SHORT NOTE

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SATELLITE-BASED ASSESSMENT OF AGRICULTURAL DROUGHT IN KARNATAKA STATE

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The State of Karnataka has been experiencing frequent droughts during the recent years resulting in severe hardship to the community dependent on agriculture. The traditional methods of drought assessment do not provide the actual impact of drought situation and the distress felt by public as these methods are purely based on statistics of rainfall data that are averaged over an area. These methods do not take account of the differences in the spatial and temporal distribution of rainfall. Also, the phenomenon of drought has no recognizable beginning and takes time to develop. Hence, there is a need for an independent system that can provide the severity, duration, and aerial extent of drought and its impact on the actual condition of the crops/vegetation so that the authorities concerned can take appropriate relief measures. Earlier studies have shown that the areas that do not receive sowing rains are the ones affected by agricultural drought (Nadkarni and Deshpande, 1982; Nageswara Rao and Rao, 1984). Many researchers have reported the use of Normalized Difference Vegetation Index (NDVI) for vegetation monitoring (Tucker, 1979), assessing the crop cover (Ayyangar *et al.*, 1980), drought monitoring (Nageswara Rao and Sugimura, 1987; Singh *et al.*, 2003) and agricultural drought assessment at national (Thiruvengadachari, 1988; Jeyaseelan and Venkataratnam, 2003) and global level (Kogan, 2000). While there are many definitions of drought (Wilhite and Glantz, 1985), for the purpose of this study the agricultural drought is defined as a "period of four consecutive weeks with rainfall less than 10 mm per week during June to September (the Kharif season)" and then remotely sensed data was used for assessing the spatial and temporal distribution of rainfall and impact of successive agricultural droughts (2001 and 2002) in the state of Karnataka.

Weekly rainfall estimation: METEOSAT–5 thermal infrared (TIR) imagery, freely available on the Internet at three hourly intervals from the website http://www.ssec.wisc.edu of Space Science and Engineering Centre, University of Wisconsin, were used to infer the distribution of rainfall. We have assumed that the diurnal maxima of rainfall over the study area is in the evening and selected two satellite passes at 12hrs (5:30 pm) and 15hrs (8:30

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pm) GMT. These two passes adequately represent the 24-hour rainfall centered on the time of the satellite observation. TIR images of India were downloaded and enlarged to 1:3 million scale to match with a map of Karnataka State having district boundaries (Fig. 1). Analysis was done using Arcview GIS software. This involved exporting image files, geo-referencing, digitizing the district administrative boundaries and converting them to shape files. The analysis was done for 18 standard weeks during June to September for the years 2000 (normal year), 2001 and 2002 (drought years) taking district as a unit. Three types of rain bearing clouds (Cumulonimbus, Nimbostratus and Cumulus Congestus) were identified mainly based on their physical appearance (shape and size) and brightness of the tone as measured by digital numbers on the satellite imagery (Brown and Wickham, 1995). Rain rates were assigned to each of them as suggested by (Follansbee, 1973; Barrett and Martin, 1981; Kidder and Vonder Haar, 1995). Cumulonimbus cloud was assigned a rain rate of 25 mm/day, Nimbostratus 6mm/day and Cumulus Congestus 0.5 mm/day. The daily rainfall (**R**) in millimeters per day was estimated as function of cloud type (i), rain rate assigned to each cloud type (r_i), and fraction of the district area over which the cloud type is seen (f_i).

$$R = \sum i\, r_i\, f_i$$

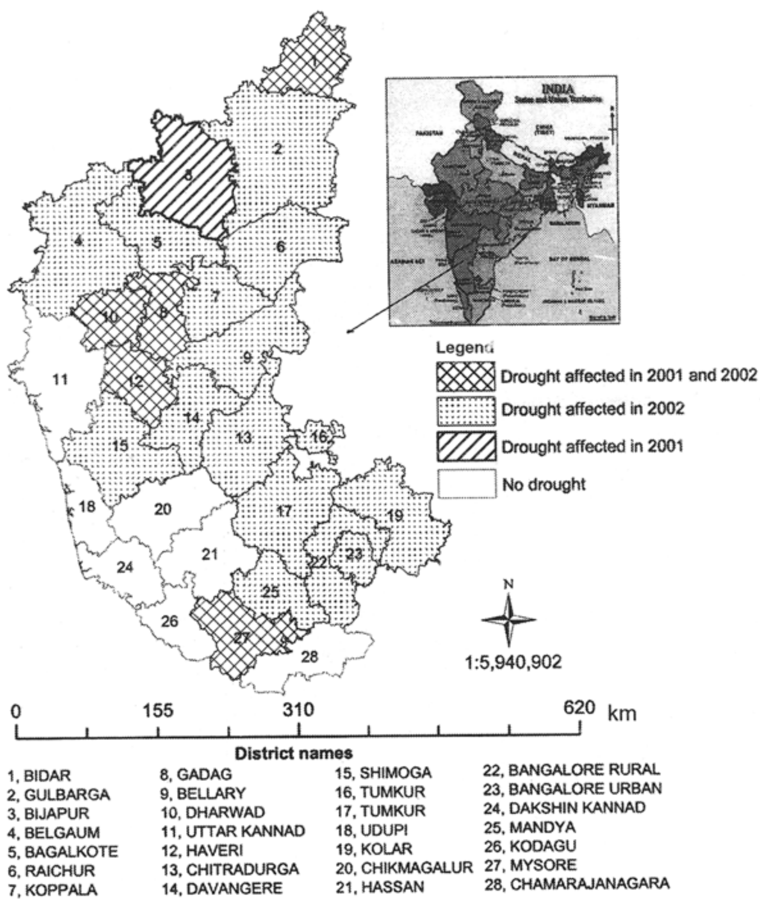

Fig. 1. Karnataka State, India showing the districts affected by agricultural drought in the year 2001 and 2002

End-of-*Kharif* season green cover estimation: Indian Remote Sensing Satellite (IRS)-P4 Ocean Colour Monitor (OCM) bands 6 (red, 660-680 nanometres) and 8 (near infrared, 845-885 nanometres) of October 16, 2000, October 29, 2001 and December 22, 2002 passes (Kharif season) were used to derive NDVI using the DN values of near-infrared and red bands. The difference in DN values of band 8 and 6 were divided by the sum of the DN values of these two bands. The output NDVI values are scaled to a range of 1-255. Using the histogram, the NDVI values were density sliced to delineate the water bodies, wastelands, crops and natural vegetation (green cover) and then colour coded. By overlaying the district boundary layer on the NDVI map, per cent area under green cover was calculated district-wise. Reduction in green cover by more than 10% compared to normal year (2000) is taken as an indicator of agricultural drought at the end of the *Kharif* season.

The satellite-based observations were verified on the ground by visiting the areas in the months of September and October every year as part of the ongoing project on remote sensing-based crop acreage and production estimation. In addition, the reports of the Drought Monitoring Cell (DMC), Government of Karnataka were also consulted as reference.

Table 1 shows the district-wise assessment of distribution of rainfall in the state of Karnataka for the years 2000, 2001 and 2002. Satellite-based rainfall monitoring showed that six districts in the year 2000, twelve in 2001 and eighteen in 2002 have experienced deficient rainfall for more than four consecutive weeks. Although satellite-based rainfall monitoring has identified a few districts like Davangere, Mandya, Koppala, Bagalkote, Shimoga and Chikkamagalur to be affected by drought during 2001, satellite-based green cover shows that they are normal. This suggests that the cloud indexing techniques should be further improved by assigning rain rates appropriate for each agro-climatic zone and by selecting the time of acquisition of image during the diurnal convection maxima that varies from place to place.

During the year 2002 satellite-based rainfall monitoring showed that all districts that were affected by agricultural drought experienced dry spell of more than four consecutive weeks during July month of that year. This shows that weekly rainfall monitoring during July (the sowing period for kharif crops in the state) is useful in early warning of agricultural drought. Similar observations were made by Nageswara Rao and Rao (1984) using NOAA/AVHRR and Landsat-MSS data during the year 1982 in the southern peninsular part of India. A few districts (Mysore, Bidar, Gadag, Haveri, Dharwad) were affected by agricultural drought in the successive years (2001 and 2002) and showed substantial reduction in the green cover indicating that the drought had affected even the natural vegetation in addition to crops/sowing operations. The 2002 drought had affected even the irrigated districts like Mandya, Belgaum, Shimoga and Bellary. However, a few districts (Bijapur, Hassan, Chikkamagalur, Kodagu, Dakshina Kannad, Udipi, Uttara Kannad) did not experience agricultural drought in the year 2002 (Fig. 1).

We have also observed significant variation in the per cent reduction in the green cover at the district level because of local factors like moisture retention capability of the soils, type of crops grown and farm operations in progress in these districts. A break in the monsoon rains of 4 consecutive weeks may not have uniform impact on all the crops/vegetation. Although, most of the drought affected districts did not receive adequate rainfall for more than 4 consecutive weeks in the beginning of the season, the heavy rainfall received at the end of *Kharif* (September) added to soil moisture and hence in some districts the moisture stress is not manifested in the NDVI images of October 2000 and 2001 and December 2002. Similar results were observed by Srivastava *et al.* (1997) in six drought prone districts of Karnataka State during 1987 to 1995. They found the relationship between integrated NDVI and seasonal rainfall is more linear and stable for the districts that are mainly dependent on rainfall than for irrigated districts.

Table 1: District-wise assessment of rainfall distribution and end-of-the season green cover

District Name	Rainfall Distribution(A)			Green cover(B)		
	2000	2001	2002	2000	2001	2002
Bangalore Urban		*	*	85	Cl	67 (-18)
Bangalore Rural			*	95	98 (+3)	66 (-29)
Kolar			*	67	Cl	28 (-39)
Tumkur			*	81	86 (+5)	41 (-40)
Chitradurga	*		*	57	68 (+11)	23 (-34)
Davangere		*	*	70	79 (-9)	31 (-39)
Chamarajanagar		*	*	96	Cl	86 (-10)
Mysore		*	*	96	72 (-24)	82 (-14)
Mandya		*	*	93	88 (-5)	82 (-11)
Bellary			*	51	56 (-5)	18 (-33)
Koppala		*	*	29	31 (-2)	4 (-25)
Raichur				32	25 (-7)	17 (-15)
Gulbarga			*	54	44 (-10)	27 (-27)
Bidar	*		*	78	59 (-19)	41 (-37)
Belgaum	*		*	52	50 (-2)	26 (-24)
Bagalkote		*	*	28	21 (-7)	15 (-13)
Bijapur				18	2 (-16)	11 (-7)
Godag		*	*	40	21 (-19)	5 (-35)
Haveri		*	*	76	55 (-21)	15 (-61)
Dharwad	*	*	*	52	28 (-24)	19 (-33)
Shimoga	*	*		95	92 (-3)	77 (-18)
Hassan				96	96	87 (-9)
Chikkamagalur	*	*		93	93	88 (-5)
Kodagu				99	ND	99
D. Kannada				92	87 (-5)	91 (-1)
Udipi				87	83 (-4)	85 (-2)
U. Kannada				90	92 (+2)	83 (-7)

A) Districts that received 4 consecutive weeks of rainfall less than 10 mm shown by aster, B) Per cent green cover based on NDVI. Values in parenthesis indicate the per cent change in green cover with reference to the normal year (2000). ND: No satellite data, Cl: Cloud cover.

A comparison of NDVI map of the year 2002, 2001 and 2000 was made and found that the districts having permanent vegetation like forests and agricultural land under irrigation did not show much variation between a normal year (2000), drought year (2001) and a severe drought year (2002). Some of the areas recorded excess rainfall for the season as a whole but they faced dry spell of more than 4 consecutive weeks during the months of June and July and hence showed very less green cover. There are some districts (Bijapur) which shows low NDVI, not because of drought but due to harvesting of early sown *Kharif* crops and field preparations for *Rabi* crops. Green cover as inferred from NDVI was much less during 2002 in all the drought affected districts. Thus, the NDVI was found to be a good indicator of agricultural drought. But, reduction in green cover due to drought or change in phenology or farm operations should be inferred and interpreted carefully by comparing the NDVI values of the year under study with a normal year.

The findings indicate that the districts that did not receive at least 10 mm rainfall per week for four consecutive weeks in June-September are affected by agricultural drought during *kharif* crop season. Due to inadequate rainfall in the month of July in two consecutive years, some of the districts are severely affected by agricultural drought. NDVI-based green cover estimates at the end of the *kharif* season confirmed the severity and spatial occurrence of agricultural drought. We conclude that METEOSAT 5 TIR images or any other geostationary satellite like INSAT or Kalpana-1 could be useful in assessing the within season spatial and temporal distribution of rainfall. IRS-P4 OCM sensor or any other wide swath sensors like IRS-1C/1D Wide Field Sensor or Advanced Wide Field Sensor on board RESOURCESAT-1 is useful in assessing the vegetation status/condition at the end of the season based on NDVI values generated from these sensors.

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