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Mathematical Optimisation of Irrigation Pipes

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Abstract

In order to secure the quality of on-farm food production, it is necessary to guarantee continuous water supply to the plants. However, this is difficult to be achieved due to the expensive irrigation systems' cost. Hence, high irrigation system installation cost is the biggest limitation, especially in the case of long pipe systems. Consequently, the decision making process should consider different combinations of pipe lengths and pipe diameters for the design of irrigation systems. Based on experience, the design engineer, usually carries-out countless trial-and-error computations to come up with a minimum acceptable head loss based on pre-established length and diameter combinations. This process is found to be very difficult since designers do not make the decisions on mathematically optimised way. Pipe design based on mathematical linear programming optimisation is the best solution to solve this kind problem. Accordingly, a mathematical linear programming based spreadsheet was developed for the design of pipe systems. The design pipe combines four diameters of 150, 125, 100 and 75 mm, which are commercially available in the Brazilian pipe markets. The minimised objective function was the pipe cost, constrained by the commercially available diameters, the admissible head loss and the maximal water velocity in the pipe. For the admissible head loss determination, six different head loss equations were tested. These are the Hazen-Williams, Manning, Scobey, Swamee-Jain, Flamant and Darcy-Weisbach equations. The lowest cost of US$ 610.59 for a 300 m pipe was found with the Scobey head loss equation, whereas the highest cost of US$ 779.71 was observed using the Darcy-Weisbach head loss equation. The difference of 28 % between the lowest and the highest costs indicates that huge discrepancies can be observed, depending on the head loss equation selected by the designer.

Keywords: Food production, head loss, hydraulic, linear programming, objective function, pipe diameters

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