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Satellite Remote Sensing of Crop Production and Diversity in Krishnarajanagara Taluk, Mysore District

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Abstract

The study was carried out in Krishnarajanagara taluk, Mysuru district, Karnataka, using data from different satellites/ sensors in the visible and near-infrared region (RESOURCESAT-2 and LANDSAT-OLI) and microwave region (India's RISAT-1 SAR) of the electromagnetic spectrum. Digital analysis of the remotely sensed data has shown that the area under paddy crop has decreased by 5175.81 hectares (ha) and the area under fallow-land has increased by 4688.29 ha during 2015 to 2016. Paddy crop yields were estimated using linear model relating the normalized difference vegetation index (NDVI) values of paddy crop at booting stage with yield values reported by Directorate of Economics and Statistics (DES). The yield estimates of paddy, thus obtained were used in its production estimation. For other crops, the preceding-three-year average yield values reported by DES and area estimated through remote sensing were used to generate the production estimates. Mapping of the cropping systems and crop rotation was accomplished using data from Advanced Wide Field Sensor (AWiFS) of RESOURCESAT-2, acquired on 28th April 2016 (summer), 17th October 2016 (*Kharif*) and 7th January 2017 (*Rabi*). Crop diversity indices *viz.,* multiple cropping index (MCI), area diversity index (ADI) and cultivated land utilization index (CLUI) were calculated. The crop maps generated during *kharif, rabi* and summer were used for preparing crop rotation map. The crop diversity was found to be low and almost same across all three seasons. The major cropping system observed was paddy-fallow-fallow (17.43% of GA), followed by paddy-fallow-vegetables (13.52) and paddy-ragi-fallow (9.11% of GA). It is also found that a large portion of crop land remain fallow throughout the cropping season in the Krishnarajanagara taluk. An overall assessment shows that the agro-ecosystem in the study area is not sustainable and needs appropriate land and water resources management plan and crop diversification.

Keywords : Satellite remote sensing, Crop production estimation, Crop diversity assessment

Doubling of farmers' income (DFI) by the year 2022 is an important target set by the Ministry of Agriculture & Farmers' Welfare, Government of India. Two of the important suggestions made by an Inter-Ministerial Committee related to DFI are improvement in crop productivity, increase in the cropping intensity and diversification towards high value crops. Also, government is implementing several schemes to improve the economic conditions of farmers through Pradhan Mantri Fasal Bhima Yogana, Pradhan Mantri Krishi Sinchayi Yojana etc. In the agriculture sector, several decisions related to fixing of minimum support price (MSP), export and import of food grains, supply of farm inputs (fertilizers, pesticides), credit and subsidy schemes, adjudication of crop insurance claims, etc. require timely, accurate and reliable estimates of crop production in advance. Successful implementation of the programmes and for taking appropriate decisions, accurate, timely and spatially verifiable information is needed.

Like many other states in India, the economy of the state of Karnataka also depends on agriculture to a large extent. Among the ten agro-climatic zones of Karnataka, the southern dry zone is experiencing repeated failures of monsoon rains often leading to scarcity conditions. Because of large area dependency on monsoon and lack of irrigation facilities, the farmers' income levels remained stagnant. The state needs a technology-based crop inventory for complete listing of crops grown, their area, yield and production which is updated every season, from time of sowing to time of harvesting. Although such estimates are generated by state level Directorates of Agriculture and Statistics & Economics, there are delays and inaccuracies.

One of the early attempts in India for crop acreage estimation using remote sensing techniques was by Ayyangar *et al.* (1980) in the Mandya district of Karnataka. They used multispectral airborne scanner data and found that the spectral responses in the red (R) and near infrared (NIR) portions of the electromagnetic spectrum provide adequate information to identify the major crops grown. Several researchers reported the use of satellite remote sensing for crop acreage and production estimation (Nageswara Rao and Rao, 1987; Navalgund *et al.*, 1991; Premalatha and Nageswara Rao, 1994; Dadhwal *et al.,* 2002; Nageswara Rao *et al.,* 2004 and Chakraborty *et al.,* 2013). Many authors have reported the use of SRS and GIS for studying crop rotation (Panigrahy and Sharma, 1997), cropping system analysis (Panigrahy *et al.,* 2011 and Yadav & Hooda, 2014).

Two major projects that have played important role in developing satellite remote sensing and geographic information system (GIS)-based techniques for improving the agricultural statistical information system are: Crop acreage and Production Estimation (CAPE) and Forecasting Agricultural output through Space, Agro-meteorological and Land observations (FASAL). These two schemes were initiated by Indian Space Research Organization (ISRO), Government of India and implemented in collaboration with several state and central agencies to estimate the production statistics of major crops cops like wheat, rice, mustard, potato, sugarcane, cotton etc. The project FASAL is now being implemented by the Mahalanobis National Crop Forecasting Centre (MNCFC) as an integrated geospatial technology-based approach for providing crop production estimates before, during and after every crop season. It integrates econometric, meteorological parameters and spectral reflectance-based vegetation indices to generate crop production figures.

Among the districts falling in the southern dry zone of Karnataka, large part of Mysore district comes under this zone. The district has been found to have the coefficient of variation (CV) in rainfall ranging between 17 to 64 per cent (Mahalingam *et al.,* 2014). The changing rainfall patterns have affected the land use, crop calendars, cropping systems and crop production in the district threatening the sustainability of agricultural ecosystem and livelihood of people in the district. The conventional system of collecting and collating agricultural information is unable to cope up with the changing scenarios, resulting in delays in generating crop area and yield estimates required for taking several decisions related to farmers' welfare programmes like crop insurance, credit and subsidy. Hence, there is a need for improving the agricultural information system. It is in this context that an attempt has been made in the present study to utilize the satellite remote sensing to (i) identify major crops and estimate their production in Krishnarajanagara taluk for the years 2015 and 2016 and (ii) assess the crop rotation practices and crop diversity in the study area.

MATERIAL AND METHODS

Study Areas : The study area is Krishnarajanagara taluk, Mysore district in the Karnataka state. This taluk has 61976 ha of geographical area (GA), of which the net sown area is 41034. It is located between 12° 20'N to 12° 40'N latitudes and 76° 5'E to 76° 30'E longitudes. It has six hoblies namely Kasaba, Hebbalu, Chunchankatte, Saligrama, Mirle and Hosa Agrahara. The main source of water is Krishnarajasagara reservoir. The annual average rainfall is 830 mm. The main crops grown in the taluk are paddy, ragi, sugarcane, pulses, oil seeds and coconut.

Satellite Data Used : For identification and area estimation of major crops and change analysis, moderate spatial resolution (30 metre per pixel) data from LANDSAT-8 OLI (Operational Land Imager), acquired on 16th January 2016, 23rd March 2016 and 17th December 2016 was used. In addition, data from India's RESOURCESAT-2 Linear Imaging Self-Scanning Sensor (LISS-3) having 23.5 metre per pixel, LISS-4 with 5.8 metre spatial resolution, acquired on

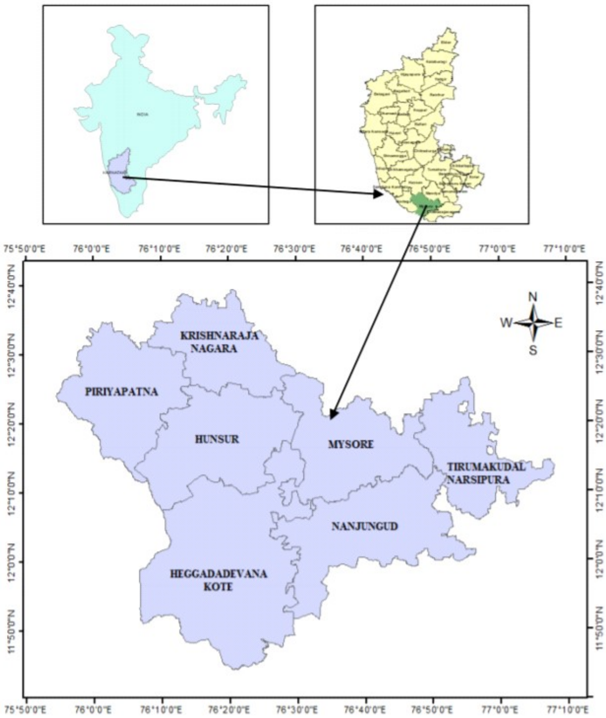

Fig. 1: Krishnarajanagara taluk is located in the north within Mysore district

25th September 2015 and 17th October 2016, were also used. Whenever cloud cover is more, especially during *kharif* season, Radar Imaging Satellite (RISAT)-1 Synthetic Aperture Radar (SAR) acquired on 25th August 2015, 8th September 2015, 23rd September 2015 were also used. For analysis of the cropping systems and crop rotation studies, the Advanced Wide Field Sensor (AWiFS) of RESOURCESAT-2 having 56 metre spatial resolution acquired on 28th April 2016 (summer), 17th October 2016 (*kharif*), 7th January 2017 (*rabi*) were used.

Ground Reference Data Collection : This data was collected during 23-24 February 2016 using an open-source application called 'GPS Map Camera' downloaded free from Play store. Using this simple application, relevant information of the place along with photograph of the land cover, crop types, latitude, longitude, date and time of ground truth collection was collected. About 40 ground control points covering Hebbal, Chunchankatte, Saligrama, Mirle, Hosa Agrahara and Kasaba hoblies were taken. This ground truth was used for developing interpretation keys and for the analysis of remotely-sensed data of various sensors described above. A few samples from this ground truth were also used for evaluating the classification accuracy (as discussed below).

Crop Identification and Area Estimation at the taluk level : Identification of major land cover and crop types was accomplished by studying the spectral response, spatial arrangement and contextual changes that occur over time in the images acquired by LISS-III and Landsat-8 OLI sensors. In general, the tone (relative brightness) seen on a satellite image depends on the reflectance from objects (land covers and crop types) which in turn depend on percentage composition of soil, water and plant biomass at the time of image acquisition. The darker an object appears on an image the less amount of light the object reflects. Colour images were prepared because, as opposed to shades of grey, we found different colours are easy to associate with land use and crop types. Reflectance (digital numbers, DN) from green, red and near-infrared (NIR) were passed through blue, green and red filters, respectively resulting in a standard false colour composite (FCC). This FCC showed water bodies in shades of blue, soils in shades of green and vegetation in shades of red depending on their physical, chemical and physiological properties. The tonal / colour changes in the FCC varied across different Hoblis in K R Nagara taluk depending on the major cover types, crop types, their growth stages and cropping patterns. In addition, we have studied the spectral signatures of major crops in the Krishnarajanagara taluk by plotting the digital numbers (DN) obtained with LISS-III sensor of RESOURCESAT-2. Sequence of steps followed in estimating crop area is illustrated in Fig. 2.

Digital Analysis of Satellite Remotely-sensed Data : This task was achieved using ERDAS Imagine 2014 software on personal computers. In this method, the spectral reflectance properties (digital numbers) of objects were processed, pixel by pixel, using statistical pattern recognition techniques. The first step in digital classification is the training of the computer programme to generate crop-wise signatures (mean vectors and covariance matrices) based on a set of

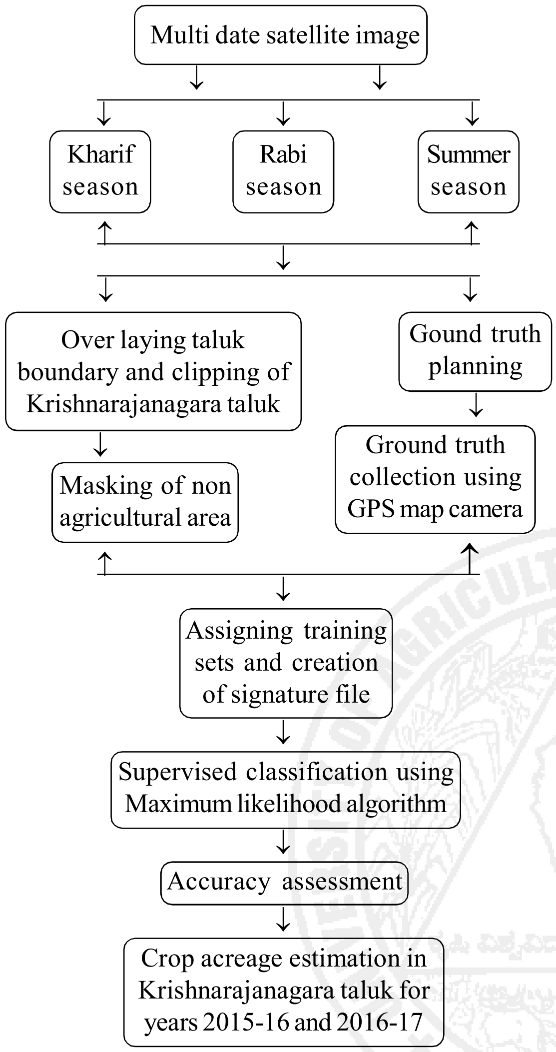

Fig. 2 : Sequence of steps followed in estimating crop area at taluk level

sample pixels (training sets) for which the ground truth was collected. Based on this analyst-identified pixels, the computer recognizes pixels with similar signature throughout the image (Supervised classification) by applying the maximum-likelihood classifier. It assumes normal probability distribution of the data and then estimates the mean, variance and covariance matrix, to be used in the classification. Total enumeration approach, in which all pixels within the administrative boundary of the taluk were analysed, for acreage estimation of major crops.

Estimation of Crop Yields and Production of Major Crops during 2015-16 and 2016-17 : Most of the crop spectral response patterns exhibit strong absorption features in the visible (400 - 700 nm) portion of the electromagnetic spectrum (EMS) due to pigment absorption. This absorption is more prominent in the red region (660 nm). The reflectance in the near-infrared (NIR) at 760 - 860 nm vary as a function of green biomass and canopy architecture. In the shortwave infrared region (SWIR) at 1650 nm, leaf water absorption is the principal determinant of reflectance. We calculated the Normalized Difference Vegetation Index (NDVI) by subtracting the reflectance from crops in the red region from that of NIR and dividing the resultant by sum of the reflectance in the NIR and red. The change in the NDVI over the crop growing period, called temporal-spectral profiles were plotted for the major crops in the taluk during the crop growing period. The profile characteristics, in terms of time of peak duration of the profile, their slope, etc gave sufficient clues for the identification of the crops as well as their yield potential. As we know crop production is a function of crop area multiplied by yield per unit area. For paddy crop, the yield per unit area was estimated through a linear regression model in which the NDVI values obtained from LISS-3 sensor on 25th September 2015 were correlated with the yield of paddy crop generated through crop cutting experiments (CCE) that were conducted by the Karnataka State Directorate of Economics and Statistics (DES). For other crops like ragi, coconut and sugarcane, the historical-yield-trend predicted (for the period 2006 to 2015) using DES data was used for generating production estimates. In case of paddy crop, the regression model developed for 2015-16 was used for estimating rice crop yield in 2016-17. The sequence of steps followed in paddy yield estimation is shown in Fig. 3.

Cropping Systems Analysis at the taluk level : Cropping system analysis and crop diversities were assessed as per the methodology suggested by Panigrahy *et al.* (2011) using multi-date RESOURCESAT-2 AWiFS data of three crop seasons for 2016-17 year.

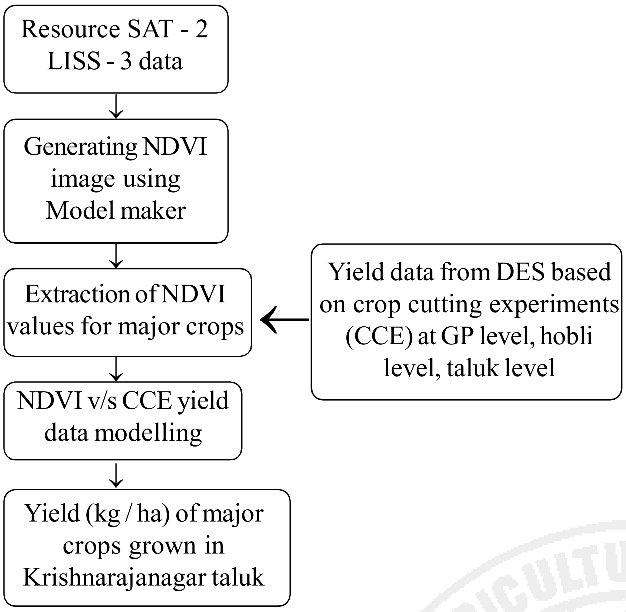

Fig. 3 : Sequence of steps followed in developing crop yield modelling

Accuracy Assessment : The accuracy assessment of crop type classification, area estimation at the taluk level. Identification accuracy of crop pixels labelled as different crops through digital classification was carried out with the help of ground truth samples collected at several specific x, y locations (mostly road and canal intersections) using a smart phone with an inbuilt Global Positioning System (GPS). These samples were divided into training and test samples. An error matrix was created between the digital classified output and ground reference data (test samples). The diagonal of the matrix gave the number of pixels that were assigned to the correct class. The sub-routine available in ERDAS® IMAGINE was used to know how well the image was classified to characterize errors and the accuracy of estimates derived from it. Overall classification accuracy (OCA) expressed in percentage and Kappa coefficient were generated as per Congalton and Green (1999). The Kappa coefficient is measure of agreement between the two sources of data. Relative deviation (RD), of area and production estimates generated using remotely sensed data, from that of Karnataka State DES statistics for the corresponding years was also calculated at only taluk level.

Results and Discussion

Identification of Crops Types in Krishnarajanagara taluk : The changes in NDVI profiles over time of major crops in the taluk are shown in Fig. 4. It was found that the coconut plantations (perennial crop) did not show the dynamic changes

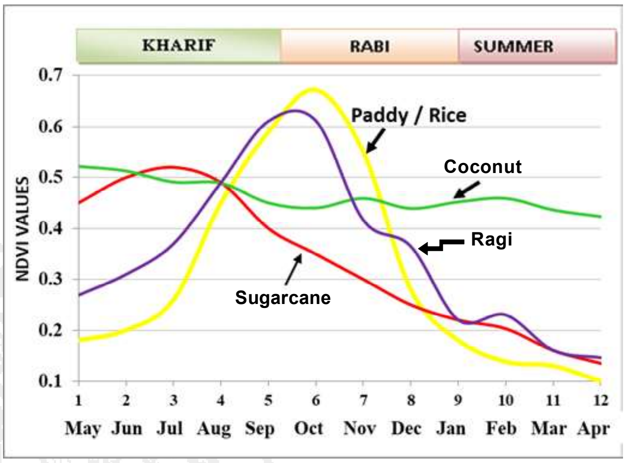

Fig. 4 : Temporal-spectral profiles of NDVI of major crops in the taluk

observed for short duration crops like paddy and ragi. The sugarcane crop profile is showing a falling trend from mid-August of 2015 till April 2016. However, the temporal-spectral profiles of the two cereal crop types (Rice and Ragi) are quite distinct at different times of the crop growing seasons. Ragi crop which is normally sown earlier than paddy crop has shown an early rise in the NDVI temporal profile than paddy crop. Also, the time of peaking of these two profiles is different. These subtle changes in spectral signatures and temporal profiles of NDVI have facilitated identification of the crop types.

Taluk-level Crop Acreage Estimates of 2015-16 : Crop acreage estimates are shown in Table 2. It may be noted that paddy crop is the most dominant crop of the Krishnarajanagara taluk, occupying about 40 per cent of the geographical area (GA) in *kharif,* 10 per cent of GA in *rabi* and 6 per cent of GA in summer seasons. It is seen that the fallow lands and dry crops constitute about 58 per cent of GA indicating that the taluk's agriculture is predominantly dependant on monsoon rains.

TABLE 1

Crop acreage estimates (ha) of Krishnarajanagara taluk (2015-16)

LULC Classes	RESOURCESAT-2 LISS-3			RISAT-1 SAR
	Kharif	Rabi	Summer	Kharif
Land not available for cultivation	3408.2 (5.58)	3258.9 (5.34)	3482.90 (5.70)	3440.30 (5.63)
Paddy	23017 (48.38)	5951.7 (37.72)	3643.2 (9.75)	29521.9 (5.97)
Coconut	1987.3 (3.25)	2465.36 (4.04)	2643.21 (4.33)	2945.2 (4.82)
Ragi	111.1 (0.18)	618.89 (1.01)	227.84 (0.37)	975.8 (1.59)
Other trees	2578.3 (4.26)	2158.18 (3.58)	2204.25 (3.61)	2247.9 (3.68)
Sugarcane	170.7 (0.27)	289.98 (0.47)	70.73 (0.14)	873.06 (1.43)
Fallow land and other crops	29746.5 (48.74)	46275.7 (75.83)	48746.57 (79.88)	21014.58 (34.47)

Taluk-level Crop Acreage Estimates of 2016-17 : The crop area estimates are given in Table 3 as observed in 2015-16 paddy crop is the major crop during 2016-17 also, followed by ragi and sugarcane. Paddy was grown in about 37.76 per cent of GA, fallow land occupied about 50 per cent of GA. The ragi crop was grown in more area during *Rabi* season of 2016-17.

Comparison Crop Acreage Estimates of 2015-16 and 2016-17 : A comparison of crop acreage estimates of 2015-16 and 2016-17 (Table 3) showed reduction in area under paddy, ragi and sugarcane in the year 2016-17. It is observed that this reduction in the acreage of major crops is due to very high deficiency in the rainfall during 2016-17 when the district received 52 per cent less than the mean annual rainfall during the year. The year-to-year changes in the crop area estimates show that the taluk is vulnerable to vagaries of monsoon and delays in release of canal water for irrigation.

TABLE 2

Crop acreage estimates of Krishnarajanagara taluk (2016-17)

LULC Classes	Kharif 17-10-2016 LISS3 (Ha) (% of GA)	Rabi 17-12-2016 LAND SAT OLI (Ha) (% of GA)	Summer 05-02-2017 AWiFS (Ha) (% of GA)
Land not available for cultivation	3344.17 (5.48)	3440.8 (5.63)	3261.70 (5.34)
Paddy	23041.6 (37.76)	5448.51 (8.92)	2582.85 (4.23)
Coconut	2680.44 (4.39)	2307.89 (3.78)	2504.93 (4.10)
Ragi	71.93 (0.11)	516.2 (0.84)	437.47 (.07)
Other trees	1892.07 (3.94)	2278.97 (3.10)	2408.06 (3.73)
Sugarcane	97.53 (0.09)	306.23 (0.15)	60.88 (0.50)
Fallow land and other crops	29891 (48.98)	46720.14 (76.56)	49762.84 (81.55)

TABLE 3

Taluk level crop area estimates of Krishnarajanagara (2015-16 and 2016-17) (Average of three seasons)

Land Cover / Crop type	2015-16 (Ha)	2016-17 (Ha)
Land not available for cultivation (built up + waterbodies + wastelands + weeds)	3397.58 (5.56)	3349 (5.48)
Paddy	11954.79 (19.59)	10357.65 (16.9)
Coconut	2510.2 (4.14)	2489 (4.09)
Ragi	483.4 (0.79)	341.86 (0.56)
Sugarcane	351 (0.57)	154 (0.28)
Fallowland and other crops	40024.62 (65.59)	42124.66 (69.05)
Other trees	2297.15 (3.76)	2193.49 (3.64)

TABLE 4
Taluk level production estimates of Krishnarajanagara during 2015-16

Crops	Remotely sensed area (Ha)	Annual average yield (kg/ha)	Production (Tonnes)
Paddy	15533.5	3372	52379
Ragi	483.41	1593.5	770.31
Sugarcane	351	120000	42120
Coconut	2510.2	2020	5071.5

Taluk-level Production Estimation of Major Crops using Remote Sensing and Conventional Statistics for 2015-16 and 2016-17 years : It is well known that production is function of area (ha) multiplied by yield per hectare (kg/ha). In the present study, taluk level yield figures, generated from the trend-prediction were used for major crops except paddy. However, the yield of paddy crop was estimated using remotely-sensed data. The production figure thus generated for major crops (paddy, ragi, sugarcane and coconut) are shown in the Tables 4 & 5. Comparison of production estimates made in 2015 and 2016 revealed substantial reduction in the production of major crops grown in the Krishnarajanagara taluk in the year 2016 due to deficit rainfall.

TABLE 5
Taluk-level production estimates of Krishnarajanagara during 2016-17

Crops	Remotely sensed area (Ha)	Annual average yield (kg/ha)	Production (Tonnes)
Paddy	10358	3372	34927
Ragi	342	1593.5	545
Sugarcane	154	120000	18480
Coconut	2489	2020	5028

Paddy Crop Yield Estimates at Taluk level : The yield of paddy crop of the 2015-16 was generated using linear regression model relating NDVI derived from LISS-3 sensor data of RESOURCESAT-2. The coefficient of determination (R^2) was 0.499 indicating that the NDVI could explain only about 50 per cent of the variation in the paddy crop yield. The same yield model was extended to generate yield estimates for the year 2016. The annual average yield values thus generated for paddy crop was found to be 3772 kg / Ha.

Cropping Systems Analysis : The cropping systems adopted by farmers indicate the sustainability of agro-ecosystems. The MCI measures the crop intensity, ADI indicates the multiplicity of crops planted in a single year and CLUI measures how efficiently the available land area has been used over the year (Panigrahy *et al.,* 2005). The results show that the Krishnarajanagara taluk has six cropping systems, out of which three are paddy-based single crop systems occupying 25 per cent of GA and three double crop systems covering only 27 per cent of the GA. The diversity of crop rotations was observed in the central part of the study area, where irrigation support is available. The cropping system indices showed that the ADI was high in *kharif* season followed by *rabi* and summer season, while cropping intensity as revealed by MCI is high in *kharif* season than in *rabi* and summer. The low ADI across all the three seasons is because most of the area is either under single crop only (paddy) or is kept follow for long time. The taluk

TABLE 6
Area statistics of cropping system analysis during 2016-17

Class	28th April 2016 (Ha) Summer	17th Oct. 2016 (Ha) *Kharif*	7th Jan. 2017 (Ha) *Rabi*
Waterbody	2000.4	3492.2	2471.2
Built up	717.2	655.4	640.8
Paddy	14494.3	20295.6	17463.34
Coconut	2987.08	2493.1	2331.3
Ragi	2265.4	1482.8	2500.8
Vegetables	112.30	-	-
Other trees	2967.6	2504.6	1588.06
Sugarcane	2604.1	2065.3	2491.8
Fallowland	30689.82	22921.9	29270.8
Scrubland	1968.4	2852.8	2207.42
Cloud	134.7	1963.7	30.10
Cloud shadow	77.4	291.3	23.08

TABLE 7

Cropping diversity indices of Krishnarajanagara taluk during 2016-17

Crop Diversity Indices	7th Oct. 2016 (Ha) *Kharif*	7th Jan. 2016 (Ha) *Rabi*	28th April 2016 (Ha) Summer
Multiple Crop Index	57.60	45.20	42.90
Area Diversity Index	1.036	1.02	1.004
Cultivated Land Utilization Index	0.24	0.202	0.209

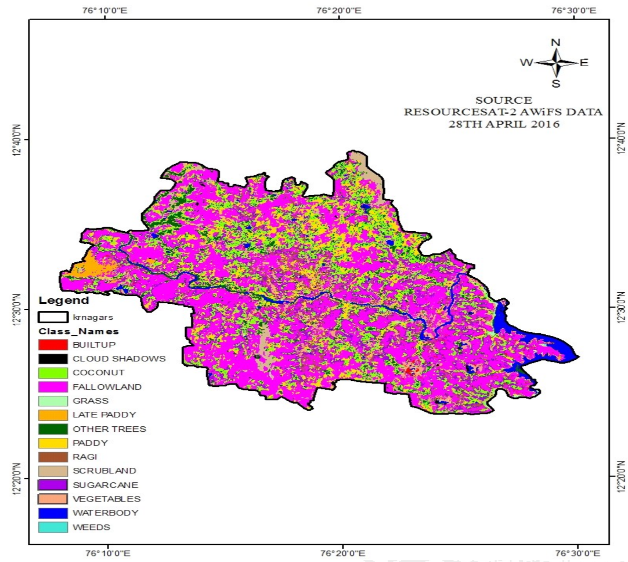

Fig. 5 : Spatial distribution of major crops during 2016-17 Summer season in Krishnarajasagara taluk

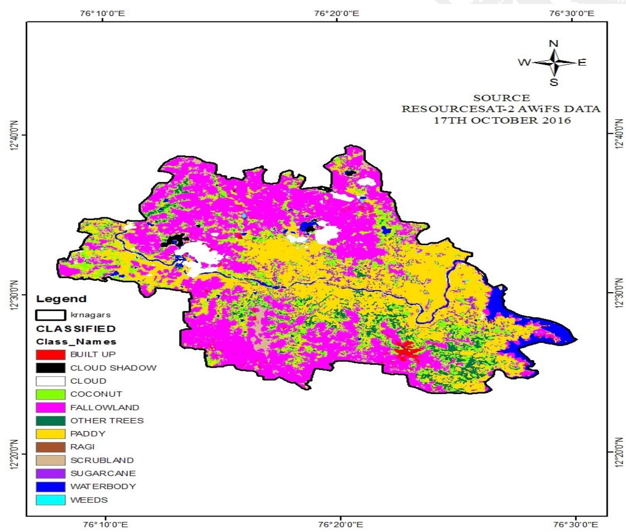

Fig. 6 : Spatial distribution of major crops during 2016-17 *Kharif* season in Krishnarajasagara taluk

has low ADI values ranging between 1.0 to 1.04 compared to 1.6 to 2.3 in the states of Punjab and Haryana (Tables 6 & 7).

As stated above, the CLUI is a measure of land utilization. For a cropping pattern, where the land remains unutilized for a very short period, the CLUI attains a value near to 1.0, whereas for a completely unutilized land (throughout the year) the CLUI is 0.0. In the Krishnarajanagara taluk, the CLUI values are 0.24 in *kharif* and negative values (much below 0.0) during *rabi* and summer seasons. From these of CLUI values, it is inferred that farmers are keeping the land unutilized, may be due to lack of timely rainfall, non-availability of canal irrigation, poor financial conditions and non-availability of farm labourers, etc.

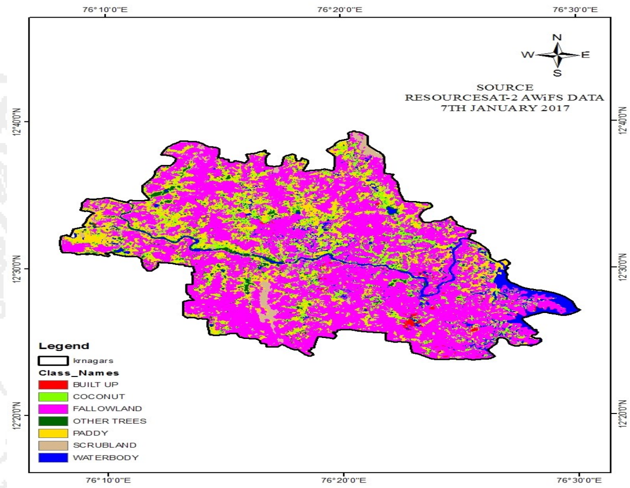

Fig. 7 : Spatial distribution of major crops during 2016-17 *rabi* season in Krishnarajasagara taluk

Taluk-level Crop Rotation Map 2016 : Satellite remote sensing helped in mapping of crop rotations. The results showed that paddy-fallowland-fallowland and paddy-fallowland-vegetables are some of the major crop rotations in the study area. It was found that there are only four types of crop rotations in Krishnarajanagara taluk during 2016-17, out of which paddy-fallowland-fallowland is the most dominant rotation observed, followed by paddy-fallowland-vegetables and paddy-ragi-fallowland (Table 8). The crop rotation map showed that in summer and *rabi* seasons most of the land is left fallow due to deficiency in supply of water for irrigation. It can be inferred that

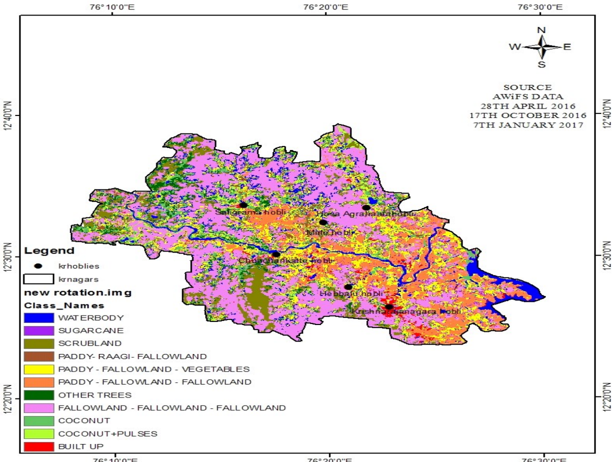

Fig. 8: Crop rotation map of Krishnarajanagara taluk using AWiFS data during 2016-17

TABLE 8

Area statistics of crop rotation map of 2016

Class	Area (Ha)	% of GA
Geographical area	61018.7	-
Waterbody	3305.34	5.42
Built up	1047.74	1.71
Paddy-Ragi-Fallowland	5560.61	9.11
Coconut	2744.07	4.49
Coconut+ Pulses	3146.98	5.15
Other trees	1898.22	3.11
Sugarcane	1499.22	2.45
Paddy- Fallowland-Vegetables	8253.64	13.52
Fallowland-Fallowland-Fallowland	21928.5	35.93
Paddy-Fallowland-Fallowland	10639.99	17.43
Scrubland	994.39	1.63

the taluk is vulnerable to unsustainable agricultural practices.

The study clearly shows that the remotely sensed data from multiple satellites' sensors could be successfully used for monitoring the change in crop area and production and crop diversity assessment at taluk level. Multispectral and multi temporal remotely sensed data acquired in optical and microwave regions of the EMS along with conventional statistics gave acceptable accuracy of yield and production estimates. The study clearly demonstrated that the multitemporal data provided by a medium spatial resolution sensor AWiFS is good enough for generating cropping system maps and crop diversity assessment.

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