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Weather – Agriculture – History

Unity in variety is the plan of universe. If it be true that God is the centre of all religions and that each of us is moving towards him along one of these radii, then it is certain that all of us must reach that centre, where all the radii meet, all our differences will cease.

- Isopanishad

1.1 Introduction

Human being (*Homo sapiens*) has been on the earth for approximately 2 million years. He has been a hunter gatherer for 99.5 percent of existence and this period is considered as the most successful. Only, 12,000 years ago he started domesticating plants and recognized weather as the most precious natural resource. He managed environments in which he lived for generations by following environmental friendly agricultural practices and without significantly damaging local ecologies. This indicates that Indigenous Technical Weather Knowledge (ITWK) has immense potential to manage the risks of climate change. However, in the past 200 years of scientific agriculture there has been an over exploitation of natural resources and the environment has degraded. Therefore, it could be deduced that even in the present day scientific era alternative ways of managing resources could be made by blending this knowledge with modern techniques of managing risks and uncertainties.

History unveils that the genesis of agriculture in Asia as a means of sustaining human life can be traced back to 10,000 BC. However, in the absence of written records about the beginning of agriculture in the prehistoric Asia, one has to depend on archeo-botanical materials obtained during several archaeological excavations conducted in Asia. According to a study, 1700 BC to 1700 AD had been very important for Indian agriculture. It was observed that the Almanacs (Panchanga) have been extensively used for rainfall forecasting and the hand written panchanga of early 17th century and later periods are available in some Asian libraries.

1.2 History of Ancient Indian Agriculture with Reference to Agricultural Meteorology

- **From 10000–7500 BC:** During droughts the tribes of Central India domesticated 165 edible plants, ate seeds of 31 plants and 19 tuber crops while using honey for sugar
- **From 7500–3000 BC:** The Vedic Indo Aryan scholars composed Rig Veda (3700 BC) in which it was mentioned in 3 hymns on rain God that strong monsoon winds blows over India. Also, several observations on rainfall were recorded. It was also mentioned that 'Sun' is purifier and protector of everything on earth and provides 'Light' by which this world feed all living organisms. "Sun" in the form of fire has divided seasons characterized by heat, rain and cold. In summer, water goes up and in rainy season it comes down
- **3000–100 BC:** During this period domestication of plants and animals gave "Food Security". During 3000–1700 BC in Western India a pre-historic large mud-embankment was constructed on "Ghod" river to store flood water. Atharvana Veda (2000 BC) and Ramayana (2000 BC) mentioned about rainfall and its prediction in several versus. In 300–400 BC, "Krishi – Parashara" a very ancient and profound treatise in Sanskrit on agriculture was composed by sage Parashara which threw new insights into ancient Indian knowledge of astrology based prediction of rainfall, describing the concept of clouds and rainfall. He took the help of ruling and minister planets to estimate the sufficiency of rains in a year. He concentrated on visible causes of rainfall i.e., clouds and described four different types of clouds which differ from each other by the type of rain shed by them. The type of clouds was identified first and the amount of rainfall that the particular type of cloud would shed during that year was estimated. Susrutha (400 BC) wrote that proper season helps the emergence of strong and non-diseased sprouts. In Kautilyas Arth-Shastra (321–296 BC) there was a mention about the distribution of rainfall in different parts of India.

He also suggested that seed grains shall be exposed to night mist and day heat for seven consecutive days for better germination

- **100 BC–600 AD:** During 100 BC to 200 AD several methods of crop cultivation based on rainfall and seasons were revealed by several proverbs, village songs etc. Six seasons were mentioned in several books as early spring, late spring, cloudy, rainy, early winter and late winter. A famous Chola king Karikala (180 AD) constructed a 160 km embankment along the Cauvery river to protect his kingdom from floods. Varahamihira (505–587 AD) the first full fledged meteorologist in the history of India worked on forecasting rainfall through modeling. He wrote "Brihat Samhita". Based on lunar mansion and zodiac sign, he developed the first ever model for forecasting seasonal rainfall
- **600–1300 AD:** Kashyapa (800–900 AD) in his "Kashyapa Krishisukthi" advised that well ripened seeds shall be preserved after sun drying in heaps of straw, vessels etc., to avoid damage from water, wind and rain. Surapala wrote "Vrikshayurveda" (900–1000 AD) in which he estimated total rainfall during the rainy season. In 1120 AD Somaskhara Deva observed that seeds of a fruit ripened naturally be dried in sun for safe preservation. Certain micro meteorological weather modifications followed during this period include: preservation of winter vegetables in pits lined with wheat straw on all four sides, bottom and top and covered with soil for safer use in summer; earthen vessels painted with castor oil (acts as a barrier to moisture ingress) were used for grain storage
- **1300–1750 AD:** Mohammad Bin Tughlaq (1325–1351 AD) undertook irrigation works through construction of dams to combat "Drought". The severe drought (1398–1414 AD) resulted in developing several drought combat techniques. During Moghal period (1530–1761 AD) elaborate observations on climate and natural resources were recorded, particularly Akbar (155–1605 AD) and Jahangir (1605–1625 AD) attempted good number of climate related works for betterment of Agriculture.

1.3 Rainfall Prediction in Ancient India

1.3.1 By Astrology

The science of astrology started with understanding seasons and weather in relation to movements of planets. All cultures and civilizations have developed a form of astrology among which the Indian system is "Luni-solar" based. The main activity in this system is the time reckoning and calendar computations. In terms of weather prognostications, two important aspects are followed; the onset of rains is linked to the wind direction and the total seasonal rainfall is linked to phases of moon constellations and other planets in cycles. Astronomical calculations can be made for any number of years. As the position of planets can be predetermined the rainfall is forecast for any time in future.

The principles Governing Rainfall Prediction by Astrology

Water is classified based on its site of availability and use. Each site is a living entity and certain effects are brought about by organic action. Rain is conceived by a site and the gestation period is 192 ± 2 days. The position of planets at the entry point of moon in a particular constellation decides the probability of conception of rain and chances of normal delivery (1, 2, 3 and more days).

The procedure of Rainfall Prediction by Astrology

A fixed reference place/point on the earth is drawn on a chart. The exposure of this point to the sun during the day, the periodic waxing and leaning of moon, the regular appearance and disappearance of planets are projected as celestial cycle on this chart. The planetary chart laid out for the time when the sun influences (enters) each aesterium is noted and the angle between two planets and most powerful position in different angles is computed. The primary planetary chart of time and date of Chaitra Pratipada, Ashwini is configured. Actual predictions are derived using the house of each planet and its angle with reference to other planets. More so, the planets which are more powerful during the year with special reference to rainfall will be watched carefully.

The unique feature of Indian astrology is "Capsular theory". The two asterium/lunar mansions are arranged in capsules of 2, 3 or 7 and their associated effect on weather is predicted. A sequence is followed in serpentine fashion and more planets in any capsule gives the effect of capsule. The Neptune, Moon and Venus are universally accepted as responsible for rain.

1.3.2 By Panchanga

In India, the classical Hindu almanac is known as "Panchanga". It is a book or record of astronomical phenomena containing a calendar of days, weeks and months of the year. Weather prognostications and seasonal suggestions for a state or country are often mentioned. It acts as an astronomical guide to farmers to start any farming activity. Panchanga making might be traced from Vedic literature more so during Vedang Jyothish period (1400–1300 BC). However, hand written panchanga of early 17th century and later periods are available in some Indian libraries.

The word "Panchanga" is derived from Sanskrit language in which "Panch" means 'five' and 'ang' means "body parts". There are several ways through which rainfall is predicted by Panchanga. Of them a few prominent are lunar day (30 days in one month); week (7 days); aesterium constellation (Twenty seven days); time (The twenty seven number of times); Joint motion of sun and moon covers the space of aesterium etc. The permanent relationship is established among all the five parts and printed in the form of a guide every year. This is useful to practice agriculture and other weather related activities by the farmers. In general, the amount of rainfall in the coming months/seasons/year is assessed on the basis of symptoms at cloud conception, positions of the sun and moon in a particular division or zodiac and related considerations. There are several ways through which rainfall is predicted by panchanga. of them a few prominent are:

A. *Type of cloud*

Panchanga identifies the different types of clouds and based on dominance of a particular type in a year the rainfall is predicted.

S. No.	Type of cloud	If dominant in a year
1.	Abartak	Rain will be received in certain places in that year
2.	Sambartak	Rain will be received in all parts of the country
3.	Pushkara	Rainfall quantity will be less
4.	Drona	Abundant rain water

B. *According to ruling planet*

The rainfall prediction based on ruling planet is as follows; Sun (Moderate), Moon (Very heavy), Mars (Scanty), Mercury (Good), Jupiter (Very good), Venus (Good), Saturn (Very low and stormy wind).

C. *According to capsular Theories*

To predict the monsoon three different capsular theories are as follows: Bi-capsular, Tri-capsular, Seven capsular. This theory is based on grouping of all asteriums into 2, 3 and 7 categories according to specific criteria. Then based on union of different genders of planets and planetary conjunctions, future rain, immediate rain etc., are predicted.

Several astrologers have developed almanacs and predicted rainfall distribution based on which cropping patterns and area were decided in the past. These almanacs had helped the farmers in ancient times in many ways.

1.3.3 Ancient Models for Prediction/ Forecasting Seasonal Rainfall in Ancient India

A. As detailed in Brihat Samhita

Varahamihira tried to evolve a technique based on astrology in which he was proficient. His technique lays down that after the occurrence of full moon day of the month of "Jyestha" (June of Gregorian calendar), the asterium or lunar mansion or "Nakshatra" of the day on which the first rainfall of that year rainy season is received should be noted. This asterium provided the basis for the forecast of seasonal rains. There were twenty seven such asteriums or lunar mansions in Indian astrology, with each one falling under a particular zodiac sign.

B. As detailed in Krishi Parashara

Of the 243 verses in Krishi Parashara 69 relate to prediction of rainfall have strong astrological content. For the prediction of rainfall in the whole year Parashara has given methods based on the "Ruling Planet" and the "Minster Planet" of the year; the type of cloud, the direction of wind, the change in level of river water on a specific day and star constellation. Each model he developed was simple and farmer with basic knowledge of calendar could learn it easily by memorizing the verses.

1.4 Indigenous Technical Weather Knowledge (ITWK)

1.4.1 Evaluation of ITWK on Rainfall Forecasting

The term "Indigenous Technical Weather Knowledge (ITWK)" is used as synonym to 'local' and 'traditional' knowledge to differentiate it from 'scientific', 'modern' and 'rational' knowledge. The ITWK products of weather in Asia are strong knowledge pools developed by different communities through keen observations, natural selection and centuries of trial and error. Those ITWKs that were proved effective and sustainable on a long term basis to counter the extreme weather events and helped reap better harvest existed through hundreds of years of adaptive evolution in Asia. Even though in many cases the ITWK on weather is 'unwritten' it did exist in different brains, languages and skills with innumerable communities and cultures because the ITWK helped for successful and persistent adoption to the environment.

1.4.2 Examples of Agrometeorological Services using ITWK

- Rainfed rice cultivation in the eastern state of West Bengal, India is highly complex, risky and uncertain due to insufficient or excess early or late rains, early or late floods, the erratic withdrawal of monsoon etc. Therefore, the farmers adopt certain traditional methods to minimize the losses of crops due to these weather abnormalities. They sow a mixture of both autumn and winter rice varieties to ensure that a good harvest of at least one variety in the event of these weather aberrations. Also, they use staggered nursery for transplanting in the main field because the cost of nursery rising is less and under flooded conditions they also transplant lengthy and aged seedlings to overcome the submergence. Similarly, to meet the optimum date of sowing they sow the seed as soon as the summer rains are received and take the advantage of initial soil moisture for germination
- In dryland areas of northern India the delayed, erratic distribution and untimely rains are the serious problems for cultivation of wheat in winter (November) and maize in rainy season (June). In winter, if excessive early rains are received it will not be possible to sow wheat crop because, due to low air and soil temperatures the drying of excessive soil moisture takes atleast one month. Therefore, traditionally farmers follow "dry sowing" method in which the seeds are sown in the soil by taking the advantage of initial soil moisture of late SW monsoon rains. The seeds remain healthy in the soil and germinate when enough rains are received. Similar method of early sowing in May is followed for maize crop also, which helps the farmers to overcome the difficulty of sowing number of times and meeting the optimum date of sowing in the event of untimely rains

- Cultivation of cucurbits, melons, gourds etc., in sandy soils of southern, northern and north western India is risky and uncertain. In northern India the seedlings of these vegetables are grown in poly bags and allowed to grow in trenches to protect them from frost damage. These seedlings are transplanted in the main field during February second fortnight and farmers reap bumper harvest. In contrast, in southern India the fully grown fruits of these vegetables are put in trenches along with their tendrils and twigs to prevent their cracking and damage due to high air and soil temperatures
- The Indian dryland farmers also developed another ITWK to overcome the menace of heavy infestation of pests and diseases on vegetables grown in off-season. In northern India the farmers raise nurseries of vegetables in November (early winter) and take the advantage of enough soil temperature for germination. However, the growth of these seedlings is restricted till January due to low soil and air temperatures in winter. The transplanting of seedlings are taken up in February such that the main field crops grow under optimum weather conditions and yield potentially. If the seedlings are grown in February (late winter) then the flowering and fruiting synchronizes with the onset of monsoon rains and the pests and disease menace cause heavy or total loss of crops.

  The above methods were being followed in India since times immemorial.

1.5 India Meteorological Department

(Adapted from "Agrometeorological Services in India", Pune. A publication of "Agricultural Meteorology Division", IMD, GOI, MOES, Pune.)

Although, India Meteorological Department (IMD) was established in 1875 subsequent to a disastrous tropical cyclone hit Calcutta in 1864 and the famines in1866 and 1871 due to the failure of the monsoons, the rainfall data/observations were started well before. India is fortunate to have some of the oldest meteorological observatories of the world, that include Madras (now known as Chennai), established in 1793, Bombay (now known as Mumbai) in 1823 and Shimla in 1841. With the gradual growth in the expansion of observational network varieties of data have been generated and accumulated in a span of many years. The daily rainfall data of all the rain gauge stations of India i.e., Mumbai from

1847, Bandra from 1855, Deesa from 1856 etc are available at IMD. The country is divided into 36 meteorological sub-divisions and long series of monthly, seasonal and annual rainfall data from 1875 onwards are available.

First long range forecast of monsoon was initiated by Sir H.F. Blanford in 1886. IMD has been issuing operational monsoon forecast regularly for the country since 1988 and subsequently started four homogenous regions.

1.5.1 Agrometeorological Services in India

Weather and Agriculture

Indian agriculture has, for centuries, been dependant on the weather and the vagaries of the monsoon in particular. Uncertainties of weather and climate pose a major threat to food security of the country. Extreme weather events like heavy rains, cyclone, hail storm, dry spells, drought, heat wave, cold wave and frost causes considerable loss in crop production every year. An efficient use of available climatic resources, besides soil and water resources, minimizes the adverse effect of extreme weather and makes benefit of favourable weather. Weather services provide a very special kind of inputs to the farmer as advisories that can make a tremendous difference to the agriculture production by taking the advantage of benevolent weather and minimize the adverse impact of malevolent weather.

Weather Services to Agriculture

In order to provide direct services to the farming community of the country an exclusive Division of Agricultural Meteorology was set up in 1932 under the umbrella of India Meteorological Department (IMD) at Pune with the objective to minimize the impact of adverse weather on crops and to make use of favourable weather to boost agricultural production.

The major activities of the Division are:

- Technical Assistance
- Research and Development
- Services
- Human Resource Development.

Integrated Agromet Advisory Services

To meet the farmer's need in real-time and to have a state-of-art Agromet Advisory Service (AAS), Integrated Agromet Advisory Service in the country involving all the concerned organizations viz., Indian Council of Agricultural Research (ICAR), Ministry of Agriculture (Centre and State), State Agricultural Universities (SAUs) and other agencies has been started from April 2007.

Collaborating Agencies under IAAS

State Agricultural Universities (SAU)

Indian Council of Agricultural Research (ICAR) and its research institutes

Indian Institutes of Technology

State and Union Departments of Agriculture

Prasar Bharati and other media (Radio, TV and Print).

Network of Observatories

The Division of Agricultural Meteorology maintains and provide technical support to a wide range of agromet observatories from where different kinds of data on agromet paramaters are generated.

AAS *Bulletins are issued from three levels*

- National Levels by National Agromet Advisory Service Centre, Agrimet Division, IMD, Pune
- State Levels by State Agromet Service Centre at Regional Meteorological Centre/Meteorological Centre (23)
- District Level by Agromet Field Units (130).

District level agromet advisory bulletins are issued for the farmers. The State level composite AAS Bulletins are issued for State level planners e.g. State Crop Weather Watch Group (CWWG) and other users like fertiliser industry, pesticide industry, irrigation department, seed corporation, transport and other organizations which provide inputs in agriculture. The National Agromet Advisory Bulletins are primarily targeted for national level planners e.g. CWWG, Department of Agriculture and Cooperation, Ministry of Agriculture, New Delhi and also communicated to all the related Ministries (State and Central), Organizations and NGOs for their use.

Main features of AAS *bulletin*

- Significant past weather
- Quantitative weather forecast for next five days
- Advisories for farming community.

Broad Spectrum of Agromet Advisories

- Sowing/transplanting of Kharif crops based on onset of monsoon
- Sowing of rabi crops using residual soil moisture
- Fertilizer application based on intensity of rain
- Delay in fertilizer application based on intensity of rain
- Prediction of occurrence of pest and disease based on weather
- Propylactive measures at appropriate time to eradicate pest and diseases
- Weeding/thinning at regular intervals for better growth and development of crops
- Irrigation at critical stage of the crops
- Quantum and timing of irrigation using meteorological threshold
- Advisories for timely harvest of crops.

IMD has started issuing quantitative district level (612 districts) weather forecast up to 5 days from 1st June, 2008. The products comprise of quantitative forecasts for 7 weather parameters viz., rainfall, maximum and minimum temperatures, wind speed and direction, relative humidity and cloudiness. In addition, weekly cumulative rainfall forecast is also provided. IMD, New Delhi generates these products based on a Multi Model Ensemble technique using forecast products available from number of models of India and other countries. These include: T-254 model of NCMRWF, T-799 model of European Centre for Medium Range Weather Forecasting (ECMWF); United Kingdom Met Office (UKMO), National Centre for Environmental Prediction (NCEP), USA and Japan Meteorological Agency (JMA).

The products are disseminated to Regional Meteorological Centres and Meteorological Centres of IMD located in different States. These offices undertake value addition to the products and communicate to 130 AgroMet Field Units (AMFUs).

The district level agromet advisory service is multi-disciplinary and multi-institutional project. For this, IMD organises District Agromet Advisory Service meeting in each of the state of the country inviting the officers/scientists and all the stakeholders with objectives to create appropriate information generation-cum-dissemination mechanism as well as extension mechanism at district level for communicating the agromet advisories to the farmers regularly.

Dissemination of Advisories

Dissemination of Agromet advisories is done through

- All India Radio (AIR) and Doordarshan
- Private TV and radio channels
- Newspapers
- Internet
- ICAR and other related institutes/Agriculture Universities/Extension network of State/Central Agriculture Departments
- Krishi Vigyan Kendras
- Advisories are delivered to the end users without any delay
- Interactive tuning of advisories with the farmers/managers as frequently as possible
- Disseminated in English and local languages/dialects and is easily understandable by farmers.

Linkages between Districts Agriculture Offices (DAOs) and AMFUs level are being developed for effective dissemination of advisories at district, block and village levels.

Extension of Advisories

Extension wing of the State Departments of Agriculture, State Agricultural Universities, Indian Council of Agricultural Research Institutes are working for application of the advisories in the farmer's fields.

Feedback and Awareness of Agromet Service

In order to improve the quality of the agromet advisory services, regular direct interactions are being made by the AMFUs with the farmers, State AAS units and Agrimet Divisions are regularly participating in Kisan Melas, farmer's gatherings etc., to interact with the farmers personally and collect the feedback from farmers. Roving seminars are being organized in different States by AMFUs to create awareness about usefulness of weather/climate information, agromet advisory services among the farming community.

Crop Yield Forecasting

A need for quantitative crop yield forecast outlooks has been felt for quite sometime. A beginning towards its realization has been made by undertaking a study of past crop yield in relation to meteorological parameters, principally rainfall and temperature. Based on these studies quantitative crop yield forecast formulae have been developed for 22 sub divisions in the country for Kharif rice and 9 sub divisions for wheat. The tentative forecast for crop yield is being issued every month during the crop season using this methodology.

Research and Development

From the inception the Agrimet Division is working on research and development programmes to strengthen the operational agro-meteorological services in the country.

Microclimatic Studies

The study of microclimate of crops was one of the earliest investigations under taken by the Agricultural Meteorology Division in Pune since 1932. The subject of micro-climates received intensive attention and significant contributions have been made in this field of research. Research activity in the field of microclimatology was carried out extensively by various personnel from IMD as well as others. Systematic observations on the characteristic micro-climates of the air layers close to the ground in the open and inside various crops have been recorded and a large volume of micro-climatological data were collected.

Agroclimatic Classification

In order to bring out agricultural potential of a region, its agroclimatic classification has to be made. Considerable work has been done on agro-climatic classification. Agroclimatic zones have been delineated using Thornthwite moisture availability index and other methods. Penman method has been used to estimate evapotranspiration of about 230 stations located in India. These estimates are used to compute water balance of these stations in India and ultimately agroclimatic classification.

The Agricultural Meteorology Division has made a detailed examination and prepared suitable diagrams of the frequencies of occurrence of various adverse weather phenomena (like hail storms, frosts etc.) that affect growing crops, extremes of temperature met with in summer and winter, estimated evaporating power of the atmosphere etc. Such diagrams help to show how often the farmer may be called upon to mitigate the effects of adverse weather phenomena by resorting to possible protective measures like artificial heating, use of wind brakes etc.

Cropping Patterns

By analyzing the rainfall records of 2000 stations for 70 years, the periods and amounts of “assured rainfall” have been worked out for various regions particularly in the dry farming tract of India. The length of dry spells and wet spells during the monsoon, drought proneness and agro-climatic classifications have also been studied with climatological data. This information is helpful in choosing appropriate crops for various regions, determining the most favourable growing seasons for rainfed crops and selecting drought tolerant crop strains.

Sowing dates

Optimum dates for sowing have been determined for the States of Maharashtra, Rajasthan, Gujarat and Madhya Pradesh, by using daily rainfall data from 1901 onwards. Such information helps in deciding the best period for sowing operations, water conservation measures and evolution of appropriate cropping patterns.

Even in those parts of the country where irrigation facilities does not exist, the crop production can be maximized by better scheduling of irrigation. Scarce resources can be economically used by providing water to crops when it is known to be most beneficial. For this, precise water requirements of crops at various growth stages are being studied through field experiments and regular lysimeter measurements of evapotranspiration.

Remote Sensing Applications

Satellite remote sensing techniques have been used for acreage estimation of jowar. Spectral response of crops at various growth stages and states are studied to help crop identification. Soil moisture studies using micro-wave remote sensing technique were made.

Crop Weather Analysis

Theoretical models of crop weather relationship enable to understand, quantitatively, the role played by weather elements on crop growth and yield. Variability of soil moisture and soil temperature and the contribution of dew have been studied in relation to crop growth. Fluctuations in weather with regard to crop factors like leaf area index, stomatal resistance, crop coefficient and dry matter production have been studied. Energy balance of the crop canopy for cereals and legumes are being worked out. A number of crop weather calendars were prepared based on crop weather studies. Crop growth simulation models (DSSAT) are being used to develop crop weather relation as well as crop yield forecasting.

Considerable research has been done on the weather conditions conducive to outbreaks of crop pests and diseases like paddy stem borer, jowar shoot fly, cotton bollworm, sugarcane borers, groundnut tikka, potato beetle and wheat rusts. The results help to organize timely crop protection measures with optimum use of expensive chemicals. The desert locust breeding and invasion has been extensively studied in relation to soil and weather conditions.

Drought Studies

By analyzing rainfall data since 1875, the probability of occurrence of drought in various parts of India has been worked out. Different parameters like water availability, soil moisture stress, aridity index have been studied. Droughts are monitored by deriving aridity anomalies on a fortnightly basis in the Kharif season and weekly basis in the northeast monsoon season over the southern peninsula.

Dry Land Farming

The area having annual rainfall between 40-100 cm and practically with no irrigation facilities is known as dry farming tract. Dry farming tract comprise 87 districts and is spread over Haryana, Punjab, Rajasthan, Gujarat, Uttar Pradesh, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka and Tamilnadu. Extensive research was carried out on assessment of short period rainfall probability, compilation of frequency, duration and intensity of dry and wet spells, assessment and seasonal and diurnal variation of meteorological parameters, derivation of agroclimatic zones and sub-zones.

Weather and Phenology of Crops

Phenology is the science which deals with the recurrence of the important phases of animal and vegetable life in relation to the march of seasons during the year. The dates of manifestation of phenophase constitute an integral of climatic effects as they take into account the weather over past periods and also the weather at the moment. Studies were made to observe the effect of climatic factors on the flowering, fruiting and maturity of four trees i.e., manblack, neem, tamarind and babul. The observations were taken at about 200 phenological stations located in the agricultural farms, soil conservation centre and meteorological stations.

Agrometerorological observations with State of Art Instruments

A number of experiments using portable photosynthesis system, infra-red thermometer, portable leaf area meter, dew point generator and dew point microvoltmeter were conducted at College of Agriculture, Pune during rabi season on impact of CO_2, photosynthetically active radiation (PAR), temperature and relative humidity on the rate of photosynthesis and other parameters like transpiration, stomatal conductance etc., in field crops like maize, jowar, safflower, sunflower and soybean.

Training Programmes in the Division

Following training programmes for national and international training for agromet observers, university teachers/departmental officers and foreign personnel are regularly arranged in the Division.

- Foreign Trainees' course of 6 months duration
- Agromet core course of 3 weeks duration for teachers and scientists of agricultural universities/institutes
- Observers course of 3 weeks duration for recording observation
- Departmental trainees (Grade 'A' officers)
- On the job training for advanced (revised) meteorological course trainees
- Basic agromet course of 3 weeks for Departmental candidates
- Refresher course of 2-3 weeks for departmental/non-departmental officers.

Future Programme

Proposed modes of dissemination – Dissemination through Common Service Centres (CSC) by DIT

- Department of information Technology (DIT) is planning to develop ICT facilities for the benefit of the citizens, especially those in rural and remote areas. 1,00,000 CSCs will be set up at village level shortly to provide all possible services. Among others, agromet services will also be provided through the CSCs
- Ministry of Agriculture is already operating "Agricultural Technology Management Agency (ATMA)" project in several districts on the line of NGO concept
- It is also planned to provide AAS link to Village Knowledge Centers at taluka level that have already been opened by M.S. Swaminathan Research Foundation and Alliance for providing the need based information at village level

- Under Integrated Agromet Advisory Service (IAAS) Scheme, IMD is exploring to tie up with different public and private organizations to use IVR and SMS technology which are already working in dissemination of agricultural information to the rural villages.

1.6 World Meteorological Organisation

(Adapted from "The World Meteorological Organisation at a Glance". A WMO Publication, Geneva, Switzerland)

1.6.1 Scope of World Meteorological Organisation

Weather, climate and water know no political boundaries. To promote international cooperation in these areas, the World Meteorological Organisation (WMO) coordinates the activities of the National Meteorological and Hydrological Services (NMHSs) of its 188 Members. Originating from the International Meteorological Organisation established in 1873, WMO was created in 1950 as an intergovernmental organization and became a specialized agency of the United Nations in 1951.

- The National Meteorological and Hydrological Services work around the clock, all year round, to protect and provide vital information to communities
- The early and reliable warnings of the occurrence of severe weather, air quality and climate events allow decision makers, communities and individuals to be better prepared, which help save life and property, protect resources and the environment and support socio-economic growth
- WMO ensure that all nations are able to take full advantages of weather, climate and water information and products for their sustainable development and the safety and well-being of their people.

1.6.2 Functions of WMO

Improving Safety and Well-being

- The WMO galvanizes the global community to improve understanding of weather, climate and water
- The WMO provides unique mechanisms for the timely exchange of data, information and products

- The WMO makes major contributions to sustainable development, the reduction of loss of life and property caused by natural hazards related to weather, climate and water, as well as safeguards the environment and the global climate for present and future generations
- The WMO through its members provides forecasts and early warnings to nations, economic sectors and individuals, that help prevent and mitigate disasters, save lives and reduce damage to property and to the environment through better risk management
- The WMO draws world attention to the depletion of the ozone layer, climate variability and change and their impacts, dwindling water resources and air and water quality
- The WMO monitors and forecasts the transport of chemical and oil spills, forest fires, volcanic ash, haze and nuclear isotopes. It assists in the formulation of global and regional strategies, conventions and the implementation of related action plans.

Taking the Pulse of the Earth System

- WMO provides up-to-date, accurate and quantitative information on the state of the Earth's atmospheric system, the oceans, surface water bodies and underground water. It also monitors the interaction of the atmosphere with the Earth's surface, ecosystems and human activities
- WMO facilitates the provision and exchange of near-real-time information from across the globe around the clock. The data are collected by 10000 land stations, 3000 aircrafts, 1000 upper-air stations and more than 1000 ships working in tandem with 188 National Meteorological Centres and 35 Regional Specialized Meteorological Centres. These are bolstered by over 16 meteorological, environmental and operational satellites and 50 research satellites
- The WMO Integrated Global Observing Systems (WIGOS) acts as an umbrella for these observational networks, using the WMO Information System (WIS) to connect together all regions for data exchange, management and processing
- The WMO research programme coordinate and integrate the research activities of Members to take full advantage of global observations in analysis of the weather and climate and to develop

computer models that represent the key underlying processes for improving the accuracy and range of weather forecasts

- WMO supports air quality services, measurements of hydrological variables and ensures that observational and monitoring instruments everywhere are accurate and provide standardized data generated in one place are to be usable elsewhere in the world
- WMO also assists countries in enhancing their data-management capacity. Data-rescue activities help NMHSs, especially those of developing countries, access historical data for various purposes
- WMO monitoring observation systems are a core contribution to the Global Earth Observation System of Systems (GEOSS), aimed at developing a comprehensive, coordinated and sustained international approach to understand and address global environmental and socio-economic challenges.

Research

- WMO coordinates and organizes research programmes that contribute to scientific understanding of the dynamical, physical and chemical processes in the atmosphere and oceans, as well as the interactions of various components of the Earth system on all time and space scales
- WMO promotes research into fundamental scientific understanding of the physical climate system and climate processes needed to determine to what extent climate can be predicated and the extent to which humankind influences climate
- It promotes the advancement of atmospheric sciences in understanding atmospheric compositing changes and consequent effects on weather, climate, urban environment and marine and terrestrial ecosystems. The WMO Atmospheric Research and Environment Programme accelerates improvements in "nowcasting" – forecasting the next six hours – and one day to two week high impact weather forecasts for the benefit of society, the economy and the environment
- It also focuses on tropical cyclones and monsoons. Other programmes aim to measure and understand the influence of greenhouse gases and other climate changing particles and chemicals in the atmosphere
- Climate research on global to regional scales and time horizons ranging from weeks to centuries is coordinated by the World

Climate Research Programme (WCRP) co-sponsored by WMO, the International Council for Science and the Intergovernmental Oceanographic Commission of UNESCO

- WMO has been one of the leaders of the International Polar Year (2007-08) and helps Earth's polar regions to enable a better understanding of our future climate, among other things.

1.6.3 Applications

Weather, climate and water impact many socio-economic sectors, agriculture and fisheries, energy, transport, health, insurance, sports and tourism. WMO's endeavours to promote the application of meteorological, climatological, hydrological and oceanographic information to human activities are therefore of great importance worldwide.

Disaster Prevention and Mitigation

About 90 per cent of all disasters are related to weather, climate or water. The human and material losses caused by natural disasters are a major obstacle to sustainable development and world safety and security. With other international, regional and national organizations, WMO coordinates the efforts of NMHSs to improve forecast services and early warnings to protect life and property from natural hazards, such as tropical cyclones, storms, floods, droughts, heat and cold waves and wildfires. In addition to public safety, such extremes affect water and food supplies, the environment, transport and many other socio-economic sectors.

Emphasis is on improved warnings and better integration of such information in disaster risk management: one dollar invested in better prediction and disaster preparedness can prevent seven dollars' worth of disaster related economic losses; a considerable return on investment. WMO's objective is to reduce by 50 per cent, by 2019, the associated 10-year average fatality of the period 1994-2003 for weather, climate and water related natural disasters.

Water Resources Assessment and Management

Global freshwater resources are both diminishing and deteriorating under demographic and climate pressures. Water is essential for life, for generating hydroelectric power and meeting irrigation and domestic requirements. WMO promotes water resources assessment and provides the forecasts needed to plan water storage, agricultural activities and urban development. It supports an integrated, multidisciplinary approach to managing water resources.

Agriculture and Food Security

The agricultural sector critically depends on timely and accurate weather, climate and water information, particularly as it faces increasing climate risks. The observations, analyses and forecasts produced by WMO Members enable the agricultural community to increase crop and livestock yields, plan their planting and harvest time, and reduce pests and diseases. Regular Regional Climate Outlook Forums, as well as training, coordination services and resources provide a range of services to improve agricultural output and sustainability and contribute to world food security.

Public Health

Through its Members, WMO provides weather and climate services to the public health community. Early warnings for disease epidemics, disaster prevention and mitigation and air quality services all aim to protect people's health and welfare. Several Regional Climate Outlook Forums, for example, now support malaria surveillance and warning systems in Africa. Heat health advisory services give early warning of heat waves. Joint partnerships with international, regional, and national health sector partners are increasing the effective use of weather and climate information in support of such efforts.

Transport

The aviation sector requires a range of information on weather conditions. Precipitation, wind, turbulence, fog and a host of other factors affect day-to-day aviation activities. WMO ensures the worldwide provision of cost effective and responsive meteorological services in support of safe, regular and efficient aviation operations. Likewise, WMO provides services in support of the safety of marine and land transport. These services provide early warning to the offshore oil and natural gas infrastructure, there by aiding energy security and transport.

Oceans

WMO promotes the protection of the marine environment and the efficient management of marine resources, based on the timely collection and distribution of marine meteorological and oceanographic data. WMO provides assistance to Members in establishing national and regionally coordinated systems to ensure that the loss of life and damage caused by tropical cyclones are reduced to a minimum. It also supports the sustainable operation of fisheries through weather and climate observations and analyses.

Energy

Climate, weather and water information supports optimal development and use of renewable energy resources such as hydropower, wind, solar and biological energy. Such information also underpins the routine operation of nuclear power plants, coal power plants and other forms of energy production. WMO facilitates the exchange of data that can help energy developers and managers better plant for changes in energy demand, the development of local energy systems and compliance with environmental requirements.

Socio-Economic Development

Through its various activities, WMO helps developing countries manage resources, prevent disaster and adjust to climate variability and change. To address the special problems and needs of Least Developed Countries (LDCs), the Fourteenth World Meteorological Congress established the WMO programme for LDCs in May 2003 to enhance the capacity of NMHSs to contribute effectively to the socio-economic development of these countries. In line with the overall Programme of Action for the LDCs for the decade 2001-2010, adopted by the third United Nations Conference on the LDCs, the WMO Programme for the LDCs encompasses the five following strategic areas: fostering a people-centred policy framework; strengthening productive capacities; building human and institutional capacities; reducing vulnerability and conserving the environment; and resource mobilization.

WMO supports developing countries, and the LDCs in particular, in their social and economic development and combat against poverty by enhancing the capacities and capabilities of their NMHSs. Capacity building in the most vulnerable communities ensures a greater ability to monitor weather, climate and water conditions and plan for future conditions. One dollar of investment in weather information returns 10 dollars worth of socio-economic development. Such actions contribute to the achievement of the UN Millennium Development Goals by 2015, and especially the eradication of extreme poverty and hunger.

1.6.4 Sharing Expertise and Building Capacity

- WMO assists the NMHSs, especially those of developing countries, in their efforts to contribute, in the most effective manner, to the development plans of their countries and to become full partners in global collaborative efforts
- WMO helps its Members develop human resources through training, the provision of educational material and the awarding of fellowships. Its more than 30 Regional Meteorological Training Centres, along with a network of cooperating universities and advanced training institutions, contribute to the global effort
- WMO promotes and facilitate technology transfer, as well as the establishment and development of specialized centres of excellence in various regions.