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Development of eAgromet Prototype to Improve the Performance of Integrated Agromet Advisory Service

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Abstract. In several countries, the systems for forecasting weather are being operated to deal with weather and its related factors affecting agricultural production. India meteorological department (IMD) is providing several types of weather forecasts. One of the forecast service is medium range forecast (MRF). As a part of MRF, the expected values of rain fall, temperature, cloud cover, humidity, wind speed and wind direction for next five days are forecasted twice a week by considering district as a unit. Agriculture is markedly affected by weather condition during crop season. IMD in collaboration with Indian Council of Agriculture Research (ICAR) and State Agriculture Universities (SAUs) has set-up about 130 Agro-meteorological Field Units (AMFUs) and each AMFU covers about five districts. Based on MRF, IMD is rendering Integrated Agromet Advisory Service to the farming community of the country in the form of agromet advisory bulletin. The agromet advisory bulletins contain possible risk mitigation measures for the major crops and livestock. Based on the weather forecast, a group of inter-disciplinary scientists and agromet scientists at AMFU prepare district-level agromet advisory bulletins. These bulletins are sent to the farmers and other stakeholders of the corresponding district. To ease the process of preparing agromet bulletins, an effort has started to build IT-based agrometeorological advisory system called, eAgromet. In this paper, we explain the concepts of eAgromet and its operation.

Keywords: agromet advice, agromet bulletin, risk management, farm management, extension service, agrometeorology, eAgromet, weather forecast.

1 Introduction

Governments are investing huge budgets and employing advanced computer information systems for weather forecast. The systems for weather forecast are

A. Madaan, S. Kikuchi, and S. Bhalla (Eds.): DNIS 2014, LNCS 8381, pp. 168–188, 2014.
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being operated to deal with adverse weather in general to the mankind and agriculture in particular. Over the years, the weather information and forewarning systems are gradually becoming powerful and location specific. India Meteorological Department (IMD) has started weather services for farmers in the year 1945. Currently, IMD is giving the following types of weather forecasts: nowcasting, very short range forecast, short range forecast, medium range forecast (MRF), and long range forecast. As a part of medium range forecast (MRF), from 1st June 2008, IMD has started issuing quantitative district level (612 districts) weather forecast up to five days, twice a week. The MRF comprise of quantitative forecasts for 8 weather parameters viz., rainfall, maximum and minimum temperatures, cloud cover, maximum and minimum relative humidity, wind speed and wind direction. In addition, weekly cumulative rainfall forecast is also provided. IMD generates MRF based on a Multi Model Ensemble Technique using forecast products available from number of models of India and other countries.

Economies of several countries are driven by agriculture and allied activities. Agriculture is significantly affected by weather condition. In India, based on MRF, IMD has launched the scheme "Integrated Agromet Advisory Service (IAAS)" in collaboration with different organisations/institutes to help farming community in carrying out weather-related farm management practices. As a part of this scheme, IMD is issuing agromet bulletins which contain risk management steps for crop and livestock management, based on the weather forecast twice in a week (Tuesday and Friday) up to 5 days. At present, Agromet advisories are being communicated to the farmers of the country through different modes of dissemination systems (Radio, TV, Newspaper, web portals, mobile phones, SMS etc.). IMD is also issuing both national and state-level agromet bulletins. The national- and state-level agromet advisory bulletins are mainly used for planning and resource distribution purposes. The district-level agromet advisory bulletins are prepared and disseminated for the benefit of the farmers of respective districts.

It can be noted that, the crop production systems are influenced by multiple factors such as soil type, crop, variety, location, weather and management practices. To improve crop productivity, farmers need integrated farm advice that consists of advice for crop protection and production problems and appropriate risk mitigation measures based on the weather pattern experienced and experiencing by the crop. The success of agricultural production depends on the degree of preventing/overcoming the ill-effects of crop production factors. Based on the prediction of weather and rainfall patterns, there is a scope to take suitable steps to improve the productivity and reduce the risk. Hence, early warnings based on weather forecasts can help farmers to adjust crop management strategies to minimize the impacts of malevolent climate and maximize the benefits of benevolent climate.

The agromet advisory bulletins provided by IMD are very unique and complements other efforts of improved agriculture technology transfer and agriculture extension methods.

To improve the process of preparing and disseminating agromet bulletins, an effort has been made to investigate the building of an IT-based system to ease the preparation of agromet bulletins, called eAgromet[1]. The main objective is to improve the efficiency of preparation and dissemination of agromet bulletins by exploiting the developments in agriculture, and information and communication technologies. The eAgromet prototype has been developed. In this paper, we explain the main concepts of eAgromet and operation methodology to prepare agromet bulletin.

In the next section, we explain the related work. In section 3, we explain the on going process of agromet advice preparation and dissemination process. In section 4, we explain the basic concepts of eAgromet system. In section 5, we explain the methodology to prepare agromet bulletin with eAgromet system. In section 6, we discuss the performance. The last section contains summary and conclusions.

2 Related Work

In India, the National Center for Medium Range Weather Forecast (NCMRWF)/IMD, Ministry of Earth Sciences is providing agro-meteorological advisory service based on the medium range weather forecast to the agriculture community on a regular basis. Starting from five units in 1991, NCMRWF/IMD has established about 130 agro-meteorological advisory units and subsequently IMD has taken over and started giving district-wise medium range weather forecast since June 2008. The impact analysis [10] has showed that the weather-based agro-meteorological service is able to reduce the cost of cultivation by 2 to 5 per cent. It was also observed that the advices have improved the yields of various crops. It was also suggested that there is a need to develop a computer-based decision support system, and automate the process of advice preparation and dissemination. The survey [18] regarding current status of agro-meteorological services in South Asia suggests the steps to improve the efficiency of agromet services. Several approaches and issues related to climate prediction and agriculture have been presented in [20].

The forecast of rainfall and temperature distributions can substantially contribute to increased agricultural productivity and farmer livelihood [9] [7]. The Agricultural Production Systems Simulator (APSIM) model developed in Australia has been widely accepted for climate risk management in Agriculture [8]. Efforts are being made to develop decision support systems to help farmers for better crop management based on weather dynamics. In [19], a system called AgClimate has been explained which is a web-based decision support system for minimizing climate risks to agriculture. CERES-Rice and WOFOST models were used to simulate the phenology and yield of low land rice in Telangana region of Andhra Pradesh [14] which helps in taking timely farm management

[1] *eAgromet* is the trademark of International Institute of Information Technology-Hyderabad (IIIT-H), Acharya NG Ranga Agricultural University, and India Meteorological Department.

decisions. Efforts have been started to develop content development framework to improve the process of agromet advice preparation [16]. A framework has been proposed for improving practical agricultural skills in [13].

In India, to resolve the crop protection and production related problems, Ministry of Agriculture, Departments of Agriculture, Agricultural Universities, Department of Electronics and Information Technology are making efforts to facilitate the advances in agricultural technology to reach farmers through print and electronic media; organizing seminars and gatherings; Web sites; and telephone. Some of efforts include, farmer portal [1], Kisan Call Centers [4], Digital Green [3], and eSagu [5] [6] [11] [12]. The development of eAgromet system was started in 2010 [15]. In this paper, we will explain the basic concepts of eAgromet and explain the process of agromet bulletin preparation with the usage of eAgromet software.

3 Description of Agromet Advice Service

Weather and climate information play a major role before and during the cropping season and if provided in advance can help farmers apply resources in order to take advantage of favorable conditions and mitigate potential losses in unfavorable ones. The agrometeorological inputs improve agricultural production both in quantity and quality. In an environment of increasing weather and climate variability under climate change, farmers are in greater need of agrometeorological information blended with weather sensitive management advisories before the start of cropping season to support adaptation of agricultural practices. In this context, agrometeorological advisories based on short and medium range weather forecasts become vital to stabilize yields through the management of agro-climatic resources as well as other inputs such as water, fertilizer and pesticides. The IAAS of IMD is intended to contribute to weather information based crop/livestock management strategies and operations dedicated to enhance crop production and food security. The main emphasis of the existing IAAS system is to collect and organize climate/weather, soil and crop information, and to integrate them with the weather forecast information to assist farmers in their management decisions.

3.1 Crop Phenophase, Climatic Normals, Weather Forecast and Agromet Advisory Bulletin

As a part of IAAS service, about 130 agrometeorology field units (AMFUs) operate in different parts of India. Each AMFU covers about five districts. The value added weather prediction values of each district are sent to the corresponding AMFU by the concerned regional meteorological units. The agromet experts at AMFU prepare agromet bulletin for each district.

We explain about the terms *crop phenopahse*, *climatic normals*, *weather forecast* and *agromet bulletin*.

Crop Phenopahse: The plant growth can be assessed as a function of completion of a series of phenophases (visible stages of development) that a plant must pass through if it is to grow (and reproduce) successfully. So, the crop growth can be divided into phenophases. Each phenophase duration is specified in number of days. The durations of phenophases may overlap. Based on the sowing date of the crop, we can determine the phenophase of a given crop.

Climatic Normals: Normally, agromet scientists understand the trends of both forecast and observed data and influence of crops and livestock, using the corresponding climatic normals. Climatologists define a climatic normal as the arithmetic average of a climate element such as temperature over a prescribed 30-year interval.

Weather Forecast: The weather forecast consists of the predicted values for the following variables concerning for each district: rain fall (RF), maximum temperature (Tmax), minimum temperature (Tmin), cloud cover (CC), maximum relative humidity (maxRH), minimum relative humidity (minRH), wind speed (WS) and wind direction (WD). The units of RF, temperature, CC, humidity, WS and WD are millimeter (mm), degree centigrade (deg C), octa, percent (%), kilometers per hour (KMPH), and degree (deg) respectively. The sample weather forecast for five days is shown in Figure 1.

Govt. of. India
India Meteorological Department.
Meteorological Centre, Airport colony,
Begumpet airport, Hyderabad 500 016

Value added forecast for next 5 days (Tabular form)
Period: 12-10-2011 TO 16-10-2011. ISSUED ON: 11.10.2011
BULLETIN NO. 81 District: Warangal

DISTRICT : WARANGAL	12/10	13/10	14/10	15/10	16/10
Rainfall (mm)	12	10	9	8	6
Max Temperature (deg C)	33	32	32	33	32
Min Temperature (deg C)	23	23	23	23	23
Total cloud cover (octa)	5	3	6	5	3
Max Relative Humidity (%)	88	87	87	86	86
Min Relative Humidity (%)	76	70	76	70	79
Wind speed (kmph)	3	4	5	3	4
Wind direction (deg)	110	100	140	160	220

Fig. 1. A sample weather forecast

Agromet Bulletin: The agromet advisory bulletin basically contains the information on weather and weather based advisories for crops and livestock. After receiving weather forecast for a given region, the agromet experts prepare the agromet bulletin based on the weather forecast, observed weather values of that region, crop stage and crop status. The agromet advice is prepared in the local language. The components of agromet bulletin are as follows.

- **Agro Meteorological Field Unit (AMFU) details:** Agromet bulletin is being prepared by agromet scientists of AMFU. So, the details of AMFU, unit details, date of forecast and advice valid period are provided.
- **Weather summary text:** The text regarding weather situation about observed weather (till forecast date) and forecast weather of next 5 days (after the forecast received date).
- **Agromet advisory for each crop:** For each major crop of the concerned region, the advice is prepared on the following aspects.
  - **Crop planning:** The advice about the influence of weather forecast on the choice of crop. Information on crop planning, selection of proper sowing/harvesting time etc. and relevant crop husbandry operations are included.
  - **Crop management advice:** After the identification of phenophase, the advice is prepared on how the change in the weather could influence field preparation, sowing/planting, irrigation scheduling, fertilizer application, weed management, pest and disease incidence, their virulence and management operations, harvest and post-harvest handling of crop produce etc.,
  - **Crop management under malevolent weather:** The advisories contain possible mitigation steps for extreme weather events such as extreme temperatures, heavy rains, floods, and strong winds etc. It should contain special steps for taking appropriate measures for saving the crop from malevolent weather are given.
- **Agromet advice for livestock:** The influence of weather forecast on the livestock health (for example, poultry, cattle and buffaloes) and the corresponding management steps are given.

A sample agromet bulletin is shown in Figure 2. It contains the details of AMFU, weather summary text, and weather-based advce for Rice, Cotton, and vegetables (Due to space constraints the advices for other crops have not shown). It also contains the agromet advice for livestock.

3.2 Process of District-Level Agromet Advisory Service

The process of district-level agromet advisory service is divided into four parts as shown in Figure 3.

i **Weather prediction by IMD (input):** The input to the system is the MRF at district level from the IMD, which is being received twice a week on Tuesday and Friday, for five days period. The AMFU receives weather forecast for each district covered by it.

ii **Preparation of agromet advisory bulletin.** To prepare the agromet bulletin, an expert committee consisting of scientists (specialists) from different agriculture disciplines meet on both Tuesday and Friday, and prepares the agro advisories for major crops based on the weather forecast, and existing weather conditions keeping in view the crop status. Agromet advices for

ACHARYA N. G. RANGA AGRICULTURAL UNIVERSITY
Agromet-Cell, Agricultural Research Institute, Rajendranagar, Hyd-30. WEATHER BASED AGRO ADVISORIES FOR THE WARANGAL DISTRICT FOR THE PERIOD ENDING 15.10.2011
(Till saturday morning)

Bulletin No. XVIII/77/2011 **Dt:11.10.2011**

During last 24 hrs, light rains occurred. The maximum temperature ranged between 36-37^{0}C and minimum temperature ranged between 22-23^{0}C. As per the forecast received from Meteorological Centre, Hyderabad, light to moderate rains may occur during coming four days. Winds may blow from North West direction with a wind speed of 3 to 5 km/hr. The maximum and minimum temperatures are likely to range between 32-33^{0}C and 22-23^{0}C, respectively.

WEATHER BASED AGRO-ADVISORIES

Rice

- Prevailing weather conditions are congenial for the incidence of brown plant hopper (BPH). Manage the pest by adopting the following measures.
  - Drain out the water from the field
  - Spray Ethofenprox @ 1.5 ml or Acephate @ 1.5 g or Buprofezin @ 1.6 ml per liter of water twice at 7-10 days interval
  - Direct the spray towards the base of the crop

Cotton

- Prevailing weather conditions are congenial for the incidence of aphids. To control,
  - Spray Monocrotophos @ 1.6 ml or Methyl Demeton @ 2ml or Acetamaprid @ 0.2g or Acephate @ 1.5 g per litre of water.

Vegetables

- Prevailing weather conditions are congenial for the incidence of Yellow Vein Mosaic Virus in bhendi. To control the white fly vector, spray Dimethoate @ 2 ml or Acephate @ 1.5 g per litre of water.

Cattle and Sheep

- Prevailing weather conditions are congenial for the occurrence of
  - Hemorrhagic Septicemia, Black Quarter, Foot and mouth disease in cattle,
  - ET and sheep pox in sheep

Principal Scientist (Agromet.)

Fig. 2. A sample agromet bulletin

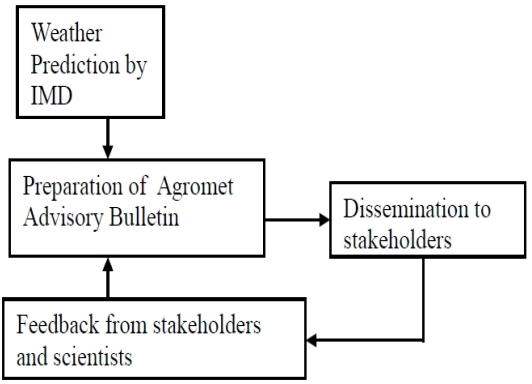


Fig. 3. Preparation of agromet bulletin and dissemination

livestock is also prepared. The agromet bulletin contains agromet advices for major crops and livestock.

iii **Dissemination to stakeholders:** The agromet bulletins are uploaded to web sites of IMD and circulated to press. In addition, the bulletins are disseminated to farmers through private television and radio channels, newspaper, mobile phone/SMS, Internet, farmer portal [1], non-governmental organizations, Kisan (Farmer) Call Centres/Indian Council of Agricultural Research and other related Institutes/state agricultural universities/state extension networks and Krishi Vigyan Kendra (KVKs).

iv **Feedback from stakeholders and scientists:** A group of scientists interact regularly with the farmers to get the feedback which will be used to refine the agromet advice.

4 Concepts of eAgromet

In this section, we explain the motivation and concepts of eAgromet.

4.1 Motivation

Preparation of agromet bulletin is the most important step in IAAS service. Currently, the agromet bulletin is being prepared manually. There are several issues with the existing process of preparation of agromet bulletins. The process is human dependent and consumes significant amount of human effort. There is a possibility of providing generic advice. It requires significant effort and coordination to cover all the crops. It is also difficult to prepare the agromet bulletin by considering several crop-, phenophase-, field-, and weather-specific dynamics at a given location and time.

The main motivation is to develop an IT-based system to ease the preparation of agromet bulletin preparation. For this, a system has to be developed to organize the agromet bulletins in a searchable and re-usable form. The objectives of eAgromet system are formulated as follows.

- The efficiency of the agromet bulletin preparation process should be improved.
- The agromet bulletins should be searchable and reusable.
- The system should be replicable, and
- The system should be simple to understand and operate.

4.2 Concepts of eAgromet

Agromet expert (or subject matter specialist) is a person who analyzes the forecast and observed weather values, and crops' (livestock) condition, and prepares agromet bulletin. It can be noted that the objective is to build an IT-based system to ease the process of agromet bulletin preparation. The system with eAgromet is depicted in Figure 4. The eAgromet system receives weather forecast from IMD through Internet. The agromet scientists access eAgromet and

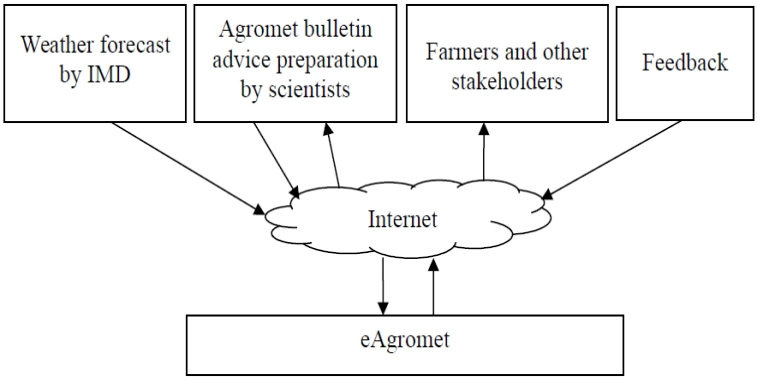


Fig. 4. Agromet Advisory Service with eAgromet

prepare agromet bullentins. The bulletins are delivered to stakeholders. The feedback is also entered into the system.

To develop eAgromet system, several interactive sessions were held with agromet scientists. It was identified that the following steps are being followed by agromet expert for preparing agromet bulletin.

- Comprehend the trend of forecast and observed weather data
  - Analyze the forecast weather data.
  - Analyze the observed weather data till date.
  - Analyze both forecast weather and observed weather data with reference to corresponding climatic normals.
- Prepare agromet advice for each crop by analyzing observed and forecast weather effects on the phenophase of the crops.
- Prepare the agromet bulletin by placing the AMFU details, weather summary, crop-wise agromet advices, and livestock-wise agromet advices.

For agromet scientists, the main issue is to understand the trend of observed and forecast weather, and corresponding influence on the crop and livestock. For this, we introduced the notion of *weather deviation* which will be elaborated as follows: Given the day of forecast, the agromet expert receives forecast values for next five days and observed weather values of the same parameters till the day of forecast. Next, the agromet expert analyzes the observed weather prior to the day of forecast and the forecast weather values and corresponding climatic normals. In other words, the agromet expert tries to comprehend (i) the trend of forecast weather as compared to observed weather (ii) trend of observed weather with reference to the corresponding climatic normals and (iii) trend of forecast weather with reference to the corresponding climatic normals. We call such notion as ***weather deviation***. After comprehending the weather deviation, agromet expert analyzes how the weather deviation affects the crops and livestock, and prepares the corresponding agromet advice.

In addition to weather deviation, we have also developed a component to find similar advice to ease the preparation of agromet advice for a crop and a module to generate weather summary. Overall we have developed three frameworks.

I A framework of weather deviation
II A framework to extract similar advice
III A framework to compute the weather summary

I. A Framework of Weather Deviation

The process of agromet bulletin preparation starts after receiving the weather forecast on some date. Let the notation *df* be the day of forecast, the notation *pd* be the past duration which is the number of days preceding to *df*, and the notation *fd* be the forecast duration. It was observed that the agromet scientists are analyzing the weather by calculating weather statistics week-wise. The day-wise values are also being examined based on the criticality.

At first, we define the term "weather statistics (ws)". Let d be the duration in days. The weather statistics for a duration d, ws(d) is given in Definition 1.

Definition 1: Weather statistics for a duration *d* (*ws(d)*): For each day, we receive values for RF, Tmax, Tmin, CC, maxRH, minRH, WS, and WD. The notation *ws(d)* is the statistics values for RF, Tmin, Tmax, CC, maxRH, minRH, WS, and WD over duration *d*, i.e., ws(d)=(s(RF), s(Tmin), s(Tmax), s(CC), s(maxRH), s(minRH), s(WS), and s(WD)). Here, the notation *s(x)* represents statistic parameter value which captures central tendency for the weather variable *x* for duration *d*. Note that appropriate function should be employed to compute the statistic parameter value. For Tmax, Tmin, CC, maxRH, minRH, WS, and WD, *s(x)* is equal to the mean value over duration *d*, whereas for RF, the *s(x)* represents the cumulative value over the duration *d*.

Given *df*, the change in the weather from *pd* to *fd* is captured through the notion of *weather deviation*. The notion of *weather deviation* is the key concept of the eAgromet system. The main issue is to develop a system to ease the comprehension of the vagaries of observed and forecast weather. We first define weather statistics based weather deviation. Next, we enrich the definition by including the aspect of climatic normals of weather variables. We define the final definition by including the notion of *weather categories*.

i **Weather statistics-based weather deviation:** Given df, the weather deviation is indicated by *wd(df)* which is equal to *<df, ws(pd), ws(fd)>*, where ws(pd) denotes the weather statistics of *pd* and *ws(fd)* denotes the weather statistics of the *fd*. Note that the *df* is included in fd. The past duration is divided into 7 days intervals and *ws* is computed for each interval. By replacing *ws(pd)* with "ws(-n),.., ws(-2), ws(-1)", the *wd(df)* is defined as follows. *<df, ws(-n),.., ws(-2), ws(-1), ws(fd)>*. Here, ws(-n) indicates the weather summary of n'th previous week with reference to *df*.

So, the weather deviation captures the trend of observed weather values over several weeks prior to df and the trend of forecast weather values.

ii **Normals-based weather deviation:** It was observed that the agromet scientists compare the weather values with the corresponding climatic

normals. So, it is possible to improve the understanding of weather deviation by providing the corresponding weather normals. So, the agromet scientist understands the vagaries of weather and corresponding effects on crops and livestock in a better manner, if the corresponding normal values are shown as a part of weather deviation.

The definition of normals-based weather deviation is as follows. Let *cn(d)* indicates the climatic normals for duration *d*. Let the past duration is divided into 7 days intervals. The definition of weather deviation for a given *df* is as follows: wd(df): *<df, {ws(-n), cn(-n)},.., {ws(-2), cn(-2)}, {ws(-1), cn(-1)}, {ws(fd), cn(fd)}>*. Here, *ws(-n)* indicates the weather statistics of n'th previous week with reference to df and *cn(-n)* indicates the climate normals of n'th previous week.

iii **Category-based weather deviation:** With *normals-based weather deviation*, the agromet expert can improve the understanding by analyzing observed and forecast weather with the corresponding climatic normals.

We introduce the notion of category to comprehend the weather deviation in a better manner. It was observed that the agromet expert does not give different advice unless a weather value changes to a considerable extent, For example, the agromet expert does not give a different advice for a small change, like 0.2 degree centigrade, in temperature value, or small change, like 2 per cent, in humidity value. Also, having real values for weather parameters for weather statistics and climatic normals, it is difficult to compare weather deviations and build a system to extract similar weather deviations and corresponding agromet advices.

We have improved the definition of weather deviation based on the notion of *category*. For agromet expert, it is relatively easy and quick to grasp the dynamics of change through categories in the weather values over several weeks. Also, the notion of tags ease the comparison of weather deviations by a software system.

Category or tag: For each weather variable, we divide the domain of that weather variable into different classes. Each class is termed as a category or a tag. The tag is a description/name of that class. For example, the domain of temperature can be divided into: VERY COLD, COLD, PLEASANT, HOT, MORE HOT and so on. Similarly, each other weather parameter is divided to different categories.

Note that, as agromet expert is involved in the preparation of agromet bulletin, the tags have been defined such that agromet expert comprehends the weather and then extends how the weather deviation will influence the crops or livestock. Alternatively, the tags can be defined by considering each crop/livestock. It will enable the building of automatic agromet advisory system which will be investigated as a part of future work.

By incorporating the notion of categories, we define the notion of *category-based weather summary* which is as follows:

Category-based weather statistics for a duration *d* (cws(d)): For each day we receive values for RF, Tmin, Tmax, CC, maxRH, minRH, WS,

and WD. Let *c(s(x))* be the category of the weather statistics of weathr variable x over duration *d*. For example, let the mean value of Tmin over one week is equal to 16 degree centigrade. So, s(Tmin)=16. Then, if this is classified as COLD, then c(s(Tmin))=COLD. The values of other variables are mapped to the corresponding categories. To design eAgromet prototype system, the tags[2] have been assigned to all weather variables (refer Table 1). Given the weather variable value, the corresponding tag could be obtained from Table 1. The cws(d) is equal to *<c(s(Tmin)), c(s(Tmax)), c(s(RH)), c(s(RF)), c(s(R)), c(s(WS)), c(s(WD))>*.

Based on the definition of category-based weather statistics, we define the final definition of weather deviation as follows. Normally, given the weather forecast, the *wd* helps to comprehend the dynamics of forecast weather and observed weather of one or several past weeks.

Definition 2. Weather deviation: Let cn(d) indicated the climatic normals for duration *d*, *ws(d)* indicates the weather statistics, *cws(d)* indicates the category of corresponding weather statistics, *ccn(d)* indicates the category of climatic normals. The definition of *wd(df)* for a given df is as follows: *<df, {ws(-n), cws(-n), cn(-n), ccn(-n)},.., {ws(-2), cws(-2), cn(-2), ccn(-2)},.., {ws(-1), cws(-1), cn(-1), ccn(-1)}, {ws(fd), cws(fd), cn(fd), ccn(fd)}>*. Given *df*, the past duration is divided into 7 days intervals. Also, both *ws* and *cws* are computed for each 7 days interval. The notations ws(-n), cws(-n), cn(-n), and ccn(-n) indicates the weather summary, category-based weather summary, climatic normals and category of weather normals of n'th previous week respectively.

So, for each variable, the weather deviation shows the corresponding statistics value, summary tag, normal value and normal tag for several preceding weeks and forecast duration. Based on the age of the crop, the agromet expert can easily comprehend the influence of weather deviation on the crop situation and prepare the agromet advice for the corresponding crop by applying the agro-climatic expertise. The example of weather deviation is shown in Figure 6.

II. A Framework to Extract Similar Advice

In addition to weather deviation, another important concept which is being developed is **the module to extract similar advice**. It is expected that, the eAgromet system is populated with several agromet advices of multiple crops attached with corresponding weather deviations. The data of agromet advices are maintained in the eAgromet system, in the following form: *<crop and location, wd, weather summary, agromet advice>*. After receiving the weather forecast and observed weather values, the *wd* is formed. Based on the crop, location, weather summary and wd, the module extracts similar agromet advices and displays as per the rank order. The agromet expert can select the agromet advice and make the modification, if required.

[2] The tags have been assigned by the design team to develop eAgromet.

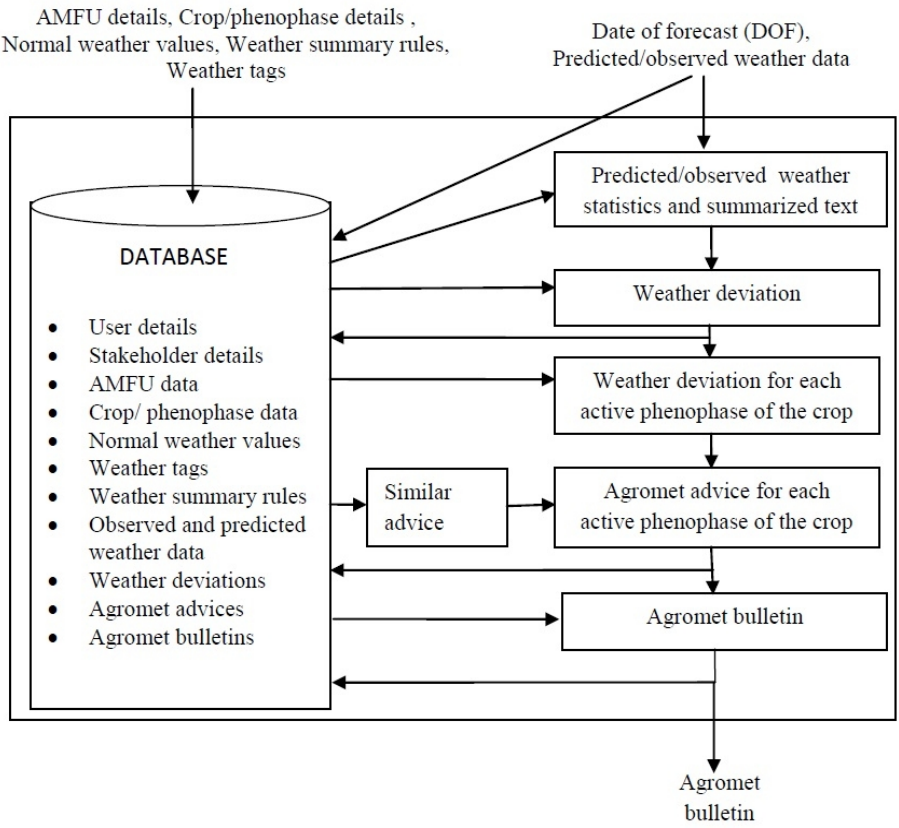


Fig. 5. Steps of agromet bulletin preparation with eAgromet. Here, the arrow indicates the data flow and rectangles indicates the processes. The DATABASE indicates several types of data maintained by the system. The process starts with the entering of forecast weather and observed weather for the region. The system facilitates the preparation of weather statistics and summary, weather deviation, crop-specific agromet advice and agromet bulletin. The agromet bulletin is disseminated to stakeholders.

III. A Framework to Compute the Weather Summary

Agromet bulletin contains weather summary and major crop- and livestock agromet advices. We have already explained how the notion of weather deviation and the method to extract similar advice have been developed to ease the process of agromet advice preparation. In addition, we have also added a module to compute weather summary based on weather summary rules.

Based on the weather summary rules, the system selects the summary sentences to form weather summary. The agromet expert can modify, if necessary. The rules[3] for forecast rain fall are given in Table 2 and the rules for observed rain fall are given in Table 3. The rules for temperature are given in Table 4. The

[3] It can be noted that these rules were developed by the design team to build eAgromet prototype. These rules were not standardized by India Meteorological Department.

Table 1. Tags for weather variables. For each weather variable, the tags were assigned which are self explanatory.

Tag Type	Range	Description (Tag)
Rain Fall (mm)	0–0	No Rain (NR)
	0.1–2.4	Very Light Rain (VLR)
	2.5–7.5	Light Rain (LR)
	7.6–35.5	Moderate Rain (MR)
	35.6–124.4	Heavy Rain (HR)
	124.5–244.4	Very Heavy Rain (VHR)
	$\geq$ 244.5	Extremely Heavy Rain (EHR)
Temperature (°C)	$\leq$-5	Freezing (F)
	-5– -3	Extreme chill-5 (ECH5)
	-3– -1	Extreme chill-4 (ECH4)
	-1–1	Extreme chill-3 (ECH3)
	1–3	Extreme chill-2 (ECH2)
	3–5	Extreme chill-1 (ECH1)
	5–7	Very chill (VCH)
	7–9	More Chill (MCH)
	9–11	Chill (CH)
	11–13	Very Cold (VCOLD)
	13–15	More Cold (MCOLD)
	15–17	Cold (COLD)
	17–19	Very Cool (VCOOL)
	19–21	More Cool (MCOOL)
	21–23	Cool (COOL)
	23–25	Cool & Pleasant (CP)
	25–27	Pleasant (P)
	27–29	Warm & Pleasant (WP)
	29–31	Warm (Wa)
	31–33	More Warm (MW)
	33–35	Very Warm (VW)
	35–37	Hot (Ho)
	37–39	More Hot (MH)
	39–41	Very Hot (VH)
	41–43	Extreme Hot1 (EH1)
	43–45	Extreme Hot2 (EH2)
	45–47	Extreme Hot3 (EH3)
	47–49	Extreme Hot4 (EH4)
	49–50	Extreme Hot5 (EH5)
	$\geq$ 51	Unbearable Hot (UH)

Weather Tags

Tag Type	Range	Description (Tag)
Relative-Humidity (%)	0–30	Low (L)
	31–60	Moderate (M)
	61–80	High (H)
	$\geq$ 81	Very high (VHi)
Cloud-Cover (Okta)	0–2	SKY Clear (SC)
	3–5	Partly Cloudy (PC)
	6–7	Mostly Cloudy (MC)
	7–8	Cloudy (C)
Wind-Direction (Degrees)	1 –20	North North East (NNE)
	21–50	North East (NE)
	51–70	East North East (ENE)
	71–90	East (E)
	91–110	East South East (ESE)
	111–140	South East (SE)
	141–160	South South East (SSE)
	161–180	South (S)
	181–200	South South West (SSW)
	201–220	South West (SW)
	221–250	West South West (WSW)
	251–270	West (W)
	271–290	West North West (WNW)
	291–320	North West (NW)
	321–340	North North West (NNW)
	341–360	North (N)
Wind-Speed (kmph)	0–0.9	Calm (Ca)
	1–5	Light Air (LA)
	6–11	Light Breeze (LB)
	12–19	Gentle Breeze (GB)
	20–28	Moderate Breeze (MB)
	29–38	Fresh Breeze (FB)
	39–49	Strong Breeze (SB)
	50–61	Near Gale (NG)
	62–74	Gale (G)
	75–88	Strong Gale (SG)
	89–102	Storm (St)
	103–117	Violent Storm (VS)
	$\geq$ 118	Hurricane (Hu)

Table 2. Weather summary rules for forecast rain fall (RF)

MinRF	MaxRF	RF Summary
0	0	Dry weather may prevail in coming five days.
0.1	2.4	Possibility of light rain at one or two places.
0.5	1	Light rains may occur in coming five days.
1.1	3	Light to moderate rains may occur in coming five days.
7.6	12	Moderate rains may occur in coming five days.
7.6	30	Moderate to rather heavy rains may occur in coming five days.
30	50	Rather heavy rains may occur in coming five days.
50	100	Heavy rains may occur in coming five days.
100	120	Very heavy rains may occur in coming five days.

rules for wind direction and wind speed are given in Table 5. The rules for cloud cover are given in Table 6. The sample weather summary generated is shown in Table 7.

Table 3. Weather summary rules for observed rain fall (RF)

MinRF	MaxRF	RF Summary
0	0	During last week Dry Weather prevailed in the district.
0.1	2.4	Light rain at one or two places.
2.5	7.5	Light rain at some places.
7.6	12	Light rain at most of the places.
20	30	Moderate rainfall.
30	50	Heavy rainfall.
50	100	Rather heavy to very heavy rainfall.
100	120	Very heavy rainfall at many places.

Table 4. Weather summary rules for temperature and relative humidity to the forecast and observed period. Here, '*' indicates the value and 'Deg.C' indicates the degree centigrade.

Weather Parameter	Summary
Temperature Forecast	Next week, the minimum and maximum temperature range between * and * Deg.C.
Temperature Observed	Last week, the minimum and maximum temperature ranged between * and * Deg.C.
Relative Humidity Forecast	The minimum and maximum relative humidity range between * and * %.
Relative Humidity Observed	The minimum and maximum relative humidity ranged between * and * %.

Table 5. Weather summary rules for wind speed (WS) and wind direction (WD). Here '*' indicates the mean value of WS. The rules to generate summary for forecast and observed period are the same, except that we use the word 'blow' in stead of 'blew' for the forecast period.

MinDeg	MaxDeg	Direction Summary
0	50	North-Eastern winds blew (blow) at a speed of * kmph.
51	90	Eastern winds blew (blow) at a speed of * kmph.
91	140	South-Eastern winds blew (blow) at a speed of * kmph.
141	180	Southern winds blew (blow) at a speed of * kmph.
181	220	South-Western winds blew (blow) at a speed of * kmph.
221	270	Western winds blew (blow) at a speed of * kmph.
271	320	North-Western winds blew (blow) at a speed of * kmph.
321	360	Northern winds blew (blow) at a speed of * kmph.

Table 6. Weather summary rules for cloud cover (CC). The rules to generate summary for forecast and observed period are the same, except that we use the word 'may prevail" in stead of 'prevailed" for the forecast period.

MinOkta	MaxOkta	Cloud Cover Summary
0	2	The clear sky weather prevailed (may prevail).
3	5	The partly cloudy weather prevailed (may prevail) The clear sky prevailed.
6	7	The mostly cloudy weather prevailed (may prevail).
7	8	The cloudy weather prevailed (may prevail) The clear sky may prevail.

Table 7. A sample of weather summary computed by eAgromet. It contains observed weather data for 7 days and forecast weather data for 5 days. The summary is generated by the system based on the weather summary rules provided in Table 2, 3, 4, 5.

Date	RF (mm)	Tmax (^oC)	Tmin (^oC)	CC (Okta)	maxRh (%)	minRh (%)	WS (kmph)	Wd (degrees)
Observed Weather Data								
17/Dec/2013	0	31.5	11.8	0	88	64	1.8	0
18/Dec/2013	0	31.0	12.4	0	91	64	2.2	20
19/Dec/2013	0	30.0	13.0	0	90	71	2.0	0
20/Dec/2013	0	29.8	13.8	0	91	64	1.9	0
21/Dec/2013	0	29.8	10.0	0	86	80	1.8	0
22/Dec/2013	0	28.0	9.0	0	92	85	2.5	20
23/Dec/2013	0	29.0	14.9	0	84	78	4.0	360
Forecast Weather Data								
24/Dec/2013	0	29	14	0	56	31	4	197
25/Dec/2013	0	28	14	0	43	34	5	163
26/Dec/2013	0	27	13	0	44	26	5	64
27/Dec/2013	0	29	15	1	59	30	5	260
28/Dec/2013	0	27	14	0	47	28	6	64
Observed Weather Summary								
During last week Dry Weather prevailed in the district. The minimum and maximum temperature ranged between 9.0-14.9 and 28.0-31.5 Deg.C. The minimum and maximum relative humidity ranged between 64.0-85.0 and 84.0-92.0%. North-Eastern winds blew at a speed of 1.8-4.0 kmph.								
Forecast Weather Summary								
As per the forecast received from IMD, Ahmedabad, Dry weather may prevail in coming five days. The minimum and maximum temperature range between 13.0-15.0 and 27.0-29.0 Deg.C. The minimum and maximum relative humidity range between 43.0-59.0 and 26.0-34.0%. Eastern winds blow at a speed of 4.0-6.0 kmph.								

5 Preparation of Agromet Bulletin with eAgromet

The notions of weather deviation, module to extract similar advice, weather summary text generation are the important concepts in eAgromet. In addition,

the eAgromet system contains several types of databases. The process of agromet bulletin preparation with eAgromet system and the corresponding data details are given in Figure 5. Here, the term *region* indicates the area for which weather forecast is received and agromet bulletin is being prepared. Currently, *region* indicates the *district* (administrative unit) in India.

The following are the steps to be followed for preparing agromet bulletins.

i Fill the region and crop details
ii On receiving weather forecast, follow the steps below to prepare the agromet advice.
  (a) Preparation of weather statistics and weather summary text.
  (b) Preparation of weather deviation
  (c) Preparation of agromet advice for each major crop, and major livestock
  (d) Preparation of Agromet bulletin

The details of each step are discussed as follows.

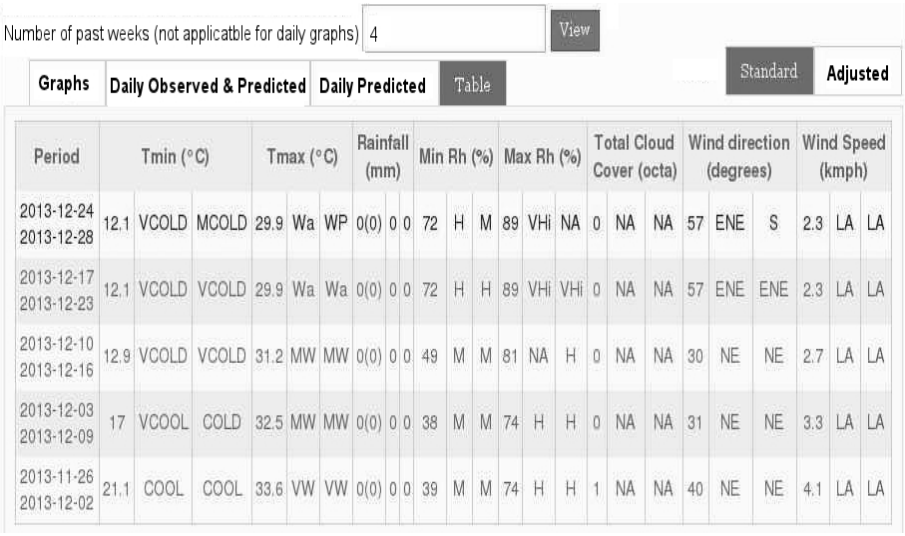
i **Fill the region and crop details.** The following details are entered into the system.
  – **AMFU details:** The name and address of AMFU, details of the districts, details of scientists and stakeholders, and agro-climatic information and user information.
  – **Crop/phenophase data:** Details of crops and the details of corresponding phenophases. Details of livestock are also entered.
  – **Observed weather data:** The observed weather data of the concerned region is being entered.
  – **Normal weather data:** The climatic normals of weather parameters for each district.
  – **Weather tags:** Details of weather categories employed in the prototype are given in Table 1.
  – **Weather summary text rules:** The rules for generating weather summary. The rules developed for the prototype are given in Figure 2, 3, 4, 5

ii(a) **Preparation of weather statistics and weather summary text:** After receiving the weather forecast data and observed weather data for a given region, it is entered into the database. For the forecast data, five day weather statistics is prepared. It is nothing but the mean values of Tmax, Tmin, CC, maxRH, minRH, WS and WD and cumulative value for RF. For the observed data weather statistics for 7 day period preceding to df is prepared. In addition, based on weather summary rules, weather summary is computed and shown to agromet expert for further editing/processing. The sample weather summary produced is shown in Table 7.

ii(b) **Preparation of weather deviation:** The weather deviation is computed as per Definition 2. Through weather deviation, the agromet expert can comprehend (i) weather phenomena prior to df and during forecast period and (ii) the deviation of weather with reference to the corresponding climatic normals. The tags help the agromet expert to comprehend the

weather deviation. The weather deviation is stored in the database. A sample weather deviation is shown in Figure 6.

ii(c) **Preparation of agromet advice for each crop, and each livestock:** After forming weather deviation, the agromet expert prepares the agromet advice for each crop and livestock. Given a crop and weather deviation, the *similar advice* tool extracts the similar advices from the repository of agromet advices. By comparing the region, crop, phenophase and weather deviation, the system displays the possible similar advices starting from most similar advice. The agromet expert can select the similar advice and carry out appropriate modification. The prepared advice is stored in the database.


Number of past weeks (not applicatble for daily graphs) 4 View

Graphs | Daily Observed & Predicted | Daily Predicted | Table | Standard | Adjusted

Period	Tmin (°C)			Tmax (°C)			Rainfall (mm)			Min Rh (%)			Max Rh (%)			Total Cloud Cover (octa)			Wind direction (degrees)			Wind Speed (kmph)		
2013-12-24 2013-12-28	12.1	VCOLD	MCOLD	29.9	Wa	WP	0(0)	0	0	72	H	M	89	VHi	NA	0	NA	NA	57	ENE	S	2.3	LA	LA
2013-12-17 2013-12-23	12.1	VCOLD	VCOLD	29.9	Wa	Wa	0(0)	0	0	72	H	H	89	VHi	VHi	0	NA	NA	57	ENE	ENE	2.3	LA	LA
2013-12-10 2013-12-16	12.9	VCOLD	VCOLD	31.2	MW	MW	0(0)	0	0	49	M	M	81	NA	H	0	NA	NA	30	NE	NE	2.7	LA	LA
2013-12-03 2013-12-09	17	VCOOL	COLD	32.5	MW	MW	0(0)	0	0	38	M	M	74	H	H	0	NA	NA	31	NE	NE	3.3	LA	LA
2013-11-26 2013-12-02	21.1	COOL	COOL	33.6	VW	VW	0(0)	0	0	39	M	M	74	H	H	1	NA	NA	40	NE	NE	4.1	LA	LA

Fig. 6. A sample weather deviation computed by eAgromet system. The notation 'NA' indicates 'not applicable'. It means that the value is not entered. The date of forecast is 24-12-2013. The first column shows the period and the other columns show the weather parameters: Tmin, Tmax, Rainfall, minimum RH, maximum RH, Total cloud Cover, Wind Direction and Wind Speed. The table contains five rows. The first row shows the weather statistics for the forecast period till 28-12-2013. Each of the other four rows show the weather statistics for the observer weather for past four weeks (the number of past weeks can be changed based on the requirement) preceding to the date of forecast. Except rainfall variable, the values for other variables are displayed in three columns as per the following order: <mean value of the weather parameter, weather statistics tag, weather normal tag>. The meaning of tags are given in Table 1. The rainfall values are displayed as the following order: <cumulative value of rainfall (the number of rainy days), normal value of cumulative rainfall, number of normal rainy days>. In addition, tools are provided to visualize the weather through *graphs* focusing on daily values and forecast values.

ii(d) **Preparation of Agromet bulletin:** The agromet bulletin is prepared by combining weather summary text and agromet advices of crops and livestock. The document is stored in the database which will be disseminated to stakeholders. The agromet bulletin for a given region is the combination of advices of the crops in that region. Based on df, the weather deviation is formed and advices for all crops have been entered. Based on df and region, all the advices are combined in an appropriate manner for forming the agroment bulletin.

6 Performance

The eAgromet prototype was developed. About 30 agromet scientists were given training for delivering agromet bulletins with eAgromet. On an average hitherto they were taking about two to three hours for preparing one agromet bulletin manually without eAgromet. They have felt that the preparation time can be reduced to 30 minutes to one hour with eAgromet. The agromet scientists have felt that the weather summary facility, and similar advice facility are the important contributors for reducing the advice preparation time. They have also felt that the system could improve quality of agromet bulletins.

7 Conclusions

India Meteorological Department is operating Integrated Agromet Advisory Service based on medium range weather forecast. It is being delivered for five days to each district and the corresponding agromet bulletin, which consists of agromet advices for major crops and livestock of that district, is disseminated to farming community to reduce the risk due to the vagaries of weather. An effort has been made to investigate the building of IT-based system to improve the efficiency of agromet bulletin. In this paper, we have explained the prototype of eAgromet, which is an IT-based agro-meteorological advisory system, to improve the process of agromet bulletin preparation. The concepts of weather deviation, similar agromet advice, and weather summary were conceived in eAgromet. The agromet experts have prepared the agromet bulletins using the prototype. The overall feeling by agromet experts is very positive. The system is very easy to use and can be deployed in any region. The agromet experts can prepare the agromet bulletins in the local language without any difficulty. The system is able to display the similar advice.

As a part of future work, we will make an effort to refine the prototype by taking into account all types of crops and livestock. By investigating the framework for crop-specific content development including the steps to deal with extreme weather events and contingency plans, we will also make an effort to minimize the human intervention for preparing agromet bulletin. Currently, IMD is planning to deliver agromet bulletins based on block-level weather forecast. We will make efforts to scale eAgromet for delivering block-level bulletins by minimizing human intervention and cost.

It is hoped that, for a given crop and region, after developing agromet bulletins for a few years, the effort to prepare new agromet bulletin could be reduced significantly due to efficient search. The agromet advice along with weather deviation and weather summary is a complex document which is prepared in local language. We are planning to investigate intelligent approaches to extract similar agroment advices for a given weather deviation and crop.

In the eAgromet prototype, we have defined the tags such that agromet expert could comprehend the weather trend and is able to prepare the agromet advice by analyzing how the weather deviation will influence the crop or live stock. Alternatively, the tags could be defined by considering each crop/livestock. For this, we will make an effort to build the system by considering cardinal weather values for all crops and livestock and define crop-specific tags. It will enable the building of intelligent agromet advisory system.

In addition to MRF, India Meteorological Department is also giving the following weather forecasts: now-casting, very short range forecast, short range forecast, and long range forecast. It is interesting to explore the building of eAgromet systems to deliver advisory information to farmers based on other types of weather forecasts.

Acknowledgements. The work is carried out as a part of the research project entitled "eAgromet: ICT-enabled Integrated Agro-Meteorological Advisory System" funded by India Meteorological Department/Ministry of Earth Sciences.

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