

Influence of Soil Profile Characteristics on the Efficiency of Water Management Practice in Northeast Florida

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Abstract

The physical and hydraulic characteristics of a typical sandy soil profile lying in the Tri-County Agricultural Area (TCAA) of northeast Florida were studied. The efficiency of the conventional water management practice, called as 'seepage irrigation' was also investigated using a simple conceptual model of the field water balance based on the soil properties and the nature of the irrigation system. Seventy soil samples collected from 22.5cm, 45cm, 67.5cm, 90cm, and 120cm were studied for the particle size distribution (PSD), bulk density (D_b), saturated hydraulic conductivity (K_s), and water holding capacities. The results showed that the soils at the surface and near the crop-root zones had very low clay content, low water holding capacity and high saturated hydraulic conductivity. The results also suggested that the soil properties changed significantly at 120cm (below 90cm) depth indicating the presence of an argillic layer of low permeability in the soil profile. The results showed that the total amount of water loss from a during a typical potato season was as high as 77% which could go up to 87% depending on the amount of precipitation. Daily water losses by surface runoff ranged from 45-75% of the total irrigation supply depending on the time of the crop season while the water loss via SLF varied from 16% to 22%. The overall efficiency of seepage irrigation in 2006 and 2007 was 27% and 23% respectively suggesting that the system was highly inefficient despite its manageability and effectiveness in the sandy soil profiles of TCAA.

Key Words

Soil profile characteristics, water management practice, Florida

Introduction

Northeast region of Florida lying along the Atlantic coastline is the most important potato production area in the state. Majority of the potato farms in this region are concentrated in the Tri-County Agricultural Area (TCAA) spread in St. Johns, Putnam and Flagler counties. These potato farms are estimated to produce approximately 65% of the total potato production in the state annually (Mylavarapu *et al.*, 2008). Soils in TCAA are mostly dominated by sand with a very small amount of clay and silt particles and therefore have a very low water holding capacity near the crop root-zone. Water management system in the area is typically based on a conventional seepage irrigation system which also covers most of the gravity-flow irrigated farms in Florida (Smajstrla and Haman, 1998). In this system, the water table is maintained near the crop root-zone during the entire cropping season (Campbell *et al.*, 1978) with the help of open drainage ditches and appropriately spaced water furrows. Water is then supplied to the crop root zones by capillarity and subsurface lateral flow (Pitts and Smajstrla, 1989). This system is preferred to other systems because of its cost effectiveness and low maintenance requirement (Haman *et al.*, 1989) while being simple to operate and effective for crop production (Bonczek and McNeal, 1996).

Despite the effectiveness and popularity, the efficiency of conventional seepage irrigation system is reported to be low, ranging from 20-70% (Smajstrla, 1991). The system requires continuous pumping of water into the field throughout the crop season as the water needs to be precisely maintained just below the crop root-zone. A large portion of water is lost by surface and subsurface runoffs not only reducing the efficiency by a great magnitude but also increasing the potential for nutrient leaching and subsequent water quality impacts. This study investigated the physical properties of a typical seepage irrigated soil profile in the TCAA by collecting soil samples from five different depth up to 120cm. Based on the soil properties and the irrigation system. Daily amounts of water loss via surface runoff (RO) and subsurface lateral flow (SLF) from the seepage irrigated field was also estimated for 2006 and 2007 potato seasons with the help of a conceptual water balance model. The conceptual model was developed based on the soil physical properties and the nature of irrigation system and water loss calculations were performed using simple equations based on daily irrigation supply and evapotranspiration (E_t) loss.

Materials and Methods

The study was performed in a 4.7ha (approx. 260m × 182m) seepage irrigated field of UF/IFAS' Research and Demonstration Site located at Hastings in St. Jones County, Florida. The field resembled a typical TCAA agricultural field and consisted 14 crop-beds each approximately 17.2m wide each of which was further divided into 16 rows raised approximately 25cm above the alleys (furrows between each crop row). Seventy soil samples were collected from a typical seepage irrigated field at five different depths: 22.5cm, 45cm, 67.5cm, 90cm, and 120cm using a core sampler and an auger. The measured physical properties included the particle size distribution (PSD), bulk density (D_b), saturated hydraulic conductivity (K_s), and volumetric water contents (θ_v) at different pressures.

Water balance components of the experimental field were recognized based on the nature of the soil profile and the irrigation method and a conceptual model (Figure 1) of the water balance for a typical seepage irrigated field was developed in order to estimate the total water loss from the field. The typical water balance of the field under water table control comprised five components. The inflow components, which consisted of irrigation supplied into the field, and lateral inflow from adjacent fields. The water loss component, on the other hand, comprised RO, SLF and Et losses. Vertical water movement is stopped during irrigation because of either the presence of the impermeable layer (perched water table condition) or the absence of the potential gradient in vertical direction due to the rise of ground water table. Therefore, it could be assumed that the system was in a steady state where the amount of irrigation applied was equal to the losses due to Et and the subsurface lateral drainage. Due to the nature of the irrigation system, subsurface lateral flow was considered to constitute the major portion of the total runoff in the field. Calculation of subsurface lateral flow (SLF) in a water table management system was given by Skaggs (1980) in the model DRAINMOD. Because of the high similarity of the water management system of the study site to the system described in DRAINMOD, the SLF was calculated using the equations given in the model. Once the SLF was calculated, the RO was obtained using the mass balance under the assumption of steady state condition. The rainfall and Et data necessary for the study were obtained from the Florida Automated Weather Network (FAWN, 2008).

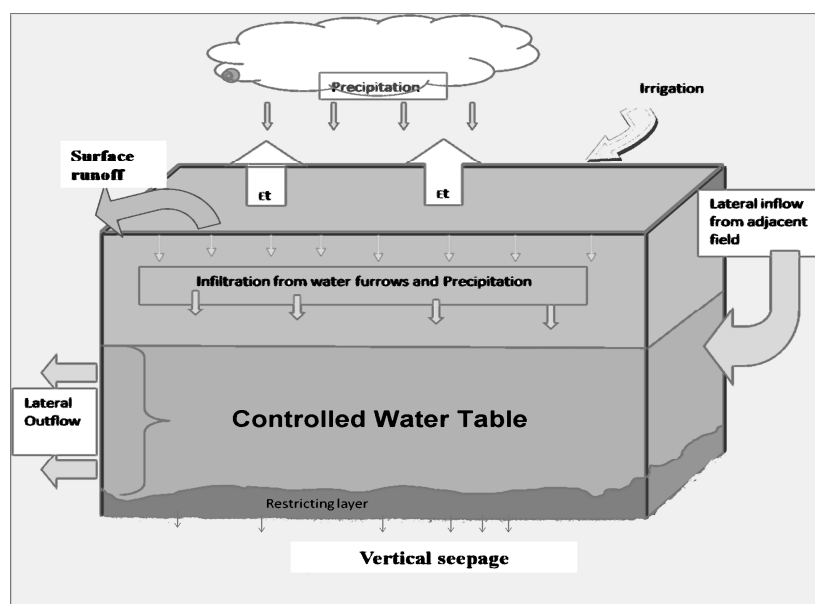


Figure 1. Conceptual representation of field water balance in a typical seepage irrigated field in TCAA.

Results and Discussion

The %clay, D_b and K_s changed significantly as the depth of the soil profile increased. Clay content at 90cm and 120cm were significantly higher than the first three depths (P -value < 0.001). The K_s of the soil decreased significantly at the 90 and 120cm depths while the K_s values of the first three sampling depths were similar. There was no significant difference in the water holding capacity of the soils up to 68cm depth from the surface which was possibly due to very low clay and organic matter content throughout the soil layers. The soil properties showed least variation at 120cm depth with an increase in variance at shallower sampling depths. Among the properties K_s showed the highest variability both within as well as between the sampling depths. The increase in %clay and D_b with decreased K_s values at deeper layers could be attributed

to the continuously shallow water table environment. Soils in the TCAA are continuously wetted by the high water table at an average depth of 40-50cm during most parts of the cropping seasons. Continuous flushing of the profile by fluctuating water table enhances illuviation of clay from upper soil layers which deposit in the lower soil layers. Deposition of fine clay particles tends to decrease K_s of a soil horizon because these fine particles occupy the void spaces between coarse sand particle sand reduce the porosity of the medium. During 2006 and 2007 growing seasons, the average daily water supply into the field was approximately 583,200 L, out of which a major portion was lost drainage (RO and SLF). The average daily, water-loss from the field during the 100 days potato season was approximately 421,860L in 2006 and 444,500 L in 2007 which respectively represented 73 % and 77% of the total irrigation supply. The amount of water loss was highest at the beginning of the season, with the water loss volume of as high as 90% of the irrigation supply. This was because of the low E_t losses from the field as there is little or no vegetative cover at the field surface.

Surface runoff losses accounted for approximately 53% of total irrigation in 2006 and 57% in 2007 while SLF losses were estimated approximately 20% for both seasons ranging from 16% to 22%. Surface runoff from the water furrows decreased as the growing season advanced while SLF did not change significantly. In February 2006, average daily RO loss was 456,815 L which reduced to 348,937 L in March and during the last two months the quantities of RO losses were less than the average daily losses observed during previous months by a magnitude of more than 100,000 L. A similar water loss trend was observed in 2007 as well. Surface runoff was as high as 450,000 L per day in February which continuously decreased during the following months. This suggested that as the E_t rate increased with the crop growth, hydraulic gradients in the soil also increased and as a result more water was drawn into the soil consequently reducing the RO volumes. It was further supported by average SLF observations that showed little change from February to May. In 2006 average daily SLF loss in February was 94,231L while in May it was 128,066L. The results were similar for the 2007 growing seasons as well. Evapotranspiration and RO showed an inverse relationship across the growing period while SLF showed statistically insignificant yet a gradual increase. These results suggested that, although the changes in average SLF were very small from February to May, it increased with increase in E_t form areas around the border of the field. Since E_t losses occur also from the surrounding road surfaces it can increase the gradient across the border causing more water to flow laterally towards the ditch or the adjacent fields.

Conclusions

This study showed that the soil properties in the TCAA changed significantly in terms of the texture, bulk density, water holding capacity, and the soil water movement with increasing depth. Presence of an argillic layer with low permeability was evident in the results which showed significant increase in clay content and D_b , and decrease in the K_s at 120cm depth. Observations of the low water holding capacity along with very high K_s of the soil near the crop root-zone also suggested that subsurface seepage irrigation system was highly relevant for the potato and vegetable farming practices in TCAA. Precise control of the water table near the root-zone, avoids any moisture stress to the crops which would be highly likely to occur under other irrigation systems.

The study also estimated that the total amount of water loss from a typical seepage irrigated field during a 100 day cropping season was up to 77% of the total irrigation supply under little or no rainfall conditions. Under normal rainfall conditions, the water loss could be as high as 87% of the total water received by the field. The average efficiency of irrigation water use was approximately 27% in 2006 and 23% in 2007. Water loss by surface runoff from the water furrow was highly dependent on the E_t rate, showing an inverse relationship. Despite the manageability and effectiveness of seepage irrigation, the aspects of water use efficiency under seepage irrigation should not be overlooked as it could potentially hasten the loss of nutrients and chemicals into the drainage waters. The results obtained from this study have therefore provided a basis for further research towards developing better water management alternatives to meet the best management practice (BMP) goals implemented in TCAA. The estimated results of water loss are however preliminary and need to be confirmed with the field measured water loss data. Currently further studies on the development of a water table management model in the TCAA are under way.

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