Theory Notes

AGM-ELE-361

Semester-VI

System Simulation and Agro-advisory

Credit: 2(1+1)

By

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Course :	*ELE AGM 361*	***Credit:***	*2(1+1)*	***Semester-VI***
Course title:	*System Simulation and Agro-advisory*			

Syllabus

Theory

System Approach for representing soil-plant-atmospheric continuum, system boundaries, Crop models, concepts & techniques, types of crop models, data requirements, relational diagrams. Evaluation of crop responses to weather elements; Elementary crop growth models; calibration, validation, verification and sensitivity analysis. Potential and achievable crop production- concept and modelling techniques for their estimation. Crop production in moisture and nutrients limited conditions; components of soil water and nutrients balance. Weather forecasting, types, methods, tools & techniques, forecast verification; Value added weather forecast, ITK for weather forecast and its validity; Crop-Weather Calendars and forewarning model; Preparation of agro-advisory bulletin based on weather forecast. Use of crop simulation model for preparation of Agro-advisory and its effective dissemination.

Practical

Preparation of crop weather calendars. Preparation of agro-advisories based on weather forecast using various approaches and synoptic charts. Working with statistical and simulation models for crop growth. Potential & achievable production; yield forecasting, insect & disease forecasting models. Simulation with limitations of water and nutrient management options. Sensitivity analysis of varying weather and crop management practices. Use of statistical approaches in data analysis and preparation of historical, past and present meteorological data for medium range weather forecast. Feedback from farmers about the agroadvisory.

Teaching Schedule

a) Theory

Lecture	***Topic***	***Weightage(%)***
1-2	*System Approach for representing soil-plant-atmospheric*	*10*

Lecture	Topic	Weightage(%)
	continuum, System boundaries for representing soil-plant-atmospheric continuum	
3-4	Crop models, concepts and techniques, Types of models, data requirements, relational diagrams, Evaluation of crop responses to weather elements	16
5-6	Elementary crop growth models –calibration and validation, Elementary crop growth models -verification and sensitivity analysis	10
7-8	Potential and achievable crop production- concept, Modelling techniques for potential and achievable crop production estimation	10
9-10	Crop production in moisture and nutrients limited conditions. Components of soil water and nutrient balance	6
11-12	Weather forecasting, its types, methods and tools. Techniques of weather forecasting and its verification	10
13-14	Value added weather forecast, ITK for weather forecast and its validity. Aerospace science and weather forecast	10
15	Crop-Weather Calendar, Crop-Weather-Pest-Disease Calendar and forewarning model, Crop weather diagram	12
16	Remote sensing- its application in agriculture, Preparation of agro-advisory bulletin based on weather forecast	8
17	Use of crop simulation model for preparation of Agro-advisory. Agro-advisory , its effective dissemination	8
	Total	**100**

b) Practical

Exercise	Topic
1	Preparation of crop weather calendars
2-3	Preparation of agro-advisories based on weather forecast using various approaches
4	Preparation of AAS based on weather forecast using synoptic charts
5-6	Study of crop-weather models using different statistical teqniques
7	Study of simulation models for crop-growth (DSSAT)
8-9	Study of forewarning models for insect pest and disease.
10	Study of crop-weather –pest - disease calendar
11	Study of Simulation with limitations of water and nutrient management options

12	*Sensitivity analysis of varying weather and crop management practices*
13-14	*Use of statistical approaches in data analysis and preparation of historical, past and present meteorological data for medium range weather forecast*
15-16	*Feedback from farmers about agro-advisory.*

Suggested Readings:

1) *Applied Agroclimatology by O.P.Bishnoi, Oxford Book Company, Jaipur, India-302108, Edition 2010.*
2) *Working with Dynamic crop models, Evaluation, Analysis, Parametrization and Applications by D. Wallach, D. Makowshi, J. W. Jones, Elsevier Oxford U.K, First edition 2006.*
3) *Remote Sensing Techniques in Agriculture by D.D.Sahoo, R.M.Solanki, Agrobios (India), Jodhpur, 2008.*
4) *Compendium on Crop Moddeling,by M.C. Varshneya and S.S.Salunke. A short Term Training Programme organized by Centre of Advance Studies in Agril. Meteorology, College of Agriculture, Pune-411005 during 14th Sep., - 12th Oct., 1998, Published by MPKV, Rahuri MPKV/EDN./PUB No. 10(99).*
5) *Database Management Systems by R. Ramkrishnan, Johannes Gehrke, M.C.Grawhill Education (India) Pvt.Ltd, New Delhi, Indian Edition 2014.*
6) *Introduction to Agrometeorology (Second Edition) by H.S.Mavi, Oxford and IBH Publishing Co. Pvt.Ltd., New Delhi, 1994.*
7) *Text book of Agril. Meteorology by M.C. Varshneya, P. Balakrishna Pillai, ICAR New Delhi, 2003.*
8) *Basic Principles of Agril. Meteoorology by V.Radhakrishna Murthy, BS Publication, Hyderabad, 2002.*

Lecture 1-2

System Approach for representing soil-plant-atmospheric continuum, System boundaries for representing soil-plant-atmospheric continuum

*The **soil-plant-atmosphere continuum** (SPAC) is the pathway for water moving from soil through plants to the atmosphere. Continuum in the description highlights the continuous nature of water connection through the pathway. The low water potential of the atmosphere, and relatively higher (i.e. less negative) water potential inside leaves, leads to a diffusion gradient across the stomatal pores of leaves, drawing water out of the leaves as vapour.[1] As water vapour transpires out of the leaf, further water molecules evaporate off the surface of mesophyll cells to replace the lost molecules since water in the air inside leaves is maintained at saturation vapour pressure. Water lost at the surface of cells is replaced by water from the xylem, which due to the cohesion-tension properties of water in the xylem of plants pulls additional water molecules through the xylem from the roots toward the leaf.*

The movement of many physical variables like heat, liquids, electricity, etc. Can be described by a relation linking a flux and a driving force, as in

Flux = - K x driving force

The negative sign of the proportionality constant K indicates that the flow is downhill. The constant K is often called "conductance" and it expresses effect of driving force on the flow. This can be explained in terms of resistance also

$$\text{Flux} = \frac{\text{Driving force}}{r}$$

where, r = 1/-K.

The equation resembles with Ohm's Law, which governs the flow of electric *current in wires. Ohm's law states that the current through a conductor between two points is directly proportional to the voltage across the two points. Introducing the constant of proportionality, the resistance, one arrives at the usual mathematical equation that describes this relationship: I=V/R, where I is the current through the conductor in units of amperes, V is the voltage measured across the conductor in units of volts, and R is the resistance of the conductor in units of ohms. In fact, this law is also applicable to describe fluxes of gases and water vapour between plants and environment.*

If we apply this to water flow in plants, we can write that the uptake of water through the root surface is given by –

$$\text{Water uptake} = \frac{\text{Water potential in soil} - \text{water potential at root surface}}{\text{Soil resistance}}$$

The water potential is a measure of how strongly water is bound to its medium. The binding energy can be expressed in energy units per mass units i.e. joule/kg or energy units per volume i.e. joule per m^3 which is equivalent to pressure. (1 Pa is equivalent to 1 joule m^{-3} and to 1 N m^{-2})

The negative potential indicates strong bonding with medium, it will move to another medium if potential is still lower (more negative).

Obviously, as there is no accumulation of water in growing plant, but rather a steady flow, hence amount of water transpired is equal to amount of water absorbed.

Water potentials are always expressed in pressure units i.e. bars and Pascal. Soil water potentials are of the of the order of -0.1 to -15 bars (-10 to -1500 J kg^{-1}) corresponding approximately to field capacity and to permanent wilting point. The water potential values found in leaves are around -2000 J kg^{-1}. The water potential tends to be high iin the soil and very low in the atmosphere.

Soil water potential is traditionally divided into osmotic, gravitational and capillary pressure. Potential of free water and leaves in dark is nil.

Plants can actively control transpiration in response to their environment by controlling opening of stomata. Plants do not only evaporate water but also assimilate carbon which is also absorbed through stomata. This is one of the numerous interactions between the various physiological functions of the crop. Soil resistance is a function of soil water content and root development. The leaf and air resistance is controlled by stomatal opening, water pressure deficit and air movement.

Components of soil water and nutrient balance

- *The most basic components of soil are minerals, organic matter, water and air.*
- *Mineral nutrients, by definition, are critical to health, vigour and productivity of plants, particularly in agriculture.*
- *Soil organic matter (SOM) not only stores nutrients in the soil but also is a direct source of nutrients. Its presence is considered an important indicator of fertile soil.*
- *Soil fertility is greatly influenced by five broad factors: parent material, climate, biota, time and topography.*
- *Two properties that have a profound impact on the soil's water holding capacity, nutrient retention, nutrient supply and drainage are soil structure and soil texture.*
- *Soil texture describes the ratio of clay, loam and sand in a specific soil.*

Lecture No. 3-4

Crop models, concepts and techniques, Types of models, data requirements, relational diagrams, Evaluation of crop responses to weather elements

Definition: *Model is an equation or set of equations which represents the behaviour of a system (France and Thornley, 1976). Crops weather models may also be defined as a simplified representation of the complex relationships between weather or climate on one hand and crop performance such as growth, yield or yield components on the other hand by using mathematical and or statistical techniques.*

Concept: *The rediscovered importance of the effect of weather and climate on crop production has brought about numerous research projects and publications dealing with crop weather relationships at different scales. Various statistical and mathematical techniques for developing these relationships have been used and term "Crops weather model" has emerged. In the physical science the term model is used to provide an explanation for certain phenomena and to postulate (to assume without proof) underlying process which gives rise to the observations under inspection (Yarranton, 1971).*

Types of models :

Models are of different types depending upon the purpose for which it is designed or use and the supporting system for the same.

1. *Statistical emperical models: These models express the relationship between yield and yield components and weather parameters. However these models*

do not explain the mechanism approach and aspects of weather parameters by which they influence yield. The models are simple in nature, crop and location specific and do not take soil variability (variation) genetic potential and management into account.

2. *Mechanistic models: These models explain not only the relationship between weather parameters and yield but also explains the mechanism of influencing dependent variables i.e. photosynthesis, leaf area development by independent variables i.e. weather parameters such as temperature etc.*
3. *Deterministic models: These models estimate/ predict the exact value of the yield or dependent variable. Usually, these are developed by mathematical techniques and have well defined coefficients.*
4. *Stochastic models: These models use the value of weather parameter at some or the other probability level. Therefore, output i.e. yield or yield components are also estimated with in a range depending upon the range or probability level of independent variable.*
5. *Static models: These models do not take into account time factor. Dependent and independent both the variables are having values which remain constant over a given period of time.*
6. *Dynamic models: These models are defined at a given time. They are usually dealing with rate variables such as, evapotranspiration, rate of photosynthesis, respiration etc. They are complex in nature and define yield or state of dependent variable at a given rate of time of independent variable.*

   Dynamic crop models are very advanced in nature and are developed by taking all physiological processes in account. Therefore, dynamic crop growth model is the assembly of number of mechanistic models which deal with various plant process such as, photosynthesis, respiration, transpiration and partitioning. The Crop Environment Resource Synthesis Model (CERES) developed by Ritchie et. al (1988) are one of the most advanced models presently available for research and operational use.

Input data requirement in modeling :

For various calculation in the crop growth simulation model and to the run model following minimum input data is set is required

a. ***Site data*** *: 1. Constants of time and location data , 2. longitude, 3. latitude 4. altitude*
b. ***Weather data*** *: 1. Mean ambient temperature (^0C), 2. amplitude of mean monthly (^0C), 3. Solar radiation ($M\ JM^{-2}d^{-1}$), 4. Maximum and minimum temperature (^0C), 5. Rainfall (mm), 6. Wind speed (ms^{-1}), 7. Humidity (%), 8. Pan Evaporation (mm)*
c. ***Soil data*** *: 1. Soil class, 2. Pedon number, 3. Soil evaporation, 4. Soil albedo, 5.*

Runoff curve, 6. Soil profile drainage coefficient, 7. Soil layer thickness, 8. Field capacity, 9. Wilting point density, 10. Bulk density

d. ***Chemical & other data** : 1. Soil PH, 2. NO_3 (mg of N/kg soil), 3. NH_4 (mg N/kg of soil), 4. Organic carban (%), 5. Sand, silt and clay (%), 6. Amount of residue/ green manure incorporated (kg/ha)*

e. ***Plant data** : Date of sowing, date of emergence, date of floral initiation, date of anthesis, date of physiological maturity, plant population, plant height, LAI, leaf weight, dry matter, grain numbers, grain yields etc.*

f. ***Management data** : Date and amount of irrigation, fertilizer application, herbicide insecticide application, weeding etc.*

***Applications of modelling:** A validated dynamic crop growth model is best operational tool since, it can calculate the development and growth of crop under variety of climatic conditions, management practices and different soil conditions. A modeller can solve most of the difficulties encountered by a farmer which are given below.*

1) *Seed rate to be utilized : Seed is costly input for small and medium farmer. Hence he is always interested in knowing the optimum seed rate for a given variety. The model can calculate optimum yield under different plant populations for given agroecological conditions by which he can immediately advice the farmer the optimum seed rate for maximum yield.*
2) *Row spacing or crop geometry: The modeller can calculate yield under different row spacing treatments and can recommend to the farmer best spacing.*
3) *Fertilizer dose and application: Modeller can estimate the yield under different fertilizer doses with splits. After calculating the benefit cost ratio he can modify the recommended dose.*
4) *Irrigation and it's stage of application: For irrigated crops quantity of irrigation water to be applied and benefits due to that can be calculated by a modeler. This modeler can estimate the monetary returns of each irrigation and its time of application.*

Thus, it can be said that validated dynamic crop growth model can reduce lot of multilocation and field trials of different crops. Also it can solve most of the queries of a farmer. Hence, a good model is like a good friend. For estimation of crop yield they are good operational tool.

Evaluation of crop response to the different weather elements.

Following elements are responsible for crop growth

1. *Radiation*

2. *Temperature*
3. *Soil temperature*
4. *Atmospheric pressure*
5. *Wind*
6. *Rainfall*
7. *Evaporation etc*

1. Radiation :

a. *From germination of seed to harvesting and even post harvest processes are affected by solar ration.*
b. *Solar radiation provides energy for*
   i. *All the phenomena related to biomass production*
   ii. *All photosynthetic processes*
   iii. *All physical processes taking place in the soil, the plant and their environment.*
c. *Solar radiation controls the distribution of temperature their by distribution of crops into different regions.*

2. Temperature :

a. *Air temperature affects leaf production, expansion and flowering.*
b. *The growth and development of crop plants are chiefly influenced by air temperature*
c. *The diffusion rate of gases and liquids changes with temperature*
d. *Solubility of different substances is depends on temperature.*

3. Soil Temperature :

a. *Governs uptake of water, nutrients etc., needed for photosynthesis*
b. *Controls soil microbial activities and the optimum range is 18-30^{o}C.*
c. *Influences the germination of seeds and development of roots.*
d. *Affects the seed of reactions and consequently weathering of minerals.*

4. Atmospheric pressure :

a. *This has important consequences for respiration, which relies on the transport of these gases in solution*
b. *The plants show stunted growth at higher altitudes as concentrations of oxygen and carbon-dioxide reaches low.*
c. *At higher altitude increased ultraviolet rays makes environment less favourable for plant growth*
d. *The plants with strong root system and tough stems can live under increased wind speeds at low pressures in high altitude areas.*

5. Wind

a. *Transports heat in either sensible or latent form, from lower to higher latitudes*
b. *Provides the moisture (to the land masses) which is necessary for precipitation*
c. *Moderate turbulence promotes the consumption of carbon-dioxide in photosynthesis*
d. *Wind prevents frost by disrupting a temperature inversion*

6. Rainfall

a. *Water plays an important role in life processes of crop plants (in the exchange of gases)*

b. *The heat capacity of water is high and its high thermal stability helps in regulation of the temperature of crop plants.*
c. *Water has highest heat conduction capacity and due to this the heat produced by the activity of a cell is conducted immediately by water and distributed evenly to all plant parts*
d. *The viscosity of water is higher than that of many solvents and this property helps in protecting the crop plants and trees against mechanical disturbances.*

Lecture 5- 6

Elementary crop growth models –calibration and validation, Elementary crop growth models -verification and sensitivity analysis

Elementary crop growth models:

Definition: *Elementary crop growth A model is a schematic representation of the conception of a system or an act of mimicry or a set of equations, which represents the behaviour of a system at Basic level. Also, a Elementary crop growth model is "A primary representation of an object, system or idea in some form other than that of the entity itself". Its purpose is usually to aid in explaining, understanding or improving performance of a system. A model is, by definition, "A simplified version of a part of reality, not a one to one copy". This simplification makes models useful because it offers a comprehensive description of a problem situation. However, the simplification is, at the same time, the greatest drawback of the process. It is a difficult task to produce a comprehensible, operational representation of a part of reality, which grasps the essential elements and mechanisms of that real world system and even more demanding, when the complex systems encountered in* *environmental management.*

Description: *Crop growth models basically applied in three sections (1) tools for research, (2) tools for decision-making, and (3) tools for education, training and technology-transfer. The greatest use of crop growth models so far has been by the research community, as models are primarily tools for organizing knowledge gained in experimentation. However, there is an urgent need to make the use of models in research more relevant to problems in the real world, and find effective means of dissemination of results from work using models to potential beneficiaries. Nevertheless, crop models can be used for a wide range of applications. As research tools, model development and application can contribute to identify gaps in our knowledge, thus enabling more efficient and targeted research planning. Models that are based on sound physiological data are capable of supporting extrapolation to alternative cropping cycles and locations, thus permitting the quantification of temporal and spatial variability. Over a relatively short time span and at comparatively low costs, the modeler can investigate a large number of management strategies that would not be possible using traditional methodologies. Despite some limitations, the modelling approach remains the best means of assessing the effects of future global climate change, thus helping in the formulation of national policies for mitigation purposes. Other policy issues, like yield forecasting, industry planning, operations management, consequences of management decisions on environmental issues, are also well supported by modelling. Models are not simple mechanisms to archive and synthesize information for producing forecasts. Modelling represents a better way of synthesizing knowledge about different components of a system, summarizing data, and transferring research results to users.*

calibration and validation of Elementary crop growth models:

Model Calibration/ Verification

After constructing the model one must ask three questions,

- *To what extent does the mathematical model represent reality*
- *Is the model exactly represented by the computer program*
- *Are the experimental data correct*

In many instances, simulated values do not exactly comply with the observed data and minor adjustments have to be made for some parameters. To make the model work correctly, some of the parameters in the equations and even some of the relationships have to be adjusted. This process is called as calibration.

Tools for Model Calibration

➢ Using the SI system throughout the program and checking of the units of all equations,

➢ developing the mass balances for the state variables,

➢ comparison of numerical and analytical solutions, usually for portions of the model,

➢ performing a robustness test using extreme, but realistic, parameter values to investigate whether the program fails or shows strange behavior, and

➢ Performing a sensitivity analysis (how strongly does model output change compared to a change in the input), both with respect to parameters and structure of the model.

Sometimes it is necessary to recalibrate a model when a different soil type, cultivar, etc., is to be simulated. For example, in soybeans, much of the variation between cultivars can be explained by maturity group number. The existence of parameters that have to be altered alerts us to the fact that our model is not as universally applicable as we might have supposed. Either there is a problem with some mechanism or we need additional input data. Even when simulation models have to be recalibrated for different situations, they can still be useful so long as the recalibration procedure is simple.

Testing model performance during development of a model usually results in calibration, which is, according to Penning de Vries (de Vries and von Laar, 1982) a "very restricted form of evaluation," and "adjustment of some parameters such that model behavior matches one set of real world data." It can "degrade simulation into curve fitting."

Before any model can be used with confidence, adequate validation or assessment of the magnitude of the errors that may result from their use should be performed. Model validation, in its simplest form, is a comparison between simulated and observed values. Beyond comparisons, there are several statistical measures available to evaluate the association between predicted and observed values, among them the correlation coefficient (r) and its square, the coefficient of determination (r2).

Test criteria have been separated into two groups, called summary measures and difference measures. Summary measures include the mean of observed values (0) and predicted values (P), the standard deviations of observations (So) and the predictions (Sp), the slope (a) and intercept (b) of the least-squares regression:

$Pi = a + b * 0i$

In addition, an index of agreement (d) (Willmott, 1982) was calculated as follows:

$d = 1 - [S (P - O) / S (|P'| + |O'|)], 0 < d < 1$

where P' = P - O and O' = O – O

Though (d) is meant to be used mainly to determine the relative superiority of alternative models, it can be valued as a descriptive parameter of model performance. The more (d) approaches 1, the more accurate the model.

While summary measures describe the quality of simulation, difference measures try to locate and quantify errors. The latter includes the mean absolute error (MAE), the mean bias error (MBE), and the root mean square error (RMSE). They all are calculated according to Willmott (1982) and based on the term (Pi - 0i):

A) Mean Absolute Error (MAE): MAE = S | Pi - 0i | / n

B) Mean Bias Error (MBE): MBE = S (Pi - 0i) / n

C) Root Mean Square Error (RMSE): RMSE = S (Pi - 0i)2 / n

MAE and RMSE indicate the magnitude of the average error, but provide no information on the relative size of the average difference between (P) and (0). MBE describes the direction of the error bias. Its value, however, is related to magnitude of values under investigation. A negative MBE occurs when predictions are smaller in value than observations.

In the test of data sets without N routines, attention was focused on the unsystematic error (RMSEu) as in the system: MSE = MSEs + MSEu

For a good model, the unsystematic error RME should approach RMSE, with RMSEs approaching 0/, which is what could be observed.

The parameters examined in the statistical evaluation were

1. *Anthesis date*
2. *Maturity date*
3. *Leaf area index (LAI) at maximum*
4. *Total above ground dry matter at maturity*
5. *Grain yield*
6. *Individual grain weight at maturity*
7. *Number of grains per m2 at maturity*
8. *Dry matter at anthesis*
9. *N uptake by the crop at anthesis*
10. *N uptake in the above ground plant parts at maturity*

11. N content of the grain

12. Grain protein percentages

Verification and sensitivity analysis of Elementary crop growth models:

Model testing involves verification, Calibration Validation and sensitivity analysis. Before the use of any model, adequate validation or assessment of the magnitude of errors that may result through it use is necessary.

Calibration: *Testing performance of a model during its development results in calibration. Calibration can be defined as a process involving adjustment of some parameters or coefficient in functional relationship so that the model behaviour matches one set of real world data. Calibration is an elementary aspects of verification.*

Calibration refers to quantifying parameters using system observations and the simulation outputs

Verification: *Verification means to test truthfulness of correctness of model or sets of model.*

Thus verification is used as evaluation for truthfulness or correctness while validation is used as evaluation of model for its usefulleness.

Validation*: Model validation in its simplest form is a comparisons between simulated and observed values. Validation is determining whether the model works with totally independent data sets, that is does it accurately predict growth, yield and process. From comparison between the values predicted by the model and the values obtained from the real experiment validation can be done.*

Validation and Verification are commonly used synonymously.

Validation is continuous process and denotes only establishment of legitimacy rather than verification.

Verification *involves the evaluation of the accuracy with which computer code represents the model.*

Accuracy*: Accuracy is defined as the degree to which the model predictions approach the magnitudes of their observed values.*

If the simulated values lie within the projected confidence level band, model can be considered valid. Test criteria from statistical analysis can determines this.

Sensitivity analysis:

Sensitivity analysis is done to explore the behaviour of the models for different values of the parameters as input. The model is said to be sensitive to input *parametrs e.g. weather variable, fertilizer etc. if major or large change occures in output when the input parametrs changes in small amount.*

Lecture 7-8

Potential and achievable crop production-concept , Modelling techniquies for potential and achievable crop production estimation

Potential crop production:

Definition:

Potential crop production is defined as the yield of a cultivar when grown in environments to which it is adapted, with nutrients and water non-limiting and with pests, diseases, weeds, lodging, and other stresses effectively controlled.

Concept: *As such, it is distinguished from potential yield, which we define here as the maximum yield which could be reached by a crop in given environments, as determined, for example, by simulation models with plausible physiological and agronomic assumptions. Several implications of the definitions given above are considered, particularly those arising from cultivar interactions with agronomic practices and with the biotic and abiotic environments. We then discuss both direct and indirect methods of measuring progress in yield potential. Continuing progress in yield potential through conventional breeding is apparent in many crops, and is significant for yield progress at the farm level under a wide range of conditions. Among the small grain cereals, greater yield potential has derived mainly from the rise in harvest index associated with dwarfing, whereas in maize (Zea mays L.), it has come from increased tolerance to closer planting. The duration of photosynthetic activity has been extended in several crops but there is little evidence of increases in photosynthetic capacity or maximum crop growth rate. The rise in genetic yield potential in wheat and maize cultivars has been associated with progressive widening of their genetic background, and there is little sign of this slowing down.*

Achievable crop production :

Definition: *Achievable crop production is defined as the yield of a cultivar when grown in environments to which is Limited by water, plant nutrients, weeds, diseases, pests and pollutants*

Concept: *Most predictions use historic data on relations between climate and crop yields. When expected future climates are imposed on current agriculture there will be change in output, and in the case of sub-Saharan Africa the change is mostly negative. Such models fail to take into account that also agriculture will change when the climate becomes different.*

- *Achievable/Attainable yield: Limited by water and plant nutrients.*
- *Actual yield: Reduced by weeds, diseases, pests and pollutants.*
- *Yield gap: Difference between attainable and actual yield.*
- *Theoretically climate change affects potential yield. In most crop production actual yield is limited mostly by non-climatic factors and there is no obvious direct relation between climate change and actual yield.*

Techniques for potential and achievable crop production estimation:

Modelling Techniques

In later units we will deal in considerable detail with modeling techniques, but we shall give an overview and introduction here. Generally models are approximations of real world artefacts which can be analysed. A good model is one which fairly accurately predicts the behaviour of the real world artefact it represents while doing away with a lot of the confusing complexity. Models are therefore tools for 'abstraction'. What is important for an analyst using a modeling technique is that it abstracts away the irrelevancies and keeps the important facts. A model that does so it called 'well scoped', it is up to the analyst to chose a modeling techniques that is well scoped for the questions they want to ask of it.

Task analysis

A task analysis technique makes a model of the job that a user is expected to perform. Analysis techniques can be applied to those models in order to determine such facts as how long it may take users to perform given tasks, or how much 'cognitive load' is placed on the user (where 'cognitive load' is broadly a measure of much information the user needs to remember).

The most researched task analysis technique is GOMS (Goals, Operations, Methods and Selection) developed by Card et al (1983). The analysts describes:

the user's goals, or the things that user wants to achieve,

the operations, or the things the user can do, perhaps such things as thinking or looking, or maybe selecting items from computer menus, typing or pointing with the mouse,

the methods, which are sequences of operations that achieve a goal, and

selections, which describe how the user may choose between different methods for achieving the same goal.

Once this model of the user's task has been compiled then measurements of the time it takes to perform the operations can be added (these measurements are taken from empirical observations of users) and a prediction of the time it will take the user to perform a task can be calculated.

GOMS only really deals with expert behaviour though and takes no account of the user making errors. It has been argued that a surprisingly large amount of user time is spent making, or recovering from, errors, even for expert users. Therefore the accuracy of GOMS models have been questioned.

GOMS analysts scored a notable victory however when they accurately predicted that users of a new computerised telephone system would take longer to perform their tasks than users using an older, apparently slower system (Gray, John and Atwood. 1993).

User modeling

Whereas task analysis aims to model the jobs that users do, user modelling aims to capture the properties of users. User models can capture and predict properties such as the way the user constructs goals, how users make plans to carry out those goals, the users' ability to do several tasks at once, how the user manages perception, etc. Such models are based to a large extent on psychological theory, which in turn is based on empirical evidence.

Typically the analyst builds a model of the interactive device that is intended to be built and then integrates this device model with an existing user model. This integrated model will be able to predict certain behaviours, and the analyst can therefore gain an idea as to whether the user will be able to reasonable perform the tasks that the analyst wants them to.

Interactive device modeling

Several techniques have taken existing software specifications and analysed them 'from the users' point of view'. In other words the analyst takes a model of the interactive device, which is typically produced as part of the design process, and analyses it for 'usability properties'. A lot of work went into proposing usability properties and then formalising mathematical equivalents of them. In this way software specifications could be mathematically analysed for usability in much the same way as they can be analysed for functional correctness.

Dix's PIE model (Dix 1991) is a classic example of interactive device modelling. The device is modelled as a collection of states with allowable transitions between them. This model can then analysed mathematically for such properties as 'reachability'; the ability of the user to get from such state to any other allowable device state. Dix also formalised what it means for a system to be so called 'WYSIWYG' (what you see is what you get) by separating the displayed output from the printed output in his model and mathematically showing correspondences between the two.

Problems with modeling

As we explained above, models must be used with care. Because they abstract details away the analyst must understand what is being abstracted away and be able to argue why those details are not important. Furthermore modeling is seen as a highly skilled and time consuming activity. The idea of modeling is to be able to predict usability issues before a system is built, but many developers have the impression that modeling can be so complicated and highly skilled that it is cheaper to just build the system and then test it on users. Refutations to this are rare, but compelling (e.g. the GOMS analysis of the phone system we alluded to above). We will return to these issues in much more depth in subsequent units

Lecture 9-10

Crop production in moisture and nutrients limited conditions. Components of soil water and nutrient balance

Crop production in moisture limited conditions:

Plant growth under extreme moisture stress

The sensitivity of plants to an unfavorable water balance varies from stage during the life cycle of the crop. Young seedlings of plants, especially cereals, can withstand a high degree of drought in the first several days of their growth. As soon as their first leaves bloom very sensitive to drought. During active growth different species respond differently to drought. Near maturity they once again lose their sensitivity to drought to same extent.

Soil moisture stress and grain yield :

There are three key stages when water stress affects the grain yield in cereals and these are:

1) *Stage of floral initiation and inflorescence development*
2) *Stage of anthesis and fertilization*
3) *Grain- feeling stage*

Inflorescence development

For most cereal crops even slight water stress can reduce the rate of appearance of floral primordia. If the stress period at this stage is sever and prolonged, the total number of spikelet's are substantially reduced.

Fertilization:

Stress at anthesis can markedly reduced fertilization in most serials. The best example is that of corn in which reduction of 50% yield is caused by wilting at this period.

Scientist are of the opinion that stress at this stage is likely to interfere with germination of pollen or growth of pollen tubes from the sigma to the ovules. This type of the injury is however, more pronounced in the case of corn as compared with other cereal crops.

For wheat, it has been observed that grain yield is reduced to a great extent when stress develop about 10 days before the emergence of wheat ears, due to pronounce effect on the number of grains formed per spikelet.

Grain filling:

The weight per grain is influenced by pre-flowering and post-flowering conditions. However, the post flowering stage is the most important. In case up wheat, virtually on the increases in dry weight after anthesis is by grain grain filling. Thus water stress by reducing photosynthesis during this period can lead to a large yield decreases.

Crop production in Nutrient limited conditions:

Several studies have shown that nutrient deficiencies can affect the rate of leaf emergence, although usually only when the nutrients concerned [e.g. nitrogen (N), copper (Cu)] are severely deficient Delayed maturity is also commonly observed in nutrient-deficient plants, e.g. N, phosphorus (P)

***Nitrogen (N) deficiency** : causes pale, yellowish-green corn plants with spindly stalks. Because nitrogen is a mobile nutrient in the plant, symptoms begin on the older, lower leaves and progress up the plant if the deficiency persists. Symptoms appear on leaves as a v-shaped yellowing, starting at the tip and progressing down the midrib toward the leaf base. The condition is favored by cold or saturated soil; dry soil, particularly after mid-season; large amounts of low-nitrogen residue; sandy soil; inadequate fertilization; leaching from heavy rainfall; and flooded or ponded soil when the temperature is warm.*

***Phosphorus (P) deficiency** is usually visible on young corn plants. It readily mobilizes and translocates in the plant. Plants are dark green with reddishpurplish leaf tips and margins on older leaves. Newly emerging leaves will not show the coloration. Phosphorusdeficient plants are smaller and grow more slowly than do plants with adequate phosphorus. Deficiency symptoms nearly always disappear when plants grow to three feet or taller. Some corn hybrids tend to show purple colors at early stages of growth even though phosphorus nutrition is adequate, yet other hybrids do not show the color symptoms even though inadequate phosphorus severely limits yields. Phosphorus deficiency is favored by cold soils that are too wet or too dry; phosphorus applied where plant roots cannot absorb it; restricted root growth in compacted soils; and roots injured by insects, herbicides, fertilizers, or cultivation.*

***Potassium (K) deficiency** is first seen as a yellowing and necrosis of the corn leaf margins, beginning on the lower leaves. Symptoms usually don't appear for some time after planting (about 4 to 6 weeks, around the V6 growth stage). If the deficiency persists, symptoms progress up the plant because potassium is mobile in the plant and translocates from old to young leaves. When potassium deficiency is severe, older leaves turn yellow with tissue necrosis along the margins, but the upper new leaves may remain green. Potassium deficient corn tends to lodge late in the growing season due to poor stalk strength. Potassium deficiency is favored by conditions that limit early root growth, development, and activity — root pruning, dry soil, compacted soil, seed trench side-wall smearing; wet soil; sandy soil; organic soil; strongly geologicallyweathered soils; potassium applied where plant roots cannot absorb it; large amounts of potassium removed by a preceding crop; and some tillage systems such as ridge-tillage and no-tillage, especially in a dry year and on soil with low levels of subsoil potassium. Calcium (Ca) deficiency is rare in corn. It has not been verified in Iowa. If deficient, leaf tips stick to the next lower leaf, creating a ladderlike appearance. Plants may be severely stunted because calcium is immobile in the plant; it is not translocated from old to growing plant tissue that needs calcium. Low soil pH and acid soil problems like excessive levels of soluble aluminum and* *manganese are more likely to occur before calcium deficiency symptoms appear. Calcium deficiency is favored by very low soil pH, below 5.0 on mineral soils and 4.8 on organic soils; non-limed, highly weathered acid soils; or by very high magnesium and potassium and very low calcium on the cation exchange complex. Magnesium (Mg) deficiency is first seen as yellow to white interveinal striping of the lower corn leaves. Dead, round spots sometimes follow, which give the impression of beaded streaking. Older leaves become reddish-purple, and the tips and edges may become necrotic if the deficiency is severe. This happens because magnesium is mobile in the plant and is translocated from old to new plant tissue. Magnesium deficiency is favored by very acid, sandy soils in regions of moderate to high rainfall where magnesium has been extensively leached from the soil profile. On soils marginal in crop available magnesium, deficiency can be induced by high soil potassium levels or high rates of applied potassium.*

***Sulfur (S) deficiency** shows on small corn plants as a general yellowing of the foliage, similar to nitrogen deficiency. Yellowing of the younger upper leaves is more pronounced with sulfur deficiency than with nitrogen deficiency because sulfur is not easily translocated in the plant. Stunting of plants and delayed maturity also are symptoms. Interveinal chlorosis of the youngest leaves may occur. This deficiency is favored by acid sandy soils; low soil organic matter; and cold - dry soils in the spring that delay the release of sulfur from organic matter. Early-season symptoms may disappear as temperature and moisture conditions improve for mineralization of sulfur from organic matter, or corn roots reach plant-available sulfate contained within the soil profile.*

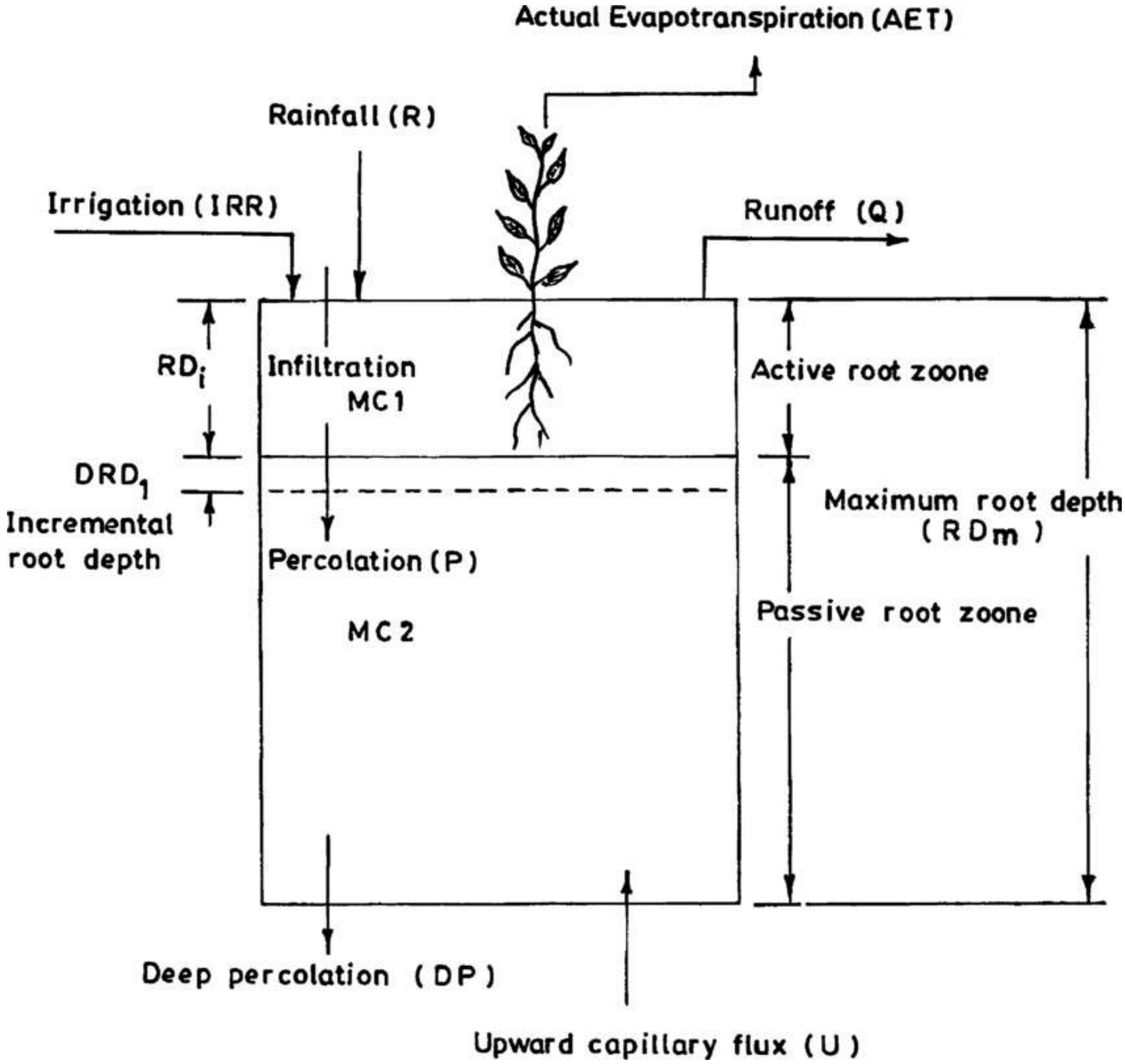
***Molybdenum (Mo) deficiency** (no picture) is rarely, if ever, found in corn. It has not been identified in Iowa. If it occurs, however, older leaves become necrotic at the tip, along the margins, and between the veins. This condition is favored by very low soil pH and strongly weathered soils, conditions not normally found in the Midwest.*

***Boron (B) deficiency** (no picture) is rare in corn. It has not been verified in Iowa. Leaves have small dead spots and are brittle. Boron is not readily translocated in the plant and as a result upper internodes do not elongate. Tassels and ear shoots are reduced and may not emerge. Corn is very sensitive to boron fertilizer. Boron toxicity can result if fertilizer is applied at rates above recommendations, or row applied. Deficiency is favored by drought; sandy soils that are low in organic matter; and high soil pH. Drought reduces the release of boron from organic matter, but lack of water also delays ear shoot emergence and possible pollination; therefore, symptoms may occur simultaneously and could be confused with each other. **Copper (Cu) deficiency** (no picture) is rare in corn. It has not been verified in Iowa. The youngest leaves are yellow as they come out of the whorl, and the tips may die. Copper is relatively immobile in the plant. Leaves become streaked, causing an appearance that is similar to iron deficiency. The stalk is soft and limp. Some necrosis of older leaf edges occurs as it does in cases of potassium deficiency. Copper deficiency is favored by organic soils (very high soil organic matter) and by high soil pH (above 7.5). Iron (Fe) deficiency turns the interveinal area along the length of the upper leaves pale green to nearly white. It has not been verified in Iowa. Iron is immobile*

and is not translocated from old to young plant tissue. This deficiency is rare on corn because of its low iron requirement,
SOIL-WATER BALANCE: LINKING SOIL, BIOTA, AND CLIMATE

Components of soil water balance:

Climate, soil, and ecology are linked together through the soil-water balance in an environment (Thornthwaite and Mather, 1955). Water availability is more important than precipitation because the amount of water available for plant growth controls the abundance and diversity of plants, which forms the basis for the food pyramid, and supports lower and higher trophic levels. All levels of life that occupy the landscape above- and belowground in continental ecosystems depend on water, which is ultimately controlled by climate



Components of soil water balance

The effects of climate on soil-water balance can be measured through the soil-water budget which is equal to the gain, loss, and storage of soil water in a column of soil (Thornthwaite and Mather, 1955; Strahler and Strahler, 1989). There are several components of the soil-water balance. Evapotranspiration (E) is defined in two ways. Actual evapotranspiration (Ea) is the actual rate at which water vapor is returned to the atmosphere from the ground and by plants, and is also termed water use. Potential evapotranspiration (Ep) is the water vapor flux under ideal conditions of complete ground cover by plants, uniform plant height and leaf coverage, and an adequate water supply; this is also termed water need. These values have been calculated for land surfaces of the entire globe based on air temperature, latitude, and time of year Intensity and duration of solar radiation received by the landscape is determined by latitude and the season. As a consequence, water need for a particular environment may be greater or lesser than the amount actually used. Soil-water shortage (D) occurs when Ea < Ep, and soil-water surplus (R) occurs when Ea > Ep. Surplus will result in (1) runoff from excess water or retarded infiltration and (2) groundwater flow through the vadose zone to the phreatic zone. Precipitation (P) is mainly the delivery of moisture to the environment, but may also be in the form of fog or mist which occurs along the coasts of most continents Moisture used by plants is termed utilization (−G); if it is not used, it is termed recharge (+G) and will pass eventually through to the phreatic zone and become part of the groundwater outflow as a form of runoff (R). Soil-water storage (S) is the sum of available water in the soil column available to plants and animals, and also affects soil formation, nutrient cycling, and overall biodiversity .

Water delivered to the soil through precipitation and runoff becomes part of the soil-water belt which is part of the groundwater profile The thickness of each zone in the groundwater profile is dependent upon the water-table depth, which reflects the soil-water balance. The upper vadose zone is the depth reached by most plant roots and associated biota in general. The intermediate vadose zone typically marks a depth too great for water to be returned to the atmosphere by evaporation. The phreatic zone is generally out of reach for most organisms in most environments .

Components of soil nutrient balance:

Negative nutrient balances in most Indian soils not only mirror poor soil health, they also represent severe on-going depletion of the soil's nutrient capital, degradation of the environment, and vulnerability of the crop production system in terms of its ability to sustain high yields. In the prevailing regime of widespread negative nutrient balances, it is difficult to foresee positive nutrient balances in most parts of India, even when all available sources of plant nutrients are deployed, unless their quantity and efficiency is raised substantially. Depleted soils cannot be expected to support bumper crops or high growth rates. An assessment of nutrient additions, removals, and balances in the agricultural production system generates useful, practical information on whether the nutrient status of a soil (or area) is being maintained, built up, or depleted. A simplified depiction of nutrient additions and removals is given in Figure Estimates of nutrient input and output allow the calculation of nutrient balance sheets both for individual fields and for geographical regions. It is a book-keeping exercise, similar in many ways to keeping a bank account. A considerable amount of information on nutrient uptake and removal by crops and cropping system is now available. In most cases, different balance sheets are not comparable due to vastly different assumptions and computation methodologies.

Several aspects of nutrient uptake, removal, and balances have been dealt with in detail elsewhere (Kanwar and Katyal, 1997; Tandon, 2004). Nutrient balance sheets in most soils of India have been deficient and continue to be so. This is primarily because nutrient removals by crops far exceed the nutrient additions through manures and fertilisers. For the past 50 years the gap between removals and additions has been estimated at 8 to 10 M t N+P2 O5 +K2 O per year (Tandon, 2004). This has been the case in the past, at present, and this will likely continue into the future. To this extent, the soils are becoming depleted – the situation is akin to mining soils of their nutrient capital, leading to a steady reduction in soil nutrient supplying capacity. On top of this deficit are the nutrient losses through various other means. For example, nutrient losses through soil erosion are alarmingly large, but are rarely taken into account. Nutrient loss through soil erosion is second only to nutrient removal as a result of crop production. An annual loss of 8 M t plant nutrients has been mentioned through 5.3 billion t of soil lost by water erosion (Prasad and Biswas, 2000). Estimates of removals through leaching and gaseous losses are not available. Cropping system based scenario: In many cases, even the well managed cropping systems raised on currently recommended rates of nutrient application end up depleting soil fertility. The rice-wheat annual cropping system, the most intensive annual system practiced in India, is cited as one example (Tiwari et al., 2006). Productivity of the rice-wheat system was tested at 10 locations across India for 2 years. Crops received recommended rates of nutrients through fertilisers as per the site specific nutrient management (SSNM) plan. Average annual grain productivity was 13.3 t/ha. In many cases, even when the nutrients were applied based on the requirement of individual fields, nutrient uptake exceeded nutrient input resulting in negative balances. The N and P balances were positive at 5 sites and negative in the other 5. The K and S balances were negative at all 10 sites; the K balances were the most negative.

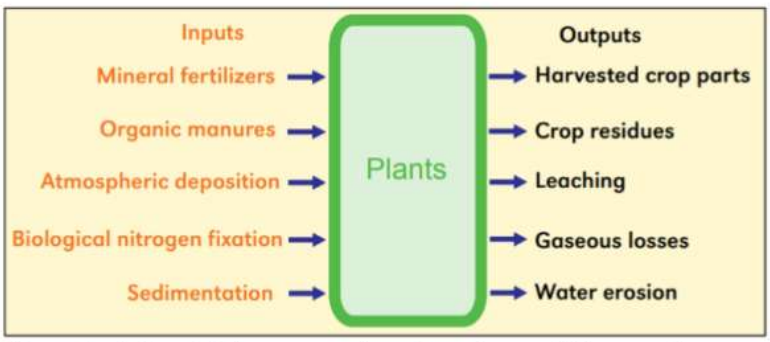


Figure 1. A simplified presentation of nutrient additions and removals in agricultural soils (Smaling, 1993)

Lecture 11-12

Weather forecasting, its types, methods and tools. Techniques of weather forecasting and its verification

Definition: *Weather in future obtained by evaluating the present and past meteorological conditions of the atmosphere is called weather forecasting. OR The prediction of weather in advance is called weather forecast. Weather forecasting is the predication of weather.*

Weather forecasting in Agriculture *: Forecasting of weather elements viz sunshine hours, occurrence of dew, relative humidity, rainfall, temperature, winds etc. which are important in agriculture and for farming operations is known as agricultural forecost.*

Classification of weather forecasting/Types of weather forecasting :

Weather forecasting on the basis of their validity period or timescale are classified as follows :

1) ***Now casting*** *: Denotes very short range, say few hours to 24 hours. Forecast at the time of cricket match during the day.*
2) ***Short range forecast*** *(SRF): Valid for 3 days or 72 hours and are issued twice a day.*
3) ***Medium range forecast*** *(MRF): This forecast is valid for 3 to 10 days period. In this forecast, irregularities (anomalies) of the weather elements such as temperature, rainfall from normal values are predicted. Agricultural operations like sowing, planting, spraying, dusting, irrigation scheduling, storing, fertilizer application, transportation of Agril & live stock goods protection from frost, hails, etc. can be forecasted.*
4) ***Long range forecast*** *(LRF) : Valid for a period more than 10 days, say a month or a season*

Methods of weather forecasting :

1) ***Synoptic method*** *: The chart or map on which various weather data and analysis are presented and describes the atmosphere for large area at a given time is called synoptic chart or map. A forecaster studies carefully past weather charts, some empirical rules are formed so as to enable to estimate the behaviour of the atmosphere. This method gives reliable forecast for short range forecast, few hours to day.*
2) ***Statistical method*** *: This involves the study of past weather data. The*

relationship between certain weather elements and the weather in general are established from the past data. From this relationship current data are used to project the future conditions. It is used in LRF.

3) ***Numerical weather prediction*** *(NWP)* **:** *This method is based on certain physical principles. By employing the laws of physics to the different atmospheric processes and phenomena. Equations controlling the atmospheric motions are formulated. The work of solving these equations is laborious one but now a days it is possible or easy with the help of super computers.*
4. ***Persistence method*** *: This method is based on the principle that weather phenomenon has some degree of persistence or continuity in time and does not perish at once but lasts for some more time. According to this phenomenon or system of thunder storm will persist and move on and will affect the areas in its path. These forecasts are used for local forecast for determining such events as the time of the arrival of a thunder storm moving towards the region.*
5. ***Analog*** *: This method is based in locating in the past weather records, the conditions those are as nearly analogous (similar) to the current conditions as possible. Once this is done, it is then presumed that weather events should parallel to the past situation. It is however has limited use.*

Forecasting network in India **:** *The observations are recorded for various parameters twice daily in the meteorological observatories. The observations are recorded in 8 times a day at large number of places, so that fairly accurate information of the atmospheric condition over large area is available. The upper air observations are recorded with the help of balloons, rockets, and earth satellites. To obtain meteorological observation over the sea area the information from ships in the sea water is saught with the wireless unit. All these data are made use of in weather forecasting.*

Since 1945 farmers weather bulletins are being issued by the forecasting unit of IMD. These are district wise forecast for 36 hrs, with an emphasis of these aspects of weather which are likely to affect crops.

The weather forecasting is broad-casted on every Tuesday at 7.15 to 7.30 pm. All India Radio, Pune as a forecast for farmers for next week. This forecast is now becoming helpful for grape growers & floriculturists in the state, moreover, this is useful for the farming community for planning their day to day work on their farms.

It is useful for air ways service, on road transport for ships in sea & also for fisherman.

Importance or significance of weather forecast in agriculture:

1. *The forecast of the weather events helps for suitable planning of farm.*
2. *It helps in to undertake or with held the sowing operation.*
3. *It helps is following farm operations.*
   a) *To irrigate crop or not*
   b) *Whether to apply fertilizer or not*
   c) *Whether to start harvesting or with held it.*
4. *It helps in transportation & storage of food grains.*
5. *Helps for management of cultural operations like ploughing, harrowing, hoeing etc.*

It helps in measures to protect live stock.

Techniques / Tools of Weather forecasting :

Weather forecasting requires several basic inputs. They are area coverage under the network of meteorological stations & the collection of meteorological data on cloud cover, sunshine, radiation, rainfall, temperature, wind & pressure along with the upper air dada on wind, humidity & temperature at various heights.

1) Pilot-balloons : *A small balloon is inflated with a gas (hydrogen/heligum) lighter than air & released for measurement of wind direction & speed at different heights in the atmosphere using a theodolite. The theodolite is an optical telescope, which measures horizontal & vertical angles of the ascending balloons of known intervals of time. The path of the balloon is determined from the data observed through graphical techniques. The main difficuly with an optical theodolite occurs when the sky is obscured, because the balloon is soon lost and can be no longer traced. This difficulty could be overcome by using radio-theodolites where radio signals are used to track the balloon. To measure temperature, humidity & pressure at different heights in the atmosphere, meteorographs were attached in the past to the ascending balloons.*

2) Radiosonde*: The radiosonde is a device with sensitive sensors, which transmit observation by radio signals to a ground receiver as the balloon ascends. It is carried aloft by means of a free balloon. The instrument measures temperature, humidity & pressure at various levels of the atmosphere through which it passes. The meteorological instruments contain in radiosonde are designed to register temperature ranging from about +40 to 90^{0}C, relative humidity from 15 to 100% & barometric pressure from 1040 to 40hPa or less. The advantage of radiosonde is that the data are immediately available and useful in weather forecasting.*

3) Radar & satellites : *They are two space tools to sense meteorological parameters using remote sensing techniques, Remote sensing techniques is used by radar (Radar stands for Radio Detection and ranging) which transmit electromagnetic pulses of a given characteristics and aslo receive them back, The Indian satellite (INSAT) is a domestic satellite system used in communication, television, radio broadcasting & meteorology. The INSAT-1A gives information on cloud spread & amount & information on temperature of the earth's surface & cloud tops. This information is used in short range & medium range weather forecasting.*

*4) **Synoptic chart:** An enormous volume of meteorological data is being collected from all over the world, continuously round the clock throught various telecommunication channels. To arrases, assimilate & analyse the above vast data, they have to be suitably presented. For this purpose, the observations are plotted on maps in standard weather codes. Synoptic chart is a chart or map on which distribution of selected meteorological elements, over a large area, at a specified instant of time is represented. The surface and upper air charts are the two types of synoptic charts currently in use.*

*5) **Crop weather calendar :** In order to provide the farmer with an efficient weather service, it is essential that the weather forecaster should be familiar with the crops that are grown in a particular agro-climatic zone. The type of forewarnings to be given depending upon the state and stages of the crops are also to be known. In case of farmers, they should become familiar with weather bulletins and learn how in interpret them. To meet the above requirement, the detailed information collected from agricultural departments has been condensed by the IMD & presented in a pictorial from known as crop weather calendar.*

*6) **Crop weather diagram :** It gives season-wise information on the crop husbandry (tillage to harvest) actual weather & normal weather month /week-wise & information on pest & disease incidence. It may help in undertaking favourable weather conditions that are responsible for better crop yields & the vice versa if they are prepared for more number of years. Using the crop weather diagrams, attempts can be made for obtaining better crop yields through agronomic manipulations &also the one can predict crop yields qualitatively based on weather conditions.*

Utility in Agriculture:

1. *Agriculture and farming are mainly dependent on seasons and weather. The temperature matters a lot in that case when it comes to the farming of different kinds of fruits, vegetables, and pulses. Previously we did not have a better understanding of weather forecasting and farmers were still doing their job based on predictions. Though sometimes they occur loss due to false predictions of weather. Now that the technology is developed and special weather forecasting mechanisms are available, the farmers can get all the updates are on a Smartphone. Education towards that is, of course, an important thing but most of the farmer population at this stage knows the basics which make it easy for them to use the features.*
2. *Occurrences of erratic weather are beyond human control. It is possible, however, to adapt to or mitigate the effects of adverse weather if a forecast of the expected weather can be obtained in time. Forecasts should ideally be used for small areas. Some aspects of weather forecasts for agriculture are quite distinct from synoptic weather forecasts. While clear weather is required for sowing operations, it must be preceded by seed zone soil moisture storage. Crop weather factors mean that crops and cropping practices vary across areas within the same season. In the case of well-organized weather systems, the desired areal delineation of forecasts*

can be realized. The area to which the weather forecasts will be applied must be unambiguously stated.

3. *Weather forecasting is a prediction on conditions of atmosphere depending on location and time. Every area will have their different predictions related to the condition of weather which makes pretty easy for the farmers to know how and what to do when. The relationship between weather and agriculture has, therefore, necessitated the need for accurate prediction of the weather; to enable farmers to make an informed decision that will not bring losses to them. Temperature, sunlight, and rainfall have major effects on the crops. For livestock, temperatures and adequate water and food are essential.*

   The forecast of the weather event helps for suitable planning of farming operations. It helps to decide whether to undertake or withhold the sowing operation. To irrigate the crop or not, when to apply fertilizer and whether to start complete harvesting or to withhold it are the major components for which forecasting is a must.

4. *Irrigation is an artificial application of water to land for agricultural production and farming. The requirements for irrigation and crop growth are affected by weather variability. The amount of timing and evapotranspiration are two main weather-related requirements.*

Lecture: 13-14

Value added weather forecast, ITK for weather forecast and its validity. Aerospace science and weather forecast

***Value added weather forecast** : It is Forecast given by State Data Centre of IMD. (for Maharashtra it is in Mumbai) this Forecasting contains Medium range weather forecast(5 days), as shown in below table . This forecast is prepared by Many of Mathematical Models e.g. NWP models, operational MM-5, ETA and T-80 models of National Centre for Medium Range Weather Forecasting (NCMRWF) and from the MM-5 model operational at IMD New Delhi. And value addition i.e. it made more accurate with satellite data, GIS data, present weather condition, study of previous 30 years etc.*

TABLE 1

District level value-added dynamical-synoptic forecast format

Name of the state	Name of the district	District index	Forecast (Rainfall in mm)																				
			T-80 (NCMRWF)			MM5 (IMD)			MM5 (NCMRWF)			ETA (NCMRWF)			Dynamical F/C			Value-added dynamical F/C			Realized (Actual) (Rainfall in mm)		
			Day-1	Day-2	Day-3	Day-1	Day-2	Day-3	Day-1	Day-2	Day-3	Day-1	Day-2	Day-3	Day-1	Day-2	Day-3	Day-1	Day-2	Day-3	Day-1	Day-2	Day-3
Anda-man & Nicobar	Anda-man	01001																					
	Nicobar	01002																					

INDIA METEOROLOGICAL DEPARTMENT					
NWP MODELS BASED DISTRICT LEVEL WEATHER PREDICTION					
ISSUED ON: 28.02.2020					
VALID TILL 08:30 IST OF THE NEXT 5 DAYS					
STATE :	MAHARASHTRA				
PARAMETERS		WEATHER FORECAST			
	DAY-1	DAY-2	DAY-3	DAY-4	DAY-5
	29022020	1032020	2032020	3032020	4032020
DISTRICT : PUNE					
Rainfall (mm)	0	0	0	0	0
Max Temperature (deg C)	34	34	34	35	35
Min Temperature (deg C)	16	16	15	15	16
Total cloud cover (octa)	1	2	2	2	2
Max Relative Humidity (%)	67	67	67	65	65
Min Relative Humidity (%)	22	22	25	25	22
Wind speed (kmph)	7	7	7	5	9
Wind direction (deg)	236	187	289	270	277

Value added forecast given for Pune AMFU

As pointed out earlier the district level forecast system is being developed based on the principles of super-ensemble method. Model outputs of different numerical models are utilized for generation of district level quantitative forecast of rainfall. While examining the performance of individual models it was found that each model had certain strengths and weaknesses. For instance some models were able to provide good forecasts in certain regions but in some areas they had some inherent problems. Similarly, some models were able to predict light rainfall correctly but failed badly in case of heavy rainfall. It is well known that monsoon rainfall over India has very high spatial variability. Based on trials on real time basis during the Pre-monsoon, SW Monsoon and Northeast Monsoon-2005 the strengths and weaknesses of different models of NCMRWF and IMD were identified. This helped in *the statistical intervention and determination of 'weights' for rainfall forecast of different models. The weights were determined objectively by computing the correlation coefficients* C_n *between the model predicted and actual rainfall. The weights,* W_n *were obtained from the following equation:*

$$W_n = \frac{C_n}{\sum_{i=1}^{4} C_i} \qquad n = 1,..$$

The dynamical prediction which is the 'weighted mean' of different model forecasts takes into account the forecasts of all constituent models. The validation results in different situations showed that the method is capable of generating 24, 48 and 72 hr forecasts of greater accuracy than the accuracies of the individual constituent models. To begin with the weights were computed on the basis of monthly data sets which have been used in the computation of dynamical predictions during succeeding months. In future the weights will be worked out on the basis of bigger data sets being generated in the system. The aim is not a mere generation of 'weighted mean' prediction. The experiences in the fields of synoptic meteorology, satellite applications etc. are being utilized in the value-addition. The dynamical predictions are modified wherever considered necessary and the final value-added forecast is prepared. It may be pointed out that due to limited experience the value-addition is not free from subjectivity at present. It would be possible to make the process objective when sufficient amount of data pertaining to different seasons/situations become available in future. The major inputs to the value-addition are IMD's synoptic charts, satellite information, climatology and the NWP products. Other than precipitation, the circulation patterns predicted by Europian Centre For Medium Range Weather Forecast (ECMWF) have been found very useful in value-addition, especially in the event of heavy rainfall over West Coast of India and concentrated rainfall associated with disturbances like Tropical Cyclones (TCs), Monsoon Depressions (MDs), Mid-Tropospheric Cyclones (MTCs), etc. The experience has shown that the tracks of systems predicted by ECMWF were closer to actual which helped in the identification of districts which were likely to receive heavy/very heavy rainfall amounts. The predicted location of low level jet core at 850 h Pa over the Arabian Sea was found to be related to heavy rainfall zones over the west coast. The relationship was extensively used for forecasting heavy rainfall cases along the west coast. The statistical correlations between different jet parameters and west coast rainfall are being studied comprehensively and the detailed results will be reported in a future publication. The technique used so far is based on the predicted location of jet hitting the west coast. The districts situated within 1.5° of this location were delineated for very heavy rainfall amounts and the method yielded good value-added forecasts. Thus the present system based on dynamical-cum synoptic approach *differs from the super ensemble method adopted by Krishnamurti et al (2000a, 2000b) in which an objective technique issued to arrive at the super-ensemble. The trials have shown that value-added forecast scores handsomely over the individual dynamical model predictions. The forecast format is given in Table 1.*

ITK for weather prediction

Out of various the factors which control agricultural production, weather is the only factor over which man has no control and hence it has an overwhelming dominance over the success or failure of agricultural enterprise. It is an accepted fact that food production is inextricably linked with climate and weather. It is also reported that weather induced variability of food production is more than 10 per cent. This variability can be as high as 50 per cent of the normal production in respect of smaller areas situated in arid and semi-arid regions. In order to reduce risks of loss in food production due to the vagaries of weather, weather per se, should be taken into account as one of the major inputs in agricultural planning. That is why forecast of weather parameters play a vital role in agricultural production. It also aids in minimize crop losses to a considerable extent. Thus development and refinement of the art of weather prediction has been essential since time immemorial.

In present times we have many improved technologies for making weather forecasts as well as for their dissemination. Previously when there was no such technology available farmers based their prediction on many natural, cultural and social phenomena. Some of these are discussed below:

Visible spectrum around the sun and the moon

People predicted weather after observing the visible spectrum around the sun or moon. If the spectrum around the sun had a greater diameter than that around the moon, they predicted rainfall after a day or two.

Some people based their weather prediction on the nature of the solar halo, specifically: "if the spectrum around the sun has a larger diameter then rainfall is assured.

All the photometers are a luminous phenomenon produced by the reflection, refraction, diffraction or interference of light from the sun or moon. The visible spectrum of light around the sun or moon is called halo, or carona according to its distance from the sun or moon. If the distance is more then it is called the halo phenomenon, which is caused by a layer of thin veil of cirrus clouds i.e. non rain bearing clouds. But if the distance is less, it is called corona phenomena produced *by somewhat dense clouds which may cause rainfall. The accuracy of this indigenous observation can be as high as 50 per cent*

Cloud and wind direction

If there is an accumulation of clouds in the South-East direction in a layered form accompanied by winds blowing from the southern direction then it is claimed that there will be rainfall within a day or two.

Weather prediction through birds and other animals

Farmers also predict weather by observing closely the different activities of various birds, animals etc. The following are some indigenous beliefs:

- *It is believed that on a hot summer day the cry of the bird called "Nialu" () for water brings rainfall*
- *During the rainy season farmers observe the "Matilari" bird (House swift) and they predict heavy rainfall if the bird flies high in the sky*
- *If the Maina () bird bathes in the water it indicates that there will be rainfall within one or two days*
- *During long hot days in summer if the cry of theapiha bird is heard then people believe that God will quench her thirst and there will be rainfall after one or two days.*
- *A group of sparrows frolicking in the sand indicates that there will be rainfall that day or the next day and if they are observed to be playing in water then it is believed that the weather will be dry for some days to come.*
- *If the "Jonks" (Leechs) are immobile/stationary at the water surface (Pond) then dry weather is predicted but if they move rapidly in the upward and downward direction in water then rainfall is predicted.*
- *If the "Tatihari" bird (Lapwing) lays her eggs on the higher portion of the field then heavy rainfall is predicted during the coming rainy season but if the eggs are laid in the lower portion of the field then a drought is predicted. These birds never construct a nest but lay their eggs on bare soil.*

Further it is also believed that if a single egg is laid, then there will be rainfall only for one month out of four months of the rainy season. If two eggs are laid then rainfall will occur for two months and similarly four eggs indicate there will be rainfall during all the four months of the rainy season.

- *If there is a swelling on the lower portion of the camel's legs then rainfall is predicted by the farmers. The swellings are probably caused due to higher* *relative humidity.*

- *If the "Tillbohara" (Dragon fly), which appears generally in the rainy season, are observed to swarm in a large group over a water surface (Pond) then dry weather is predicted but if they swarm over open dry lands or fields then early rainfall is predicted by the farmers.*
- *If the colour of the clouds is similar to the colour of the wings of the Titar bird (Partridge) i.e. grey or black-grey and strong eastern winds are also blowing then assured rainfall is predicted by the farmers. The clouds of a colour similar to that of the said bird are rain bearing clouds i.e. of cumulonimbus type.*
- *If centipedes emerge from their holes carrying their eggs in swarms in order to shift them to safer places (within the house) then farmers predict early rainfall The centipedes do this so as to avoid egg damage which can be caused by rain water.*
- *When spider nets are plentiful on grasses, sticks of tomato crop and on trench bean crop then it is estimated that the rainy season is over.*

Social and cultural beliefs

Many cultural, social and religious beliefs and activities superstitious pertaining to the prediction of future weather prevail since generations. From time immemorial farmers have predicted the weather on the basis of these beliefs/activities. The following are some examples from the western Himalayana region.

- *If the first10-15 of the month "Jeth" (May-June) are very hot then good rainfall/monsoon is predicted during the ensuing rainy season. This results probably from the low pressure zone in north-west India that is generated due to the high temperatures.*
- *The Soolini Mela (Festival) is organised in Solan, during the month of June every year. People of this area firmly believe that rainfall will occur on the very day of the festival or one day before or day after the festival*
- *It is also believed, that when grey coloured clouds descend below the hill tops then they definitely cause rainfall.*
- *If the "Khejri" tree bears good fruit in a particular year then farmers predict good rainfall during the next rainy season and vice versa less rain is predicted in the event of a poor fruit crop.*
- *If the Chakla Belan,(rolling pin and board), used in the Kitchen, show moisture on them then within few days rainfall is expected.*

- In villages elderly farmers usually carry a small bag for "Tambaku"(Tobacco) for Hukka(Smoking device). When this bag shows more moisture in the Tambakku then farmers predict rainfall within one or two days.

Some Folk-lore Regarding Weather Forecasting

The folk-lore of the popular poet Gag and his wife Bhahdari, who lived during the 17th century, regarding weather forecasting are still very popular in northern India. Some are given as under:

"When strong eastern winds blow continuously then it is estimated that the rainy season has come"

- When days are very hot and there is dew at night, then according to Gag, there are very limited chances of rainfall.

- When cloudy days are accompanied by clear nights and the eastern winds blow somewhat strongly, then according to Gag no rainfall is predicted. Thus there is accompanied by a shortage of water in ponds, rivers etc. Consequently clothes are washed using water from wells.

- When a rainbow is formed in the direction of Bengal then there will be rainfall, if not by the evening then definitely by next morning.

- During the rainy season, if a cloud appears on Friday and Saturday then rainfall is predicted either for Sunday or Monday.

Aerospace science and weather forecast

***Definition**: Aerospace Science is the human effort in science, engineering, and business to fly in the atmosphere of Earth (aeronautics) and surrounding space (astronautics). Aerospace organizations research, design, manufacture, operate, or maintain aircraft or spacecraft.*

Weather forecast based on Aerospace science

Aerospace activity is very diverse, with a multitude of commercial, industrial, Agriculture and military applications.
A leading supplier of algorithms, test beds and toolkits

Satellite-borne, airborne and ground-based sensors provide a unique, multispectral perspective for monitoring environmental processes over the Earth. Over the past three decades, remote sensing technologies have become increasingly sophisticated and accurate, greatly expanding our ability to study and understand natural processes on Earth and other planets.

Remote sensing leader preferred by aerospace contractors

Regardless of the spectral region, sensor system design requires a detailed knowledge and understanding of:

- *Earth's atmospheric and oceanographic processes*
- *How this geophysical information translates into what can be measured*
- *How to interpret the data for weather and climate information*

End-to-end analysis capabilities include sensor design trade-off studies using leading-edge sensor simulation and radiative transfer tools to evaluate retrieval performance and the impact of remotely sensed data upon assimilation into application modes. Services include:

- *Design, development and optimization of sensor test beds*
- *Ground test and operational performance enhancement and radiometric calibration*
- *Validation and analysis of the measured radiometric and geophysical parameters*
- *Sensor measurement calibration and testing*

Unique simulation modeling across the spectrum

scientists are experts in across-the-spectrum sensing and simulation modeling.

- *Models can be coupled to geophysical models and databases to provide an algorithm test bed specifically tailored to your program needs. This allows for robust sensor simulation, testing and validation against both simulated data and existing measurements and sensor systems.*
- *Aerospace experts provide local meteorological forecasts for sensor tasking. Knowing the weather forecast is one thing; knowing the impact to mission-critical sensor systems is another.*
- *Our tools to assess weather impacts on sensor technology (WIST) use advanced physical modeling of the environment to predict the consequences of weather on operations that utilize both imaging and non-line-of-sight acoustic sensor systems. We make extensive use of multispectral satellite imagery and GIS/image processing for state-of-the-art description of near-surface conditions.*
- *Studies and tool kits assess the impact of space weather events on spacecraft, instrumentation and communications. For example, the Space Environment and Effects Tool for AGI's Systems Tool Kit (STK/SEET) provides comprehensive modeling of the near-Earth space environment and its expected impacts on space vehicles.*

Data retrieval and processing at the speed of technology

Scientific algorithms, which accurately translate sensor data into weather and environmental products. Our algorithm experts combine deep scientific knowledge with robust software engineering. Whether we're developing algorithms or validating them, clients in government and industry rely on AER to confirm that the algorithms accurately reflect the underlying science.

Lecture No. 15

Crop-Weather Calendar, Crop-Weather-Pest-Disease Calendar and forewarning model, Crop weather diagram

Crop weather calendar

- *This is the pictorial from of chart containing different stages of crop, optimum and unfavorable water condition for different stage of crops.*
- *This chart helps the weather forecaster to look at a glance and issues warning to a particular area at a given weather. Situation and during a particular phase of crop. This calendar has three (3) parts*
- *Bottom part*
- *Middle part*
- *Top part*

1. ***Bottom part**: This provide the activities related to crops or information related to phonological stages of the crop and about the months.*
2. ***Middle part**: This gives information reg normal weather condition required for active crop growth. It is divided into different section according to Rain fall, rainy days minimum and maximum temp. pan evaporation and sunshine hours.*
3. ***Top parts** : This gives information related to weather abnormalities or to take precautionary measures. Top part is divided into diff section according to dry spell, length, high wind, heavy rainfall and cloudy weather.*

Crop -Weather -Pest-Disease Calendars for improved Agromet Advisory Services

Weather is one of the most important factors affecting the agricultural production. The increase in climatic variability and associated extreme weather episodes such as erratic rainfall distribution, abrupt change in day and night temperatures during crop season and sudden outbreaks in pest disease population, especially in developing countries, are throwing challenges to sustaining production levels of different crops. One strategy that farmers can adopt to sustain or increase crop yields in the face of a highly variable climate is to manipulate the crop environment through improved management strategies for adaptation. Agriculture is one of the most important sectors for India. Proper planning for this sector requires relevant and reliable information in timely manner. Information on crop, its stages and the week by week weather during the crop season is essential for proper management of agriculture. Thus, farm operations planned in conjunction with weather information are very likely to curtail the costs of inputs and various field operations. Crop weather calendar is a comprehensive guide for farmers. It is a tool that provides information on average weather of every week, planting, sowing and harvesting periods of locally adapted crops in a specific agro-ecological zone. Further, stage-wise pest disease infestation information can also be added.

It also provides information on the sowing rates of seed and planting material and the main agricultural practices. This tool supports farmers and agriculture extentionists in taking appropriate decisions on crops and their sowing period, respecting the agro- ecological dimension. It also provides a solid base for emergency/contingency planning of the rehabilitation of farming systems after disasters.

The concept of using crop-weather calendar is not new. For instance, FAO calendars provide information on the crop sowing and harvesting dates, seed rate, operation timings of mechanical equipment in the period etc. Also, the University of Kentucky prepared production calendars for soybean and maize crops. This calendar describes the month wise weather and operations to be taken up during the period.

Data and Methodology

Climatic data requirement

Weekly climatic normal for standard meteorological weeks for each location were computed for all the 25 AICRPAM centres. These normal meteorological data sets were arranged in a weekly format for the cropping season from the month of sowing till the harvest of the crop in question.

Information on crop phenology

Crop phenological information collected from sowing to maturity is arranged on a weekly basis. Important 'phases' like sowing, germination / emergence, transplanting (in case of rice), vegetative growth, f lowering, grain formation and maturity are tabulated as per the Standard Meteorological Weeks. Further, information on the favourable meteorological conditions for the crop (stage-wise or *whole crop growth period) which lead to high yield were deduced from the long-term experimental data and tabulated.*

Information on pest and diseases

The data on weather conditions favourable for incidence of pests and diseases and the nature of the weather warnings were collected. Structure of crop weather calendar designed by AICRPAM consists of three parts in the main body as depicted in the Figure 1. Climatic normals for location specific crop growing season is presented in the upper portion. Phenological events of the crop are represented in a weekly time frame in the middle portion together with favorable climatic parameters to realize potential or optimum yield. On the lower part of the calendar, the favourable weather conditions for development of pests and diseases are reported. The components of each part of the calendar are discussed here under.

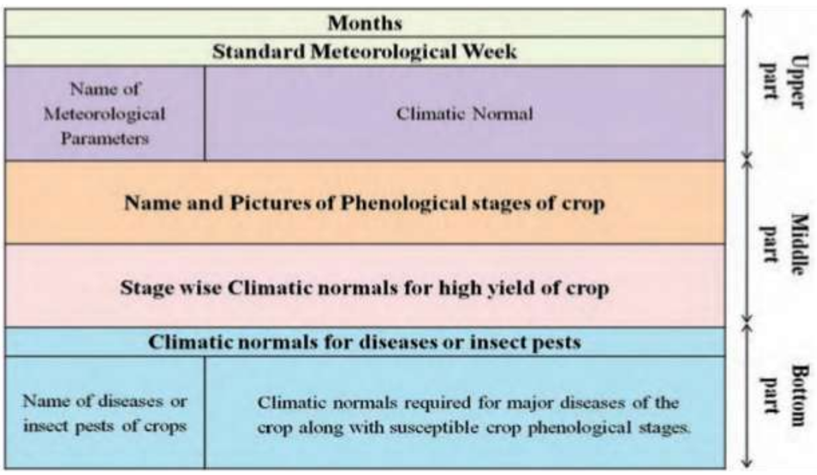
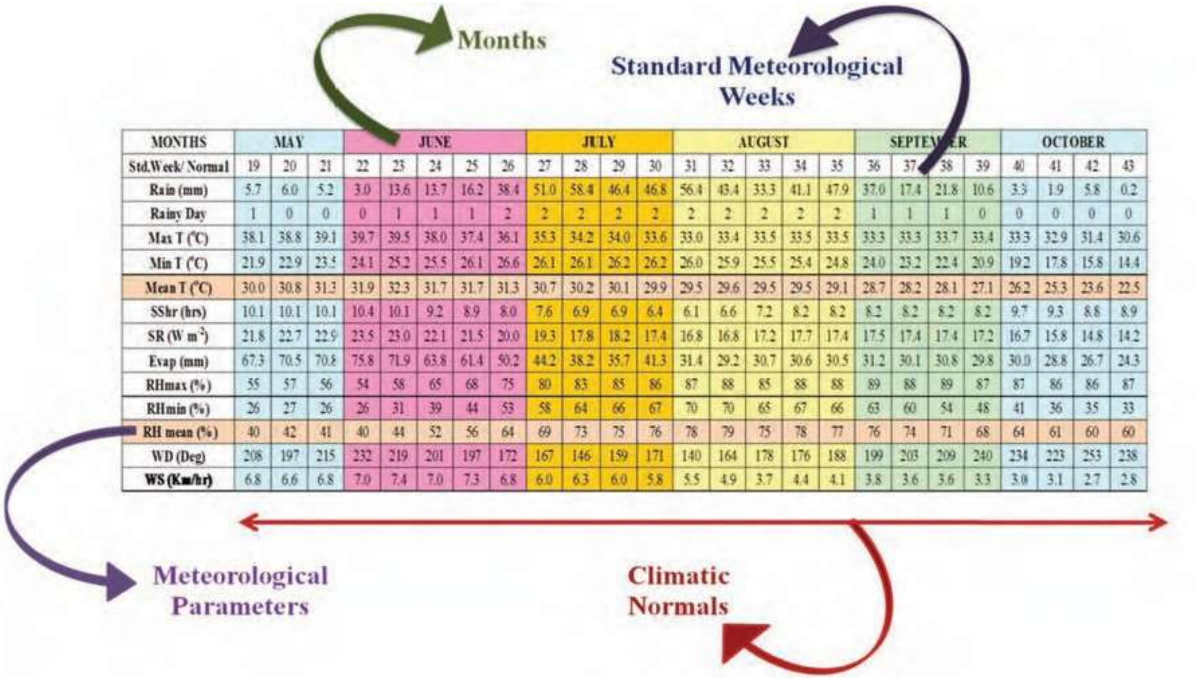


Figure.1: Structure of crop weather calendar

Part I - Climatic normals

These climatic normals of each centre computed for total weekly rainfall (mm), number of rainy days, evaporation (mm), weekly maximum temperature (°C), minimum temperature (°C), mean temperature (°C),sunshine hours (hours), solar radiation, maximum relative humidity (%), minimum relative humidity (%), mean relative humidity (%), wind speed (Km/hr) and wind direction (degree) arranged in standard meteorological week wise in the upper portion of crop weather calendar as per the above Proforma. An example of arranged climate normal for Ludhiana centre is depicted as Figure 2.



MONTHS	MAY			JUNE					JULY				AUGUST					SEPTEMBER				OCTOBER			
Std.Week/ Normal	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Rain (mm)	5.7	6.0	5.2	3.0	13.6	13.7	16.2	38.4	51.0	58.4	46.4	46.8	56.4	43.4	33.3	41.1	47.9	37.0	17.4	21.8	10.6	3.3	1.9	5.8	0.2
Rainy Day	1	0	0	0	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	0	0	0	0	0
Max T (°C)	38.1	38.8	39.1	39.7	39.5	38.0	37.4	36.1	35.3	34.2	34.0	33.6	33.0	33.4	33.5	33.5	33.5	33.3	33.3	33.7	33.4	33.3	32.9	31.4	30.6
Min T (°C)	21.9	22.9	23.5	24.1	25.2	25.5	26.1	26.6	26.1	26.1	26.2	26.2	26.0	25.9	25.5	25.4	24.8	24.0	23.2	22.4	20.9	19.2	17.8	15.8	14.4
Mean T (°C)	30.0	30.8	31.3	31.9	32.3	31.7	31.7	31.3	30.7	30.2	30.1	29.9	29.5	29.6	29.5	29.5	29.1	28.7	28.2	28.1	27.1	26.2	25.3	23.6	22.5
SShr (hrs)	10.1	10.1	10.1	10.4	10.1	9.2	8.9	8.0	7.6	6.9	6.9	6.4	6.1	6.6	7.2	8.2	8.2	8.2	8.2	8.2	8.2	9.7	9.3	8.8	8.9
SR (W m^{-2})	21.8	22.7	22.9	23.5	23.0	22.1	21.5	20.0	19.3	17.8	18.2	17.4	16.8	16.8	17.2	17.7	17.4	17.5	17.4	17.4	17.2	16.7	15.8	14.8	14.2
Evap (mm)	67.3	70.5	70.8	75.8	71.9	63.8	61.4	50.2	44.2	38.2	35.7	41.3	31.4	29.2	30.7	30.6	30.5	31.2	30.1	30.8	29.8	30.0	28.8	26.7	24.3
RHmax (%)	55	57	56	54	58	65	68	75	80	83	85	86	87	88	85	88	88	89	88	89	87	87	86	86	87
RHmin (%)	26	27	26	26	31	39	44	53	58	64	66	67	70	70	65	67	66	63	60	54	48	41	36	35	33
RH mean (%)	40	42	41	40	44	52	56	64	69	73	75	76	78	79	75	78	77	76	74	71	68	64	61	60	60
WD (Deg)	208	197	215	232	219	201	197	172	167	146	159	171	140	164	178	176	188	199	203	209	240	234	223	253	238
WS (Km/hr)	6.8	6.6	6.8	7.0	7.4	7.0	7.3	6.8	6.0	6.3	6.0	5.8	5.5	4.9	3.7	4.4	4.1	3.8	3.6	3.6	3.3	3.0	3.1	2.7	2.8

Figure.2: Top portion of crop weather calendar of rice crop containing climatic normals

Part-II Phenological observations and Climatic normal for high yield of crops

Collect the pictures of individual stage of each crop and arrange in such a way that the stage wise figure should adjust to the week of start of that stage to end of Stage wise climatic normals for high productivity of the crop in a location will be computed based on a simple procedure. Select the best 3 high productivity years of a crop from minimum 10 years of continuous field experiment data. growth stage wise meteorological normals will be computed and arranged for the selected high productivity years. Then arrange the range of each parameter for individual stage. The arrangement is shown in the Figure .3.

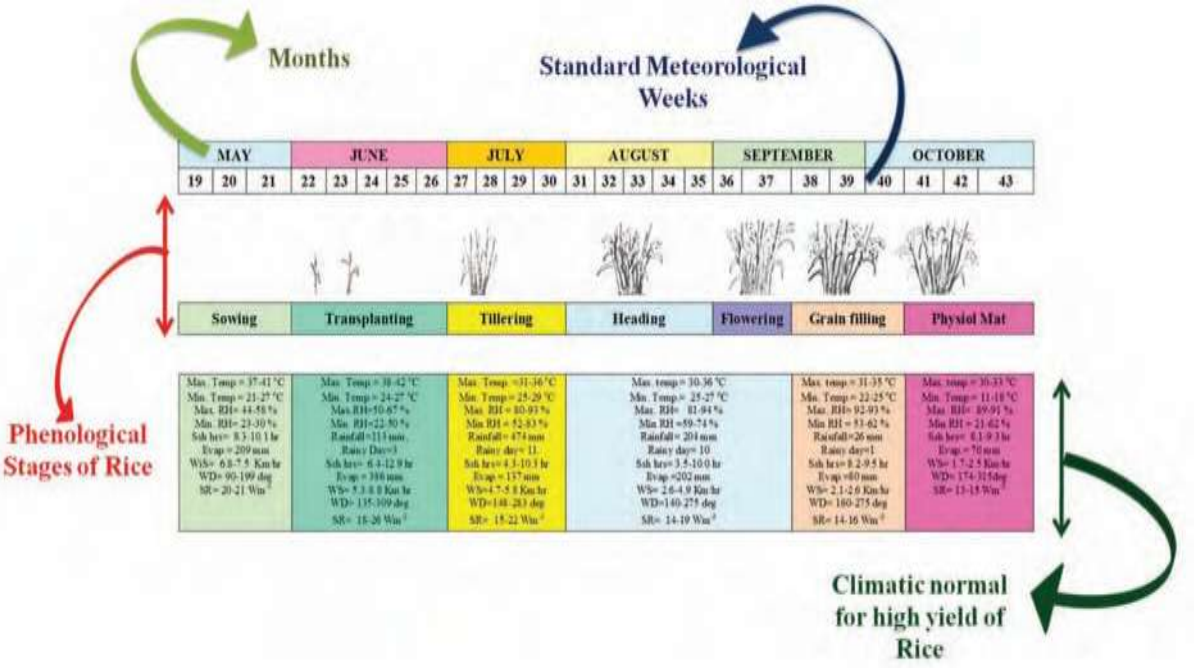


Figure.3: Middle portion of crop weather calendar containing phenological stages and climatic normal for high yield

Part-III Climatic normal favourable for incidence of major pest of rice crop

The Crop-Weather-Pest and Disease calendars comes as bottom part of the calendar which contain the climatic normals required for major pest or diseases of the crop as well as susceptible crop phenological stages. Thus if the climatic conditions are favourable and the pathogen is present, there are chances of occurrence of the pest and disease (Figure 4).

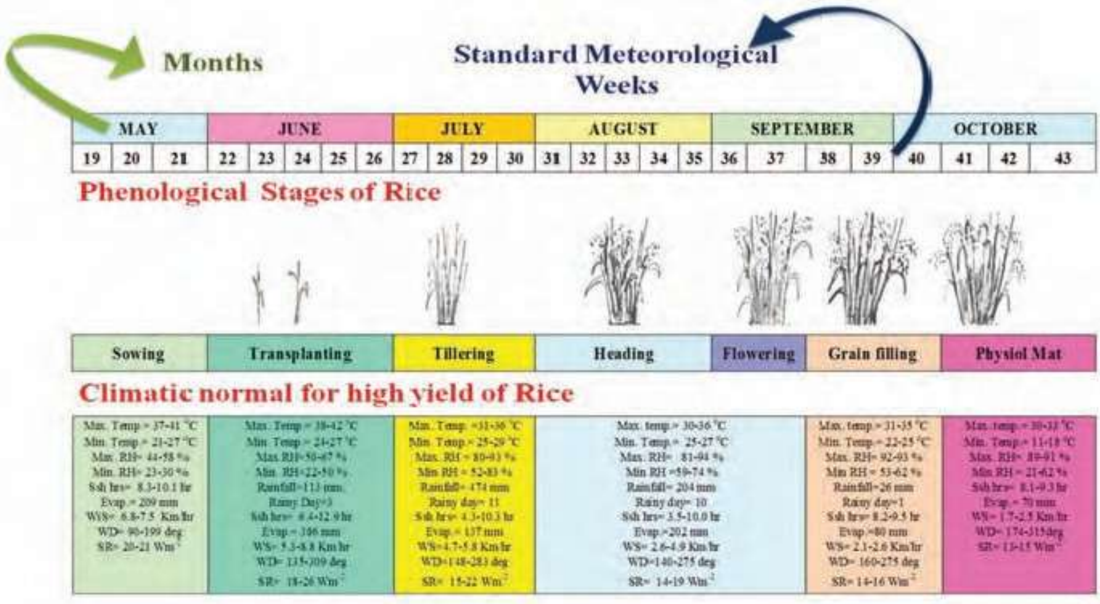


Figure.4: Bottom portion of crop weather calendar containing climatic normal favourable for incidence of major pest of rice crop

These crop-weather-pest and disease calendars act as a guiding tool while issuing Agromet-advisory for the farmers of the region. These calendars can also be used for advising the farmers for need based spraying of the insecticides and pesticides

Crop weather diagram

It gives season wise information on the crop husbandry (tillage to harvest), actual weather and normal weather month/week wise and information on pest and disease incidence.

- *Help in understanding favourable weather conditions that are responsible for better, crop yields and vice-versa if they prepared for more, number of years.*
- *Use of crop-weather diagrams for obtaining better crop yield through agronomic manipulation and predict crop yield quantify based on weather condition.*
- *Current state of information on crops and weather*
- *Latter state of information on crops and weather including forewarnings and the periods during which they are to be issued.*
- *Crop weather diagram as a tool*
- *To assess the crop condition and its yield in relation to weather*
- *To a weather forecaster, for providing efficient weather service.*
- *Base for improving the quality of crop weather calendars.*
- *Both re handy and useful in agro-advisory*
- *Helps to improve crop yield through better agronomic practices.*

Lecture No. 16

Remote sensing- its application in agriculture, Preparation of agro-advisory bulletin based on weather forecast

REMOTE SENSING

Remote sensing is a tool to monitor the earth's resources using spaces technology in addition to ground observations. It can be used in soil mapping, land use pattern, forest mapping, geological and hydrogeological purposes, drought and flood monitoring in addition to mapping of crop coverage. In essence, the remote sensing techniques can be use to sese the earth's resources. It has several applications in the field of agrometeorological research. The earth and cloud surface temperatures, radiation, rainfall, soil moisture and crop yield estimates based on spectral indices can be worked out. Attempts can also be made to monitor insect pest and disease surveillance using remote sensing techniques along with the field the field observations. Remote Sensing inputs combined with crop growth simulation models are very useful tools in crop yield forecasting. The methods are being evolved for analyzing crop area coverage and crop yield using remote sensing data and agroclimatic indices, which will be inputs in crop simulation modeling.

Definition and spectral reflectance

Remote Sensing is the science/technology of making inferences about material objects from measurement made at a distance with out coming into physical contact with the objects under study. Human eye and Camera are the best examples of remote sensing as per the definition Remote Sensing technology uses the visible, infrared and microwave regions of the radiation to collect information about the various objects on the earth's surface. The response of the objects to different regions of the electromagnetic spectrum is different. These typical responses are used to distinguish objects such as vegetation, water, bare soil, concrete and other similar features. The reflectance percentage is the maximum in infrared band for vegetation while less in case of water. The reflectance values for other materials in the infrared band vary between water and vegetation.

Remote Sensing platforms

There platforms are generally used remote sensing techniques. They are ground based, air based and satellite based. Infrared thermometer, Spectral radiometer, Pilot-Balloons and Radars are some of the ground based remote sensing tools while aircrafts are air based remote sensing tools. Since the ground based and air based platforms are very costly and have limited use, space based satellite technology has become handy for wide application of remote sensing techniques. There are two types of microwave remote sensing techniques viz. active and passive in addition to visible and infrared remote sensing. The digital image processing, using powerful computers, is the tool for analyzing and interpretation of remotely sensed data. The advantage of satellite remote sensing are:

- Synoptic view – Wide area can be covered by a single image/photo (One scene of Indian Remote Sensing Satellite IRS series cover about 148 x 178 sq.km area).
- Receptivity – Can get the data of any area repeatedly (IRS series cover the same area every 16-22 days).

  Coverage – Inaccessible areas like mountains, swampy areas and thick forests are easily covered.

Space based remote sensing is the process of obtaining information about the earth from the instruments mounted on the Earth Observation Satellites. The satellites are subdivided into two classes and the types of satellites are as follows:

Polar orbiting satellites

These satellites operate at an altitude between 550 and 1,600 km along an inclined circular plane over the poles. These satellites are used for remote sensing purposes. LANDSAT (USA), SPOT (FRANCE), and IRS (INDIA) are some of the Remote Sensing Satellites.

Geostationary satellites

These have orbits around the equator at an altitude of 36,000 km and move with the same speed as the earth so as to view the same area on the earth continuously. They are used for telecommunication and weather forecasting purposes. INMSAT series are launched from India for the above purposes. All these satellites have sensors on boards operating in the visible and near infrared regions of the electromagnetic spectrum. INSAT – 3A was launched on 10th April, 2003.

Role of Remote Sensing in agriculture

Agricultural resources are important renewable dynamic natural resources. In India, agriculture sector alone sustains the livelihood of around 70 per cent of the population and contributes nearly 35 per cent of the net national product. Increasing agricultural productivity has been the main concern since scope for increasing area under agriculture is rather limited. This demands judicious and optimal management of both land and water resources. Hence Comprehensive and reliable information on land use/cover, forest area, soils, geological information, extent of wastelands, agricultural crops, water resources both surface and underground and hazards/natural calamities like drought and floods is required. Season-wise information on crops, their acreage, vigour and production enables the country to adopt suitable measures to meet shortages, if any, and implement proper support and procurement policies, Remote Sensing systems, having capability of providing *regular, synoptic, multi-temporal and multispectral coverage of the country, are playing an important role in providing such information. A large number of experiments have been carried out in developing techniques for extracting agriculture-related information from ground borne, air borne and space borne data. Some of the broad agricultural application areas are:*

Cropped area

Crop production forecasting

Mapping of wastelands

Drought monitoring and its assessment

Flood mapping and damage assessment

Monitoring of surface water bodies

Land use/cover mapping and area under forest coverage

Soil mapping and

Groundwater exploration.

Types of platforms

*1. **Ground-borne platforms:** Ground borne platforms are used to record detailed information about the surface which is compared with information collected from aircraft or satellite sensors i.e. for ground observation. Ground observation includes both the laboratory and field study, used for both in designing sensors and identification and characterization of land features Ground observation platforms include – handheld platform, cherry picker, towers, portable masts and vehicles etc. Portable handheld photographic cameras and spectroradiometers are largely used in laboratory and field experiments as a reference data and ground truth verification.*

*2. **Air-borne platforms:** Airborne platforms are used to collect very detailed images and facilitate the collection of data over virtually any portion of the Earth's surface at any time. Airborne platforms were the sole non-ground-based platforms for early remote sensing work.*

***Balloon :** Balloons are used for remote sensing observation (aerial photography) and nature conservation studies.*

***Drone :** Drone is a miniature remotely piloted aircraft. It is designed to fulfill requirements for a low cost platform, with long endurance, moderate payload capacity and capability to operate without a runway or small runway.*

***Aircraft :** Special aircraft with cameras and sensors on vibration less platforms are traditionally used to acquire aerial photographs and images of land surface features.*

***High Altitude Sounding Rockets :** High altitude sounding rocket platforms are useful in assessing the reliability of the remote sensing techniques as regards their dependence on the distance from the target is concerned.*

*3. **Space-borne platforms**: In space-borne remote sensing, sensors are mounted on-board a spacecraft (space shuttle or satellite) orbiting the earth. Space-borne or satellite platform are onetime cost effected but relatively lower cost per unit area of coverage, can acquire imagery of entire earth without taking permission. Space borne imaging ranges from altitude 250 km to 36000 km. Spaceborne remote* *sensing provides the followingadvantages:*

- *Large area coverage;*
- *Frequent and repetitive coverage of an area of interest;*
- *Quantitative measurement of ground features using radiometrically calibrated*
- *sensors; Semi-automated computerized processing and analysis;*
- *Relatively lower cost per unit area of coverage.*
- *There are two types of well recognized satellite platforms- manned satellite platform and unmanned satellite platform.*

***Manned Satellite Platforms**: Manned satellite platforms are used as the last step, for rigorous testing of the remote sensors on board so that they can be finally incorporated in the unmanned satellites.*

***Unmanned Satellite Platforms** : Landsat series, SPOT series and IRS series of remote sensing satellite, NOAA series of meteorological satellites, the entire constellation of the GPS satellites and the GOES and INSAT series of geostationary environmental, communication, television broadcast, weather and earth observation satellites etc are examples of unmanned satellite category*

Applications of Remote sensing in Agriculture :

Remote sensing is the acquisition of information about an object or any phenomenon without making any physical contact with the object. It is a phenomenon that has numerous applications including photography, surveying, geology, forestry and many more. But it is in the field of agriculture that remote sensing has found significant use. There are very many applications of remote sensing in the agricultural sector. Below is a summary of these applications.

1. ***Crop production forecasting:** Remote sensing is used to forecast the expected crop production and yield over a given area and determine how much of the crop will be harvested under specific conditions. Researchers can be able to predict the quantity of crop that will be produced in a given farmland over a given period of time.*
2. ***Assessment of crop damage and crop progress:** In the event of crop damage or crop progress, remote sensing technology can be used to penetrate the farmland and determine exactly how much of a given crop has been damaged and the progress of the remaining crop in the farm.*
3. ***Horticulture, Cropping Systems Analysis:** Remote sensing technology has also been instrumental in the analysis of various crop planting systems. This technology has mainly been in use in the horticulture industry where flower growth patterns can be analyzed and a prediction made out of the analysis.*
4. ***Crop Identification:** Remote sensing has also played an important role in crop identification especially in cases where the crop under observation is mysterious or shows some mysterious characteristics. The data from the crop is collected and taken to the labs where various aspects of the crop including the crop culture are studied.*
5. ***Crop acreage estimation:** Remote sensing has also played a very important role in the estimation of the farmland on which a crop has been planted. This is usually a cumbersome procedure if it is carried out manually because of the vast sizes of the lands being estimated.*
6. ***Crop condition assessment and stress detection:** Remote sensing*

technology plays an important role in the assessment of the health condition of each crop and the extent to which the crop has withstood stress. This data is then used to determine the quality of the crop.

7. ***Identification of planting and harvesting dates:*** *Because of the predictive nature of the remote sensing technology, farmers can now use remote sensing to observe a variety of factors including the weather patterns and the soil types to predict the planting and harvesting seasons of each crop.*
8. ***Crop yield modelling and estimation:*** *Remote sensing also allows farmers and experts to predict the expected crop yield from a given farmland by estimating the quality of the crop and the extent of the farmland. This is then used to determine the overall expected yield of the crop.*
9. ***Identification of pests and disease infestation:*** *Remote sensing technology also plays a significant role in the identification of pests in farmland and gives data on the right pests control mechanism to be used to get rid of the pests and diseases on the farm.*

10. Soil moisture estimation: 11. Irrigation monitoring and management: 12. Soil mapping: 13. Monitoring of droughts: 14. Land cover and land degradation mapping: 15. Identification of problematic soils: 16. Crop nutrient deficiency detection: 17. Reflectance modeling: 18. Determination of water content of field crops: 19. Crop yield forecasting: 20. Flood mapping and monitoring: 21. Collection of past and current weather data: 22. Crop intensification: 23. Water resources mapping: 24. Precision farming: 25. Climate change monitoring: 26. Compliance monitoring: 27. Soil management practices: 28. Air moisture estimation: 29. Crop health analysis: 30. Landmapping:

Preparation of agro-advisory bulletin based on weather forecast

Agro-advisory bulletin :

It is a Farm decisions taken in response to changing weather. Farm decisions include agronomical, pest and disease, water and input managements. This agro-met advisory taken in response to past, current and future weather change. Basic considerations to prepare weather based agro advisories are weather sensitive crops, their weather sensitive stages and weather sensitive farm operations.

Weather parameters influence on agricultural operations and farm production. Aberrant weather is one of the most important reason for crop losses in India. The losses could be minimized by making modification in field operation by using weather based agro advisories. IMD provides weather based crop and location specific advisories and disseminated to the farmers. Studies of different location showed an increase in benefit of farmers those are followed weather based advisories as compared to no advisory followed farmers. The additional benefit was due to the crop management done by the farmers according to weather condition.

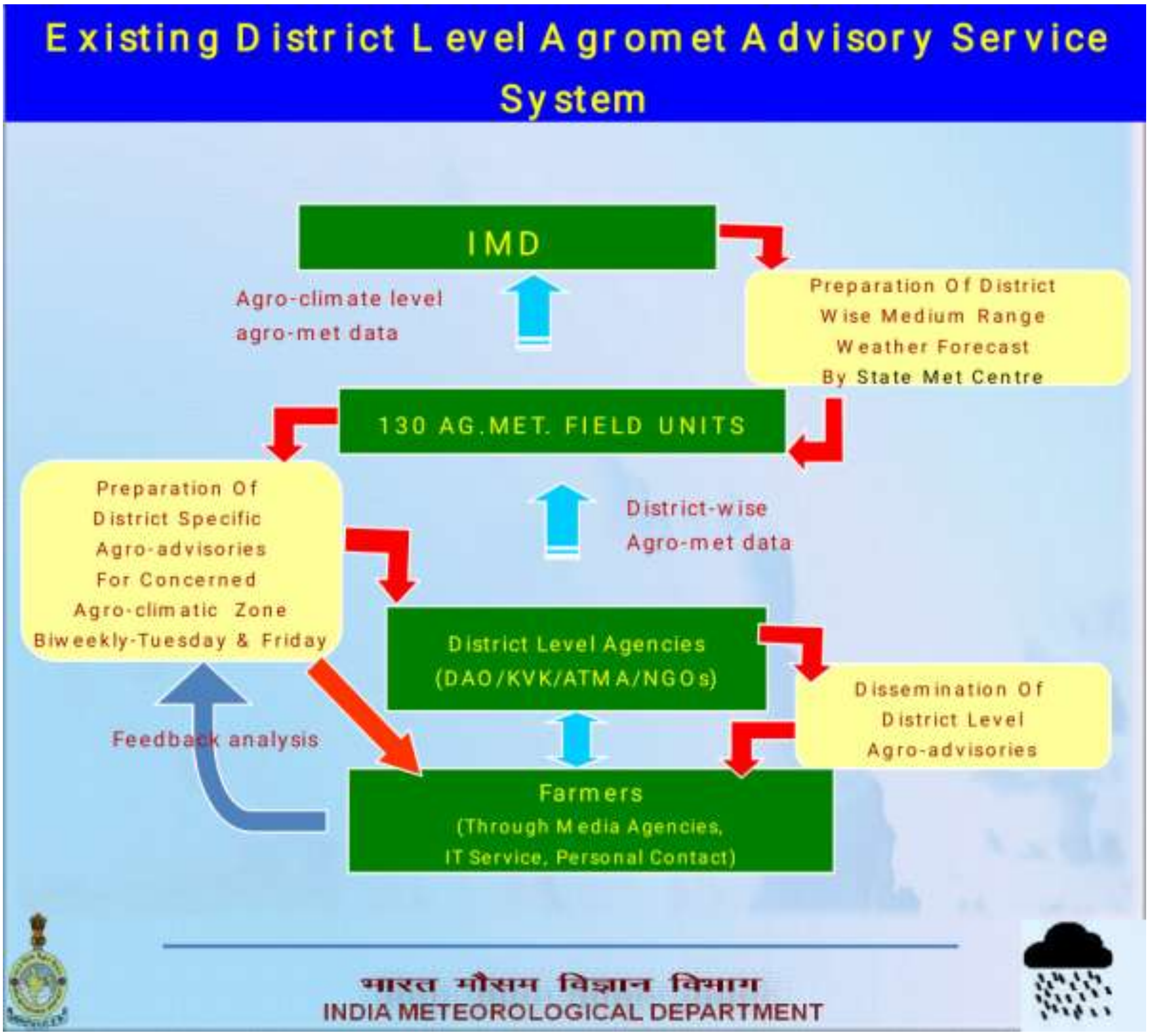
Weather plays an important role in agricultural production. Besides rainfall, others weather parameters are also playing an important role in influencing *agricultural production. Unfavourable weather conditions are major concerns to the farming community. The advance prediction of these weather events and crop planning based on prediction would help the farmer enormously in reducing the crop losses under aberrant weather situations and also taking-up suitable contingency measures. India Meteorological Department, Ministry of Earth Science in collaboration with State Agricultural Universities /Indian Council of Agricultural Research etc. is issuing crop and location specific weather based agro advisories for the benefit of farming community on every Tuesday and Friday. The major objective of this programme is to guide timely and requirement (weather condition) based crop management practices.*

[illegible]

Elements of medium range weather forecast for issuing agro advisory bulletin

Medium range weather forecast should refer to all weather elements that immediately affect farm operations. Normally a medium range weather forecast includes the following parameters and forecast issued for 5 days in advance.

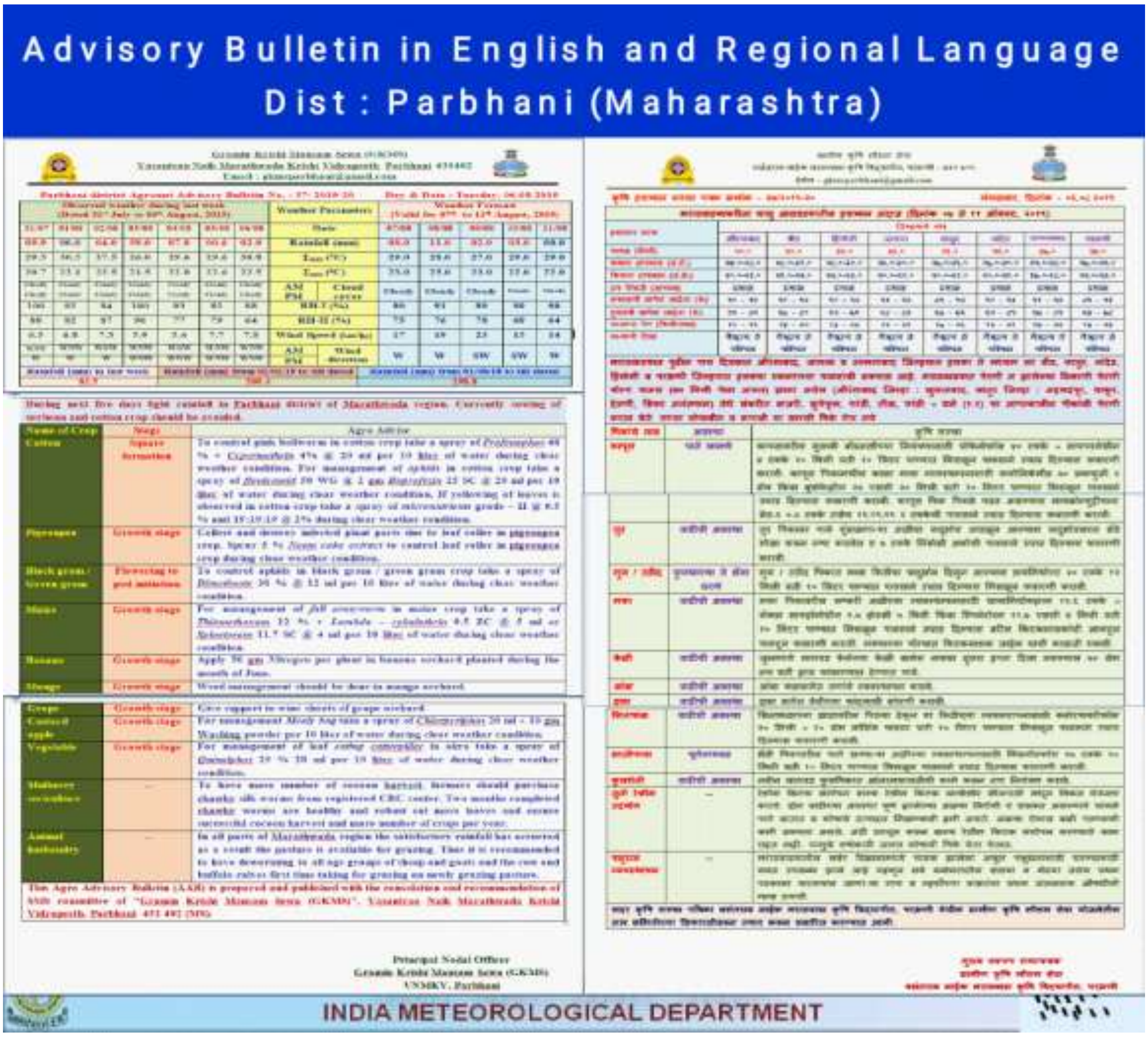
i. *amount of rainfall*
ii. *maximum and minimum temperature*
iii. *type of cloud over*
iv. *maximum and minimum temperature*
v. *wind speed and direction*



How to prepare bulletins

Weather forecast data is received from State Data Centres of each state on each Tuesday and Friday. The data are clarified by a team of experts on every Tuesday and Friday. Bi-weekly Agro-advisory bulletin is prepared with the help of expert members based on the information on weather forecast, crop condition obtained from the farmers' field (such as crop growth stage, incidence of pest attack and diseases and water stress) and weather condition of previousdays.

IMD also provide the information of actual rainfall, NDVI images, SPI maps in 5 days forecast. Some Other Agrometeorological product like Evaporation data, Radar images, Satellite images and products, Soil moisture, NWP model product etc. are also useful which can taken directly from IMD Agrimet website of Pune



Usefulness of weather based agro advisory bulletins

Agro-met Advisory on set of monsoon rain is very much useful in deciding sowing time of kharif crops. The advisory is useful for planning of irrigation and fertilizer management in crops. Advisory on plant protection is very much helpful for protecting crops from insect pest and diseases of crops. Advised on kept harvested crops in a safe place during rainfall forecasted days restrict post-harvest losses. Standard Precipitation Index map is useful for providing irrigation and sowing information. Normalized difference vegetation index provide crop vigour and benefited for better crop management.

Farmers need both weather and climate services for better crop production. Agromet Advisory services are the provision of accurate and locally-appropriate climate and weather information play a vital on risk mitigation in agriculture. At the district level, AAS is underway to extend up to sub-district/block level with dissemination up to village level to meet the end user's requirements in both the irrigated and rainfed systems. Establishment of 660 DAMUs in each district of India at KVK is under pipeline which includes 130 existing AMFUs till 2019 for the weather forecast. So that small and marginal farmers will be benefitted by these services

Benefits : *The farmers who adopted Pro- active measures based on our forecasts have been benefited in the following terms saving of spray, prophylactic spray before attack of disease, timely harvesting of field and horticultural crops, protection to grapes at the time of post-harvest processing. The monitory benefits range from a few hundred rupee per quintal of produce to a few thousand rupees per acre depending on the crop and situation. A few examples are given in the following Table. The number of farmers to whom the forecasts are provided has increased exponentially in the 2-3 years and the present strength of the farmers who confidently use the forecasts is around one to two thousand in each village. It is also learnt that these farmers in turn communicate the message either orally or by forwarding the forecast message to his friends and neighbors for their use. Thus, Location-specific forecasts, their timely dissemination and successful adoption by the farmers have been made a reality*

Table

Lecture: 17

Use of crop simulation model for preparation of Agro-advisory. Agro-advisory , its effective dissemination

Use of crop simulation model for preparation of Agro-advisory.

Crop simulation models can be useful for Agroadvisory by following means

a) As research tools

1) Research understanding:

Model development ensures the integration of research understanding acquired through discreet disciplinary research and allows the identification of the major factors that drive the system and can highlight areas where knowledge is insufficient. Thus, adopting a modelling approach could contribute towards more targeted and efficient research planning. For example, changing the plant density in a sugar beet model resulted in model failure. This failure stimulated studies that gave additional information concerning biomass partitioning in the sugar beet.

2) Integration of knowledge across disciplines:

Adoption of a modular approach in model coding allows the scientist to pursue his discipline-oriented research in an independent manner and at a later stage to integrate the acquired knowledge into a model. For example, the modular aspect of the APSIM software allows the integration of knowledge across crops as well as across disciplines for a particular crop. Adoption of a modular framework also allows for the integration of basic research that is carried out in different regions, countries and continents. This ensures a reduction of research costs (e.g., through a reduction in duplication of research) as well as the collaboration between researchers at an international level.

3) Improvement in experiment documentation and data organization:

Simulation model development, testing and application demand the use of a large amount of technical and observational data supplied in given units and in a particular order. Data handling forces the modeller to resort to formal data organisation and database systems. The systematic organisation of data enhances the efficiency of data manipulation in other research areas (e.g., productivity analysis, change in soil fertility status over time)

4) Genetic improvement:

As simulation models become more detailed and mechanistic, they can mimic the system more closely. More precise information can be obtained regarding the impact of different genetic traits on economic yields and these can be integrated in genetic improvement programs, e.g., the NTKenaf model. Researchers used the modelling approach to design crop ideotypes for specific environments.

5) *Yield analysis:*

When a model with a sound physiological background is adopted, it is possible to extrapolate to other environments. The use of several simulation models to assess climatically-determined yield in various crops . The CANEGRO model has been used along the same lines in the South African sugar industry. Through the modelling approach, quantification of yield reductions caused by non-climatic causes (e.g., delayed sowing, soil fertility, pests and diseases) becomes possible. Almost all simulation models have been used for such purposes. Simulation models have also been reported as useful in separating yield gain into components due to changing weather trends, genetic improvements and improved technology.

b) As crop system management tools

1) *Cultural and input management:*

Management decisions regarding cultural practices and inputs have a major impact on yield. Simulation models, that allow the specification of management options, offer a relatively inexpensive means of evaluating a large number of strategies that would rapidly become too expensive if the traditional experimentation approach were to be adopted. Many publications are available describing the use of simulation models with respect to cultural management (planting and harvest date, irrigation, spacing, selection of variety type) and input application (water and fertiliser).

2) *Risks assessment and investment support:*

Using a combination of simulated yields and gross margins, economic risks and weather-related variability can be assessed. These data can then be used as an investment decision support tool.

3) *Site-specific farming:*

Profit maximisation may be achieved by managing farms as sets of sub-units and providing the required inputs at the optimum level to match variation in soil properties across the farm. Such an endeavour is attainable by coupling simulation models with geographic information systems (GIS) to produce maps of predicted yield over the farm. But, one of the prerequisites is a systematic characterisation of units that may prove costly.

c) As policy analysis tools

1) *Best management practices:*

Models having chemical leaching or erosion components can be used to determine the best practices over the long-term. The EPIC model has been used to evaluate erosion risks due to cropping practices and tillage.

2) *Yield forecasting:*

Yield forecasting for industries over large areas is important to the producer (harvesting and transport), the processing agent (milling period) as well as the marketing agency. The technique uses weather records together with forecast data to estimate yield across the industry.

3) *Introduction of a new crop:*

Agricultural research is linked to the prevailing cropping system in a particular region. Hence, data concerning the growth and development of a new crop in that region would be lacking. Developing a simulation model based on scientific data collected elsewhere and a few datasets collected in the new *environment helps in the assessment of temporal variability in yield using long-term climatic data. Running the simulations with meteorological data in a balanced network of locations also helps in locating the industry.*

4) Global climate change and crop production:

Increased levels of CO2 and other greenhouse gases are contributing to global warming with associated changes in rainfall pattern. Assessing the effects of these changes on crop yield is important at the producer as well as at the government level for planning purposes.

5) Precision Farming

An interface between PC ARC/INFO GIS and SIMPOTATO simulation model to study potato yield and N leaching distribution for site-specific crop management (precision farming) in a 50 ha field. The GIS input layers, corresponding to important distributed input parameters for the model, were irrigated water/N layer, soil texture layers and initial soil N layers. For each unique sub-area stored in the GIS database, the interface program extracts the attribute codes of that sub-area from the GIS database, converts the attribute codes to the input parameters of the SIMPOTATO and sends them to the model. After running the model, the interface program retrieves the output data (potato yield and N leaching), converts them to the attribute codes and stores the output data in the GIS database.

Agro-advisory , its effective dissemination

Dissemination

Weather based advisories were directly send to farmer's mobile number through mkisan portal. Bulletins were also uploaded in website of IMD Pune, website of IMD, website of university, website of KVK Knowledge network and website of the department of agriculture and farmers' empowerment (Govt. of Maharashtra) by the respected officials. Medium range weather forecast issued by India Meteorological Department and agro advisory bulletins based on predicted and observed weather is useful for farming community to improving the agricultural activity. Study also revealed that, the farmers received more benefit those are followed weather based advisories in their agricultural operations.

Modes of Dissemination

- ***Electronic media (Radio, TV, E-mail, Internet)***
- ***Written bulletin, newspaper***
- ***voice messages***
- ***SMS***
- ***Call Centres***
- *At present, 40.2 millions farmers are getting SMS advisories*
- *SMS through Farmers Portal biweekly on Tuesday and Friday.*
- *Website*

  Farmers portal

  IMD-Agrimet website

  State Agricultural University website

  State Govt. system (Extention)

  Biweekly Agromet Advisory also uploaded on KVK portal of ICAR
- *Dissemination through TV*

  DD KISAN Daily bulletin

  DD KISAN Weekly summary
- *Newspaper and Radio*

- *PPP Mode- IFFCO KISAN SANCHAR LIMITED*
  RELIANCE FOUNDATION
- ***The AAS bulletin is sent via mail to***
- *All India Radio*
- *Doordarshan*
- *ETv*
- *Print media*
- *State Government authorities*
- *Kisan Call Centre*