Current Journal of Applied Science and Technology

39(14): 71-79, 2020; Article no.CJAST.56870
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Geospatial Techniques for Paddy Crop Acreage and Yield Estimation

Krishna Desai[1], N. L. Rajesh[2*], U. K. Shanwad[1], N. Ananda[1], B. G. Koppalkar[1], B. K. Desai[3], V. Rajesh[2], Kirana Kumara[2] and Chandralekha[4]

[1]Department of Agronomy, College of Agriculture, Raichur, India.
[2]Department of Soil Science and Agricultural Chemistry, College of Agriculture, Raichur, India.
[3]University for Agricultural Sciences (UAS), Raichur, India.
[4]Sujala-III RS & GIS Lab, University for Agricultural Sciences (UAS), Raichur, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author NLR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KD and UKS executed and managed the analyses of the study. Author BGK managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2020/v39i1430704
Editor(s):
(1) Dr. Diony Alves Reis, Federal University of the West of Bahia, Brazil.
Reviewers:
(1) Augrey Hicigaali Malambo, Victoria Falls University of Technology, Zambia.
(2) Ali Atef Masria, Jouf University, Saudi Arabia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/56870

Original Research Article

Received 24 March 2020
Accepted 01 June 2020
Published 11 June 2020

ABSTRACT

Paddy crop acreage and yield estimation using geospatial technology were carried out in North Eastern Dry Zone (Zone-2) covering Shorapur taluk, Yadgir district, Karnataka state, India, during *rabi* late sown or *summer* 2016-17 season. The study area is located between 16° 20' to 17° 45' north latitude and 76° 04' to 77° 42' east longitude, at an elevation of 428 meters above mean sea level. The RESOURCESAT-1 LISS III satellite image of 31st January 2017, 24th February 2017, 20th March 2017 and LANDSAT-8 of 15th April 2017 were used for paddy crop acreage estimation at taluk level. Paddy signatures were identified using ground truth GPS data and then, these temporal imageries were subjected to NDVI classification and estimated the paddy biomass and further validated with the ground-truthing in corresponding to *Green Seeker* NDVI value. The estimated paddy crop acreage through imagery NDVI were 2145.75 ha, 17602.21 ha, 19838 ha and 23004.01 ha area during Jan-2017, Feb-2017, March-2017 and April-2017 respectively. When these results were compared with acreage estimates as reported by the State Department of

**Corresponding author: E-mail: rajesh.neralikere@gmail.com;*

Agriculture, shown a relative deviation of 11.41, 35.78, 23.01& 3.89 per cent for Jan-2017, Feb-2017, March-2017 and April-2017 respectively. Therefore, LandSat-8 NDVI paddy acreage has showed significantly on par with the ground truth data at the crop harvest stage. Relative deviation of 10.75 for yield comparison among imagery NDVI biomass yield with the DOA yield estimation infer that NDVI biomass yield estimation would give better result at 90 days after sowing. Positive correlation of NDVI values with estimated acreage and yield, indicates that application of remote sensing techniques for forecasting paddy biomass yield is more accurate, economical and could be beneficial to the policy makers for quick decisions.

Keywords: Geo-spatial technology; paddy crop acreage; NDVI and yield estimation.

1. INTRODUCTION

Rice as a staple food in large parts of the country India, it is necessary for timely forecasting of the acreage and yield as a factor of cereals production and productivity estimation to decide the import and export strategies and to hold food security of the nation. Remote sensing tools are vital in estimating crop area and yields at field-level and regional scales [1]. Remote sensing technique has the potential to provide information on agricultural crops quantitatively, instantaneously and above all, non-destructively over large areas [2,3]. Vegetation indices have direct relation with the condition of the plants, so that they can be used for the purpose of yield estimation in advance [4,5,6]. The Normalized Difference Vegetation Index (NDVI) at regular time interval provides useful information about various crop growth stages and behavior of crop condition in a season [7]. This study conducted with an objective to assess the paddy crop acreage using imagery NDVI and ground truthing with *Green Seeker* proximal sensor and yield records of department of agriculture in Shorapur taluk of Yadgir district in Northern Eastern Karnataka, India.

2. MATERIALS AND METHODS

The experiment was conducted during *rabi* or summer season of 2016 in Shorapur taluk, Karnataka state in India. It is situated at 16° 20 to 17° 45' north latitude and 76° 04' to 77° 42' east longitude and at an elevation of 428 meters above mean sea level. The study area falls under North Eastern Dry Zone (Zone-2) of Karnataka (Fig. 1). Initial survey was carried out to collect GCPs (Ground Control Points) of intensive paddy crop areas using hand held *Trimble Juno* Global Positioning System (GPS,) and these points were imported on temporal satellite imageries (IRS LISS III of Jan to March, 2017 and Landsat8 of April, 2017). This helped in identifying the signatures of Paddy crops which improves the Normalized Difference Vegetation Index (NDVI) classification accuracy. NDVI was calculated by using following equation.

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Where,

NIR and R are the reflectance in the Near Infrared and Red regions, respectively.

Discrete randomly collected geo-tagged NDVI values of *Green Seeker* were imported on to classified imagery NDVI to confront the accuracy of the classified NDVI output of satellite imagery. Meanwhile paddy sown area statistics and yield data were collected from Department of Agriculture (DOA, Government of Karnataka) for calculating the relative deviation of yield. The temporal imageries were chosen to study variations in paddy crop acreage may be due to stress (decrease) or late sown (increase). As NDVI values vary with paddy growth stage, monthly repeated ground data were collected from the same locations to validate the imagery NDVI output. The imageries were processed to derive NDVI values and area statistics using *ERDAS Imagine* (Version 2014) image processing software at Remote sensing (RS) and Geographical Information System (GIS) lab Sujala-III project, Agriculture College, University of Agricultural Sciences, Raichur and are presented in result and discussion.

Data validation of remote sensing NDVI output with ground truth was evaluated using the following relative deviation technique, relative deviation (RD) percentage.

$$\text{RD}\ (\%) = (\text{RS} - \text{DOA})/\text{RS}\ \text{x}\ 100$$

Where,

RS - Estimates through Remote Sensing
DOA - Estimates from the office of the State Department of Agriculture

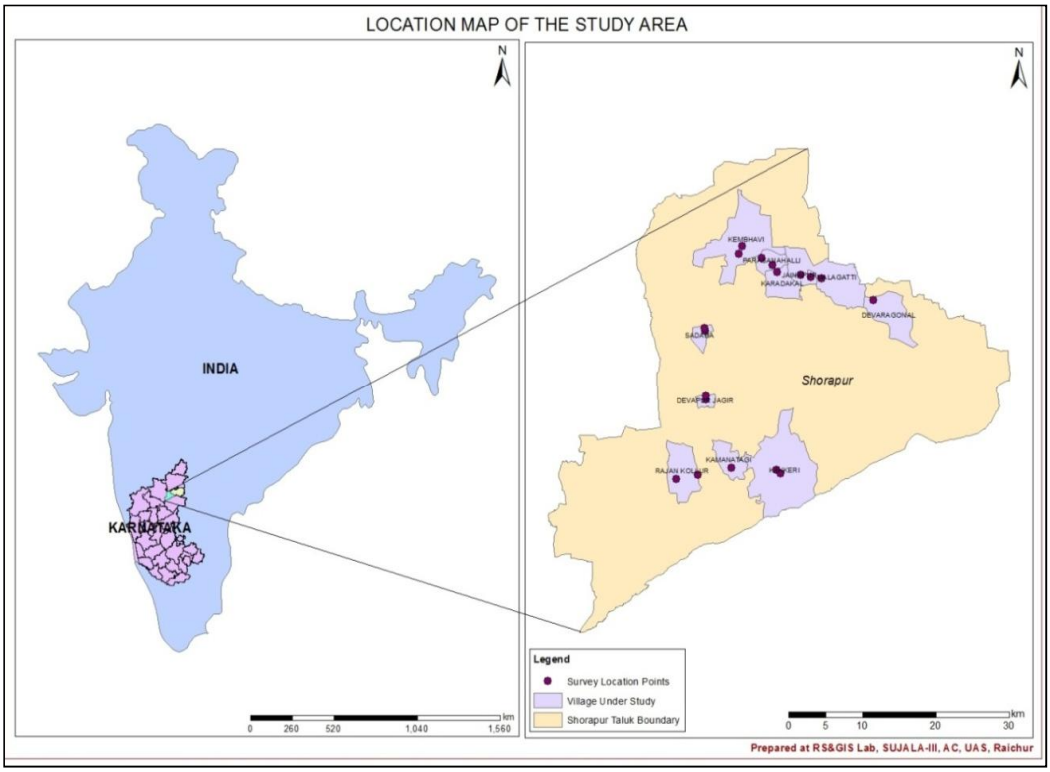

Fig. 1. Location map of the study area

Pearson correlation was calculated for averaged NDVI values, acreage and yield of paddy using SPSS v.16 package.

3. RESULTS AND DISCUSSION

3.1 Paddy Acreage Estimation Using NDVI Values

3.1.1 Area covered under paddy as observed from classified NDVI values of LISS-III January-2017

The area statistics as observed from Table 2 and Fig. 2a, indicates different NDVI values classified from LISS-III of January, 2017. The total area of 28830.74 ha derived with NDVI value ranging from -0.100 to 0.700, of which as per the ground truth the paddy area reflects the NDVI value from 0.254 to 0.700 accounting 21451.75 ha total area which is almost matching with department of agriculture (DOA) area given, with a relative deviation of +11.41.

3.1.2 Area covered under paddy as observed from classified NDVI values of LISS-III February-2017

The area statistics as observed from Table 2, and Fig. 2b, indicates different NDVI values classified from LISS-III of February, 2017. The total area of 28830.74 ha derived with NDVI value ranging from -0.040 to 0.482, of which as per the ground truth, the paddy area reflects the NDVI value from 0.158 to 0.482 accounting 17602.21 ha total area which is almost matching with the department of agriculture (DOA) area given, with a relative deviation of +35.78. The low NDVI value for paddy is observed because of early growth stage and may be because of low nitrogen content in crop canopy [8].

3.1.3 Area covered under paddy as observed from classified NDVI values of LISS-III March, 2017

The area statistics as observed from Table 2, and Fig. 2c, indicates different based on NDVI values classified from LISS-III of March, 2017. The total area of 28830.03 ha derived with NDVI value ranging from -0.014 to 0.709, of which as per the ground truth, the paddy area reflects the NDVI value from 0.286 to 0.709 accounting 19838.38 ha total area which is almost matching with the department of agriculture (DOA) area given, with a relative deviation of +23.07.

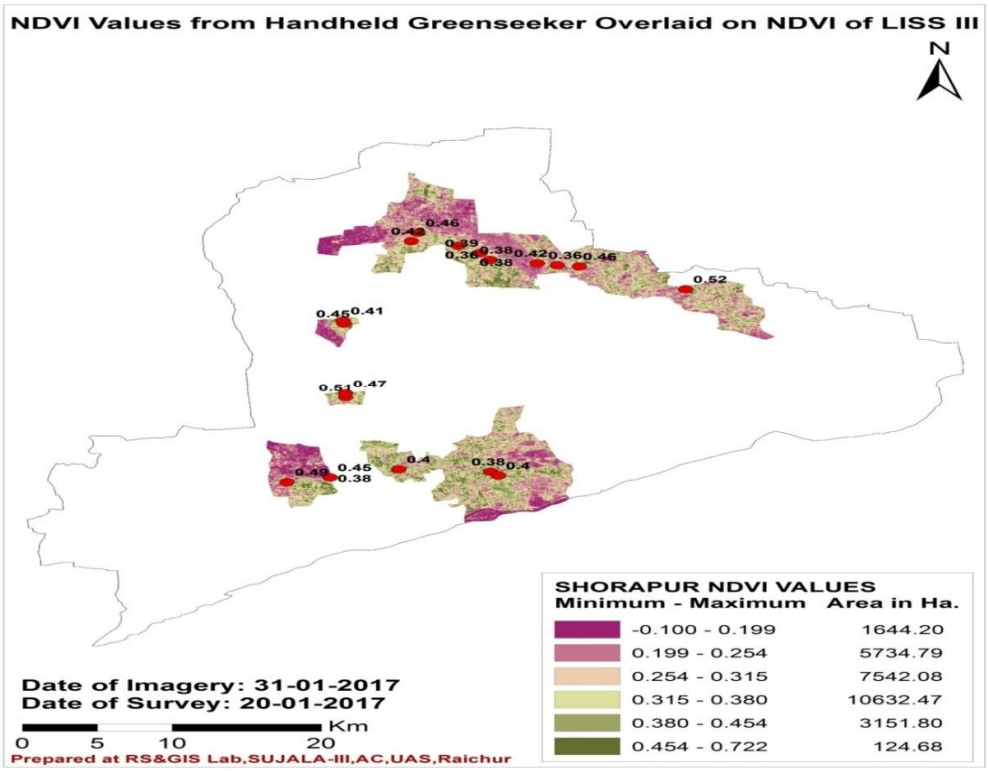

Fig. 2a. NDVI classified LISS III imagery of Shorapur taluk, Yadgir district in North East Karnataka

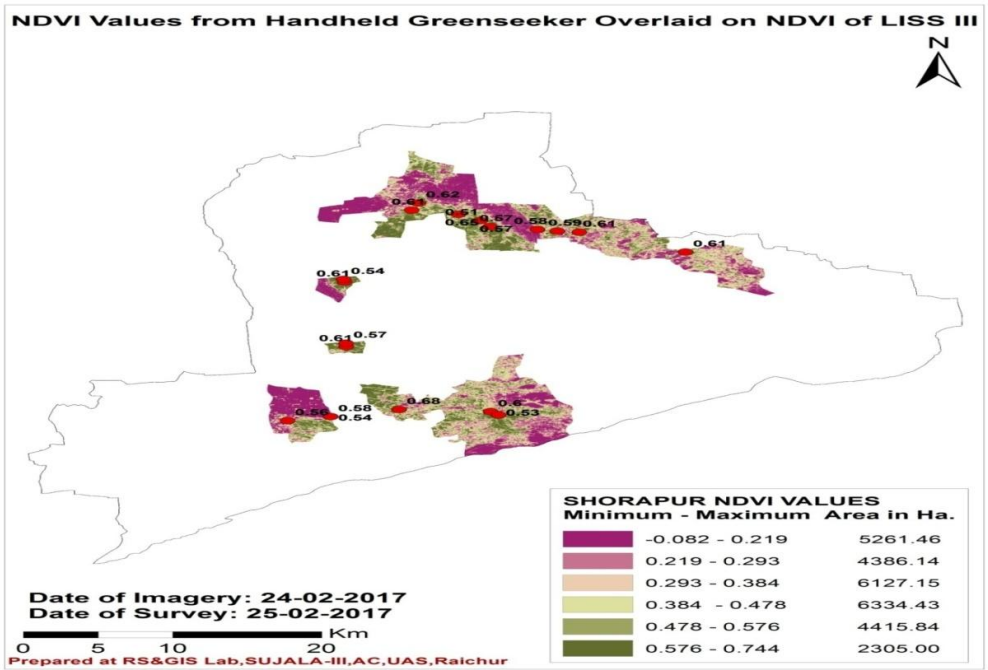

Fig. 2b. NDVI classified LISS III imagery of Shorapur taluk, Yadgir district in North East Karnataka

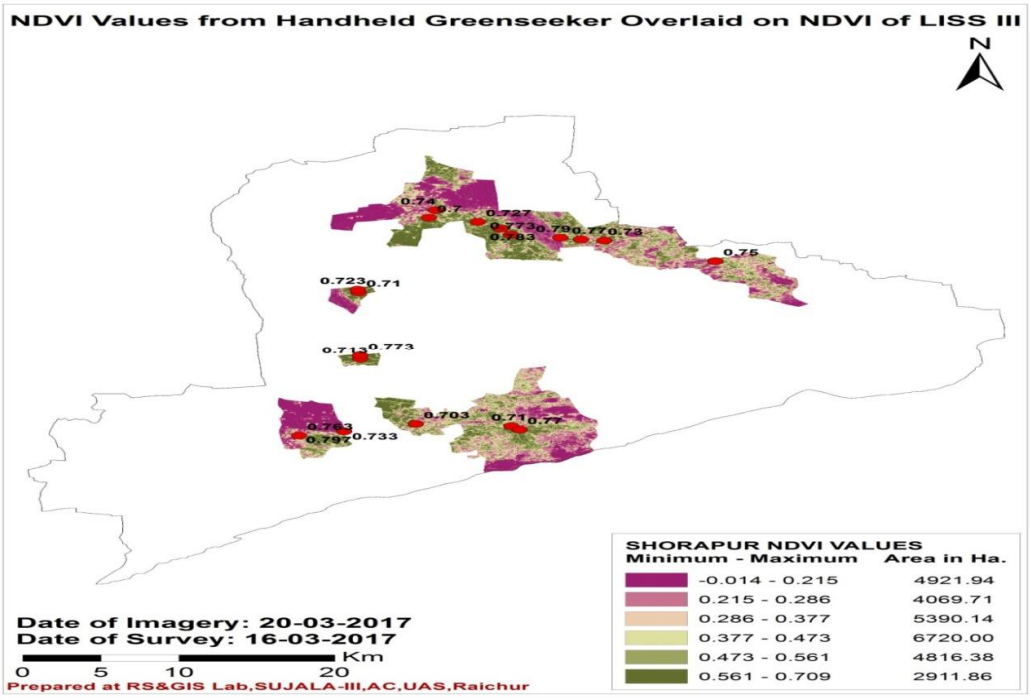

Fig. 2c. NDVI classified LISS III imagery of Shorapur taluk, Yadgir district in North East Karnataka

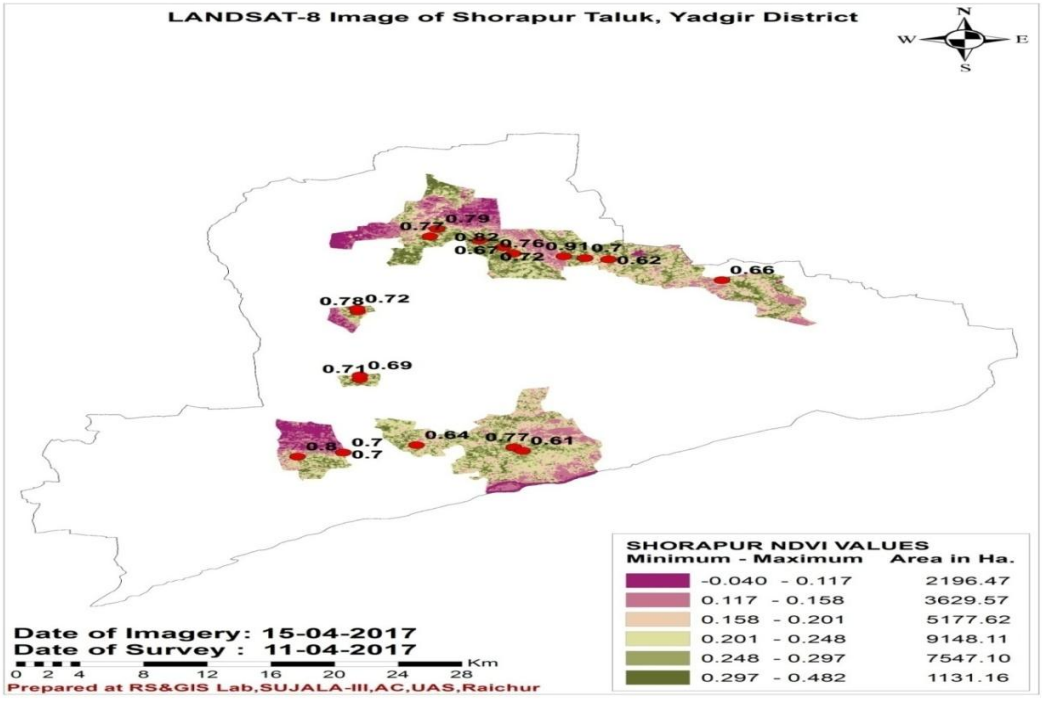

Fig. 2d. NDVI classified LANDSAT-8 of Shorapur taluk, Yadgir District in North East Karnataka

3.1.4 Area covered under paddy as observed from classified NDVI values of LANDSAT-8, April-2017

The area statistics as observed from Table 2 and Fig. 2d, indicates different NDVI values classified from LANDSAT-8 of March-2017. The total area of 28830.05 ha derived with NDVI value ranging from -0.040 to 0.482, of which as per the ground truth, the paddy area reflects the NDVI value from 0.158 to 0.482 accounting 23004.01 ha total area which is almost matching with department of agriculture (DOA) area given, with a relative deviation of +3.89.

3.2 Yield Attributes of Paddy (Grain and Straw Yield in q ha^{-1}, and Their Harvest Index)

The attributes such as Grain yield, Straw yield and Harvest index of rice in different farmers field are presented in Table 1.

Lowest grain yield of 35.90 q ha^{-1} was recorded in *Sadab* village whereas the highest grain yield of 49.12 q ha^{-1} was recorded in *Devargonal* and average grain yield of 42.3 q ha^{-1} was observed. The standard deviation of 3.93 with 9.29 per cent of co-efficient of variation in the paddy yield observed. Similarly, lowest straw yield of 58.02 q ha^{-1} was recorded in *Kembhavi* village whereas the highest straw yield of 75.92 q ha^{-1} was recorded in *Parsanhalli* and average straw yield of 63.1 q ha^{-1} was observed for shorapur taluk. The standard deviation of 4.69 with a 7.43 per cent of co-efficient of variation in the paddy yield was observed. The low harvest index of 0.35 was recorded in *Parsanhalli* village whereas highest harvest index of 0.43 was recorded in *Devargonal* and average harvest index of 0.39 percent was observed. The standard deviation of 0.02 with a 5.38 per cent of co-efficient of variation in the paddy Harvest index was observed. The variations of these yield attributes are may be because of differences in agricultural input and crop management by individual farmers [9].

Table 1. Grain yield, straw yield and harvest index of paddy at different farmers field and area under paddy as DOA

Sl. no.	Farmers name	Villages	Yield parameters			Area (ha) under paddy as per the DOA
			Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index	
1	Sh. NagappaKampi	Kakkera	46.34	64.00	0.41	6559.38
2	Sh. NandappaKamatagi	Kakkera	39.23	58.21	0.37	
3	Sh. Bairappa	Kamantigi	46.80	71.00	0.42	1445.25
4	Sh. Chidanandappa	Kamantigi	41.12	64.28	0.39	
5	Sh. Basappa	Rajankollur	47.92	64.20	0.42	2779.28
6	Smt. Annapurna	Rajankollur	40.60	58.47	0.40	
7	Sh. Sangappa	Devapur (J)	40.76	58.82	0.40	271.98
8	Sh. Gurulingappa	Devapur (J)	38.46	59.60	0.39	
9	Sh. Ningappa	Sadab	36.26	62.21	0.36	631.48
10	Sh. Sangangouda	Sadab	35.90	60.82	0.37	
11	Smt. Boramma	Kembhavi	40.00	59.06	0.40	5905.51
12	Sh. Mudhigouda	Kembhavi	39.49	58.02	0.40	
13	Smt. Mallamma	Parasanhalli	41.96	64.86	0.39	1014.21
14	Smt. Padmavathi	Parasanhalli	41.99	75.92	0.35	
15	Sh. G. Raju	Kardakal	46.80	67.80	0.40	1637.27
16	Sh. Shankargouda	Kardakal	46.92	67.07	0.41	
17	Smt. Shankaramma	Jainapur	41.00	64.00	0.39	394.18
18	Sh. Sahebgouda	Jainapur	46.00	61.01	0.42	
19	Sh. M. Sathyanarayan	Malagathi	41.12	59.06	0.41	1522.75
20	Sh. Devendrappa	Devargonal	49.12	64.80	0.43	1739.05
Total of selected farmer's field for taluk		Shorapur	847.79	1263.21	0.40	Total area covered under paddy in Shorapur Taluk = 23900.34 ha
Mean			42.3	63.1	0.39	
SD			3.93	4.69	0.02	
CV %			9.29	7.43	5.38	

Table 2. Area covered under paddy as observed from classified NDVI values of LISS-III January, 2017, LISS-III February, 2017, LISS-III March, 2017 and LANDSAT- 8 April, 2017

Sl. no.	LISS-III January, 2017		LISS-III February, 2017		LISS-III March, 2017		LANDSAT- 8 April, 2017	
	NDVI	Area (ha)	NDVI	Area (ha)	NDVI	Area (ha)	NDVI	Area (ha)
1	-0.100 – 0.199	1644.20	-0.040 – 0.117	2196.47	-0.014 – 0.215	4921.94	-0.040 – 0.117	2196.47
2	0.199 – 0.254	5734.79	0.117 – 0.158	3629.57	0.215 – 0.286	4069.71	0.117 – 0.158	3629.57
3	0.254 – 0.315	7542.80	0.158 – 0.201	5177.62	0.286 – 0.377	5390.14	0.158 – 0.201	5177.62
4	0.315 – 0.380	10632.47	0.201 – 0.248	9148.11	0.377 – 0.473	6720.00	0.201 – 0.248	9148.11
5	0.380 – 0.454	3151.80	0.248 – 0.297	3151.80	0.473 – 0.561	4816.38	0.248 – 0.297	7547.10
6	0.454 – 0.722	124.68	0.297 –0.482	124.68	0.561 – 0.709	2911.86	0.297 – 0.482	1131.18
Total area	-	28830.74	-	28830.74	-	28830.03	-	28830.05

**Total area includes other than paddy having NDVI value < 0.158*

Table 3. Comparison of remote sensing and department of agriculture acreage estimation for the year 2016-17 in Shorapur Taluk Yadgir District

Remote sensing data used	Paddy NDVI value	Estimated area (ha) 'a'	RD (%) Calculated with DOA acreage of 23900.34 ha [(a-23900.34)/a]*100	Production estimated by multiplying crop cutting yield of 57.1 q/ha with NDVI acreage (tones) b=(a*57.1)	RD (%) calculated with DOA yield of 10109 tons [(b-10109)/b]*100
NDVI of LISS-III.Jan-2017	0.254-0.700	21451.75	11.41	12249	17.47
NDVI of LISS-III.Feb-2017	0.158-0.482	17602.21	35.78	10051	-0.57
NDVI of LISS-III.March-2017	0.286-0.709	19838.38	23.07	11327	10.75
NDVI of LANDSAT-8.April-2017	0.158-0.482	23004.01	03.89	13135	26.71

3.3 Comparison of the Remote Sensing Based Acreage Estimates with Area Reported by Karnataka State Department of Agriculture

The estimated acreage under paddy crop in Kakkera, Kamantgi, Rajankollur, Devapur (J), Sadab, Kembhavi, Parsanhalli, Kardakal, Jainapur, Malagathi and Devargonal villages. It was compared with the acreage reported by the office of State Department of Agriculture, Shorapur. The results of the comparison of acreage estimation are presented in Tables 1 and 3. The deviation of the estimated acreage was +17.10 per cent.

3.4 Comparison of NDVIi Biomass Yield and DOA Yield Estimates

The comparison of forecast yield estimates between the biomass yield obtained through remote sensing studies to that of manually recorded crop cutting experiment yield data of the State Department of Agriculture, Shorapur Taluk, indicated relative deviation of 11.41, 35.78, 23.01 & 3.89 per cent for Jan-2017, Feb-2019, March-2017 and April-2017 respectively. Whereas a relative deviation of 10.75 for yield comparison among imagery NDVI biomass yield with the DOA yield estimation infer that NDVI biomass yield estimation would give better results at 90 DAS.

The monthly average values of paddy NDVI were correlated with forecasted acreage and yield estimation (Table 4), which showed positive correlation whereas, acreage estimation and yield shown a significantly positive correlation at 1% level therefore, the estimation of biomass yield of paddy using NDVI values of satellite imageries helps in forecasting yield in advance with decreased human errors due to the unbiased nature of the remote sensing technology [10].

Table 4. Correlation of NDVI with yield and acreage estimation

Variables	NDVI	Acre
NDVI	1	
Acre	0.066	1
yield	0.066	1.000**

***Correlation is significant at the 0.01 level (2-tailed)*

4. CONCLUSION

Advance acreage estimates using remote sensing data when compared with acreage estimates as reported by State Department of Agriculture (DOA), showed a relative deviation of 11.41, 35.78, 23.01 & 3.89 per cent during Jan-2017, Feb-2017, March-2017 and April-2017 respectively. Among which, LandSat-8 NDVI paddy acreage has showed significantly on par estimation with the ground truth data at the crop harvest stage. Relative deviation of 10.75 per cent in yield comparison using imagery NDVI biomass with the DOA yield estimation infer that NDVI biomass yield estimation would give better result at 90 days after sowing. Therefore, the overall social benefits from reducing the error in estimation of biomass yield from satellite imageries would result from improvement in decisions regarding inventory management, price fixation, import and export decisions based on improved estimates even before the crop is harvested.

ACKNOWLEDGEMENTS

Authors acknowledge "The World Bank" and the "Watershed Development Department", Govt. of Karnataka for funding the establishment of Sujala-III laboratories (Soil Testing lab, RS&GIS lab & Data Centre) at University of Agricultural Sciences Raichur. Co-authors appreciate Dr. Rajesh N. L., Lead Scientist & Lab Head (LRI & GIS), for supporting students and researchers of UAS, Raichur to utilize geospatial technological facilities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/56870