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Advances in agrometeorology research in India: A review

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Abstract
Agriculture in India depends mainly on rainfall and it is highly vulnerable to vagaries of climate change its distribution. In modem agriculture, observations of the physical and biological variables in the environment are essential in agricultural meteorology. Without quantitative data, agro meteorological planning, forecasting, research and services cannot properly assist agricultural producers to survive and to meet the ever-increasing demands for food, fodder and agricultural by products. Hence detailed observations/monitoring and real-time dissemination of meteorological information, quantification by advanced instruments, remote-sensing (radar and satellites), and derived indices and operational services are essential to take agrometeorological decisions in the planning of agricultural operations for better and sustainable crop yields. Similarly, in order to adapt the agricultural system to increased weather variability the information should be well-organized, customary produced and coordinated dissemination of this information linked with agromet advisory services are essential.

Keywords: Agricultural meteorology, forecasting, crop yields, agromet advisory services

Introduction

Agrometeorology is an interdisciplinary, holistic science forming a bridge between physical and biological sciences and beyond. It deals with a complex system involving soil, plant, atmosphere, agricultural management options, and others, which are interacting dynamically on various spatial and temporal scales. Specifically, the fully coupled soil-plant-atmosphere system has to be well understood in order to develop reasonable operational applications or recommendations for stakeholders. For these reasons, a comprehensive analysis of cause-effect relationships and principles that describe the influence of the state of the atmosphere, plants, and soil on different aspects of agricultural production, as well as the nature and importance of feedback between these elements of the system is necessary. Agrometeorological methods therefore use information and data from different key sciences such as soil physics and chemistry, hydrology, meteorology, crop and animal physiology and phenology, agronomy, and others. Observed information is often combined in more or less complex models, focused on various components of system parts such as mass balances (*i.e.* soil carbon, nutrients, and water), biomass production, crop growth and yield, and crop or pest phenology in order to detect sensitivities or potential responses of the soil-biosphere-atmosphere system. However, model applications still involve many uncertainties, which calls for further improvements of the description of system processes. A better quality of operational applications at various scales (monitoring, forecasting, warning, recommendations, *etc*.) is crucial for stakeholders. For example, new methods for spatial applications involve GIS and Remote Sensing for spatial data presentation and generation. Further, tailor-made products and information transfer are critical to allow effective management decisions in the short and long term. These should cover sustainability and enhancement strategies (including risk management, mitigation and adaptation) considering climate variability and change.

In spite of many technological developments in recent decade, Agriculture in India is still vulnerable to vagaries of weather. Agriculture in India depends mainly on rainfall and its distribution because major portion of land is rainfed. In modem agriculture, ecology and economy are on equal provisions; through weather issues they are even interdependent. Scarcity of resources, ruin of ecological systems and other environmental issues are becoming ever more serious. Observations of the physical and biological variables in the environment are essential in agricultural meteorology. Meteorological deliberations enter into assessing the performance of plants and animals because their growth is a result of the combined effect of genetic characteristics (nature) and their response to the environment (nurture). Without quantitative data, agrometeorological planning, forecasting, research and services cannot properly assist agricultural producers to survive and to meet the ever-increasing demands for food, fodder and agricultural by products. Such data are also needed to assess the impacts of agricultural activities and processes on the environment and climate.

Hence detailed observations/monitoring and real-time dissemination of meteorological information, quantification by advanced instruments, remote-sensing (radar and satellites), and derived indices and operational services are essential to take agrometeorological decisions in the short-term planning of agricultural operations for better and sustainable crop yields. Similarly, in order to adapt the agricultural system to increased weather variability it becomes more and more important to supply meteorological information blended with weather sensitive management operations before the start of cropping season. The well-organized, customary production and coordinated dissemination of this information linked with agromet advisories services are essential.

Recent advances in agrometeorology research

Many research advances are done in crop simulation models, climate change: adaptation and mitigation, drought assessment, forewarning pest and disease incidence, prediction of yield, agromet advisory services and agro climatic onset of cropping season.

Crop simulation models

A Crop Simulation Model is a schematic representation that describes processes of crop growth and development as a function of weather conditions, soil conditions, and crop management. Crop simulators are computer programs that mimic the growth and development of crops. Data on weather, soil, and crop management are processed to predict crop yield, maturity date, efficiency of fertilizers and other elements of crop production. The calculations in the crop models are based on the existing knowledge of the physics, physiology and ecology of crop responses to the environment. Ultimately, the breeders can anticipate future requirements based on the climate change by simulating the characteristics of the natural environmental system that studied in an abbreviated time scale through an appropriate model.

Crop models can be used to understand the effects of climate change such as elevated carbon-dioxide, changes in temperature and rainfall on crop development, growth and yield. A model can calculate probabilities of grain yield levels for a given soil type based on rainfall. showed that for maize, both simulated and measured mean yields with weeds are 86% of the weed-free yields. Also, investment decisions like the purchase of irrigation systems can be taken even when these equipment's are acquired for long term usage, through the predictions from growth models.

FAO-Aqua Crop is one of the most comprehensive crop models developed by the Food and Agriculture Organization (FAO) for calculating water use demand, predicting the effect of environment and estimating the ICC on crop yields (Abedinpour *et al*., 2012; Balvanshi and Tiwari, 2019) [1, 3]. The advantages of the model are that using only a relatively number of parameters and the simulation steps are quite simple however output results still ensure an accuracy (Silvestro *et al*., 2017; Lee and Dang, 2018) [30, 14]. A detailed description of the FAO-AquaCrop model is given in FAO (2017).

Table 1: Simulation models for different crops

Crop	Model
Rice	Ceres-Rice Model, Dssat
Maize	Epic, Alamanc, Cropsyst, Wofost, Adel, Apsim-Maize And Ceres-Maize
Sorghum	Sorkam, Sormodel, Sorgf And Almanac
Pearl Millet	Ceres-Pearl Millet Model, Cropsyst, Pmmodel
Cotton	Gossym And Cotons
Groundnut	Pnutgro
Chick Pea	Chikpgro
Wheat	Wtgrows
Soybean	Soygro
Sunflower	Qsun

Das *et al.* (2009) [6] observed the highest grain yield (5.83 Mg ha^{-1}) when NPK was applied at 64:51:50 kg ha^{-1} to achieve the target yield of 6 Mg ha^{-1} and irrespective of treatments 92–97% of predicted grain yield (based on QUEFTS) was in agreement with observed yield and also, the highest uptakes of N (52.5 kg ha^{-1}) P (14.6 kg ha^{-1}) and K (109.2 kg ha^{-1}) were observed when NPK was applied based on QUEFTS at 64:51:50 kg ha^{-1} and the observed N, P and K uptake were close (85–95%) to their corresponding predicted values which indicates QUEFTS model can be used efficiently for prediction of grain yield and fertilizer recommendation in farmer's field. Jagdish *et al.* (2013) [10] conducted a study involving a comparison between Kamel® and Hydrus_1D® for soil moisture simulation under two different soil types and they reported that Kamel® was more promising in terms of ability to couple dynamics of the internal hydro structural state of the soil medium to external climatic conditions and biological processes in the critical zone. DSSAT-CSM-CERES model used to simulate the phenology (days to anthesis and maturity) of wheat crop during the baseline period at four locations *viz*., Ludhiana (1999-2010), Raipur (2001-2012), Akola (1998-2011) and New Delhi (1993-2009) and it is in close agreement with observed values at all sites as seen from high D-index values and minimum nRMSE values and the model can be effectively used in simulating phenology and yield in crop plants (Pramod *et al.*, 2017) [22]. Jashandeep *et al.* (2018) [11] reported that for different phenological stages, growth as well as yield attributes, the maximum RMSE remained below 8.65 which confirmed the strength of the model and different statistical procedures adopted for validation of the model proved the efficiency of the DSSAT-CANEGRO model for simulation of the crop growth and production with fair degree of accuracy. Similarly, under varying sowing dates and varieties, the simulated and observed values of biological yield and grain yields of wheat during the years 2015-16 and 2016-17 were nearer to each other for all the varieties under different sowing dates and DSSAT-CSM-CERES model can be used for growth and yield simulation under varying sowing environments of Himachal Pradesh (Ranu *et al.*, 2019) [27].

Rajkumar *et al.* (2019) [24] concluded that InfoCrop-wheat model satisfactorily simulate the growth, development and yield of wheat crop under varied management practices at farmers' fields, and hence can be applied for agricultural applications for farmers.

Climate change: adaptation and mitigation

Climate change is a change in global or regional climate patterns (temperature, rainfall, moisture and wind velocity), in particular a change that is attributed to the increased levels of atmospheric carbon dioxide (CO_2) produced by fossil fuels. Climate change has several impacts on ecosystems and societies and we have to protect ourselves from these impacts. But we are not only victims of climate change, we also contribute to it. Human activities, including agricultural sector activities, are causing climate change through increasing concentration of greenhouse gases in the atmosphere. There are two main actions we can take: on the one hand, we need to adapt to climate change effects (adaptation); on the other hand, we should intervene on its causes (mitigation). Naveen *et al.* (2020) [18] suggested that impact of climate change on crop yield varies across regions, hence it is pertinent to formulate adaptation strategies and farm practices suitable to the crop and location specific needs that mitigate the likely exposure of food production and livelihoods to climate variations.

Ramachandran *et al.* (2015) [25] observed that rainwater harvesting and its use for supplementing irrigation through watershed projects have shown promise and could help in improving adaptive capacity of farmers. Adjusting the date of sowings can become helpful as an adaptation strategy to identify the optimum date of sowing under future climate change scenarios and, in turn, increase productivity (Subbarao *et al.*, 2015) [34]. Divesh *et al.* (2015) [8] projected the yield of *kharif* maize *cv.* GS-2 for the 30 years in the future with the different climate change adaptation measures like providing additional irrigation, additional fertilizers and organic manures with fertilizers and the results showed that by applying two supplementary irrigations by check basin method one at tasselling and the other at silking stage to kharif maize gave nearly 18 per cent higher mean grain yield over rain fed condition during projected periods. Likewise, Kadiyala *et al.* (2016) [12] reported that during the future climate change period (2040-2069) the yield advantages were higher with advancing the sowing window measured with three models over other mitigation options. The advancement of sowing date reduces the impact of temperature stress and facilitates to attain the targeted yield at Rahuri in 2075 (Sandeep *et al.*, 2018) [19].

Drought Assessment

Drought is the period of water shortage due to extended unusual dry weather in certain regions resulted in crop damage and other losses. The lack of adequate precipitation, either rain or snow, can cause reduced soil moisture or groundwater, diminished stream flow, crop damage, and a general water shortage. Droughts are the second-most costly weather events after hurricanes. Drought can be classified into three categories *i.e.* meteorological drought, hydrological drought and agricultural drought. Agricultural drought is deficit in soil moisture requirement to grow the plant leading to low crop production. Because of slow transition, it is difficult to determine the beginning of the drought event and sometimes the duration may vary from months to years and the core area or epicentre get changed over time. The Irrigation Commission of India defines that where rainfall is less than 75 per cent of normal rainfall as drought area. Therefore, in order to acquire the information about drought occurrence and get better understanding and knowledge about the fluctuations in recent climate, it is worthwhile to study long-term series of precipitation in the region.

Some of the indices used to assess the severity of the drought are;

- Moisture adequacy index (MAI),
- CRIDA drought severity index (CDSI),
- Standardized precipitation index (SPI), *etc.*

Table 2(a & b): Drought classification based on moisture adequacy index (MAI) and CRIDA drought severity index (CDSI) (Vijay *et al.*, 2019) [37].

Category	MAI threshold
No drought	MAI > 0.75
Mild drought	MAI < 0.75 and > 0.50
Moderate drought	MAI < 0.50 and > 0.25
Severe drought	MAI < 0.25

Category	CDSI
Safe (SF)	$\leq (M - \sigma)$
Less vulnerable (LV)	$> (M - \sigma)$ and $\leq M$
Moderately vulnerable (MV)	$> M$ and $< (M + \sigma)$
Highly vulnerable (HV)	$> (M + \sigma)$

M and σ are mean and standard deviation, respectively

Table 3: SPI Values for different drought category (McKee *et al.*, 1993) [16]

SPI values	Drought Category
2.00 and more	Extremely wet
1.50 to 1.99	Very wet
1.00 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.00 to -1.49	Moderate drought
-1.50 to -1.99	Severe drought
-2.00 and less	Extreme drought

Panday *et al.* (2020) [21] concluded that SPI values give the accurate results by using only monthly rainfall as input even without using other climatic parameters like minimum and maximum temperature, humidity, evapo-transpiration and sunshine hours and this method gives better results when used for agricultural applications since it is simple and effective.

Criteria for declaration of drought: The Manual for Drought Management, released in December 2016 by the Union Ministry of Agriculture and Farmers Welfare, prescribes “new scientific indices and parameters” for a “more accurate assessment of drought” in the country. The five categories of indices listed in the new manual, which include rainfall, agriculture, soil moisture, hydrology, and remote sensing (health of crops), are expected to help the state governments make scientific assessment of drought rather than “rely on the traditional practice such as annewari/paisewari/girdawari system of eye estimation and crop cutting experiments”.

Table 4: Different ccategories of indices used for declaration of drought

Category	Type of Indices
Rainfall related Indices	1. Rainfall Deviation
	2. Standardised Precipitation Index
	3. Dry Spell
Remote Sensing Based Indices	1. Normalised Difference Vegetation Index (NDVI)
	2. Normalised Difference Wetness Index (NDWI)
	3. Vegetation Condition Index (VCI)
Crop Situation Based Indices	1. Area Sown
Soil Moisture Based Indices	1. Percentage of available Soil Moisture (PASM)
	2. Moisture Adequacy Index (MAI)
Hydrological Indices	1. Reservoir Storage Index (RSI)
	2. Ground Water Drought Index
Socio Economic Indicators	2. Fodder availability,
	3. Scarcity of drinking water supply,
	4. migration of labour, Supply of food grains, and
	5. price situation of essential commodities
Ground Truth Verification	Ground Truthing (GT) in each of the 10% of the drought affected villages, selected on a random basis

Percentage of available Soil Moisture (PASM): Available Soil Moisture is a very relevant indicator of drought, especially in rainfed regions. Soil moisture balance provides the amount of moisture available to crops depending upon the "crop water requirement" "climate evaporative demand" and "Soil Water holding Capacity".

Table 5: Classification of drought based on PASM.

Percentage of available Soil Moisture (PASM)	
PASM (%)	**Agriculture Drought Class**
76-100	No Drought
51-75	Mild Drought
26-50	Moderate Drought
0-25	Severe Drought

Forewarning pest & disease incidence

Weekly average population of the pest was used for the study. The weekly meteorological parameters *viz*., rainfall (RF), maximum temperature (Tmax), minimum temperature (Tmin), morning relative humidity (RHI), evening relative humidity (RHII) and Bright Sunshine Hours (BSSH) for different SMW during the entire crop period for all the years of study were obtained from the National Data Centre, India Meteorological Department (IMD), Pune. Information on weather forecast were collected from the Weekly Weather Reports and synoptic charts prepared by the Weather Forecasting Section, IMD, Pune. Both statistical tools and graphical superimposition techniques were used to find out the inter relationship between the pest population and meteorological parameters. Correlation analysis was carried out between the pest population and meteorological parameters. Correlation analysis between pest the population and weather parameters for the current week as well as at four weeks lag period was carried out. Das *et al.* (2013) [7] concluded that the spectral reflectance curve and spectral indices offers scope for potential use of this technology to distinguish healthy and YMV infected soybean crop in a rapid and cost-effective manner from large and continuous soybean growing areas. NDVI derived from hyper-spectral sensor data was found to be the best in this regard. The fruit borer damage correlated with weather parameters indicated highly significant positive correlation with maximum temperature, mean temperature and bright sunshine hours while the correlation with minimum temperature and morning vapour pressure was significant at 5% level (Mutkule *et al*, 2017) [17]. Chattopadhyay *et al.* (2019) [5] observed that critical weather parameters causing the outbreak of *S. litura* in soybean were maximum temperature around 26-27 °C, minimum temperature around 21-22 °C, morning relative humidity above 90 per cent and occurrence of rainfall during the previous week. It was also observed that cloudy weather (fewer sunshine hours) and rain during the previous week increased the pest population. Pests' process-based phenology model might be used as a tool for specific pest risk assessments and for improving pest management strategies for *S. litura* (Srinivasa Rao and Prasad, 2020) [33].

Prediction of yield

Pre-harvest prediction of crop yields can be done through regression models along with the use of weather parameters like maximum (T_{max}) and minimum (T_{min}) temperatures, relative humidity in the morning (RH I) and evening (RH II) and rainfall during the Standard Meteorological Weeks (SMW). Significance of co-efficient of determination R^2 at P=0.05 indicates the suitability of the regression model for pre-harvest prediction of crop yields. If error % is less than 10 between the observed and predicted yields then it shows the significance of the regression model in prediction of crop yields. Verma *et al.* (2003) [36] concluded that both weather parameters and NDVI together seem to be more important predictors for pre-harvest yield prediction than using the NDVI parameter alone. Wheat yield could be predicted well in advance using NDVI derived from LANDSAT images using ENVI-4.8 and fortnightly weather parameters (Rajeev *et al.*, 2012) [23]. The CERES-Maize simulated significant decrease in duration and grain yield of maize crop under projected climate scenarios (Navneet and Prabhjyoth, 2019) [19]. Banakara *et al.* (2019) [4] concluded that preharvest rice yield forecasting with MLR found superior as compared to principal component analysis. During the years of validation, the observed yields were in good agreement with forecasted yields for wheat as well as mustard using statistical model (Samita *et al.* 2018).

Agromet advisory services (AAS)

AgroMet Advisory Service (AAS) deals with extension agrometeorology and is defined as 'all agrometeorological and agro-climatological information that can be directly applied to improve and/or protect the livelihood of farmers' (ICAR-CRIDA). AAS has been adopted at district level since 2008 by the Indian Meteorological Department (IMD) and is continued even now. The district level AAS is provided to farmers making use of medium range weather forecast of the

National Center for Medium Range Weather Forecasting (NCMRWF) and IMD.

A typical Agromet Advisory Bulletin enables farmers to reap benefits of benevolent weather and minimize or mitigate the impacts of adverse weather are: 1) District specific weather forecast, in quantitative terms, for next 5 days for weather parameters like; rainfall, cloud, maximum and minimum temperature, wind speed/direction and relative humidity, including forewarning of hazardous weather events (cyclone, hailstorm, heat/cold waves, drought and flood, *etc*.) likely to cause stress on standing crop and suggestions to protect the crop from them. 2) Weather forecast based information on soil moisture status and guidance for application of irrigation, fertilizer and herbicides, *etc*. 3) Advisories on sowing/planting dates and suitability of intercultural operations covering the entire crop spectrum from pre-sowing to post harvest to guide farmer in their day-to-day cultural operations. 4) Weather forecast based forewarning system for major pests and diseases of major crops and advises on plant protection measures. 5) Propagation of techniques for manipulation of crop's microclimate *e.g*. shading, mulching, surface modification, shelter belt, frost protection etc. to protect crops under stressed conditions. 6) Reducing contribution of the agricultural production system to global warming and environmental degradation through judicious management of land, water and farm inputs, agro-chemicals and fertilizers. 7) Advisory for livestock on health, shelter, and nutrition.

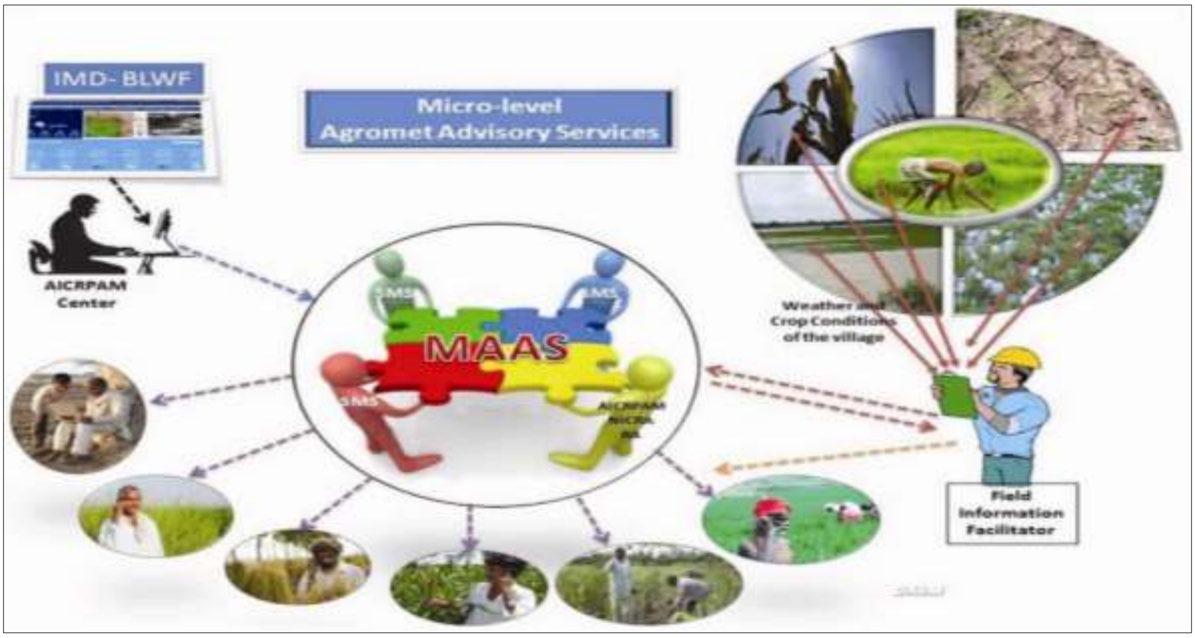

Fig 1: Conceptual diagram of block-level AAS (Vijay *et al.*, 2017) [38].

The scientific staff receives block level weather forecast from IMD website, and advisories are developed in consultation with Subject Matter Specialists of respective KVKs. Another important and useful concept has been introduced in micro-level AAS in the form of appointing 'Field Information Facilitator (FIF)' to serve as the interface among the farmers, AICRPAM and KVK. Further, FIF collects information (prevailing local weather conditions, crops and their growth stage, vigour, incidence of pests and diseases, *etc*.) and disseminates advisories to the farmers. Feedback from FIF provides real situation at village level based on which and the block level forecast, micro-level advisories are prepared. Thus, the Agrometeorologist of the AICRPAM centre develops the Agromet advisory bulletins with the help of SMS at KVK using the field level crop information blended with weather forecasts and communicate to the FIFs by email who pass on the bulletins to farmers. The micro-level AAS is generated in the name of Program Coordinator, KVK and is disseminated by multiple communication modes, *viz*. mobile text and voice SMS, display at public places, personal contact, *etc*. The feedback obtained from the farmers is being evaluated for improving and expanding services for the benefit of farming community. The monitory benefits from this AAS ranged from a few hundred rupees to a few thousand rupees per acre depending on the crop and weather situation.

The economic impact studies indicated that there was considerable benefit to farmers who adopted the agromet advisories and the per cent gain in income due to adoption of suggested contingency cropping systems ranged from 22 to 397% over traditional cropping systems (Ramachandrappa *et al*, 2018) [26]. And also reported that, the agro advisory messages written near milk collection centre remained most popular and easily accessible through which 77% farmers could get information on weather forecast. Rest of the farmers could access detailed weather-based agro advisory through telephone/ personal contact and take required crop management practices. Better crop management practices based on advisories such as timely sowing, selection of improved crop cultivar, timely application of fertilizer, pest and disease management, lifesaving irrigation and harvesting which helps them to reduce the cost of production over non-AAS farmers (Ravi *et al.*, 2020) [28].

Agro-climatic onset of sowing date

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 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).

The agro-climatic onsets: Huggi *et al.* (2020) [9] defined the agro climatic onset date as the date after 1st 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.

MatLab GUI interface: 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.

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.

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 loses. In dryland like our study area, the crop can sustain up to 10 days even after reaching the dry day threshold.

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.

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) [35]. 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) [31, 13]. 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) [31, 20].

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. Average of all the dates simulated for each station indicated that, 14th June (30 days after start of simulation. May-15) and 13th June (28 days after start of simulation, May 15 as a start date) will be the agro-climatic on set dates for zone 4 and zone 5 of Karnataka, respectively (Huggi *et al*., 2020) [9].

Summary and conclusion

There was considerable economic benefit of 12 to 33 per cent increase in profit for AAS farmers as compared to non-AAS farmers. Negative impacts of climatic change over crop growing areas of India can be minimized by adjusting sowing time, revising irrigation and fertilizer scheduling. Agro-climatic onset of cropping season acts as an alternative for making decisions on selecting proper sowing date since the methodology considers many parameters along with the post-rainfall events. South and southwestern regions of the Andhra Pradesh with low rainfall, poor water-holding capacity and limited irrigation potential are highly vulnerable to agricultural droughts.

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