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Study of crop condition and assessment of agricultural drought in rabi season using IRS – AWiFS images

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ABSTRACT

Although kharif season crops are more vulnerable to agricultural droughts due to uncertainty in monsoon rains, crops of rabi season grown under residual soil moisture and rainfed minor irrigation tanks are equally vulnerable to drought hazard. The present study was undertaken in Bagalkot district of north interior Karnataka to assess the extent of crop area affected by agricultural drought during rabi 2005-06, using Advanced Wide Field Sensor (AWiFS) images of Indian Remote Sensing Satellite, Resourcesat-1. Normalised Difference Vegetation Index (NDVI) images which represent density, health and vigour of crops were generated from satellite images and analyzed in association with cropping pattern, crop calendar, rainfall pattern and soil depth. The area affected by agricultural drought was delineated in each taluk. The study indicated the feasibility for detailed assessment of agricultural drought during rabi season on near real-time basis using the indigenously available AWiFS images.

Key words : Agricultural drought, crop condition, AWiFS, IRS, NDVI

India experiences localized drought almost every year in some region or other. In the post independence era, major droughts that effected more than 1/3rd of the country were reported during 1951, 1966-67, 1972, 1979, 1987-88 and 2002-03 (Subbaih, 2004). Thus, despite significant technological advances since independence, Indian agriculture continues to be periodically affected by droughts. The immediate and more devastating impact is on agricultural crops leading to loss of production, unemployment, fodder shortage etc. In view of the increasing economic importance of drought disaster, there is a need for building up the capabilities by using innovative technological and management measures for effective management of droughts in general and agricultural droughts in particular. Generation of information in a comprehensive manner, integrating data from various sources is essential for assessment, mitigation and prediction of drought.

Agricultural drought is caused by deficiency of soil moisture during crop growing period. Non availability of objective and spatial information on the agricultural areas affected by droughts in different administrative units such as districts, taluks or blocks is a major bottleneck to evolve better in-season crop management to minimize loss and end-of-season relief management to offer social and economic strength to the affected areas. Spatial information technology like remote sensing from a wide range of satellite sensor systems currently available, offer a different dimension to the task of agricultural drought assessment compared to conventional subjective, non spatial and non consistent mechanisms being practiced. Integration of remote sensing derived inputs on land cover and biophysical parameters with crop simulation models under GIS environment would enhance the accuracy of crop monitoring and crop yield estimation methods in agriculture. The Drought Monitor of USA using NOAA-AVHRR data (www.cpc.ncep.noaa.gov), Golbal Information and Early Warning System (GIEWS) and Advanced Real Time Environmental Monitoring Information System (ARTEMIS) of FAO using Meteosat and SPOT – VGT data (Minamiguchi, 2005), International Water Management Institute (IWMI)'s drought assessment in South west Asia using Modis data (Thenkabail *et al* 2004) and NADAMS drought monitoring of India with IRS –WiFS/AWiFS and NOAAAVHRR data are the proven examples for successful application of satellite remote sensing for operational drought assessment.

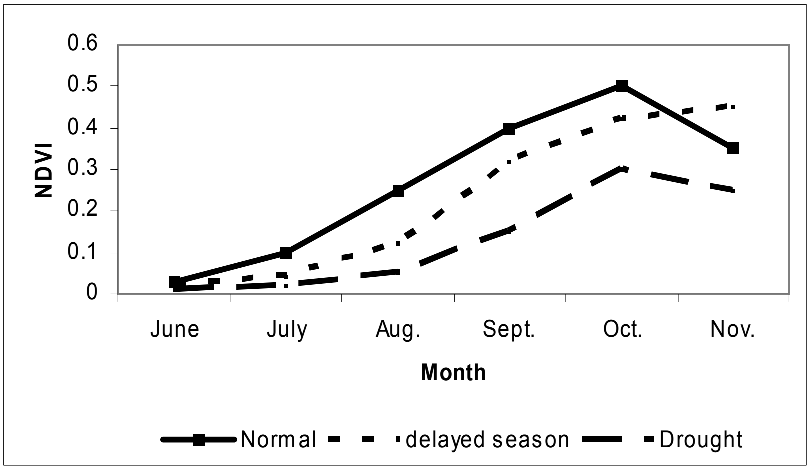


Fig. 1: Typical seasonal NDVI profiles and drought impact

Although *kharif* (monsoon season) is the main agricultural season with 2/3 of agricultural area, cultivation of crops in *rabi* season/post monsoon season under rainfed conditions is also widely practiced in different parts of India. *Rabi* season starts from October and ends by February and mostly short duration (3-4 months) crops like jowar, sunflower etc are cultivated. The south west monsoon season which accounts for about 80 percent of rainfall ends by September. The crops in *rabi* season are sustained by residual soil moisture resulting from normal to excess rainfall in August/September months and also the intermittent rainfall during October – November months. Some of the crops are also cultivated under rainfed minor irrigation tanks. Rainfed crops in *rabi* season occupy significant area in the country and contribute to country's production of coarse grains, pulses and oilseeds. From farmers' point of view, cultivation in *rabi* season has many economic advantages such as less capital requirement, supplementation of fodder needs of live stock etc. Incidence of agricultural drought resulting from soil moisture deficiency is also a recurrent phenomenon in rabi season. In some of the states like Karnataka, crops are mostly cultivated under residual soil moisture and rainfed minor irrigation tanks during *rabi* season. Such crops are highly vulnerable to impending soil moisture stress conditions.

The main objective of the study is to detect the agricultural drought situation, assess the extent of rabi crop area affected by agricultural drought using high resolution images from Advanced Wide Field Sensor (WiFS) of Indian Remote Sensing Satellite (IRS) in Bagalkot district of north interior Karnataka state.

MATERIAL AND METHODS

Acquisition of satellite data, analysis of satellite data to generate crop condition images, analysis of ground data on cropping pattern, crop calendar, rainfall and soil type and assessment of agricultural drought by integrating satellite derived information with ground parameters constitute the methodology of current study.

Satellite data

AWiFS data of IRS P6 corresponding to 4th Nov, 28th Nov, 12th Dec, 17th Dec, 31st Dec 2005 and 5th January 2006 was procured. The overpass dates of satellite images represent the different phases of both early sown and late sown *rabi* crops as per the crop calendar information provided by department of Agriculture. Analysis of satellite data which includes geometric correction, cloud masking, NDVI generation etc was done using the standard procedures of satellite data analysis followed under drought monitoring project of NRSA.

Normalized difference vegetation index (NDVI)

Among the various vegetation indices that are now available, Normalised Difference Vegetation Index (NDVI) is an universally acceptable index for operational drought assessment because of its simplicity in calculation, easy to interpret and its ability to partially compensate for the effects of atmosphere, illumination geometry etc (Tucker and Chowdhary 1987, Kogan 1995, Nageswara Rao *et al* 2005).

NDVI is a transformation of reflected radiation in the visible and near infrared bands of and is a function of green leaf area and biomass. Bare soil and rocks exhibit similar reflectance in both visible and near IR regions and the index values are near zero. The NDVI values for vegetation generally range from 0.1 to 0.6, the higher index values being associated with greater green leaf area and biomass.

NDVI and crop phenology

Temporal changes in NDVI follow the phenonological changes of crops during the season and reflect the impact of moisture stress on crops. Typical NDVI profiles depicted in Fig. 1, indicate two aspects; (1) the changes in NDVI from June to November with a bell shaped profile are in agreement with crop phenology i.e., low NDVI in the beginning because of more soil exposure, increasing NDVI as the crop puts up vegetative growth, maximum NDVI during peak vegetative stage of crops and decrease in NDVI corresponding to senescence of crops. The impact of agricultural drought on crops is manifested in the form of slow rate of change in NDVI and very low peak NDVI. Slow rate of change in the beginning of the season and then normal progression in NDVI as seen in an NDVI profile of Fig. 1 is the result of early season drought (delayed season).

Rabi agricultural area mask

By analyzing the sequence of AWiFS images, the rabi season agricultural area was isolated for further analysis. The agricultural area NDVI images were generated for all overpass dates of AWiFS images. Seasonal NDVI profiles of November to January period covering rabi season were generated.

Soil information

Soil depth maps produced by NBSS & LUP in 1:250000 scale were scanned and registered with satellite data base. Soil depth map was derived from the soil map after identifying the polygons with deep soils, moderate deep soils and shallow soils. Depth of soil influences the moisture retaining capacity of soils and hence directly related to incidence of agricultural drought. The proportion of different soil depth classes in the district indicate that deep soils with higher capacity of water retention occupy 48 percent, shallow soils with poor water holding capacity occupy 42 per cent of geographic area followed by moderate soils with only 10 per cent.

Field visits

Ground data on crop sown area and rainfall during *kharif* and *rabi* seasons was analysed. Field visits were conducted to get first hand information on the condition of various standing crops pertaining to different NDVI classes and soil depth classes in different taluks.

RESULTS AND DISCUSSION

Cropping pattern

The total crop area in *rabi* season of 2005-06, in the district was 2,96,058 ha against a normal of 2,61,000. Crop composition indicates jowar (136371 ha), sunflower (68826 ha), bengal gram (32481 ha) , maize (16620 ha), wheat (16086 ha). etc. *Rabi* crop is normally preceded by short duration *kharif* crops like green gram. Crops like sunflower, bengal gram are generally sown early i.e., in September compared to Jowar which is sown during October. Most of the rabi crops are grown under rainfed conditions using the residual moisture resulted from September/October rainfall. On the basis of cropping pattern the taluks of the district are categorized into two groups. Taluks with predominant cultivation of jowar (Bagalkot, Badami and Hungund) and taluks with sunflower, bengal gram etc (Mudhol, Bilgi and Jamkhandi).

Rainfall

During south west monsoon season (June-Sep) of 2005, the district had received rainfall of 335 mm against the normal of 350 mm. The temporal distribution of rainfall indicates two events of heavy rainfall - one in the middle of July and the other in the first week of September. The July rainfall was beneficial to expedite the kharif sowings. Normal rainfall in the second week of August and heavy rainfall from the last week of August to first fortnight of September had triggered the rabi sowing activity. Taluk wise rainfall

Table 1: Taluk wise rainfall (mm) during Sep to Nov 2005

S. No	Taluk	September 05		October 05		November 05	
		Actual	Normal	Actual	Normal	Actual	Normal
1	Badami	99	159	108	89	0	45
2	Bagalkot	82	156	147	89	0	39
3	Bilgi	76	149	146	84	0	36
4	Hungund	144	161	138	86	3	42
5	Jamkhandi	93	149	116	94	3	34
6	Mudhol	86	140	89	2	2	43

during September to November which is considered beneficial to rabi cultivation in the district is shown in Table 1.

Excess rainfall reported in all taluks during October was beneficial to completion of *rabi* sowings and for the growth of early sown *rabi* sown crops. Absence of rainfall during November and December months affects the sustenance of crops in December month and the intensity of stress is determined by crop species, sowing time and soil type.

Satellite derived crop condition

AWiFS NDVI images were generated for all the selected scenes. The *rabi* agricultural area mask was overlaid on the NDVI images and the seasonal NDVI mean values were extracted for each scene. NDVI recorded in the mid of December represents the maximum greenness achieved by different crops like sunflower, jowar etc. It covers all the rabi crops. Therefore, NDVI on 17th December was stratified into four homogenous groups corresponding to different growth stages of crops. The NDVI stratification was done to enable identification of different crop groups during the field visit. Each class of NDVI was verified with respect to crop type and crop sowing time.

On the basis of field information and seasonal NDVI progression, the four classes of NDVI represent ground situations as given under:

- Class 1 (NDVI >0.25) – early sown rabi crop (Sept) after the harvest of short duration kharif crop. Corresponds to sunflower, bengal gram etc. Harvested by January.
- Class 2 (NDVI 0.2 to 0.25) – Normal sown crop (Sept/Oct). Sunflower/jowar. Maintained high during Nov/Dec. Harvested by the end January.
- Class 3 (NDVI 0.1 to 0.2) – late sown rabi crop– maintaining low NDVI. This is mostly jowar as second crop. To be harvested by middle of February.
- Class 4 (NDVI <0.1) – Late sown crops (maize, wheat etc) after harvest of kharif crops, under tank irrigation.

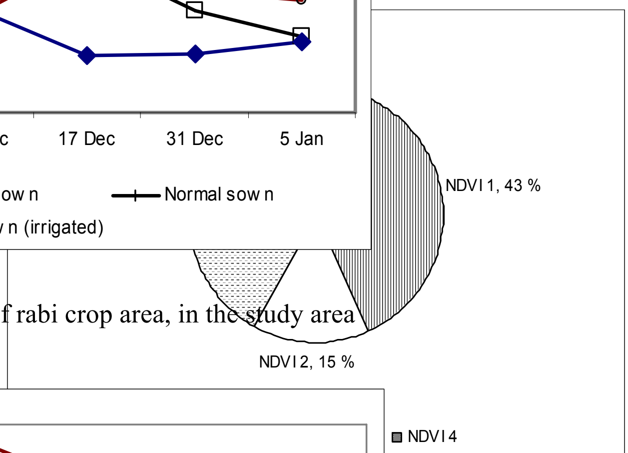
The proportion of NDVI classes in the district is shown in Fig. 3. NDVI class 1 and class 4 represent normal progression of season and hence not subjected to drought and constitute 52 per cent of rabi crop area. NDVI class 2 and 3 consists of mostly rabi jowar and sunflower and forms 48 per cent of crop area. Part of this class is subjected to moisture stress in the season as observed during field visits.

Agricultural drought assessment

The assessment of agricultural drought in each taluk was done based on cropping pattern, rainfall, soil depth as causative factors and their impact seen on NDVI. The seasonal changes in NDVI from Nov to January were used to study the crop response to drought. The typical NDVI profiles in different parts of the district were presented in Fig. 3.

On the basis of crop calendar, the rabi crop was classified as three groups early sown, normal sown and late sown areas. The NDVI profile of early sown areas are characterized by high NDVI in November month followed by gradual reduction. This profile mostly corresponds to crops like sunflower which were sown during September. Due to normal rainfall in the month of October, the crop has escaped drought situation. The crop was harvested in the month of December and

Fig. 2: Proportion of NDVI classes in *rabi* crop area



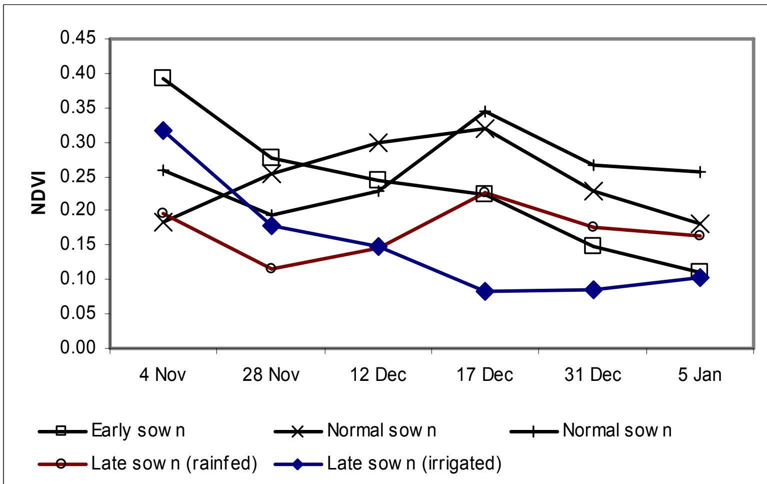


Fig. 3: Seasonal NDVI profiles of rabi crop area, in the study area

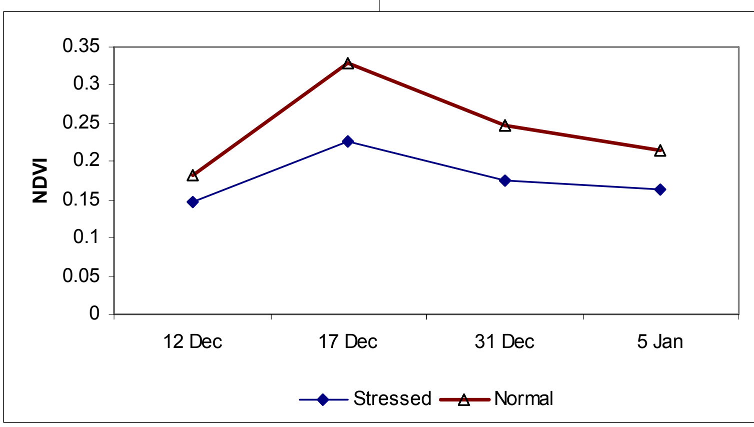


Fig. 4: NDVI profiles of stresses and normal crop

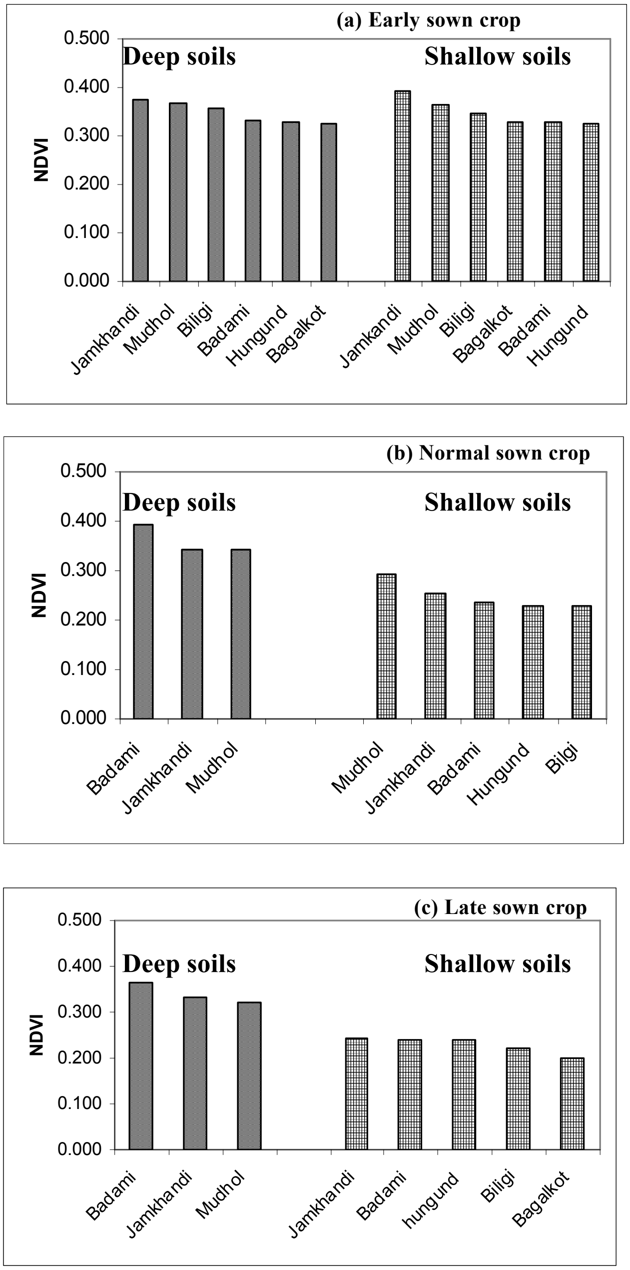


Fig. 5: Comparison of season's maximum NDVI in shallow and deep soils

recorded normal yields. Normal sown crops which started from end of September reached their maximum greenness during December. This crop corresponds to jowar and bengal gram and was mostly associated with deep and moderate deep soils. The late sown crop was under two categories: (1) rainfed crops mostly of jowar which was sown late by 15 days due to heavy rainfall in the first week of October. This crop was subjected to moisture stress due to complete cessation of rainfall in November month. (2) irrigated crops which were sown after the harvest of first crop in kharif season – due to irrigation support, this crop was nor subjected to moisture stress.

The assessment of agricultural drought was done taking in to consideration the rate of seasonal progression of NDVI in different soil groups within each taluk and rainfall situation. The season's maximum NDVI and its spatial variability within each taluk across soil types and crop groups was evaluated. The areas with slow rate of NDVI transformation as well as with reduced maximum NDVI were delineated and identified as affected by moisture stress. These areas were associated with late sown jowar crop in shallow soils of the districts. The seasonal NDVI profiles of normal and stressed jowar crop is shown in Fig. 4. The stressed profile corresponds to jowar crop that was cultivated in shallow soils and subjected to stress in the current season. The profile of normal crop corresponds to jowar crop cultivated in deep soils and sown early. Since the crop has escaped from drought due to early sowing, the maximum NDVI attained was much higher.

Seasons' maximum NDVI

Season's maximum NDVI is one of the important indicators of maximum vegetative growth of standing crops. Moisture stress during growing period directly affects the canopy development and maximum growth of crops which ultimately affects the crop yield. In this section, crop response in terms of season's maximum NDVI in deep and shallow soils and with respect to sowing time was studied. Comparison of maximum NDVI for normal, early and late sown crops in Fig. 5 showed that early sown crop, which mostly consists of sunflower performed equally well in both deep and shallow soils, since the maximum NDVI did not differ significantly. The crop was sown in the month of September and faced normal to excess rainfall in October which has sustained its growth till November. With senescence phase in December and harvesting in the last week of December and first week of January the crop has successfully escaped drought situation.

Table 2: Per cent of *rabi* area affected by agril. drought in Bagalkot district, 2005-06

Taluk	Crop area in rabi (ha)	Area effected by agril. drought (ha)	% area effected
Jamkhandi	49267	2922	6
Biligi	25762	2580	10
Mudhol	36928	2074	6
Bagalkot	50482	10571	21
Hungund	94269	7380	8
Badami	46500	5064	11
District	296058	30591	10

Due to short duration of crop and normal rainfall, the crop performance was normal in both shallow and deep soils. In the areas with normal sowing time i.e., end of September/beginning of October, the differential crop performance in shallow and deep soils was evident with maximum NDVI of shallow soils being less than that of deep soils. The impact of moisture stress on crops due to scanty rainfall in November was manifested in maximum NDVI. In case of late sown crop areas, the difference in maximum NDVI of deep and shallow soils was more conspicuous because these areas were exposed to moisture stress for more time during growing time. These areas mostly correspond to jowar crop which was sown in second to third weeks of October and harvested in middle of February.

Area affected by agricultural drought

The drought affected area was delineated based on Taluk wise NDVI for deep and shallow soils and early sown, normal sown and late sown crops. (Table 2).

The affected areas mostly correspond to jowar crop area in shallow and moderately shallow soils in different taluks. The crop was sown in October. Due to absence of rainfall during November the crop experienced stress in the month of December leading to reduction in vegetative growth.

From the above, it is evident that the performance of early sown crop (mostly sunflower) was normal in both deep and shallow soils, since the crop has not been subjected to rainfall deficit stress for much longer time. In case of normal time sown area crop, the performance was better in deep soils than in shallow soils. The differential performance of crop in deep and shallow soils was clearly evident in case of late sown crop area which is mostly jowar, with season's maximum NDVI of crop in shallow soils being significantly less than that of crop in deep soils.

The areas affected by agricultural drought were delineated and at district level, 30 591 ha accounting for 10 per cent of *rabi* crop areas was affected. The drought affected areas is high in Bagalkot taluk with 20 per cent of *rabi* area and low in Jamkhandi and Mudhol taluks with 6 percent of *rabi* area. The affected areas mostly correspond to jowar crop in shallow and moderately shallow soils in different taluks

CONCLUSIONS

Operational assessment of agricultural drought situation using AWiFS/WiFS images of IRS satellites is being done regularly during kharif season. This study clearly indicated the feasibility of agricultural drought assessment using AWiFS data at taluk level in near real-time mode during *rabi* season for the crops grown on residual soil moisture. There is further scope to extend the methodology to other states like Maharashtra and Madhya Pradesh states which also have significant area under rainfed rabi cultivation.

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