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Coordinated research on agrometeorology: India perspective

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ABSTRACT

The All India Coordinated Research Project on Agrometeorology (AICRPAM) was initiated in 1983 to utilize the climatic resource potential for better agricultural planning, enhanced productivity, profitability and sustainable livelihoods. The project has generated valuable research output in the areas of agroclimatic characterization, crop-weather relationship and weather effects on pests and diseases. Such information has been used for developing crop weather calendars, agroclimatic atlases, decision support systems, android apps, software for agromet data analysis, weather-based pest forewarning models, weather triggers for crop insurance etc. These products are being used for preparing agromet advisories and weather-related risk management systems. AICRPAM has completed forty years of its very meaningful existence with significant achievements and recommendations of practical value for the benefit of various stakeholders, particularly farmers. However, in view of the increase in intensity and frequency of the extreme weather events such as heat and cold waves, floods and droughts etc. under changing climatic conditions, the coordinated project envisages characterizing and identifying the hotspots, to minimize risks in crop production.

Key words: AICRPAM, weather, climate, crop, pest, agromet-advisory, DSS

Agrometeorology is a multi-disciplinary science, concerned with all the physical and dynamic processes associated with the crop growing environment. Its primary objective is to discover and define such effects, and thus to apply scientific knowledge of the weather and climate to operational use towards sustainable development of agricultural production. Despite the technological advances that has taken place so far in Indian agriculture, the inter-annual variation in food production has remained in consonance with the weather variability. The ever-increasing extreme weather events like extended dry spells, heatwaves, one-day extreme rain events, hailstorms (Bal and Minhas, 2017, Rao *et al.,* 2014)) have become a real concern for all of us. The heat wave 2022 in India (Bal *et al.,* 2022a) and other parts of the globe, has impacted the *rabi* season crops significantly and have necessitated the need to strengthening the application of agrometeorological knowledge towards tactical decision-making to minimize the crop loss.

HISTORY OF AGROMETEOROLOGY IN INDIA

The first decade of the 20th century saw the development of agricultural meteorology as a field of study in the nation. At the Agricultural Research Institute (ARI) at Pusa, Bihar, which is the progenitor to the current Indian Agricultural Research Institute, IARI, New Delhi, measurements of soil temperatures, soil gases, soil moisture, and evaporation from water surface have been a focus since 1905. Since the formation of a division in the Pune meteorological offices in the 1930s, it has gained momentum. Research, training, and extension efforts in agrometeorology got developed during the 1980s and 1990s with the introduction of postgraduate study, the launch of a coordinated research program, and weather-based agro-advisory services encompassing various regions of the nation.

Under the guidance of the India Meteorological Department, a number of agricultural meteorological observatories were built as part of the All India Crop Weather Scheme, which was first implemented in the 1940s at state agricultural research stations and experimental farms. At several AGROMET stations, lysimeter stations were set up in the 1970s to monitor evapotranspiration from crops, and actual evapotranspiration from major crops was recorded.

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At 83 centres of the former NARP program of ICAR located throughout the various agroclimatic areas, the Agro Advisory Service Units (AASU) program was launched in the early 1990s for the dissemination of medium range weather forecast from the National Centre for Medium Range Weather Forecast (NCMRWF). The Agro Advisory Service Units (AASU) at the State Agricultural University Research Centers generate weather-related agro-advisories based on the MRWF received twice a week for distribution to the farming community through various communication platforms. One noteworthy aspect is that several of the agromet observatories are shared by the various initiatives described above, preventing effort duplication. In order to maintain and run the agromet observatories on a daily basis, close cooperation is required between the various entities involved.

After realizing the significance of the subject Agricultural Meteorology and expanding research, teaching, and extension activities in this field, Indian Council of Agricultural Research, Govt. of India approved the establishment of Dept. of Agricultural Meteorology in State Agricultural Universities in the 1980s. It was designed to promote the development of human resources, organize various postgraduate in-service training programs, launch weather-based agricultural advisory services for farmers, and create an All India Coordinated Scheme on Agrometeorology, serving the various agroclimatic regions of the nation.

START OF COORDINATED PROGRAM FOR RESEARCH ON AGROMETEOROLOGY

In the year 1983, Indian Council of Agricultural Research, Govt. of India started the All India Coordinated Research Project on Agrometeorology (AICRPAM), with Hyderabad as the head quarter, to initiate coordinated research on various agrometeorological aspects to understand the relationships between weather and crop production systems. The project was started with 10 cooperating centers and later 13 more centers were added. Initially, AICRPAM had eight thrust areas of research viz., agromet data base management, agroclimatic characterization, characterization of crop growing environments, microclimatology of crops, spatial dynamics of insect pests and diseases, water production functions, crop weather modelling and agromet advisory services.

As there was shortage of trained manpower at the beginning of the project, an Indo-US Project on Strengthening Agrometeorological Research in India with US aid of 1.6 million dollars was taken up during 1989 to 1993. Under this project 16 Indian Scientists were trained in reputed US Universities for a period of six months each. In addition, 8 in-service training programs of 3 to 4 weeks duration on each of the thrust areas identified were organized in India for about 30 scientists each inviting the US Scientists. Further, all the cooperating centres were equipped with essential equipment for collection of data from field experiments. Hands on training programs on use of computers for data base management and analysis of agrometeorological data were also conducted. The Indo US project laid firm foundation for organizing research in a systematic manner at the ten cooperating centres of the project initially created. The ICAR after having convinced with the initial beginning made by the project decided to establish

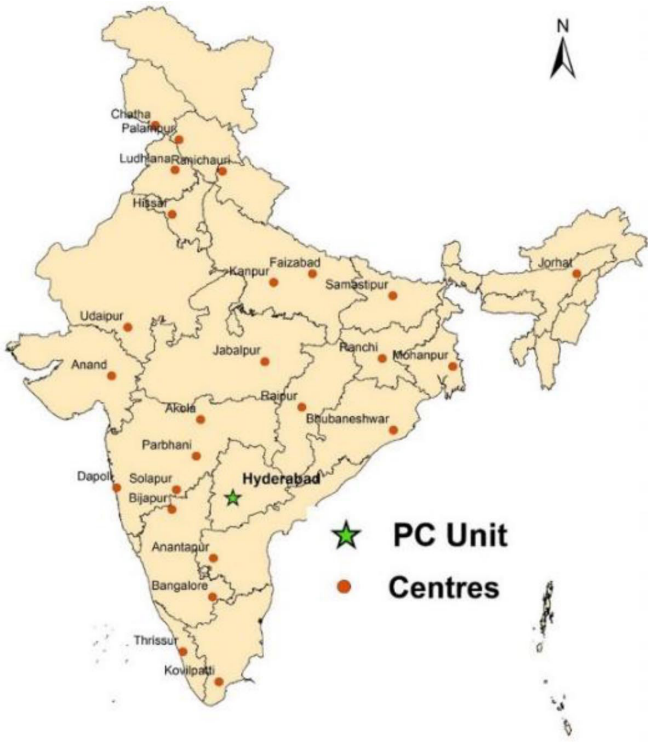

Fig. 1: AICRP on Agrometeorology (AICRPAM) network in India

cooperating centres of the project in all the 25 SAUs existing at the time of 8th plan (Fig. 1) (Rao *et al.*, 2010). At present, AICRPAM undertakes research and extension work on five themes *viz.*, agroclimatic characterization, crop-weather relationships, crop growth modelling, weather effects on pests and diseases and agromet advisory services.

AICRPAM has conducted extensive agroclimatic characterization of the states where its cooperating centres are working and has come out with agroclimatic atlases. Crop-weather relationships were quantified by all the cooperating centers and are being published as agrometeorology of respective crops. AICRPAM has also improved IMD's crop weather calendar by adding more components to it *viz.*, standard meteorological week-wise optimum range of weather parameters for obtaining higher yield and conducive range of weather parameters for incidence of pests and diseases. Further, the project has developed 'Dynamic Crop Weather Calendar', a software which guide for favourable sowing and irrigation decisions based on soil moisture dynamics based on historical, real-time and forecast weather. The DCWC is proposed to be linked to the Decision Support System (DSS) of India Meteorological Department (IMD) for automation of agromet advisory services (Vijaya Kumar *et al.*, 2021). Under crop growth modelling, location and crop-specific genetic coefficients are being calibrated and validated for various crops and impact of projected climate was assessed using crop simulation models like DSSAT and Info-Crop. Location-specific thumb rules are being developed for fore-warning of pest/disease incidence. In collaboration with IMD, AICRPAM is also issuing National Agromet Advisory Services' bulletin (NAAS) based on Extended Range Weather Forecast (ERFS) on every Friday.

LONG-TERM COORDINATED RESEARCH AND MAJOR ACHIEVEMENTS

Long-term weather data was collected by the cooperating centers from the local observatories, district level weather data from IMD for analysis of climate, crop weather relations, crop simulation modeling, crop-pest weather analysis and also providing necessary research backstopping to IMD, since the year 1989 for the success of Agromet advisories under NCMRWF through 127 Agro-Met Field Units (AMFUs).

Agroclimatic characterization

Agroclimatic analysis of a location helps in identifying the variable characteristics of various weather parameters namely rainfall, minimum and maximum temperatures, humidity both in morning and evening, wind speed and direction, sun shine hours and solar radiation, soil moisture and length of growing period etc. and their impact on the local major crops, horticulture, livestock etc.

Under this theme, Agro-met databank was established during the year 1998 as a repository of weather and crop data collected from ICAR institutes, IMD and SAUs. The data was quality checked and a database was developed. This data was supplied to the researchers of different ICAR-Institutes/ organizations, State Agricultural universities, Government organizations etc. on request and also analyzed for characterization of crop growing environments. During the year 2001, The crop weather outlook website (www.cropweatheroutlook.in) was developed to cater the needs of the AICRPAM centers for dissemination of AAS benefitting stakeholders viz., researchers, extension workers, line department personnel and farmers etc.

Agro-climatic characterization of different zones, regions and states have been analyzed by using long term-weather data by all 25 AICRPAM centers for their respective states / jurisdiction areas. This analysis includes the rainfall occurrence in a location on weekly, monthly, seasonal and annual basis along with distribution, variation, long term trends, periodicities. Further, meteorological and agricultural droughts, climatic water balance studies, evaporation and soil moisture variability, length of growing period were calculated and reported. The project evolved characterization of agricultural droughts in dry farming regions and documented principles and practices for management of agricultural droughts after the Country experienced severe drought in many parts of the country during the year 1987. Characterization of crop growing environments for several crops including mustard, groundnut, chickpea, pigeon pea etc. to identify the favorable environments for achieving high productivity with low variability in the yields in different parts of the country were undertaken. The most favorable weather conditions contributing to higher yields of the crops were also determined.

The research continued further to look at agroclimatic onset of crop growing season, Dry Spell Index for identifying the frequency, impact of dry spells and drought situation analysis and their impact on the crop yields; Percent Available Soil Moisture estimation for declaring crop-based drought impact etc. were developed for helping in timely declaration of drought and supporting the farmers. Frost is one of the major extreme weather events that occurs during winters especially in the northern parts of the country. A frost forecasting model was developed during the year 2020 (Bal *et al.,* 2021). This will strengthen the early warning of frost occurrence and timely issue of frost related agromet advisories. A compilation covering spatial and temporal hailstorm events was undertaken (Rao *et al.,* 2014) and vulnerable districts to hailstorm was identified.

Using the long-term weather and crop data, AICRPAM project coordinating unit conceptualized and prepared "Agroclimatic Atlas" during the year 2013 for the erstwhile Andhra Pradesh (Rao *et al.,* 2013). Based on these guidelines, cooperating centres of AICRPAM have prepared Agroclimatic Atlases for their states/ regions. Some of the major achievements are trend analysis of long-term temperature, rainfall, rainfall probability analysis, analysis of extreme weather events (drought, frost, fog, hailstorm etc.), changes in Length of Growing Period (LGP), impact of El-Nino and La-Nina events on weather etc.

Crop weather relationships

Right from sowing to harvest of the crop, crop growth depends on the prevailing weather. The variability in the weather and the stage of the crop decides the impact on the final yields of the crop. Under this theme, AICRPAM has developed yield prediction models with the help of identified important weather parameters. Some examples of crop weather relationships developed by different AICRPAM centers are 10 mm increase in rainfall in cotton, during reproductive phase increased the yield by 93 kg ha^{-1} (Akola); continuous dry spell during the flower bud initiation and flowering stages at Vijayapura was identified as the most critical weather condition to reduce the sunflower yield (less than 600 kg ha^{-1}); a unit increase in minimum temperature during reproductive period reduced the yield by 77.5 kg ha^{-1} in mustard crop under irrigated conditions at Jammu; yield of Chickpea decreased by 100 kg ha^{-1} with increase of maximum temperature by 2 °C during reproductive stage within the temperature range 27.2 to 33.8 °C at Faizabad; higher relative humidity during reproductive phase was found to be favourable for producing more seed yield of mustard while it was having detrimental effect during vegetative stage (Hisar); mean temperature above 18 °C during flowering to physiological maturity was found to be detrimental for chickpea yield at Jabalpur; based on long-term crop weather relation studies at Mohanpur, optimum transplanting window of *kharif* rice was identified as the period from last week of June to 1st week of July for all the varieties and delay in transplanting by 15 and 30 days reduced the yield by 670 and 920 kg ha^{-1}, respectively; a temperature range of 20.6 to 27.1 °C and 8.2 to 13.3 °C, for maximum and minimum temperature, respectively during the reproductive stage, were identified as optimum for producing wheat yield of 3500 kg ha^{-1} at Palampur; the thresholds of maximum and minimum temperature during anthesis were worked out to be 27.5 and 11.5 °C, respectively for attaining wheat yield of 4000 kg ha^{-1} at Ranchi; a mean temperature of 15.2 to 18.3 °C and 18.5 to 21.2 °C during heading to milk stage and milk to dough stage, respectively was found favourable for getting higher grain yield of wheat and an increase in mean temperature by 1.0 °C during reproductive phase of the crop caused reduction in

grain yield of about 554 kg ha^{-1} in wheat at Udaipur. (http://www.cropweatheroutlook.in/crida/amis/annualreport.jsp)

Crop growth modelling applications

Crop simulation models are very important tools for helping in devising different management strategies for increasing and sustaining the crop yields. It is also used to assess the impact of climate change on various crops and developing adaptation strategies for reducing yield losses. These models require the experimental field data and long-term weather data sets for their calibration and validation to simulate real world experimental results. These input files are called as Minimum Data Sets (MDS) which are required for all the crops. So far, the centers have developed these MDS, characterized the crop-specific genetic coefficients for models such as DSSAT, InfoCrop, APSIM etc. and came out with management practices for enhancing the yield levels of the crop.

Using the DSSAT CERES rice model and future climate change scenarios, a simulation was run for the four rice-growing regions of Eastern India, including areas of the IGP of India. At all four locations—Kanpur, Faizabad, Raipur, and Ranchi—the effects of climate change could be seen on rice yields. Because of the ecosystem of rainfed rice growth, Ranchi was found to have the highest yield loss in rice. With the exception of Ranchi, all of the locations saw an increase in rice yields when CO_2 levels rose. The type of rice grown in Ranchi is not sensitive to decreased CO_2 levels. Under rainfed conditions, rice's phenology may accelerate as a possible physiological mechanism to control source sink partitioning and achieve the highest feasible source strength and sink capacity. The ideal time to sow under potential future climate change scenarios can be determined by adjusting the date of sowings, which will boost productivity. (Subba Rao *et al.,* 2015).

Maize Model simulations were done based on the location specific data resources and analyzed district wise maize yields as well as CC impacts with future climate change scenarios at selected districts were simulated and compiled. Under RCP 4.5 and RCP 8.5, climate change might reduce maize yield by 16% (Tumkur) to 46% (Jalandhar) and 21% (Tumkur) to 80% (Jalandhar). Without any adaptation, the yield could only stay marginally higher or constant at Dharwad compared to the baseline period (1980-2009). (Subba Rao et al., 2022). The grain yield of rice, wheat and maize are likely to be reduced by 8.0 to 26.0%; 12.1 to 17.6%, and 4.1 to 19.1%, respectively as per A1B increasing temperature scenario (2020-2050) at Ludhiana; mustard yield simulated using Info-Crop model showed reduction by 450 kg/ha and crop maturity was advanced by 5 days with 1°C rise in temperature at Mohanpur; the effect of providing single day protective irrigation (50 mm) during dry spell (1-19 Sept 2016) in soybean under variable sowing windows at Akola was simulated using DSSAT and found to be more effective for delayed sowing condition and many more findings.

Weather effects on pests and diseases

The biotic stress on crops are seasonal and particularly weather based. When there is a congenial environment that favours certain pests and diseases, it spatially spreads and damage the entire crops in a location within no time. That is where the relationship studies of pest and diseases of crops with weather is one of the very important aspect for developing plant protection measures and also developing the forewarning systems. AICRPAM scientists are collaborating with entomologists and pathologists of their respective universities and are collecting the crop, pest and weather data at different stages during the crop season. With this information, centers have developed statistical equations for weather-pest relations, forewarning equations and thumb rules for different pest occurrence. Some of the information generated on different crops, weather and pests are on mustard aphids (Anand, Jammu, Palampur), groundnut leaf miner (Anantapur), flea beetle infestation in grapes, thrips and mealybug (Vijayapura), yellow rust of wheat (Jammu), pigeon pea pod borer (Faizabad), Karnal bunt of wheat (Hisar), white fly in cotton (Ludhiana, Hisar), leaf curl virus in cotton (Hisar), rice blast disease (Palampur), safflower aphid (Akola, Solapur) and safflower leaf spot (Solapur), sorghum shoot fly (Solapur) etc.

Agromet advisory services

Farmers require timely and accurate weather forecasts and advisories information to plan the operations and remedial measures to reduce the losses in farm produce due to aberrant weather conditions. Inputs (seeds, fertilizer, plant protection chemicals, etc.) as well as the entire crop can be saved when agromet advisories are delivered in a timely way (especially at the maturity stage). Agromet Advisory Service (AAS) is a part of extension Agrometeorology and is defined as "Agrometeorological and agro-climatological information that can be directly applied to improve and/or protect the livelihood of farmers". AICRPAM centres as part of GKMS program publishes AAS bulletins twice a week in local languages with the support of its cooperating centres across the nation. The dynamic web portal "Crop weather outlook" hosted by AICRPAM-CRIDA updates daily and weekly weather & crop information and Agromet advisories of the 20 states, where the AICRPAM centers are located in (http://www.cropweatheroutlook.in/). Apart from this, the coordinating unit at CRIDA in collaboration with 25 cooperating centres play a major role in issuing daily met sub-divisional rainfall charts, weekly Agromet advisories based on Extended Range Weather Forecasts, and monthly crop and weather bulletins for "NITI Aayog" on status of monsoon, progress in *kharif* sowing and AAS for deficit/excess rainfall areas of the country during the southwest monsoon.

Looking at the shortcomings of district-level Agromet advisory services, AICRPAM conceptualized and implemented a Micro-level Agromet Advisory Services (MAAS) on pilot mode in 50 selected villages across 20 states of the country in 2011. An Automatic Weather Station Network of ICAR at 100 locations across the country under AICRPAM-NICRA project was also established to enhance the accuracy and operational feasibility of block-level Agromet advisories. Further, several research outputs from AICRPAM's research themes are incorporated and enriched the Agromet Advisory bulletins. These scientific inputs and improved preparation processes attracted the country's leading weather provider IMD to collaborate with AICRPAM unit for developing National Agromet Advisory Services bulletin every week and also conceptualized and developed a DSS system for

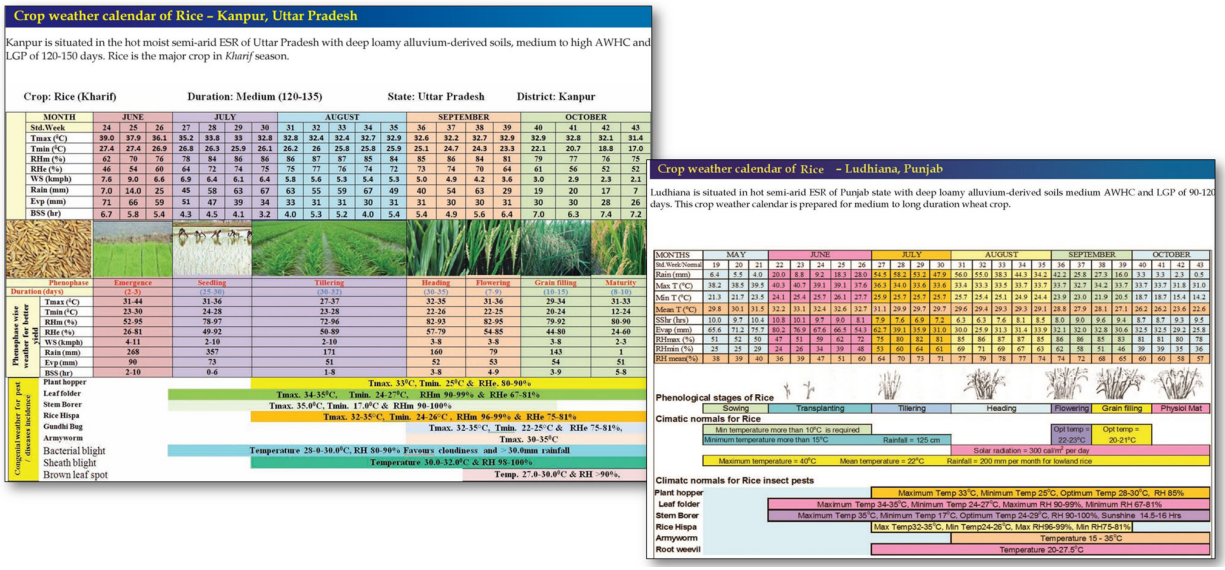

Fig. 2: District-level crop weather calendars prepared by AICRPAM

generating very precise information on sowing time of the crop, crop water requirements, LGP, Irrigation water requirements etc. AICRPAM unit and its cooperating centers are generating several reports and updating several ministries, high level functionaries, line department personals and most importantly the farmers.

Human resource development

AICRPAM unit at ICAR-CRIDA has conducted 37 national trainings on various Agrometeorological topics including Droughts, Crop weather calendars, crop simulation modeling, Extreme weather events, crop weather relationships etc. AICRPAM has also conducted a customized training program for Agriculture Insurance Company (AIC) personal on Agroclimatic inputs for crop weather Insurance. AICRPAM, ICAR-CRIDA has conducted One national training on crop simulation modeling inviting the international experts from University of Florida, USA was organized during 2013. AICRPAM enriches the knowledge of its scientist at cooperating centers by organizing the capacity building programs.

PRODUCTS DEVELOPED THROUGH COORDINATED RESEARCH

Agroclimatic atlases

The study of a region's climate, crop performance, and assessment of climatic variability and climate change and its effects on agriculture are all undertaken using agro-climatic analysis. Agro-climatic data is required for better agricultural planning, including land use, water resource availability, crop suitability, pest and disease control, and weather-based agro-advisories, to increase crop productivity. Knowledge on the site specific as well as agro-climatic region specific resources is crucial, if one is to produce a greater number of crops while utilizing agricultural resources sustainably. Therefore, having a good awareness of the climate would be helpful in choosing the best agricultural management techniques for maximizing the benefits of favourable weather and limiting the hazards associated with unfavourable weather. The project coordinating unit of AICRPAM has come up with an 'Agroclimatic atlas of Andhra Pradesh' in 2013. The atlas included general agricultural scenario, rainfall characteristics (distribution, trends in weekly, monthly, seasonal and annual rainfall), rainfall probability analysis, PET, drought probability analysis, estimation of length of growing period, trends in various weather elements etc. This served as a reference publication for cooperating centres of AICRPAM and so far, eleven agroclimatic atlases have been published by them.

Agrometeorology of crops

The data generated from long-term field experiment studies under AICRPAM was analyzed for establishing crop-weather relationships. The effect of weather parameters on crop phenology, growth, development and final grain/seed yield was quantified. It was published in the form of agrometeorology of crops by respective AICRPAM centres.

Crop weather calendars

A crop calendar was developed as a means to illustrate the sowing and harvesting windows for a crop in a particular area. Additionally, it offers details on seed rates, planting materials for sowing, and other agricultural management procedures. Crop calendars, however, did not include the "weather" component, which is essential for agricultural decision-making. By adding a weather component, the crop weather calendar (CWC) evolved from the crop calendar. The CWC is a visual depiction of data on sowing, phenological stages and their duration, harvesting time, typical weather factors during important growth stages, favourable time and weather conditions for pest and disease incidence, etc. of a specific crop or variety in a location. In general, CWC is suitable for crops sown on normal sowing dates, assuming that monsoon onset would be standard. As a result, it serves as a ready reckoner for farmers, assisting in the arrangement of timely inputs and crop management strategies for crop production. For India's major crops, the India Meteorological Department (IMD) has prepared district level CWCs decades back. Later, IMD revised it by incorporating

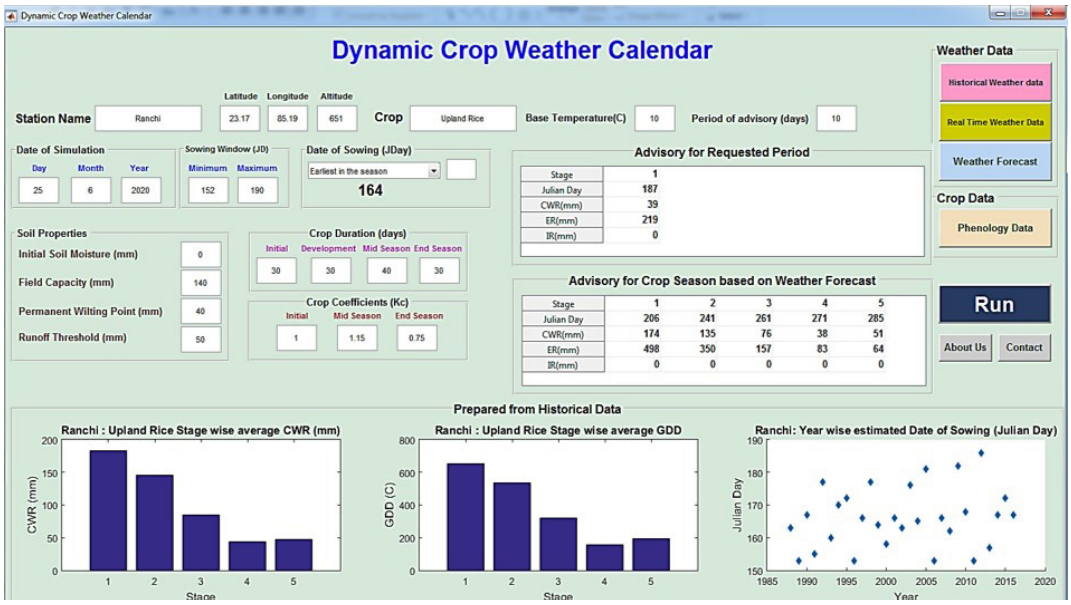

Fig. 3: Dynamic Crop Weather Calendar developed by AICRPAM

existing cropping patterns, soil types and conditions favourable for development of pests and diseases. In 2015, AICRPAM has prepared district level CWC for major crops in India (Rao *et al.,* 2015) (Fig.2). The improvements made in CWC prepared by AICRPAM, compared to that prepared by IMD were (i) optimum range of weather parameters during critical phenological stages of crop to achieve higher yield were identified using long term field experimental data of AICRPAM centers and (ii) optimum range of weather parameters for incidence of pests and diseases were quantified from long term experimental data.

SOFTWARE DEVELOPED THROUGH COORDINATED RESEARCH

Dynamic crop weather calendar (DCWC) a decision support system

There are numerous drawbacks to the current crop weather calendars produced by AICRPAM and IMD. For instance, they assume a regular onset of the monsoon, are static in nature, contain static management practises, and do not account for changes in sowing and harvesting dates according to the date of the onset of the monsoon, changes in crop phenology due to biotic and abiotic stresses, changes in cultivars, the current weather and weather forecast, etc. To address some of these issues, AICRPAM developed DCWC, in which algorithms for generation of sowing schedule, prediction of crop phenology based on historical and forecasted weather, computation of phenophases-wise crop water requirement etc. were included (Vijaya Kumar *et al.,* 2021). The developed modules were validated with long-term field experimental data of nine AICRPAM centres and the results are quite promising.

Agroclimatic onset of crop season (AOCS) delineator

As the success of rainfed crop production is highly dependent on timely sowing/planting decisions, to facilitate the technical personnel involved in decision making for optimizing the sowing window, a software was developed namely Agroclimatic Onset of Crop Season (AOCS) delineator. This software has inbuilt modules to determine optimum sowing window using three methods namely Soil Water Balance (SWB), Depth and modified Morris & Zandesta methods. The software also determines onset date using Modified Threshold Combination (MTC) method comprising 40 combinations of threshold values *viz.* rainfall amount, wet spell duration, dry spell duration and dry spell search period (Bal *et al.,* 2022b). The software is quite useful for improving practical utility/ decision making, especially in the semi-arid and arid regions of India.

Dry spell index (DSI) estimator

The dry spells within the crop season, along with cumulative rainfall deficit, play a vital role in determining the productivity of various rainfed crops in India. To estimate the cumulative impact of dry-spell on various rainfed crops, a new software was developed using the newly defined Dry Spell Index (DSI). The software was validated across major arid and semi-arid regions of the country using observed rainfall data of 1636 stations over six states of India. A comparison of DSI with Standardized Precipitation Index (SPI), hitherto, a widely used drought index was also carried out to assess the comparative performance of DSI over SPI and was found promising. The impact of DSI on yield of major rainfed crops *viz.,* cotton, groundnut, maize, pearl millet, pigeon pea and sorghum has also been estimated by employing appropriate statistical methods. From the correlation analysis of DSI and SPI, it was observed that the impact of number and duration of dry spells integrated in the form of DSI was higher in comparison to the influence of total rainfall indicated by SPI on yield of six major rainfed crops in India (Bal *et al.,* 2022c).

Weather cock

Weathercock is a software developed for carrying out the agroclimatic analysis. It has various features for data management

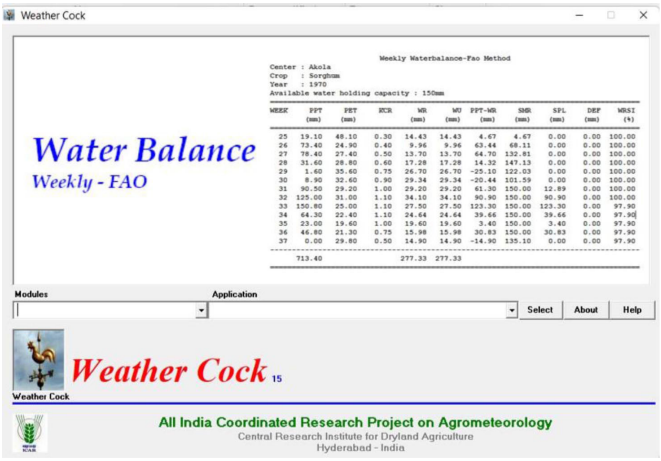

Fig. 4: The graphical user interface of Weather Cock software

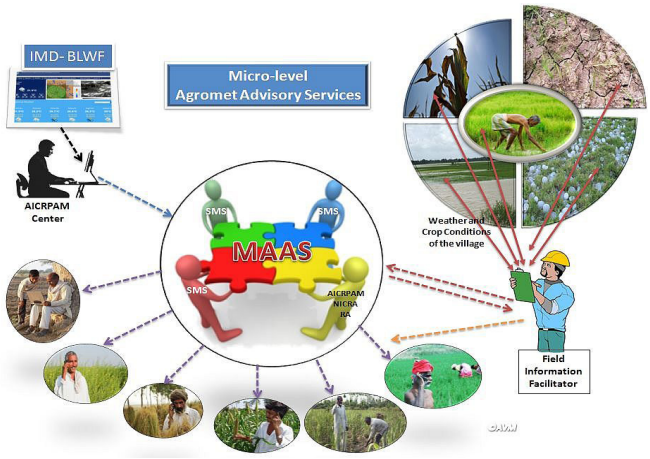

Fig.5: Conceptual diagram of block-level AAS

viz., date conversion, bulk file renaming, unit conversion, data quality checking, agricultural and meteorological drought analysis, rainfall probability analysis, analysis of extreme weather events like heat wave, cold wave, estimation of length of growing period, climatic water balance etc. (Rao, 2011). (Fig.4). This software is being used by many researchers and scholars across the world for carrying out agroclimatic analysis.

Meghdoot app

Scientists of the coordinated project on Agromet were actively involved and significantly contributed to the development of "Meghdoot" an android app along with ICRISAT, IITM and IMD. The app is being used by more than 4 lakh stakeholders to assess location-based forecast as well as district-wise Agromet advisories.

Support to agromet advisory services

The coordinated research project on agrometeorology has been acting as a technical support to the operational agromet advisory services (AAS). The Dynamic Crop Weather Calendar (DCWC), a Decision Support System developed by AICRPAM is being used by the SMSs of DAMUS/AFMUs to identify optimum sowing time and phenology prediction and presently being used in 75 districts of the country for preparing contents for AAS (DTE, 2022). The validity of blanket advisories disseminated at district level is under question as the variability in terms of crops, varieties, weather anomalies will be higher while issuing district level AAS. Further, issuing of block level forecasts by IMD enabled AICRPAM to think in an experimental way to develop and disseminate micro level AAS at block level with the help of AICRPAM cooperating centers and subject matter specialists of Krishi Vigyan Kendras (KVK). AICRPAM initiated block level AAS at Belgaum district of Karnataka with the help of its Vijayapura cooperating center. The conceptual diagram of block-level AAS developed by AICRPAM is presented in Fig.5.

Under this scheme, 50 villages across India received block level AAS on a pilot basis from AICRPAM facilities. The Krishi Vigyan Kendra (KVK) of that area receives block level weather forecast from IMD website through the scientific staff. Additionally, we developed a new concept of "Field Information Facilitator (FIF)", to act as the interface between the farmer, AICRPAM, and KVK for the collecting and transmission of agricultural information (growth stage, vigour, incidence of pests and diseases, etc.). Feedback from FIF offers an accurate picture of the situation at the village level, upon which AAS is built (Vijaya Kumar et al., 2017). As a result, the agrometeorologist at the AICRPAM centre uses SMS at KVK to generate agromet advisory bulletins that are distributed to farmers via FIFs and integrate field-level crop information with weather forecasts. AAS is developed under the name of the Program Coordinator, KVK, and distributed through a variety of communication channels, including voice and text SMS on mobile devices, display in public areas, personal contact, etc. The feedback from the farmers is being considered for service expansion and improvement for the benefit of the farming community. According on the crop and climatic conditions, the monitory benefits from this AAS range from a few hundred to a few thousand rupees per acre.

Contribution to crop insurance services

The project has contributed significantly in the development of various weather triggers for use in weather-based crop insurance and thresholds for assessing damage due to hailstorm, frost and pest-diseases using technologies in Pradhan Mantri Fasal Bima Yojana.

Contribution to human resource development in Agrometeorology

AICRPAM is supporting the research work undertaken by post-graduate and doctoral students of State Agricultural Universities (SAUs) in Agricultural Meteorology discipline across the country. The students make use of AICRPAM experimental fields, instrumentation and IT facilities to conduct their research to fulfill the requirement for degree. Apart from this, since the beginning, AICRPAM is a focal point for capacity building in agricultural meteorology. The project has conducted various training programs on different aspects of agrometeorology for faculty members, research scholars, technical staff and farmers at ICAR-CRIDA Hyderabad. Every year, PC unit of AICRPAM is also conducting capacity building program for the scientists of its cooperating centres where focused sessions on data analytics and product development are carried out (http://www.icar-crida.res.in/Newsletter/).

Creating farmers' awareness on climate change

The coordinated project is also conducting awareness programs for farmers to sensitize various aspects of climate change and its impact on agriculture. The feedback of farmers is also collected in these programs. As an example, during the last five years (2017-2022), AICRPAM has conducted 141 farmers' awareness programs on climate change, benefitting 14954 farmers across the country (http://www.cropweatheroutlook.in/crida/amis/annualreport.jsp).

WAY FORWARD

The man-made induced changes to the landscape and atmosphere have brought an increase in extreme weather events, causing serious concern for agriculture. In these scenarios, the focus of the coordinated research on agricultural meteorology should be to make more efforts in understanding the historical database, for analyzing to aid in crop planning, soil and water management strategies. This can be achieved by thorough characterization of extreme weather events causing decline in productivity; quantifying the climatic shifts including inter-seasonal and intra-seasonal variability of weather factors, its trends, that might provide clues on climate change and if possible the impact of such variability on crop production. In addition to this, the project also envisages to undertake evaluating suitability of long, medium and short-range weather forecasts for decision making in crop planning and management; better understanding of weather-pest relationships and developing support systems for agromet advisory services of the country. This will not only improve the livelihood of the farmers but also support the scientific personnel and policy makers for taking vital on-farm and off-farm decisions.

There is a need to reorient education in agricultural meteorology with major emphasis on interpretation of long, sub-seasonal, medium and short-range weather forecasts for formulation of advisories in different sectors of agriculture including crop production, animal husbandry, horticulture and fisheries. Major emphasis on research at post graduate level should be on development of regional specific problems that require agrometeorological interventions.

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