SWE-01

OPTIMIZATION OF ZONE LEACHING FOR SALINITY CONTROL IN ARID AND SEMIARID REGIONS – A NUMERICAL ANALYSIS

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ABSTRACT

Soil salinity involves the excessive accumulation of solutes in soil and affects over 20% of the World's irrigated land. Whether salinity is manmade or occurs naturally, it always reduces and even prevents the agricultural use of land that would otherwise be more productive. To make sustainable use of these soils, water must be applied in excess of a crop's consumptive needs, to leach salts out of the soil. This leaching process requires large amounts of water and often the installation of subsurface drains to prevent water logging. Due to these demands, any improvement made in the leaching process can save significant quantities of water. Partial sequential flooding has been proposed as an effective strategy to save water when leaching is required. The HYDRUS computer model was used to simulate the leaching process in a series of sand tank leaching laboratory experiments, which were designed to study partial sequential flooding. The results showed that water outflow and breakthrough curves determined by the HYDRUS computer modeling compare favorably with laboratory measurements. The sequential partial flooding technique is more efficient than traditional complete flooding, thereby conserving valuable water resources. Moreover, this technique proved to be effective at saving time and producing a more uniform salt leaching pattern by reducing excessive leaching in the areas proximate to the sub-surface soil drains. These results show that HYDRUS simulations can be applied in developing and improving desalinization strategies, reducing the water needed to ameliorate the negative effects of salinity.

Keywords: HYDRUS, drainage, leaching, sequential flooding

INTRODUCTION

Soil salinity is central global problem, worldwide affecting over 1,000 million hectares and limiting crop productivity in more than 100 countries [5, 6]. Flood irrigation in conjunction with subsurface drainage (Fig.1) is a commonly applied method for leaching excess salts from agricultural soils in arid and semiarid regions, therefore increasing its efficiency would lead to significant and valuable water savings.

- Water outflow and breakthrough curves simulated with the HYDRUS model compared favorably with laboratory measurements.
- Results showed that sequential partial flooding requires less ;me and more importantly conserves water, producing a more uniform salts leaching pattern.
- Sequential partial flooding was more efficient than complete flooding, thereby conserving valuable water resources, and reducing off site impacts.
- Results showed that HYDRUS can be successfully applied to develop and improve desalinization strategies than can be later tested under field conditions.

Fig. 1 Border strip irrigation system (Photo by Jeff Vanuga, USDA Natural Resources Conservation Service).

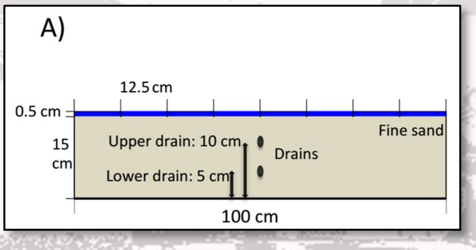
MATERIALS AND METHODS

The HYDRUSc2D/3D (V 1.12) so-ware package [4] was applied to simulate solute leaching under various flooding conditions. Results were compared to data previously obtained with laboratory sand tank experiments [2, 3].

The solute transport properties required to parameterize HYDRUS shown in Table 1, were determined from breakthrough experiments conducted in triplicate with potassium bromide as a nonreactive tracer, calculating the longitudinal (λL) and transversal dispersivities (λT). The silica sand was compacted to the same bulk density (ρb) as used with the sand tank laboratory tests (Fig. 2 A) performed by [2, 3]. The van Genuchten soil water characteristic parameters were determined from water retention analysis.

Table 1: Soil parameters used to parameterize HYDRUS.

ρ_b	K_s	θ_r	θ_s	α	n	l	Kd	λ_L	λ_T
1.60	0.61	0.008	0.382	0.016	3.065	0.5	0.125	0.3137	0.0314



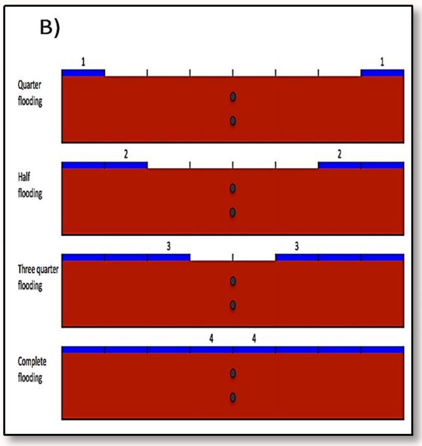


Fig. 2: A) Sketch showing the laboratory experimental setup and B) Sketch showing simulated and measured flooding conditions.

The works performed by [2, 3] considered 5 different flooding condition 1/4, 1/2, 3/4, complete surface flooding, and sequential partial flooding and 2 drain depths -5 and 10 cm (Fig. 2). Thus 10 HYDRUS simulations were first calculated for an 82 min period. Sequential partial flooding condition consists of a progressive flooding starting with 1/4c 1/2c 3/4 and finally the complete surface is flooded.

Mirjat and Rose (2009) based on [7] and using the velocity of stream flows measured on their sand tank experiments, calculated that 82 min of sequential flooding would be required to leach the top 5 cm of the sand. Thus, following their calculations the simulations for Sequential partial flooding condition consists of 1/4 of the surface flooded for 23 min, then 1/2 surface flooded (19 min), followed by 3/4 surface flooded (20 min) and finally the complete surface flooded (20 min).

Also all but sequential scenarios were simulated again with HYDRUS, but for a 500 min flooding period, calculating a breakthrough curve for each scenario. Every simulation started with the profile saturated with water with a concentration of 1 mmol cmc^{-3}, and flooding water had a concentration of 0.

RESULTS

The solute distributions after 82 minutes of leaching are plotted in Fig. 3. The yellow dashed lines mark the lower boundary of the upper 5 cm of the profile.

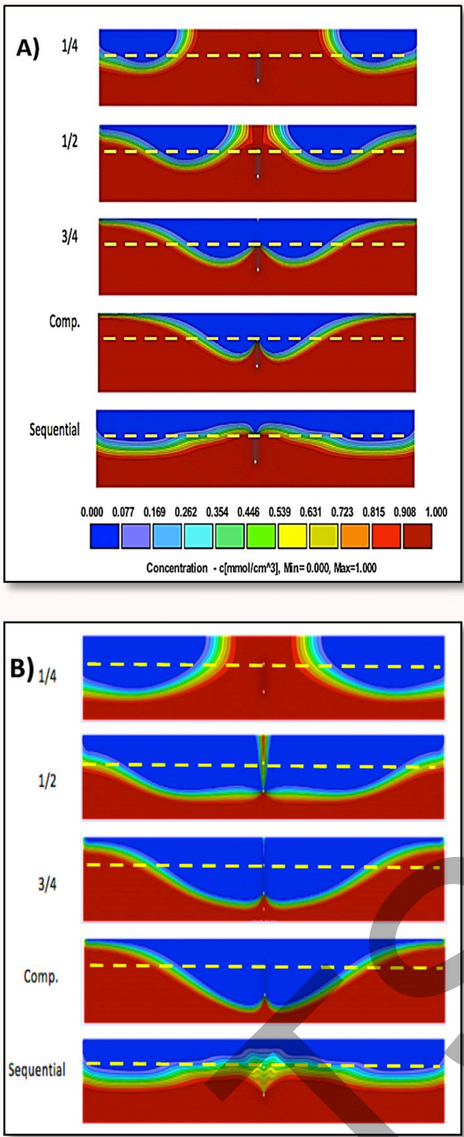


Fig. 3: Solute distribution pattern, for different flooding conditions, after 82 min of flooding, for: A) Upper drain and B) Lower drain scenarios.

Table 2: Drain outflow characteristics after 82 min flooding

Drain	Surface flooding condition	Drain outflow Cumulative water (cm^3)	Cumulative solute (mmol)	Average concentration ($mmol\ cm^{-3}$)
Upper	1/4	1474	147.42	1.000
	1/2	1930	192.67	0.998
	3/4	2753	192.24	0.698
	Complete	4593	145.89	0.318
	Sequential	2646	249.71	0.944
Lower	1/4	2813	281.33	1.000
	1/2	3674	337.51	0.919
	3/4	5140	294.57	0.573
	Complete	6767	256.26	0.379
	Sequential	2641	262.69	0.995

From these plots it is evident that 1/4 flooding, for the simulated; me, removes salts mainly from the area close to the flooded surface, and this is more pronounced in the upper drain simulations. In contrast, all other conditions yield less leaching in the areas most distant from the drain, which agrees well with observations of Anapali et al. (2001).

Sequential partial flooding developed the most uniform leaching patterns for both upper and lower drain simulations.

Table 2 shows that quarter flooding is the most efficient condition (outflow concentration=1 mmol cm^{-3}), and that efficiency decreases as more surface is flooded.

However, Sequential partial flooding achieves almost the same efficiency, but with higher uniformity (Fig. 3) than 1/4 flooding condition. This last result agreed with the analytical analysis performed by Mirjat et al. (2008).

RESULTS

Figure 5 shows that the breakthrough curves based on HYDRUS simulations agree well with those obtained from the sand tank laboratory tests. The greatest agreement was found for the complete and the 3/4 surface flooding conditions.

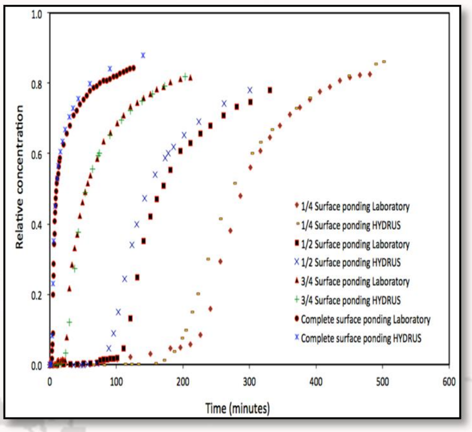


Fig. 5 Breakthrough curves of leaching water in drainage effluent under different flooding conditions, for the upper drain scenario, as function of time.

NEXT STEPS

- Develop models based on field conditions to test different leaching strategies, including intermittent flooding, under different soil textural conditions and the presence of textural contrasts

- Set up leaching experiments under field conditions in Buckeye (AZ).

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