Extraction of Multicrop Planning Rules in a Reservoir System: Application of Evolutionary Algorithms

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Abstract: Multicropping is the practice of growing two or more crops in the same space during a single growing season. Planning rules are mathematical equations that use previous experiences of a water resource system to balance the system's water supply and demand, and calculate multicrop areas in various periods. In this paper, linear and nonlinear planning rules are developed for optimal multicrop irrigation areas associated with reservoir operation policies in a reservoir-irrigation system. Reservoir operations are related to water allocations to each irrigated area by considering inflow and storage volume of the reservoir as the water supply in a monthly operation period. Evolutionary algorithms (EAs) can determine optimal multicropping patterns planning rules by considering various mathematical patterns. In this paper, three EAs, namely, (1) genetic algorithm (GA), (2) particle swarm optimization (PSO), and (3) shuffled frog leaping algorithm (SFLA) are employed and compared to maximize the total net benefit of the water resource system by supplying irrigation water for a proposed multicropping pattern over the planning horizon. Results show that the SFLA achieves the best solution, with the maximum value of the objective function in both linear and nonlinear planning rules compared to the GA and PSO. Moreover, the best yield of nonlinear rules is 45.52% better (higher) than that obtained by linear rules. **DOI: 10.1061/(ASCE)IR.1943-4774.0000572.** *© 2013 American Society of Civil Engineers.*

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Introduction

Agriculture is a large sector of water consumers (Grafton and Hussey 2011) in which its allocation affects directly the system efficiency in general, and benefits crop production in particular. Simulation and optimization are tools that help determine cropping patterns and water allocation for leaching and irrigation purposes.

Dudley and Burt (1973) developed integrated intraseasonal and interseasonal stochastic dynamic programming (SDP) to determine an optimal decision rule with respect to the following three classes of crop irrigation decisions: (1) intertemporal water application rates, (2) whether or not some acreage should be "abandoned" from further irrigations for the remainder of a season, and (3) optimal acreage to plant for potential irrigation at the beginning of the season. Results indicated a significant trade off between expected net benefits and their variability in determination of the optimal developed acreage for irrigation of a single crop. Matanga and Mariño (1979a, b) addressed irrigation planning in a district by using linear programming (LP) to determine optimal cropping patterns and SDP to determine optimal water allocations for leaching and irrigation purposes. Bras and Cordova (1981) applied SDP to extract control policies for a single crop at each irrigation decision point, conditional on the state of the system, including soil moisture content. Vedula and Mujumdar (1992) developed a model for the optimal operating policy of a reservoir for irrigation under a multicrop scenario using SDP in an existing system in India. To determine allocations to individual crops, state variables consisted of reservoir storage, inflow to the reservoir, and soil moisture in the irrigated area. Vedula and Nagesh Kumar (1996) proposed an integrated model which is conceptually made up of two modules: (1) an intraseasonal allocation model to maximize the sum of relative yields of all crops for a given state of the system using LP, and (2) a seasonal allocation model to derive the steady-state reservoir operating policy using SDP. Malek-Mohammadi (1998) used mixed integer linear programming (MILP) to maximize the net benefit associated to plan irrigation systems including surface reservoir capacity, ground-water and spring withdrawal, delivery system capacities, and possible cropping pattern. Paul et al. (2000) used two stage models: (1) a single crop intraseasonal model that employs a SDP including weekly canal releases and evapotranspiration of the crop as the variables, and (2) a dynamic programming (DP) model that takes into account the multicrop situation. Teixeira and Mariño (2002) developed a forward dynamic programming (FDP) model to solve the problem of reservoir operation and irrigation scheduling in a real watershed with a two-year planning horizon for an interseasonal model, and 6 months for an intraseasonal model. Moradi-Jalal et al. (2007) used LP to determine optimal multicropping patterns and allocation of irrigated areas corresponding to reservoir operation and irrigation scheduling in a coupled reservoir-irrigation system. Bozorg Haddad et al. (2009b)

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