STUDIES ON WATER LOGGING - CROP YIELD RELATIONSHIP FOR DEVELOPING DRAINAGE INDEX*

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PROJECT SUMMARY

Land drainage is an essential pre-requisite to ensure sustainability of irrigated agriculture in the cropped land. However, despite including benefits of drainage while planning irrigation projects, it has not yet found support in practice mainly because the benefits of drainage are not documented as clearly as that of irrigation.

In the cropped land, surface stagnation of rain/irrigation water is becoming a serious problem because of unplanned development, rising water table in irrigation commands, changes in the land use including development of low lying depressions, unrealistic drainage system designs and inadequate maintenance of the drainage system. The problem is much more severe in areas with stretches of barren or partially reclaimed alkaline lands. The rising water table in the irrigation commands has also caused increased degree and duration of water stagnation. The extent of damage or yield reduction depends upon the crop, crop growth stage at which water stagnation occurs, duration of water stagnation/flooding, soil type and the agro-climatic conditions. Surface water stagnation in the cropped land and its effect on the crop yield has been qualitatively known but the quantitative evaluation has been lacking. The main objectives of the project were:

- To evaluate the effect of time and duration of water stagnation/high water on crop growth, yield and mineral composition of rice and dry food crops;
- To develop mathematical model/index(es) for their generalized applications in evaluating crop production under conditions of water stagnation or high water table;
- To quantify drainage requirements of crops and to develop a methodology for application of the proposed model/index(es) in surface and subsurface drainage designs, and to prepare a computer simulation model for facilitating field application of the methodology by planners; and
- To explore the possibility of reducing adverse effects of water stagnation/high water table through application of nutrients in order to devise a wet farming technology.

To assess crop production functions with respect to duration of submergence, studies were carried out at CSSRI, Karnal and CIRB Farm, Hisar covering several

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crops such as mustard, barley, sorghum, berseem, sunflower, pigeon pea etc. To evaluate the effect of time (growth stage) and duration of water stagnation on crop growth, crop yield and mineral composition and aeration, water stagnation treatments were imposed at two pre-decided growth stages with different durations of water stagnation. For example, in case of mustard it was found that short-term water stagnation for different durations affected the plant height, number of pods per plant and grain yield. There was 8.4, 16.1, 21.7, and 28.7% decrease in grain yield, respectively, with 1, 2, 4 and 6 days of submergence compared to when there was no submergence. The effect of water stagnation was found to be more at early growth stage (20 days after sowing) than at later stage (60 days after sowing).

As regards the problem of water stagnation, for a short-term solution, one possible approach is through the application of additional nutrition in the form of nitrogen (N) or phosphorus (P). This hypothesis was tested by conducting experiments on different crops. Four crops, namely sunflower, sorghum, pigeon pea and berseem were selected for testing. It was found that enhanced fertilization in general increased the crop yield by minimizing the adverse effects of temporary flooding on crops.

To design a surface drainage system, the drainage coefficient is selected based on old practices prevalent in the region as well as on individual's thinking on the subject. In order to assess realistic drainage coefficient, a user interactive software was developed to compute the appropriate drainage coefficient of an area.

To evaluate the performance of a subsurface drainage system, a field site at Sampla with an installed subsurface drainage system was selected. Performance Assessment Indicators (PAIs) were calculated by using field data monitored over the last 12 years, and guidelines were formulated for evaluation of subsurface drainage projects. A new drainage criterion to design subsurface drainage was proposed which also helps in reducing cost of the drainage system.

To estimate the magnitude of the drainage problem in an area in North India, a drainage index was prepared, and guidelines were prepared so that the waterlogging problem can be rated as low, moderate, high and acute (refer Table 1).

Table 1 Drainage index and the degree of water logging problem.

Index	Degree of problem
< 25	Low
25-50	Moderate
50-75	High
75-100	Acute

It was observed that if the water logging problem is low, drainage may not be a serious issue and with proper land and crop management, good crops can be grown by avoiding the adverse effect of drainage. As the value of the drainage index increases, the degree of drainage to be provided increases and management alone may not be sufficient if the index is more than 50.

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STUDY OF SOIL AND WATER QUALITY DEGRADATION USING GIS*

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PROJECT SUMMARY

Abandonment of formerly productive soils in many areas around the world has resulted from continued use of irrigation waters containing high or moderate quantities of dissolved salts. Thus, the need to determine and monitor the effects of salts on soils and plants is of great importance to agriculture.

Broadly, two types of models are used to predict the soil salinity. First type of model accurately estimates the variation of salt in the root zone with respect to time and depth. Other type of model employs the simplified salt balance principle to predict the salt storage in the root zone. In field, the salt balance model can be utilized effectively to predict the soil storage. But at the regional scale, monitoring of soil salinisation involves management of voluminous spatial and temporal data which requires creation of a good data base that is linked with the model. Moreover, conventional methods like field sampling are expensive when used to monitor the soil resources at regional level. Hence, it becomes necessary to employ a cheaper methodology using latest techniques available. In this study, a methodology has been formulated which combines salt balance modeling and Geographic Information System (GIS) to predict the soil salinity. The developed methodology was tested at the regional scale, in the Minjur-Panjetty area, a part of Arani-Korttalayar river basins located to the North of Chennai city, Tamil Nadu. The main objectives of the study were:

- To analyse the soil and water quality degradation due to agricultural practices;
- To study and map the salt affected areas through Remote Sensing and allied data; and
- To model the optimum utilisation of land and water to increase the yield without damaging the environment.

Data related to irrigation water, soil and land use/land cover were collected systematically. Field sampling and analyses were carried out to obtain soil and water quality details. Data available with Government Departments were also used. Though there are several parameters to classify the irrigation water, only the Electrical Conductivity (EC) value was analysed because other parameters were found to be within the limits. Also, salt balance modeling uses only the EC value to predict the salt storage in the root zone of the soil. The water quality details were

*Final report submitted in December 2000 input into GIS by taking village as a unit. Detailed water quality analyses were carried out in order to understand the temporal and spatial water quality variations. Soil boundary map was digitised as input into GIS. The soil properties of each soil class were added as attribute values. Soils, which are prone to salinisation, could be obtained from analysis of the soil properties. The necessary details of soil properties for salt balance modeling could be retrieved from this soil sub model. The land use information was obtained from satellite imagery. Multi-temporal nature of the land use data was effectively handled using land use sub model. Using these models, it was possible to get the geographical location of saline soils and the cultivated area affected by irrigation-induced salinity.

Salt balance model was formulated with the conceptual information gained from the detailed study of soil, water and land use. The salt balance model was used to compute the salt storage in the root zone of the soil. Using this methodology, the crop losses were easily estimated. The results were verified by field tests. The simulation of results of salt balance model over a year gives the picture of salinity status, trend of accumulation and leaching of the soil. Hence, this model can be used as a management tool to evaluate the irrigation induced salinity on a regional scale.

From this study it was concluded that in the intensively cultivated portion of agricultural land of Minjur-Panjetty area, the water quality has got degraded due to leaching of salt and fertilisers into the aquifer. Near the coastline, ground water salinity is due to saline water intrusion. Poor drainage and presence of backwater are the reasons for saline groundwater in the North-Eastern part of study area. It was also found that the failure of monsoon creates high salinity level in most of the places. Before commencing the next agricultural operation, the soil has to be leached with good water or a crop with higher salt tolerance is to be cultivated. Hence, it is essential to monitor all irrigated area, irrespective of present condition, in order to avoid the soil salinity problem in future.

SYSTEM SIMULATION AND RESERVOIR OPERATION FOR KUTTIYADI SCHEMES IN KERALA*

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PROJECT SUMMARY

Power generation and irrigation are important aspects of reservoir operation with regard to water resources development schemes in Kuttiyadi river basin. Future development plans for the region include augmenting the water supply for Calicut City and adjacent areas as well as increasing the hydro electric power capabilities. The application of system analysis to reservoir system operation can be quite useful in developing an integrated and comprehensive operation policy to meet the present and future power and irrigation demands. In this context, the major objectives of this project were:

- To develop water allocation policies for the Kuttiyadi hydro electric and irrigation schemes through the use of synthetic streamflow generation, system simulation and multi-objective analysis; and
- To prepare operation policies for the existing system, considering also the proposed Kuttiyadi augmentation, tail race, extension and water supply schemes.

Through the use of simulation and optimisation techniques, water allocation priorities for the Kuttiyadi hydel and irrigation schemes were developed for the past i.e. without diversion from Banasurasagar reservoir; for the present scenario i.e. with actual diversion; and, for the future scenario i.e. accounting for the proposed diversion, Kuttiyadi extension, Kuttiyadi tail-race and also for allocation of water for drinking water supply. The systems approach to the Kuttiyadi river basin covered several elements of analysis and modelling, including derivation of daily runoff using Tank Model, synthetic generation of runoff data by Thomas-Fiering model, and simulating the system for the past, present and future scenarios.

It has been found from the analysis that the daily runoff obtained using the Tank Model compared well with the measured inflow, and the correlation coefficient obtained was between 0.90 and 0.95. For monthly streamflow generation, the Thomas Fiering Model gave good results at all the three sites at which data was available. The overall fit of the generated streamflows with the historic data was found to be generally good. In reservoir operation for both hydroelectric and irrigation projects, the requirement of firm power generation was given top priority,

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and only after satisfying the power requirement, the irrigation withdrawal was considered.

The reservoir operation was simulated for the past scenario, in which the diversion from Banasurasagar was not considered. Then it was simulated for the present scenario in which actual diversion form Banasurasagar was considered. The reservoir operation was also simulated for the future scenario in which diversion was considered as a variable and water supply demands for Banasurasagar, Kakkayam, Peruvannamuzhi and Greater Calicut were considered as first priority, in addition to the power generation and agricultural demands. Simulations for the present scenario showed that the demand for power generation can be met with 90% dependability which comes to about 82% of the power requirement specified by the CBIP. Also, irrigation requirement for Puncha crop (third crop) for half the command area can be met with 75% dependability and full area can be irrigated for Mundakan crop. Future scenario simulations showed that that the annual power output can be increased to 410 Mu, and thus, about 84% increase in annual power generation can be attained with diversion. Also, for all the years, irrigation demand (for both Puncha and Mundakan) can be fully met with 75% dependability.

INCOH Sponsored Research Projects

MODELLING FOR OPTIMAL RESERVOIR OPERATION FOR MULTICROP IRRIGATION*

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PROJECT SUMMARY

The objective of the investigation was to formulate a model to determine the steady state optimal operating policy to maximize weighted crop yield function for the irrigation command area under the reservoir. For this purpose, a four state variable stochastic dynamic programming (SDP) model has been developed to provide a steady state optimal operating policy for a single irrigation reservoir irrigating multiple crops. The model determines the optimal crop water allocations for each crop in the command area taking into account the soil moisture variations in the cropped area. The weights attached to the crop yield are based on the harvest prices of the crops. The performance of the reservoir can be studied by simulating the operation of the reservoir based on the derived operating policy.

The following specific features were included in the optimisation model for reservoir operation for irrigation: (a) stochasticity of reservoir inflow and rainfall in the command area, (b) sensitivity of crop yield to a deficit supply, (c) soil moisture continuity, and (d) economic objective functions. The model formulation took into account the steady state probabilities (unconditional probabilities) of rainfall in different periods, and economic weights based on the harvest prices of crops. The latter were used in optimally allocating the available water among different crops in a given period for a given state of the system.

The model application has been illustrated with an existing case of Malaprabha Reservoir in the Krishna Basin, Karnataka State. The reservoir is a single purpose irrigation reservoir on the river Malaprabha put into operation since 1973. The model has been applied to the right bank canal command whose requirements were approximately two-thirds of the total canal release. It was therefore assumed that whatever release was made to the canals, only two-thirds of it was released into the right bank canal, and the optimal policy for reservoir operation was derived based on allocating this available water among the crops (grown in the right bank canal command). A time interval of 10 days was chosen for irrigation allocation decisions. All crops in the command were grown under a single soil type, the black cotton soil. However, the model application was not limited to a single soil type alone. It was seen that, for the case study, the policies were quite sensitive for low values of rainfall and soil moisture when there was a severe competition for water use among various crops.

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A major contribution of the study has been to enhance the scope of the earlier studies on modelling for reservoir operation for multicrop irrigation. It is shown through this study, that how simultaneous treatment of randomness of inflow and rainfall may be considered in a SDP model to arrive at the steady state operating policy.