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Agricultural Meteorology

Agriculture Sector is changing the socio-economic conditions of farmers due to liberalization and globalization.About 75% people are living in rural areas and are still dependent on Agriculture. About 43% of India's geographical area is used for agricultural activity. Agriculture continues to play a major role in Indian Economy. It 1)Provides about 65% of the livelihood. 2) Accounts for 27% of GDP. 3) Contributes 21% of Total Exports, and Supplies Raw materials to Industries. 4) Growth Rate in production - 5.7%. 5) Food grains production – ~240 mt
The factors, which determine the agricultural production are environmental conditions and management. The environment includes biophysical factors (climate, soil, pests, land) Management decisions are determined by the knowledge of the interactions between the biophysical factors and crops.
Among the biophysical factors, weather remains the largest source of variability of farm outputs, directly and indirectly (pests). Depending on the level of development, roughly 20 to 80% of the inter-annual variability of yield is due to variability of weather. Weather directly or indirectly influences the crops in their growth cycle. Directly affects-structural characters like stand, leaf area, #tillers, #heads per plant etc. Indirectly affects-pests and diseases, weeds etc. The development and ultimate productivity of crops is the resultant of many physiological processes,each of which are affected individually or jointly by weather parameters
Though weather or climate is the least manageable natural resource,understanding of its interaction with agricultural parameters is a powerful tool to develop weather based management strategies

Changes in concept of crop weather relationship studies

CWR in earlier years were based on statistical techniques like correlation,simple and multiple regression,step-wise regression etc. CWR were based on yield and total seasonal rainfall. Later,yields were related with rainfall during different stages of crop. After the introduction of PET (by Penman)and Water budgeting (Thornthwaite), a new variable called Water use or Evapotranspiration found its use in CWR. Realizing the importance of other climatic factors multi-variate crop weather relationships were developed. All the statistical models developed with data from a place have location-specific bias. To overcome this problem,dynamic crop simulation models ,applicable universally were initiated.

Radiation Use Efficiency (RUE)

Quantity of biomass produced per unit of intercepted radiation (g/MJ)

Water Use Efficiency (WUE)

Amount of dry matter produced by a crop per unit of water transpired
How they are important?
They can be used for yield simulation through the following relations
Yield = Radiation absorbed*RUE*HI
Yield = Total water use*WUE*HI

Temperature effect on crops

Variations in duration of phenological events
Variation in magnitude and time of occurrence of peak in biomass
Significant increase/decrease in growth rates
Variation in growth pattern deviating from sigmoidal curve
Ultimately effect grain yield /harvest index

Photoperiodism and Solar Radiation:

Three aspects of solar radiation are important for plant processes:
Intensity, duration (i.e., photoperiod or day length), and quality.

Intensity influence growth by altering the size of organs by influencing photosynthesis.
Photoperiod is primarily influential in controlling the phenological stages of flower formation and timing of flag leaf appearance.

Methods to evaluate Crop-weather Relationship

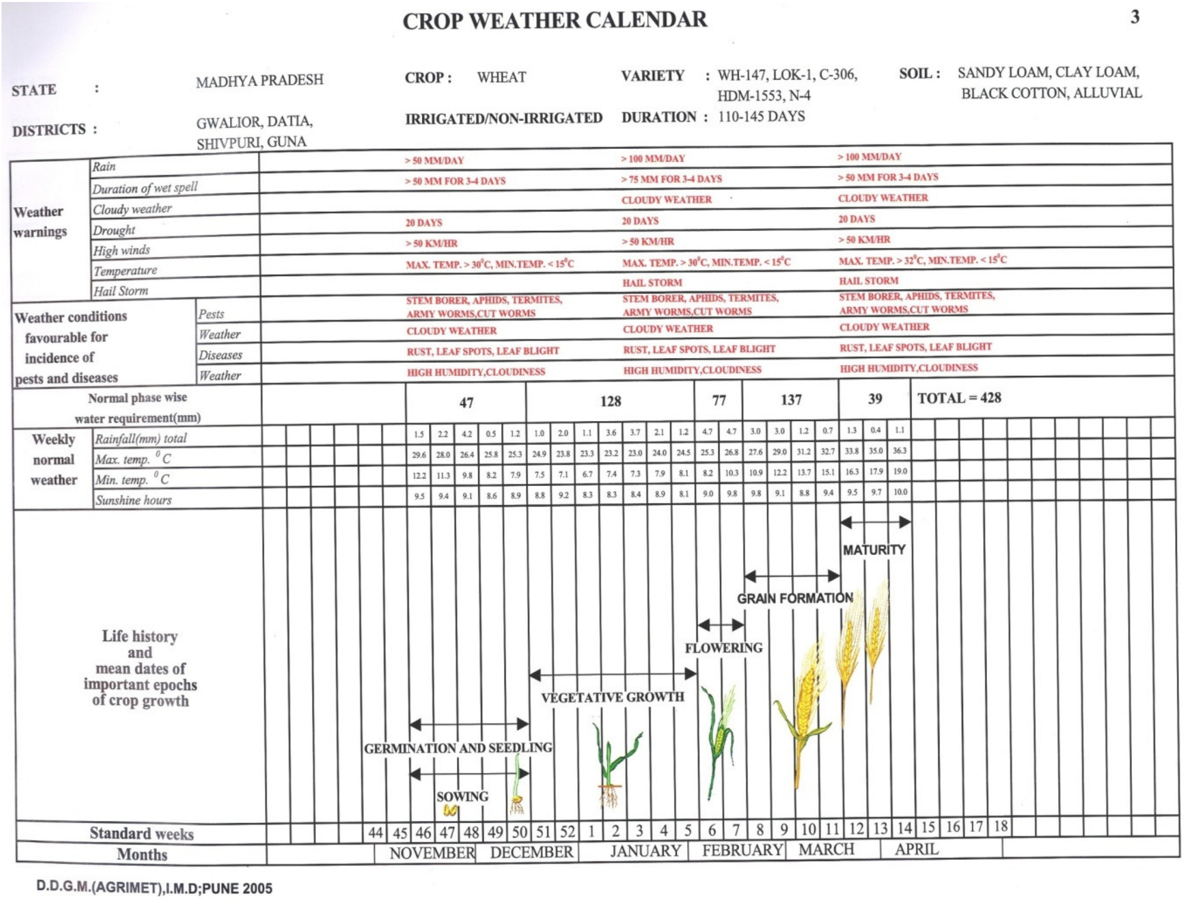
The three commonly used approaches are:
Correlation techniques
Crop weather analysis model
Crop growth simulation models
Correlation analysis provides a measure of the degree of association between variables
Regression analysis describes the effect of one or more variables (independent variables) on a single variable (dependent variable)
Regression and correlation procedures can be classified according to the number of variables involved
Simple (If only 2 variables, one independent and another dependent)
Multiple (If more than 2 variables)
The procedure is termed linear, if underlying relationship is linear or non-linear, if otherwise

Crop weather calendar

In preparation of crop weather calendars, information collected from state agricultural department have been analysed in relation to agro-climatic factors.
There are critical periods in the life history of a crop from the date of sowing to the date of harvesting. Sowing time is also one of no small anxiety to the farmer. He knows that a heavy shower just after sowing will wash away the seed and seedlings and depress germination considerably. Again, if a prolonged drought follows after sowing, the tender seedlings would wither away necessitating resowing. It is well known that the weather at sowing time determines even the nature and variety of the crop that the farmer decides to grow in his field.
If conditions are favourable during the first phase (germination and the early vegetative growth) the crop gets a good start. Thereafter, intervals of clear weather are required for interculture and weeding. During the period of rapid vegetative growth, the water requirement and need for sunshine for photosynthesis are maximum. Then follows the period of flowering and reproduction with little vegetative growth.
During the period of flowering and grain-formation, clear weather and minimum cloudiness are favourable. Cloudy wet weather during this period can ruin an otherwise promising crop. When the grains are forming and/or are in the milk stage, one day's hot wind can shrivel up the grains. Even after the entire season has been passed safely, the crop is not free from the danger of adverse and unexpected weather. A heavy shower of rain and hail can do incalculable damage to a standing crop ready for harvest. If warned in time, the farmer would hurry up his harvesting operations. Later on, when the harvested crop is lying on the threshing floor, it is again on the mercy of any sudden shower. Here, also timely warning may help the farmer a lot.
The information collected have been condensed and represented in a pictorial form in what is called the "Crop Weather Calendars". The crop weather calendar consists of three parts.
At the bottom of the calendar is shown diagramatically the life history of the crop from the date of sowing to the date of harvest and threshing. The important "phases" like sowing, germination, transplantation (in the case of rice), tillering, elongation, flowering, grain formation and harvest are also indicated. These "phases" cover certain time intervals indicated by horizontal arrows, which depend upon variations in (a) crop variety, (b) sowing dates from place to place and from year to year, and (c) in the nature of the crop itself. For ready reference, the months and standard weeks are marked at the bottom of the diagram.

The middle of the calendar shows the normal weather conditions of rainfall, temperature and sunshine hours. Normal phasewise water requirement are also indicated here.

The uppermost portion of the calendar indicates the nature of the weather warnings and the periods during which they are to be issued by the forecasting office concerned.



CROP WEATHER CALENDAR

STATE : MADHYA PRADESH

DISTRICTS : GWALIOR, DATIA, SHIVPURI, GUNA

CROP : WHEAT

IRRIGATED/NON-IRRIGATED

VARIETY : WH-147, LOK-1, C-306, HDM-1553, N-4

DURATION : 110-145 DAYS

SOIL : SANDY LOAM, CLAY LOAM, BLACK COTTON, ALLUVIAL

Weather warnings	Rain	> 50 MM/DAY	> 100 MM/DAY	> 100 MM/DAY
	Duration of wet spell	> 50 MM FOR 3-4 DAYS	> 75 MM FOR 3-4 DAYS	> 50 MM FOR 3-4 DAYS
	Cloudy weather		CLOUDY WEATHER	CLOUDY WEATHER
	Drought	20 DAYS	20 DAYS	20 DAYS
	High winds	> 50 KM/HR	> 50 KM/HR	> 50 KM/HR
	Temperature	MAX. TEMP. > 30°C, MIN.TEMP. < 15°C	MAX. TEMP. > 30°C, MIN.TEMP. < 15°C	MAX. TEMP. > 32°C, MIN.TEMP. < 15°C
	Hail Storm		HAIL STORM	HAIL STORM
Weather conditions favourable for incidence of pests and diseases	Pests	STEM BORER, APHIDS, TERMITES, ARMY WORMS,CUT WORMS	STEM BORER, APHIDS, TERMITES, ARMY WORMS,CUT WORMS	STEM BORER, APHIDS, TERMITES, ARMY WORMS,CUT WORMS
	Weather	CLOUDY WEATHER	CLOUDY WEATHER	CLOUDY WEATHER
	Diseases	RUST, LEAF SPOTS, LEAF BLIGHT	RUST, LEAF SPOTS, LEAF BLIGHT	RUST, LEAF SPOTS, LEAF BLIGHT
	Weather	HIGH HUMIDITY,CLOUDINESS	HIGH HUMIDITY,CLOUDINESS	HIGH HUMIDITY,CLOUDINESS

Normal phase wise water requirement(mm): 47 | 128 | 77 | 137 | 39 | TOTAL = 428

Standard weeks	46	47	48	49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12
Rainfall(mm) total	1.5	2.2	4.2	0.5	1.2	1.0	2.0	1.1	3.6	3.7	2.1	1.2	4.7	4.7	3.0	3.0	1.2	0.7	1.3	0.4	1.1
Max. temp. °C	29.6	28.0	26.4	25.8	25.3	24.9	23.8	23.3	23.2	23.0	24.0	24.5	25.3	26.8	27.6	29.0	31.2	32.7	33.8	35.0	36.3
Min. temp. °C	12.2	11.3	9.8	8.2	7.9	7.5	7.1	6.7	7.4	7.3	7.9	8.1	8.2	10.3	10.9	12.2	13.7	15.1	16.3	17.9	19.0
Sunshine hours	9.5	9.4	9.1	8.6	8.9	8.8	9.2	8.3	8.3	8.4	8.9	8.1	9.0	9.8	9.8	9.1	8.8	9.4	9.5	9.7	10.0

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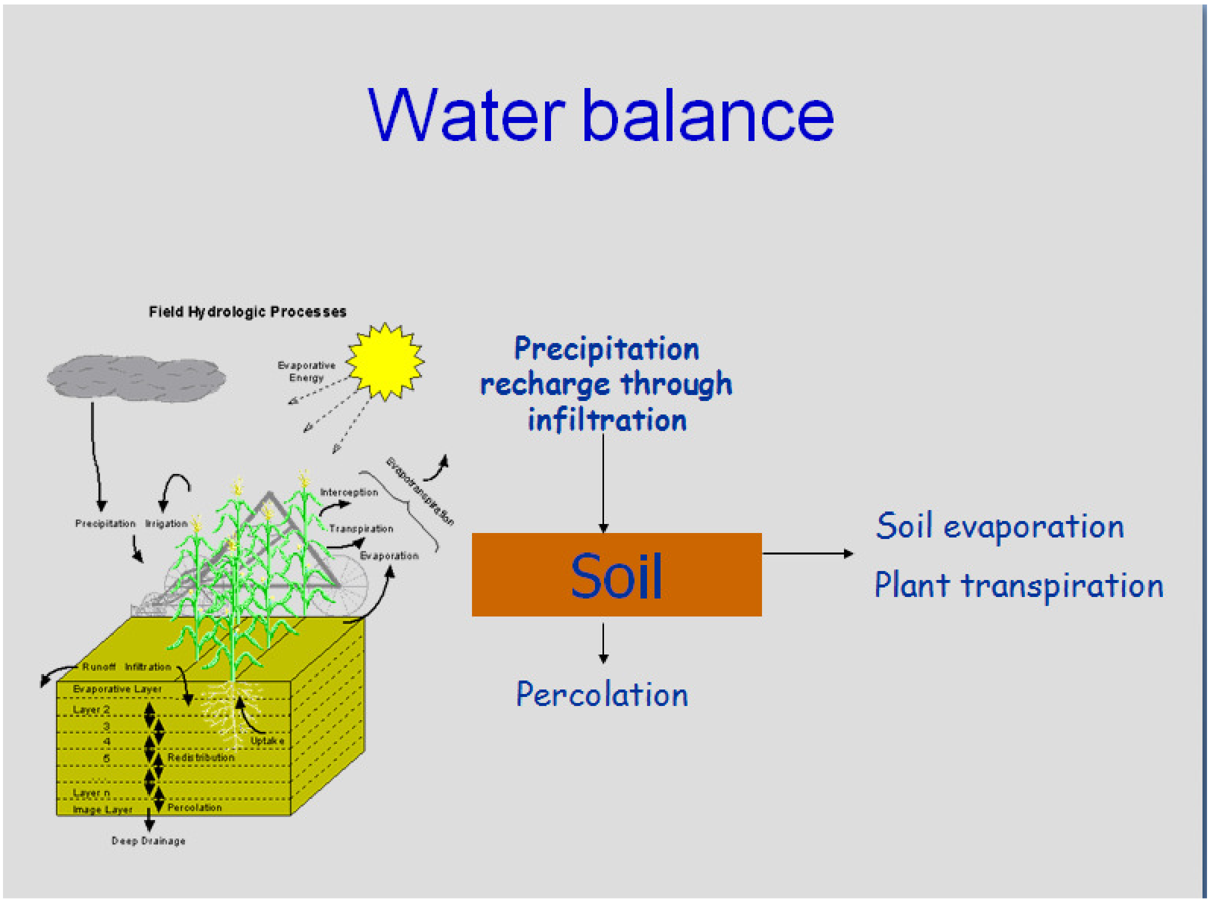
The energy budget approach

Evapotranspiration is the process of turbulent transfer as well as of energy transformation.
The complete energy budget equation:
Qn –horizontal divergence of sensible and latent heat
S- A- E –heat storage in the crop – photosynthesis
Where, Qn is net radiation
S is sensible heat flux to the soil
A is heat flux to the air
E is evapotranspiration
Most crops use less than 1 % of the solar radiation in photosynthesis during their life cycle.
The heat storage in the crop is negligible during the day, but may be relatively important during sunrise and sunset when the temperature range is rapid, and when the values of Qn, E and A are small.
For all practical purposes, both the photosynthesis and the heat storage in the crop may be neglected in the energy budget equation.
The horizontal divergence term represents the net gain of advected energy by the crop stand.
The divergence term may be quite large in arid climate, or in a small irrigated field in a humid climate.
In arid climates, the divergence term may equal the net radiation.
The divergence term usually is omitted, largely because of no simple way to measure it.
However, the divergence term can be minimized by taking readings near the crop surface and at appropriate distance downward in a uniform cover.
By ignoring the advected energy, photosynthesis, and the heat storage in the crop, energy budget equation is reduced to
Qn= S+ A+ E
Which States that the net radiation is disposed in three ways: heat flux to the soil, heat flux to

the air, and evapotranspiration.
Heat flux to the soil is smallest, especially under a dense vegetation cover.
When heat flux to the soil is neglected, the energy budget equation is reduced to its simplest form
$Qn = A + E$
Bowen ratio is the ratio of sensible heat flux to latent heat flux (heat flux to ET) lost by a surface to the atmosphere by the process of conduction and turbulence.
$\beta = A/E$
Bowen ratio is negative when heat is transferred from air to crop, and positive when heat transfer is from crop to air.
Bowen ratio indicates moisture availability in soil.
Less Bowen ratio = more moisture
High Bowen ratio = less moisture
In the absence of advected energy, potential evapotranspiration is determined by the net radiation.
During the warm seasons in the middle latitudes, 80 to 90 percent of the net radiation is consumed in evapotranspiration.
During the winter season in the middle and high latitudes, the fraction of net radiation used in evapotranspiration is usually lower than 80 percent.
In the presence of advected energy, the potential maximum evapotranspiration may well exceed the net radiation.
Therefore, in arid climates, the potential maximum evapotranspiration cannot be approximated from the net radiation alone.
The fraction of solar radiation used in evapotranspiration varies with the development of the canopy and the physiological stage of plant.
The E/Q ratio increases as the vegetative cover develops.
The low ratio in the early stage of the crop cycle is a result of the present of a large proportion of bare ground.
The maximum ratio is reached just before heading and decreases almost linearly after heading because of the senescence of the crop.

The water budget approach

The total water in the root zone on a particular day can be represented by the water balance formula:
$TW_T = TW_{T-1} + Irr + Rain - ET_C - DEEP - Runoff + FLUX_{net}$
where:
TW_T = total water in the root zone on day T
TW_{T-1} = total water in the root zone on the previous day (T-1)
Irr = irrigation water applied
Rain = rainfall
ET_C = evapotranspiration (soil evaporation plus plant use)
DEEP = drainage or percolation below the root zone
Runoff = runoff
$FLUX_{net}$ = any change in total water in the root zone from underground water movement (e.g. high water table or water moving laterally in the soil)



The water balance approach to irrigation scheduling chooses starting point total soil water in the root zone. Then the water balance equation is solved on a daily basis, considering the amounts of water that move into and out of the root zone for that day