M.Sc. Thesis

FORMULATION OF A BI-LEVEL MULTI-OBJECTIVE MODEL FOR OPTIMAL ALLOCATION OF WATER RESOURCES

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ABSTRACT

Agriculture is one of the biggest sectors of economy in Pakistan, contributing 18.9% in gross domestic product (GDP). Resulting to increasing population growth, food and fiber requirements are increasing at an alarming rate and putting a constant pressure on the available water (AW) resources. Pakistan had surplus water resources from the upper Indus river basin, however, per capita water availability has been depleted from 5600 m^3 to 1017 m^3 since independence, due to which water shortages often occur in the country. Therefore, an optimal water allocation system is required to optimally allocate the AW among competing water users (Agriculture, domestic, industry etc.) in such a way that each water user gets maximum share based on its actual demand.

In this study, a linear bi-level multi-objective model was formulated for optimal allocation of limited water resources among competing users. The upper level decision makers (DMs) allocate the water to lower level DMs based on two objectives, i.e., equity and stability, and it was determined by using GINI coefficient and Coefficient of Variance (COV), respectively. After that, lower level DMs allocate the AW among different crops based on three objective functions. The first individual objective function (OF_1) maximizes the satisfaction rate (SR) of various water users, whereas, second individual objective function (OF_2) maximizes Net Economic Benefits (NEB) and the third multi-objective function (OF_3) combines the first two individual objectives which maximizes the SR and NEB together. Multi-objective function was solved by using the Simultaneous Compromise Constraint (SICCON) technique which creates a compromise between first two individual objective functions. The developed model was applied to Taunsa Barrage Pakistan for the optimal allocation of AW to evaluate the model applicability in real-time situation. Six major

crops (wheat, cotton, sugarcane, rice, onion and sunflower) were considered for modeling the optimal allocation of AW in the study area. Various scenarios were analyzed for model testing by varying priority given to different objective functions and crops.

When first individual objective function (OF_1) was considered, maximum value of satisfaction rate of 61% was achieved against NEB of Rs. 9.813 billion from the whole system. When second individual objective function (OF_2) was considered, maximum NEB of Rs. 10.77 billion was achieved against satisfaction rate of 46 percent. When third multi-objective function (OF_3) was considered, to maximize both SR and NEB of the whole system, SR of 52 percent was achieved against NEB of Rs. 10.03 billion and values of both SR and NEB lies between single objective function. The results show that the model successfully optimized both objective functions, simultaneously and the model developed in this study is effective, efficient and easy to use in solving the real world water allocation problems.