A Comparison of Sequential and Conventional Flood Irrigation Under Field Conditions

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Introduction

- Soil salinity poses an increasing global threat to sustainable agriculture, adversely affecting crop quality and productivity. Salinity is commonly ameliorated by means of flood irrigation in conjunction with tile drains. This practice not only consumes excessive amounts of water, but can also have undesirable side effects.
- Experimental and theoretical evidence suggests that surface flooding promotes faster flushing of salts from areas directly above the tile drains. However, salt leaching from areas between the drains is less efficient. While it has been demonstrated in laboratory experiments (*Mirjat et al., 2008*) and via numerical computer simulations that partial sequential flooding (PSF) is more efficient in leaching salts than conventional flooding (CF), its performance under actual field conditions has yet to be documented. With the goal to reclaim a salt affected field under commercial farming conditions in Arizona (Fig. 1), the performance of both strategies was evaluated based on pre- and post- flooding electromagnetic induction (EMI) surveys with a Dualem-1S sensor.

Figure 1: Soil pit on a field with salt affected sorghum cultivated before the experimental plot was established.

Materials and Methods

- An 90 m wide and 60 m long experimental plot (Fig. 2) was established on a salt affected field at a commercial farm in Palo Verde (AZ).
- The experimental field is commonly planted with either sorghum (Fig. 1) or barley and flood irrigated with reclaimed municipal waste water. Tile drains run parallel to the field slope at a depth of 1.5 m with 15 m spacing.
- The experimental plot was divided into 10 sub-plots (7.5 m x 53 m), which each were subdivided into three 2.5 m wide and 53 m long strips (Fig.3). PSF and CF treatments were randomly assigned to 5 subplots each, which corresponds to treatment replicates.
- Before and after flooding the field was surveyed by a Dualem-1S electromagnetic induction sensor, geo-referencing the data with a Trimble XH GPS at sub meter accuracy. Readings were taken by walking the sensor along every strip (30 transects), while taking one reading every 2 seconds (1746 pre- and 1779 post treatment readings).
- In addition, monitoring points were marked every 10 m on each strip (150 points total) to take Dualem-1S readings exactly on the same site pre and post irrigation.

Figure 2: Location of the experimental site in Palo Verde AZ and a panoramic view of the site before establishing the experimental plot.

Materials and Methods - Continued

- Both flooding treatments were applied at the same time; CF consisted of 29.5 h flooding of the entire sub-plot, as has been traditionally done by the grower to reduce salinity in the top 0.6 m of the profile; PSF was applied as depicted in Fig. 3.

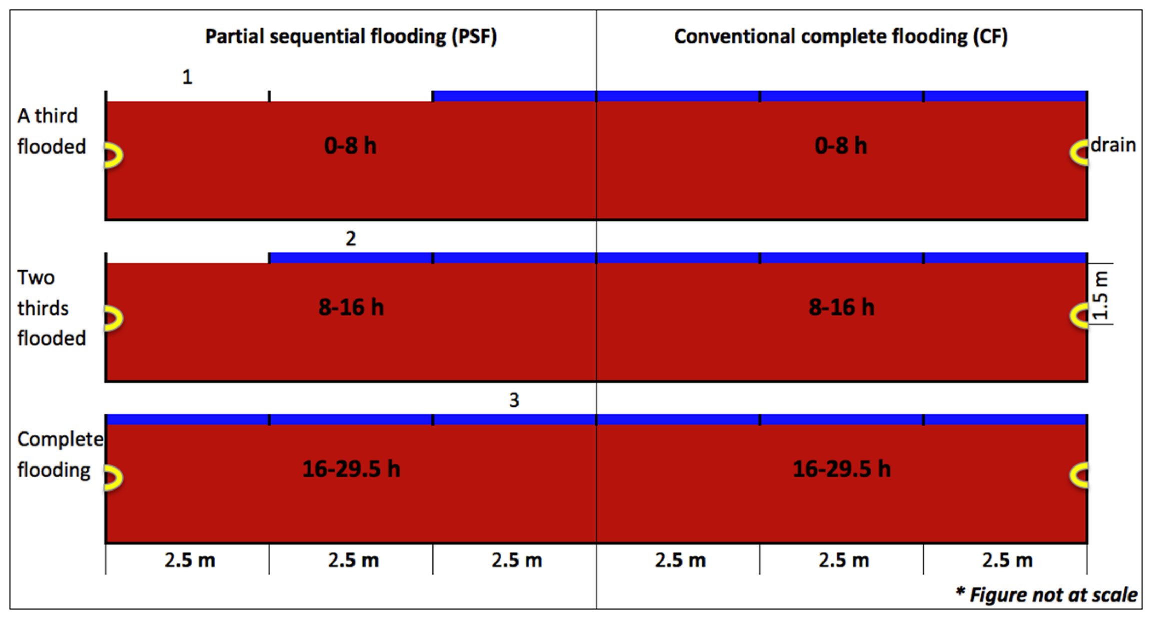

Figure 3: Experimental plot setup with PSF (left) and CF (right) treatments. The blue bars indicate the flooded areas.

- Dualem-1S survey data was processed with ESAP (*Lesch et al., 2000*) to select sampling points (10 pre- and 12 post-irrigation), where soil samples were taken at 3 depths (0.3, 0.6, and 0.9 m). Soil samples were analyzed for particle size distribution, water content and electrical conductivity (EC). The data was used to calibrate the Dualem-1S data.
- Dualem-1S calibrated data was then further processed with ArcGIS to study spatial distribution patterns, and source information for statistical comparison of flooding methods.

Preliminary Results

- HYDRUS modeling results indicate that both treatments lead to distinctly different leaching scenarios. The seepage collected with the drains is significantly higher for CF than for PSF irrigation management (Table 1).

Table 1: Simulated cumulative seepage flow of drain per each 53 m long plot replicate (m^3)

Treatment	Cumulative flooding time (h)		
	8	16	29.5
CF cumulative seepage flow (m^3):	0.00	6.98	21.79
PSF cumulative seepage flow (m^3):	0.00	0.00	9.22

- Figure 4 shows that both treatments are effective in lowering the salt content in the top 90-cm of the soil profile, thus improving the soil for the next crop.
- EC_e was reduced by 50% on average for the entire plot. However, the changes were between 8 and 80%.
- Highest relative salinity reductions (Fig. 4, center plot) were observed in areas with the highest salinity concentrations, which may be indicating the presence of high concentrations of rather soluble salts before start of the experiment.

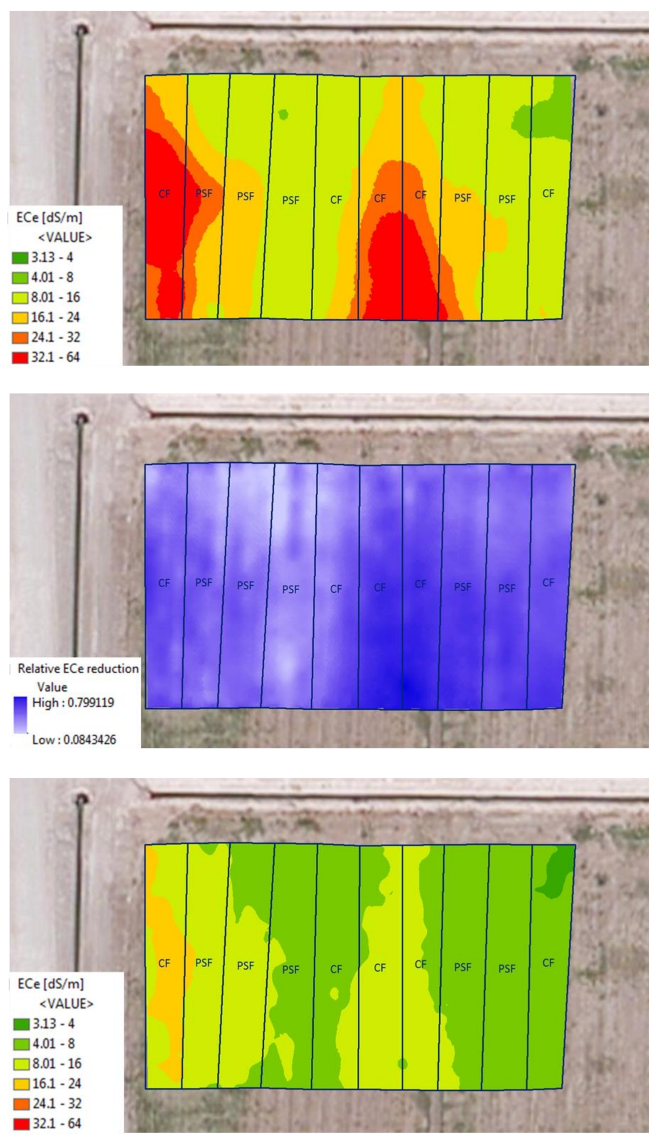

Figure 4: Average EC_e for the top 90-cm of the soil as estimated via kriging before and after treatments, top and bottom figures respectively. Center plot depicts relative EC_e reduction as consequence of flooding treatments.

Preliminary Results - Continued

Figure 5: Simultaneous application of CF and PSF irrigation.

- The observed differences in average EC_e reductions between both treatments were found to be significant ($p>0.11$) based on the F-test. We believe that using only 3 strips per replicate reduced the impact of PSF on generating a more uniform leaching pattern, compared with a 4 step flooding like it was proposed by *Youngs and Leeds-Harrison (2000)*, and this might have reduced its efficiency.
- However the approximately 20% more salts that CF removed from the target zone compared to PSF, comes at the cost of using more than twice as much water (Table 1). Increasing drain outflow has also other negative impacts like off site contamination, and removing of excessive amounts of nutrients beneficial for crops like nitrogen or phosphorous.

Ongoing and Future Work

- The data collected from the flooding experiment is being used to calibrate a HYDRUS-2D/3D model (*Šimůnek et al., 2016*). The calibrated model will then be used to inform additional field trials with different flooding scenarios.
- Applying PSF with four divisions or strips per replicate is an alternative that should be tested in the field, as preliminary computer modeling has shown that it can potentially improve the leaching uniformity. Unfortunately, for this first experiment the drain spacing and the machinery available at the experimental site did not allow for more than 3 strips per replicate.
- Once the HYDRUS-2D/3D model is properly calibrated we envision using it to provide economical optimization of flooding time for different crop rotations, based on variables such as soil salinity, crop tolerance to salts, and water resources costs.

Acknowledgments

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