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Evaluation of Surface Water Quality on Soil Leaching Fraction and Alfalfa Yield in the Delta

***Principal Investigators*:**

Michelle Leinfelder Miles (Principal Investigator)
Cooperative Extension San Joaquin County, UCANR

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Project Summary

The Sacramento-San Joaquin River Delta region – for its soil type, climate, and water sources – is a unique agricultural region of California. Diverse crops grow in the Delta region, but alfalfa is a particularly important one. According to the Agricultural Commissioners of the five-county Delta region, alfalfa was grown on approximately 72,000 acres in the Delta in 2012, making it the second most widely grown crop. Border check flood irrigation using surface water is the primary method of irrigation in Delta alfalfa.

As a forage crop, the marketed product of alfalfa is the vegetation, or alfalfa hay. Hay yields are directly related to crop evapotranspiration (ET), or the water transpired by the crop plus the water evaporated from the soil. As crop ET increases, so does alfalfa yield up to maximum ET. Nevertheless, agronomic and economic reasons put constraints on this relationship. For example, irrigation must be managed properly due to the susceptibility of alfalfa to Phytophthora root and crown rot disease. This is a common disease of alfalfa and occurs in poorly-drained soils or when the water application to meet the crop water requirement exceeds the capacity of the soil to take in the water.

In the Delta region, soil salinity can also affect the relationship between evapotranspiration and alfalfa yield. In general, plants are stressed by saline conditions because they must expend more energy to take up water, leaving less energy for plant growth. This can cause plant stunting and reduced yields. To prevent harmful accumulation of salts, the soil profile must be leached periodically with an amount of water in excess of what is used by plant ET. The leaching fraction is defined as the minimum fraction of the total amount of applied water that must pass through the soil root zone to prevent a reduction in crop yield from an excess of salts. Leaching occurs whenever irrigation and rainfall exceed ET (Hoffman, 2010).

Two factors establish the leaching fraction. One factor is the salt concentration of the applied water, as irrigation and rainfall. Salinity of applied irrigation water can vary substantially in the Delta based on time of year and location. The other factor establishing the leaching fraction is the salt tolerance of the crop. Some crops are more tolerant of salinity than others; alfalfa is moderately sensitive. Beyond a soil salinity threshold (ECe) of 2.0 dS/m, alfalfa yield reductions are expected (Ayers and Westcot, 1985).

Excess soil salinity in the Delta is a sporadic problem in the short term – varying with the quality of the surface irrigation water, depth and quality of the groundwater, and volume of winter rainfall. Water tables in the area are typically within 1.5 meters of the soil surface, and the groundwater quality is near the threshold water quality tolerance for alfalfa (ECsw) of 1.3 dS/m. Additionally, many Delta soils growing alfalfa are rated in the slow and very slow permeability category.

At an ECe of 2.0 dS/m and an ECsw of 1.3 dS/m, the leaching requirement (LR) necessary to maintain alfalfa yields is calculated using the equation $LR = ECsw/[5(ECe) – ECsw]$ (Ayers and Westcot, 1985), and therefore, is 15% of the total applied water. If a 15% leaching requirement is not possible due to poor soil permeability, proximity of groundwater, or other agronomic considerations, lower salinity irrigation water may be necessary to maintain yields. Thus, soil salinity will continue to be an issue in the Delta in the long run, especially under conditions of reduced water flows or a higher surface water salinity standard.

The surface water salinity standards, or objectives, for the south Delta were established by the California State Water Resources Control Board in the 1978 Delta Plan. The objectives were determined using knowledge of the soil types, irrigation practices, and salinity standards of predominant crops in the area (Ayers and Westcot, 1985). In particular, the objectives were based on the salt sensitivity of beans and alfalfa, and the maximum salinity of applied water that would sustain 100 percent yields for these crops. Since beans were the most salt sensitive summer crop, the objective for the months of April through August was set at 0.7 mmhos/cm (or dS/m), and the objective for the months of September through March was set at 1.0 mmhos/cm based on the sensitivity of seedling alfalfa. When the 2006 Bay-Delta Plan was adopted, these salinity objectives were not altered due to a lack of scientific information to justify a change (Hoffman, 2010).

The objective of this work is to gain knowledge on the current leaching fraction being achieved in south Delta alfalfa soils and update the state of knowledge on how surface water quality and rainfall affect the leaching fraction. The work being proposed will further a project that commenced in March 2013. With one growing season of soil and water monitoring already achieved, the proposed work will continue to assess the effect of surface water quality on the leaching fraction during the 2014 growing season, but it will also use the 2013-14 rainfall season to ground-truth the proposed effect of rainfall on spring soil salinity (Hoffman, 2010).
The knowledge gained from this study will provide current data to inform water policy that sets south Delta salinity objectives, and it will also assist growers with irrigation strategies for effective salinity management.

Methods:

The study will be conducted in seven commercial fields of mature alfalfa in the southern Sacramento-San Joaquin River Delta region. South Delta alfalfa fields will be selected based on similar soil characteristics but differing irrigation source water. In particular, the Merit, Ryde, and Grangeville soil series are of interest. These three soil series characterize over 62,000 in the San Joaquin County Delta, or 29% of the San Joaquin County Delta region. The Merit and Ryde series are silty clay loams. Merit and Ryde soils have a low saturated hydraulic conductivity (Ksat), approximately 10 mm/hr in the top 124 cm and 60 cm, respectively. The Grangeville series is a fine sandy loam, with a moderate Ksat of 101 mm/hr in the top 152 cm. Irrigation water in the South Delta is sourced from the San Joaquin River, including Old River, Middle River, and connecting canals and sloughs.

<u>Winter rainfall.</u> Winter rainfall for the 2013-2014 season will be measured using a tipping bucket rain gauge and data logger at one field site that is central for all seven sites, which are within an eight mile radius. Additionally, data will be collected from the Tracy CIMIS station.

Soil and groundwater sampling. Modified procedures of Lonkerd et al. (1979) will be followed during sampling. Spring soil samples will be collected after rainfall ceases and before irrigations commence, approximately March and April. Before sampling, holes will be augured, and the soil will be visually assessed for its representation of the Merit, Ryde, or Grangeville soil survey classification. Once visually confirmed as representative soils, samples will be collected from one border check per field. Each check will be measured and divided into "top," "middle," and "bottom" sections, where the top of the field is where irrigation water enters, and the bottom is where irrigation water drains.

Three replicate holes will be augered (4.5-cm diameter) each from the top, middle, and bottom sections. The holes will be augured in 30-cm increments to a depth of 150-cm. The three replicate-depths from the top, middle, and bottom sections will be composited into one bulk sample; thus, there will be 15 bulk samples collected from each field. Bulk samples will be oven-dried at 38 degrees C and ground to pass through a 2-mm sieve.

At the same time that bulk soil samples are taken, soil moisture samples will also be collected using a volumetric probe (60-cm^3). These samples will be collected from the center 7 cm of each 30-cm depth increment. After extracting the soil, it will be sealed in a metal can to prevent moisture loss. The soil will be weighed before and after oven-drying at 105 degrees C for 24 hours, and the soil moisture content (as a percent of the soil volume) will be calculated.

Groundwater samples will be collected by auguring until water is visually or audibly reached. The depth to groundwater will be measured, and a sample (200-mL) collected. Samples will be taken from the top, middle, and bottom sections. Water will be stored in a cooler until analyzed.

These procedures for soil and groundwater sampling will again be followed in the fall, after irrigations have ceased for the season.

Irrigation water sampling. Water samples (200-mL) will be collected when irrigation water is applied. Water will be collected at the top of the field from the source pipe or ditch. Water samples will be vacuum-filtered for clarity and stored in a cooler until analyzed.

Soil and water analysis. Soil salinity will be determined by measuring the electrical conductivity (EC) and chloride (Cl) ion concentration of the saturated paste extract, where higher EC and Cl indicate higher levels of dissolved salts in the soil. To conduct these procedures, a saturated paste extract will be made by saturating a soil sample with deionized water until all pores are filled but before water pools on the surface (Sparks et al., 1996). When saturation is achieved, the liquid and dissolved salts will be extracted from the sample under partial vacuum. The EC of the saturated paste extracts, and of the irrigation and groundwater, will be measured in the laboratory of UC Cooperative Extension in San Joaquin County using a conductivity meter (YSI 3200 Conductivity Instrument). Chloride in the saturated paste extracts and water will be measured at the UC Davis Analytical Laboratory by flow injection analysis colorimetry (http://anlab.ucdavis.edu/analyses/soil/227). We will calculate the leaching fraction for the seven sites and compare to the leaching requirement models for average root zone salinity, crop water use pattern (40-30-20-10), and the exponential model (Hoffman, 2010) in order to ground-truth these models with actual data for winter rainfall and seasonal irrigation.

Alfalfa Yield Sampling. Additionally, yield samples from each field will be collected from the first, a middle, and the last cuttings to investigate salinity effects on yield. Three 0.25-m^2 samples will be taken from each of the top, middle, and bottom sections of the field. Plants will be cut approximately 5-cm above the ground level, bagged, and weighed for fresh weight. Plants will then be dried in an oven at 60 degrees-C for 48 hours and weighed for dry weight.

Notable Achievements

With a primary objective of the proposed work being to gain knowledge on the leaching fraction actually being achieved in south Delta alfalfa, an anticipated outcome of the proposed work will be to update the state of knowledge, which dates back to the 1978 Delta Plan, and inform future policy on south Delta salinity objectives.

The proposed work will also benefit south Delta alfalfa growers – all of whom use surface water to irrigate their crops. The knowledge gained from this project on the actual leaching fraction being achieved will be extended to growers along with strategies for effective salinity management. This change in knowledge will assist growers in knowing how much water should be applied to leach salts in their fields, provided that there is the quantity and quality of water needed for leaching.