OPTIMIZING FERTIGATION FOR HIGH VALUE CROPS

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ABSTRACT

In irrigated farming systems, soluble and mobile fertilizers, such as sources of nitrogen, are often applied to crops through irrigation water. Fertigation presents both opportunities and challenges. Potential opportunities include better synchronization of available nutrients with crop demand through the growing season, reduced soil compaction or crop damage, and energy and labor cost savings. Challenges include having the right infrastructure for the injection of nutrients into irrigation delivery and distribution systems, having the tools to forecast crop demand, and having the management guidelines to optimize uniformity and efficiency. This presentation will briefly summarize models and algorithms we have developed to optimize fertigation in surface and sprinkler irrigation systems, present the analytical framework for the evaluation of fertigation events, and present a case field study showing the implementation of a successful fertigation program.

INTRODUCTION

In irrigated farming systems, soluble fertilizers are often applied to crops through fertigation. Fertigation offers both benefits and limitations. Potential benefits include better synchronization of nutrient availability with crop demand through the growing season and reduced costs. Limitations consist of the need for the additional investment in infrastructure for nutrient injection into the irrigation conveyance and distribution system and the development and maintenance of management tools (including models for demand forecasting and guidelines to optimize fertigation performance). This presentation will focus on tools (i.e., mathematical models and performance evaluation methods) developed over the last two decades for optimal management of fertigation systems in surface and sprinkler-irrigated fields. The fertigation models addressed here can be used to simulate fertigation events where water-soluble fertilizers are applied. These models are not intended for direct use by growers but to allow advisors to make customized system operation recommendations via simulations across varying scenarios.

MODEL DEVELOPMENT AND PERFORMANCE EVALUATION SCHEMES

Surface Fertigation

Approximate advective transport fertigation models were developed by Boldt et al (1994), Playan and Faci (1997), and Strelkoff et al. (2007). These models were based on plug flow type conceptualization of the movement and distribution of nitrate fertilizers over surface irrigated fields. A physically based coupled surface-subsurface hydraulic and solute transport model capable of simulating the longitudinal and subsurface distribution of soluble fertilizers and water in irrigation basins was developed by Zerihun et al. (2005a,b,c). The subsurface component of the model can compute the redistribution of water and fertilizer in the soil profile, as a function of time, between irrigation events and over a cropping season. A capability that allows for a dynamic approach to the partitioning of soil water and fertilizer into crop available, deep percolated, and surplus fractions and hence for a more accurate determination of seasonal fertigation system performance. The model was calibrated and validated using field data collected in agricultural production fields (Figure 1). Following this work, other physically based s surface fertigation models were developed based on alternative numerical solutions to the advection-dispersion equation (e.g., Bautista and Schelgel, 2020; Burguette et al., 2009a,b; Perea et al., 2010; Zerihun et al., 2014).

A surface fertigation performance evaluation method (consisting of a set of equations and solution techniques) was developed for determining the efficiency, uniformity, and adequacy of fertigation events (Zerihun et al., 2003). The method can be used to determine the performance of real-world fertigation events using field-measured data or can be integrated into a fertigation model to assess the performance of simulated scenarios.

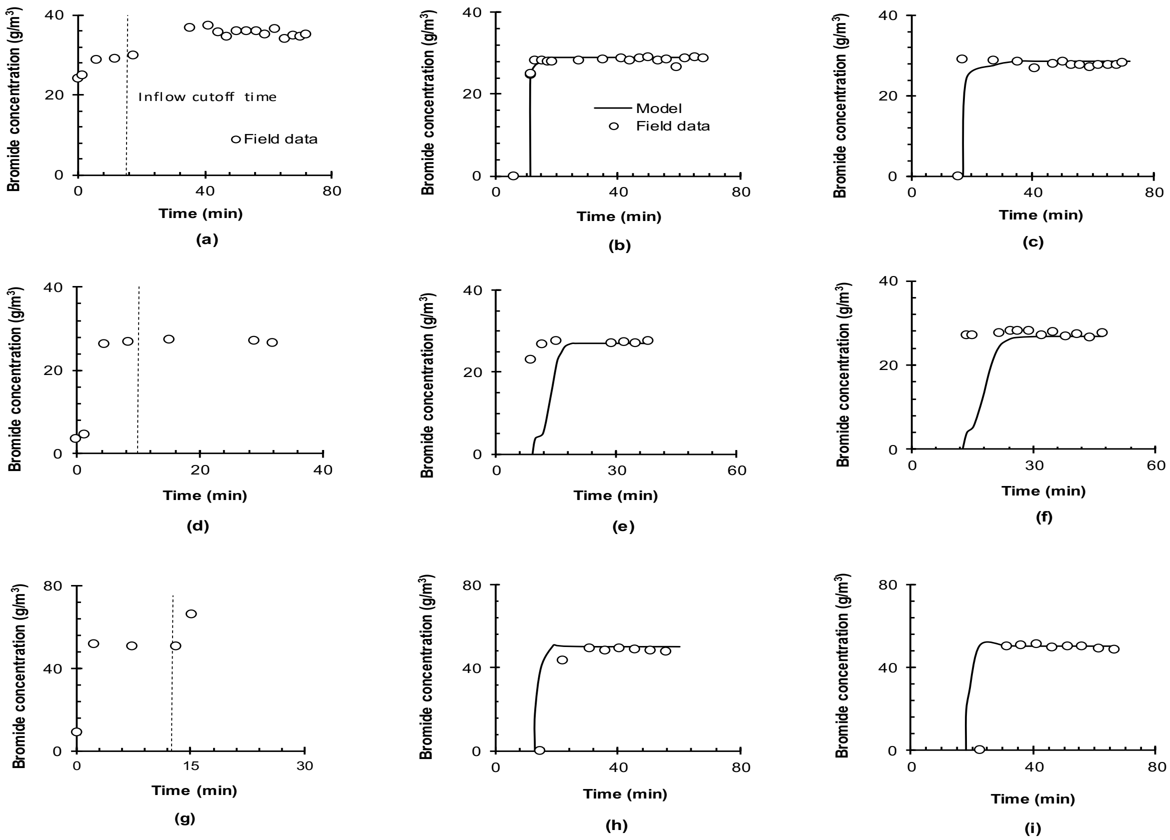

Figure 1. Comparison of model-predicted and field-observed bromide breakthrough data collected in the Yuma Mesa: First row, level basin: (a) basin inlet, (b) 100m from the basin inlet, and (c) 142m from basin inlet; Second row, graded basin: (d) basin inlet, (e) 107m from basin inlet, and (f) 142m from basin inlet; Third row, free-draining border: (g) border inlet, (h) 120m from border inlet, and (i) 160m from border inlet

Sprinkler Fertigation

Recently, a model for simulating the transport of solutes, in a sprinkler irrigation lateral was developed and evaluated by Zerihun et al (2023). The model is designed to simulate the time- and distance-evolution of the concentration of a nonreactive solute in an irrigation lateral over a chemigation event, given the hydraulic condition, the solute input function specified at the lateral inlet, and the initial concentration profile along the lateral. For modeling purposes, a lateral is conceptualized here as a hydraulic network consisting of a series of connected pipes, each delimited by outlet nodes. At the pipe-scale, flow is deemed steady and uniform and solute transport is modeled as an advective process in which the equation governing advection, in a hydraulic conduit, is solved with a quasi-Lagrangian integration scheme. Solutions to the transport problem, in a pair of consecutive pipes, are coupled through a nodal condition, which can be stated as: the concentration computed at the downstream-end node of a pipe constitutes the upstream boundary condition for the advective transport problem in the pipe just downstream.

The model was evaluated in two phases. First, the soundness of the formulation and programmatic implementation of the numerical solution, to the pipe-scale advective transport problem, was tested through a comparison of model outputs with an analytical solution. Evaluation of the predictive capacity of the lateral-wide model, in the context of a real-world application, was then conducted by comparing computed breakthrough curves of a nonreactive tracer with data measured along a pair of laterals. The results suggest that model performance is satisfactory (Figure 2).

A methodology (consisting of a field protocol and equations) for evaluating the uniformity of fertigation events under sprinkler irrigation systems were proposed by Zerihun et al. (2017). Irrigation uniformity indices are adapted for use in fertilizer application uniformity evaluation. Fertilizer application rate, given as a function of irrigation depth and fertilizer concentration, is identified as the appropriate variable to express fertilizer application uniformity indices. The results of the study show that the spatial overlap patterns between depth and concentration data sets are the main determinants of test-plot scale fertilizer application rate uniformity (Figure 3). The study also shows that often the uniformity levels of irrigation and fertilizer concentration data sets cannot be uniquely related to the uniformity of the resultant application rate data. However, some practically useful qualitative interrelationships between the uniformity of irrigation depth, solute concentration, and application rate data sets were identified.

Application

Legislative mandated "Best Management Practices" has prompted us to seek avenues for enhancing N use efficiencies, and fertigation management is among the practices currently being evaluated, where practical. Synchronizing applications with anticipated crop uptake creates opportunities for enhanced efficiencies (Sanchez and Doerge, 1999). However, high-value vegetable crops in the desert are planted daily from the middle of September through late February, the growth period varies, and days from planting is not a reliable prediction of the crop growth stage. Therefore, we have implemented growth-tracking based on growing degree days (GDD) or normalized difference vegetative index (NDVI) from satellite imagery. The use of GDD and NDVI to track above-ground N accumulation by baby spinach is shown in Figure 4. Data we have collected show N fertilizer use can be reduced by 50% for baby spinach using fertigation system operation protocols specified from models and the generalized N accumulations curves. This approach is being expanded to other sprinkler-irrigated crops.

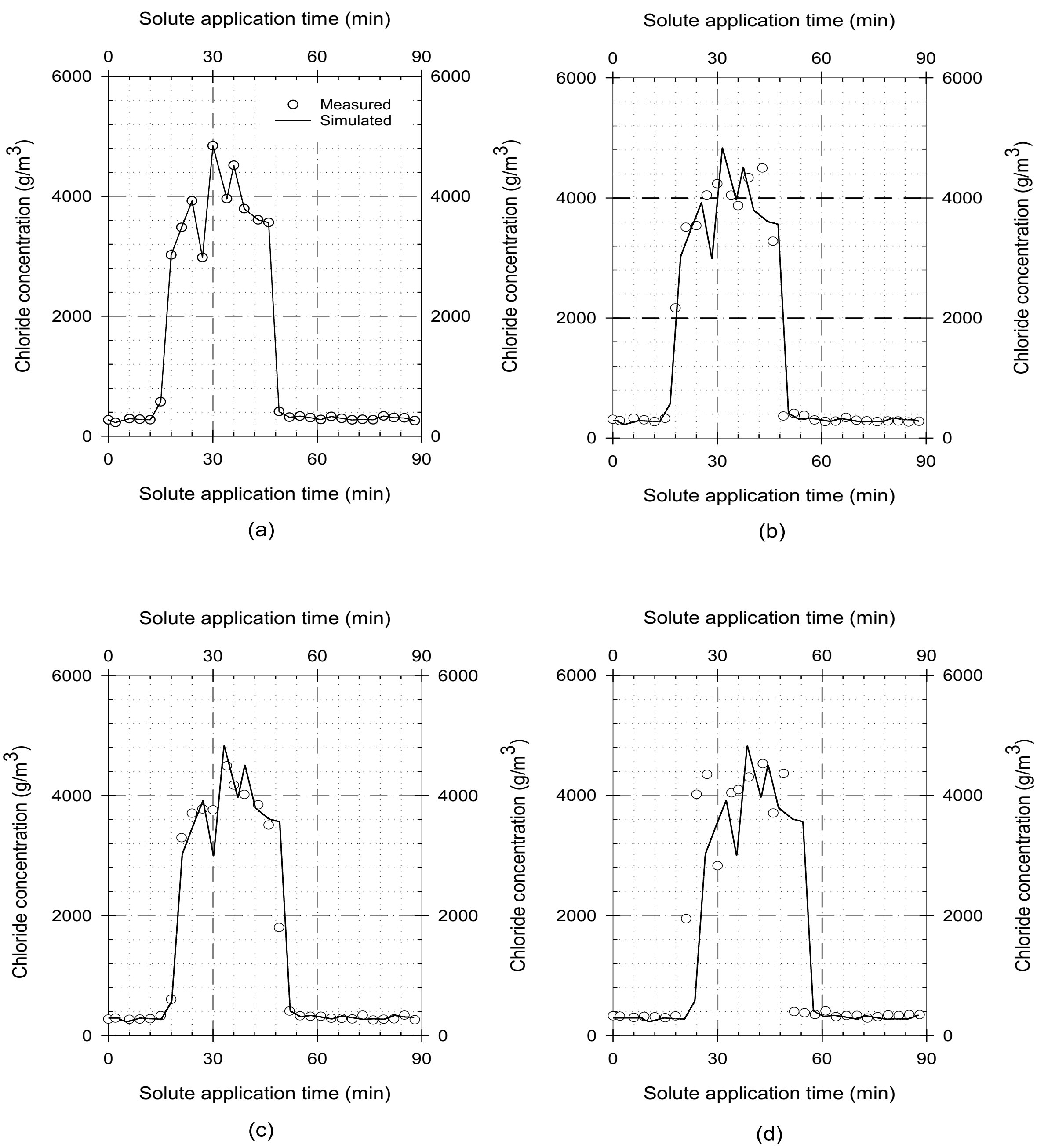

Figure 2. Comparison of measured and simulated solute (chloride) concentrations breakthrough curves sprinkler lateral a, input, b 91.4 m, c 173.7m and d 310.8 m from lateral inlet

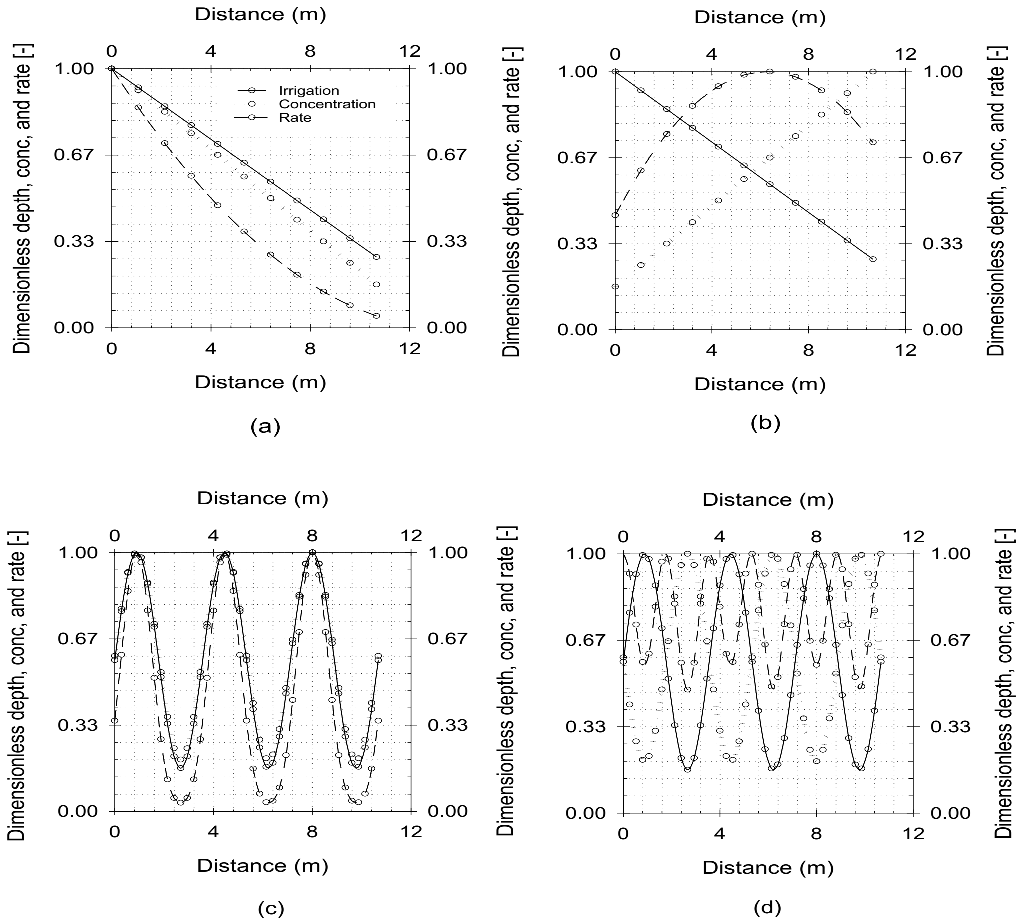

Figure 3. The relationship between spatial trends in irrigation depth, fertilizer concentration, and the spatial variability of the resultant fertilizer application rate. Scenarios where dominant spatial trend spanning the test–plot exists and depth and concentration show: (a) same monotonicity, (b) opposite monotonicity; and Scenarios where local spatial trends dominate and depth and concentration show: (c) same monotonicity, (d) opposite monotonicity.

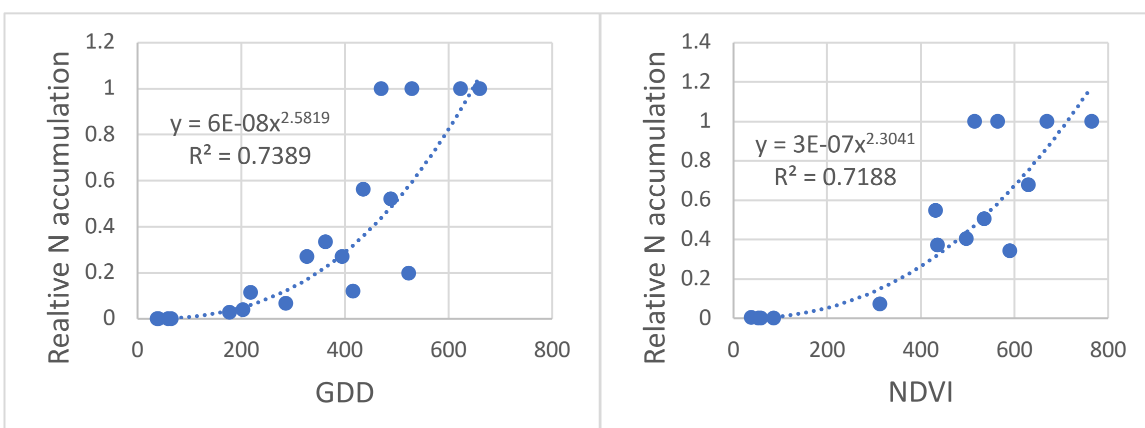

Figure 4. Generalized above ground N accumulation for baby spinach by GDD or NDVI derived from field experiments (unpublished data of Sanchez).

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