CHAPTER 2

# LITERATURE REVIEW

## SYSTEMS AND SIMULATION MODELS

Systems approach and simulation technique have been used by engineers over 30 years (Jintrawet, 1990), and are presently being applied in agricultural production systems (Holt, 1985; and Lemmon, 1986). The approach is being characterized in three terms, (i) system, (ii) model and (iii) simulation.

A system is a limited part of reality that contains interrelated elements such as agricultural systems consists of crop, animal, and man (Jintrawet, 1990). A model is a simple representation of a system. Generally, there are two types of models, physical and symbolic models. Physical models are present the real object. Such models will look like and often function in a similar way to the real object. Symbolic models are abstract in form and are perhaps more difficult to comprehend than physical models (Dent and Blackie, 1979). Symbolic models can be classified into two main classes which are empirical and mechanistic model (Acock and Acock, 1991). Empirical models are sometime called correlative or statistical models, describe relationships between variables without referring to the processes connecting those variables. Mechanistic models which are also known as process-level, explanatory model or simulators attempt to explicitly represent causality between variables (Acock and Acock, 1991).

Simulation is the process of building the model (Jintrawet, 1990) and use of the model to study existing, or imagined (Jintrawet, 1990; Penning de Vries et al.,1991).

Penning de Vries et al. (1991) stated that the advantages of simulation models are directly related to the mechanistic approach in the sense that they:

i) help researchers to gain a better understand of the systems. This leads to either finding gaps in knowledge and data, or to determine opportunities for improving management of the real system. In both cases, simulation models help focus research and experimentation.

ii) improve extrapolation of research findings to new environments, whether existing or not e.g., global climatic change. Greater extrapolation allows for more extensive use of experimental data and reduces the need for additional experimentation. This increases the efficiency of adaptive research in similar extrapolation domains.



iii) provide means for communication within and among organizations for accelerated knowledge transfer and application.



**CROP MODELS**

Crop models are basically and mainly computer programming instructions, which are simply a set of commands of a given computer language. Each command expresses the governing equation of a particular relationship based on the existing knowledge (Jintrawet, 1990).

Jintrawet et al. (1990) disclosed that system analysis in combination with crop models can be used as a powerful analytical tool in evaluating alternative practices in many agricultural production systems. It can be used as decision aids at the farm level (Lemmon, 1986) or as a tool to study the effects of climate changes (Ritchie et al., 1989). However, understanding and application of crop models are mostly restricted to those who developed the model (Jintrawet et al., 1990; Penning de Vries et al., 1991).

Generally, there are two types of crop models; empirical and mechanical models. Empirical model is constructed based on known empirical relationships between elements of a system in a particular circumstance. It is concerned with the abilities of users to predict the outcomes of alternative options in a given situation. Mechanistic model is constructed based on known physical laws and underlying biological processes that explain observed natural phenomena. Therefore, mechanistic models can be used with reasonable efforts of validation in a broader scale than empirical models (Jintrawet, 1990).



Several rice crop models, utilizing different modeling approaches are found in the literature. Yao and LeDuc (1980), and da Mota and da Silva (1980) used the empirical approach to develop weather dependent yield prediction models. McMennamy and O'Toole (1983), and Alocilja and Ritchie (1991) developed multi-level mechanistic rice crop models. Stansel and Fries (1980); Angus and Zandstra (1979) and Hayes et al. (1982) used the physiological and process approach in developing rice model and are described by Terjung et al. (1985) as examples of hybrid models using both the empirical and mechanistic approach.

Penning de Vries (1982) proposed a classification system of crop production simulator based on growth limiting factors and distinguished four levels of plant production.

Production level 1- crop models are developed under assumptions of adequate nutrients and water and without pest induces stresses. Its growth rate depends only on the current state of crop and on current weather particularly radiation and temperature.

Production level 2- includes the effects of soil water deficits.

Production level 3- adds the possible limitations due to nitrogen availability.

Production level 4- includes the effects of phosphorous and other plant nutrients in addition to the factors from the first three levels.



However, crop growth reducing factors such as diseases, insects and weeds can occur at each of these production levels and give them an extra dimension. The fact that actual situation is often more complex does not contradict the general usefulness of the scheme of production levels as a basis for distinction between causes and consequences of plant growth (Penning de Vries et al., 1989).

MODEL VALIDATION

Model validation is an essential step and continuous processing systems simulation process prior to its application. The validation process is simply the comparison of model outputs with observed field data. There are many management and practical applications that users in different levels allow to do with a validated crop model. Testing, screening and evaluation of various promising strategies systems is one possible application (Jintrawet, 1990).

Acock and Acock (1991) stated that the validation of crop models requires more types of data than does the development of empirical models. Many of the data used to develop crop models come from studies in controlled environment plant growth chambers where environment factors can be manipulated independently. However, it is widely recognized that plants grown in chambers differ from those in field and model parameters often have to be adjusted to fit field data. Thus, field data are essential to the final stages of model development and validation.



Validating simulation models remains a difficult and elusive task despite extensive literature dealing with validation procedures (Shannon, 1975). Different validation methods have been applied ranging from simple visual comparison of model predictions with field observation to highly sophisticated statistical tests (Graf et al., 1991). However, some of the testing procedures violate the basic assumption of statistical independence and can not be legitimately used (Curry & Feldman, 1987). Non-parametric test for the regression slope described by Hollander and Wolfe (1973) has been suggested by Welch et al. (1981) for model validation in pest management. The method consists of plotting observed versus predicted values, and testing whether the points deviate significantly from 1:1 line.

An important facet of the modeling process is to apply appropriate statistical test to evaluate model accuracy. Dent and Blackie (1979) suggested a t-test to determine whether the slope and intercept of linear regression between model simulated and observed values are different from unity and zero. Willmolt (1982) contended that although the model is less sensitive to extreme values, bias (eq.(1)) and root mean square error (RMSE) (eq.(2)) which are the "best" among over all measures of model performance.

$$Bias = (1/N) \sum_{i=1}^{N} (Si - Oi) \qquad (1)$$

$$RMSE = \sqrt{(1/N) \sum_{i=1}^{N} (Si - Oi)^2} \qquad (2)$$

Where Si = Simulated value, Oi = Observed value, and N = Number of observations.

Graf et al. (1991) used a standardize bias (R) (eq.(3)) and a standardize mean square error (V) (eq.(4)) to test goodness of fit and evaluate visual comparing simulated data corresponding with observed data for dynamics of rice growth and development.

$$R = \frac{\sum_{i=1}^{N} (Si - Oi)}{\sum_{i=1}^{N} Oi} \qquad (3)$$

$$V = \frac{\sum_{i=1}^{N} (Si - Oi)^2}{\sum_{i=1}^{N} Oi^2} \qquad (4)$$

Where N = Number of field observation, Oi and Si are observed and simulated values, respectively. At the *i*-th observation R and V are estimate for the overall error of the method with regard to field data. R quantifies the model's ability to reproduce the observed growth pattern. Negative deviations (Si - Oi < 0) compensate for positive deviations (Si - Oi > 0) and vice versa (eq. 3). On the other hand V is a measure that reveals the model's tendency to generally overestimate or underestimate simulating field observation. However, both procedures give heaviest weighing to large values, toward maturity.