UNIVERSITY OF AGRICULTURE, FAISALABAD

DEPARTMENT OF MATHEMATICS AND STATISTICS

(Synopsis for MPhil degree in Statistics)

TITLE: Evaluating the impact of climate changes on maize productivity in Punjab using dynamic crop models

Name of the Student	:	Name of Student
Registration Number	:	Reg. No of Student

ABSTRACT

Agriculture is highly dependent on climate and therefore, changes in global climate could have major effects on crop yield and thus food supply. The future prosperity and economic stability of Pakistan mainly depend upon the material resources and utilization. Therefore, there is a dire need for advanced planning to increase food production and improve quality to meet the needs of increasing population. Dynamic crop modeling is a technique which is used in crop production. The essential characteristic of simulation method is reproduced in model, which is studied in different time scale. Crop models are mathematical models which described the growth and development of a crop interacting with soil. In Pakistan maize is the fourth largest grown crop after wheat, cotton and rice. In this study maize crop data will be used. This modeling will be used to estimate the agriculture maize production as a function of soil and weather as well as crop management. The study will computed state variables rate over time, from planting until harvest maturity or final harvest and estimate the parameters of dynamic model such as excitation coefficient, radiation use efficiency, maximum leaf area index, analysis the effect of nitrogen and cultivars are expected to evaluate the capability of maize model growth and yield of different locations in Punjab.

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1 INTRODUCTION

Crop models have been established and used in wide-range as operational and decision maintenance tools in resource management system or crop production. Crops models at their simplest yield and at their most complexes simulate the processes involved in crop growth and development. Crop models are also used to estimate the effect of environment change on crop production as a consequence of increasing greenhouse gasses. All crop models, mechanistic or empirical require data which can be collected using measurements or the trawling through in the case of regional yield estimates. Crop models are mathematical models which described the growth and development of a crop interacting with soil. There are two forms of crop modeling dynamic crop modeling and response crop modeling. Response crop model is set of equations for responses of interest as function of explanatory variables. Loomis *et al.* (1968) discussed the mechanistic of models in simulating cropping structures at one level that described by processes at a low level.

Dynamic system models are generally used in extension or agronomic research. These models represented in differential or difference equations that represent the dynamics of the different components of the system (plant, soil etc.) and can also be used to explore the effects that caused changes in the environments. Maize is maximum yielding cereal crop in the world. It has a significant importance in Pakistan where rapidly increase in population has already out exposed the available in food supplies. In ranking maize is in fourth most grown crop in the world with an area of more 118 million hectares with an annual production of about 600 million metric tons. The expanded use of maize in industry gives this crop a prominent place in agricultural economy. In Pakistan, maize is the fourth largest grown crop after wheat, cotton and rice (Rasheed *et al.*, 2004). The area under maize is over one million hectares and production 3.5 million metric tons. The area cover maize is over one million hectares and its production is 3.5 million metric tons. Punjab contributes 39% area; KPK contributes 56% area and 3% of the area contributed by Sindh and Baluchistan. The future economic stability and prosperity of Pakistan mainly depends upon the quantum of material resource, utilization, and judicious explanation.

Maize grows from sea level to 3000 meters and it is a warm weather plant. Maize requires extensive moisture and warm weather from germination to flowering. The most appropriate temperature for germination is 21°C and for growth 32°C . It also can be grown under different condition. Monsoon season gives the highest production of maize. Extreme high temperature and low humidity during flowering damage the underground and interfere with proper pollination, resulting in poor grain formation. Maize is very sensitive to stagnant water especially during its early stages of growth. The elements of dynamic crop model are state variables and explanatory variables. These variables play an important role in the crop modeling. State Variables describe the conditions of system components such as change with time in dynamic models as system components interact with each other and the environment such as Soil water content, crop biomass, leaf area index, and plan emergence time.

Sinclair *et al.* (1996) suggested that crop dynamic models have been developed as a creative tool for agronomic management strategy evaluation. Various fields have used these models for decision making in agriculture field and studied the relationship among management, environment yield variability.

1.1 Objectives

The objectives of this study are :

- Simulate a dynamic crop model for maize and make modification to the maize model for improving the ability of the model to predict response to weather at different locations of Punjab.
- Estimate the parameters of complete dynamic maize model.
- Evaluate the effect of cultivars and nitrogen rates on growth of maize.

2 Review of Literature

A crop model is based on mathematical representation of a canopy. Such models may be built for a multiplicity of purposes they may be differing extensively in complexity, scope and focus. This has led to a wide range of models simulating particular aspects of the processes and particular crops involved in plant growth and development to be created. Empirical model is the type of model in which no knowledge of underlying processes is involved. Purely mechanistic modeling which incorporate knowledge of intermediate between semi-empirical models and processes acting within the system.

Crop models also subdivided in terms of the basic units modeled. Model the canopy as a homogeneous medium with state variables representing spatial averages of concentration such as Leaf Area Index (LAI) which is leaf area of one-sided per unit ground or biomass. In recent times, advances in computing power have made possible the modeling of the canopy as a population of individually modeled plants, which in turn may be modeled as an ensemble of individual organs. In theory modeling at the plant level should be accurate and satisfying since many important processes such as assimilation occur at the level of the individual plant, however such models tend to require heavy parameterization and thus present their own particular problems.

Fisher *et al.* (2000) explained crop modeling area covers several plants and trees of interest, from fowers to financial crops, rice Jame *et al.* (1996) and maize. Models can also be presented which in genetics of the plant development, growth and also root structure and development.

2.1 Empirical Model and Semi-Empirical Models

Marcelis *et al.* (1998) studied the crop-growth models are mathematical functions, or Statistical relationships such as exponential functions, polynomial's and sigmoidal curves representing the state of the canopy as a function of time. Statistical models involve wide-ranging data collection, growing season of the crop of interest and over many years. These models are essentially limited in their application and genotype from which data was collected to create the models. The predictive value of descriptive models can be in elevation, because obliquely take into account all the unknown affects as as well. Empirical models are invented in statistical relationships between a variable of interest such as biomass or LAL and time. Empirical models have little heuristic value but can produce good predictions, especially in the environmental conditions for which the models are applied in within the range of variation which the model is parameterized. Empirical models are used in substantial re-calibration. Now empirical elements in models are still common in many mechanistic models.

Bloomenthal (1985) suggested that empirical models of crop structure require data on the plant's geometric features. The architecture of a plant plays a fundamental role in the allocation of resources acquisition, tolerance to damage and competition. Such models incorporate the geometry and structure that are useful tools for plant scientists and in ecology, biology, agronomy, pest management and remote sensing.

Fournier *et al.* (2003) demonstrated the order to increase their ability to be applied in different locations and the generality of these models and they must encompass more knowledge of the processes involved. These models are known as semi-empirical models and an example of dynamic empirical model. This is computed by temperature instead of time and observations based on growth rate are constant within limited range of temperature. Dynamic model expressing growth and biomass as a differential equation. The behavior of the system is obtained through integration of the model.

Waggoner (1984) suggested that additional variables can also be included in the model to increase its generalization, which predicts wheat yield is a function of meteorological variables, such as precipitation number of days warmer than 32°C temperature. In Presence of extra variables within the model aid in increasing and its applicability as it can be more easily re-calibrated of areas other than those where the data was collected to create the model.

Prince (1991) examined modular structure of PEM has allowed it to be modified by other researchers, included different stress factors which enables the maximum efficiency from departure and caused a physiological reactions to restrictive environmental conditions. Another improvement has included making the use of efficiency in function of water, nutrient stress, temperature and joining the models. PEM is used to estimate global network net primary production (NPP), global carbon cycle, and at regional scale of crop production.

Disney *et al.* (2000) recongnized various options for MC Ray Tracing in canopy applications. These models also used in detailed architecture of the canopy structure and calculate the intersections of rays fired into the 3D scene. The objects are determined whether the photons are observed or scattered at each intersection this method can be used static empirical models of the canopy. Large computational times are associated with this model especially when diffuse scattering is simulated and combined AFRC wheat and sail or found that only up updating the model later on in development within the use of remote sensing data that Leaf Area Index prediction was improved. This is not a great value of farmers at this late stage in development and no methods exist to aid in increasing the yield if it predicted to reduce. However, it can help to produce a more accurate yield map which is of used in precision farming.

2.2 Effect of Nitrogen and Cultivars

Costa *et al.* (2002) evaluated effect of nitrogen rates on maize genotypes. The genotypes were NLRS, LNS, LRS and conventional hybrid and late maturity. The genotype consistently yielded 12.39 and 10.29 in 1997 and 1998 respectively, while NLRS performed not well, however genotype yield grain placing varies among sites. In General leafy reduced stature out yielded its conservative counter part by 26% at the one side and 12% at other.

Oikeh *et al.* (2003) presented N differential equations of maize cultivars in West Africa under N fertilization and stated that TZB-SR cultivars composed additional N in above ground parts of plant, both years as related to the other cultivars. All, excepting at the time of slinking the (SPL) semi-prolific late variety, happened about 50-60 % of their N requirements. In both years, SPL had the maximum grain concentration and least deceptive of N loss over leaching which has greater capacity to take up N through the grain filing period in the next year.They determined that the use of maize with high N acceptance capacity during the grain filling period.

D'Andrea *et al.* (2006) conducted a study in Argentina to analyze the response of N different availability of morph physiology traits in a set of 12 maize ingrained lines, from breeding eras and different origins (Argentina and USA). Traits involved in the analysis were related to yield components, shoot biomass production, canopy structure, grain yield and light interception. They concluded that difference for these parameters were significant among genotypes. Andrade *et al.* (1993) studied relationship between intercepted radiation, kernel number per umit area in maize and flowering found a significant positive association and 5.9 kernels radiation utilization were obtained under shading experiments.

Kiniry *et al.* (2001) suggested that simulation of crop development, yield and growth accomplished through evaluating the growth rate, the stage of crop development and partitioning of biomass into growing organs. All of these processes are affected by environmental and cultivar specific factors. These processes are dynamic. The detailed description of key processes in crop provide help to system of simulating grain yield production and provides a means of quantifying how cultivars differ using crop model.

Ogunlela *et al.* (1988) conducted an experiment on yield component of field grown by using nitrogen fertilization ranging 50 to 200 kg. They estimated the kernel depth and plant height and described how whole plant should be simulated at the organ smooth and how crop models should simulate processes at the whole plant level.

2.3 MAIZE PRODUCTION AND CLIMATE CHANGE

Parry (2000) explained climate change affect agriculture field in different parts of the world. The properties among various continents are influenced by on soil conditions, availability of resources current climatic conditions and infrastructure use to crop with change. These differences are also probable to greatly influence the reaction to climatic change.

Tao *et al.* (2006) studied the developments in phenology, climate change and yield of crops (rice, wheat, maize) in China. Some Significant results tend to observed at most of the investigated areas in which during the two decades some results were changes in temperature had shifted crop phenology and affected crop yields. The study highlighted the concentration on physiological processes, further investigation showed that the mutual impacts of temperature and mechanisms growth.

Ritchie *et al.* (1998) studied the cereal crop growth, yield and development included Decision Support System for Agro-technology (DSSAT) using CERES Crop simulation model. Results were obtained to show that when the cultivar, weather and management information are realistically quantified, the yield results are usually within acceptable limits.

Probert (2001) collected climate data of seven sites and used as input for the maize model CMKEN to explore a number of management options that impinge on maize yields and reported that the cultivar Katumni composite B is well adapted for whole region as compared to other cultivars. They further concluded that yield potential is strongly dependent on rainfall regime and soil type, nitrogen rates also vary with rainfall regime.

3 Materials and Methods

3.1 Data Source:

Maize crop data of different locations will be taken from Observatory of Crop Physiology, Department of University of Agriculture Faisalabad and Regional Meteorological Center Lahore.

3.2 A crop model is a dynamic system model

The general form of a dynamic systems model (Brun *et al.*, 2006) in discrete time is

$$U_s(t + \Delta t) = U_s(t) + g_s[U(t), X(t); \theta] \tag{1}$$

Here t is the time, Δt is some time increment, $U(t) = [U_1(t), ..., U_s(t)]^T$ is the vector of state variables at time t , $X(t)$ is the vector of explanatory variables at time t, θ is the vector of parameters and g is a function of state variables. For crop models, Δt is often one day. The state variables $U(t)$ could include for example leaf area index (leaf area unit soil area), biomass root depth, soil water content in each of several soil layers etc. The explanatory variables $X(t)$ include initial condition such as initial moisture, soil characteristics such as maximum water holding capacity, climate variables such as maximum and minimum temperature and management variables such as irrigation date and amount.

3.3 DYNAMIC CROP MODEL FOR MAIZE

We will be work with three state variables, temperature Sum (TT), plant biomass (B) and leaf area index (LAI). The equations are:

$$TT(j+1) = TT(j) + \Delta TT(j) \tag{2}$$

$$B(j+1) = B(j) + \Delta B(j) \tag{3}$$

$$LAI(j+1) = LAI(j) + \Delta LAI(j) \tag{4}$$

with

$$\Delta TT(j) = max[\frac{TMIN(J) + TMAX(j)}{2} - T_{base}, 0] \tag{5}$$

$$\Delta B(j) = \begin{cases} RUE(1 - e^{-k.LAI(j)})\mathrm{I}(j) & \text{if } TT(j) \leq TT_M \\ 0 & \text{if } TT(j) \ > TT_M \end{cases} \tag{6}$$

$$\Delta LAI(j) = \begin{cases} \alpha \Delta TT(j) LAI(j) max[LAI_{max} - LAI(j), 0] & \text{if } TT(j) \leq TT_L \\ 0 & \text{if } TT(j) \ > TT_L \end{cases} \tag{7}$$

The index j is the day. The model has a time step Δt of one day. The exploratory variables are $TMIN(j)$, $TMAX(j)$ and $I(j)$ which are respectively minimum and maximum temperature and solar radiation on the day. The parameters are T_{base} that is the base line temperature for growth, RUE that is the radiation use efficiency, k is excitation coefficient which determines the relation between leaf area index and intercepted radiation, α is the relative rate of leaf area index increase for small values, LAI_{max} maximum leaf index, TT_M is the temperature sum for crop maturity and TT_L is the temperature sum at the end of leaf area increase, evaluate the capability of maize growth in different locations and also analysis the effect of nitrogen and cultivars with the help of dynamic crop model.

3.4 FORECAST ACCURACY OF DYNAMIC MODEL

Standard descriptive measures of goodness-of-fit will be used to evaluate predictability or accuracy of Dynamic models (Hansen *et al.*, 2004). Mean-Absoulte error, Mean-squared error of prediction and prediction variance will be used .

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