hemavathi basin

III. DATA USED

A. MODIS data products

For the analysis, one date in summer and one date in winter of 2019 and one date in summer and one date in winter of 2012 were selected to evaluate differences in land surface temperature (LST), albedo and fraction of vegetation (FV) as influenced by season. Totally four images of the year 2019 and 2012 with eight days difference are for Julian days (57, 345) in 2019 and (57, 345) in 2012. Satellite images are obtained for the same days from the MODIS sensor mounted on the Terra platform. MOD11A1 product of LST at 1000 m resolution, MOD09GA product of LSR at 1000 m resolution and ASTGTM product of digital elevation model (DEM) at 30 m resolution for the Hemavathi basin region is used in the analysis. Preliminary processing of MODIS images was performed using the MODIS reprojection tool (MRT) and then converted to a standard format that can be read by MATLAB while processing. Rainfall data is collected to evaluate the differences in all the fourteen LU/LC classes as influenced by rainfall. To evaluate inter-annual differences, two different years were selected where one year experienced high and another year experienced low rainfall. It was observed that year 2012 experienced very less rainfall than year 2019. Therefore, the year 2019 was wet and 2012 was dry year.

B. Land Use/Land Cover map

Table 1: Composition of LU/LC classes in the Hemavathi river basin

Sl. No	LU/LC class	Year 2012		Year 2019	
		%	Area (km^2)	%	Area (km^2)
1	Built-up	0.24	13	0.45	24
2	Kharif only	29.34	1595	22.43	1220
3	Rabi only	14.95	813	5.71	310
4	Double/Tripple	19.84	1069	22.16	1195
5	Current fallow	4.58	249	17.82	969
6	Plantation/Orchard	21.90	1191	22.52	1224
7	Evergreen forest	1.07	58	0.86	47
8	Deciduos forest	3.39	184	3.31	180
9	Scrub/Degraded forest	1.27	69	1.30	71
10	Grassland	0.13	7	0.13	7
11	Other wasteland	0.52	28	0.50	27
12	Gullied	0.18	10	0.18	10
13	Scrubland	0.07	4	0.04	2
14	Waterbodies	2.52	137	2.59	141
	TOTAL	100	5427	5427	100

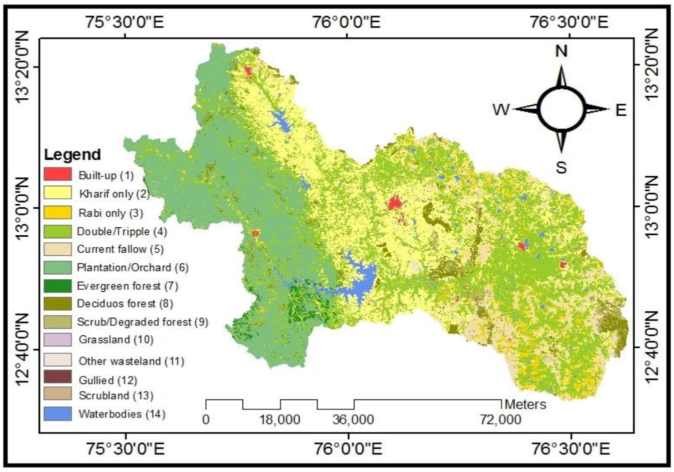


Figure 2: LU/LC map of Hemavathi river basin

LU/LC data for the year 2019 and 2012 was freely downloaded from Bhuvan - Thematic services website (http://bhuvannoeda.nrsc.gov.in/theme/thematic/theme.php) which facilitate LU/LC data for the entire Indian region [8]. The data used in the present study is of scale 1:250000 derived from Resourcesat-1 satellite Linear Imaging Selfscanning Sensor (LISS) - III data.

This data consists of 19 classes (2nd level), but only 14 classes consist of the Hemavathi river basin. The derived LU/LC map of the Hemavathi river basin is shown in Figure 2. It can be seen
that plantations exist in the higher elevations of the basin (towards the West) by comparing Figure (1) and LU/LC maps.

It was found that agricultural crops and Plantation/Orchard is the predominant class in the Hemavathi river basin.

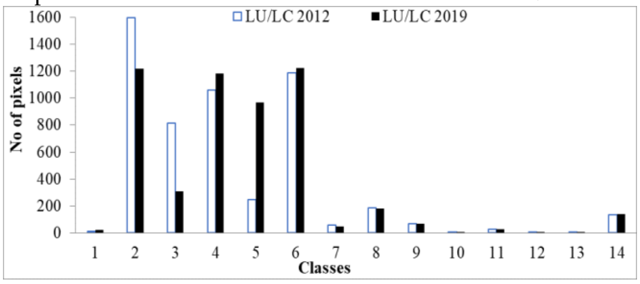


Figure 3: Composition of LU/LC classes in the Hemavathi river basin

IV. METHODOLOGY

LST, albedo and FV parameters were computed for each Pixel of the basin using MODIS data products. The dates selected for the analysis of parameters are four dates in summer and winter of 2019 and 2012. The following three equations were used to estimate the variations in parameters for different LU/LC classes.

The model proposed by [10] is used to calculate albedo from MODIS LSR data.

$$\alpha=0.160R_1+0.291R_2+0.243R_3+0.116R_4+0.112R_5+0.081R_7-0.0015 \quad (1)$$

where R_1 to R_7 are seven LSR band values of the MODIS data.

Normalized Differential Vegetation Index (NDVI) for each Pixel was computed using [2],

$$NDVI=\frac{R_2-R_1}{R_2+R_1} \quad (2)$$

where R_1 and R_2 are two LSR band values of the MODIS data.

The formula proposed by [1] is used to estimate the pixel-wise Fraction of Vegetation (FV).

$$FV=\left(\frac{NDVI-NDVI_{min}}{NDVI_{max}-NDVI_{min}}\right)^2 \quad (3)$$

Minimum and maximum values of NDVI were used from Eq. (2) to estimated FV.

MODIS Reprojection Tool (MRT) is used for preliminary processing of MODIS images so that all data products are converted to a standard format, which can be read by MATLAB while processing. Estimation of parameters in the Hemavathi basin using the above three equations for each date of acquired MODIS images was carried out using MATLAB software. ARC-View 9.3 software was used for pre-processing inputs and post-processing like georeferencing and subsetting corresponding to the study area of results. Algorithm used input data of MODIS land surface temperature and surface reflectances.

V. RESULTS AND DISCUSSIONS

Rainfall data from eight rain gauges were selected (Table 2) which is located in the Hemavathi basin for analysis based on the fact that 2019 was wet year and 2012 was dry year. Cumulative antecedent monthly rainfall totals for 6 months were computed and results shows that that year 2019 was a wet year and having rainfall was higher in both summer and winter in comparison to year 2012 for all the rain gauges. Rainfall for the selected dates is useful in the interpretation of seasonal variations in albedo, LST and FV for all the LU/LC classes which were influenced by wetness and temperature conditions.

A. Rainfall

Rainfall data from eight rain gauges were selected (Table 2) which is located in the Hemavathi basin for analysis based on the fact that 2019 was wet year and 2012 was dry year. Cumulative antecedent monthly rainfall totals for 6 months were computed and results shows that that year 2019 was a wet year and having rainfall was higher in both summer and winter in comparison to year 2012 for all the rain gauges. Rainfall for the selected dates is useful in the interpretation of seasonal variations in albedo, LST and FV for all the LU/LC classes which were influenced by wetness and temperature conditions.

Table 2: Rainfall totals (mm) data for the selected years of analysis

Rain Guages	Altitude (m)	Summer		Winter	
		2019	2014	2019	2014
Belur	980	343	286	845	423
Channenahally	1003	389	284	873	515
Hanbal	903	700	323	3123	1825
Chikkamagalur	1034	414	274	563	473
Sukravar Santhe	941	960	556	1620	1646
Shanthigrama	948	215	197	342	237
Alur	968	349	372	750	428
Arkalgud	923	609	225	855	432
Mean		497	315	1121	747
Std. Dev		227	104	831	577
CV (%)		46	33	74	77

B. Variations in albedo, FV and LST for all the fourteen LU/LC classes

In order to check the accuracy of results analysis for variations in all parameters with respect to 14 different LU/LC classes (Table 1) were considered. Implementation of Eqs. using MODIS and Bhuvan satellite data yielded values of albedo, Fr and LST for each Pixel in the Hemavathi basin on the four selected dates, i.e., Julian days 57 and 345 in 2019 and Julian days 65 and 345 in 2012. Pixels were then segregated corresponding to each LU/LC class. Figure (4) shows that with respect to the soil moisture and LST conditions, the average albedo for all the LU/LC classes was higher in summer in comparison to winter for both years. Average albedo was significantly higher in the summer and winter of 2012 due to low wetness conditions and high LST in comparison to the year 2019.

Variations in albedo for LU/LC classes show higher values for dry soil class when compared to water bodies since the reflectivity of water was very low. Lower values can be observed for Waterbodies, followed by Plantation/Orchard and evergreen forest, and highest values for the Current fallow and Other Wasteland. From all the above variations in albedo for different LU/LC classes, it is evident that the methodology considered to calculate albedo is good.

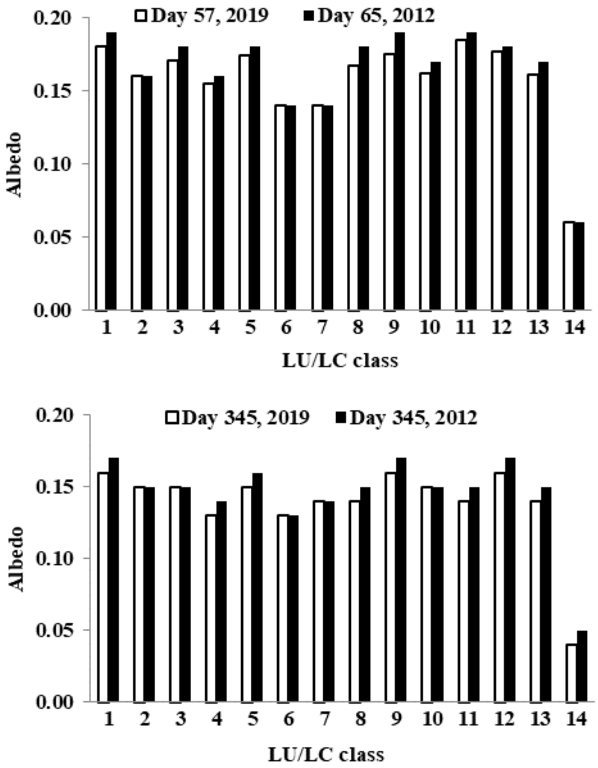


Figure 4: Comparison of Albedo with corresponding LU/LC class

FV and NDVI values were similar for all classes and all dates since FV is derived from NDVI data. Hence for the discussions in Figure (5), FV values are only considered and show realistic variations in FV for all the 5427 pixels, with lower values being observed in summer in comparison to winter in both years 2019 and 2012. Average FV was higher in winter due to high wetness conditions and low LST in comparison to summer for all the LU/LC classes. Due to the low antecedent rainfall in the year 2012, slight variations in low average FV values can be observed for all the classes in comparison to the year 2019 with higher rainfall. Variations in NDVI values show good results for all the LU/LC classes with lower values for waterbodies since vegetation is less in the waterbodies pixel when compared to Plantation/Orchard and evergreen forest. It is evident that results show good variations in higher FV values can be observed for Plantation/Orchard and evergreen forest.

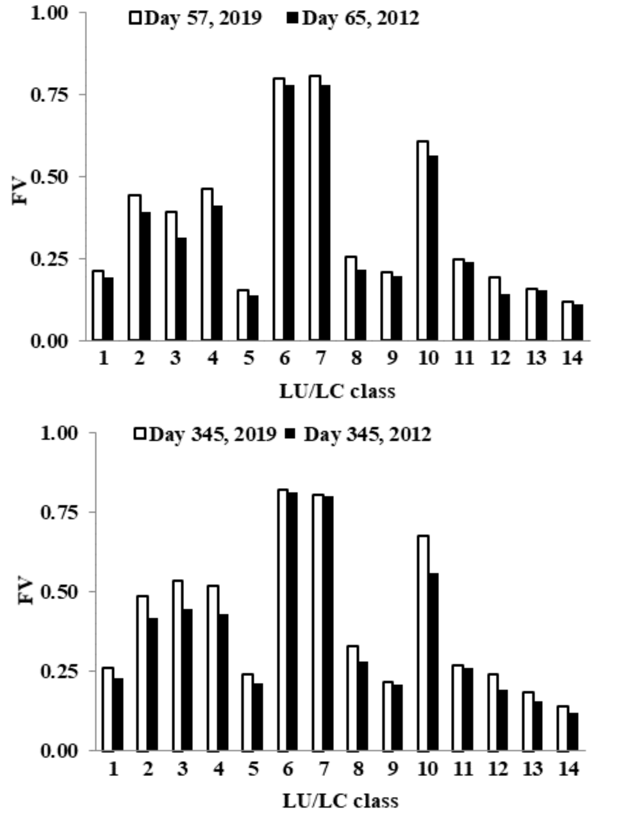


Figure 5: Comparison of FV with corresponding LU/LC class

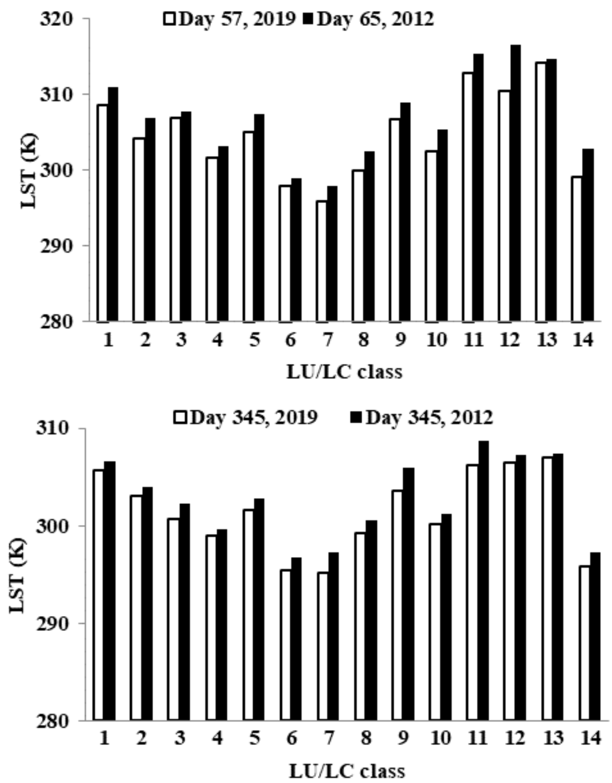


Figure 6: Comparison of LST with corresponding LU/LC class

Figure (6) shows that type of LU/LC class and moisture conditions are related to LST variations.

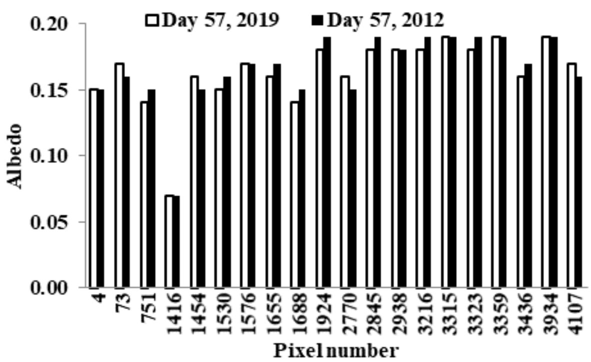
Very low LST values were expected for the winter season and high during the summer season. The major differences with the highest LST values can be observed from 4^0–7^0 K during 2012 due to the extreme summer and winter and lower differences are in the range of 3^0–6^0 K due to wetness conditions for all the different LU/LC classes. Different LST values can be observed for all LU/LC classes with the highest values for dry soil when compared to waterbodies since heat is transferred to lower levels only. Thick green vegetation confines the sun rays to penetrate through it; hence LST in Plantation/Orchard and evergreen forest is less when compared to barren lands.

C. Albedo, FV and LST variations for selected pixels with corresponding Elevation and LU/LC class

Table (3) shows for further analysis in order to understand the variations in parameters for all the LU/LC classes for selected 20 pixels considered located at corresponding elevations and LU/LC class in the Hemavathi basin.

Table 3: LU/LC class and elevations of 20 selected pixels

LU/LC Class	Elevation	Pixel
Plantation/Orchard	1352	4
Grassland	1003	73
Evergreen forest	1046	751
Waterbodies	982	1416
Rabi only	950	1454
Rabi only	950	1530
Kharif only	982	1576
Kharif only	1013	1655
Evergreen forest	915	1688
Current fallow	980	1924
Double/Tripple	1022	2770
Built-up	933	2845
Built-up	940	2938
Deciduos forest	955	3216
Scrub/Degraded	905	3315
Deciduos forest	850	3323
Scrub/Degraded	953	3359
Double/Tripple	968	3436
Current fallow	885	3934
Double/Tripple	929	4107



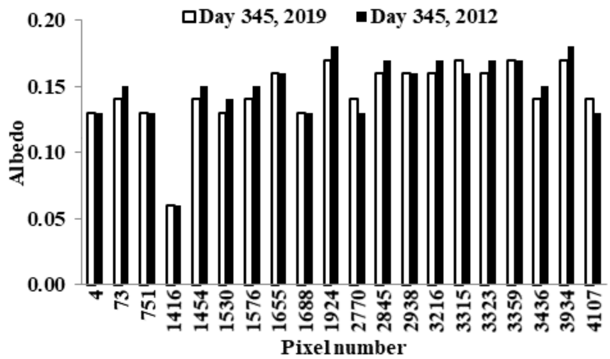


Figure 7: Comparison of albedo with the corresponding Pixel no.

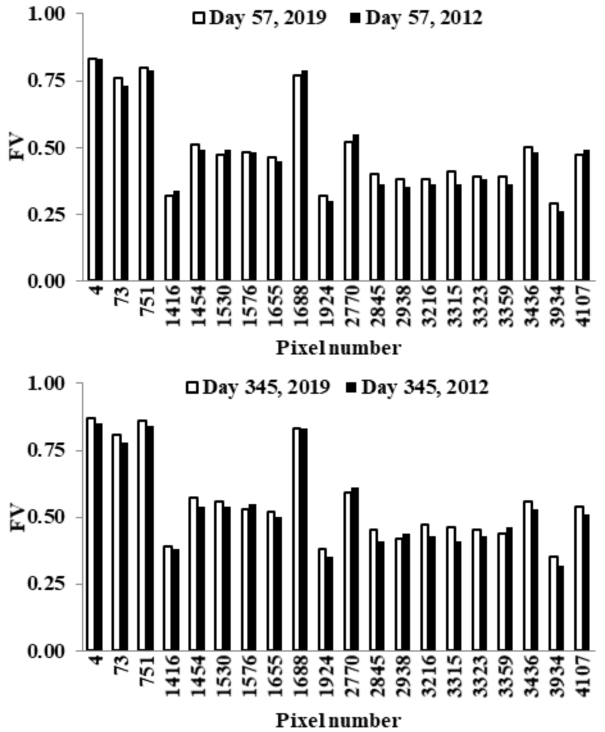
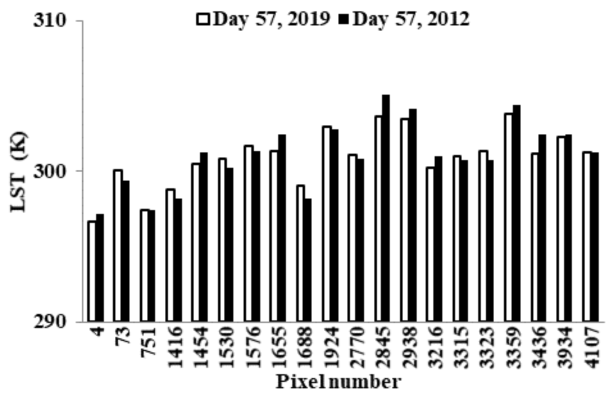


Figure 8: Comparison of FV with the corresponding Pixel no.



All the above Figures (7-9) show that albedo and LST are quite sensitive to wetness and temperature conditions. Albedo and LST values are high due to less wetness and high-temperature conditions, which shows an opposite trend to low values of albedo and LST in the winter season.

FV values are low due to less wetness and high-temperature conditions, which shows an opposite trend to high values of FV in the post-monsoon season. From the figures, it is observed that there is a slight variation in albedo, LST and FV that even if 2012 is a dry year and antecedent rainfall in both summer and winter is less as compared to the year 2019, it can be observed that for some pixels even in the dry year 2012 the FV values are high since it depends on high soil moisture availability and less temperature conditions. Similarly, for some pixels, even in the wet year 2019, albedo and LST values are high due to less soil moisture availability and high-temperature conditions.

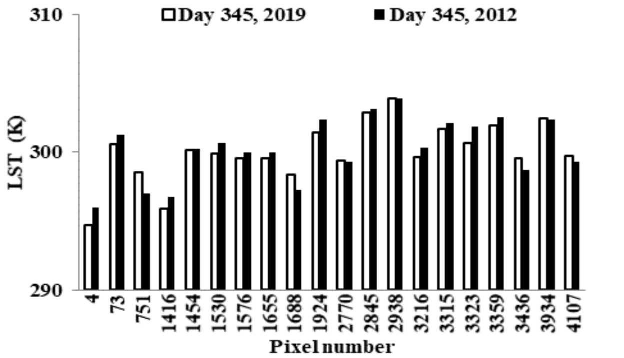


Figure 9: Comparison of LST with the corresponding Pixel no.

VI. SUMMARY AND CONCLUSIONS

The algorithms developed in this study were to estimate and understand the variations in albedo, LST and FV for different LU/LC classes in the Hemavathi basin, Karnataka, India. From the Bhuvan - LU/LC data 1:250000 scale, it was found that agricultural crops and Plantation/Orchard is the predominant class in the Hemavathi river basin. The rainfall data collected shows that 2019 is wet and 2012 is a dry year. Variations in albedo, LST and FV for all the LU/LC classes were found that changes are due to the wetness and temperature conditions. Albedo and LST show the same pattern in both summer and winter of the year 2019 and 2012. Similarly, the FV pattern shows an opposite trend to LST that high values are due to the more wetness and low temperatures in the post-monsoon season. Variations in these characteristics were analyzed for all the fourteen LU/LC classes present in the study area. Results and discussions show that LU/LC characteristics can be derived from MODIS and Bhuvan satellite data products in a convenient and cost-effective manner.

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