FORTNIGHTLY ASSESSMENT OF MODIS -NDVI DATA TO UNDERSTAND GROUNDNUT YIELD BEHAVIOUR IN MID SEASON FOR PRODUCTION ESTIMATES - A CASE STUDY IN ANANTAPUR DISTRICT OF ANDHRA PRADESH, INDIA

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KEY WORDS: Remote sensing, MODIS, NDVI, Groundnut, Yield.

ABSTRACT

The study explored the suitability of the Normalized Difference Vegetation Index (NDVI) from the Moderate Resolution Imaging Spectrometer (MODIS) obtained for Anantapur district, over ten years (2008–2017) to understand the behaviour of Groundnut (*Arachis hypogaea*) yield in mid season (at peak crop growth stages) and its total production. Pre-harvest crop yield forecasting plays a vital role in coping with the challenges of the impacts of climate change on agriculture. NDVI product of MODIS (MOD13Q1-250mt) of 16 days composite (fortnightly) were analysed for predominant groundnut growing mandals of Anantapur from August to September. For this study, Anantapur district selected as since this is a perennially drought prone district of Andhra Pradesh and the major kharif crop is Groundnut, contributing 6 to 8 lakhs ha in kharif season per year. It is essential to frequently monitor the Groundnut crop condition within crop growing season and assess the yield prospect. The peak vegetative growth of Groundnut crop is mainly covered in August and September month in Anantapur district. The average yield of nine years (2008 to 2016) of selected mandals is varying from 136 kg/ha. to 496 kg/ha. Initial relationship between NDVI and yield were made fortnightly from June to September and a significant relationship were observed between NDVI and yield in selected mandals for 1st fortnight of August, 2nd fortnight of August and 1st fortnight of September varying from R^2 = 0.08 to 0.44, R^2 = 0.09 to 0.52 and R^2 = 0.05 to 0.52 respectively. The current year (2017) fortnightly NDVI values were used to forecast yield in mid season and a significant correlation were observed between predicted yield and observed average yield (2008 to 2016) for 1st fortnight of August, 2nd fortnight of August and 1st fortnight of September with R^2 = 0.74, R^2 = 0.82 and R^2 = 0.48 respectively. The total production was estimated in mid season using groundnut actual crop sown year up to 12th September, 2017 at mandal level.

1. INTRODUCTION

Remote sensing applications to agriculture have grown to a stage where such inputs are being used for number of policy level decisions related to food security, poverty alleviation and sustainable development in the country. Decision on buffer stock of food grains could be based on pre-harvest crop acreage and production estimation. Monitoring crop condition with remote sensing can get the condition of crop, as well as the status and trend of their growth. It also helps to acquire the crop production information (Rao M. V. K, Ayyangar R. S, 1982). Acquiring the crop condition and pre-harvest crop yield/production information at early stages of crop growth is even more important than acquiring the exact production after harvest time, especially when large scale commissariat shortage or surplus happens. Acquiring crop condition as early as possible has great influence on the policymaking on the price, circulation and storage of commissariat (Chen Shupeng, 1990). Satellite systems provide temporally and spatially continuous data cover most of the globe using relatively few instruments. Along with the development of remote sensing applications, satellite data has become the uppermost data source to monitor large-scale crop condition. USDA of U.S. and MARS programme of EU, as well as FAO, all have build their own crop monitoring systems based on remote sensing (Liu Haiqi, 1999, Rassmussen, 1997). Anantapur is a perennially drought affected district of Andhra Pradesh and the major kharif crop is Groundnut that contributes contributing 6 to 8 lakhs ha in kharif season per year. It is essential to monitor frequently NDVI based crop condition for pre-harvest yield behaviour. Satellites remote sensing images provide access to spatial information at global scale: of features and phenomena on earth on an almost real-time basis. They have the potential not only in identifying crop classes but also of estimating crop yield (Mohd. *et al*. 1994): they can identify and provide information on spatial variability and permit more efficiency in field scouting (Schuler 2002). Remote sensing could therefore be used for crop growth monitoring and yield estimation. The Moderate Resolution Imaging Spectroradiometer (MODIS) has the capacity of daily observation and its products have spatial resolutions of 250 m, 500 m, and 1000 m. MODIS time series have been used to analyze crop phenological changes and to discriminate vegetation types at regional and global scales. Improvements in the timeliness and accuracy of yield forecasting by incorporating near real-time remote sensing data and the use of sophisticated statistical methods can improve our capacity to respond effectively to these challenges.

2. STUDY AREA, DATA USED AND METHODOLOGY

2.1 Study Area

Anantapur is the southern-most district of the Rayalseema region of Andhra Pradesh. While agriculture remains the most important economic activity of the district, it is characterised by high levels of instability and uncertainity. Being located in the rain-shadow region of Andhra Pradesh, the district is drought-prone. The district has a total geographical area of 19.13 lakh hectare. For administrative purposes, the district is divided into three revenue divisions, namely, Anantapur, Dharmavaram, and Penukonda; there are sixty-three revenue mandals. Anantapur District is in the arid agro-ecological zone and is marked by hot arid bioclimatic condition with dry summers and mild winters. The soils of Anantapur originated from both the granite and granite-gneisss land forms, as wells as the Dharwar landforms. Both these land forms are characterised by hills and ridges and undulating and gently-sloping lands.

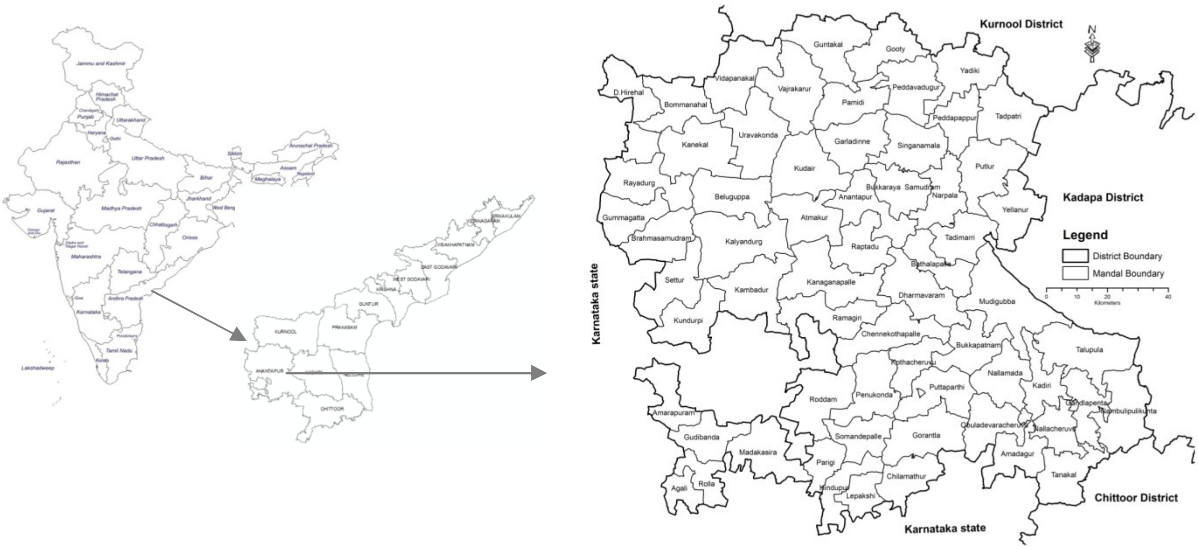


Figure 1: Study Area

2.2 Data

2.2.1 Satellite data

Satellite data ten year time series (2008–2017) of 16-Day composite, Global 250m product (MOD13Q1) was downloaded through the online Data Pool at the NASA Land Processes Distributed Active Archive Centre (LP DAAC). In MODIS/TERRA MOD13Q1 Blue, red and near infrared reflectance cantered at 469 nm, 645 nm and 858 nm, respectively are used to determine the MODIS daily vegetation indices. NDVI data of MOD13q1 Collection six were obtained from MOD13Q1.006. The Correction factor was applied to get MOD13Q1- NDVI product in range (+1 to -1).

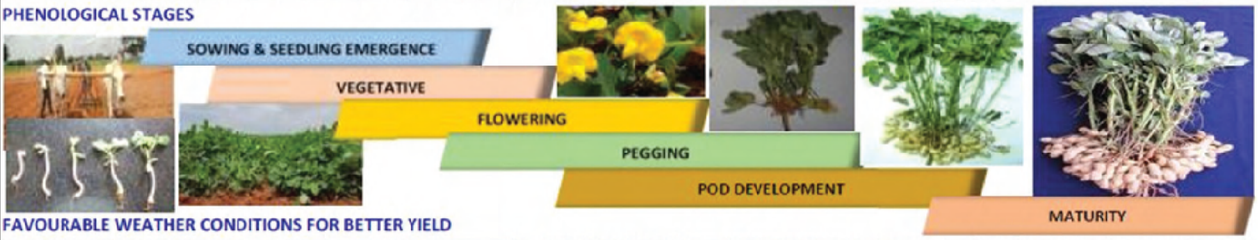
2.2.2 Agronomic and Rainfall Data

The agronomic (yield and cropped area) data were obtained for Anantapur district. Groundnut yield data at mandal level from 2008 to 2016 were obtained from DES (Department of Economics and Statistics, Govt. of Andhra Pradesh). The Groundnut crop calendar of Anantapur district is described in figure (2):

CLIMATIC NORMALS DURING CROP GROWING PERIOD

STD Wk	JULY				AUGUST					SEPTEMBER				OCTOBER				NOVEMBER			
	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
T max (°C)	35	34	34	33	33	33	33	33	33	33	33	33	33	33	33	32	32	31	31	31	31
T min (°C)	24	24	24	23	23	23	23	23	23	23	23	23	23	23	22	22	21	20	20	19	18
RH m (%)	72	76	75	76	76	78	78	78	79	78	78	79	80	81	81	80	81	84	83	85	83
RH e (%)	41	44	45	46	46	47	47	47	47	47	45	47	47	48	46	45	48	50	47	47	44
WS (KMPH)	19	18	19	18	18	18	17	15	15	13	11	10	8	7	6	6	5	6	6	6	6
RF (mm/Week)	10.3	22.7	25.7	21.2	14.1	13.2	11.9	34.0	26.1	32.0	28.7	31.3	28.7	26.9	19.7	18.8	15.2	13.3	13.8	7.3	3.8
Rainy Days	1	1	1	1	1	1	1	2	1	2	1	2	2	2	1	1	1	1	1	1	0
BSS (Hrs/Day)	5.4	5.0	5.2	4.7	5.0	5.0	5.2	6.0	5.7	6.3	6.9	6.7	7.2	7.0	7.2	7.4	7.0	6.7	7.2	7.8	8.0
EVP (mm/Week)	65	58	58	56	57	56	54	55	53	52	53	49	47	44	43	42	41	38	39	37	37

PHENOLOGICAL STAGES



FAVOURABLE WEATHER CONDITIONS FOR BETTER YIELD

	Sowing & Seedling Emergence (6-7 days)	Vegetative (16 – 27 days)	Flowering to Pegging (10 – 19 days)	Pegging to Pod Development (11 – 19 days)	Pod Development to Maturity (40 – 76 days)
T max (°C)	30 - 33	32 – 35	32 - 35	32 - 33	31 – 33
T min (°C)	23 - 24	23 – 24	22 – 24	23 - 24	20 – 23
RH m (%)	-	73-81	75-83	76-88	82-87
RH e (%)	-	39-56	38-49	45-59	44-55
RF (mm)	14.3	68.0	23.1	83.6	153.6
Rainy Days	0-2	1 – 5	1 – 3	1 – 6	5 – 18
BSS (Hrs/Day)	-	3.0-6.4	4.2-6.8	4.2-5.2	4.8-7.5

Source: District Level Crop Weather Calendars of Major Crops in India, ICAR-CRIDA, Hyderabad.

Figure 2: Anantapur district Groundnut crop calendar

2.3 Methodology

The mandals were selected based on high Groundnut production mandals in Anantapur district to study the behaviour of yield by using historical yield information and fortnightly NDVI values from August to September. The NDVI values were extracted for selected mandals. A simple regression analysis were performed using dependent variable (yield) and predictive variable (ndvi). The regression analysis were executed for August 1st fortnight, August 2nd fortnight and September1st fortnight. The time frame was selected based on crop calendar and peak crop growth stage.

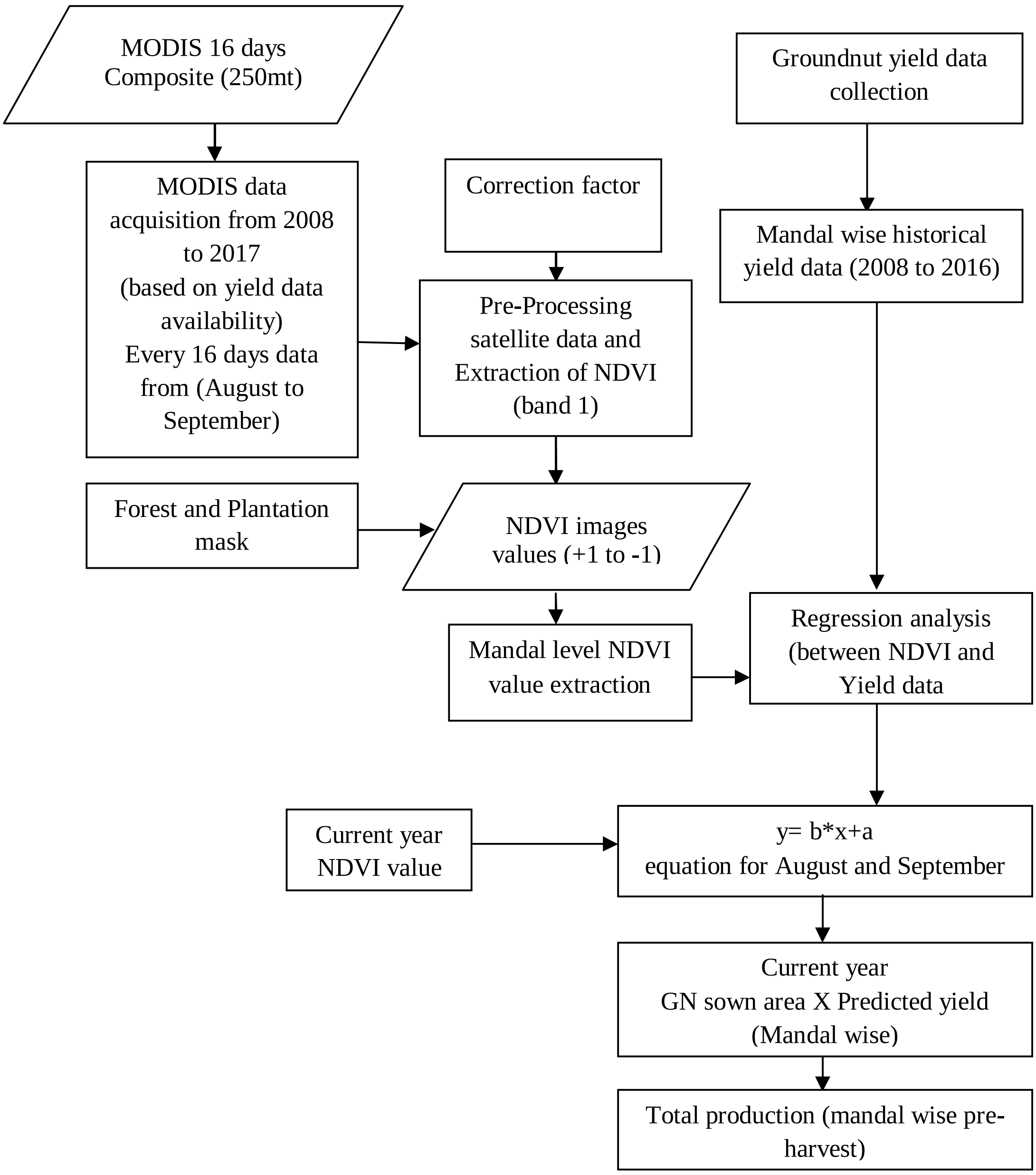


Figure 3: Flow chart

3. RESULTS AND DISCUSSION

3.1 Yield data variability

The Figure (4) demonstrates the groundnut yield data variability. The groundnut yield data (dependent) variable at the mandal level of Anantapur district were collected from the Department of Economics and Statistics (DES), Govt. of Andhra Pradesh for the year 2008 to 2016.

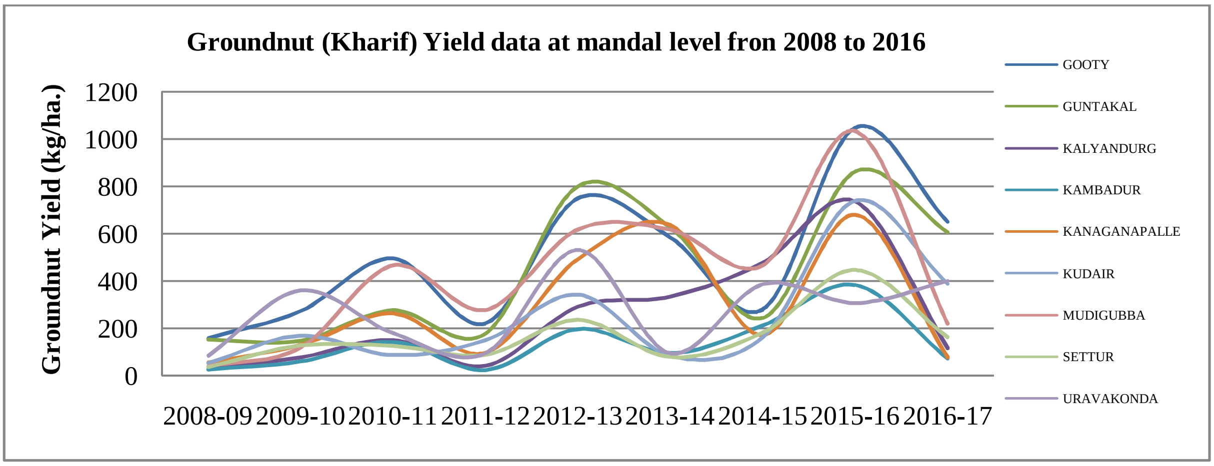


Figure 4: Groundnut (Kharif) Yield data at mandal level from 2008 to 2016

3.2 NDVI data Variability

The NDVI data (predictor) at mandal level from 2008 to 2017 were estimated from MODIS, Global 250m product (MOD13Q1). Cloud, Forest and Plantation area were masked from NDVI data and fortnightly satellite data were acquired from June to September (based on the groundnut crop calendar of Anantapur district) for mandal level statistics generation. The NDVI variation from 2008 to 2017 for two mandals (Guntkal and Gooty) shown in figure (5). Spatial view of NDVI variations from 1st fortnight of July to 1st fortnight of September are shown in figure (6).

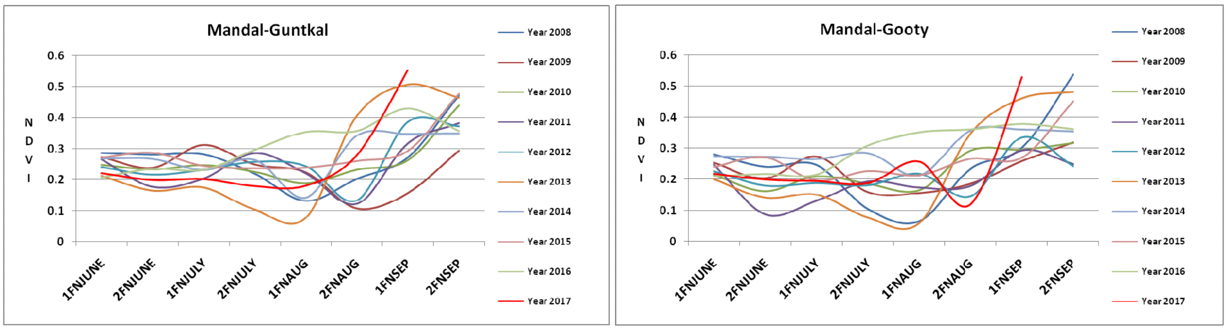


Figure 5: Fortnightly/yearly NDVI Variability in Guntakal and Gooty mandals

3.3 Normalized Difference Vegetation Index (NDV) spatial variation fortnightly from MODIS-250 m

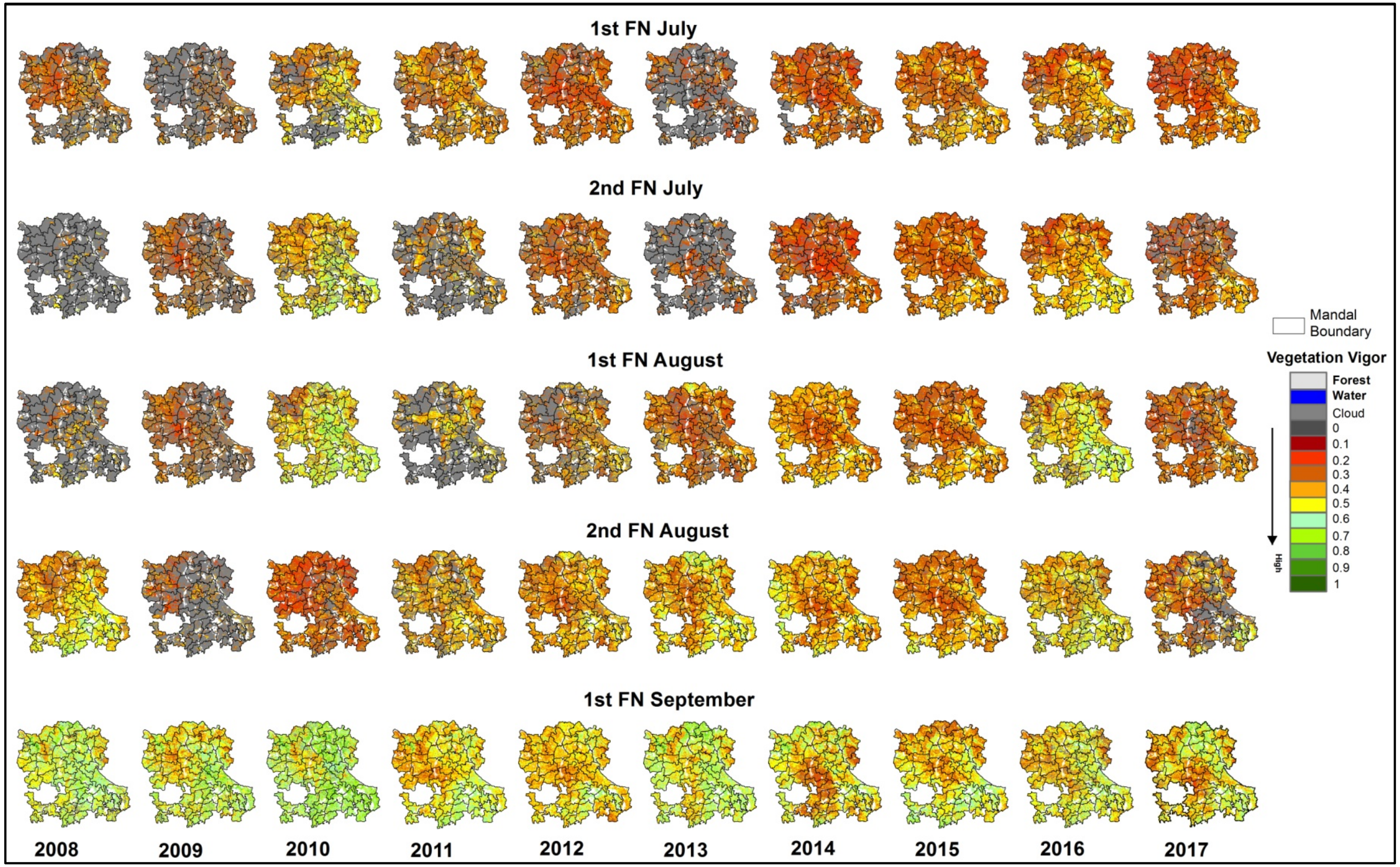


Figure 6: MODIS-250m NDVI, Fortnightly from 2008 to 2017

3.4 Relationship between Yield and NDVI

Mariano F. Lopresti, *et al*, (2015) observed in his study, the use of remote sensing allows estimating yield in advance. Since the time of maximum leaf area in wheat corresponds with the critical period of the crop, a good relationship is expected between the Normalized Difference Vegetation Index (NDVI) and yield and found that the MOD13q1 image corresponding to Julian day 289 showed the best fit between NDVI and yield to estimate wheat yield early. In initial, fortnightly relationship were studied between NDVI and Groundnut yield from June to September. A good relationship were observed from August 1st fortnight, 2nd fortnight of August and September 1st fortnight. In June and July month the correlation between NDVI and yield was not considerable to use for yield prediction, it is because of seedling emergence stage and initial vegetative growth stage of crop. In this study, In initial stage As per the crop calendar of Groundnut crop in Anantapur, sowings start in late June to July and seedling emergence and initial crop growth in late July. In August and September months, groundnut crop will be in peak growth, flowering, pegging and pod formation stage and crop will be easily observed by MODIS-Terra (250 mt.) sensor in these months. The following table is showing the fortnight wise prediction equation and current year (2017) NDVI values as a predictor value. Predicted yields and Average yield are also mentioned in the table (1)

Table 1: Correlation, Prediction equation, NDVI, predicted yield and Avg. Yield.

1) Mandal -Kanaganapally					
Fortnight	R^2	Prediction Equation	NDVI value (2017)	Predicted Yield in kg./ha.	Avg. Yield kg./ha. 2008 to 2016
1st Fortnight of August	0.171	y = 1916.x - 22.62	0.131	228	289
2nd Fortnight of August	0.264	y = 1704.x - 96.86	0.184	217	
1st Fortnight of September	0.060	y = 765.7x + 101.3	0.290	323	
2) Mandal - Kalyandurg					
1st Fortnight of August	0.202	y = 1377.x + 16.15	0.169	249	251
2nd Fortnight of August	0.354	y = 1521.x - 23.19	0.266	382	
1st Fortnight of September	0.329	y = 2157.x - 371.3	0.433	563	
3) Mandal -Mudigubba					
1st Fortnight of August	0.436	y = 1684.x + 81.70	0.279	552	429
2nd Fortnight of August	0.242	y = 1490.x + 8.045	0.338	512	
1st Fortnight of September	0.091	y = 801.2x + 164.1	0.431	509	
4) Mandal - Urvakonda					
1st Fortnight of August	0.438	y = 1371.x - 14.55	0.239	313	271
2nd Fortnight of August	0.524	y = 1226.x - 80.52	0.267	247	
1st Fortnight of September	0.519	y = 1389.x - 125.2	0.329	332	
5) Mandal - Kudair					
1st Fortnight of August	0.279	y = 1524.x - 92.09	0.161	153	242
2nd Fortnight of August	0.233	y = 1263.x - 21.74	0.304	362	
1st Fortnight of September	0.374	y = 1719.x - 239.0	0.479	584	
6) Mandal - Settur					
1st Fortnight of August	0.368	y = 2513.x - 517.3	0.245	98	166
2nd Fortnight of August	0.389	y = 1108x - 97.68	0.313	249	
1st Fortnight of September	0.064	y = 317.3x + 61.98	0.359	176	
7) Mandal - Kambadur					
1st Fortnight of August	0.044	y = 367.7x + 53.34	0.203	128	136
2nd Fortnight of August	0.332	y = 589.7x + 36.79	0.232	174	
1st Fortnight of September	0.409	y = 1060.x - 160.8	0.357	218	

8) Mandal - Guntkal					
1st Fortnight of August	0.088	y = 1076.x + 215.0	0.180	409	433
2nd Fortnight of August	0.193	y = 936.8x + 228.9	0.279	490	
1st Fortnight of September	0.308	y = 1566.x - 84.92	0.553	745	
9) Mandal - Gooty					
1st Fortnight of August	0.142	y = 1017.x + 303.5	0.257	565	496
2nd Fortnight of August	0.171	y = 918.5x + 289.5	0.324	587	
1st Fortnight of September	0.055	y = 654.6x + 294.3	0.530	641	
10) Mandal - Gorantla					
1st Fortnight of August	0.287	y = 2114.x - 199.8	0.223	244	450
2nd Fortnight of August	0.256	y = 1834.x + 13.43	0.282	234	
1st Fortnight of September	0.333	y = 1284.x + 23.43	0.407	546	

3.5 Relationship between observed and predicted yield

Furthermore, a graph (figure-7) is plotted herewith to observe the significance of fortnightly (August 1st fortnight, 2nd fortnight of August and September 1st fortnight) predicted yield with average yield of nine years. (2008 to 2016). A good relationship were found R2= 0.74, R2=0.83 and R2=0.48 after comparing predicted yields of August 1st fortnight, 2nd fortnight of August and September 1st fortnight with official yields respectively (figure- 8).

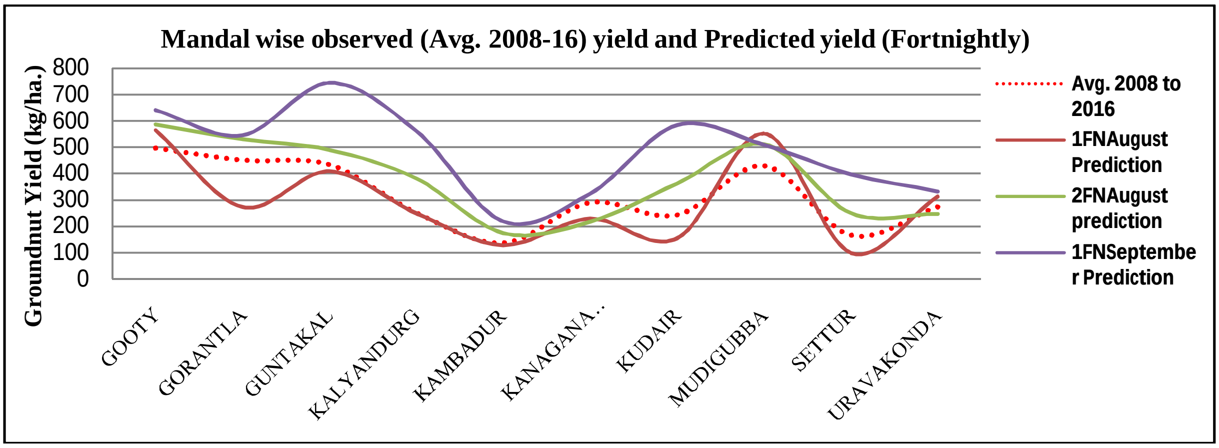


Figure 7: Avg. observed yield and predicted yield.

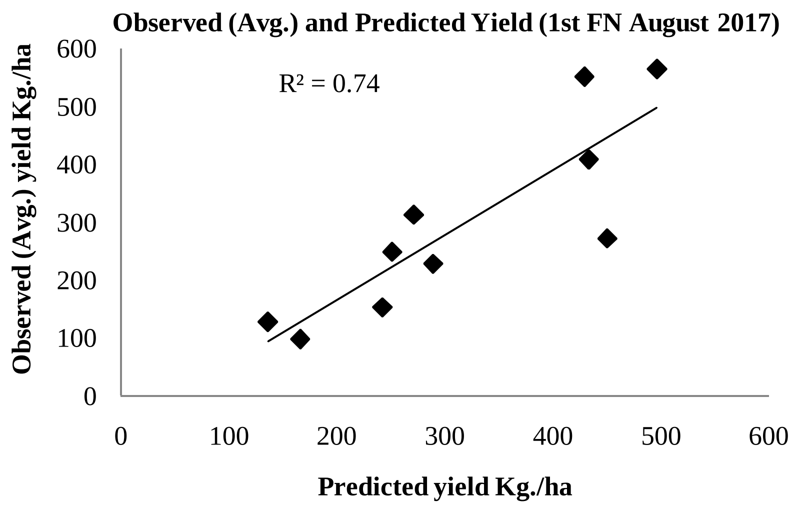


Figure 8: Relationship between observed (Avg.) yield and predicted yield (1st FN August, 2017)

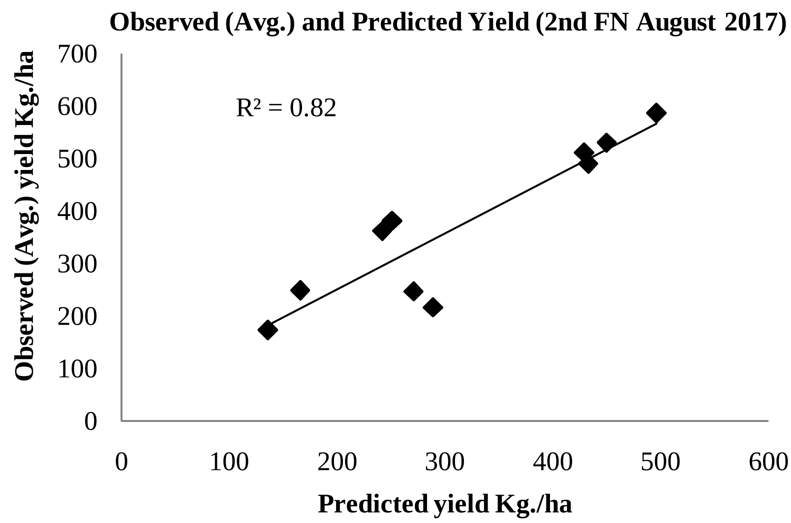


Figure 9: Relationship between observed (Avg.) yield and predicted yield (2nd FN August, 2017)

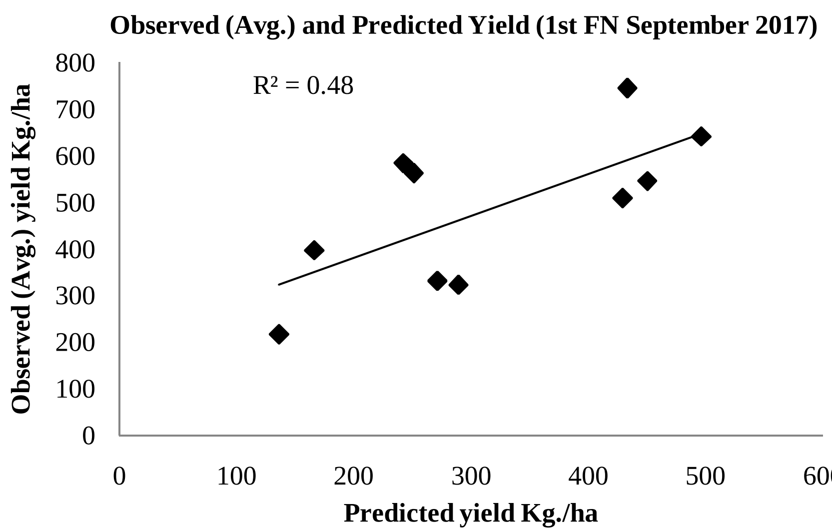


Figure 10: Relationship between observed (Avg.) yield and predicted yield (1st FN September, 2017)

3.6 Pre-Harvest Groundnut Production behaviour for Kharif, 2017

The pre-harvest mandal wise groundnut total production were estimated using predicted yield correspond to fortnightly predicted yield. The actual groundnut crop sown area up to 12th September 2017 (kharif) were used to estimate mandal wise pre-harvest groundnut production. The actual crop sown was taken from Department of Agriculture, Andhra Pradesh. The mandal wise total pre-harvest groundnut production is given in table (2) and a graph sown in figure (11).

Table 2: Fortnightly production estimates and crop sown area up to 12^{th} September, 2017

Mandal Name (Selected Mandals)	Crop sown area up to 12th September 2017	1FNAugust Production (in Tonne)	2FNAugust Production (in Tonne)	1FNSeptember production (in Tonne)
Gooty	13399	7569	7866	8592
Gorantla	11953	3255	6342	6527
Guntakal	16999	6947	8334	12665
Kalyandurg	15178	3777	5792	8540
Kambadur	5317	680	923	1157
Kanaganapalle	18902	4317	4096	6112
Kudair	10520	1612	3810	6148
Mudigubba	9908	5465	5073	5047
Settur	13902	1368	3463	5525
Uravakonda	7285	2281	1799	2419

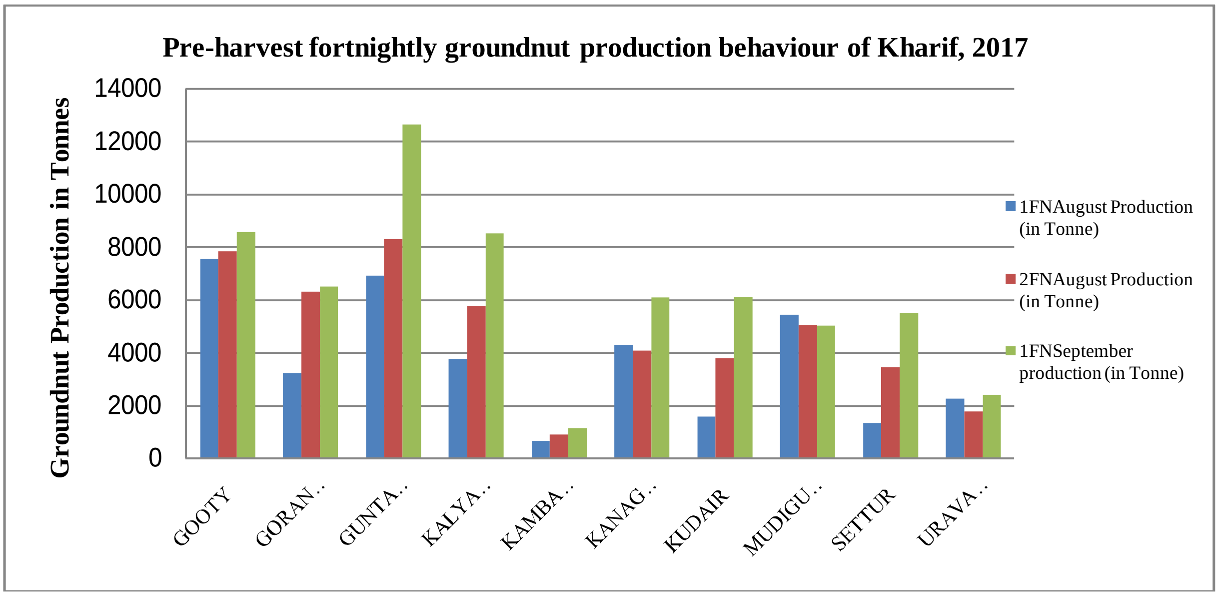


Figure 11: Pre-harvest fortnightly production behaviour of kharif, 2017

4. CONCLUSION

In this study, a regression model is used to predict groundnut yield (fortnightly) from August to September (mid-season) to get the yield behaviour and corresponding pre-harvest production estimates based on fortnightly variation in crop condition. The estimation of harvests is an elementary requirement. Besides providing objectivity, the use of remote sensing allows estimating yield in advance. In this study it is concluded that estimating yield by Normalized Difference Vegetation Index (NDVI), obtained in an early, fast and inexpensive way will be used for number of policy level decisions related to food security, poverty alleviation and decision on buffer stock of food grains based on pre-harvest production estimation.

5. ACKNOWLEDGMENTS

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