



Variability in Length of Crop Growing Period Causing Agricultural Vulnerability in India

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Abstract: Satellite-data based Normalized Difference Vegetation Index (NDVI) can indicate state of agriculture, crop vigour and hence can also be used to assess agricultural vulnerability. Analysis of trends in NDVI for a given region can indicate the factors that cause variability and the drivers that impart vulnerability to agriculture. One such driver is variability in Length-of-Crop-Growing - Period (LGP). A methodology was developed to determine LGP from time-series NDVI datasets from Start-of-Season or greening-up phase to End-of-Season or drying-up phase. Public domain data like NOAA-AVHRR based GIMMS data product (1982-2006) and MODIS-TERRA data (2000-2013) were used to analyse variations in LGP contributing to agricultural vulnerability in various agro-ecological sub-regions (AESR) in Peninsular India. Study carried out at ICAR-CRIDA under NICRA indicates the variable trends in LGP and its impact on agricultural production leading to agricultural vulnerability in India.

Key words: LGP, NDVI, agricultural vulnerability, crop phenology, AESR, rainfed agriculture.

Rainfed agriculture extends over 85 million ha out of national net sown area of 142 million ha in India covering the semi-arid tropics (SAT) and hot dry and moist sub-humid regions. In large parts of the states of Telangana, Andhra Pradesh, Maharashtra, Karnataka and Tamil Nadu in Peninsular India, rainfed agriculture predominates and impact of climate change on agriculture is a major cause of concern to farmers and the governments. A study was initiated at ICAR-CRIDA under the National Innovations in Climate Resilient Agriculture (NICRA) program to assess agricultural vulnerability using satellite data and derived Normalized Difference Vegetation Index and the impact of climate change driving it (ICAR-CRIDA, 2017). According to Census of India - 2011 (ORGCC (MHA), GOI, 2011) over 900 million persons live in 15 states and 2 Union Territories where predominantly rainfed agriculture and allied activities are practiced. Out of these 833 million persons live in rural India out of which 200 million persons are main workers involved in agriculture and allied activities in rainfed regions in India.

The rainfed agro-ecological regions encompasses regions from arid regions in Rajasthan where 300 mm annual precipitation is received to semi-arid Kovilpatti in southern

Tamil Nadu and dry sub-humid Jammu in northern India to moist sub-humid region in Jorhat in Assam where over 1250 mm average annual rainfall is received. Thus, there is a vast variability in rainfall pattern and crop and cropping systems practiced in this vast region in India where rainfall occurs in 45 to 50 days and half of it occurs by way of a thunderstorm that last for a few hours. There have been a large variability in rainfall resulting in drought and flood events leading to economic losses and distress to farmers that necessitated the launch of NICRA program to study agricultural vulnerability and the drivers that may be the result of climate change, so that adaptation and mitigation practices could be prioritized and implemented.

With this objective in view, the Normalized Difference Vegetation Index (NDVI) derived from satellite data was used to study vegetation vigour and dynamics which could indicate regional agricultural vulnerability. For the present study, NDVI was used to evaluate the state of agriculture over a period of time and change in LGP across rainfed AESR in India. Time-series NDVI data product was used to study vegetation vigour in Jalgaon (Maharashtra), Mandya (Karnataka), Prakasam (Andhra Pradesh) and Erode (Tamil Nadu) and impact of change in LGP in these regions. This paper describes the concepts used to analyse

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vegetation vigour in the region in addition to assessing agricultural vulnerability in rainfed AESR in India and the methodology developed to estimate LGP using NDVI data and impact of change in LGP in selected vulnerable districts in Peninsular India. To analyse LGP variations, several types of vegetation indices (VI) were assessed. For the current study GIMMS dataset of NOAA-AVHRR (8 km, 15 days) NDVI data product and MODIS-TERRA (250 m, 16 days) NDVI data product were used (Kaushalya *et al.*, 2013a, b; 2014a, b, c; 2015; Defries *et al.*, 2000; Friedl *et al.*, 2002; Nemani *et al.*, 2003; Krishnaswamy *et al.*, 2004; Thenkabail *et al.*, 2004, 2007; Heumann *et al.*, 2007; Jain *et al.*, 2009).

A methodology to derive LGP from NDVI time-series data products were developed based on literature review. The dates of Start-of-Season (SOS) and End-of-Season (EOS) were identified using White's NDVI Reflectance Coefficient of 0.5 (White *et al.*, 1997). White's study was based in temperate and alpine vegetation of Montana in USA that had a higher NDVI value compared to the semi-arid and dry sub-humid regions prevalent in Peninsular India. Hence a typical NDVI (reflectance coefficient) was generated for each AESR in Peninsular India as undertaken by Vrieling *et al.* (2008).

Variations in LGP as a result of variations in SOS or EOS, leads to agricultural vulnerability in cropping systems in a region which require undertaking soil and water conservation (S&WC) measures under watershed development in order to provide supplemental irrigation to preserve precious crop if EOS sets in earlier. Harvested water can also support in nursery development and sowing in case of a delay in onset of rains during monsoon to overcome perils of shortening of season. The present study indicates the trends in variability in LGP in the country since 1982 that is contributing to agricultural vulnerability in India so that strategies could be drawn to cope with an emerging scenario in order to help in the formulation of suitable policies to support rainfed agriculture.

Materials and Methods

Temporal study of NDVI variations was carried out using Global Datasets of NDVI data products from Advanced Very High-Resolution Radiometer (NOAA-AVHRR) (15-day, 8 km)

and Moderate Resolution Imaging Spectroradiometer (MODIS-TERRA) (16-day, 250 m). Time-series NDVI datasets were downloaded from the respective websites and used to assess the sensitivity of cropping systems in various agro-eco-regions in India in order to map agricultural vulnerability in the country. GIMMS (Global Inventory Modelling and Mapping Studies) dataset of NOAA-AVHRR with 8 km resolution composited at 15-days interval, was used to analyse sensitivity of agricultural systems in India at the state and agro-eco-sub-region (AESR) level for 1982-2006, while MODIS-TERRA NDVI data product with a higher spatial resolution of 250 m was used to assess agricultural sensitivity at the district-level (2001-2012) which is the unit for administration in India. Standard Precipitation Index (SPI) estimated from actual rainfall data was used to corroborate sensitivity of agriculture to climate variations and incidence of extreme weather events during the study period (McKee *et al.*, 1993; Tucker *et al.*, 1985; Thenkabail *et al.*, 2004; Dadhwal, 2011; SeshaSai *et al.*, 2011a and b; Murthy *et al.*, 2008; Murthy and SeshaSai, 2011).

Methodology for assessing agricultural vulnerability

A methodology was developed to assess agricultural vulnerability using global datasets of NDVI data. NDVI data products of NOAA-AVHRR series of satellites available as 15-days composites at 8 km resolution for the period 1982 to 2006 and from MODIS-TERRA series of satellites available as 16-days composites at 250 m resolution for the period 2001 to 2012 were downloaded from NASA-USGS site (Kaushalya *et al.*, 2015). NDVI data products were pre-processed for scale, cloud cover, water vapour and missing data. The data was assessed for quality and stacked to produce annual NDVI image for 1982-2012. The data stacks were smoothened using the Savitzky-Golay technique. Permanent vegetation, water body, snow, built-up area and desert sand were masked to eliminate them from analysis. Co-efficient of Variation (CV) of Max NDVI was estimated by using modeller in ERDAS Imagine software and degree of agricultural vulnerability was estimated as follows: CV of <10% was termed marginally vulnerable; 10-20% termed moderately vulnerable while >20% was termed severely vulnerable.

Methodology for estimating length-of-crop-growing-period (LGP)

Information on normal LGP derived from the water-balance model for each AESR based on several station data are available (Velayutham *et al.*, 1999). To understand variations in LGP based on NDVI, a seasonal NDVI Threshold Value for kharif (SW Monsoon season) and rabi (NE Monsoon period) seasons was derived using Mean NDVI value for three normal rainfall years viz., 1986, 1991 and 1999 (Kaushalya *et al.*, 2014 a,b,c). This Threshold Value (TV) was then used to verify changes in LGP at AESR-level in India. Cropping season-wise LGP was assumed to start when NDVI value crossed the TV and continued in an upward trend. Similarly, LGP was considered to end when TV fell below TV. Season-wise sum of stacked images were imported and multiplied with a factor of 15 or 16 i.e., no. of days based on NDVI composite) to obtain a LGP map.

Methodology to estimate standard precipitation index (SPI)

SPI is a better tool to analyse and corroborate a climatic event or extreme weather situation compared to actual rainfall (Mckee *et al.*, 1993). Available district-wise daily rainfall data for 1982-2011 was converted to monthly rainfall using Weather Cock software (V1.0) (AICRPAM-CRIDA, 2011). Derived SPI was plotted for each AESR using Kriging technique in Spatial Analysis Tool in Arc GIS 10.3.

Variations in NDVI or Vegetation Index in India

Seasonal NDVI was studied using Mean and Max NDVI values for kharif (SW monsoon season) and rabi (winter season) cropping seasons in the form of a continuum for 1982-83 and 2005-2006 as indicated in Fig. 1. Kharif cropping season in 1982-83 started in 1st week of May 1982 and ended in the first week of November in 1982 while the rabi season started in 1st week of November 1982 and ended in the last week of March 1983. In 2005 the kharif season started in 2nd week of June 2005 and ended in last week of November 2005. Rabi season started in the 1st week of December 2005 and ended in the last week of March 2006. Thus, we see a delay in the start of both kharif and rabi cropping seasons in 2005-2006 and an effective reduction in length of cropping seasons during kharif and rabi. Variability in Start of Cropping Season (SOS) - both during kharif and rabi cause a reduction in the phenological growth of crop at various stages; require new seed varieties suitable for the new crop window, thus adversely affecting current agricultural production in the country.

Estimating extent of agricultural vulnerability

Using the global datasets of AVHRR and MODIS NDVI data products, it was possible to estimate the spatial extent of vulnerable regions in India based on the coefficient of variation (CV) of Max NDVI using the methodology stated earlier. This information is useful for developing strategies to mitigate the impact

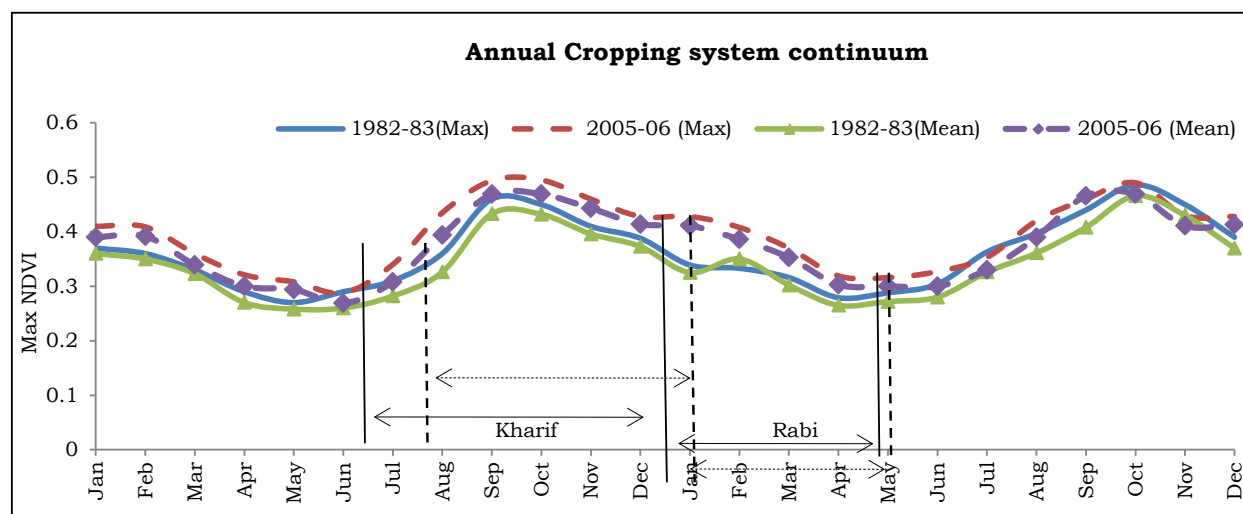


Fig. 1. Shift in seasonal Max NDVI during cropping seasons indicating a change in cropping window.

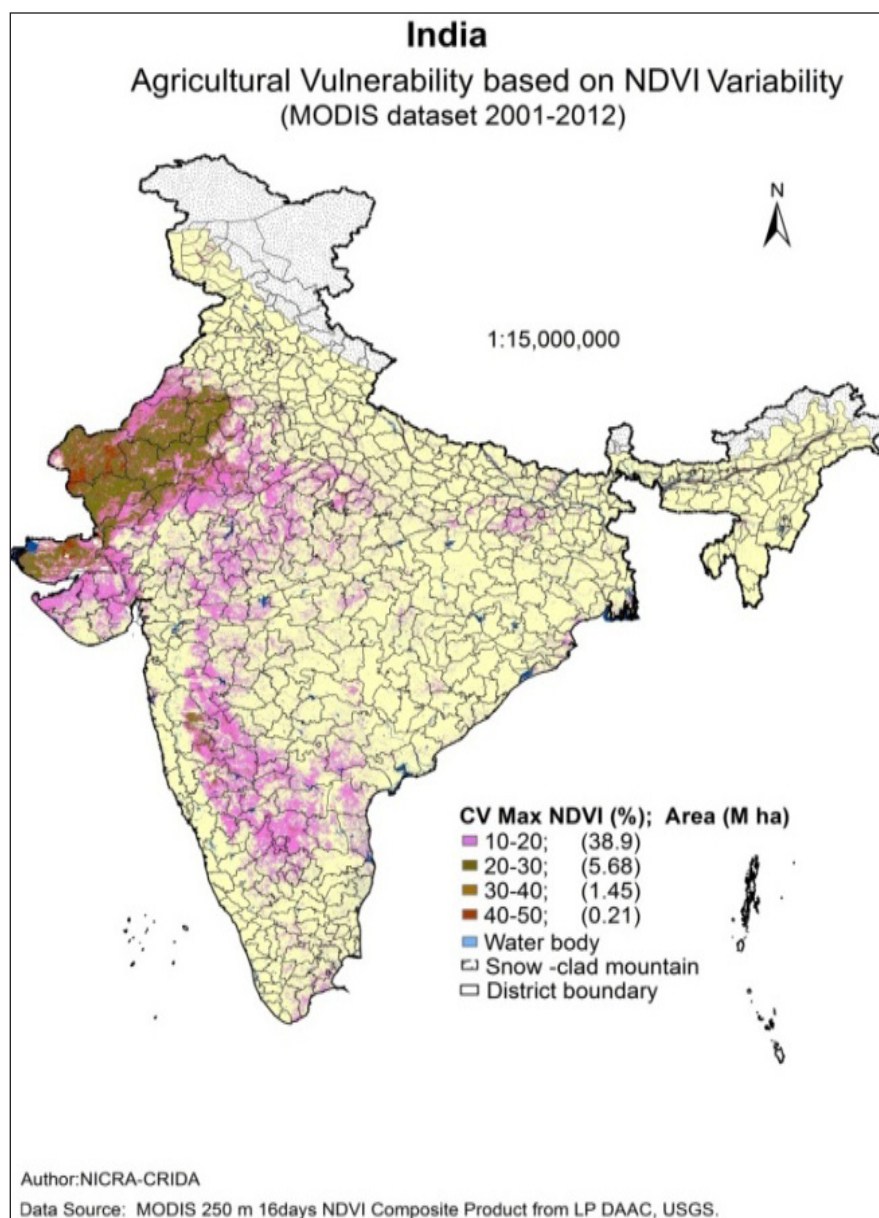


Fig. 2. Extent of agricultural vulnerability at district-level based on MODIS NDVI dataset.

of climatic aberrations. CV of Max NDVI at each pixel-level was estimated and a vector layer of AESR, state and district boundary was overlaid to estimate the extent of agricultural vulnerability.

Study of MODIS-TERRA NDVI dataset indicated that over 47 million ha of Net Sown Area (NSA) or 33.1% of the country's agricultural land is vulnerable to climate change. Figure 2 depicts the extent of agricultural area vulnerable to climate change. A total of 127 districts in 12 States in India were identified as agriculturally vulnerable to climate change. Based on CV of

Max NDVI it was seen that over 39 million ha was mildly vulnerable (CV 10-20%), 5.6 million ha was moderately vulnerable (CV 20-30%) and over 1.4 million ha was severely vulnerable (CV of >30%) to it. Study using coarse dataset of NOAA-AVHRR with 8 km resolution indicated that over 29 million ha or 20.4% of net sown area was vulnerable.

Assessing variations in LGP using temporal NDVI data composite

AVHRR-NDVI composite data for 1982-2006 were used to identify crop phenological stages. NDVI threshold value was identified for a

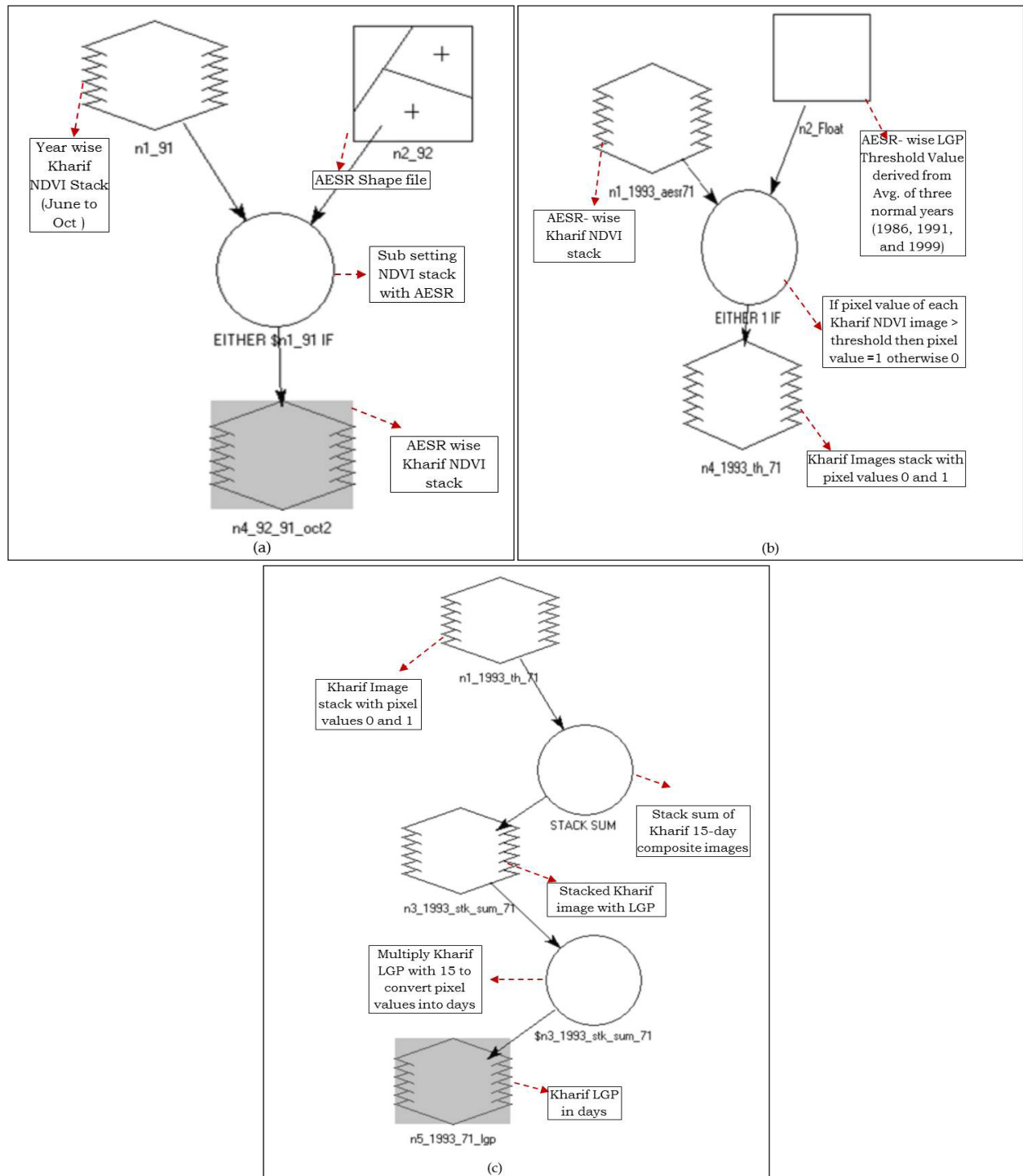


Fig. 3. Methodology for determining LGP (a) Input for determining LGP (b) Determining Threshold Value of LGP for each AESR and (c) Determining LGP (No. of days).

typical AESR in Telangana (AESR 7.2) by using average NDVI value of three normal rainfall years for two primary crop growing seasons in the region viz., kharif (Summer monsoon) and rabi (post-monsoon season) (Velayutham *et al.*, 1999). NDVI value was generated for three

normal monsoon rainfall years i.e., 1986, 1991 and 1999. Threshold Value pertaining to Start/Onset of Season (SOS) corresponds to the period when NDVI crosses the threshold value and continues in an upward direction. End-of-Season (EOS) corresponds to when

NDVI moves below the threshold. To find Threshold Value (TV), actual NDVI value of 15-day composite of each AESR was plotted. Least NDVI value of a 15-day NDVI composite of corresponding season was taken as the Threshold Value (TV). Identification of SOS for kharif season was done by extracting and stacking 15-day NDVI composite from June to October for each year and imported in digital interpolation software viz., *ERDAS Imagine* version 2.5 II for identifying SOS Threshold for kharif (Fig. 3 a - c). SOS threshold is the value after which NDVI shows an increasing trend during the corresponding season viz., kharif. In this manner threshold value of SOS for each AESR was identified. EOS for kharif was identified as the fortnight (15-day composite) when NDVI value fall below Threshold Value and indicates a continuing decreasing trend.

Due to availability of NDVI data as 15-day composite, kharif crop season data (10 in number annually) pertaining to the months of June, July, August, September was stacked and a pixel-wise sum of NDVI was derived. This value was multiplied with 15 i.e., number of days of NDVI composite to derive LGP in number of days. This method was applied for images of kharif season from 1982 to 2006 to study deviation in LGP, as a result of variations in SOS and EOS for each AESR in the region. Variations in LGP in various AESR were identified and mapped for each year.

Results and Discussion

LGP variations in selected agriculturally vulnerable districts in India

LGP variations were analysed in AESR with vulnerable districts identified in the study carried out under NICRA (Kaushalya *et al.*, 2015). The states where agriculture have been

identified as vulnerable were Maharashtra, Tamil Nadu, Telangana, Andhra Pradesh, Rajasthan, Gujarat, Karnataka, Bihar, Madhya Pradesh and Uttar Pradesh. Variations in LGP in each AESR in the above-mentioned states were analysed for both seasons-kharif and rabi. A study was carried out in 4 typical districts in Peninsular India-Jalgaon in Maharashtra, Mandhya in Karnataka, Prakasam in Andhra Pradesh and Erode in Tamil Nadu to indicate how LGP variations have contributed to agricultural vulnerability as agricultural production have been impacted (ICAR-CRIDA, 2014) .

Some of the vulnerable districts identified under the study were analyzed to assess the state of natural resources management (NRM) and prevalent pattern of land use - land cover (LULC). This was essential to understand the strategies required to improve the adaptive capacity of farmers in order to cope with climate change. Table 1 indicates the LULC pattern in these districts. NDVI-based LGP or the *Greenup Phase* is usually 2 to 3 weeks shorter at the stage of sowing compared to LGP estimated meteorologically as satellite data senses crop germination only after a sufficient time-lag of 3-4 weeks after date of sowing (DOS) (Murthy and Sesha Sai, 2011).

Agricultural vulnerability in Jalgaon district, Maharashtra

Jalgaon district is located in AESR 6.3 in Maharashtra and the AESR extends from south-western Maharashtra to north Karnataka Plateau and experiences hot dry semi-arid climate. The soil is shallow to medium loamy black with medium to high available water-holding capacity (AWC). The region has a normal LGP of 120-150 days; however study

Table 1. LULC in selected vulnerable districts (Area in '000 ha)

LULC Type	Jalgaon (AESR 6.1)	Prakasam (AESR 7.3)	Mandya (AESR 8.2)	Erode (AESR 8.3)
Built-up (rural and urban)	17.434	30.355	13.227	26.467
Plantation	66.648	8.139	22.259	64.093
Forest (Deciduous)	179.430	465.863	33.487	201.214
Barren/Uncultivable	54.951	204.315	26.947	15.822
Wetlands/Water Body	35.592	82.625	28.591	9.397
Agriculture (Crop land)	757.780	703.222	257.370	220.727
Agriculture (Fallow)	61.596	257.074	113.984	155.932

Source: Bhuvan (ISRO) NRSC (2011).

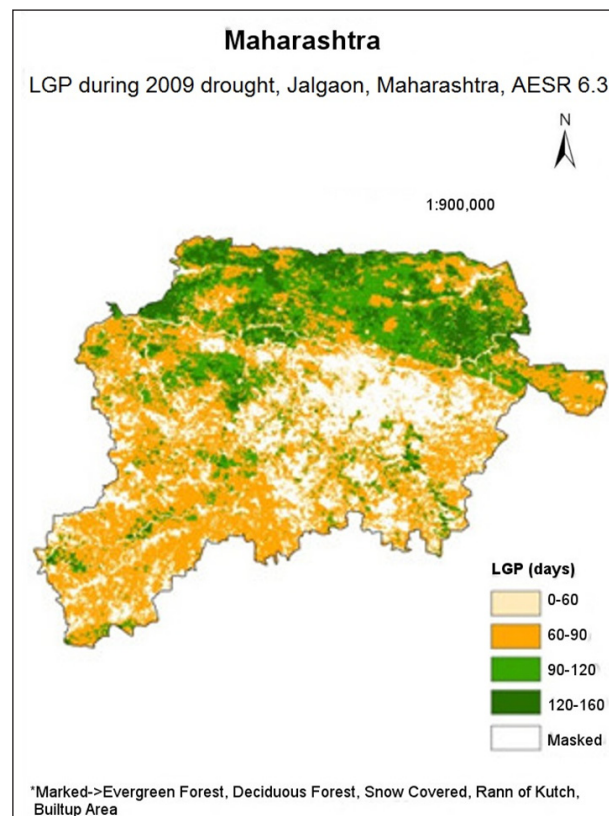


Fig. 4. LGP during 2009 drought in Jalgaon district, Maharashtra.

based on AVHRR-NDVI indicated a decrease in both lower-limit and upper-limit of LGP. LGP derived from MODIS indicated a decrease in lower-limit but no change in the upper-limit of LGP. Drought as experienced in 2009 indicated a sharp decrease in LGP in the district (Fig. 4).

Similar trend was seen in the neighbouring AESR 6.2 which extends over plateau region in central and western Maharashtra, north Karnataka and north-western Telangana. The region experiences hot moist semi-arid climate and has shallow to medium loamy to clayey

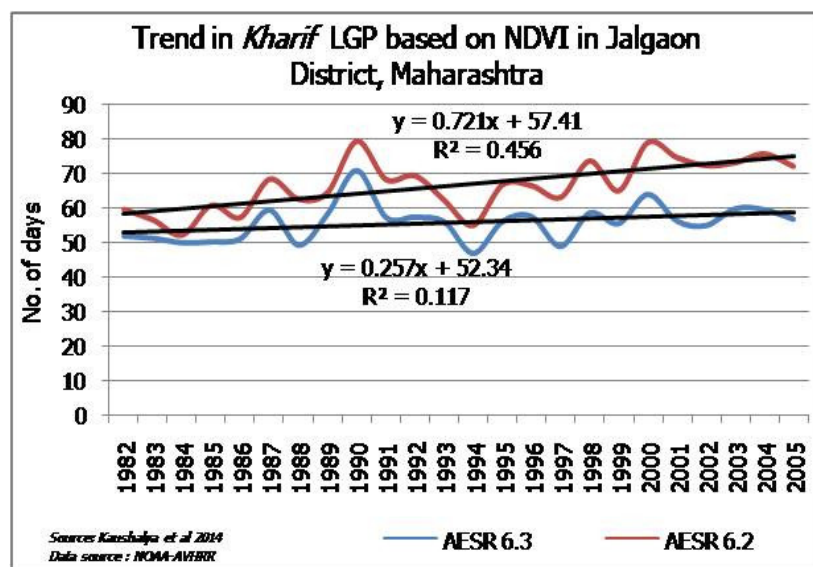


Fig. 5. LGP during kharif season based on AVHRR NDVI composites in AESR 6.2 and 6.3 covering Jalgaon district in Maharashtra.

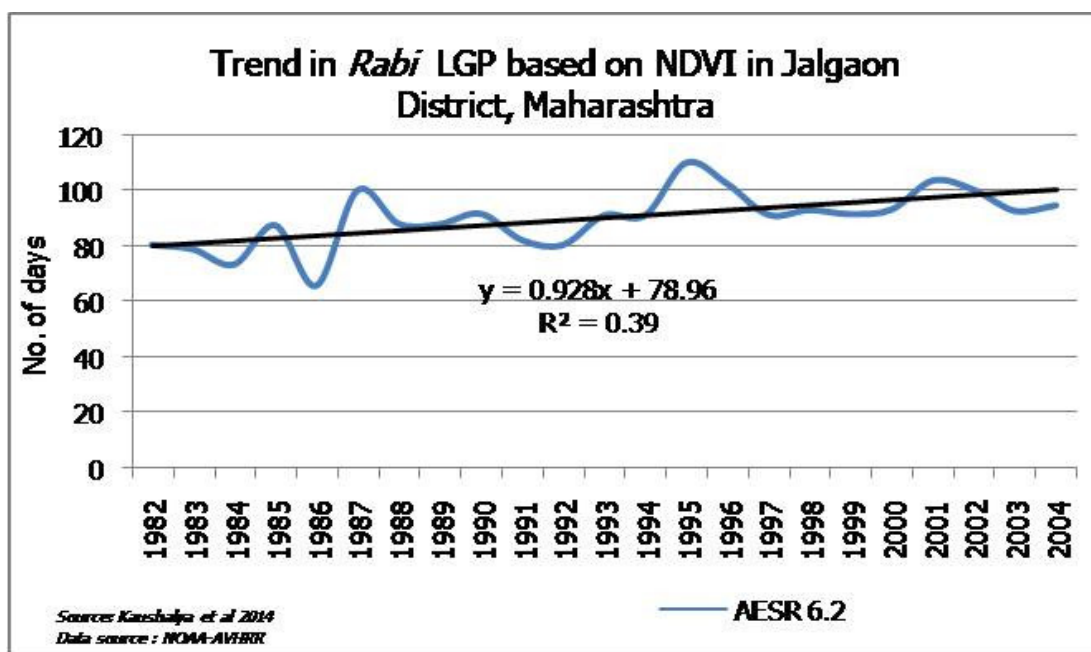


Fig. 6. LGP during rabi season based on NOAA-AVHRR composites in Jalgaon district in Maharashtra.

black soils with medium to high AWC. The region has a normal LGP of 120-150 days and variations in LGP are similar to that of AESR 6.1. Figure 4 indicates LGP in 2009 when the district experienced drought. Figure 5 indicates the trend in kharif LGP based on AVHRR NDVI composites while Fig. 6 indicates the rabi season LGP based on MODIS-NDVI composites. Figure 7 indicates the impact of variability in LGP on cotton productivity, a major cash crop in the state of Maharashtra.

Typology of agricultural vulnerability in Prakasam district, Andhra Pradesh

The state of Andhra Pradesh is covered by several AESR namely AESR 7.1 (Kurnool and Cuddapah districts), AESR 7.3 (covering Prakasam, Guntur, Krishna and West Godavari districts), AESR 3.0 covering Anantapur, AESR 8.3 covering Chittoor, AESR 18.3 covering the coastal plains besides AESR 12.1 and 12.2 covering Visakapatnam and parts of northern

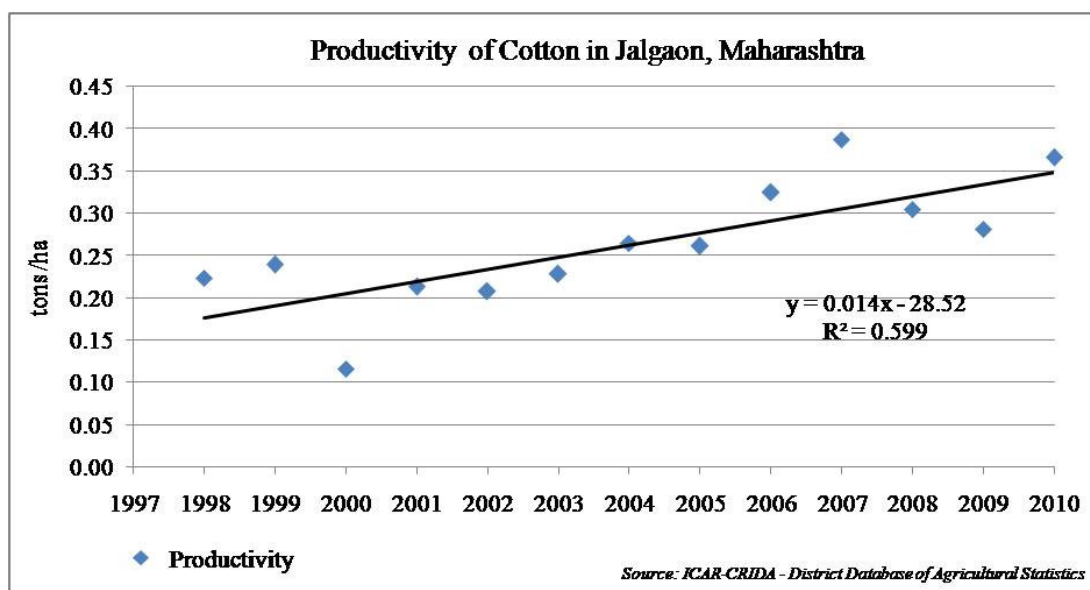


Fig. 7. Impact of variability of LGP on cotton productivity.

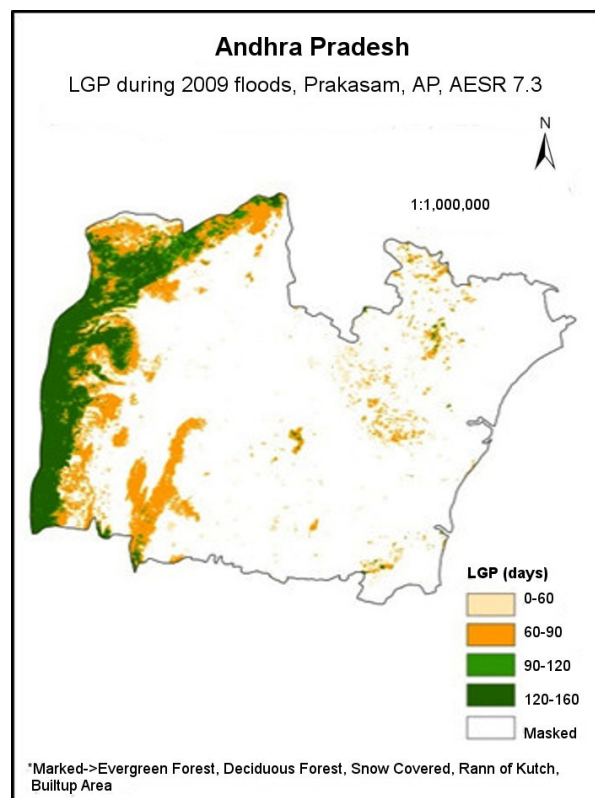


Fig. 8. LGP during 2009 flood in Prakasam district in Andhra Pradesh.

districts of the state adjoining Odisha. Prakasam district which has been identified as vulnerable is located in AESR 7.3 which covers the Eastern Ghats region and experiences hot dry semi-arid climate and has deep loamy to clayey mixed Red and Black soils with medium AWC.

The normal LGP indicated for this region is 150-180 days and according to study of

AVHRR and MODIS-NDVI datasets, there is a decrease in both lower-limit and upper-limit of LGP which may adversely impact several major crops in this region viz., paddy, chillies, turmeric and groundnut. In fact Prakasam district has a large area under paddy cultivation which may be adversely affected due to variability caused by floods of 2009 in

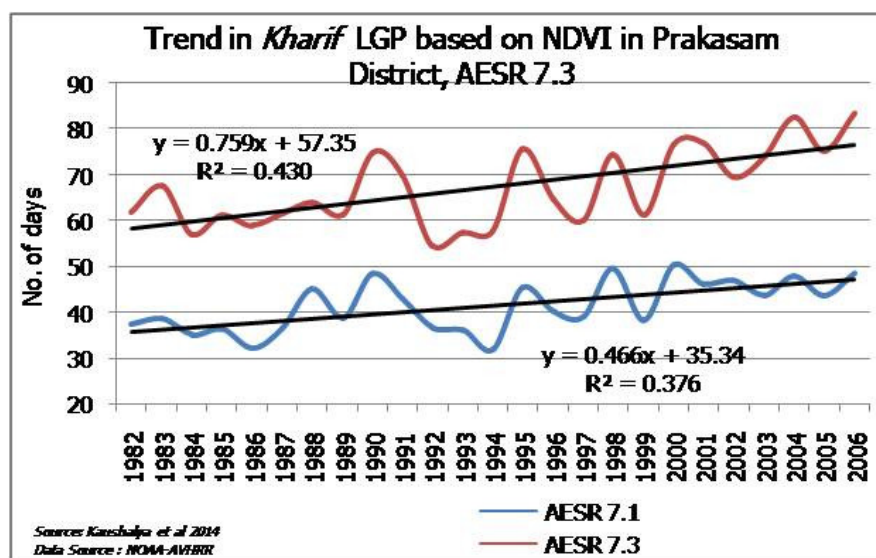


Fig. 9. Trend in seasonal LGP based on AVHRR-NDVI datasets in Prakasam district.

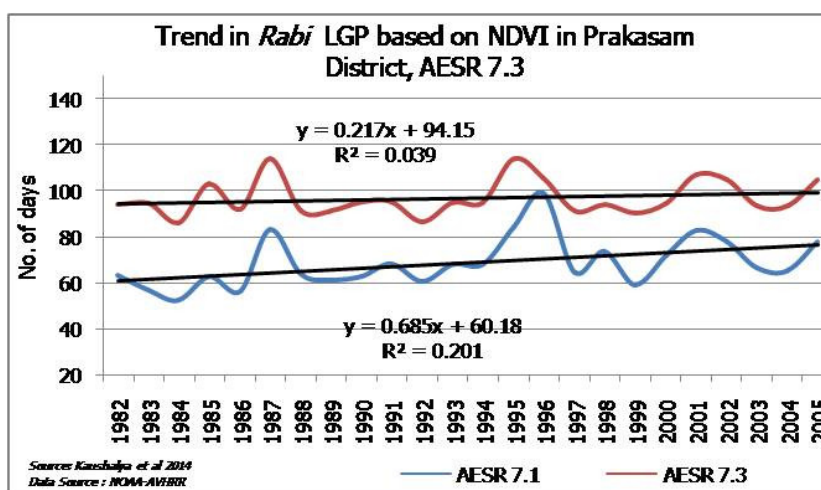


Fig. 10. Variations in seasonal LGP based on NOAA-AVHRR in Prakasam district.

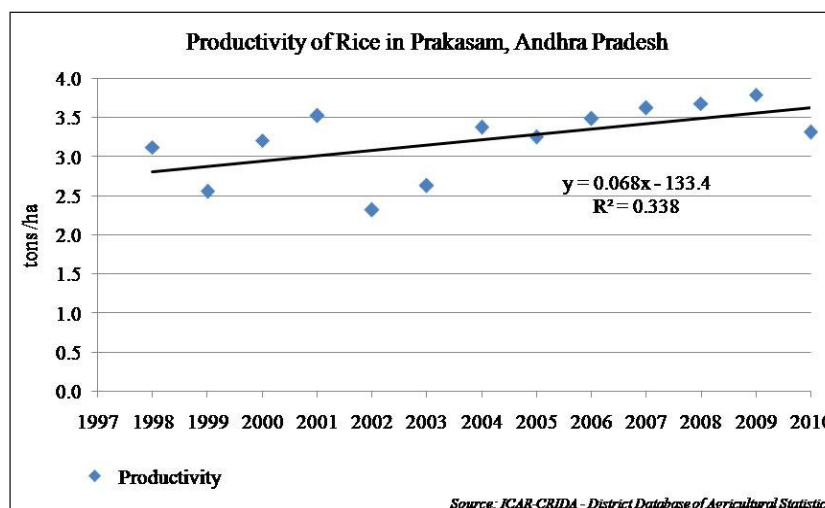


Fig. 11. Variations in LGP impacting productivity of rice in Prakasam district.

LGP (Fig. 8). Figures 9 and 10 indicate the trend in variations in seasonal LGP based on NDVI from AVHRR. Figure 11 indicates the impact of variations in LGP on productivity in rice in the district.

Typology of Agricultural Vulnerability in Mandya District in Karnataka

The two agro-ecological sub-regions vulnerable to climate change in Karnataka are AESR 6.4 and 8.2. In AESR 6.4 covering North Sahyadris and Western Karnataka Plateau, the climate is hot dry sub-humid with shallow and medium loamy and clayey black soils with medium to high AWC. Mandya district has been identified as vulnerable to climate change due to drought and flood occurrences. Normal LGP for the region is 150-180 days; however AVHRR data indicates a decrease in the lower-

limit but no change in the upper-limit of LGP (1982-2006) while later MODIS data (2006-2012) indicates no such change. Figure 12 indicates LGP pattern in the district during flood in 2009.

AESR 8.2 covering Central Karnataka Plateau experiences hot moist semi-arid climate and has medium to deep red loamy soils with low AWC. The region has a normal LGP of 120-150 days however, AVHRR data indicated an increase in lower-limit and upper-limit of LGP while MODIS indicated a decrease in lower-limit and no change in upper-limit of LGP during the periods indicated earlier. Reduction in LGP due to drought would impact the biome of Western Ghats and adversely affect the plantation crops of the region namely coffee, cardamom, cashew and black pepper which are high value cash crops. Occurrence of flood adversely impacts the field crops in the region. Figures 13 and 14

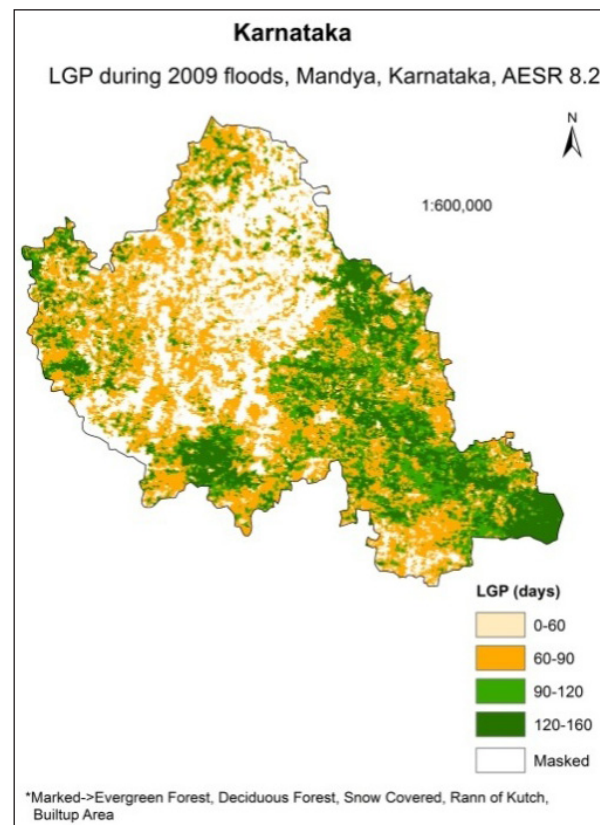


Fig. 12. LGP during 2009 flood in Mandya district in Karnataka.

indicate variations in LGP during kharif and rabi seasons based on NDVI data.

Agricultural vulnerability in Erode district, Tamil Nadu

AESR 8.1 covering Southern Tamil Nadu Uplands and rain-shadow region of Western Ghats experiences hot dry semi-arid climate with moderately deep to deep, loamy to clayey,

mixed red and black soils with medium AWC. Normal LGP in the region is 90-120 days. The study indicated a decline in lower-limit of LGP and an increase in upper-limit of LGP based on AVHRR-NDVI while MODIS data indicated an increase in both lower- and upper-limits of LGP during the corresponding periods mentioned earlier. AESR 8.3 which covers major part of Tamil Nadu Uplands and Plains

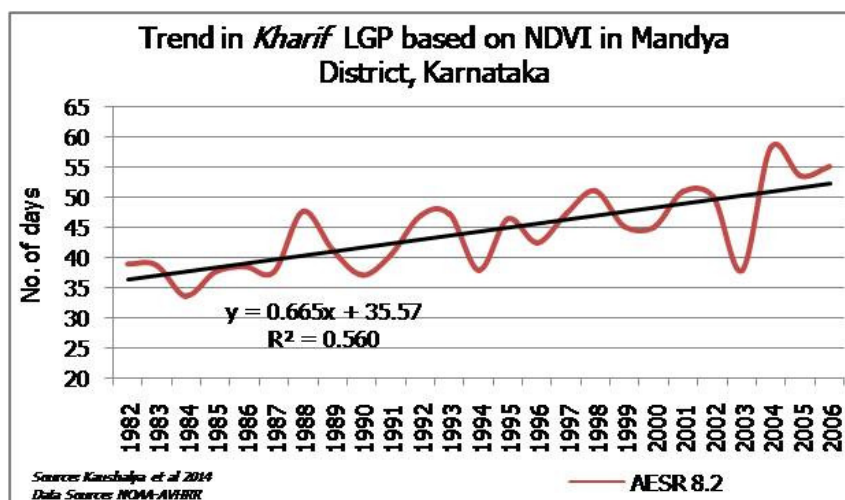


Fig. 13. Variations in kharif LGP in Mandya district in Karnataka.

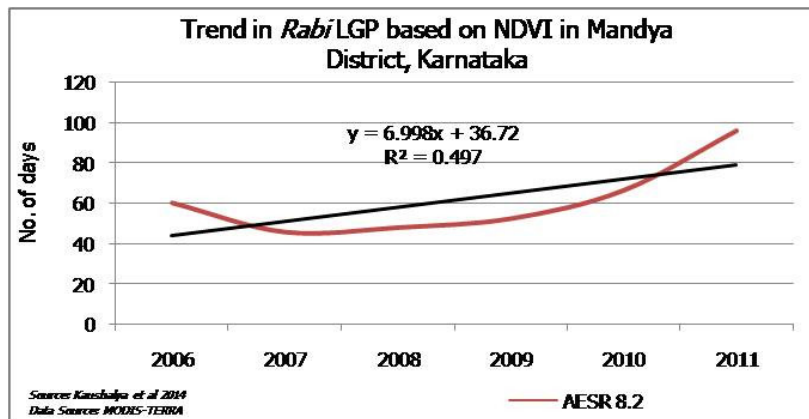


Fig. 14. Variations in rabi LGP in Mandya, Karnataka.

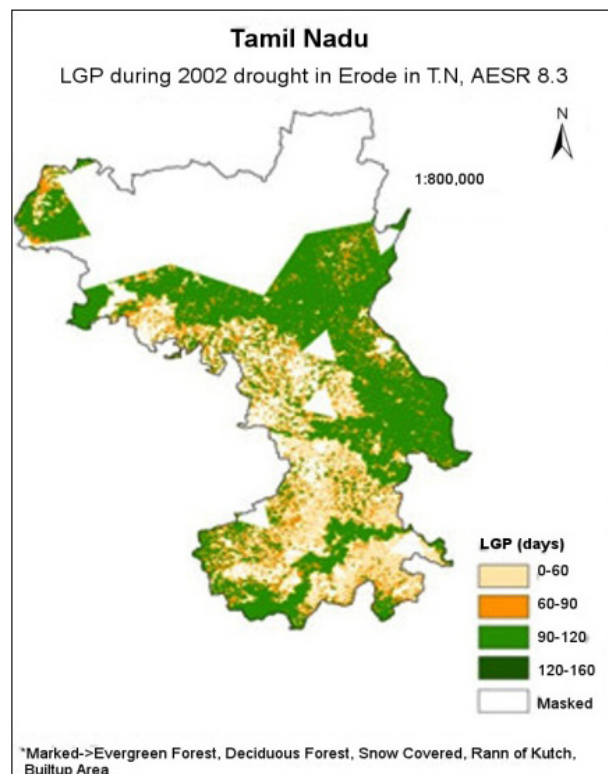


Fig. 15. LGP during 2002 drought in Erode district, Tamil Nadu.

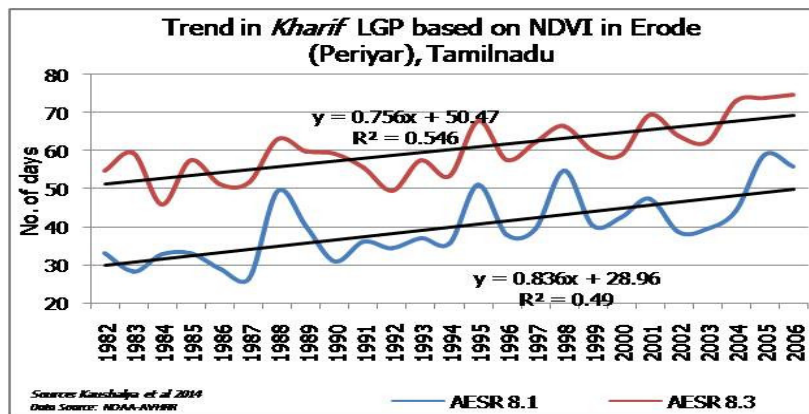


Fig. 16. Variations in LGP in Erode (Periyar) district in Tamil Nadu based on NDVI dataset.

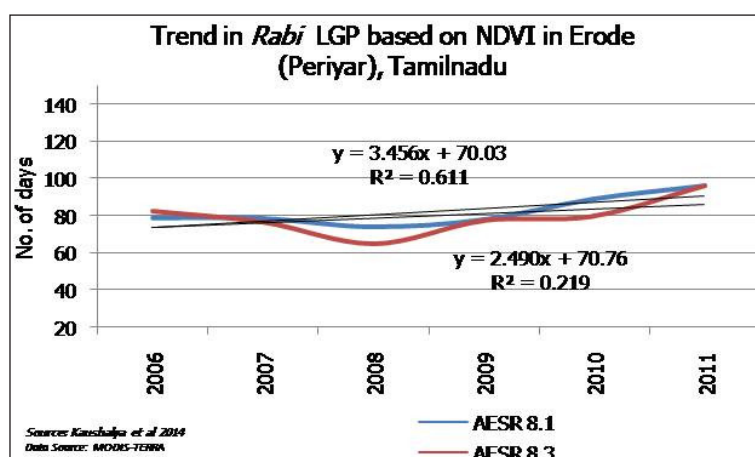


Fig. 17. Variations in rabi LGP in Erode (Periyar) district, Tamil Nadu.

that experiences hot moist semi-arid climate and has deep red loamy soils with low AWC, has a normal LGP of 120-150 days. The study indicated a decline in lower- and upper-limits of LGP based on AVHRR-NDVI. MODIS dataset indicated a decrease in the lower-limit but no change in upper-limit of LGP. Erode district located in AESR 8.3 was identified as vulnerable to climate change and Figure 15 indicates variations in seasonal LGP during drought in 2002.

Figure 16 and 17 indicate variations in LGP during kharif and rabi seasons while Figure 18 indicate the impact of a change in LGP on Rice productivity in the district.

Climate change and variability contributing to change in LGP in Peninsular India

Drought occurrence at AESR-level resulted in significant variation in LGP (Table 2). In 2002 and 2009 the LGP were reduced to 60-70 days, about half of the usual length of LGP. This resulted in massive loss to agricultural production.

Table 2. Variations in LGP/Green-up phase at AESR-level

AESR No.	Normal LGP	NDVI derived Green-up phase (1982-2012)	NDVI derived LGP (No. of days) in drought year
6.1	90-120	85-90	60
7.3	150-180	60-83	69
8.2	120-150	60-87	50
8.3	120-150	50-98	64

Study of agricultural production indicated the impact of variations in LGP as a result of climate change contributing to agricultural vulnerability.

Impact of change in LGP on agricultural productivity resulting from climate change

The study has indicated that drought and floods are not uncommon in India especially in Peninsular India that causes change in LGP and reduction in agricultural productivity as indicated earlier. The country recorded wide variation in cropping area in the last decade owing to variation in rainfall pattern. During

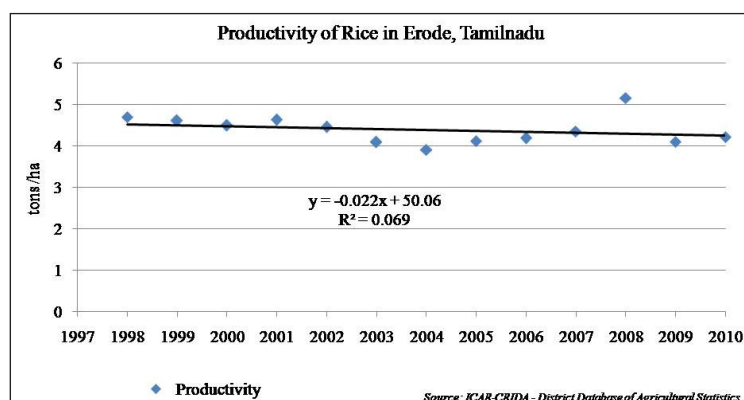


Fig.18. Impact of change in LGP on Rice productivity in Erode (Periyar) district.

last decade in 2007 which is considered a normal year, total area under food crops (cereals, millets and pulses) was 31.53 million ha which had fallen to 31.42 million ha in 2002 - a severe drought year when production had fallen by 16.67 million tons. In 2005 when floods occurred, food crop production fell by 6.69 million tons. In 2009, the country experienced drought in some areas and floods in others, which lead to a fall in the cropped area by 5.7 million ha and a loss in production by 17.1 million tons. Losses in oilseeds, fiber crops and sugarcane in a drought year were 1.4 million ha and 9.1 million tons. In 2004 when drought and floods occurred simultaneously in several parts of the country, the total cropped area fell by 1.5 million ha with a production losses of 36.6 million tons.

Conclusion

The study indicates that variability in LGP due to climate change has led to losses in agricultural sector causing economic losses to farmers by way of loss of livelihood resulting often in pressure of mounting debt besides food and fodder shortages. In Erode (Periyar) district (Tamil Nadu) in 2003 drought, rice cultivated area fell by 58,384 ha resulting in a loss of over 2 lac tons. In 2009 floods, rice acreage fell by 22,214 ha resulting in a loss of production by 1.21 lac tons. In 2010, a normal year in Jalgaon district, cotton was cultivated in 509700 ha with a production of 1.86 lac tons whereas, in 2009 a drought year, acreage fell by 98200 ha and a production loss of 1.38 lac tons leading to farmer's distress. In the case of Mandya (Karnataka), rice production in 2002 drought fell by 2.17 lac tons and in 2008 drought and floods, the loss was 1.39 lac tons. In case of Prakasam (Andhra Pradesh), rice acreage in 2010- normal year was 1.56 lac ha with a production of 5.19 lac tons. During 2002 drought year, area under rice in Prakasam fell by 91,781 ha with a production loss of 3.68 lac tons. In 2009 flood year, area under rice crop fell by 27,781 ha resulting in a crop loss of 30,450 tons.

Thus it is evident that climate variability and change is causing change in LGP contributing to agricultural vulnerability and it is essential to develop resilient technologies for farming systems and crops to insulate and/or manage climate change in order to improve farmers'

adaptive capacity to mitigate negative impacts of agricultural vulnerability.

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