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Integration of a Climatic Database and Weather Simulation Model for the Planning and Design of Agricultural Projects in Africa

Introduction

Few developing countries have adequate climatic data to make intelligent decisions, with respect to probabilities, for the proper planning and design of agricultural development projects. The costs of not having sufficient climatic data can exceed the potential benefits of a given project: project reservoirs, spillways, canals, and command areas may be under or over designed; unsuitable crop varieties and agricultural practices may be introduced; and incorrect estimates of project returns may lead to inappropriate or unfortunate decisions.

We have developed and tested a model, WMAKER, which simulates daily weather data given long term monthly mean climatic data. Initial research has demonstrated the applicability of using WMAKER to generate the weather data necessary to drive crop yield models, estimate irrigation requirements and schedules, and to determine rainfall frequency distributions.

We have also created a database with the necessary inputs for the WMAKER model for 299 climatic stations scattered throughout Africa. This proposal is a request for funding to support continued research and enhancement of the WMAKER model, and to support integration of the climatic database for Africa with WMAKER to predict crop yields, rainfall frequencies, and irrigation requirements for any location in Africa.

Previous Research and Development

Several models have been developed for generating daily weather values from monthly climatic data. The model that seems most useful for world-wide application is the WMAKER (Weather Maker) model developed by Keller and described by Samani, et al.(1987). Monthly climatic data tables have been prepared and published by the International Irrigation Center at Utah State University for Africa, Latin America, and 10 Asian countries. These monthly tables are adequate for use with WMAKER for generating daily weather values for a pre-determined number of years.

Various crop yield or crop growth and development models are available for use with daily weather values. These crop models are used after calibration with

results from field trials for predicting crop yields as various factors of production or management practices are varied. The principal variations considered are soil moisture factors, climate, fertilizer practices, planting dates, and amounts and frequencies of irrigation.

Samani, et. al. (1987) summarized results of comparisons of predicted yields from crop yield models using actual historical daily weather values and those generated by means of the WMAKER model from the monthly climatic data tables. The range in differences in relative yields found for the data evaluated was from zero to only 17%.

Samani and Hargreaves (1986) described a procedure for estimating probabilities of assured monthly rainfall from average values. The monthly climatic tables have been used to generate rainfall probabilities for various locations. The estimated probability values usually differ slightly from probabilities calculated from historical monthly values by means of the Gamma probability distribution.

Hargreaves (1988) evaluated and described the usefulness of an exponential probability distribution of extreme rainfall amounts. Unpublished research for four locations indicates that the exponential probability distribution and WMAKER generated values can be used to predict probable extreme values of depth-duration-frequency rainfall amounts. For the locations evaluated estimated values were of the same order of magnitude as those calculated from the historical weather records.

It was assumed that the approximate range in probable crop yields could be modeled by using the WMAKER model to generate three years of daily values consisting of a favorable year, an average year and a poor year. Limited testing of crop yield models with only three years of synthetic data indicate that this assumption offers considerable potential for use in agrotechnology transfer and as a substitution for trial and error field testing of crop varietal performance over many locations and years.

Hargreaves and Samani (1986) prepared precipitation probability tables for the world. These tables give monthly values of the 95,75,50 and 5 percent probabilities of assured precipitation, mean rainfall, mean temperature, mean potential evapotraspiration and a moisture or rainfall adequacy index.

Hargreaves (1988) developed procedures for estimating the standard deviation of potential evapotraspiration (ETP) from latitude and the standard deviation of temperature. Further investigation indicates that the standard

deviation of ETP can be approximated from latitude alone. By using these procedures the climatic data tables provide mean values of ETP, temperature, number of rainy days, rainfall amounts and the standard deviations of these variables.

By making use of the monthly climatic data tables and with suitable modifications of the WMAKER model it should be possible to generate daily weather values for the years corresponding to the mean precipitation, the 95,75,50 and 5 percent probabilities of assured amounts and to the mean plus or minus one standard deviation. It is assumed that the synthetic daily values from three years or from seven years or some suitable combination of probabilities can be used to define the general range of probable yields that can be estimated by crop yield models.

Proposed Work to be Performed

1. Modification of the WMAKER model to facilitate the estimation of extreme rainfall amounts and use of the model in hydrologic studies.
2. Comparisons of management decisions possible through generating many years of daily weather values with those possible from generating only three to seven years of values.
3. Modifications of the WMAKER model so as to make possible the generation of daily values for the years corresponding to pre-determined probabilities of rainfall amounts and yield predictions.
4. Verification of model performance through comparisons with actual crop field trial data and with probabilities resulting from historical records of actual daily climatic data.
5. Preparation of software and users guides for the new or improved models developed.
6. Preparation of professional papers and course material to be used in training courses for teaching the existing technology and the new technology to be developed as part of this project.
7. Improve manageability of climatic database (search by lat. & long., name, etc.).
8. Expert system model to generate climatic data for any lat.,long. and elevation in Africa.

Benefits from Proposed Work

The models and relationships described above are powerful tools for improving agricultural production, appropriate agrotechnology transfer, irrigation operations, hydrologic modeling, economic analysis and water resource planning and management in general. Major benefits are possible particularly in the developing countries where reliable weather records are frequently in short supply and in some cases of questionable accuracy. Possible uses include but are not limited to:

1. Estimation of the amounts and variabilities of command area and main system irrigation requirements.
2. Estimation of depth-duration-frequency rainfall amounts for use in flood hydrology, watershed models, agricultural drainage and similar hydrologic and water resource planning and development.
3. Studies related to the probable production of firm and peak hydro-power generation.
4. Studies related to the determination of the minimum soil moisture and other soils data required for reliable crop yield modeling.
5. Management planning for optimizing agricultural production by evaluating the most desirable planting dates, amounts and frequencies of nitrogen applications, benefits possible from irrigation supplemental to rainfall, etc.
6. Improving agrotechnolgy transfer by using crop yield models and crop genetic coefficients to replace trial and error testing over many locations and years with varietal testing through crop simulation of multi-year performance for various conditions of soils, climate, and management.

Requested Support

We are requesting support for three years at $133,000 per year to complete the proposed work listed above. Much of the work will be performed by graduate research assistants under the direction of a full time principle investigator.

Itemized annual costs:

Principle investigator	$ 50,000
3 graduate research assistants	24,000
Computer charges	10,000
Support staff	6,000
Contingencies at 10%	9,000
University overhead at 35%	34,000
Total annual	$133,000

References

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