Irrigation and Nitrogen Management

Section 4

Irrigation and Nitrogen Management

We are now going to talk about irrigation water management and nitrogen management.

Irrigation and Nitrogen Management

Successful nitrogen management depends on efficient irrigation water management:

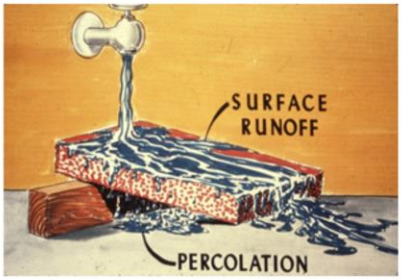
- Nitrate is mobile and moves with water.
- Inefficient irrigation may result in N-deficient crops and potentially add nitrates to groundwater.

- **Bottom Line: If you don't irrigate efficiently, you can't be an efficient nitrogen manager.**

Irrigation management can have a major effect on the "right place" component of the 4Rs. Since nitrate moves with water, nitrogen fertilizers may initially be deposited in the right place but may not stay there without careful attention to water management.

You can apply the right amount of N in the root zone, but N can leach past the root zone unless the correct amount of water is applied at the correct time.

Irrigation Efficiency



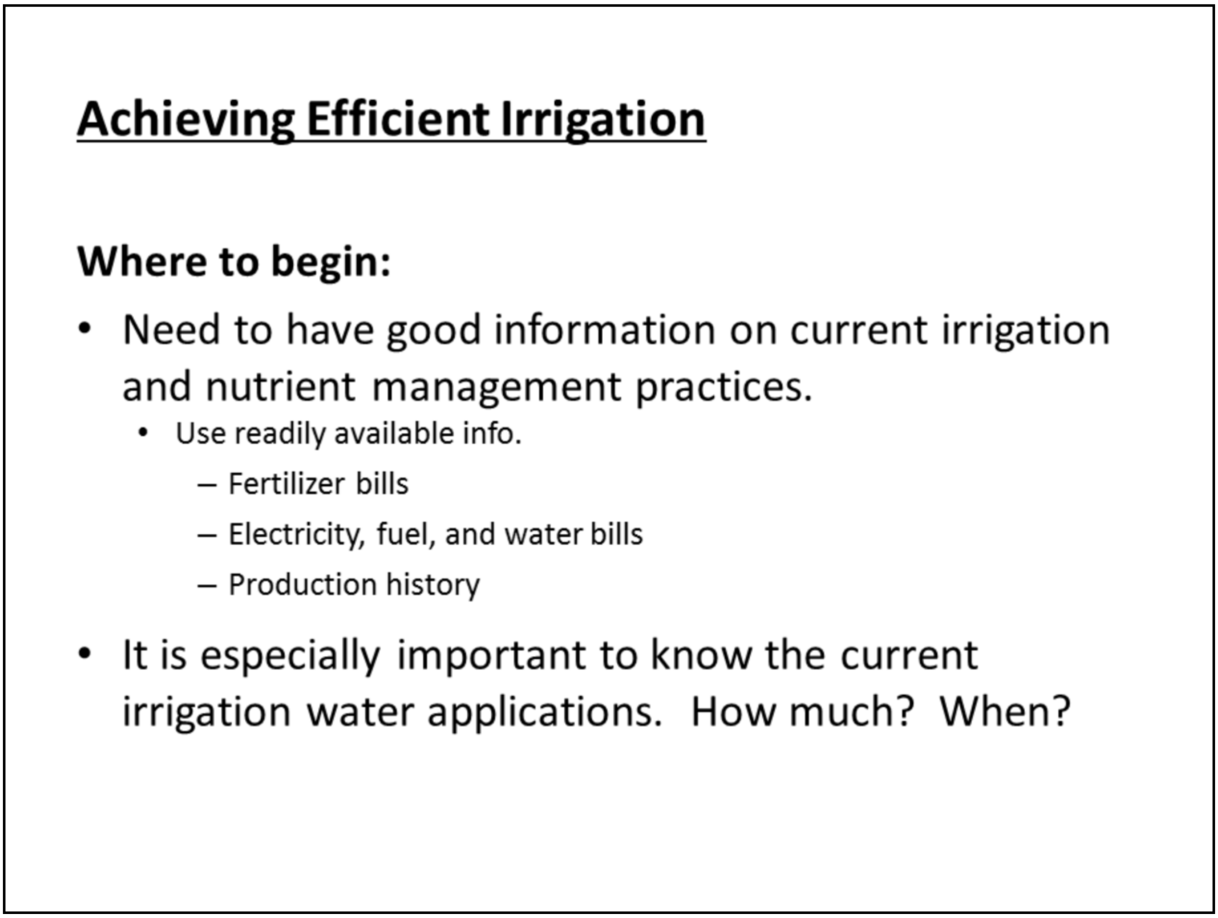
- Measure of how much of the applied water goes to beneficial uses.
  - The major beneficial use is to supply plant water needs and grow productive crops.
  - Non-beneficial uses or losses are:
    - Deep percolation below root zone except the amount needed to manage salinity.
    - Tailwater runoff that is not reused.

$$\text{Irrigation Efficiency (\%)} = \frac{\text{Benefically} - \text{used Water}}{\text{Total Water Applied}} \text{ x } 100$$

Other beneficial uses include salt leaching and frost protection, but both of these can lead to N leaching if not carefully done.

How Do We Become More Efficient Irrigators?

Where Do You Start?



As a first approximation, fields with high farming costs and low yields may indicate inefficient irrigation. While growers may lack data to quantify irrigation efficiency, they may track other farming costs and crop responses, listed on the slide, that can serve as indicators of inefficiency. The best information is direct measurements of applied water using a flow meter, but if that is not available, other available information is a place to start.

More in-depth irrigation evaluations can be performed at a later time to measure average applied water and irrigation distribution uniformity to confirm a field's efficiency and identify steps to improve it.

How Do We Become More Efficient Irrigators?

Know how much water to apply

Irrigation Scheduling

- Determining how much water to apply
  - Quantify how much water has been used by the crop since the previous irrigation or rainfall.
  - When the correct amount of water is applied at the proper time, potential for deep percolation and leaching of nitrate is minimized.

When the correct amount of water is applied, it is stored in the crop's root zone for later use by the crop.

Irrigation Scheduling: Soil Monitoring Approach

There are numerous soil moisture monitoring techniques, devices, and services available to growers.

"Feel Method," squeeze soil in hand to estimate its moisture level

Sophisticated devices continuously monitor soil moisture and upload data to online databases growers can check.

Since the plant is taking up water applied to and stored in the soil, monitoring soil moisture level can be used to determine **when to irrigate** and **how much** water to apply.

When: Soil moisture monitoring techniques range from the simplest "Feel Method" where you squeeze some soil in your hand to get an idea of how wet it is to sophisticated devices that continually monitor the soil moisture. With the most sophisticated sensors and radio telemetry equipment, it is possible for a grower to upload field information real-time and on demand. A **review of various soil moisture sensors** is available at*:* http://ucmanagedrought.ucdavis.edu/Agriculture/Irrigation_Scheduling/Soil_Moisture_Monitoring/.

Irrigation Scheduling: Soil Monitoring Approach: Drawbacks

- Most soil monitoring techniques tell when to irrigate, but not all provide how much to irrigate.
- Effectiveness is subject to representative placement of sensors and good understanding of the crop root zone.

How much: This can be answered indirectly by monitoring the soil moisture before and after irrigations. Was the soil profile refilled by irrigation? Was too much or too little water applied? Monitoring devices that allow continuous measurements using a data logger to store the information are extremely useful. The photos show some of the older, less expensive soil monitoring methods, but most can be retrofitted to collect and send continual data.

Note: Soil moisture monitoring can be challenged by soil variability and by limited numbers of sensors. This challenge is more likely to occur with drip irrigation, where moisture can differ drastically over short distances, so representative readings across a field are difficult. It can also be challenged by deeper rooted perennial crops if assumptions about root zone depth are incorrect and if too few sensors are used to monitor moisture in the root zone. This can affect decisions about the "when to irrigate".

Irrigation Scheduling: Plant Monitoring Approach

- Monitoring the plant itself for signs of water stress
- Relatively new approach, equipment and knowledge still developing


Traditionally, growers have used early, visual signs of crop stress such as wilting or color change to help decide when to irrigate. Today, technology exists to quantify crop water stress and make informed decisions. Some examples are provided in the above slide.

Left and right: Infra-red gun to monitor canopy temperature. A water-stressed plant closes its stomata, reducing transpiration (evaporation from the leaves). This causes the leaves to heat up, which is detected by the gun.

Middle: Pressure bomb. A leaf is cut and placed into the stainless steel cylinder on the left side of the device with the stem sticking out the top. Pressure is applied until moisture is forced out of the stem's cut surface. The more water stressed the crop, the more pressure is required to exude water from the stem. Guidelines for what a particular crop's readings mean are available for some of the major irrigated crops in California such as almond, walnut, French prune, wine grapes, and cotton. Some useful references are available at :
1) http://anrcatalog.ucdavis.edu/Details.aspx?itemNo=8503 (walnut, almond, prunes);
2) http://ucanr.org/sites/CE_San_Joaquin/files/35706.pdf (wine grapes) 3)
http://www.cotton.org/tech/physiology/cpt/plantphysiology/upload/CPT-v12No2-2001-REPOP.pdf (cotton)

Another technique is to "calibrate" by comparing plant readings before and after irrigations, similar to soil monitoring processes.

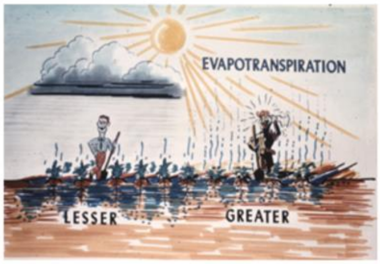
Irrigation Scheduling: Plant Monitoring Approach: Drawbacks

- **Limited information**, available for some crops & not for others
  - Interpreting pressure bomb readings and crop stress levels for most CA crops is unexplored
- Methods tend to be **labor intensive** – working toward automation
- Crop stress and readings tell you **when** to irrigate (plant is stressed) but not **how much**
  - How much water is needed can be learned with experience or by coupling plant monitoring with other approaches (i.e. ET)

While it is exciting to have a way to monitor a crop's water status, the timing for taking readings can be challenging. For example, pressure bomb readings are most reliable when taken mid-afternoon during high temperatures.

Irrigation Scheduling: Weather Monitoring Approach

- Climatic conditions drive the water use of plants.
- Monitor the weather and use it to estimate crop water use (evapotranspiration).

Climatic conditions, especially solar radiation, drive plant water use (Evapotranspiration or ET). Crop ET can be calculated by modeling the relationship between weather conditions and plant water use. Information from calibrated models is then made available to agricultural and urban water users through newspaper, radio, e-mail, web, etc.

A concise review of irrigation scheduling using crop ET calculations is available at:
http://ucmanagedrought.ucdavis.edu/Agriculture/Irrigation_Scheduling/Evapotranspiration_Scheduling_ET/

Irrigation Scheduling: Weather Monitoring Approach

California has the CIMIS network to provide weather information and estimates of **Reference Crop ET** (ET of pasture grass). That needs to be converted to the ET of the crop (ET_c) desired.

Date	ET_o Reference crop ET	k_c Crop coefficient	ET_c inches Crop ET
1June	0.25	0.95	0.24
2June	0.25	0.95	0.24
3June	0.25	0.95	0.24
4June	0.25	0.95	0.24
5June	0.24	0.95	0.23
6June	0.24	0.95	0.23
7June	0.24	0.95	0.23
		Weekly	**1.65**

$$ET_c = ET_o \times k_c$$

CIMIS is a network of weather stations, operated by the Department of Water Resources. Information from the stations is collected and used to determine evapotranspiration at each of the station locations.

Note: **Reference Crop ET (ET_O)** is the evapotranspiration of pasture grass. Further calculations are needed to estimate the ET of any particular crop (ET_C). ET_C must account for canopy development and size of crops.

Crop coefficients are available, especially for the major crops in CA. In general, it is easier to determine the crop coefficients of permanent crops than the crop coefficients of annual crops where planting dates and crop canopy vary.

The amount of water used by the crop since last irrigation is estimated as the crop evapotranspiration (ET_C). ET_C approximates soil moisture depletion and indicates **when** and **how much** to irrigate. Moisture depleted from soil should be replaced with irrigation. This is easier with microirrigation systems where water is being used and replaced frequently.

The crop ET_c is determined by multiplying the reference crop ET (Et_o) by a crop coefficient (k_c). In California, the reference crop ET_o is the ET of pasture grass. The crop coefficient is dependent on the crop and its developmental stage.

Irrigation Scheduling: Weather Monitoring Approach: Drawbacks

$$ET_c = ET_o \times k_c$$

- Models rely on weather measurements taken in irrigated grass pasture to predict reference crop ET_o.
- k_c values depend on the crop and phase of canopy development.
- k_c is a potential source of variability and error from one field to the next, especially with annual crops.
- Additional questions arise when the crop is deficit irrigated.

Like the other approaches - soil moisture and plant monitoring - there are challenges to estimating ET_C. Models rely on weather measurements taken in irrigated grass pastures to predict reference crop ET_O. Then ET_O is multiplied by crop coefficients (K_C) to compute ET_C. K_C values depend on the crop and phase of canopy development. K_C is a potential source of variability and error from one field to the next and creates additional questions when the crop is not fully (deficit) irrigated.

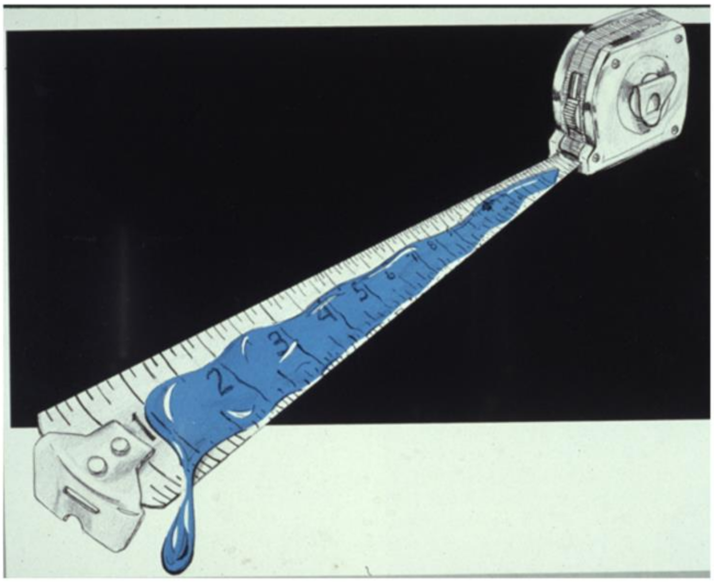
How Do We Become More Efficient Irrigators?

Once we know how much water we want to apply, then we need to apply the correct amount of water with a good irrigation system

Sound Irrigation System Design Concepts

- Ability to measure applied water and thus control leaching

Our ability to manage water improves if we have the ability to measure it.



While a first step is knowing how much water **should** be applied, a manager must also know how much water **is being applied** in order to irrigate efficiently and minimize leaching.

Sound Irrigation System Design Concepts

How much water is being applied? Measure with a flow meter

Saddle Propeller Meter, the most common type of flow meter, attached by cutting through the pipe. It is sufficiently accurate for agricultural purposes.

Electromagnetic flow meter, known as a MagMeter. It is a very accurate type of meter, but locating it near elbows and forks can decrease accuracy.

Propeller flow meters can be used to measure water in pipelines or tubing, but they are not appropriate for open channels. Velocity meters, weirs, and flumes are better suited for measuring water in open channels but require additional expertise.

One of the greatest challenges of using a flow meter is to relate flow information - in gallons, cubic feet per second, acre-inches, or acre-feet of water - to the crop ET information, given in inches per day, inches per week or even inches per month.

Rapid Assessment

Step 1 Determine soil moisture depletion since last irrigation (ET)

Corn water use at various locations

Corn (Planted April 1) ET (in/day)

	Location						
	Orland	Madera	Merced	Stockton	Modesto	Parlier	Visalia
May 1-15	0.04	0.04	0.04	0.04	0.04	0.04	0.04
May 16-31	0.05	0.05	0.05	0.04	0.05	0.05	0.05
Jun 1-15	0.13	0.14	0.14	0.13	0.14	0.14	0.14
Jun 16-30	0.22	0.24	0.24	0.23	0.23	0.24	0.24
July 1-15	0.31	0.30	0.30	0.28	0.28	0.29	0.29
July 16-31	0.30	0.30	0.30	0.28	0.28	0.27	0.29
Aug 1-15	0.25	0.28	0.27	0.25	0.25	0.25	0.27
Aug 16-31	0.17	0.20	0.19	0.19	0.18	0.20	0.20
Sept 1-15	0.09	0.13	0.13	0.07	0.13	0.13	0.14
Total*	23.79	24.88	24.59	22.52	23.51	24.03	24.64

Rapid Assessment is a 3-step process to determine whether the amount of water being applied exceeds the amount being used, in order to see if there is risk of leaching, known as deep percolation.

Step 1: A crop's ET information provides an idea of the amount of water used since the last irrigation.

Table: Corn's water use in inches per day (ET) at multiple locations. Daily ET amounts can be summed up since the last irrigation event to determine how much water the crop has depleted from the root zone. This is the amount which should be replaced with an irrigation. Irrigation in excess of this amount can lead to deep percolation and nitrogen leaching.

Early season irrigations of row and field crops often generate the most drainage water. This is because, at this time, the crop (e.g. corn) has a small root zone and low water usage, but still needs to be irrigated frequently. If surface irrigation is used, the necessary small but frequent irrigations are very difficult to achieve. This results in unnecessarily large irrigations and subsequent deep percolation.

Rapid Assessment

Step 2 Measure flow rate and determine how much water has been applied

- Flow meters the best way - on all pumps
- Irrigation District information
- Pump test - discharge will change (often a lot) if groundwater level changes.

Step 2. Determine how much water is being applied to a field so it can be related to the soil moisture depletion since the last irrigation.

Note: Pump test information can quickly become inaccurate due to changes in groundwater level or pump performance. Test results should be recent.

Rapid Assessment

Step 2 Measure flow and determine how much water has been applied (inches)

$$D = \frac{(Q \div 449) \times T}{A}$$

D = inches of water applied
Q = gpm (gallons per minute) flow rate
T = hours irrigation set time
A = acres in irrigation set

***If flow is measured in cfs, no need to divide by 449 in equation**

Step 2 (continued): This formula can be used to convert amount of applied water from the flow rate found in the previous step into inches.

Note: the formula can be altered to use Cubic Feet per Second (CFS) as the units for flow rate.

Rapid Assessment

Step 3 Is the risk of deep percolation high?

Compare the amount applied to the amount used since last irrigation.

- Leaching is likely to occur when runoff is minimal and applied water is greater than crop use since the last irrigation.

Step 3: Compare amount of applied water to amount of crop water use (ETc) since last irrigation.

Since ET information (Step 1) is also in inches, it can easily be compared to water applied in inches (Step 2).

If more water was applied than could be used, the risk of deep percolation is high and nitrate leaching is likely.

Sound Irrigation System Design Concepts

How much water is being applied? Irrigation system evaluation

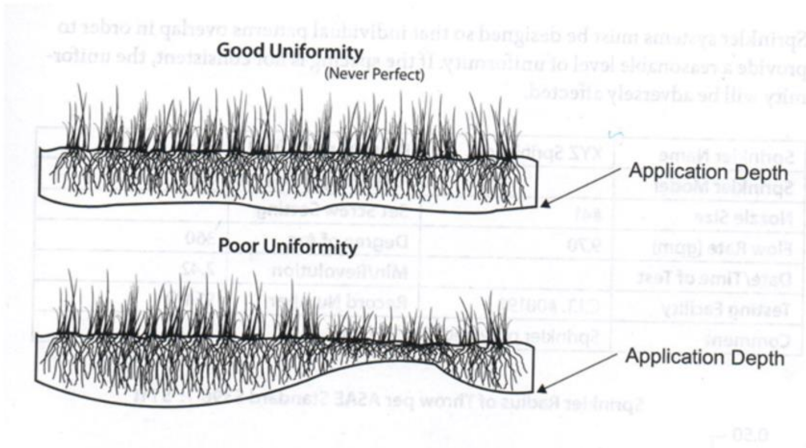
Water application rate and uniformity

For sprinkler and microirrigation systems, an irrigation system evaluation determines both the **average application rate** and a measure of the application rate variability, often called **the irrigation distribution uniformity**. While this is essential information for managing a pressurized irrigation system and the evaluations are not particularly difficult, relatively few growers have had their systems evaluated.

It is more difficult to evaluate performance of flood and furrow systems, but some simple techniques can be applied to gain perspective. Evaluations of surface irrigation systems need to be done by professionals.

Irrigation System Evaluation: Irrigation Uniformity

A measure of how evenly water is applied to the field



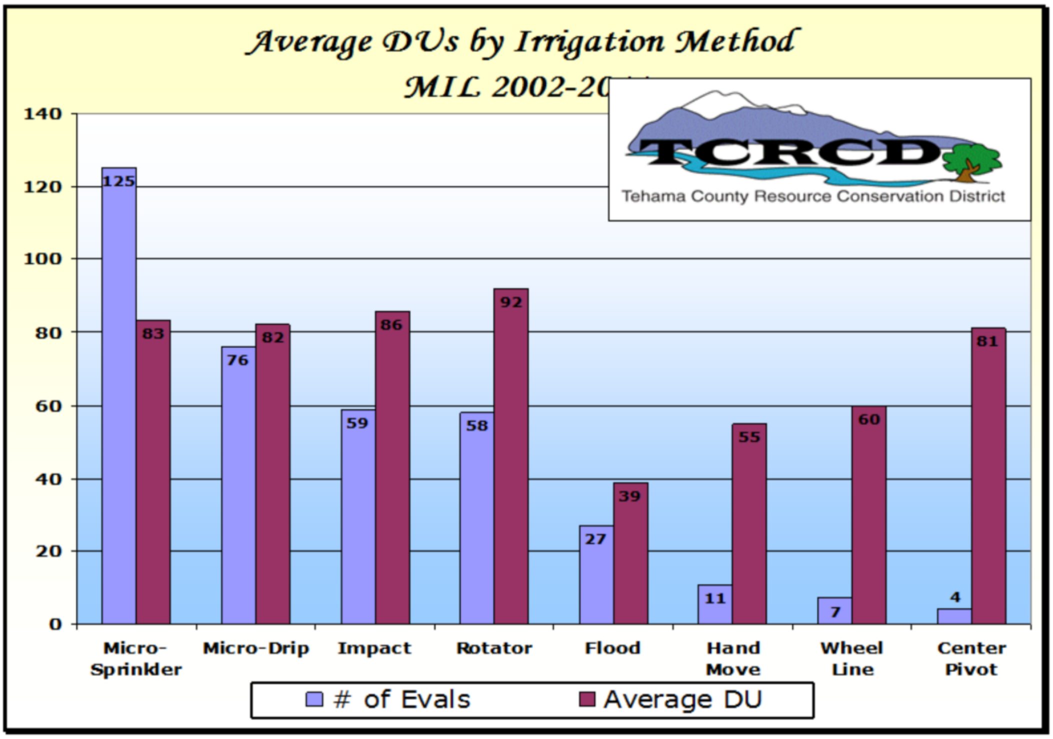
The second goal is to evaluate how evenly the water is applied, which indicates where in the field lies the greatest leaching risk.

Irrigation efficiency is given as percentage with 100 % being perfect.

Irrigation efficiency is quantified using various measures including Distribution Uniformity (DU), Coefficient of Uniformity (CU), and Emission Uniformity (EU), but knowing the general concept is more important than the details about the different measurement methods of irrigation uniformity.

Poor irrigation uniformity means that portions of the field are getting less water than others. Most growers do not want to under-irrigate even a portion of the crop, so they irrigate to make sure the area receiving the least water gets enough. With non-uniformity, some portions of the field receive too much water. Too much water leads to deep percolation losses (leaching of water), and if nitrate is in the soil profile, it can be leached with the water. Thus, poor irrigation uniformity makes N leaching more likely.

Irrigation Uniformities of Various Irrigation Systems



A uniform irrigation system is more likely to use water and N efficiently. However, the level of irrigation efficiency achieved and the amount of N leaching occurring still depends on irrigation scheduling decisions.

Figure: Data from 370 irrigation systems evaluated in the northern Sacramento Valley and Fall River Mills Valley. Many pressurized systems show ranges of 80-90% DU (distribution uniformity). In this data set, flood-type methods show significantly less uniformity. The uniformity achieved with surface depends on design and the field's soil properties. With good design, surface irrigation can achieve comparable uniformity. Features that yield uniform surface irrigation will be discussed later in this module.

Note: These evaluations were done by a **mobile irrigation lab** run by the Tehama County Resource Conservation District. The lab is a great resource for growers in the northern Sacramento Valley looking to have their irrigation system performance tested: http://www.tehamacountyrcd.org/services/lab2.html. **Other resources for this type of data** include Santa Clara County Water District, Yolo County Resources Conservation District, the Kings River Conservation District, and the Kern County Resources Conservation District, and the Irrigation Training Research Center, California Polytechnic State University.

Note: Rotator is Nelson Rotator, a brand of solid-set sprinkler

Types of Irrigation Systems

Lets look at different irrigation types of irrigation systems and see how they can be improved.

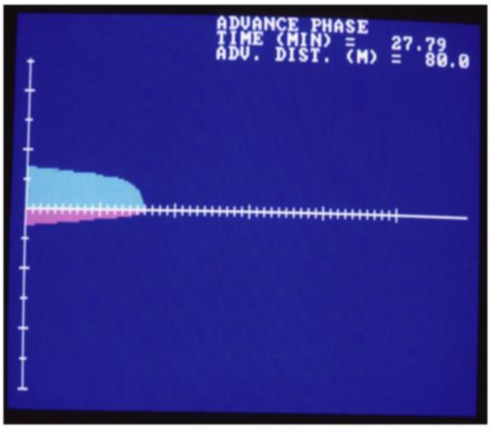
Surface Irrigation

Furrow and border strip irrigation

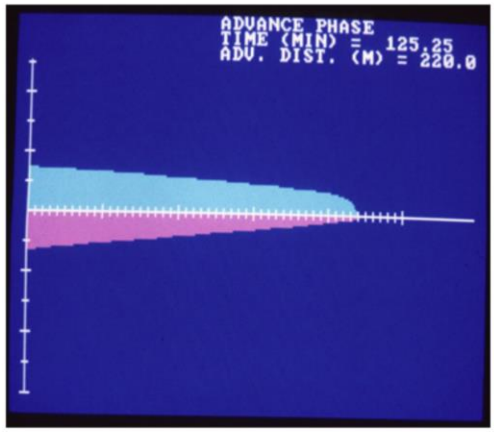
Surface Irrigation includes furrow and border strip irrigation, also known as flood irrigation or border irrigation. Water advances across the soil surface from one end of the field to the other, and the soil's infiltration rate controls the amount of water applied.

The following three slides illustrate the **water advance**, **surface storage**, and **infiltration** phases of flood and furrow irrigation and provide an example of a relatively uniform water application.

Surface Irrigation: Furrow Irrigation Example



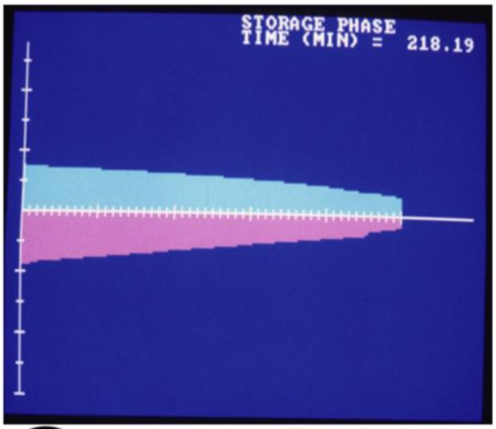
① Water flows field top to bottom in furrow irrigation. Blue segment represents water on field surface; pink is infiltration.



② More water has infiltrated at field head, where it has been present the longest.

Figures 1 and 2: Early stages of **water advance (light blue)** and **infiltration (pink)** with furrow and flood systems. During the early phases of a furrow or flood irrigation, the top of the field is irrigated while the bottom is not. There is more opportunity for water to infiltrate and leach the top of a surface irrigated field. The technical term for the time irrigation water is present at a location is “intake opportunity time”.

Surface Irrigation: Furrow Irrigation Example cont'd.



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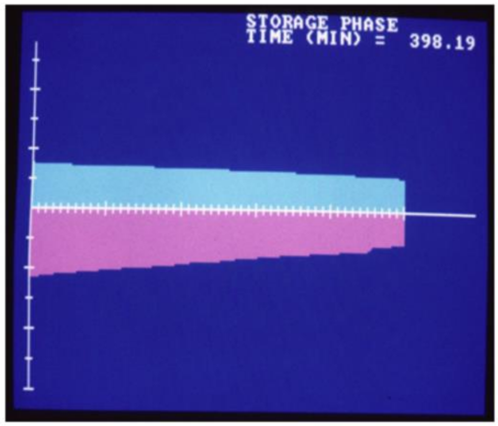
Water is run off the field tail to allow enough to infiltrate there to satisfy the crops' needs. The runoff should be collected and reused.



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End of irrigation event. Water has infiltrated field tail, and field head has received excess. This water goes to deep percolation, potentially leaching any N present.

Figures 3 and 4: Later phases of **water advance (light blue)** and **storage (also light blue**) of water on the soil surface that will continue to **infiltrate (pink)** even as tailwater is running off the field. This example represents a uniform furrow or flood irrigation pattern. Design choices concerning furrow or border inflow rates, field length, check width, field slope, and tillage that affect surface roughness and soil density will influence infiltration patterns. Efficiency of this example depends on depth of water applied, crop root zone, and soil moisture depletion at the time of irrigation. If these match closely, the irrigation should be efficient because the distribution uniformity is relatively high.

Surface Irrigation: Improvement with Shortened Field Length

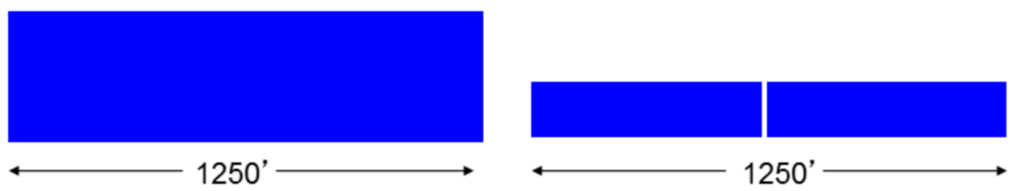
Shortening field length gets water across the field more quickly, resulting in less deep percolation.

Shortening field length can significantly improve furrow irrigation, though the prospect is not always well-received by growers. Shorter field lengths necessitate use of tailwater return systems and mean more labor and frequent set changes. Longer fields with less turning around of equipment can be more cost effective. Overall, shorter field lengths tend to be more expensive and less convenient to farm but they improve irrigation uniformity.

Surface Irrigation: Improvement with Shortened Field Length Example

- Reduce field length
  - Often the most effective option
  - Also often the least popular option since shorter fields are more difficult to farm.

	1250’ Field	**2 – 600’ Fields**
Irrigation Applied	**9.1”**	**5.4”**



In this example, cutting the field length in half resulted in needing only about half of the irrigation amount. Decreasing field length is usually the best method of sustaining higher flows per square foot of wetted area and accomplishing faster advance across the field. Irrigation set times must be reduced accordingly to realize efficiency. More information on this study and some others can be found here: http://cetulare.ucanr.edu/files/170597.pdf

Surface Irrigation: Improvement with Increased Field Slope Example

	0.001 slope	0.002 slope
Irrigation Amount Applied	5.1"	4.8"

In this example, increasing field slope decreased the amount of irrigation water necessary to irrigate the field, though it was not as effective as field length reduction. Changing field slope is often the first design feature considered.

Surface Irrigation: Improvement of Border Check Irrigation

Increase the flow per foot of border check

Field Study: Usually run 2 valves per check; make checks half as wide and run 1 valve at a time → more flow per foot of check width

	Wide check (200′)	Narrow check (100′)
Irrigation Water Applied	5.1″	4.3″

In this example, increasing flow per foot of check decreased the amount of water used. Irrigation set times must be changed to take advantage of the increased flow rate on to the field.

Note: Increasing flow in furrow systems tends to be even less effective than for border flood because it increases the depth of water in the furrows and the wetted soil surface. Increasing flow into a flood or furrow system is usually not as effective as reducing field length.

Surface Irrigation: Improvement with High Flow Rates

Water losses can be from deep percolation and tailwater runoff.

Losses from deep percolation and tailwater runoff are competing outcomes of surface irrigation management:

- Steps that improve irrigation uniformity and reduce deep percolation often increase tailwater runoff

Using high flow rates in surface irrigation causes the water to move across the field more quickly, resulting in improved irrigation uniformity. Since water still needs to “sit” at the end of the field for enough time to refill the crop’s root zone, there will be tailwater runoff generated. Some growers will practice cut-back irrigation in which flow to the field is cut back when the advancing water reaches near the end of the field. This reduces the water leaving the field as tailwater. Tailwater generated should be collected and reused, using a tailwater return system.

Surface Irrigation: Improvement with Torpedoes

Using a torpedo gets water across the field more quickly, resulting in less deep percolation.

A torpedo is a weighted steel cylinder dragged through furrows prior to irrigation. This smooths furrows, allowing water to advance faster, which increases uniformity. Using torpedoes along with other modifications like shorter field lengths, increased field slopes, higher flow rates, and tailwater return can yield cumulative efficiency improvements.

Surface Irrigation: Improvement with Torpedoes Example

Field study: Newly cultivated furrows, some "torpedoed" and some not

	Torpedoed Furrow	Non-torpedoed Furrow
Irrigation Water Appied	**9.4"**	**12.9"**

In this example, decreasing soil roughness, by using torpedoes, reduced the amount of irrigation water necessary, though it was not as effective as field length reduction.

Torpedo use is the most effective early in the season or after cultivation when the furrow is "rough". They are not as effective if used between irrigations where no cultivation has occurred.

Surface Irrigation: Improvement by Reusing Tailwater Runoff

Collecting and reusing tailwater runoff makes the best use of expensive and limited irrigation water.

Water is collected and carried to a sump pump by underground pipelines, where it is pumped to a standpipe for use.

A small pond is used to collect tailwater, which is then pumped back to the head of the field using a sump pump.

Tailwater return systems work in concert with the other improvements discussed that advance irrigation water more rapidly and apply water more uniformly with less deep percolation.

An additional benefit of tailwater reuse is that it keeps tailwateter, and any chemicals or constituents in it, on the grower’s land. The Irrigated Lands Regulatory Program applies to water leaving a grower’s land, so keeping water for reuse satisfies the regulation.

Surface Irrigation: What if these options for improvement are not practical or effective?

- A change in irrigation method may be needed

Generally, improvements in surface irrigation design result in higher costs and increased irrigation water management time and effort. Whether the improvements work well enough to cover the cost and effort is always an issue. In some cases, changes in method only need to target a specific irrigation event, such as pre-irrigation of annual crops. In other instances, a complete change in method makes sense, especially if there is potential to achieve corresponding yield or quality improvements.

It is also possible to target specific irrigation events (e.g. pre-irrigation of row crops using sprinklers instead of surface irrigation) to improve irrigation water management.

Often there will be a corresponding improvement in crop productivity when poorly performing irrigation systems are improved.

Pressurized Irrigation

- Invest in irrigation hardware and sound irrigation system design to gain more management control of applied water

Pressurized irrigation systems include **sprinklers**, **microsprinklers**, **surface drip**, and **sub-surface drip**. Amount of water applied is controlled by sprinkler *or* emitter choices, design features, and scheduling decisions. Investments are made in pressure regulators, filters, pipelines, and polyethylene tubing to control distribution and delivery of water and N. This is in contrast to surface systems*,* which largely allow soil infiltration properties to govern the distribution and efficiency of applied water and N.

Pressurized Irrigation: Sprinkler

- How can sprinkler system performance be improved?
  - Know the **application rate**
    - We provide water use information (ET) in units of "inches of water use (per day or per week……..)"
    - Need to know the system application rate (in/hr) in order to know how long to run the system

Use **ET_C** and the system's **application rate** to figure out how long the system should run in order to provide enough water. The following slide details how to calculate this application rate.

Pressurized Irrigation: Sprinkler Application Rate

Calculating sprinkler application rate:

$$\text{Sprinkler Application Rate (in/hr)} = \frac{96.3 \text{ x Nozzle discharge (gpm)}}{\text{Spacing along lateral line (ft) x Spacing between laterals (ft)}}$$

Sprinkler nozzle discharge can be determined from widely available tables or by measuring the discharge from sprinklers using a hose and bucket.

Given these terms, the one unknown piece of information in the formula is the nozzle discharge in gallons per minute. There are tables widely available for determining the nozzle discharge if the orifice size and operating pressure are known. The orifice size is often stamped on the side of the nozzle or can be measured by using a drill bit of known size. Some plastic nozzles are color-coded and manufacturer tables can be used to determine discharge rate. Operating pressure at the nozzle can be determined using a pitot tube (available from irrigation supply stores) attached to a pressure gauge. The pitot tube is placed in the water stream just outside the nozzle opening and the pressure gauge registers the operating pressure.

Using a hose placed over the nozzle discharge with the water directed into a bucket of known volume allows an easy way determination of the nozzle discharge. You just need to time how long it takes to fill the known-volume bucket and make the calculation of the discharge in gallons per minute.

Note: 96.3 is the unit conversion factor to transform gallons per minute into inches per hour. It comes from 60min/hr ÷ 7.48 gallons/ft^3 x 12 in/ft.

Pressurized Irrigation: Sprinkler Application Uniformity

- How can sprinkler performance be improved?
  - Determine and improve sprinkler application uniformity using a catch can test.

Determine uniformity with a **catch can test**. A consultant or mobile evaluation team can be hired to conduct this type of test and provide suggestions for improvement.

Sprinkler uniformity is particularly important in row and field crops since their root zones are not as extensive as are those of permanent trees and vines.

Note: Sprinkler application uniformity should be a minimum of 80%, and it is reasonable to expect it to be higher on calm days. If it is routinely lower than 80%, there is opportunity to make improvements.

Note: Sprinkler application uniformity should be a minimum of 80%, and it is reasonable to expect it to be higher (85 to 90% or higher) on calm days. If it is routinely lower than 80%, there is opportunity to make improvements.

Pressurized Irrigation: Microirrigation Systems

- Apply the correct amount of water – good irrigation scheduling.
- Apply it with a high uniformity system.

Irrigation is then efficient and uniform

Pressurized Irrigation: Microirrigation Application Rate

- You need to know how much is being applied (application rate) to match the irrigation requirement (from irrigation scheduling).
- Field sample emitter discharge rates to determine the application rate.

To irrigate efficiently, you need to know how much is being applied.

Field sampling of emitters also provides information on emitter clogging problems (if any). For more information on evaluating microirrigation systems, see: http://micromaintain.ucanr.edu/emClog/clogInfo/selfEval/

Since microirrigation emitter discharge rates are most often measured in gallons per hour (gph), it is often useful to convert ET rates (inches) to gallons per tree or vine. For trees and vines, the following formula can be used:

$$\text{Water use (gallons)} = \text{Water use (inches)} \times \text{Plant Spacing } (ft^2) \times 0.623$$

Information on determining drip tape application rates, used for row and field crops, is available at:
http://micromaintain.ucanr.edu/emClog/clogInfo/selfEval/SubsurfaceDrip/SDflowMeters/Drip_tape_systems_IV-13B/

Pressurized Irrigation: Microirrigation Application Uniformity

- Irrigation uniformity can be a problem with microirrigation systems too.
- What causes non-uniformity?
  - Poor microirrigation system design – pressure differences too great

Pressure differences that lead to non-uniformity are generally caused by **elevation changes** (left) or by **inappropriately sized pipelines or lateral lines**(right).

Note: Pressure differences can also be caused by retrofitting a system with enlarged nozzles or emitters - or by adding irrigated acreage - without assuring the existing system can handle the flow requirements.

Pressurized Irrigation: Microirrigation Application Uniformity

Pressure differences cause changes in rates of discharge, affecting uniformity:

The discharge rate (gph) of drippers and microsprinklers changes with the operating pressure.

- As the pressure increases, the discharge rate increases.
- For example, a 1 gph dripper is only 1 gph at a certain pressure (e.g. 15 psi). If operated at a higher pressure, the discharge rate is higher.

The discharge rate for drippers and microsprinklers really needs to be measured in the field.

The discharge rate varies as the pressure changes. As the operating pressure goes up, the discharge rate goes up. Each dripper or microsprinkler product has its own flow versus pressure characteristics, information which is available from manufacturers.

It is not enough to say that a 1 gph dripper is being used. It’s actual discharge rate varies depending on the pressure it is operating at.

Pressurized Irrigation: Microirrigation Application Uniformity

How do system designers address pressure differences that cause non-uniformity?

Pressure-compensating (PC) drippers (left) and microsprinklers (right) are used to equalize discharge when pressure is not constant.

PC drippers and PC microsprinklers have a nearly constant discharge rate across a range of operating pressures.

This results in a more uniform irrigation system.

Once the system reaches a minimum pressure, pressure compensating (PC) drippers and microsprinklers make discharge rates less sensitive to pressure variations.

PC drippers and microsprinklers are therefore a good tool to be used where there will be pressure differences in the irrigation system due to elevation changes or due to frictional pressure losses in the system.

Pressurized Irrigation: Microirrigation Application Uniformity

- What causes non-uniformity?
  - Maintenance problems
    - Clogging can lead to serious non-uniformity problems. Almost all clogging problems can be solved or prevented with good filtration and routine maintenance.

Clogging problems are most easily detected by a system evaluation which will pick up the clogging of microirrigation emitters. Delaying until emitters stop discharging due to complete clogging makes maintenance approaches to cure the problem very difficult.

Clogging can also be detected by closely monitoring the flow rate, using a flow meter, of the system. Decreasing system flow rate, measured at the same operating pressure, indicates that clogging is likely occurring.

Pressurized Irrigation: Microirrigation Application Uniformity

Maintenance Tips:

- Clean and flush filters regularly.
- Flush mainlines, submains, and lateral lines regularly.
- Monitor for leaks and breaks frequently.
- Check emitters for biological and chemical clogging at least twice per season.

Many types of sand media, screen, and disk filters are available for filtering irrigation water. They primarily remove course sediments and some biological contaminants. Surface water sources typically require more filtration than groundwater. Some of the filters have automatic backflush systems to ensure that they are regularly cleaned.

No filtration system will remove all fine sediments and microbiological contaminants in the irrigation water, so periodic flushing of lateral lines is necessary. Silt and clay are small enough to make it through filters but often settle in the lateral lines of drip tape and tubing. Flushing reduces the risk that sediment that has settled in the bottoms of hoses between irrigations will be re-suspended and enter drip emitters or nozzles when the system is turned on again.

Many of the most successful microirrigation system managers check for leaks and breaks every time the system is turned on. The picture (above right) shows where a microsprinkler has been broken off.

Emitters and nozzles should be checked for bacteria or calcium buildup. Groundwater is more prone to chemical precipitation problems while surface waters are prone to organic problems (bottom right).

Note: Filtration and line flushing **will not control** chemical clogging and all biological clogging. Chlorination, acidification, or other water treatments may be needed periodically. Knowledge of the irrigation water quality will help assess the chance of chemical clogging.

Fertigation

Application of a fertilizer through the irrigation system by mixing the chemical with the irrigation water.

Fertigation is the use of the irrigation system to deliver nutrients to the crop as it is being irrigated, commonly used with N fertilization. Additionally, irrigation water itself can be a source of N for crop consumption.

Fertigation in Surface Systems

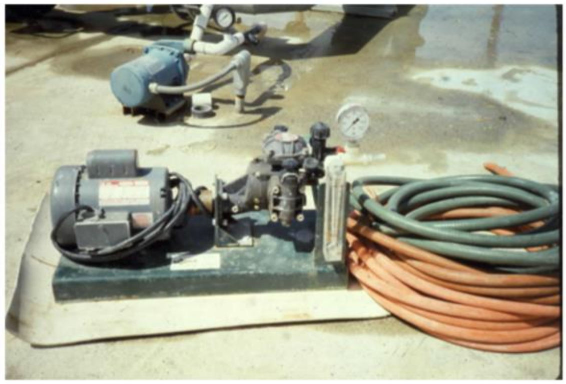
If there are deep percolation losses of irrigation water while fertigating, there is a good chance there will be N losses

In surface systems, soil infiltration rate influences how much fertilizer is applied, how it is distributed, and to what extent it is retained in the crop root zone.

Soil textures have unique infiltration characteristics, but all follow general patterns. Infiltration is higher when water is first applied (initial intake rate). This rate is influenced by existing soil moisture, soil structure/porosity from tillage, and cracks in dry soil. Rates then decline as soil aggregates and cracks swell closed with moisture. After a few hours, soil reaches a slower, stable infiltration rate (basic). If N fertilizers are injected at this point, the amount of fertilizer applied can be controlled and retained in the root zone.

Fertigation in Microirrigation Systems

- Material injected into the drip system should be applied as evenly (**uniformly**) as water applied by the system. Short injection periods are not good.
- Water needs to continue to run after an injection is stopped.



Positive displacement pumps available to inject fertilizers into pressurized irrigation systems. In the figure on the right, a Venturi/Mazzei suction or vacuum injection had been used, but the grower had switched to a positive displacement pump to get greater injection accuracy. Irrespective of injection method, other factors affect rate of fertilizer injected, uniformity of application, and how well it is retained in the root zone.

It takes time for water and injected chemical time to move through a drip irrigation system. This needs to be accounted for in order to achieve a uniform chemical application.

Fertigation in Drip Systems:

- Trees & vines: injections should last at least 1 hour for uniform application, and at least 1 hour of clean water irrigation should follow so that all fertilizer is delivered to the crop uniformly.
- Row crop drip with long lateral lines: injection periods may need to be even longer and periods of clean water after injection may need to be longer.

Note: For row crops, longer times assume longer rows and larger irrigation sets. Longer means longer than the 1 hour recommendation for tree and vine systems. When fertilizers or other water treatment products are injected too rapidly, there is insufficient time to distribute the fertilizer uniformly across the field. If fertilizer injections are not followed with adequate water, the fertilizer application will not be uniform and fertilizer may be left in the system to drain randomly, usually at lower elevations. Additionally, remaining fertilizer can foster biological growth and cause plugging.

Fertigation in Pressurized Systems

Goals: Timing of injection during an irrigation event

- Target fertilizer **in the root zone** where crop can use it
- Inject N during the middle to near end of an irrigation event.

Left: A venturi injector with a small pump used to inject fertilizers into pressurized irrigation systems. This eliminates the requirement that the venturi injector be plumbed across a pressure drop. Right: A differential pressure tank used for fertilizer injection. It is difficult to obtain a constant injection rate using such a tank.

Whatever injection equipment is used, it is important to time the injection so that the injected material stays in the crop’s root zone.

Remember that there needs to be a period of clean water irrigation following an injection so that the chemical is applied uniformly and there is not material left in the lateral lines.

Salinity: Tips for Leaching Salts and Not Nitrate

- Leaching is not necessary every irrigation or perhaps even every season but only when crop tolerances are approached.
- Periodic soil and irrigation water testing will help determine when leaching is needed.
- Leaching is most efficient in the winter when land is fallow or crops are dormant and should not coincide with critical periods of nitrogen uptake and fertilization.

These are tips to consider when it is necessary to leach salts but not not nitrate from the soil profile. Salinity leaching may or may not be needed every season. Soil and water testing will help determine when leaching is necessary and how much is needed. In general, irrigating with high salinity water or under-irrigating may lead to a greater need for salinity leaching. To the extent possible, time irrigations to leach salinity during fallow or dormant periods. This will avoid periods of crop growth and development when nitrogen is needed.

Rainfall

- Rainfall can be a source of water for leaching.
- We have little control over the amount and timing of rainfall.
- Can we control the N available to be leached at the time of rainfall?
  - Coordinate timing of N fertilizers with the period of highest crop demand
  - Apply reasonable rates for crop production levels
  - Minimize amount of N in the root zone going into rainy season

Rainfall can be a challenge when trying to minimize nitrogen leaching. We want rainfall to infiltrate and refill the soil profile and in many cases to recharge the groundwater, so minimizing the nitrogen in the soil going into the rainy season is the best method of reducing nitrogen leaching.

Summary

Efficient irrigation practices are critical to good nitrogen management. If you control your irrigation water leaching, you will control your nitrogen leaching. To do this, we talked about:

1. Use weather, soil moisture, or crop stress information to understand irrigation needs.
2. Measure applied water.
3. Design and maintain high performing irrigation systems.
4. Be aware of your options for improving irrigation efficiency.

Good Irrigation Water Management (putting on the correct amount of water, at the correct time, with an efficient irrigation system) is critical to good nitrogen management. Bottom line is that if you minimize the amount of water you leach, you minimize nitrate leaching. We talked about ways to accomplish this.