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CROP CONDITION ASSESSMENT OF GROUNDNUT USING TIME SERIES NDVI DATA IN ANANTAPUR DISTRICT, ANDHRA PRADESH

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ABSTRACT

Assessment of crop condition is essential for crop monitoring and to predict productivity of the crops. The Remote Sensing data can provide near real time information about the seasonal crop status. A normalised difference vegetation index (NDVI) evaluates crop stages by inter-seasonal comparison with spatial and temporal variability. The present study is aimed to assess the crop condition of groundnut in Anantapur district for 2016. Phenological stage retrieval of crop growth is characterised by NDVI. It shows the growth stages for early to high growth period and harvesting period. NDVI images are generated using moderate resolution imaging spectroradiometer (MODIS) reflectance time series data and identified crop area. Composite seasonal NDVI images were classified into clusters using unsupervised classification (ISODATA) and crop temporal spectral response profiles were prepared from the NDVI images from June to November for 2010, 2012 and 2016. The specific NDVI changing patterns were observed with different crops, this indicates the feasibility of crop delineation with time series NDVI. The extent of groundnut cropped area was extracted in the study area using time series NDVI. The deviation of the NDVI is used to understand the crop growth in different stages and Season's Max NDVI is used to assess the crop condition in the study area. The study revealed that crop productivity is showing a significant change from 2010 to 2016. In 2010, there were 6 mandals having poor or low condition, where as in 2016, 20 mandals were affected. By adopting this approach crop condition maps were generated.

Keywords: Crop Condition Assessment, Normalised Difference Vegetation Index, Seasons's Max NDVI.

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Introduction

The demand for agriculture monitoring is increased for past 20 years, from global level to sub-national level with various applications to enhance the food security.The estimation of crop condition in the early stages of crop growing period can identify the shortages of food surpluses, which support in related decision making (Meng et al., 2008).The remote sensing data are widely being used in agricultural monitoring applications like crop acreage, production estimation, cropping system analysis with precision farming. Several countries established their own crop-monitoring systems (Bingfang et al., 2014). The UNFAO Global Information and Early Warning System (GIEWS) identifies food crises. The USAID Famine Early Warning Systems Network (FEWS NET) identifies the food-insecure conditions in Sub-Saharan Africa, Central America, Afghanistan and Haiti (Becker-Reshef et al., 2010).The mission of MARS FOODSEC, a European Commission's Joint Research Centre, produces wide risk and security policy from regions to world. ESA Global Monitoring for Food and Security (GMFS) promotes data utilisation project through EUMETCast (Zhang et al., 2014). Chinese Academy of Sciences (CAS) crop watch system can predict crop growth in China. The Mahalanobis National Crop Forecasting Centre (MNCFC) of Department of Agriculture and Cooperation (DAC), provides crop production forecasts in India. Crop Acreage and Production Estimation (CAPE) and Integrated Seasonal Condition Monitoring System (ISMS) monitor the seasonal conditions (Ray et al, 2014). Canada has the Crop Condition Assessment Programme (CCAP) and Brazil has the Geosafras programme (Zhang et al., 2014).The remote sensing data play a significant role in crop classification and crop health assessment. Vegetation Indices (VI) are reliable in monitoring the vegetation changes. Normalised Difference Vegetation Index (NDVI) is a widely used index for monitoring the crop conditions with seasonal variations (Gitelson, et. al., 2013) and classification of land use (Franco and Mandla, 2012).The NDVI time series data are used in different applications in environmental and agricultural fields like seasonality extraction of vegetation, climate change, drought monitoring (Vani and Mandla, 2017), biodiversity and wildlife distributions and natural disasters (Konda et al, 2018). Crop growth profile monitoring method is the contrast between present year with the previous year crop growing profiles during crop season, can identify the seasonal growth (Murthy et. al., 2014).The time series of NDVI data have been produced by many sensors like Global Inventory Modeling and Mapping Studies (GIMMS), Advanced Very High Resolution Radiometer (AVHRR) with twice daily coverage for entire globe. The Moderate Resolution Imaging Spectroradiometer (MODIS) products are available daily with 250m resolution. NDVI data products are being generated from most of the satellite sensor systems like MODIS 250m and 1km, SPOT VGT NDVI of 1km, NOAA-AVHRR NDVI of 1km and 8km, and IRS AWiFS NDVI of 188m, which can be effectively used in crop vigour and growth studies.

In this study, we analyse the seasonal NDVI time series (June to Nov) data for 2010 normal year with best crop condition, 2012 is the drought year with low crop productivity and present year 2016 to estimate the crop condition. MODIS vegetation product (13Q1) with climate data was used.

Study Area and Data

The study area is Anantapur located in Andhra Pradesh, India. Area of the district is 19,197 sq km. Anantapur district lies in tropical region between 13°30' and 15°-15' latitudes, 76 ° -50'and 78 ° -30' longitudes (Figure 1).The district has 63 mandals and 964 revenue villages and the total population is 4.08 millions (as per 2011 census). The district belongs to the arid agro-ecological zone. The temperature ranges between 31.7° C to 38.9° C. The normal annual rainfall is 553mm. Agriculture is mostly dependent on drought-prone, rain-fed agricultural practices and mostly a single crop of groundnut is sown in about 8 lakh hectares under such harsh and agro-climatic conditions.The study area comprises deep loamy and clayey mixed red and black soils.

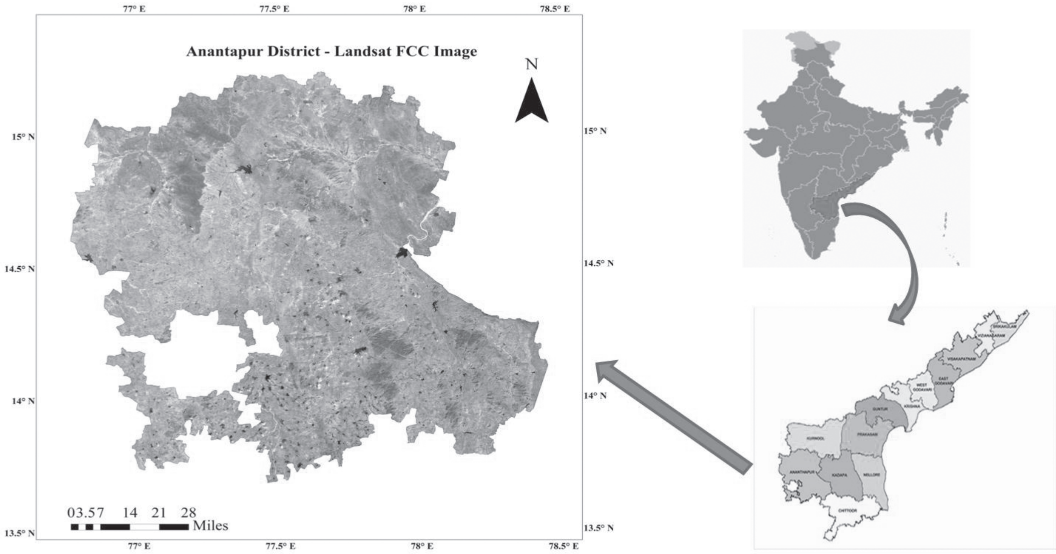


Figure1: Study Area Anantapur District in False Colour Composite Image

The present study area occupies 19, 13,000 hectares. 10, 00,000 hectares area is under rain-fed and 1, 08,000 hectares under irrigation (Rukmani and Manjula, 2009). This is the only drought-prone district with a 10 per cent of cultivated area under irrigation and a large 90 per cent under rain-fed farming.

The present study uses MODIS vegetation reflectance products 13Q1 datasets with 250 meters resolution with 16 days revisit time and composite images from June to November for 2010, 2012 and 2016. MOD 13Q1 data provide every 16 days at 250-meter spatial resolution. The blue band with 500m resolution was used to correct atmospheric effects. The mandal level NDVI layer and district boundary layer was overlaid to observe crop condition. The district level crop statistics and crop calendar was used as an independent evidence of the agricultural drought to improve the understanding of crop patterns.

Methodology

MODIS 13Q1 products are available in HDF format. A series of pre-processing steps like importing HDF format to image format, missing data interpolation through weighted average, the layers of surface reflectance in red, NIR and blue band region are extracted and subjected to layerstacking. The 2010, 2012 and 2016 bi-weekly seasonal images (June to November) were layerstacked separately. The stacked images were reprojected from sinusoidal projection to lambert conformal conical projection. The data layers were scaled with respective multiplication factor 0.0001, after sub-setting the images with study area boundary. The clouds distort the real reflectivity of the land surface, hence these are eliminated by masking using blue band. NDVI is calculated for 16-day composite images for the time series from June to November to assess crop condition during Kharif season. Normalised Difference Vegetation Index (NDVI):

The NDVI is a measure of the vigour of vegetation at the surface. The magnitude of NDVI shows the level of photosynthetic activity from observed vegetation. The NDVI is very high in NIR portion for healthy vegetation (Rouse et al, 1974).

NDVI is derived as :

$$NDVI = (NIR - RED)/(NIR + RED) \qquad \text{Eq (1)}$$

Where, NIR - Near Infra Red portion of spectrum and RED - Red Portion of the spectrum. The NDVI values range from –1 to +1.

Extraction of Groundnut Crop Cover: The prominent crop identification is necessary to generate crop maps which provide the spatial distribution information about the agricultural fields (Zhang et al., 2014). The crop map was generated using MODIS NDVI datasets. The NDVI profiles of different vegetations like forest and scrub area overlap the crop profiles. To avoid the influence the non-agriculture area overlap, masking is essential (Manjunath et al., 2015). The non-agricultural area is mostly occupied with forest and follows land. The end of the NDVI threshold for each season is shown in Figure 2. The SM NDVI represents summer monsoon (June to October), W NDVI represents winter max NDVI and the S is the summer season NDVI (Roy and Josi, 2017). Map masking is used for extraction of agricultural area from LULC level-1. It shows better visualisation.

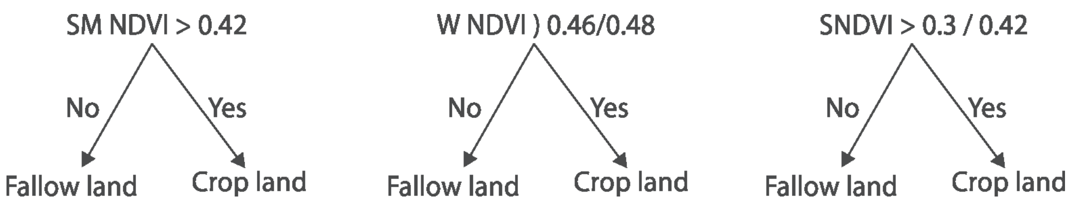


Figure 2: NDVI Threshold for the Cropland in Different Seasons

The non-agricultural masked seasonal NDVI images for 2010, 2012 and 2016 were stacked and classified using the ISODATA clustering algorithm. This iterative process performs repetitively for the entire class and calculates statistics, and then it forms the clusters. In this method, minimum spectral distance formula is used to locate the clusters which are inherent in the data. The image was classified into 15 clusters. The average NDVI profiles of the 15 clusters were then visually explored and the clusters with similar temporal characteristics were observed. The clusters which show similar time-series patterns were merged. The crop is identified from the cluster using crop calendar for the study area. The groundnut crop was identified using points collected during the field investigations. The NDVI profiles for the groundnut crop are illustrated in Figure 3 for 2010 and 2016.

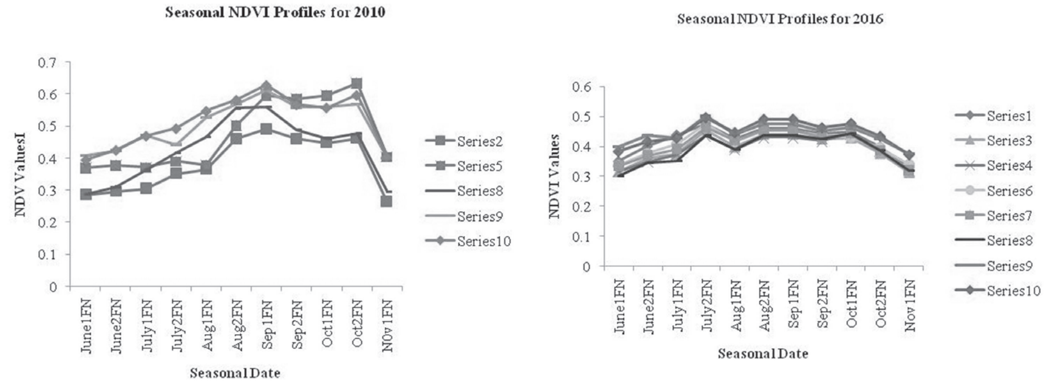


Figure 3: Spectral Profile of Groundnut Crop Classified Using ISODATA Clusters 2010 and 2016

Crop Condition Monitoring Method: The NDVI time series data were used for crop condition assessment. The NDVI profiles were employed based on the mean values for each image. The NDVI images for 2016 were compared with previous normal year and extreme crop damaged year to identify areas, where crop conditions are worse, better or normal (Wu.2010). If the difference between NDVI for current year with previous (normal) year is less than -0.075, then it can be identified as worse condition. If NDVI difference is larger than 0.075, it represents better crop condition. If NDVI is between these values, then the crop condition is considered as normal. The inter-seasonal comparison is very useful to identify the abnomal cropped areas (Genovese et al., 2001).

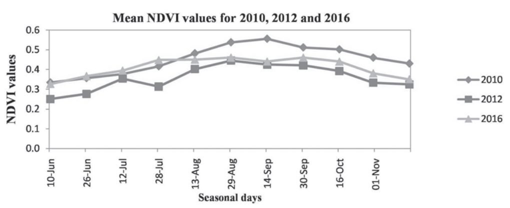
Season's Max NDVI: The seasonal NDVI images from June to October were used for creating Season's Max NDVI (SMN) for 2010, 2012 and 2016 season. SMN shows most extreme NDVI value for the whole season for groundnut crop. The maximum NDVI value can be extracted for every pixel in the season which represents SMN value for the entire season (Murthy et al., 2014). This gives the maximum NDVI value for the location in that particular year. Overlaying the mandal shape file, the dominant SMN values at mandal level were obtained for each year for groundnut crop area.

Results and Discussion

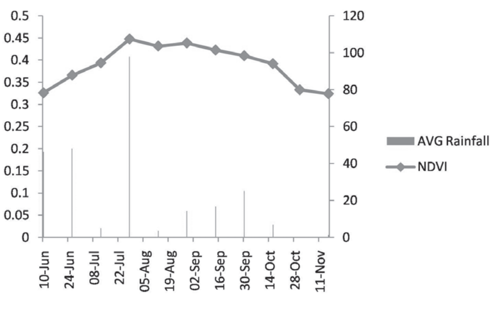
The groundnut crop is the major crop which occupies more than 8 lakh hectares, where as the total crop area is 11 lakh hectares (as per statistics for 2010). The NDVI time series images were used to assess the crop growth using inter-annual comparisons of NDVI profiles. The crop calender of Anantapur district shows that the kharif season starts at June and ends by November and length of the crop growing period is 60 to 90 days for groundnut crop. The NDVI profiles for the normal year (2010) and severe drought year (2012) were compared with present year (2016). The NDVI profiles employed are based on the mean values of bi-weekly images. NDVI difference between a normal year and present year helps to assess the area under cultivation and stress conditions in groundnut crop. The NDVI values show the relation with the precipitation. The inter-seasonal comparison can pinpoint with this study.

Seasonal Patterns of NDVI

The profiles of time series NDVI for kharif season of 2010, 2012 and 2016 (Figure 4) were compared to study about the present year crop condition. Since 2010 the NDVI values were 0.3 to 0.4 for June month, which shows that crop sowing period has started. The maximum NDVI value reached 0.6 in August and 0.4 by end of the season. In 2010, NDVI values show good crop productivity. In 2016, NDVI value for the June month started with 0.3 to 0.4 till July and followed 2010 profile. In August, NDVI value decreased, which shows decreased crop growth condition. There was sufficient rainfall till July and due to lack of rainfall in August, the NDVI values slowly came down, which indicates suppressed crop growth (Figure 4(b)). Year 2012 which was extremely drought-affected year, has show low NDVI values compared to 2010. In 2016, NDVI profiles from the August month followed the pattern of 2012 NDVI values. It shows decreased crop productivity when compared with 2010.



(a)



(b)

Figure 4(a): Seasonal Mean NDVI Time Series for 2010, 2012 and 2016 (b) June to November Bi-weekly Profiles of NDVI and Rainfall for 2016

Seasonal Patterns of NDVI Deviation

The statistical average of NDVI for entire time series was calculated for the study area. NDVI deviation images between 2010 and 2016 were compared to identify crop condition. The NDVI deviation images are shown in Figure 5. Table 1 shows the variation in NDVI average values. The June and July values are in between -0.003 and 0.01. 2016 August, September, October and November NDVI images show worse condition. In August, the deviation values have increased negatively up to -0.078, whereas -0.075 deviation is marginal value to identify the normal condition. In September, the deviation values have reached very high, due to the rainfall deficiency which reduced crop growth. November NDVI values indicate that the harvest of the crop was done earlier. There is a delay in crop starting season and length of growing period. In 2010, crops sowing was done in early days of June, whereas in 2012, it was delayed by 10 days. The harvesting period in 2012 and 2016 started early in November, that resulted in low NDVI values. It shows the reduction in crop length of growing period (LGP). The spatial greenness during monitoring period was compared to the reference period to estimate the crop growth for better cropping practices.

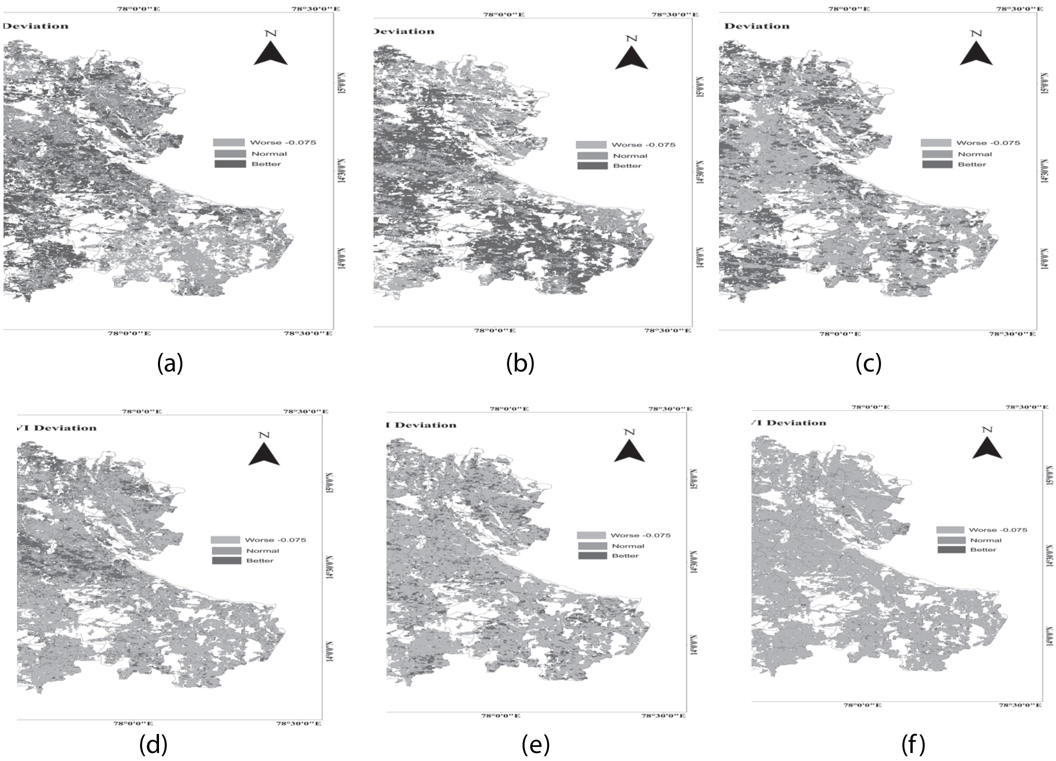


Figure 5: NDVI Deviation Images for the 2016 with Normal Year (a) June (b) July (c) August (d) September (e) October (f) November

Table 1: Deviation of NDVI Values from Normal Year to Current Year

Date/Year	2010	2016	Deviation
10-Jun	0.334	0.326	-0.003
26-Jun	0.356	0.366	0.010
12-Jul	0.377	0.394	0.017
28-Jul	0.416	0.448	0.032
13-Aug	0.482	0.45	-0.032
29-Aug	0.538	0.46	-0.078
14-Sep	0.556	0.44	-0.116
30-Sep	0.512	0.46	-0.052
16-Oct	0.502	0.44	-0.062
31-Oct	0.460	0.38	-0.080
16-Nov	0.430	0.35	-0.080

Crop Condition Assessment Using Season's Max NDVI

Seasonal NDVI time series datasets were composited with maximum values and generated the Season's Max NDVI image for 2010,2012 and 2016 kharif season (Figure 7).The SMN images were grouped into the crop condition classes based on the max NDVI values. It was noticed that the comparison with best ground observation, good resolution of sensor data product with frequent revisit time help to precisely estimate the crop condition. A large potential agricultural area was cultivated with groundnut crop in this study area. It was decreased by 6 per cent in 2016 compared to 2010.

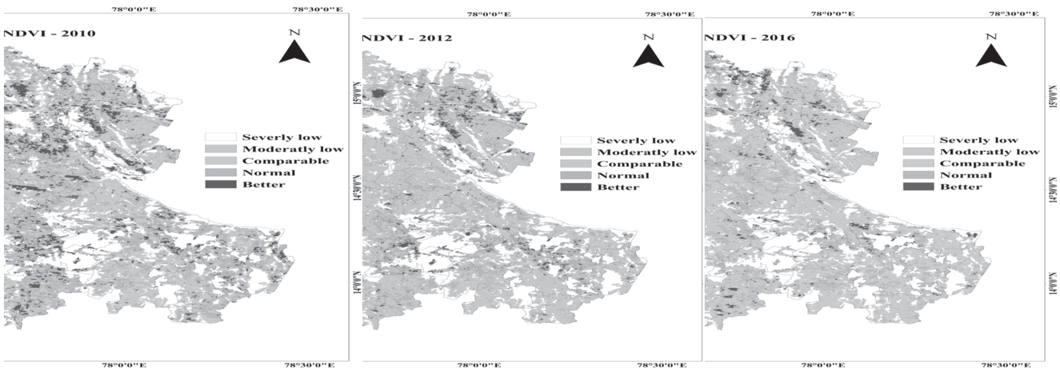


Figure 6: Seasonal Max NDVI Image for 2010, 2012 and 2016

Mandal Level Crop Assessment

The district has 63 mandals. Most of the mandals show large groundnut crop cultivation. The rainfall deviation shows negative in all mandals except Peddavadugur and Atmakur.The NDVI deviation shows worse (below -0.075) condition in 46 mandals and 17 mandals were showing normal (-0.075 to 0.075) condition. It was noticed by the NDVI deviation with seasonal time series data that 50 per cent of the mandals show in sowing crop due to monsoon delay in 2016. Crop condition assessment was carried out at mandal level, by overlaying mandal level boundary map on SMN image. Extracted information related to crop growth is presented in Table 4 and Figure 8 representing crop condition maps.

Table 4: Mandal-wise Crop Condition Assessment

Crop Condition	Mandals-2010	Mandals-2012	Mandals-2016
Severely low	NIL	6	5
Moderately low	6	26	15
Comparable	28	22	34
Normal	26	8	8
Better/Good	4	1	3

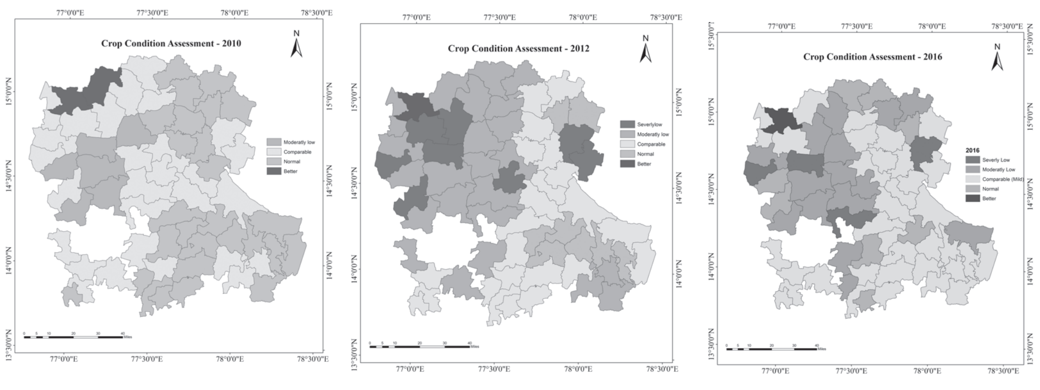


Figure 8: Crop Level Classification Mandal-wise 2010, 2012 and 2016

In 20 mandals low crop condition was identified from this study in 2016, and 6 mandals were affected in 2010 (normal years) and above 50 per cent mandals are affected by low crop condition in 2012. Bomanala mandal was showing the normal crop condition for three years due to irrigation support. Kothacheruvu and Puttaparti represent normal conditions in 2010, 2012 years and mild crop condition in 2016 due to lack of sufficient rainfall at the end of the season. The rainfall deviation was more than -55mm and the NDVI deviation was showing between -0.08 to -0.11 for these three mandals.

It shows that the greenery percentage was decreasing with low rainfall, which results in low NDVI values. Crop condition assessment is based on spectral similarity to identify crops with the low productive condition. This gives better results to monitor crops and study about the drought conditions to support sustainable agricultural growth for rural development.

Conclusion

NDVI deviation analysis explains the relation between crop pattern and the amount of precipitation.The three-year seasonal images show the variation in crop length of growing period and crop condition.The 2016 year shows the vulnerability and risk occurrence of the drought in the study area.This study reveals that the MODIS NDVI time series data are useful for investigating the slow process of the crop growth with climate data.The inter-seasonal variations can be derived from NDVI deviation between a normal year and present year to assess crop condition.The seasonal max NDVI shows the area with crop change between two years. This method can easily identify the crop change in particular area between years. The proposed method for crop condition assessment is transferable and directly applicable to other regions for groundnut crop area.

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