

## Agro-climatic onset of cropping season: A tool for determining optimum date of sowing in dry zones of southern Karnataka

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### ABSTRACT

The study was conducted to analyse the rainfall pattern of dry farming zones of Southern Karnataka to arrive at proper date of sowing by considering parameters like threshold rainfall (20 mm), threshold dry day (2.5 mm) and threshold dry spell period (10 days) as a main defining parameters for decision making in sowing of major crops (finger millet, pigeonpea, groundnut, etc.). In all the three zones, the agro-climatic onset of cropping season was earlier as compared to meteorological onset (June 1<sup>st</sup> week) due to bimodal distribution of rainfall having its peaks in May and September month. In Central Dry Zone, Southern Dry Zone and Eastern Dry Zone, fourteenth June, thirteenth June and twenty-third May were the agro-climatic onset dates (average of all stations in each zone), respectively. Station wise analysis of the rainfall revealed different agro-climatic onset dates. Ninth May in central dry zone, eighth May in eastern dry zone and fifth May in southern dry zone were the earliest onset dates. These variations in between zonal and station specific onset dates were due to spatio-temporal variations in rainfall. Therefore, advancements in sowing of crops based on the agro-climatic onset should be taken into account for betterment of crop production.

**Key words:** Sowing date, onset date, agro-climatic onset, dry zones, southern Karnataka.

In tropical countries, the economy and food security of the rural population are strongly dependent on farming. Indeed, rain-fed crops are the main source of food, livestock fodder and incomes. In India, a typical tropical country, dryland agriculture occupies 68% of India's cultivated area and supports 40% of the human and 60% of the livestock population. It produces 44% of food requirements, thus has and will continue to play a critical role in India's food security (Harish *et al.*, 2004). In dry farming zones of southern Karnataka, major soil types are sandy loam (*Alfisols*), some of drought tolerant crops like pigeon pea, finger millet etc. are grown. One of the most important risk factors is the high spatial and temporal variability of rainfall across the region (Ravindrababu *et al.*, 2010); this is exacerbated by poor soil fertility (Wani *et al.* 2011). The rainy season lasts from April to November and receives between 528 to 1374 mm of rainfall with an average of 914 mm (Venkatesh *et al.* 2016). Several climatic factors such as seasonal rainfall amount, intra-seasonal rainfall distribution and dates of onset/cessation of the rains influence crop yields and determine the agricultural calendar (Sivakumar,

1988; Kesava Rao *et al.*, 2013). In particular, the onset of the rainy season appears to be the most crucial information (Ingram *et al.*, 2002; Barbier *et al.*, 2009) for agricultural management since it determines the planting period (Tiwari *et al.*, 1992; Sivakumar, 1992; Omotosho *et al.*, 2000). The agro-climatic approach defines the onset as the optimal date that ensures sufficient soil moisture during planting and early growing periods to avoid crop failure after sowing (Sivakumar, 1988; Omotosho *et al.*, 2000).

Traditionally, sowings begin as early as possible and coincide with the first substantial rainy event (Bacci *et al.*, 1999), which occurs generally around one month before the full establishment of the monsoon (Sultan and Janicot, 2003). Since the monsoon season has not begun yet, the probability of a post-sowing dry spell is high, increasing the risk of a sowing failure. Farmers balance this risk, by re-sowing of the crop inducing a loss of seeds and an increase of labor devoted to re-sowing. Moreover, late sowings shorten the growing season and increase weed pressure and weeding (Andrews, 1973; Stoop *et al.*, 1981). In this paper an attempt is made to illustrate how rainfall determines the

choice of sowing date and evaluates the relationship between sowing and onsets dates defined using agro-climatic approaches.

## MATERIALS AND METHODS

### *Meteorological data*

Daily rainfall data records from each station falling under the respective taluk comprised by each zone were collected from Annual Reports of AICRPAM (All India Coordinated Research Project on Agrometeorology), UAS, GKVK, Bengaluru. The study area is located in South of Karnataka (13.18° E to 13.32° E and 75.82° to 76.59° N). A summary of zones under study, districts, taluks or stations falling under each zone is provided in Table 1 and meteorological stations used in the study along with their location and average annual rainfall amount is indicated in Table 2.

### *Onset of the rainy season*

Onset is defined using different methods that fall into two distinct approaches: a) the meteorological point of view based on first rains and, b) the agro-climatic one which considers crop suitability. Note that for onset definition, a day receiving at least 2 mm of rainfall is considered here after as wet.

### *The meteorological onsets :*

The first wet day after April 15th of a 3-day wet spell receiving at least 20 mm. Note that the 20 mm threshold corresponds roughly to the mean rainfall amount received in 3-day wet spell (i.e. >1 mm). Balme *et al.* (2005) defined a “meso-scale” onset date (here in after referred to as MSO) as the first day of a 2-day wet spell when at least 90% of stations record rainfall (>1 mm) at least during one day in a radius of 300 km. This area is related to the mean scale of Meso Convective Systems (MCS)

### *The agro-climatic onsets*

Based on the agro climatic onset concept (Sivakumar, 1988) and the work of Marteau *et al.* (2009), we defined the agro climatic onset date (here in after referred to as AO) as the date after 1<sup>st</sup> May, when rainfall accumulated over three consecutive days is least 20 mm and when no dry spell within the next 30 days exceeds seven days.

Sowing date is defined as the day when simulated plant available water in soil is greater than 10 mm at the end of the day, followed by a 20-day period during which crop establishment is monitored. The juvenile stage of the crop is considered failed, triggering automatic re-sowing, if the

simulated daily total biomass decreases during 11 out of 20 days. Simulated sowings are possible from 15 April to 31 August. Note that the ideal sowing date may not be “ideal” from an agro-ecological, agronomic, socio-economic point of view, since it does not take into account nutrient dynamics, pests and diseases, or labor availability.

A MATLAB GUI interface was developed by AICRP on Agrometeorology, Anand, Gujarat with taking into consideration of the above pre-requisites to determine the agro climatic onset. It runs on MATLAB runtime environment. The interface requires criteria specific inputs for determination of the agro-climatic onset. They are explained as follows.

***Start date (calendar date):*** An estimated date of onset of rainfall, used for start the simulation of agro-climatic onset. In our case, April 1 is considered as a start date in order to check the influence of pre-monsoon showers on deciding the date of sowing in southern Karnataka.

***Rainfall threshold (mm):*** Minimum amount of rainfall required to sow the crop. Major area under study is being a dryland, around 20 mm rainfall will be sufficient for sowing of major dryland crops like finger millet, pigeon pea and other crops (Morris and Zandstra, 1979).

***Dry day threshold (mm):*** The minimum amount of soil moisture to meet the evaporation need of soil. In the study area major soils are red sandy loams. An amount of 2.5 mm soil moisture is considered and, if the soil moisture goes less than 2.5 mm, that particular day is considered as a dry day.

***Dry spell threshold (days):*** the maximum number of days that crop can sustain even after reaching the dry day threshold. That is, if the crop undergoes moisture stress even up to 10 days, there will not be considerable yield losses. In dryland like our study area, the crop can sustain up to 10 days even after reaching the dry day threshold. So, 10 days is considered as dry spell threshold for our study.

***Dry spell search period (days):*** This is decided on the concept that ability of that particular crop to sustain after germination. If the dry spell occurs before this search period, the model postpones the sowing date to next moisture abundance period. If not, the first day of search period will be considered. In our case, 20 days is considered since crop will last up to 20 days since majority of dryland crops have ability to sustain up to 20 days with minor amounts of soil moisture.

After considering all above ‘defining inputs’, data is loaded using ‘data’ tab and run to indicate the dry and wet

**Table 1:** Zones under study, Districts and taluks in Karnataka coming under each zone from where rainfall data was collected

Zone	District	Taluks/ Stations
Zone 4 (Central Dry Zone)	Chitradurga	Chitradurga, Hosadurga, Challakere, Molakalmuru, Holalkere, Hiriyuru
	Davanagere	Davanagere, Harihara, Jagaluru
	Tumakuru	Madhugiri, Pavaghadha, Sira, Chikkanayakanahalli
	Chikkamagaluru	Kaduru
Zone 5 (Eastern Dry Zone)	Tumakuru	Gubbi, Koratagere
	Bangalore (rural)	Devanahalli, Doddaballapura, Nelamangala, Hosakote
	Ramnagara	Ramnagara, Magadi, Kanakapura, Channapattana
	Bangalore (urban)	Bangalore (north), Bangalore (south), Anekal
	Kolar	Kolar, Maluru, Bangarapete, Shrinivasapura, Mulabagilu
Chikkaballapur	Chikkaballapur, Shiddalaghatta, Chintamani, Gudibande, Gouribidanuru, Bagepalli	
Zone 6 (Southern Dry Zone)	Mandya	Mandya, madduru, malavalli, Shrirangapattana, Pandavapura, K R Pete, Nagamangala
	Mysore	Mysore, K R Nagar, T Narasipura, Nanjanagudu
	Chamrajnagar	Chamrajnagar, Yalanduru, Gundlupet, Kollegala
	Tumakuru	Tumakuru, Kunigal, Tipaturu
Hassan	Channarayapattana, Arasikere	

periods in the data matrix window in the top right and onset date indicator at the bottom (both date and days after start of simulation).

### GIS mapping

ArcGIS, widely used GIS software in research and development purposes, was employed in this study. Geo-referencing of administrative map of Dry Zones of Southern Karnataka and digitization of district boundaries were carried out. Then output data pertaining to agro-climatic onset dates were linked to the polygon map of the study area. Thematic maps pertaining to these parameters were generated using ArcGIS 10.2.2 software.

## RESULTS AND DISCUSSION

### Rainfall variability in the study area

Monthly average rainfall of 50 and 30 years over the three dry zones (4, 5 and 6) of southern Karnataka is depicted in Fig.1. Rainfall in all the zones is distributed in bimodal pattern attaining a peak at May and September (Venkatesh *et. al.* 2016). In zone 4, 20.1 per cent (123 mm) of total rainfall is received during Jan to May months, 49.6 per cent (303 mm) during June to September period and remaining 30.3 per cent during October to December (185 mm). In Zone 5, 19.2 per cent (149 mm) of total rainfall is received during January to May months, 52.1 per cent (404 mm) during June to September period and remaining 28.7 per cent during October to December (223 mm) and in Zone

6, 27.4 per cent (201 mm) of total rainfall is received during Jan to May months, 41 per cent (301 mm) during June to September period and remaining 31.6 per cent (232 mm) during October to December.

### Sowing and rainfall

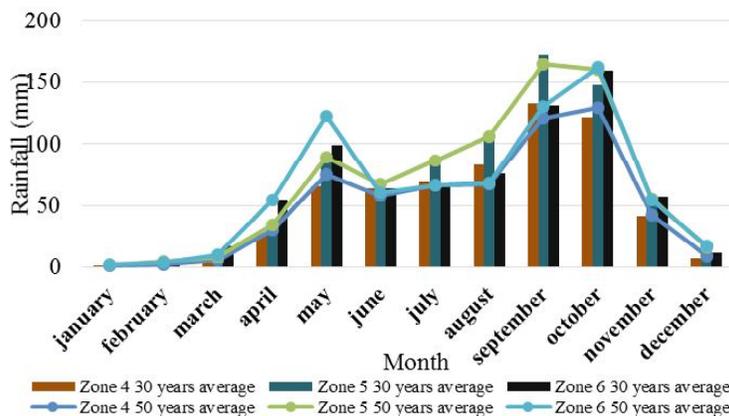
In Southern Karnataka, two different sowing strategies are used: 'dry seeding' and 'wet seeding'. The former strategy consists of sowing before the rains, i.e. when the soil is still dry. This practice tends to ease the germination, reduces the time needed to prepare farmable land before the first rains. However, this strategy is risky since high soil temperatures associated with dry weather as well as scarce and erratic rainfall before the full installation of the monsoon, which are insufficient for a full germination of the plant, may spoil the seeds (Graef and Haigis, 2001). As the temporal rainfall variability increased, this strategy is less used (McCorkle, 1994). Most farmers await a significant rainy event and sow the crops on the same day or the day after. Majority of the area is sown in 5 consecutive days after rainfall. However, this practice does not eliminate the risk of sowing failure in case of a dry spell just after the sowing.

### Sowing date based on agro-climatic onset

**Zone 4:** Being a dry zone, receives an average rainfall of 608.8 mm, most of it is received during the month of April and May as a pre monsoon showers (Venkatesh *et. al.* 2016). Simulation was carried out for all the stations coming under each taluk of four districts of the zone. The result showed

**Table 2:** Meteorological stations in Karnataka used in the study along with their location and the average annual rainfall amount

Sl. No.	Station	Latitude (°N)	Longitude (°E)	Annual Rainfall (mm)	Sl. No.	Station	Latitude (°N)	Longitude (°E)	Annual Rainfall (mm)
1	Chitradurga	14.23	76.29	641.69	27	Malur	13	77.94	745.46
2	Hosadurga	13.79	76.28	687.65	28	Mulabagilu	13.16	78.39	804.32
3	Challakere	14.31	76.65	620.86	29	Chikkaballapur	13.43	77.72	752.91
4	Molakalmuru	14.71	76.74	552.91	30	Chintamani	13.4	78.05	781.06
5	Holalkere	14.05	76.18	750.51	31	Siddalaghatta	13.39	77.86	682.88
6	Hiriyur	13.94	76.61	589.99	32	Gouribidanur	13.61	77.51	717.26
7	Davanagere	14.46	75.92	626.33	33	Gudibande	13.61	77.7	671.16
8	Harihara	14.53	75.8	640.4	34	Bagepalli	13.78	77.79	648.47
9	Jagaluru	14.52	76.33	555.78	35	Maddur	12.58	77.05	770.45
10	Madhugiri	13.66	77.2	693.29	36	Malavally	12.38	77.05	687.7
11	Pavagadha	14.1	77.28	596.17	37	Mandya	12.56	76.73	682.97
12	Sira	13.74	76.89	666	38	Pandavapura	12.49	76.66	708.11
13	Chikkanayakanahalli	13.42	76.6	715.43	39	Shrirangapattana	12.42	76.69	683.29
14	Tumkur	13.33	77.11	864.59	40	Krishnarajpete	12.65	76.48	768.23
15	Gubbi	13.31	76.91	792.83	41	Nagamangala	12.81	76.76	785.31
16	Devanahalli	13.24	77.71	815.54	42	K R Nagar	12.43	76.38	675.87
17	Doddaballapur	13.29	77.53	819.15	43	Mysore	12.29	76.64	776.2
18	Hoskote	13.06	77.79	820.14	44	Nanjanagud	12.11	76.67	776.37
19	Ramanagara	12.72	77.28	874	45	T Narasipura	12.42	76.71	762.95
20	Chanapattana	12.65	77.2	823.94	46	Gundlupet	11.8	76.69	758.05
21	Kanakapura	12.54	77.41	813.88	47	Yelandur	12.04	77.03	817.93
22	Magadi	12.95	77.22	925.17	48	Kunigal	13.02	77.04	816.41
23	Banalore north	12.97	77.59	962.58	49	Tiptur	13.26	77.46	711.21
24	Anekal	12.7	77.69	860.11	50	Channarayapattana	12.9	76.38	687.47
25	Kolar	13.13	78.12	774.9	51	Arasikere	13.31	76.25	731.86
26	Bangarpet	12.99	78.17	695.43					



**Fig. 1:** Monthly average rainfall of 50 and 30 years over the three dry zones (4, 5 and 6) of southern Karnataka

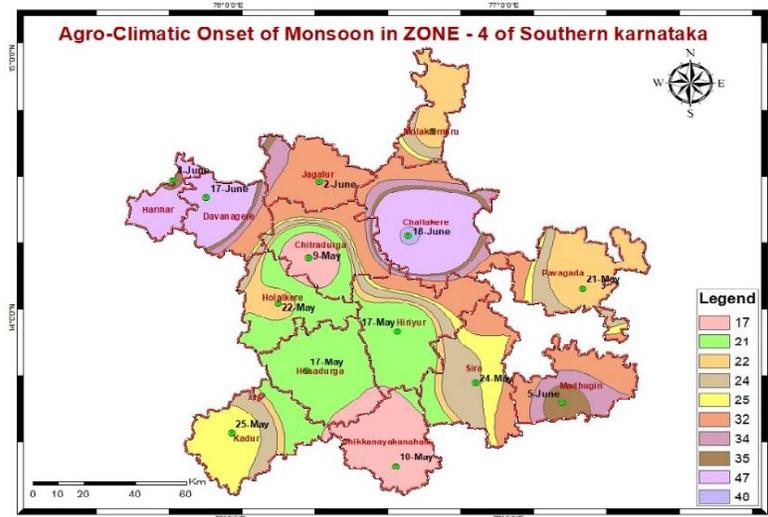


Fig. 2: ArcGIS maps indicating the Agro-climatic onset of monsoon in Zone-4 of Southern Karnataka

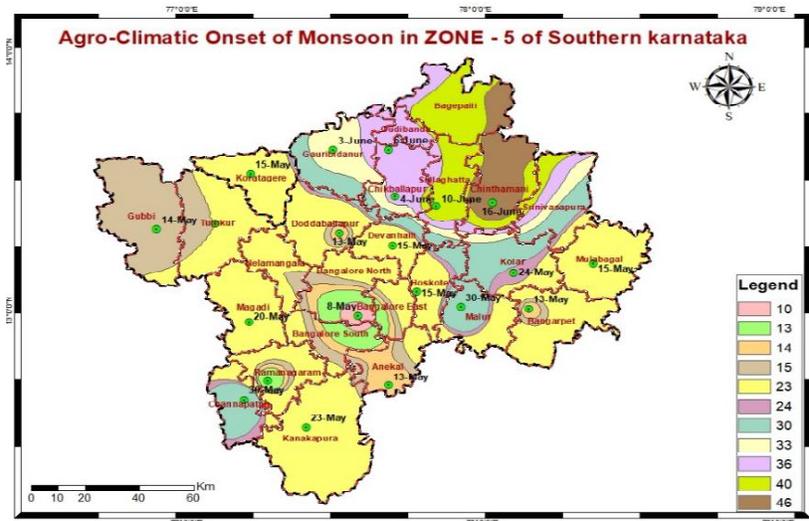


Fig. 3: ArcGIS maps indicating the Agro-climatic onset of monsoon in Zone-5 of Southern Karnataka

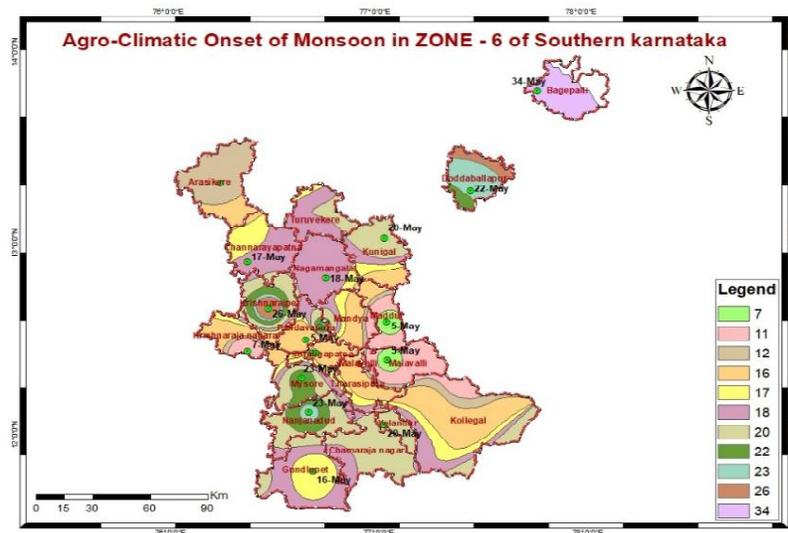


Fig. 4: ArcGIS maps indicating the Agro-climatic onset of monsoon in Zone-6 of Southern Karnataka



**Fig. 5:** MATLAB GUI showing earliest Agro-climatic onset dates (representative locations) of 3 Zones (top to bottom) of Southern Karnataka

**Table 3:** Simulation results of running MatLab expressed in terms of days after start date and agro-climatic onset dates of Zone-4 of Karnataka

District	Taluk	Days after start date	Agro-climatic onset date
Chitradurga	Chitradurga	38	09-May
	Hosadurga	32	17-May
	Challakere	34	18-Jun
	Molakalmuru	30	21-May
	Holalkere	37	22-May
	Hiriyur	32	17-May
Davanagere	Davanagere	33	17- June
	Harihara	34	04- June
	Jagaluru	32	02- June
Tumkur	Madhugiri	35	05- June
	Pavagadha	36	21-May
	Sira	39	24-May
	Chikkanayakanahalli	25	10-May

different onset dates for each taluk since the variability of rainfall amongst them (Table 3 and Fig. 2). Among all the taluks, an earlier date of 9<sup>th</sup> May was predicted by the model (38 days after start of simulation. That is, April-15). Average of all the dates simulated for each station indicated that, fourteenth June will be the agro-climatic on set date (30 days after start of simulation. May-15).

**Zone 5:** This zone receives an average annual rainfall of 776.7 mm, 19.2 per cent (149 mm) of total rainfall is received during January to May months, 52.1 per cent (404 mm) during June to September period and remaining 28.7 per cent during October to December (223 mm) month (Venkatesh *et. al.* 2016). Due to this temporal and spatial variability of rainfall, different onset dates were simulated by the model for different taluks coming under each district of the zone (Table 4 and Fig. 3). Among all the taluks, an earlier date of 8<sup>th</sup> May (23 days after start of the simulation. April 15 (as a start date) was predicted by the model for Bangalore north taluk. In this zone, 13<sup>th</sup> June (28 days after start of simulation, May 15 as a start date) is said to be agro-climatic monsoon onset date after taking average of all the dates simulated for each station.

**Zone 6:** An average annual rainfall of 753.4 mm is received by this zone. Amongst 734 mm, 27.4 per cent (201 mm) of total rainfall is received during Jan to May months, 41 per cent (301 mm) during June to September period and remaining 31.6 per cent (232 mm) during October to December (Venkatesh *et al.*, 2016). Variability of simulated

agro-climatic onset dates was expected due to the spatio-temporal variability of rainfall across each station of the zone (Vinaykumar *et al.*, 2017). An earliest onset date 5<sup>th</sup> May (20 days after start of simulation, April 15 as a start date) was simulated at Maddur, Malavally and Pandavapura taluks of Mandya (Table 5 and Fig. 4). Zonal average of 23<sup>rd</sup> May (22 days after start of simulation, May 1<sup>st</sup> as a start date).

The normal decision making rule to sow the crops in dry regions of southern Karnataka is, waiting for the first rainy event receiving at least 20 mm and sowing immediately (but, sometime even if the rainfall is not necessarily more than 20 mm), even though, dry-seeding is practiced under anticipated rainfall, may end up with the losses right after sowing since the first wet event is not always followed by the full installation of the monsoon which usually occurs later than the first wet spell (Sultan *et al.*, 2003), dry spells could occur afterwards, i.e. during the early stages of the crop growth. If a dry spell lasting more than 7 days is often associated with failure of the crop and re-sowing is necessary. So it is better to take into account of rainfall threshold, dry day threshold, and dry spell threshold etc. rainfall variables in order to arrive at a perfect date of onset suitable for the sowing without initial losses to the farmer. As we analysed the rainfall data from 1980 to 2018, we observed that there was a shift in rainfall pattern in southern Karnataka (Fig. 1) causing early onset and cessation of monsoon. Under such conditions, by considering defining inputs like rainfall threshold, dry day threshold, dry spell threshold etc., we estimated date of onset was 15<sup>th</sup> of May month in most parts

**Table 4:** Simulation results of running MatLab expressed in terms of days after start date and agro-climatic onset dates of Zone-5 of Karnataka

District	Taluk	Days after start date	Agro-climatic onset date
Tumkur	Tumkur	30	15-May
	Gubbi	29	14-May
	Koratagere	29	14-May
Bangalore (rural)	Devanahalli	30	15-May
	Doddaballapur	28	13-May
	Nelamangala	29	14-May
	Hoskote	30	15-May
Ramnagara	Ramanagara	25	10-May
	Chanapattana	29	30-May
	Kanakapura	22	23-May
	Magadi	19	20-May
Bangalore (urban)	Bangalore North	23	08-May
	Anekal	28	13-May
Kolar	Kolar	23	24-May
	Bangarpet	28	13-May
	Malur	29	30-May
	Mulabagilu	30	15-May
Chikkaballapur	Chikkaballapur	34	04-June
	Chintamani	32	16- June
	Siddalaghatta	26	10- June
	Gouribidanur	33	03- June
	Gudibande	36	06- June
	Bagepalli	30	14-June

of the southern Karnataka. Further, there is a need to subjective tuning (namely amount of rainfall and length of the initial wet spell, length and intensity of post-onset dry spell, etc.) since the onset date is equivocal (Marteau *et al.*, 2009; Marteau, 2010). In the future, efforts should be made to balance the effect of onset date with other intra-seasonal characteristics of the rainy season, notably the wet/dry spells distribution, especially close to the end of the rainy season. Any medium-term or seasonal prediction of the timing/ intensity of the monsoon's withdrawal would thus have a critical impact.

## CONCLUSION

In crop production, the non-monetary inputs like date of sowing, spacing, etc., play a vital role. In dry zones of southern Karnataka, the traditional method followed by

the farmers for sowing of the crops (soon after receiving of first rainfall) affect crop germination and initial growth due to moisture availability constraints right after sowing. As the results showed that trends in rainfall are shifting towards April-May, there was a need to search for an alternative for reducing crop losses. Agro-climatic onset of cropping season acts as an alternative for making decisions on selecting proper sowing date since the methodology considers many parameters like rainfall threshold, dry day threshold, dry spell threshold and dry spell search period along with the post-rainfall events. In all the three dry farming ones of southern Karnataka, the agro-climatic onset of cropping season is earlier as compared to the traditional sowing dates. Thus, advancements in sowing of crops based on the agro-climatic onset should be taken into account along with all other possible interventions for betterment of crop production.

**Table 5:** Simulation results of running MatLab expressed in terms of days after start date and agro-climatic onset dates of Zone-6 of Karnataka

District	Taluk	Days after start date	Agro-climatic onset date
Mandya	Maddur	20	05-May
	Malavally	20	05-May
	Mandya	22	23-May
	Pandavapura	20	05-May
	Shrirangapattana	19	20-May
	Krishnarajpete	25	26-May
	Nagamangala	17	18-May
Mysore	K R Nagar	22	07-May
	Mysore	22	23-May
	Nanjanagud	22	23-May
	T Narasipura	27	12-May
Chamrajnagar	Chamrajnagar	16	17-May
	Gundlupet	15	16-May
	Yelandur	19	20-May
Tumkur	Turuvekere	19	20-May
	Kunigal	19	20-May
	Tiptur	21	22-May
Hassan	Channarayapattana	32	17-May
	Arasikere	26	11-May

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