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Spatial Variability in Length of Growing Period Using Meteorological and Space-based Data in Nagpur District of Maharashtra

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Abstract: The LGP was assessed using meteorological data (1988-2018) and MODIS-based NDVI data between 2000 to 2018. The meteorological data indicated that highest rainfall (1569 mm) was observed in Nagpur-Rural tehsil and the lowest rainfall was recorded in Narkhed tehsil (982 mm). Highest PET was observed in Hingna tehsil (1758 mm) and the lowest PET was recorded in Nagpur-Rural tehsil (1656 mm). The LGP map of Nagpur district generated using meteorological data showed that LGP ranged from 139 to 155 days. The pixel-wise LGP data computed using MODIS NDVI time series data has been reclassified in to 5 classes *viz.*, 90-120, 120-150, 150-180, 180-210 and 210-240 days in which LGP class150-180 days occupied maximum area (40.7%) followed by 210-240 days (17.7%), 180-210 days (15.4%), 120-150 days (14.8%), whereas, the lowest area (11.8%) was under LGP class 90-120 days. LGP found in different landforms indicated that maximum LGP was in lower pediplains (46.4%) followed by pediments (21.7%) and plateau (11.1%). Lower LGP was observed in upper pediplains (7.1%), hills (5.4%), pediplain (hillside) (2.5%), scarp slope (1.9%), valley (1.6%) and gully land (0.9%). LGP with different land use/land cover indicate that maximum LGP was under agriculture (69.5%) followed by forest (23.3%) and scrubland (7.1%). Out of the 5 classes of LGP, 93.7 per cent of total agricultural area has LGP ranging from 120-240 days.

Keywords: *Length of growing period, moderate imaging spectroradiometer, potential evapotranspiration, normalized difference vegetation index*

Introduction

The 'length of the rainy season' is the duration between the onset and end of agriculturally significant rains. Soil moisture is the key parameter in the physiological processes of the soil-crop-atmosphere system and also plays a vital role in agro-ecological systems and this approach defines LGP as the number of days when soil moisture and temperature permit crop growth (Fischer *et al.* 2002) or more specifically, the period during the year when actual evapotranspiration exceeds half of the potential evapotranspiration (Fischer *et al.* 2012). This includes the period of soil moisture storage at the end of the rainy season, the post rainy season and winter rainfall, which can all meet the crop water needs. Therefore, the LGP depends not only on the climatic conditions but also on the type of soil, soil depth, and water retention and release characteristics of the soil, air temperatures and daylight hours. LGP is also an important input to the Agro-Ecological Zoning (AEZ) approach of the International Institute for Applied Systems Analysis (IIASA) and the Food and Agricultural Organization. Therefore, spatial assessment of LGP helps in land preparation, crop planning, agricultural operations and water management. Kruska *et al.* (2003) used LGP thresholds to distinguish between arid, semi-

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arid, sub-humid and humid livestock production systems. Information on LGP of a particular region helps in selection of cultivar (short/medium/long duration) of a particular crop. Therefore, farmers can select their crops carefully based on LGP by reducing the risks of not meeting the crop demands in specific years.

Several methods have been used to estimate the LGP using rainfall (IMD 1991; Sivakumar *et al.* 1993) and rainfall and potential evapotranspiration (Velayutham *et al.* 1999). An alternative approach to estimate LGP is through the direct use of multi-temporal remote sensing MODerate Imaging Spectroradiometer (MODIS) data in which Normalized Difference Vegetation Index (NDVI) reflects the growing status of green vegetation (Thirupathi *et al*. 2015). Crop monitoring could be realized by using remote sensing technique on the basis of time series NDVI data together with agriculture calendar (Dong *et al.* 2003). NDVI is calculated as the near infrared minus red reflection, divided by the sum of the two (Tucker 1979). Many authors have reported that phenological changes in the crop during the growing season can be studied by examining changes in remote sensing-based NDVI (Brown *et al.* 2010; Kaushalya *et al.* 2014). The objective of this study is to **c**ompute and compare LGP using meteorological and remote sensing data (MODIS) of Nagpur district in GIS environment to suggest suitable agricultural planning.

Materials and Methods

Study area

The study area is Nagpur district (Fig. 1) of Maharashtra (2030 to 2145N; 7815 to 7940E) with a total geographical area (TGA) of 9892.30 km^2. Major geology of the area is Deccan Traps having flat topped hills and isolated knolls Granite-gneiss, sand stone and shale also occur at places. The elevation varies from 200 to 600 m above mean sea level. Major landforms of the area are very gently to gently sloping plateau, hills and ridges, escarpments with steep slopes, subdued plateau, nearly level to very gently sloping alluvial plain and valley. The climate of Nagpur district is sub-tropical dry sub-humid with a mean annual temperature of 26.8^{o}C and mean total rainfall of about 1127 mm. The soil temperature and moisture regimes are hyperthermic and ustic, respectively. The dominant *kharif* crops are cotton (*Gossypium spp.)*, soybean (*Glycine max*), paddy (*Oryza sativa*), pigeonpea (*Cajanus cajan*), sorghum (*Sorghum bicolor*), cowpea (*Vigna sinensis*), while, wheat (*Triticum spp*.) and gram (*Cicer arietinum*) are major *rabi* crops. Mandarin *(Citrus reticulata blanco)* is an important horticultural crop of the district.

Datasets used

For the assessment of length of growing period (LGP), climate data (1988-2018) of the past 30 years were downloaded for each block (14 blocks) of Nagpur district from www.worldclimate**.** MODIS (MODerate resolution Imaging Spectraoradiometer)-based-NDVI (Normalized Difference Vegetation Index) data was obtained between 2000 to 2018 from MODIS Terra Vegetation Index (VI) Products (MOD13Q1 Collection 5) and used for computation of length of growing period. The data was acquired from United States Geological Survey (USGS) Land Process (LP) Distributed Active Archive Centre (DAAC) at the Earth Resources Observation and Science (EROS) data Centre. The MODIS VI archive is available at nominal 250 m special resolution and composited with a time interval of 16 days. The length of growing period was also computed using meteorological data and the information available on soil and other attributes both in the maps and reports of Nagpur district (ICAR-NBSS&LUP, 1990)**.**

Methodology

Characterization and mapping of land resources

Major landforms have been identified using ALOS digital elevation model (DEM) having 12.5m resolution and Sentinel-2A having 10 m resolution. The elevation and derived information in terms of slope, contour and drainage from ALOS DEM and false colour composite (bands NIR, red and green) and normalized difference vegetation index (NDVI) were stacked and

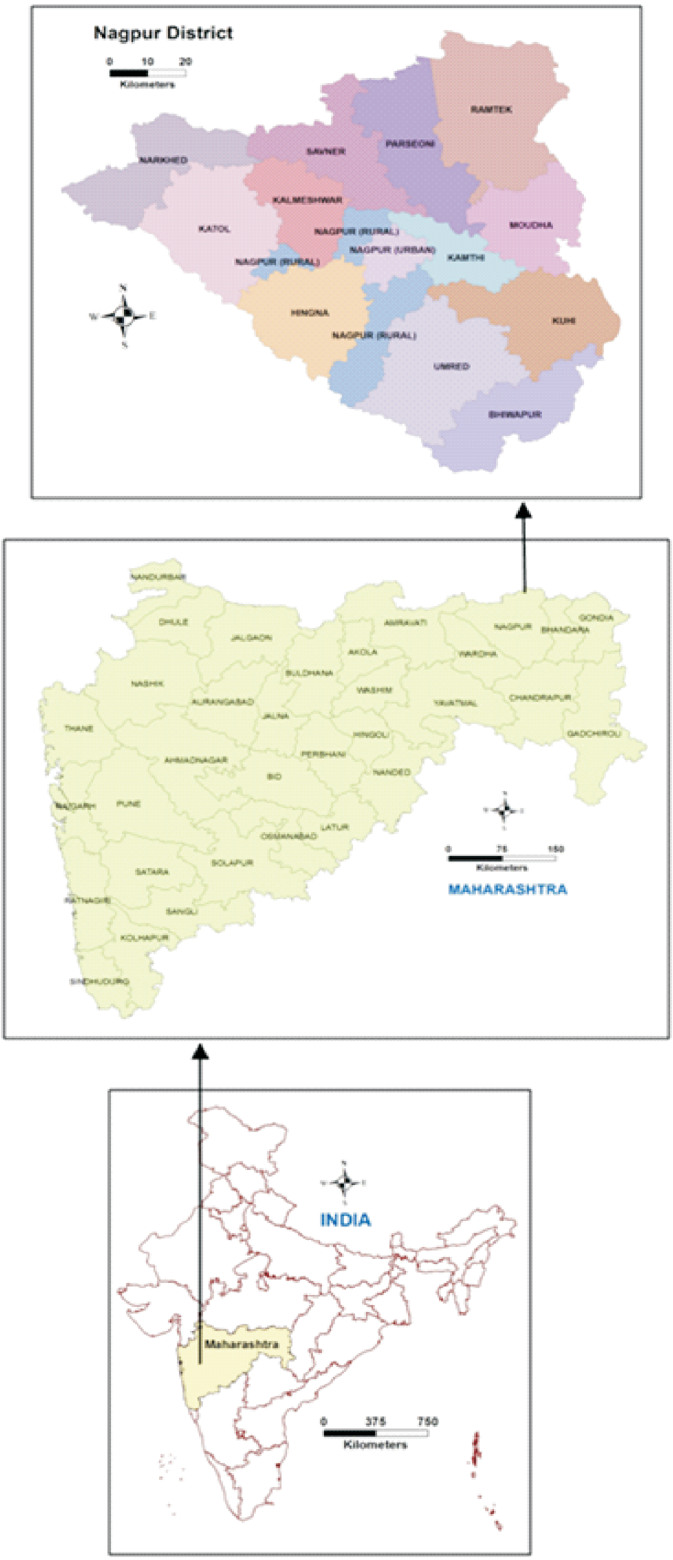

Fig.1. Location map of the study area

segmented using multi resolution segmentation tool of *eCognition® software.* A semi automated approach was adopted for delineation of broad landforms. Major land use/land cover has been identified using Sentinel-2 data. The false colour composite (NIR, red and green bands) and NDVI and brightness index derived from Sentinel-2A data have been integrated and segmented in to objects using *eCognition® software.* These objects were visually interpreted and classified into different major classes as agricultural land, fallow land, built up, water, river, mining and forest land. The soil map of Nagpur district (ICAR-NBSS&LUP 1990) on 1:50000 scale was prepared and mapped as soil series association. The existing soil map was superimposed on landform map and correlated with new landform units and their boundaries. During this process, the soil database has been upgraded and used in length of growing period (LGP) computations.

Computation of LGP using meteorological data

In the present study, tehsil-wise potential evapotranspiration (PET) of Nagpur district has been computed using the ETo calculator software from meteorological data by using FAO Penman-Monteith equation as

$$ET_0 = \frac{0.408\,\Delta\,(Rn-G) + \gamma \dfrac{900}{(T+273)} u_2\,(es-ea)}{\Delta + \gamma\,(1+0.34)\,u_2}$$

Where,

ET_0=reference evapotranspiration (mm day^{-1}) G

Rn= net radiation at the crop surface (MJ m^{-2} day^{-1})

G= soil heat flux density (MJ m^{-2} day^{-1})

T= mean daily air temperature at 2 m height ($^{\circ}$C)

u2= wind speed at 2 m height (m s^{-1})

es= saturation vapour pressure (kPa)

ea= actual vapour pressure (kPa)

es-ea=saturation vapour pressure deficit (kPa)

Δ= slope of vapour pressure curve (kPa $^{\circ}C^{-1}$)

γ =psychrometric constant (kPa $^{\circ}C^{-1}$)

The FAO Penman-Monteith equation requires information on site location and data in air temperature, humidity, wind speed, radiation for monthly PET calculation. For computation of LGP, we used the available water holding capacity of different soils for each tehsil from legacy data (Mandal *et al.* 1999). Using the meteorological data and legacy data, the length of growing period has been calculated following the FAO model (Higgins and Kassam 1981) (Fig. 2). The flow chart of the methodology is presented in figure 3.

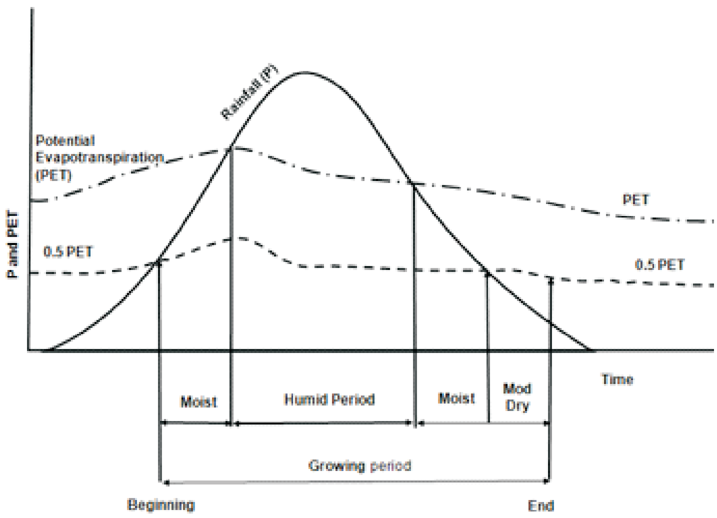

Fig. 2. Length of growing period (LGP) model

Computation of LGP using MODIS-NDVI time series data

Pre-processing of MODIS data includes extraction of the NDVI layer from the 12 layered data, calculation of original NDVI values, conversion of projection system and data format from .hdf to .tif using R software (Fig. 4a). Timesat ver. 3.3 (Eklundh *et al*. 2017) was used for smoothing the time series data (Fig. 4b) and to get the seasonal parameters (Fig. 4c). Savitzky-Golay filter (Savitzky and Golay 1964) was then applied to the images to get a smoothen data (Fig. 4d). Once the images were smoothened, the season end and start time in each year was determined using the fraction of the amplitude of the NDVI, defined between the base level and the maximum value for each individual season. The start occurs when the left part of the fitted curve has reached a specified fraction of the

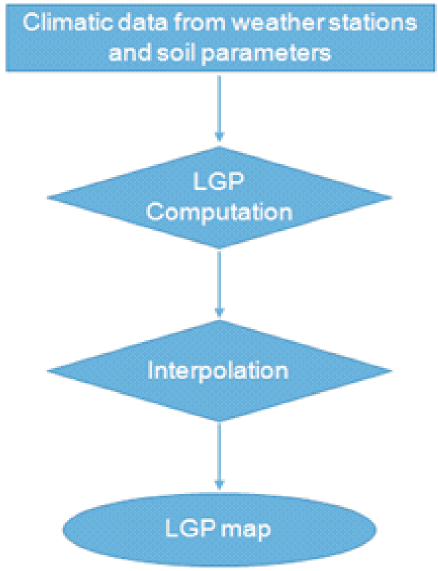

Fig. 3. Flow chart of the methodology for LGP computation using meteorogical data

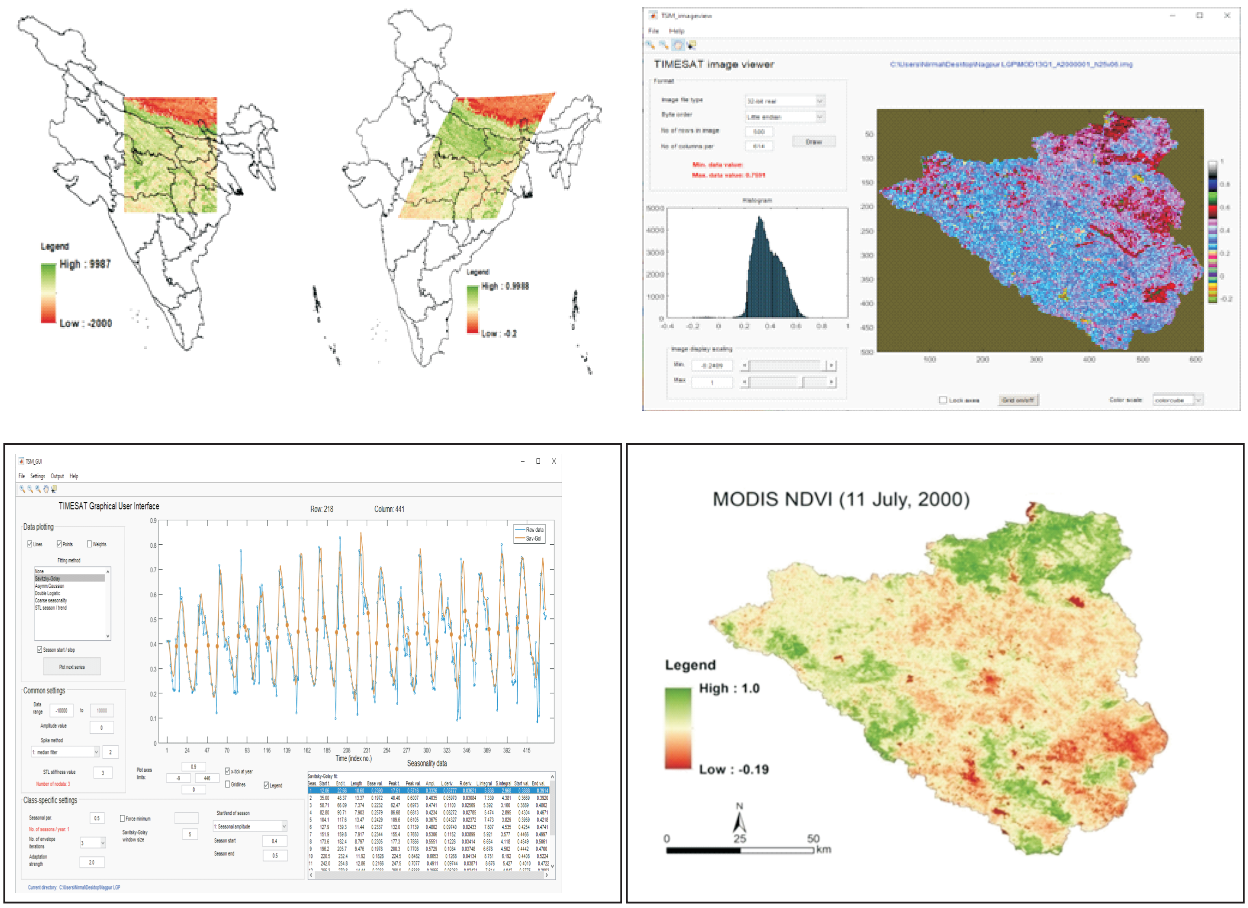

Fig. 4. Pre-processing of NDVI data a) conversion of projection system, b) smoothening of NDVI time series data, c) application of Golay filter, d) smoothened NDVI image

amplitude counted from the base level. Similarly, the end of season is defined but for the right side of the curve.

Results and Discussion

Major landforms

Nine major landforms *i.e.,* hills, plateau, scarp, pediments, pediplain, valley, gullied land, butte/mesa/ridge and mining area have been identified. The pediplains were further divided in to hill pediplains, upper pediplains and lower pediplains. The landform map is presented in figure 5. The extent of area under different landforms is presented in table 1. The data indicate that major area is under lower pediplains (44.4% of TGA) followed by pediments (20.9% of TGA) and plateau (10.5% of TGA).

Table 1. Area under different landforms of Nagpur district

Landforms	Area	
	Hectares	% of TGA
Hill	56884	5.8
Plateau	103218	10.5
Scarp	13987	1.4
Pediment	205230	20.9
Hills pediplain	18581	1.9
Upper pediplain	63985	6.5
Lower pediplain	436161	44.4
Valley	8730	0.9
Gullied land	3616	0.4
Butte/Mesa/ridge	7291	0.7
Reservoir/river	55671	5.7
Quarry	9921	1.0
Total	983275	100

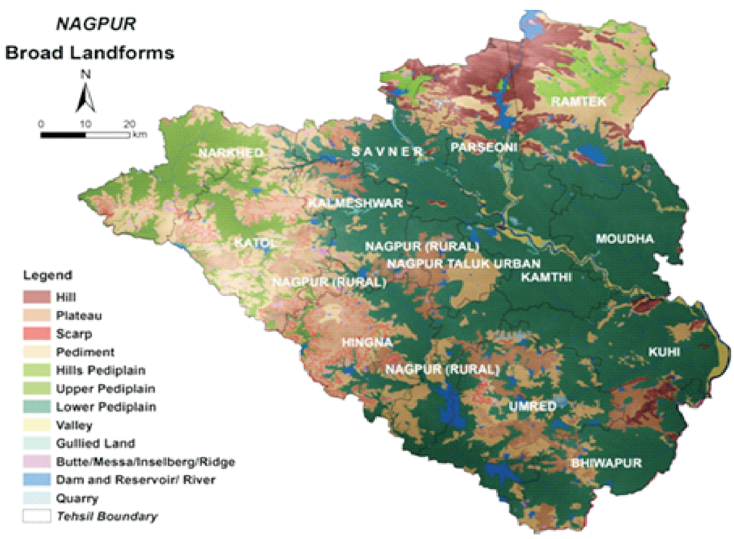

Fig. 5. Landforms map of Nagpur district

Major land use/land cover

Six major land use/land cover classes *viz.*, agriculture, forest, scrubland, builtup area, mining and waterbodies have been identified based on satellite image analysis (Fig.6). The extent of area under each land use/land cover is presented in table 2. The results indicate that major area is under agriculture (65.9% of TGA) followed by forest (19.6% of TGA). Scrubland, waterbodies and built-up area occupied 4.4, 5.7 and 3.4 per cent of TGA, respectively.

Table 2. Land use/land cover classes of Nagpur district

Land use/land cover	Area	
	Hectares	% of TGA
Agriculture	647502	65.9
Forest	192763	19.6
Scrubland	43809	4.4
Builtup	33609	3.4
Mining	9921	1.0
Waterbody	55671	5.7
Total	**983275**	100

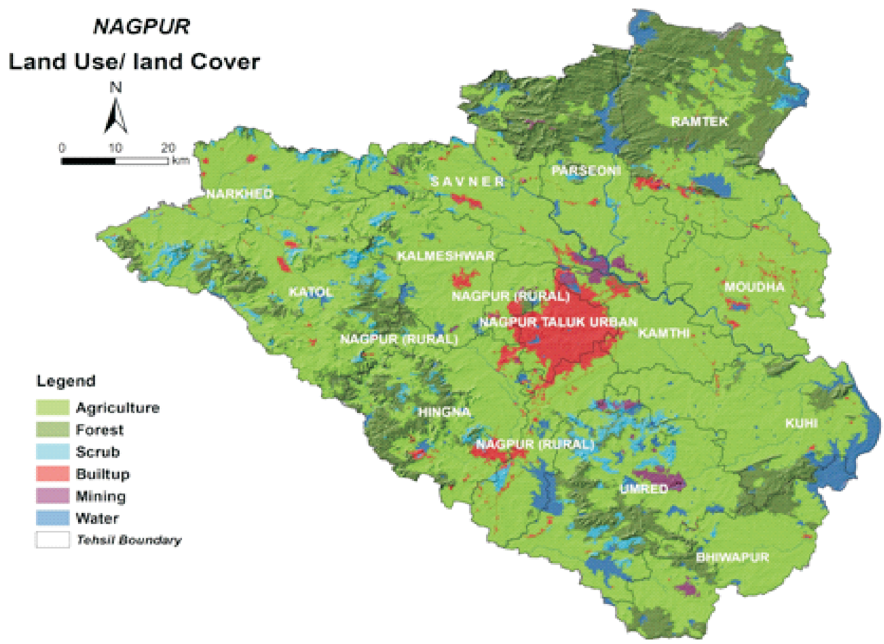

Fig. 6. Land use/land cover map of Nagpur district

Length of growing period using meteorological data

The results (Table 3; Fig. 7a) indicate that the highest rainfall was observed in Nagpur-Rural tehsil (1569 mm) and the lowest rainfall was observed in Narkhed tehsil (982 mm). Highest PET was observed in Hingna tehsil (1758 mm) and the lowest PET was recorded in Nagpur-Rural tehsil (1656 mm). LGP varied from 139 to 155 days. Maximum LGP was observed in Nagpur Rural (155 days) followed by Bhivapur (151 days), Umred (150 days) and the lowest LGP were observed in Kalmeshwar and Katol tehsils (139 days). The variability in the rainfall in Nagpur district has reflected in LGP. In general, higher LGP was observed in areas with higher rainfall. Significant and positive correlation has been observed between rainfall and LGP (r=0.60*).

Table 3. Rainfall, PET, AWC, LGP in different tehsils of Nagpur district

Tehsil	Rainfall (mm)	PET (mm)	AWC (mmm^{-1})	LGP (days)
Bhivapur	1357	1730	165	151
Hingna	1070	1758	165	140
Kalmeshwar	1025	1735	163	139
Kamtee	1094	1747	161	149
Katol	989	1704	162	139
Kuhi	1010	1743	159	149
Moudha	1194	1734	156	148
Nagpur Rural	1569	1656	168	155
Narkhed	982	1694	157	147
Parseoni	1005	1682	158	149
Ramtek	1124	1716	155	140
Umred	1237	1733	170	150
Savner	991	1731	158	147
Nagpur Urban	1092	1751	165	140

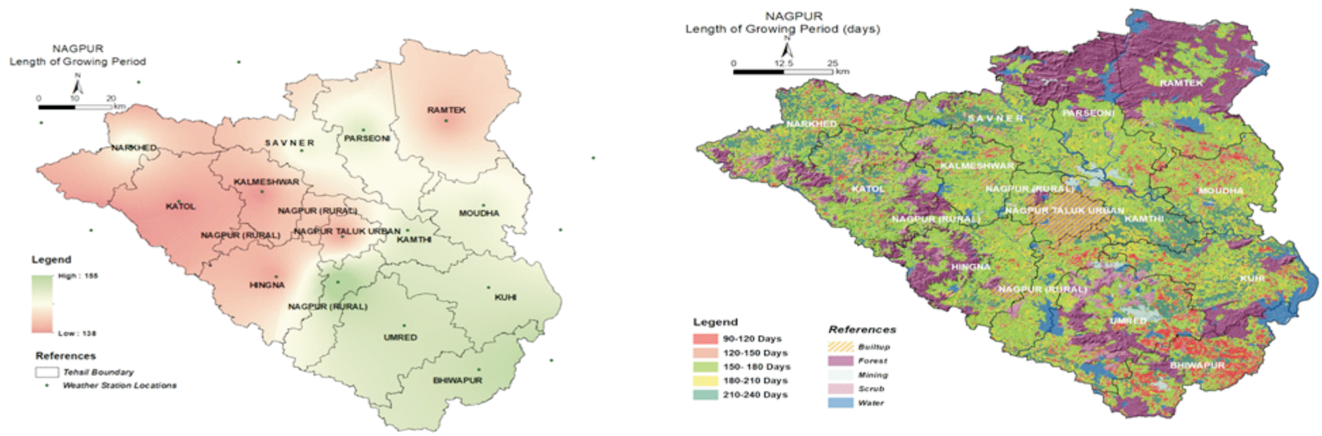

Fig. 7. Length of growing period (days) using a) meteorological data b) MODIS data

Length of growing period using MODIS-NDVI data

LGP in different tehsils of Nagpur district

The pixel-wise LGP data computed using MODIS NDVI time series data has been re-classified in to 5 classes *viz.*, 90-120, 120-150, 150-180, 180-210 and 210-240 days (Table 4). The re-classified map is presented in figure 7b. The data indicated that LGP class 150-180 days occupied maximum area (40.7%), whereas, LGP class 90-120 days has least area (11.8%). Bhiwapur tehsil had maximum area under LGP class 150-180 days (26.7%), whereas, least area was observed under LGP class 180-210 days (10.7%). Hingna tehsil

Table 4. Tehsil-wise area (ha) under each LGP class of Nagpur district generated with NDVI time series data

Tehsil	90 - 120 Days	120 - 150 Days	150 - 180 Days	180 - 210 Days	210 - 240 Days	Total
Bhiwapur	18788 (26.2)	16314 (22.7)	19133 (26.7)	7671 (10.7)	9699 (13.5)	71605
Hingna	6526 (9.2)	8239 (11.6)	36896 (52.1)	11021 (15.5)	8105 (11.4)	70787
Kalmeshwar	6507 (9.5)	9758 (14.2)	33071 (48.3)	8989 (13.1)	10050 (14.7)	68375
Kamtee	6388 (11.6)	6283 (11.4)	13596 (24.7)	10777 (19.6)	17950 (32.6)	54994
Katol	7726 (9.1)	12171 (14.3)	40233 (47.3)	9189 (10.8)	15568 (18.3)	84887
Kuhi	9495 (11.3)	11639 (13.8)	26521 (31.5)	17089 (20.3)	19399 (23)	84143
Moudha	8257 (10.2)	16121 (20)	31864 (39.3)	13202 (16.3)	11575 (14.2)	81019
Nagpur (Rural)	7307 (10.4)	8939 (12.7)	34596 (49.3)	10352 (14.7)	8912 (12.7)	70106
Narkhed	7525 (9.6)	10589 (13.5)	26377 (33.6)	12802 (16.3)	21050 (26.8)	78343
Parseoni	6601 (10)	8021 (12.2)	31496 (47.9)	12289 (18.7)	7225 (11)	65632
Ramtek	6876 (10)	9064 (13.3)	36589 (53.6)	10458 (15.3)	5168 (7.5)	68155
Savner	6251 (8.4)	8758 (11.7)	33689 (45.3)	10708 (14.4)	14956 (20.1)	74362
Umred	12163 (14.7)	14927 (18)	29827 (36)	12083 (14.6)	13656 (16.5)	82656
Nagpur (Urban)	5932 (21)	5258 (18.6)	7121 (25.2)	5289 (18.7)	4608 (16.3)	28208
Total	116342 (11.8)	146083 (14.8)	401009 (40.7)	151921 (15.4)	167920 (17.7)	

had maximum area under LGP class 150-180 days (52.1%), whereas, least area was observed under LGP class 90-120 days (9.2%). Kalmeshwar tehsil had maximum area under LGP class 150-180 days (48.3%), whereas, least area was observed under LGP class 90-120 days (9.5%). Kamptee tehsil had maximum area under LGP class 210-240 days (32.6%), whereas, least area was observed under LGP class 120-150 days (11.4%). In Katol tehsil, maximum area is under LGP class 150-180 days (47.3%), whereas, least area was observed under LGP class 90-120 days (9.1%). Kuhi tehsil had maximum area under LGP class 150-180 days (31.5%), whereas, least area was observed under LGP class 90-120 days (11.3%). In Moudha tehsil, maximum area was under LGP class 150-180 days (39.3%), whereas, least area was observed under LGP class 90-120 days (10.2%). Nagpur (Rural) tehsil had maximum area under LGP class 150-180 days (49.3%), whereas, least area was observed under LGP class 90-120 days (10.4%). In Narkhed tehsil, maximum area was under LGP class 150-180 days (33.6%), whereas, least area was observed under LGP class 90-120 days (9.6%). Parseoni tehsil had maximum area under LGP class 150-180 days (47.9%), whereas, least area was observed under LGP class 90-120 days (10%). In Ramtek tehsil, maximum area was under LGP class 150-180 days (53.6%), whereas, least area was observed under LGP class 210-240 days (7.5%). Savner tehsil had maximum area under LGP class 150-180 days (45.3%), whereas, least area was observed under LGP class 90-120 days (8.4%). In Umred tehsil, maximum area was under LGP class 150-180 days (36%), whereas, least area was observed under LGP class 180-210 days (14.6%), In Nagpur (Urban) tehsil, maximum area was under LGP class 150-180 days (25.2%), whereas, least area was observed under LGP class 220-240 days (16.3%). The data also indicated that 56.1 per cent of total geographical area (TGA) is occupied by LGP from 150-210 days and gives an idea that these areas have sufficient storage of moisture for the second crop after the harvest of *kharif* crop.

The variability in LGP is attributed to the variability in NDVI. Thirupati *et al.* (2015) studied the variability on the length of growing period (LGP) using MODIS data for the selected Mandals of Warangal district of Andhra Pradesh and reported LGP ranging from 141 to 181 days for the selected Mandals. Estimating LGP through the direct use of multi-temporal remote sensing data is gaining importance with the availability of continuous time series data from many satellites. The Normalized Difference Vegetation Index (NDVI) reflects growing status of green vegetation, hence, crop monitoring could be realized by using remote sensing technique on the basis of time series NDVI data together with agriculture calendar. Time series of vegetation indices derived from optical sensors onboard satellites, provide information about the green-up and senescence of vegetation during the year. A good number of studies indicated that NDVI and rainfall was highly correlated in water limiting areas with highest correlation of NDVI-rainfall obtained for rainfed crop followed by irrigated crop (Benhadj *et al.* 2012; Rajkumar *et al.* 2013; Patel *et al.* 2018).

LGP in different landforms

The length of growing period (LGP) under different landforms was obtained by superimposing the LGP map on landform map in ArcGIS. The length of growing period in different landforms of the district is presented in table 5. The data indicated that maximum LGP was observed in lower pediplains (46.4%) followed by pediments (21.7%) and plateau (11.1%). Lower LGP was observed in upper pediplains (7.1%), hills (5.4%), pediplain (hillside) (2.5%), scarp slope (1.9%), valley (1.6%) and gully land (0.9%).

LGP in different land use/land cover

We obtained the length of growing period (LGP) under different land use/land cover after superimposing the LGP map on land use/land cover map in ArcGIS. The results of length of growing period in different land use/land cover are presented in table 6. The data indicate that maximum LGP is under agriculture (69.5%) followed by forest (23.3%) and scrubland (7.1%). Out of 5 classes of LGP, 93.7 per cent of total agricultural area

Table 5. Area (ha.) distribution of LGP in different landforms of Nagpur district

Landforms/LGP	90-120	120-150	150-180	180-210	210-240	Total
Hill	181	1413	21800	16580	13619	53593
	(0.3)	(2.6)	(40.6)	(30.9)	(25.4)	(5.4)
Plateau	1669	37919	48288	9706	11743	109325
	(1.5)	(34.6)	(44.1)	(8.8)	(10.7)	(11.1)
Scarp slope	25	3350	10288	981	4969	19613
	(0.1)	(17.0)	(52.4)	(5)	(25.3)	(1.9)
Butte/	13	1888	4388	994	4937	12220
Messa/Ridge	(0.1)	(15.4)	(35.9)	(8.1)	(40.4)	(1.2)
Pediment	5000	70106	86544	37294	14950	213894
	(2.3)	(32.7)	(40.4)	(17.4)	(6.9)	(21.7)
Pediplain (hillside)	69	4706	12225	2538	5106	24644
	(0.2)	(19.0)	(49.6)	(10.2)	(20.7)	(2.5)
Upper Pediplain	1663	13944	13344	9956	31031	69938
	(2.3)	(19.9)	(19.0)	(14.2)	(44.3)	(7.1)
Lower Pediplain	30025	144200	127781	66406	87412	455824
	(6.6)	(31.6)	(28)	(14.5)	(19.2)	(46.4)
Valley	306	1925	4419	2431	6526	15607
	(1.9)	(12.3)	(28.3)	(15.6)	(41.8)	(1.6)
Gullied land	81	856	1781	712	5187	8617
	(0.9)	(9.9)	(20.6)	(8.2)	(60.1)	(0.9)

Table 6. Area (ha.) distribution of LGP in different land use/land cover

Land use/LGP	90-120	120-150	150-180	180-210	210-240	Total
Forest	7960	25753	97047	70547	28097	229404
	(3.4)	(11.2)	(42.3)	(30.7)	(12.2)	(23.3)
Agriculture	42191	229672	206666	89847	115097	683472
	(6.1)	(33.6)	(30.2)	(13.1)	(16.8)	(69.5)
Scrubland	8091	22728	21435	9878	8266	70398
	(11.5)	(32.2)	(30.4)	(14)	(11.7)	(7.1)

had LGP from 120-240 days. **V**aidya *et al.* (2008) reported variability in LGP of 12 to 24 weeks with variation in rainfall in South Gujarat. Based on 30-year climatic data, Kadu *et al.* (2003) reported a length of growing period of 183 days in Nagpur using water-balance approach. Wide variability in LGP with variation in rainfall has been reported by many workers **(**Bhuarya *et al.* 2018; Lotlfie *et al.* 2018; Sattar *et al.* 2019).

Conclusion

It is concluded that the length of growing period (LGP) computed using point meteorological observatories and soil database has been interpolated to prepare the surface map of LGP. The LGP ranged from 139 to 155 days in different tehsils of Nagpur district. The LGP map generated using MODIS NDVI time series data had 5 LGP classes with 90-120 days to 210-240 days. The study is useful in areas with limitations of weather data collection in remote and inaccessible areas for better crop planning.

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