INTEGRATED IRRIGATION MANAGEMENT MODEL FOR DEFICIT IRRIGATION

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by

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CERTIFICATE

This is to certify that the thesis titled, "**Integrated Irrigation Management Model for Deficit Irrigation**", being submitted by **Ms Sushmita Mukherjee** to the Indian Institute of Technology, Delhi, India for the award of the degree of **DOCTOR OF PHILOSOPHY**, is a record of bonafide research work carried out by her under my supervision and guidance. The thesis work, in my opinion, has reached the standard, fulfilling the requirements for **DOCTOR OF PHILOSOPHY** degree. The research report and the result presented in this thesis have not been submitted, in part or in full to any other university or institute for the award of any degree or diploma.

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ABSTRACT

It is a big challenge to produce more food with less water as the population is continuously increasing and deficit irrigation can be a possible alternative in this regard. Deficit irrigation can be defined as intentionally under irrigating crops to reduce water requirement while minimizing the adverse affect of extreme water stress on crop yield. The reduction in the yield may be small as compared to the benefits gained through diverting the saved water to cover more cropped area under irrigation. The adoption of deficit irrigation requires knowledge on the response of the different crops to water stress applied at various growth stages.

In the present study, an inverse formulation is proposed to estimate the crop yield response factors for crop growth stages. The proposed methodology was applied to Lower Indus Basin. Modified crop yield response factors for crop growth stages are estimated for eight major crops of the command area. Modified crop yield response factors are found to be different for additive and multiplicative approaches and there was a good agreement between the relative yield reductions using modified crop yield response factors and seasonal crop yield response factors. However, there was a complete mismatch in relative yield reductions using FAO 33 stage wise crop yield response factors and using seasonal crop yield response factors. Modified crop yield response factors may be more representative in taking into account the recurring effect of deficit irrigation of one stage to another stage of deficit irrigation leading to a combined effect on the yield reduction at the end of the crop period. This is also reflected by the small RMSR values between .0001 to .0377 and .0019 to .0081 using $mod\_K_{y\_ADD_i}$ and $mod\_k_{y\_MULT_i}$ values respectively. However, RMSR values varied between 0.1269 to 0.8767 and .0709 to 0.3751 for additive and multiplicative approaches respectively using FAO 33 K_{yi} values.

Further, non linear optimization models for deficit irrigation are proposed in the present study to maximize the net economic return within the available resource constraints. The deficit levels of irrigation are kept as variables in the models with a flexibility to keep the crops either at full irrigation or deficit irrigation in order to maximize the net economic return. The deficit levels in the proposed models are fixed and varied during crop period. The models also optimize the decade (10 days) optimal withdrawals from the existing water resources and the cropped areas. The fixed deficit level model is applied to the seven canal command areas of the Lower Indus basin. The optimal net economic return is increased and the total optimal cropped area is enhanced under deficit irrigation as compared to the existing cropping pattern for the seven canal command areas. The optimal economic return can further be increased if the existing tube well capacity is augmented in the command area. The overall maximum increase in economic return is found to be around 90% along with 115% increase in the total cropped area under deficit irrigation as compared to the existing ones. The optimal results using the additive and multiplicative approaches are found to be comparable with modified crop yield response factors. The surface water availability was also reduced to work out its impact on the optimal cropped area. Although there was a significant reduction in the net economic returns as the availability of surface water is reduced to 50% but the optimal economic return still came out to be more than the existing ones. However the cropping pattern and optimal deficit levels of different crops changed as the surface water availability is reduced.

The varying deficit level NLP model is applied to the Dadu canal command area of the Lower Indus Basin. The results of the canal command area demonstrates that net economic returns and optimal cropped areas are increased under deficit irrigation using proposed varying deficit level NLP model for both the approaches (additive and multiplicative) as compared to the existing economic return under full irrigation. Both the models are applied

on the Dadu canal command area and results are compared (net economic returns and optimal cropping areas) between the varying deficit level and fixed deficit level under additive and multiplicative approaches. The net economic returns and the total optimal cropped areas are only marginally increased by adopting the stage wise varying deficit irrigation levels as compared to fixed deficit levels. Therefore, fixed deficit level during crop period under deficit irrigation can be more practical in comparison to varying deficit levels during crop period as varying deficit levels are more difficult to implement and results only with a minor increase in the benefits. Both the proposed models are general and can also be used to find out the optimal cropping pattern under deficit irrigation in other regions.

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