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BI-LEVEL LINEAR PROGRAMMING MODEL FOR UDAWALAWE WATER RESERVOIR MANAGEMENT

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Bi-level programming is an effective mathematical framework to address hierarchical decision making problems commonly encountered in real-world applications. This study develops a bi-level linear programming model to optimise the management of the Udawalawe water reservoir system, which plays a crucial role in ensuring reliable water supply for agriculture. No previous studies have addressed bi-level programming model for Udawalawa water reservoir management in Sri Lanka. Hence this study fills an important research gap. The model captures the interaction between two levels of decision makers: central authority and agricultural users (farmers). At the upper level, the water management authority or government aims to determine the optimal schedule for monthly water releases and reservoir storage over a one-year planning horizon. These decisions are made with the objective of managing limited water resources efficiently while meeting agricultural demands. At the lower level, farmers respond to the water release policies by deciding the area to cultivate for different types of crops, purposing to maximize their profit. These decisions are subject to constraints related to water availability in each month, crop-specific water requirements and yield targets. To solve this hierarchical model, the bi-level problem is reformulated into a single level optimisation problem using the Karush-Kuhn-Tucker (KKT) conditions, allowing for the use of conventional non-linear programming solvers. Real-world data, including inflow rates of the Udawalawe reservoir, crop water requirements, and economic parameters are used to validate the model. Data were sourced from the Mahaweli Authority. The results provide an optimal monthly water release strategy and a land allocation plan for crop cultivation that satisfies both upper and lower-level objectives. This research highlights the potential of bi-level optimisation techniques in water resource planning. The proposed model offers a systematic and computationally efficient approach that supports better coordination between government and farmers. It enables improved reservoir operation, increased water use efficiency and enhanced agricultural productivity under limited resource conditions.

Keywords: Bi-level programming, Karush-Kuhn-Tucker (KKT) condition, Optimisation, Single-level reformulation, Water reservoir management