Journal of Agrometeorology 6 (1) : 98 - 105 (Jun 2004)

Climatic characterisation of crop productivity and input-needs for agrometeorological advisory services*

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ABSTRACT

The complex nature of characterising climate in terms of crop productivity is brought out. The need for (i) delineation of crop- climate zones (ii) demarcation of homogenous rainfall zones and (iii) identification of endemic areas and periods for major pests and diseases for assessing productivity potential of various areas under dryland and irrigated farming is highlighted. The usefulness of agrometeorological analyses in the unification of apparently diverse data on development, water needs and pest and disease afflictions of crops is pointed out paragraph.

The need for agromet advisories and input requirements for agromet advice on (i) field operations (ii) assessment of crop prospects and yield (ii) regular and supplementary irrigation and (iii) combating incidence of pests and diseases and adverse weather are mentioned. Intricacies involved in crop-drought warnings and crop yield forecasts are pointed out. Some areas for research in (a) long and medium range weather forecasting (b) space-based remote sensing and (c) use of crop-weather models are indicated. The coordination required for real-time agromet advisory work is spelt out.

Keywords: Yield per day, crop-climate, phytometeorology, crop-weather services

Maximal gross crop production per unit area of land will be a simple definition of crop productivity. The unit area yield of a crop, not subject to a soil moisture stress, can be expressed as a product of its yield per day (YPD) (Swaminathan, 1968) and its field-life duration. The life-duration and growth rhythm of all crop varieties are affected by the temperature factor due to the phenomenon of Thermoperiodicity, which is the differential response of crop species to daytime, nocturnal and mean air temperatures (Went, 1957). Breeding varieties for thermo-insensitivity has so far not been possible. The YPD of crops varies with (i) crop types on account of photorespiration (ii) varieties as YPD is genetically manipulable and (iii) with seasons due to the temperature and solar radiation factor. Water needs of all crops (Allen *et.al*,1998) and soil moisture accretion for use of rainfed crops (Ritchie, 1972) are affected by the evaporative power of air (EPA). Crop physiology determines

*Paper presented in the National Seminar on " Agrometeorological Research for Sustainable Agricultural Production" held at GAU., Anand during 27-28 September 2001.

water needs during maturity (Hattendorf *et. al,* 1988; Venkataraman, 1995). The maximum amount of water that roots can forage, which has a vital bearing on susceptibility of rainfed crops to droughts and interval of irrigation for irrigated crops, varies amongst crops, with varieties of the same crop and with soil types for the same variety. For the same crop variety and same soil type the quantum of easily available root zone moisture varies with the evaporative power of air, being most in cool and least in hot weather. The lag period between germination and active uptake of water varies with crops and for the same crop with seasons. Crops with minimum lag period are prone to soil moisture stress in the early phases. As initial stand-density of crops can influence the final yield and as weather influences germination, to ensure productivity, seed rates must be season based and in the season weather based such as in delayed sowings. Work of Asha and Bhatia (1997) indicate that the type and quantum of fertilizers to be applied to a crop have to be weather based.

CROP PRODUCTIVITY

In view of the concept of YPD, higher unit area yields of crops can be obtained only due to longer occupancy of the field. It may be argued that in low-yield areas more time is available to raise more crops subject to water availability. However, the weather requirements for growth and development vary amongst crops, with varieties of the same crop and with growth stages of a variety. The weather parameters show temporal, spatial and year-to year-ariations, with differing degrees of intensity. Thus even under irrigated relay cropping, for a given crop its rotational crops are not the same in all areas. Besides yield the economic returns of rotational crops can vary. Thus gross crop productivity will show wide areal variations even under irrigation. Because of the above an area which may be less suited to a particular crop may be more productive for another crop and for a given crop maximum yield is realised in specific areas and periods-

Crop climate classification

For assessing climatic potential of crop productivity it is necessary to know as to what crops can be grown where, when and how best even under irrigation. For this classification of climatic zones has to be done on a crop-wise basis. Significant fraction of gross crop production comes from rainfed areas. Therefore, characterization of production potential in various areas of the dryfarming tract is also necessary. Scientists are continuously evolving new varieties for better yields. However, the response of varieties to weather parameters will be one of degree than of type and the relativity in differences in yield potential in different zones for existing cultivars will hold good for the newer varieties also. Herein lies the advantage of crop-climate classifications.

Zonation of irrigated crops

For purposes of zonation of irrigated crops information/data need to be collected, from the literature on weather relations of crops, for all prospective crops on (a) optimum temperatures (day, night-time or mean temperatures as the case may be) for various growth stages in the vegetative phase (b) optimum solar radiation cum temperature regime in the reproductive phase and (c) pheno-meteorological models or relationships to determine the duration of various growth phases. The information/data compiled as above can then be used to determine, for a prospective crop, the proper growing period for its maximum possible yield. For the above crop other alternate growing periods can be delineated with indications of yield realisable thereof. This may be necessary to fitting of the crop suitably under relay cropping at the place. Once the growing period for the crop is delineated at a network of meteorological stations it is possible to demarcate homogenous zones for the crop. Such a zonation will help decide the agronomic strategy that would bring out the potential yield of the crop at the location. For areas in each zone the same agronomic strategy can be adopted.

Rainfall zones

Rainfall is the most variable of all weather parameters. The year-to year-variation of weekly rainfall is so great that one has to work in terms of rainfall probabilities. Therefore, selection of a minimum network of representative stations to cover an area becomes obligatory. For this delineation of rainfall zones with intra-zonal homogeneity with reference to start and end of agricultural rains and soil moisture accretion at end of rains rainfall is necessary and methodology for the same is available (Venkatarman 2001b).

Dryland productivity

Methodologies to assess, from data of EPA. (i) evaporative depletion of rainfall from soil surfaces of bare and cropped fields (Ritchie, 1972) and hence of soil moisture accre...on for use of rainfed crops and (ii) quantitative phasic needs of soil moisture for many crops for optimal transpiration (Allen *et al*, 1998) are available. EPA can be related to evaporation from mesh- covered class a pan (EP) in various areas and seasons (Venkataraman *et al*, 1984). Lysimetric and other studies give the limits for soil moisture carry-over for many Kharif crops and soil types. It is, therefore, possible to assess the temporal march of soil moisture stress days for any given distribution of rainfall (Venkataraman, 2001a). When applied to long series rainfall data the technique can give the frequency of occurrence of various durations of crop growth periods at a place and hence of crop productivity potential at the location under dryland farming.

Endemic areas and periods of pests and diseases

The range of weather conditions a pest or disease can endure and the congenial weather requirements for quick development and multiplication vary with the infective organisms. The bionomics of alternate hosts, vectors, carriers, parasites and predators of pest and disease organisms is weather controlled. While deciding on suitable growing periods for crops in an area and season it is necessary to avoid or at least minimise the setbacks due to pests and diseases. An examination of data on intensity of incidence of pest and disease afflictions with concurrent meteorological data can help specify the pre-disposing weather conditions for virulent outbreaks. Such information can then be used for weather-based demarcation of susceptible areas and periods for incidence of specific pests and diseases. Now a crop is susceptible to a pest or disease at a certain growth stage only and the pest or disease organism does damage at a certain development stage only. Therefore, once endemic areas and periods for a pest or disease is identified a change in sowing date from the optimum may become necessary to avoid setbacks due to pests and diseases. However, this adjustment to avoid chronic incidence of pests and diseases will impair the optimal climatic potential for crop productivity at that place.

Agrometeorological processing of crop related data

Apparently diverse data on water consumption and water needs of crops can be unified by relating such data to the derived meteorological parameter EPA. Similarly, derived meteorological parameters like growing degree days, photo-thermal units, helio-thermal units and cumulative EPA can be used to arrive at the times and durations of various crop phases for a given crop and date of sowing. There are indications that though varieties may differ in the quantum requirement of a derived parameter to complete their life cycle, the fractional percentage of the total requirement to complete the various phases may be the same for all cultivars of the crop.

Meteorological data are more extensive, both in time and space, better archived and more readily available than crop data. By calibrating crop performance and behaviour in terms of meteorological data, phytometeorological models can be developed to generate crop data and agronomic information from weather data at locations where no crop data is available. The same holds good for incidence of pests and diseases.

AGROMET ADVISORY SERVICES (AAS)

The agricultural strategy in post-independent India has been characterised by (a) wasteful use of resources like irrigation, biocides and fertilizers in production and protection of crops (b) diminition of natural vegetation, ground water and top spoil and (c) growing of crops in wrong areas and/or periods. Since growth and yield, water needs and incidence of pests and diseases of crops, groundwater recharge, availability of surface runoff, fertiliser requirements and regeneration of natural flora are weather controlled, it can be seen that our present position of crop production has risen due to the neglect of the effect of climate on several aspects of crop culture. By the same token agroclimatological analyses have important roles to play in avoiding past mistakes and in ensuring future agricultural sustainability. However, despite climate-oriented planning of crops and cropping practices, the crop-weather situation realized on a real-time basis will be different even at the same place in different years. In dealing with actually realized weather situations, Agromet. Advisory services have a role to play in management, protection and monitoring of crops at field-level as detailed below.

Growth of AAS

Weather services for agriculture like the frmers' weather bulletins and crop outlooks have suffered for lack of requisite and authentic data on standing crops. The satellite instructional television experiment

(SITE) in 1975 made a beginning in issue of weather based farming advisories after joint examination of crop and concurrent weather data by a team of agricultural experts, agrometeorologists and weather forecasters. This experience formed the basis for the IMD scheme on agromet advisory services (AAS) at state level. Now the National Centre for Medium Range Weather Forecasting (NCMRWF) is running its own AAS. The Indian Space Research Organisation (ISRO) is issuing drought warnings and crop yield forecasts. The National Remote Sensing Agency (NRSA) provides advice on extent and state of crop cover based on Satellite Imagery.

AAS- needs and opportunities

At present agromet advisories are mainly confined to issue of advice to the farming community on the timing of cultural operations, and initiation of prophylactic measures against adverse weather. Developments in the field of Agricultural Meteorology enable us to (a) simulate growth development and yield of crops (b) quantitatively asses physical and physiological processes of crops and (c) foresee incidence of crop pests and diseases through computerised models requiring the use mainly of weather data. Monitoring of crop situations on a large scale from space through satellite imagery can now be done in a routine manner. Thus AAS can be broad based to include (a) advisories for irrigation scheduling and control operations against pests and diseases (b) monitoring (i) areal spread of crops and (ii) incidence of crop droughts and (c) forecasting of crop yields. The dynamic crop-weather simulation models are eminently useful for agroclimatological usage. However, for purposes of AAS the data requirements and procedural methodology render use of such models for operational, real-time applications not practicable. Simpler methods/models requiring the use of only readily available meteorological data will be required for real-time AAS. In light of the above some suggestions for (a) research in the fields of (I) weather forecasting and (b) inputs, infrastructure and coordination needed for improvement of real-time agromet advisory services are detailed below.

Forecasting Bay depressions

Bay depressions form at the Head Bay at the beginning of the rainy season, in the Central Bay in the middle of the season and in the South Bay towards the end of the season. The westward movements of the depressions are vital for receipt of satisfactory rains over Central India. Thus in the monsoon period, climtologically there is a progressive southwards shift in the favoured locations for cyclogenesis. The reasons for this needs to be fully investigated so as to identify factors (a) responsible for (i) initiation of cyclogenesis and (ii) southerly shift of such locations with progress of the monsoon and (b) conducive for long distance westward progress of the depressions. If the above is successfully done we will have a tool for pre-seasonal crop planning in central India.

Medium range weather forecasting (MRWF)

Studies leading to (a) identification of conditions which aid or hamper the northward or westward progress of the monsoon current after onset over Sri Lanka and Andamans respectively (b) relationships between early, normal and late start of rains and subsequent quantum and distribution of rains (Narain *et al* 1991) and (c) association of areas in the incidence of drought years, as observed between Orissa and East Madhya Pradesh (Prasad, 2001), would give us MRWF tools to advise farmers on correct pre-seasonal crop planning.

Remote sensing

An assessment of the quantum of soil moisture available to crops when they are at the ground cover state will greatly help in keeping track of subsequent soil moisture status of crops. Mounting of a suitable Gamma Ray Attenuation Sensor on a satellite and making quantum estimates of soil moisture availability for field crops at ground-cover state over large areas is called for.

Validation and use of crop-weather models

Validation of crop-Weather models need to be done at a number of spatially well distributed stations covering all possible climatic regimes for the crop so that the duration of various crop phases cover a wide range. This is especially true for rainfed crops where one does not have the luxury of choice of sowing dates at a station.

A crop-weather model has amongst its components derived parameters for deducing times and duration of various crop phases. If properly validated such models offer considerable scope for demarcation of homogenous crop zones as unit area yield is directly proportional to crop-life duration and as phenological data give scope for unification of crop development in terms of weather data and/ or assessment of percentile development of various phases of crop in terms of its full life.

Drought warnings

Failure of a dryland crop in the establishment phase is not frequent. The optimal moisture needs of a vegetative ground -covering crop are nearly the same. However, the moisture needs during maturity vary amongst crops and varieties. Crops and/or varieties vary in their resistance to soil moisture stress. Thus crop drought warnings should be crop and variety specific.

Yield forecasts

Unit area yields are sought to be predicted in terms of kg ha^{-1}. For dryland crops, it would be better if expected yield is expressed as a percentage of the possible yield of the crop if it had not been subject to any soil moisture stress. For irrigated crops whether use of absolute values or departures of weather parameter(s) from the normal in the models would give a truer picture of deviations of actual yield from the potential one needs to be addressed.

Since the effect of a aberration in weather parameter and soil moisture stress is critically influenced by the growth stage of the crop when they occur, feed-back information on crop phenology from a network of minimum number of representative stations on a crop-wise basis is a must for agrometeorological anticipation of crop yields.

Prediction models for unit area yield of crops have to take account of the technology trend. For this crop-weather models should not be validated at the high input technology status of research stations but at the level of technology the farmer uses. For this recording of yields on fields of farmers by properly designed crop cutting experiments on a regular basis and careful archiving of such data for retrieval and use in future is essential.

SOME USEFUL IMPUTS FOR AAS

Crop-climate normals

AAS formats lack provision for crop normals like dates of sowing and duration and periods of various crop phases. Unless one knows as to what is normal for a crop one cannot decide if the current status of a crop is abnormal. Crop-climate normals should be an integral part of AAS.

Survey of pests and diseases

Mere occurrence of favourable weather conditions will not automatically lead to a pest or disease outbreak. The presence of an initial inoculum is necessary for the same. So systematic survey of pests and diseases cooperatively organised by state and central directorates of plant protection should form part of AAS.

Irrigation advisories

Meteorological scheduling and advice for regular irrigation of clear season crops and supplementary irrigation of *Kharif* crops is possible. The main tool for rendering this advice is the data on evaporation from a mesh covered Class A Pan (EP). Weekly values of EP show very little coefficient of variation between the years. So normal weekly values of EP for all available stations should form an essential item of the data bank for AAS.

Forecasting of frosts

Crops exposed to clear skies can have a surface temperature much lower than the screen temperatures. So crop frosts can occur even when screen minimum temperatures are above freezing. Excellent data of grass radiation minimum temperatures (GRN), which a give a measure of nocturnal minimum temperatures of crop surfaces have been compiled by the Agrimet. Div. of IMD. These should be used to arrive at the depression of GRN below the Minimum temperatures on a weekly basis for as many stations as possible in the frost-prone areas.

Real-time working arrangements

The agromet. units of State Agricultural Universities (SAUs) must attend to the development of agromet models for use in AAS. The state deptts. of agriculture should train their extension workers in the use of outputs of AAS for proper and timely execution of farming practices. The Principal Scientists in charge of All India Coordinated Trials of specific crops should select minimum number of representative stations for their crops, which would provide the requisite set of data/observations as ground-truth. A national crop-weather-watch group with representatives from ICAR, IMD, DST, ISRO, NRSA, IASRI etc. must be constituted to meet twice an year in early September and February to review the progress of *kharif* and *rabi* crops and issue tentative yield forecasts thereof.

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