Crop Weather Models: Concepts Types and Applications

Slide 2 to 10 show relationship between weather variables and plant response. These slides are not directly part of course contents. However these have been given to understand modelling concepts.

Slide 11 to 76 contain important information on crop weather models, types, applications; ICT applications in water and nutrient computation etc.

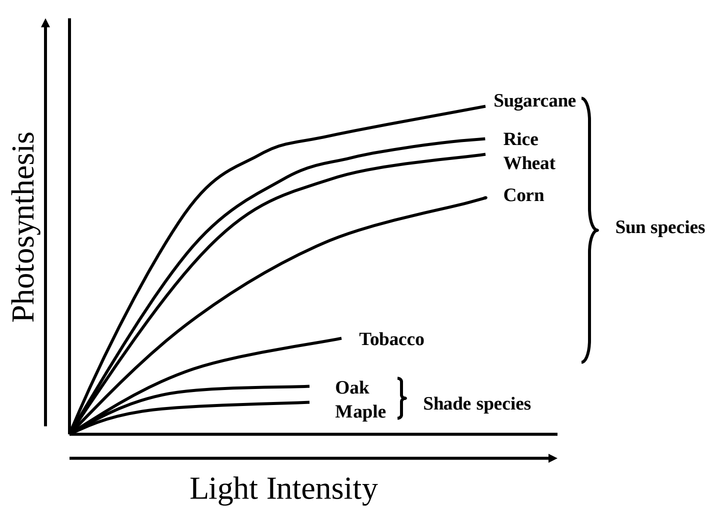


Figure: Photosynthesis response to light intensity

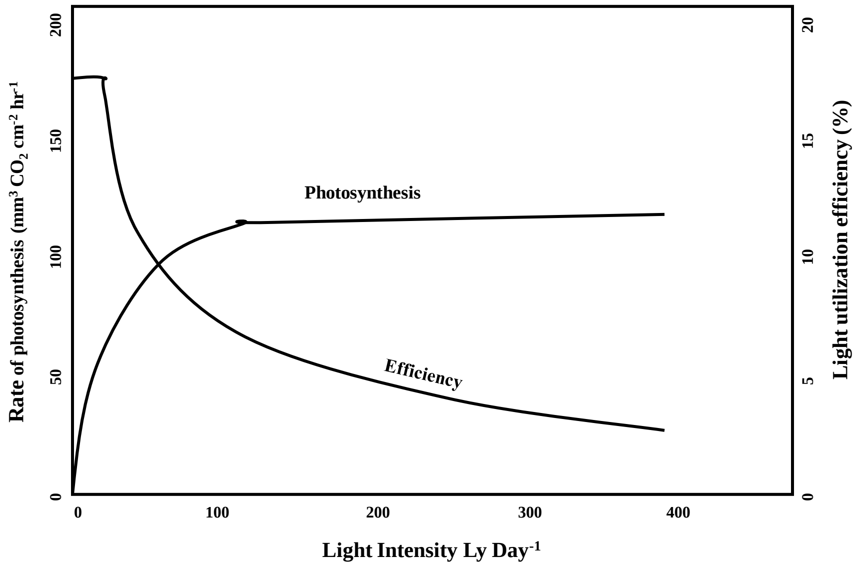
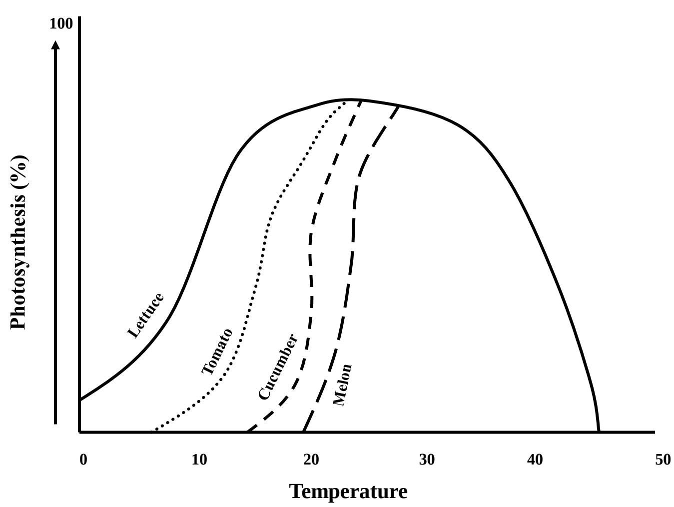
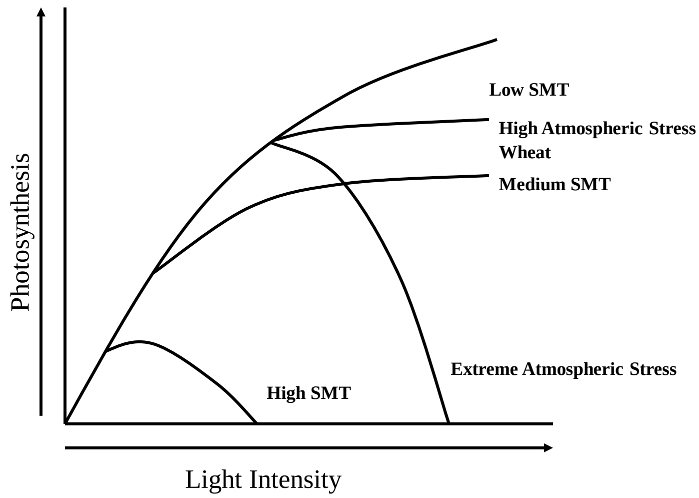


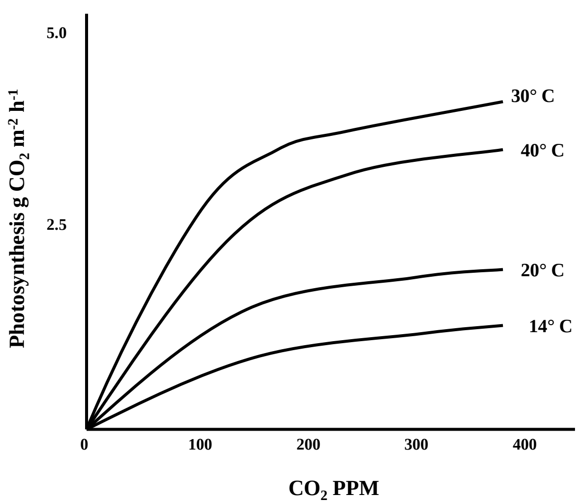
Figure : Rate of photosynthesis and efficiency of radiation utilization.



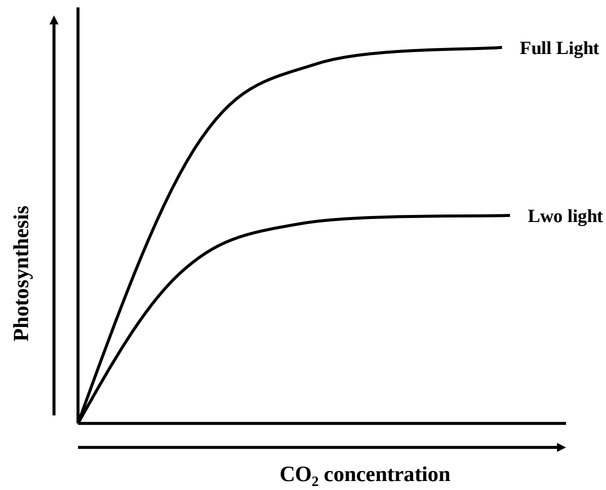
Temperature limit for Photosynthesis



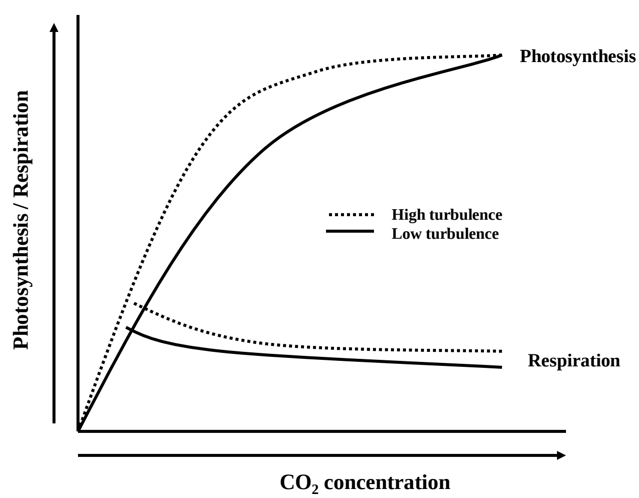
Expected effects of soil moisture stress (SMT) and atmospheric moisture stress on photosynthesis (P) at different light intensities



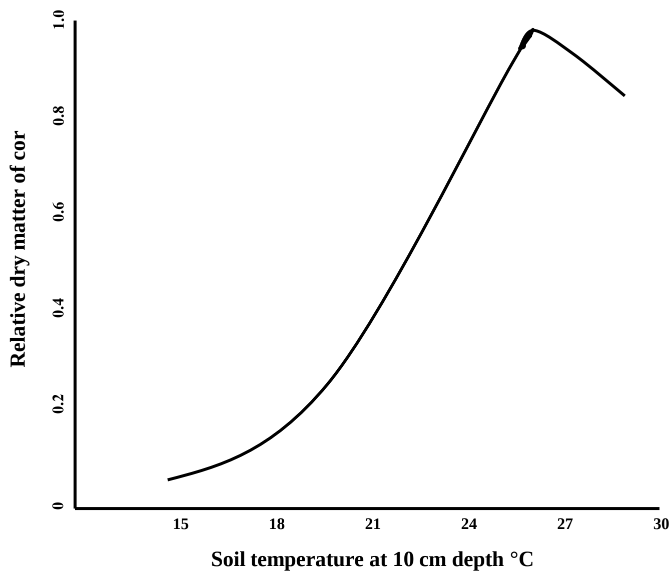
Relation between photosynthesis of maize and CO2 concentration at different temperature



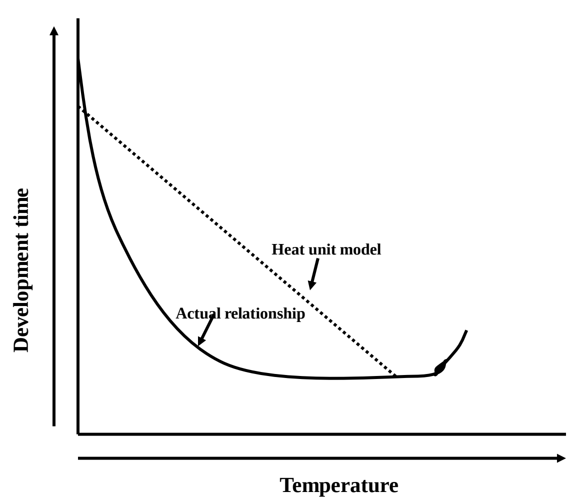
Effect of light intensity and CO_2 concentration on photosynthesis



Role of CO2 concentration and turbulence in photosynthesis



Relative yield of dry matter of young corn plants as affected by soil temperature

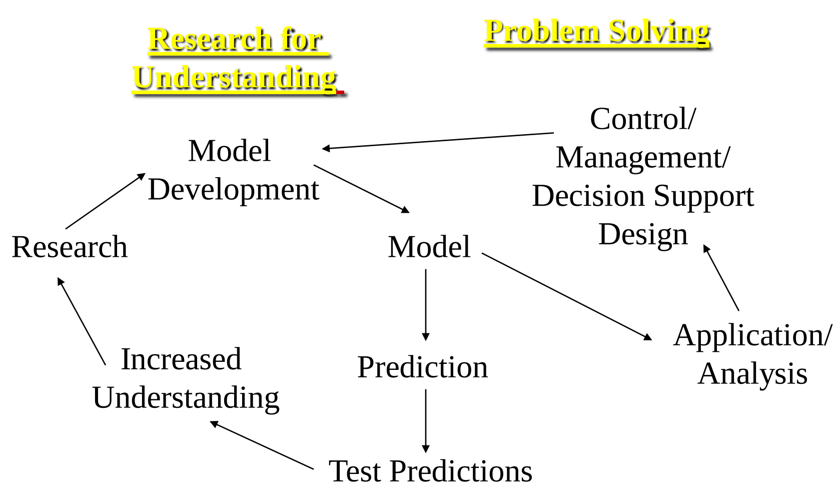


Development time and temperature relationship.

Systems Approach

- Traditional agronomic approach:
  - Experimental trial and error
- Systems Approach
  - Computer models
  - Experimental data
- Understand → Predict → Control & Manage
  - (H. Nix, 1983)

Systems Approach



What is a model ?

- A model is a mathematical representation of a real world system.
- The use of models is very common in many disciplines, including the airplane industry, automobile industry, civil eng., industrial eng., chemical engineering, etc.
- The use of models in agricultural sciences traditionally has not been very common.

Simple Model

- Air temperature
  ==>Vegetative and reproductive development
- Solar radiation
  ==>Photosynthesis and biomass growth

Development * Biomass = Yield

Simple Model

- **Yield = *f* (Development, Biomass)**
- Development = *f* (Environment, Genetics)
- Biomass = *f* (Environment, Genetics)
- Environment = *f* (Weather, Soil)
- Other factors:
  - management
  - stress (biotic and abiotic)

Model

A model is a schematic representation of a system. A model can also refereed as a representation of relationship under consideration and may be defined as an act of mimicry.

Model in Physical Sciences

In the physical science, the term "model" is used to provide an explanation for certain phenomena and to postulate underlying processes which give rise to the observations under inspection (Yarranton, 1971).

Model in Agricultureal Sciences

A crop-weather model is thus defined as a simplified representation of the complex relationship between weather or climate on the one hand and crop performance (such as growth or yield) on the other hand by using established mathematical and / or statistical techniques (Baier, 1979).

Types of crop-weather models

1. Empirical-statistical models or Simple statistical model,
2. Crop-weather analysis models or Parameterization models, and
3. Crop growth simulation models or Analog-physical model.

Empirical-statistical models or Simple statistical model

Empirical statistical model are developed on the basis of long term relationship between crop yield and several variables (representing weather, soil characteristic, technology trend, etc.,).
There are two types of Statistical models:

a) Trends model, and
b) Agrometeorological Model

a) Trends model

Trend models are those model in which yield or other crop parameters are related with time. These model represent the technological advancement and can be expressed as:
$Y = a + bX$,
Where Y is yield or any other plant entity,
"a" is constant (intercept),
"b" is slope,
X is independent variable such as time

b) Agrometeorological Model

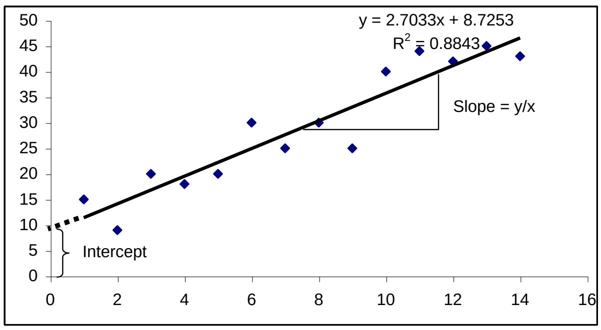
Agrometeorological model involve meteorological parameters which are important for growth and development of plants. These model can be further divided in two categories:

I) Linear models and

II) Non linear models

I) Linear models

Linear model show straight relationship between crop entity and independent variables and can be of two type A) Single variable type model and B) Multiple variable regression model.



A) Single variable type model: These type of model uses only one independent weather variable and can be represented by following expression:

Y = a + bX, where X is weather variable

B) Multiple variable regression model: These type of model uses two or more independent weather variables and can be represented by following expression:

Y = a + bX1 + cX2……..nXn ,

where where b, c…n are slope coefficients and X1, X2….Xn are independent variables

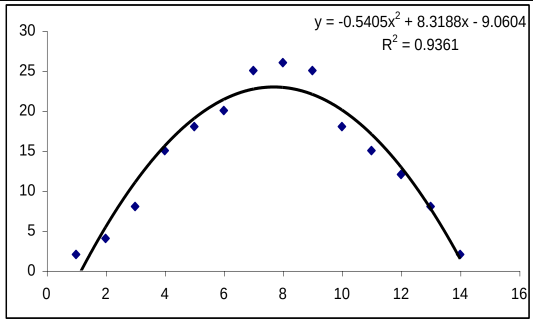
II) Non linear models

These models represent the nonlinear relationship between crop yield and weather variables. These kind of relationship is very common weather and crop yield or other entity. Mainly there are two type of non-linear models A) Quadratic models, and B) exponential models.

A) Quadratic models

Quadratic model uses only one independent variable. The dependent variables first increases with increasing independent variables and after certain point it decreases.

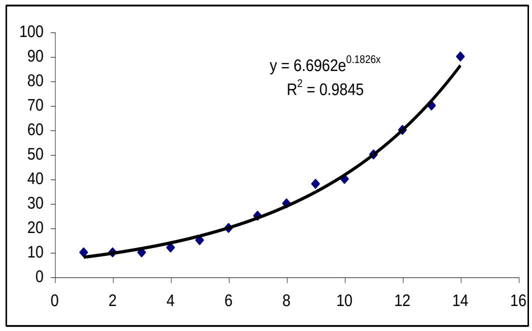
$$Y = a + bX - cX^2$$



B) exponential models

in exponential model the dependent variables increases slowly during first stage and then tends to be increase sharply in later stage when relationship is positive, while it show reverse trend when relationship is negative.

$$Y = a * Exp^{(bx)}$$



Crop Weather Analysis Models

The crop-weather analysis models are defined as the product of two or more factors, each representing the simplified functional relationship between a particular plant response (e.g., yield) and the variations in selected variables at different plant development phases (Baier, 1977). Time interval of one day or more is used.

$$Y = \sum_{t=1}^{m} V_1 * V_2 * V_3$$

Where, V_1 = Maximum temperature,

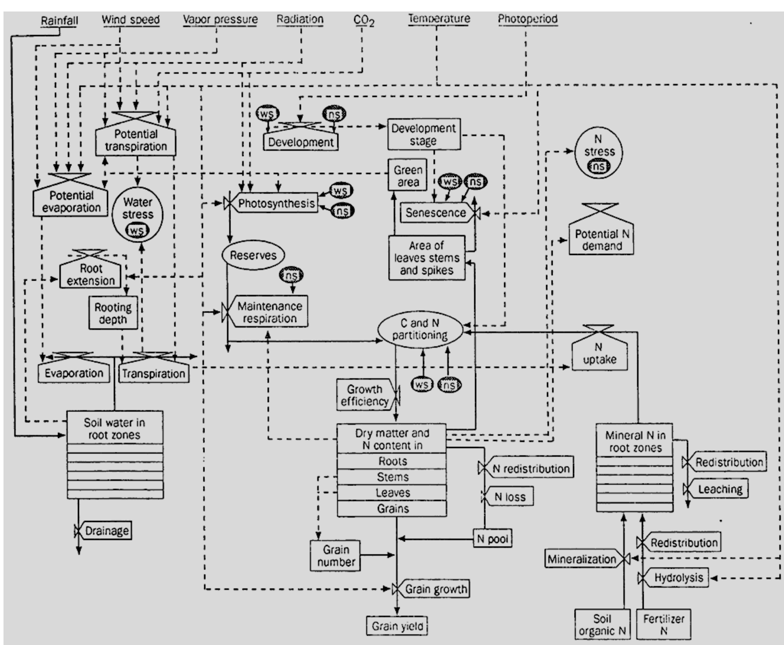
V_2 = Minimum temperature

V_3 = Ratio of actual to potential evapotranspiration

Crop Growth Simulation Models

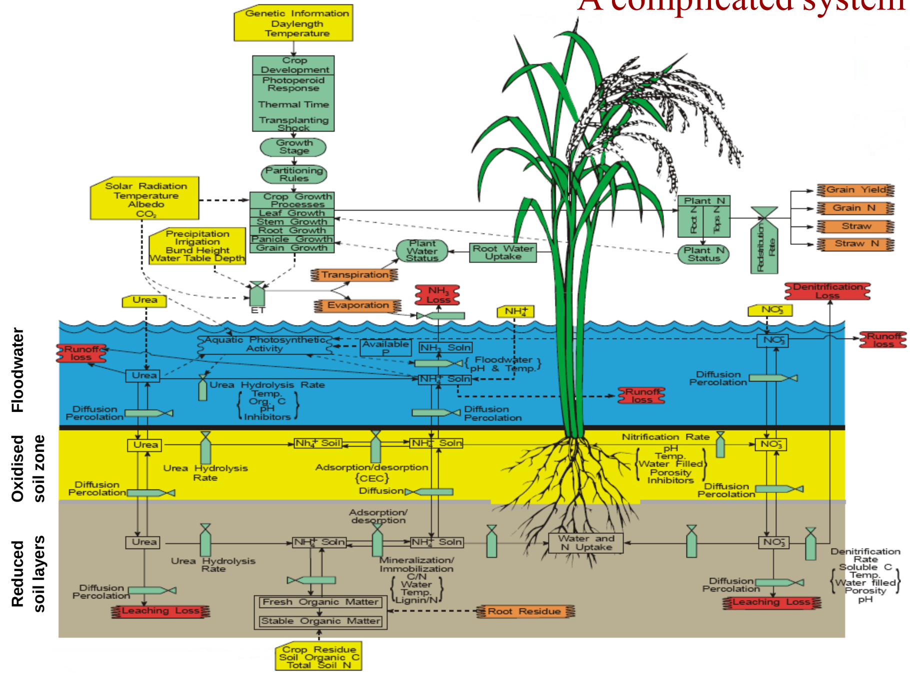
Crop growth simulation models are simplified mathematical representation of the complex physical, chemical and physiological mechanisms underlying plant growth and its response to environment. They are dynamic models, which provide prediction as well as explanation of the integrated behaviour from more detailed knowledge of the underlying physiological processes. In these models the crop is described by a set of state variables (e.g., weight of various organs) that are updated at each iteration of the variable by rate variables (e.g., flow of carbon in photosynthesis and respiration) defining changes in the state variables. The rate variables are assumed to be constant during the iteration interval, which is generally one hour and sometimes even less.

Crop growth models can be categorized as Qualitative model and Quantitative model. Qualitative models represent the conceptual relationships and feedback among the various components of the system. While Quantitative models, are the translations of a qualitative model into a computer program.



The relational diagram of crop simulation model (WTGROWS) explaining interrelationships and feedback among various physiological and soil processes. The valves are rates, rectangles are quantities and circles are auxiliary variables. Solid lines show flow of material and dashed line the flow of information

A complicated system .

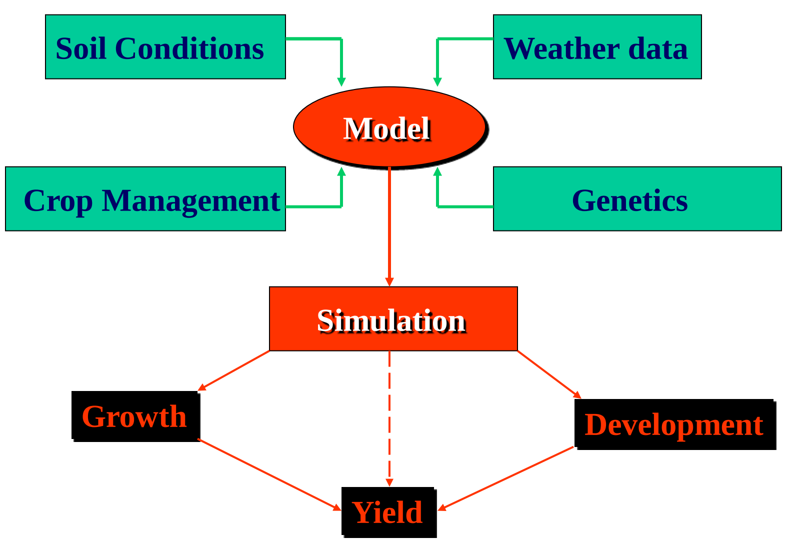


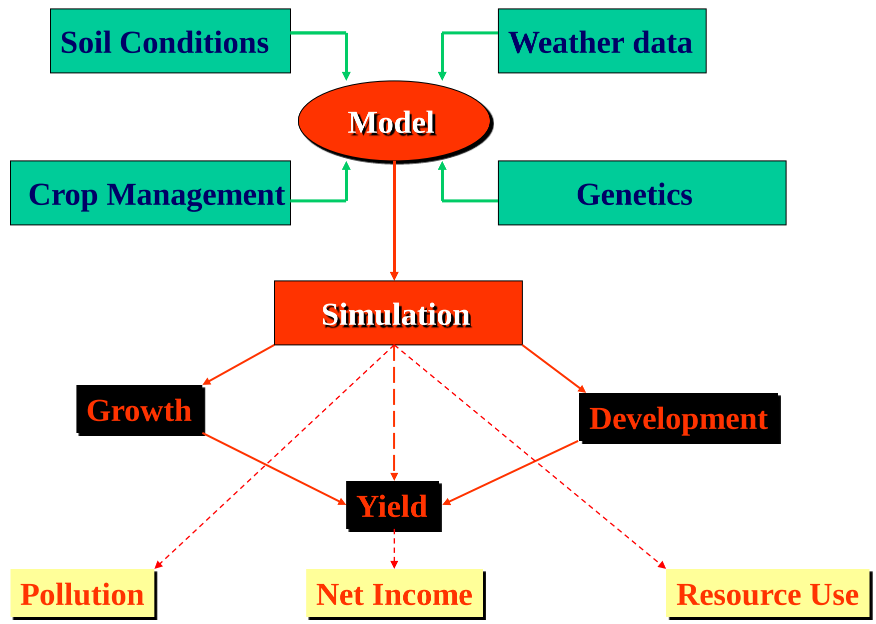
Crop Simulation Models

- Crop simulation models integrate the current state-of-the art scientific knowledge from many different disciplines, including crop physiology, plant breeding, agronomy, agrometeorology, soil physics, soil chemistry, soil fertility, plant pathology, entomology, economics and many others.

Agricultural Models

- Crop simulation models in general calculate or predict ***crop growth and yield*** as a function of:
  - Genetics
  - Weather conditions
  - Soil conditions
  - Crop management





Crop Simulation Models

Four levels or phases (School of De Wit)

LEVEL 1

- Potential Production
  - Solar radiation and temperature as input
  - Simulate growth and development
  - Plant carbon balance (photosynthesis, respiration, partitioning)

Level 2

Water-Limited Production

- Potential production +
- Precipitation and irrigation as input
- Soil profile water holding characteristics
- Plant water balance (transpiration, water uptake)
- Soil water balance (evaporation, infiltration, runoff, flow, drainage)

Level 3

Nitrogen-Limited Production

- Water-limited production +
- Nitrogen fertilizer applications as input
- Soil nitrogen conditions
- Plant nitrogen balance (uptake, fixation, mobilization)
- Soil nitrogen balance (mineralization, immobilization, nitrification, denitrification)

Level 4

Nutrient-Limited Production

- Nitrogen-limited production +
- Fertilizer applications as input
- Soil nutrient conditions
- Plant nutrient balance (uptake, mobilization)
- Soil nutrient balance

• Phosphorus, potassium, other minerals

Level 4

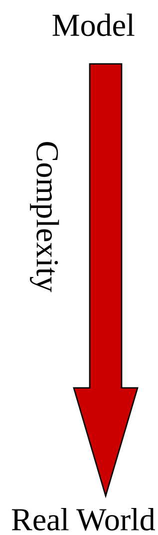
Pest-Limited Production

- Nitrogen-limited production +
- Pest inputs - scouting report
- Dynamic pest simulation

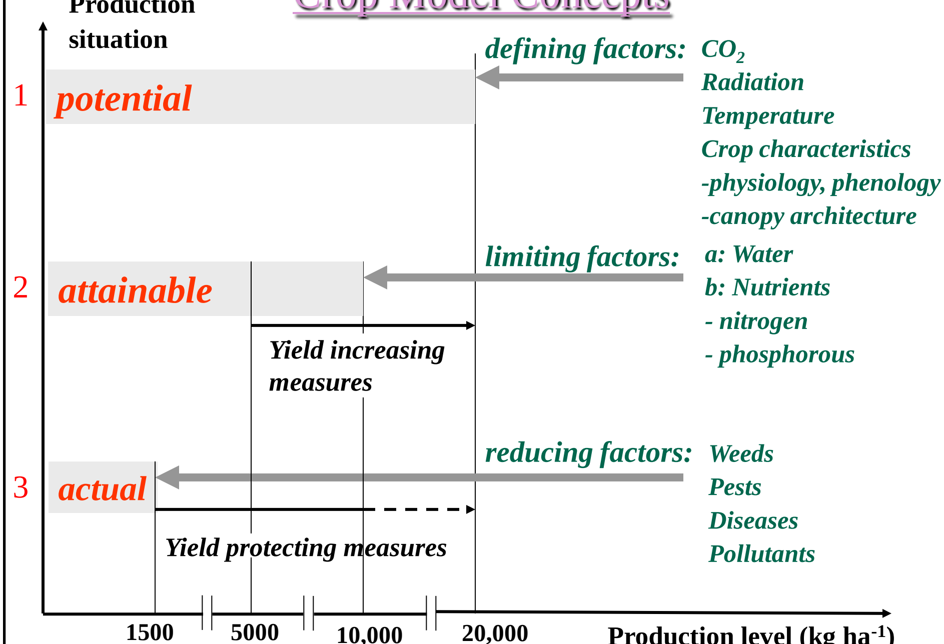
• Insects, diseases, weeds

Complexities of Agricultural Production

- Potential production
- Water-limited production
- Nitrogen-limited production
- Nutrient-limited production
- Pest-limited production
- Other factors
  - Extreme weather events
  - Salinity



Crop Model Concepts

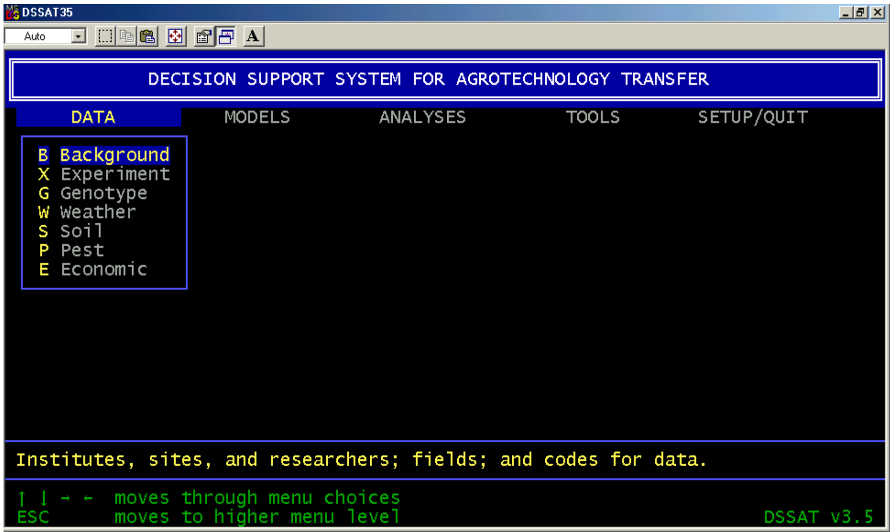


Source: World Food Production: Biophysical Factors of Agricultural Production, 1992.

Crop Simulation Models

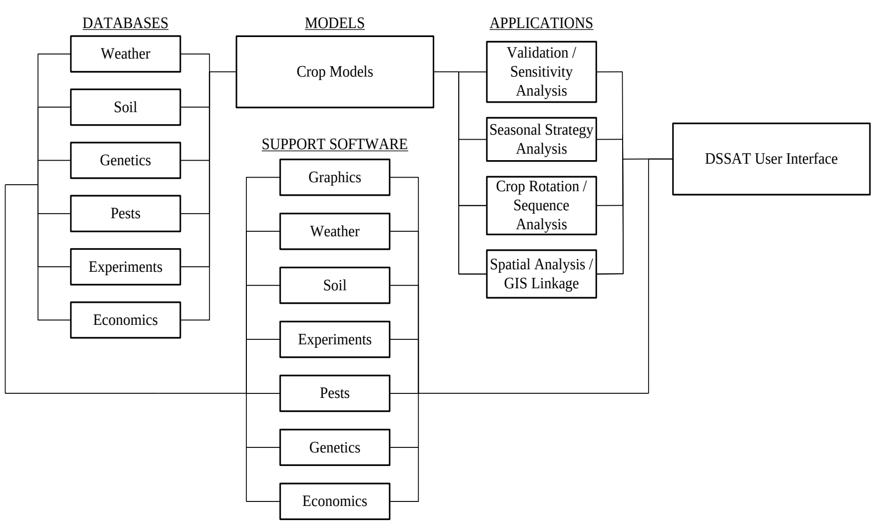
- Require information (Inputs)
  - Field and soil characteristics
  - Weather (daily)
  - Cultivar characteristics
  - Management
- Model calibration for local variety
- Model evaluation with independent data set
- Can be used to perform "what-if" experiments

DSSAT
Decision Support System for Agrotechnology Transfer



DSSAT v2.1 in 1989 → DSSAT v4.5 2010
About 2000 users in over 90 countries

Components of DSSAT



DSSAT v4.5

- Windows-based
- Incorporates DSSAT CSM (+ Legacy Models)
- Field scale

- Data management tools
  - XBuild: Input crop management information in standard format
  - SBuild: Create and edit soil profiles
  - GBuild: Display graphs of simulated and observed data, compute statistics
  - ATCreate: Create and edit observations from experiments, formatted correctly
  - WeatherMan: Assist users in cleaning, formating, generating weather data
  - ICSim – Introductory tool to demonstrate potential yield concepts

DSSAT v4.5

Several different analytical capabilities

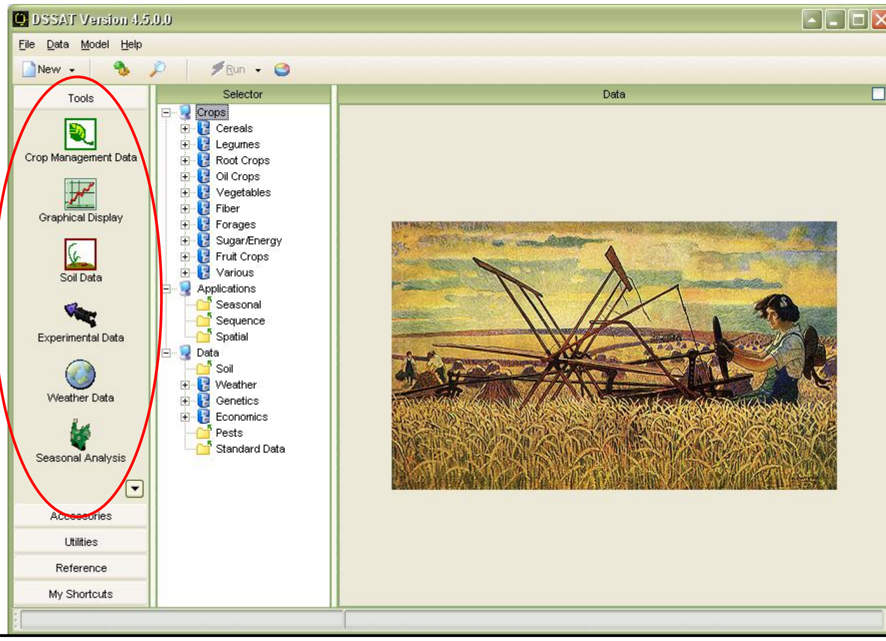
- Sensitivity Analysis: vary soil, weather, management or variety characteristics for insight

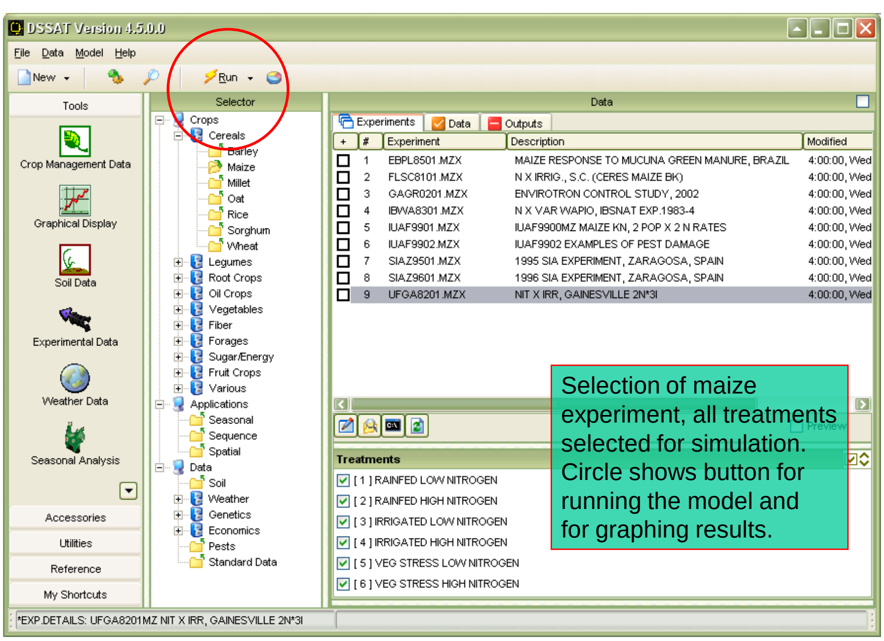
- Seasonal Analysis: multiple-year simulations to evaluate uncertainty in biophysical and economic responses

- Rotation/Sequence Analysis: long-term simulations to analyze changes in productivity and soil conditions associated with cropping systems

- Spatial Analysis: define spatially variable soil, weather, management characteristics across a field or region for analysis

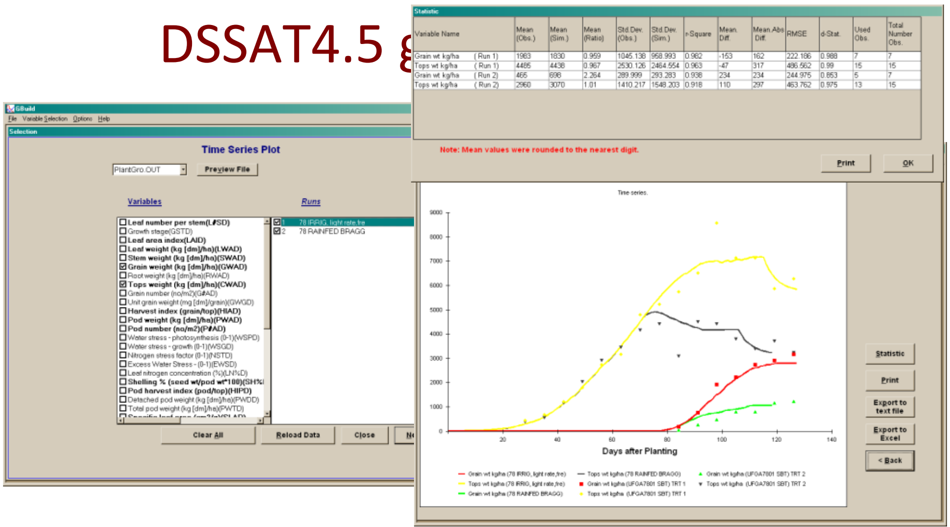
Main window in DSSAT v4.5



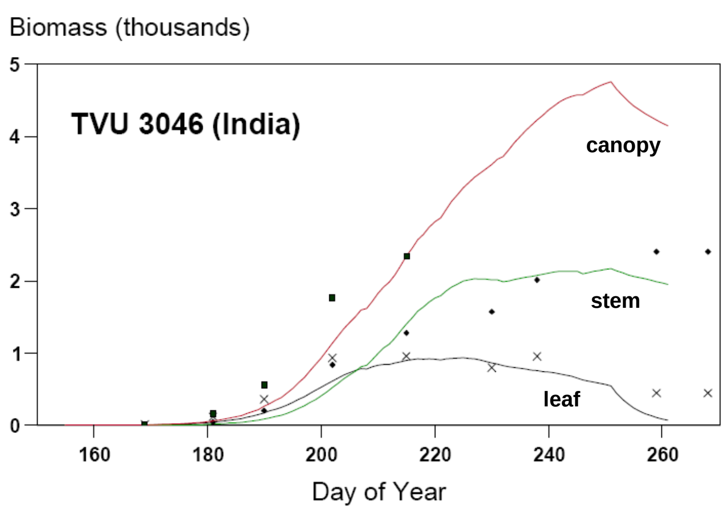


Selection of maize experiment, all treatments selected for simulation. Circle shows button for running the model and for graphing results.

DSSAT4.5 g



Simulated and observed biomass accretion (kg DM/ha) for cowpea cultivar TVU 3046 grown in Griffin, Georgia, in 1998



Hoogenboom et al., 2000

Input-Output files

Input Files	Output Files
Mandatory files	Plant Growth (at chosen time step)
-Management File	Plant Nutrient (mostly Nitrogen)
-Genotypic file (cultivar characteristics)	Soil Nitrogen Balance
-Soil File (soil horizon)	Soil Water Balance
-Weather File	Soil Temperature
Optional Files	Evapotranspiration
- Pests and disease	Overview
-Economics	Summary
-Plant out put (summary- for comparison with model output)	Errors and Warning
-Plant Growth (for graphical comparison with model output)	

Verification, Validation & Calibration of Model

Verification of a model is the process of confirming that it is correctly implemented with respect to the conceptual. Verification is done on the same dataset which has been used to build the model to find and fix errors in the implementation of the model. The objective of model verification is to ensure that the implementation of the model is correct.

Validation is the process of determining the degree to which a model and its associated data are an accurate representation of the real world from the perspective of the intended uses of the model. Validation is done on independent data set. A certain degree of error is acceptable depending upon application.
Calibration refers to the estimation and adjustment of model parameters to improve the agreement between model output and a data set. It is done on independent dataset.

Sensitivity and Uncertainity Analysis of Model

The aim of **sensitivity analysis** is to determine how sensitive the output of a crop model is, with respect to the elements of the model which are subject to variability. A sensitivity analysis consists of estimating the influence of parameters on the state variables or on the model outputs.

Uncertainty analysis consists of evaluating quantitatively the uncertainty or variability in the model components (parameters, input variables, equations) for a given situation, and deducing an uncertainty distribution for each output variable rather than a misleading single value. It provides methods to assess the probability of a response to exceed some threshold. This makes uncertainty analysis a key component of risk analysis.

Limitations of Model

Crop simulation model assumes that crop field is homogenous in respect to soil, microclimatic conditions, and crop conditions, while large variability is actually found in field.

Crop models are not able to give accurate projections because of inadequate understanding of natural processes and computer power limitation.

Measured parameters also vary due to inherent soil heterogeneity over relatively small distances.

Model performance is limited to the quality of input data.

It is common in cropping systems to frequently measure above-ground crop growth and development, but data relating to root growth and soil characteristics are generally not as extensive.

Simulation models require meteorological data, which is not always reliable and complete.

At times, parameters that were not routinely measured may turn out to be important and they are then arbitrarily estimated.

Sampling errors also contribute to inaccuracies in the observed data

Model Application

As a Research Tool
-Synthesize Research Understanding
-Integrate Knowledge Across Disciplines
-Experiment Documentation
-Assist in Genetic Improvement
-Yield Gap Analysis
-Separating Weather trend and technology trend
Crop System Management
-Assist in cultural management (planting time, row spacing, fertilizer application, irrigation, chemical application, harvesting etc.

Model Application

-In season Decision- Contingent operations
-Site Specific or Precision Farming
Policy Analysis Tool
-Best Management Decisions to reduce Fertilizer and Pesticide Leaching
-Option for reducing Soil Erosion
-Yield Forecasting
-Climate Change : Impact and resource optimization
-Introduction of new crop / cultivar/cropping syst

Crop Water Requirement

Water requirement of crop is equal to the water loss through Evapotranspiration. Some scientists / schools also add water retained by crops at the time of harvesting.

Thus CWR= ET+ Water Retained

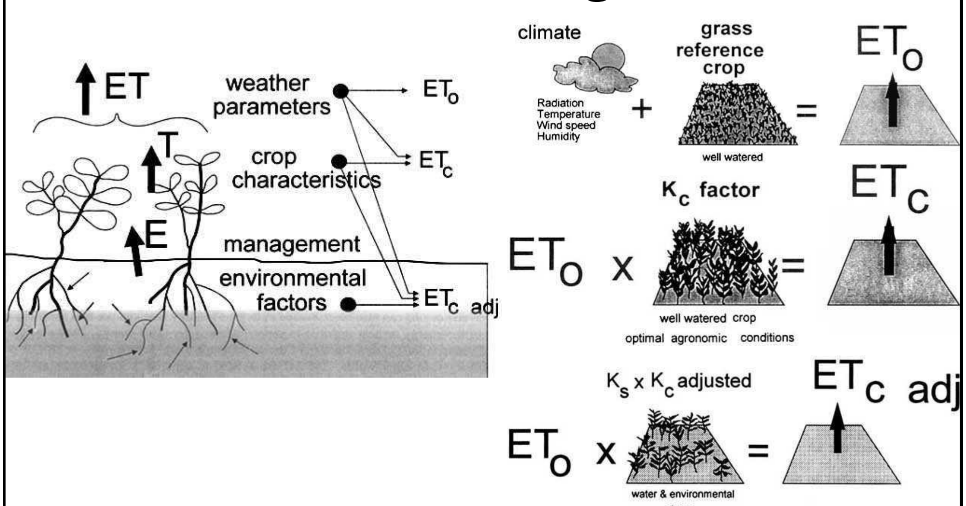
This is also known as consumptive use of water.

Note: Amount of water retain is so small that often water requirement of crop is considered as equal to water loss through ET

There are several approached for computing water requirement.

1) Conventional Approach –Evaporimeter and Lysimeter
2) Climatic parameters driven approach
3) Simulation Model Based Approach
4) Remote Sensing Based Approach
5) GIS based approach (for large area)

Understanding ET



Understanding ET

Reference crop evapotranspiration (ET_o)
The evapotranspiration rate from a reference surface, not short of water, is called the reference crop evapotranspiration or reference evapotranspiration and is denoted as ET_o. The reference surface is a hypothetical grass reference crop with specific characteristics. The only factors affecting ET_o are climatic parameters. Consequently, ET_o is a climatic parameter and can be computed from weather data.

Crop evapotranspiration under standard conditions (ET_c)
The crop evapotranspiration under standard conditions, denoted as ET_c, is the evapotranspiration from disease-free, well-fertilized crops, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic conditions.

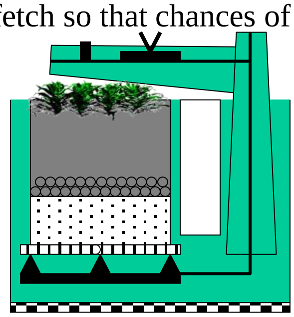
$ET_c = K_c \times ET_o$; where K_c is crop coefficient

Crop evapotranspiration under non-standard conditions ($ET_{c\ adj}$)
The crop evapotranspiration under non-standard conditions ($ET_{c\ adj}$) is the evapotranspiration from crops grown under management and environmental conditions that differ from the standard conditions. When cultivating crops in fields, the real crop evapotranspiration may deviate from ET_c due to non-optimal conditions such as the presence of pests and diseases, soil salinity, low soil fertility, water shortage or waterlogging. This may result in scanty plant growth, low plant density and may reduce the evapotranspiration rate below ET_c.

$\mathbf{ET_{c\ adj}} = Et_c \times K_s$; where K_s is stress coefficient

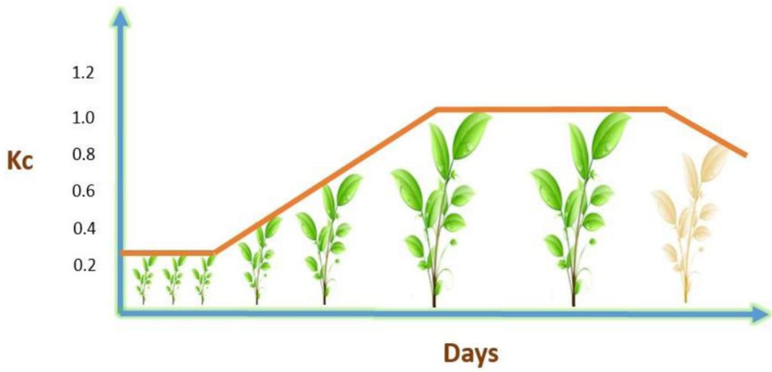
Lysimeter

Lysismeter is the most accurate instrument to measure the loss of water from soil and crop surface. Lysimeter is considered reference for other methods. The precautions that should be taken during lysimetric observations are that the soil inside the lysimeter should be exact representation of the field. The environmental conditions, plant population, plant health should be kept at par with rest of the field. There should be sufficient fetch so that chances of errors could be ruled out.



Weighing Lysimeter

Crop Coefficient /Factor Kc

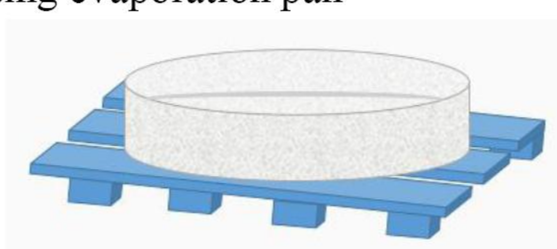


Kc : mainly depends on
- The type of crop
- The growth stage of the crop
- The climate

ET_o using Pan Evaporimeter

Reference evapotranspiration, ET_o

- Using evaporation pan



$$\mathbf{ET_o = K_p \times ET_{pan}}$$

Kp : pan coefficient

ET_{pan} : Evaporation of the pan

ET_o using Thornthwaite Method-

Climatic method

$$ET_0 = 16 \times \left(\frac{10T_i}{I}\right)^a \left(\frac{N}{12}\right)\left(\frac{1}{30}\right)$$

$$I = \sum_{i=1}^{12}\left(\frac{T_i}{5}\right)^{1.514}$$

$$a = \left(492390 + 17920I - 771I^2 + 0.675I^3\right)\times 10^{-6}$$

where,
T_i is the mean monthly temperature [°C],
N is the mean monthly sunshine hour.
N/12 can be replaced with already available coefficients generated using mean latitudinal sunshine hours

ET_o using Penman-Monteith Equation

Climatic method

Radiation + Aerodynamic

$$LE_{PM} = \frac{\Delta(R_n - G)}{\Delta + \gamma\left(1 + \frac{r_c}{r_a}\right)} + \frac{\rho C_p\left[e_s(T) - e\right]/r_a}{\Delta + \gamma\left(1 + \frac{r_c}{r_a}\right)}$$

Where,
R_n is the net radiation,
G is the soil heat flux,
$(e_s - e)$ represents the vapour pressure deficit of the air,
ρ is the mean air density at constant pressure,
Cp is the specific heat of the air,
Δ represents the slope of saturation vapour pressure temp. relationship,
γ is the psychrometric constant, and
r_c and r_a are the (bulk) surface and aerodynamic resistances

How do we get the aerodynamic resistance (r_a)?

ET_c using Crop Simulation Model

Crop growth simulation models, which integrate the effects of meteorological, soil and management variables to simulate plant growth and development, have been developed for many crops (Baker, 1980). Crop Simulation model includes sub-routines on the main program, plant growth module, soil water balance module and a weather input routine. Status of the soil water balance is dependent on water supply by irrigation and rainfall and water demand by evapotranspiration as well as antecedent soil moisture.

Crop simulation model simulate all the soil and plant processes daily by considering weather, soil, crop genotype and management data. Therefore it also compute rate of ET on daily basis. Thus water requirement will be

$$CWR = \sum_{n=1}^{\text{CD}} (\text{ETdaily})$$

; CD is crop duration

There are few models which has been specially developed for computing water requirement like CROPWAT and AQUACROP. Other models like DSSAT, CropSyst, WOFOST etc also be used

ET_c using Remote Sensing

Four different categories were introduced for ET estimation using remote sensing. They are empirical direct, residual, inference, and deterministic methods.

Empirical direct methods

This approach assumes that a portion of net radiation is utitlized as latent heat, which is directly proportional to Evapotranspiration.

Assessing the energy balance using some surface properties like albedo, canopy cover, leaf area index (LAI) and surface temperature is the principle of ET estimation by remote sensing.

$Rn = LE + H + G$

The net radiant energy (Rn) is divided to soil heat flux (G) and atmospheric fluxes (sensible heat flux H and latent energy exchanges LE).

Empirical direct methods cont…

Empirical direct methods are based on the theoretical assumption of a constant value of the ratio H/Rn during the day and no soil flux:

$ET24 = Rn24 + A - B(Ts - Ta)$

where ET24 is daily ET, Rn24 is net daily radiation, Ts − Ta is the difference between the mid-afternoon surface temperature and the maximum air temperature (this is termed the Stress Degree Day or SDD), and A and B are calibration parameters.

ET_c using Remote Sensing

Residual methods

In this method, empirical and physical relationships are combined to estimate the energy balance components (except ET) directly through remote sensing. ET is estimated as the residual of the energy balance equation. L

$$LE = Rn - H - G$$

ET_c using Remote Sensing

Inference methods

This method is termed inference method or vegetation indices. It is based on RS application to measure a plant adjustment factor (such as crop factor or landscape factor) to determine the actual evapotranspiration. Given the formula

$$ETc = Kc \cdot ETo$$

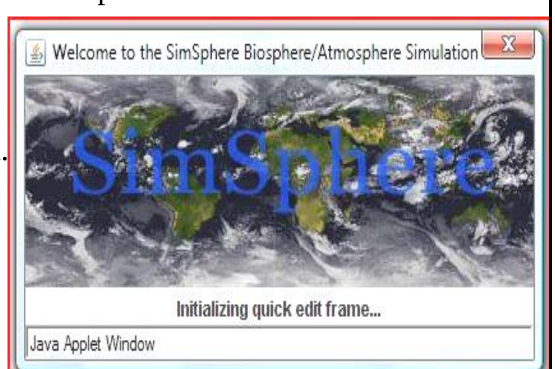
The actual crop evapotranspiration rate (ETc) is readily calculated from the reference evapotranspiration (ETo) and plant adjustment factor (Kc). Equation has been broadly described in FAO-56.

ET_c using Remote Sensing

Deterministic methods

This method is established based on the complex soil, vegetation, atmosphere transfer models (SVAT). Remote sensing can be employed to either estimate energy balance components or to integrate (or calibrate) particular input data.

In order to interpolate remote sensing data temporally, ground measurements are required. There are several benefits of combining remote sensing data and SVAT models for ET estimation.



ETo using GIS

GIS allows to hand handle geospatial data and integrates different layers to analyze large area events. Following steps are required to compute large are Evapotranspiration.

i) Collection of weather data from different stations and apply quality checks.
ii) Create CSV file, import it in GIS environment and create layers of meteorological parameters by applying interpolation techniques.
iii) Compute ETo by applying climatic equation in Raster math function.
iv) Create a layer of crop coefficient (Kc) by inserting field wise value. Alternatively remote sensing can also be used to derive the field level value of Kc.
v) Multiply ETo by Kc in Raster math calculator for estimating field specific ETc.

Crop Nutrient Requirement

Nutrients are required for proper growth and development of plants. The nutrients are absorbed by roots of the plant from soil. The requirement of the nutrients for a particular crop depends on the crop biomass and the content of nutrient in biomass. However when nutrients are applied in the field to fulfill its requirement, the nutrient use efficiency should also be considered.

1) Simple Crop nutrient removal approach
2) STCR approach
3) Crop Simulation Model based Approach
4) Remote Sensing based Approach

Crop Nutrient Requirement

Simple Crop nutrient removal approach

This approach works on the basis of nutrients removed by the crop for completing it full growth cycle. The crop nutrient requirement can be worked out by measuring crop biomass of the previous years crops and multiplying it by nutrient contents. Usually 3-5 years past (recent) data is taken for computing average biomass. While nutrient content in plant is analyzed in labs.

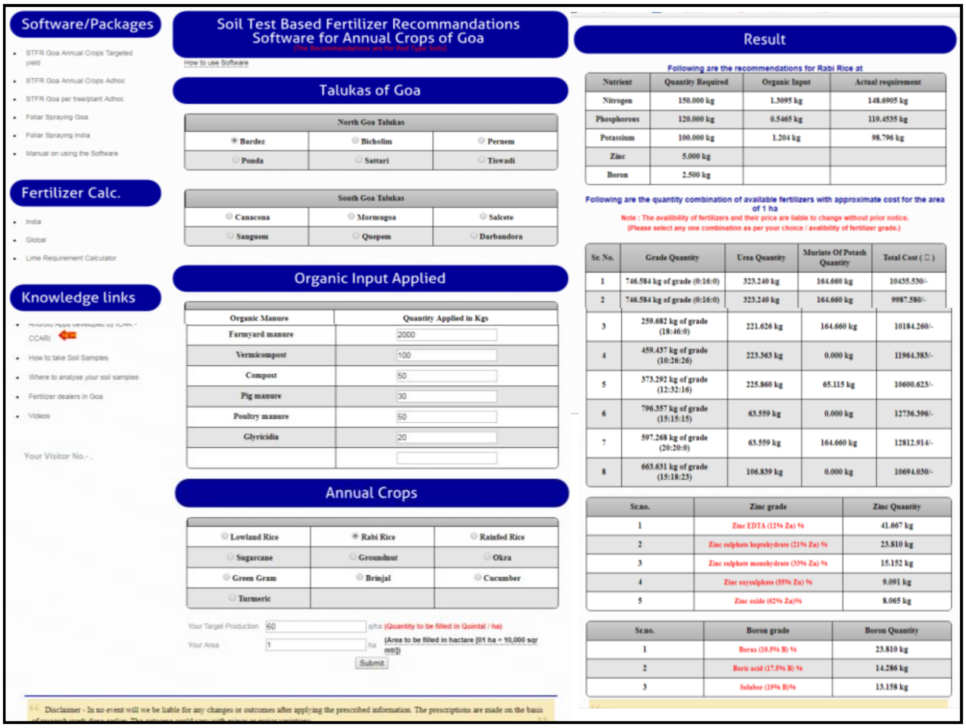
Crop Nutrient Requirement

STCR approach

Soil Test Crop Response (STCR) works on the basis of soil test values and target yield set by the farmer. The approach relies on the Agro-ecological zone based potential of crop production. The simple statistical equations at Agroecological zone have been developed for computing fertilizer requirement of the crop. Available soil nutrient values are offset from the total fertilizer requirement of the crop.

STCR equation for wheat at target yield of 40-45 Q/ha

Fertilizer adjustment equations for different yield target.	
Wheat (Var. HD 2687) With FYM	**Wheat Var. (UP 2382) With FYM**
FN = 7.96T-0.96 SN-1.04FYM-N FP = 1.25T-0.80 SP-0.17 FYM-P FK = 1.99T-0.29 SK-0.44 FYM-K	F N (N kg/ha) =6.28 x YT (q/ha) – 0.67SN-0.371FYM-N F P (P kg/ha) =0.94 x YT (q/ha) –0.28SP-0.173FYM-P F K (K kg/ha) = 1.36x YT (q/ha) –0.16SP-0.079FYM-K



Crop Simulation Model based Nutrient Requirement

Crop growth simulation models, which integrate the effects of meteorological, soil and management variables to simulate plant growth and development. Crop Simulation model includes sub-routines on the main program, plant growth module, soil module and a weather input routine.

Crop simulation model simulate all the soil and plant processes daily by considering weather, soil, crop genotype and management data.

The soil module/sub-routine of CSM simulate the processes like Decomposition, Mineralization, Nitrification, Denitrification, Immobilization, Volatilization etc.,.

There are few models which has been specially developed for computing nutrient requirement like DNDC, CENTURY etc. Other models like DSSAT, CropSyst, WOFOST etc also be used.

Remote Sensing Based Estimation of Nutrient Requirement

Remote sensing technique is used to directly view/assess crop conditions and properties. Broadly remote sensing based techniques can be divided into two categories: i) biomass based ii) Chlorophyll based computation of nutrient requirement, iii) soil sensing for nutrient detection, iv) Portable instrument (SPAD Chlorophyll meter).

i) Biomass based nutrient removal technique: Remote sensing based techniques have been widely used to determine biomass of crop with quite high accuracy. Remote sensing based indices such as NDVI, Greenness Index etc can be used to estimate plant biomass. The fraction of nutrient in plant is multiplied by biomass to estimate removal of nutrient by crop. For accurate estimation of nutrient, 3-5 years average of nutrient removal is taken. Fertilizer requirement can be computed by considering nutrient use efficiency.

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

$$GVI = -0.290G - 0.562R + 0.600NIR\_1 + 0.491NIR\_2,$$

Remote Sensing Based Estimation of Nutrient Requirement

ii) Chlorophyll detection based nitrogen assessment: This can be further divided into:

a) Multispectral reflectance based detection: Multispectral scanner generated images in multiple bands typically 3 bands to 15 bands. Blue, Red bands are important for detection of chlorophyll. These two bands are strongly absorbed by chlorophyll. While green exhibits slightly higher reflectance. NIR band is also used with blue / red band to accurately detect chlorophyll as with increasing green cover reflectance in NIR increases. NDVI (Normalized Vegetation Difference Index) index could be used for the purpose.

Remote Sensing Based Estimation of Nutrient Requirement

Hyperspectral Reflectance based Detection: Narrow band (typically 10 nm band width) sensing with higher number of band usually more than 100 is known as hyperspectral imaging. Narrow bands provide pure spectral response and are more sensitive to chlorophyll content. There produces higher accuracy.

Thermal Radiation for Nutrient Deficiency Detection: The radiation which is emitted by object is known as thermal radiation. The emittance of thermal radiation from object depends on its temperature. With increasing temperature the intensity of radiation increases forth time of temperature. The temperature of the object is proportional to the stress arising due to shortage of water supply and nutrient. If moisture supply is good, the increasing temperature of plant will be proportional to nutrient deficiency

SPAD Chlorophyll Meter

Fast method using the detection method to measure chlorophyll content of the chlorophyll meter: chlorophyll absorption peak is blue and the red region is absorbed in the green region of the trough, and almost no absorption in the near infrared region. Based on this, select the red light area and near infrared region measuring chlorophyll. The specific process by the light emitting diode emitting red light (peak wavelength 650 nm) and near infrared light (peak wavelength 940 nm). The chlorophyll absorption wavelength of 650 nm red light, but it does not absorb the wavelength of the infrared light of 940 nm, the transmission and reception of the infrared light is mainly in order to eliminate the blade thickness and other aspects of the impact on the measurement results.

Calculating SPAD in the following steps: 1) Under the standard condition, the two light sources sequentially emit light and converted to electrical signals, and to record the intensity of the emitted light; 2) Inserted into the blade, the two light source light again, the blades of the transmitted light is converted to an electric signal recording the transmitted light intensity; 3) Use chlorophyll to determine the relevant formulas to calculate the chlorophyll content of plant leaves.