University of California

Nitrogen Management Training

for Grower Nitrogen Management Plan Self-certification

A training program developed in cooperation with:

California Department of Food and Agriculture -- Fertilizer Research and Education Program
and
University of California

University of California
Agriculture and Natural Resources

University of California

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for Grower Nitrogen Management Plan Self-certification

Original presentation materials developed by:

University Of California, Davis

- Patrick Brown
- Daniel Geisseler
- Allan Fulton
- Tim Hartz
- Stuart Pettygrove
- Terry Prichard
- Larry Schwankl
- Carol Frate
- Marsha Campbell Mathews

- Gabriele Ludwig, Almond Board of CA
- Asif Maan, CASS
- Rob Mikkelsen, IPNI
- Jerome Pier, Crop Production Services
- Sebastian Saa, Universidad Católica de Chile

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Irrigated Lands Regulatory Program (ILRP)

- Managed by Regional Water Quality Control Board
- Applies to all growers who irrigate commercial crops
- Board uses Waste Discharge Requirements (WDR) to specify what growers and coalitions must implement to protect groundwater and surface water.

Notes:

- Eliminating nitrates from drinking water is expensive and cannot be done with charcoal filters. Only by ion exchange, reverse osmosis or electrolysis, can nitrate be removed from water.
- Accounting for all the sources of nitrogen in the system - including mineralization, residual nitrogen and nitrogen in irrigation water – leads to more efficient use of nitrogen and fertilizer products. This saves the grower money and improves conditions in affected communities.
- *Note*: The dairy order to control nitrate groundwater pollution by confined animal feeding operations is also a part of the ILRP, but is not a part of this course.

Regulations: Waste Discharge Requirements

- Growers with irrigated lands must either join regional coalitions or meet WDR requirements individually.

- Coalition Tasks in the Central Valley:
  - Groundwater quality assessments and plans
  - Monitoring long term groundwater quality trends
  - Assess which BMPs protect groundwater quality
  - Surface water quality monitoring
  - Compilation of data submitted by growers and reports to Regional Water Board

Notes:

- Tasks carried out by the coalitions will be funded by the per acre assessment fees collected. The coalitions will also manage the certified nutrient management plans. After they compile data, average performances will be reported regionally.

- For a grower, preparing to meet WDR requirements individually is riskier and more burdensome than joining a regional coalition.

Regulations: Waste Discharge Requirements

- Growers are responsible for:
  - Annual Farm Management Plans
    - Review whole operation for possible impacts on ground and surface water
  - **Annual Nitrogen Management Plans**
    - Will require plan certification in 2016 if in high *vulnerability areas*
    - *Certification is by Certified Crop Advisor or certified grower*
  - Sediment and Erosion Management Plans where needed
  - Submitting data to Coalition or Water Board

Notes:

- For 2015 plan must be kept on site
- For 2016 plan must be certified
- Non vulnerable zones must fill out NMP but no certification required

Certifying Nitrogen Management Plans

Required if field located in a **high vulnerability** groundwater area

Coalition will identify which parcels are in high vulnerability areas (based on groundwater assessment report (GAR)

- Certified Crop Adviser with Nitrogen Training

  Any crop and any field

- Grower Self-Certification

  Owned or managed fields

Grower Self-Certification

- Requirements:
  - Nitrogen Management Training – 4 hours
  - Passing grade (70%) on test*
- Certification Period:
  - 3 years
- Re-certification
  - Continuing education– 3 hours in 3 years.

* Test can be taken multiple times

Notes:

- Nitrogen management training and passing test constitutes certification
- The 3 hours of continuing education provides for re-certification for the next 3 year period

Nitrogen Management Plan Certification Training

- Sponsored by **CDFA/FREP** Grant
- Project administered by Coalition for Urban Rural Environmental Stewardship (**CURES**)
- CCA presentations at grower meetings funded by FREP grant
- Coalition facilitates the training meeting

Nitrogen Management Plan Certification Training

- Regulatory Oversight of Grower Trainings
  - Water Board has approved this NMP training approach
  - Expect scrutiny to gauge effectiveness of the program
  - **CDFA** and the **coalitions** will audit presentations at grower trainings to ensure professionalism by CCAs

Nitrogen Management Plan Certification Training

- Provide information for:
  - Efficient use of nitrogen fertilizers
  - Minimize environmental impacts
  - Meet Regulatory compliance requirements
    - Nitrogen Management Plan

NITROGEN MANAGEMENT PLAN WORKSHEET

NMP Management Unit: ______________________________

1. Crop Year (Harvested):		4. APN(s):	5. Field(s) ID	Acres
2. Member ID#				
3. Name:				

CROP NITROGEN MANAGEMENT PLANNING		N APPLICATIONS/CREDITS	15. Recommended/ Planned N	16. Actual N
6. Crop		**17. Nitrogen Fertilizers**		
7. Production Unit		18. Dry/Liquid N (lbs/ac)		
8. Projected Yield (Units/Acre)		19. Foliar N (lbs/ac)		
9. N Recommended (lbs/ac)		**20. Organic Material N**		
10. Acres		21. Available N in Manure/Compost (lbs/ac estimate)		
Post Production Actuals				
11. Actual Yield (Units/Acre)		**22. Total Available N Applied** (lbs per acre)		
12. Total N Applied (lbs/ac)		**23. Nitrogen Credits (est)**		
13. ** N Removed (lbs N/ac)		24. Available N carryover in soil; (annualized lbs/acre)		
14. Notes:		25. N in Irrigation water (annualized, lbs/ac)		
		26. Total N Credits (lbs per acre)		
		27. Total N Applied & Available		

PLAN CERTIFICATION		
28. CERTIFIED BY:	**29. CERTIFICATION METHOD**	
	30. Low Vulnerability Area, No Certification Needed	
	31. Self-Certified, approved training program attended	
DATE:	32. Self-Certified, UC or NRCS site recommendation	
	33. Nitrogen Management Plan Specialist	

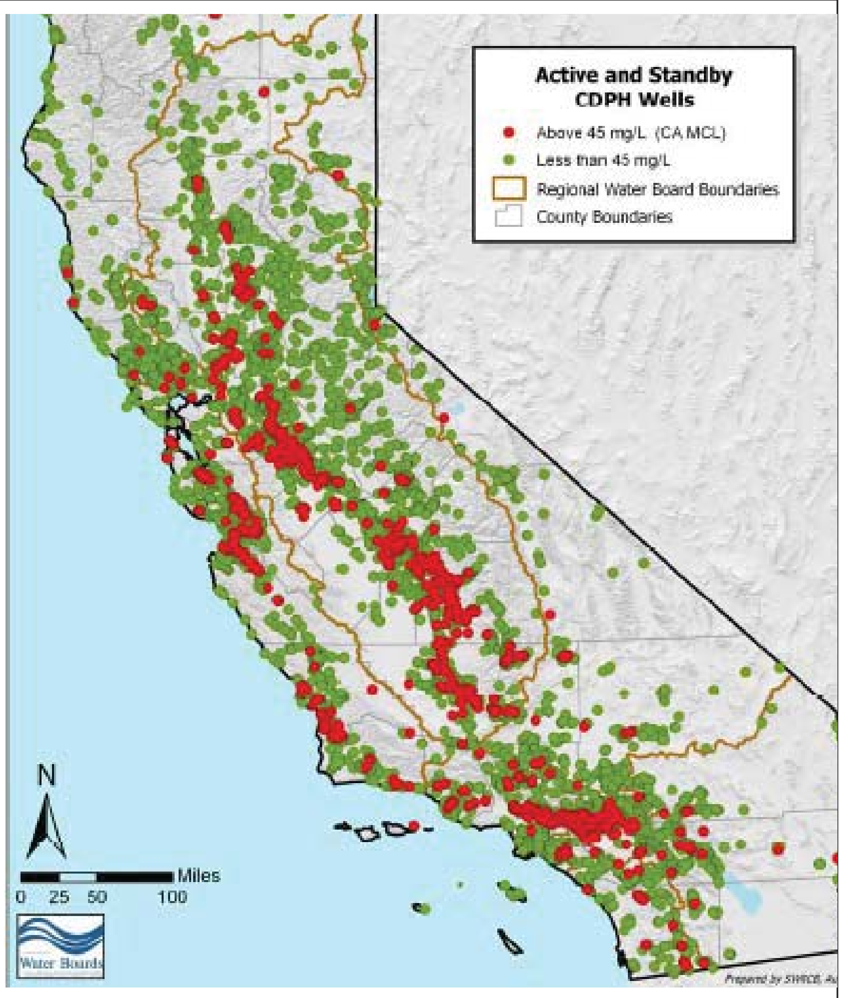
Note: Full instruction for this worksheet are provided by the local water quality coalitions This is a condensed (reduced APN's) version for a better fit.

Overview of Nitrogen and Groundwater Quality Issues
Section 1

Nitrate Problem Areas in California

Areas with shallow groundwater and intensive agriculture are vulnerable to nitrate contamination

- **Above** MCL
  Maximum Contaminant Level
- **Below** MCL

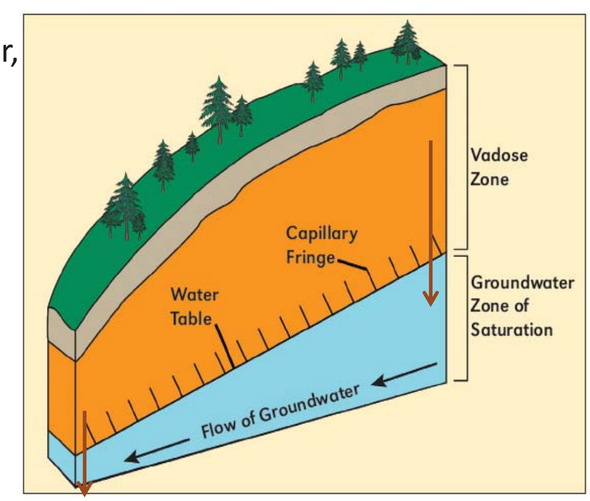


- *Figure:* From the State Water Resources Control Board, this image shows red dots as active and standby California Department of Public Health (CDPH) wells that are in excess of the 45 ppm nitrate MCL as of June 2010. The main areas of concern are the Coast, the Delta, the Tulare Lake Bottom and the East Side of the San Joaquin Valley. All these areas have shallow depth to ground water combined with intensive agriculture.

Why is Shallow Groundwater Most Affected?

- Nitrate (NO_3^-) is an anion (negatively charged) and is not retained by soil. It moves with the wetting front.
- Water moving below the root zone carries nitrate with it.

- After years of downward flow with water, nitrate eventually reaches the aquifer.
- The farther from the source, the longer nitrate takes to reach the groundwater.



Notes:

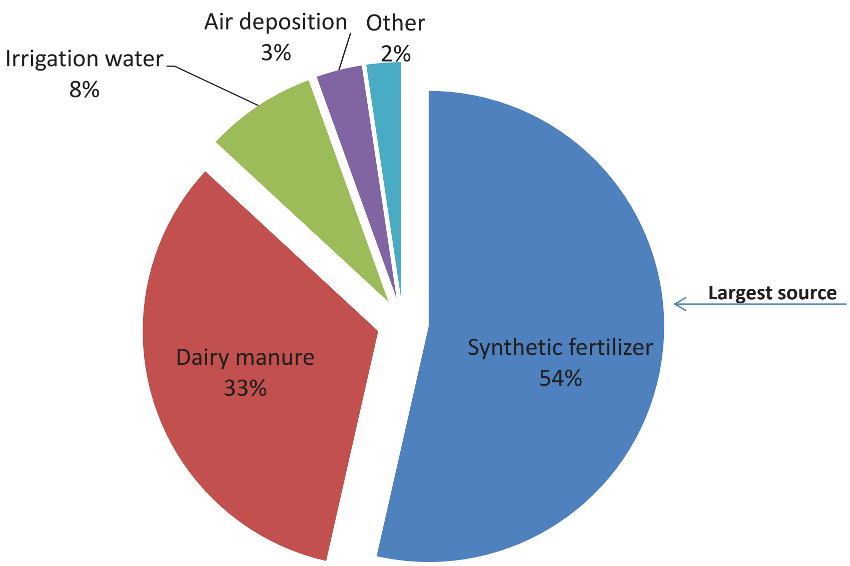
- Ground water may become polluted more quickly where soils are layered (e.g.. alluvial soils) and exhibit preferential flow that can shorten the time it takes for nitrate to reach the groundwater.
- Arrows show different distances to water table

How Did Nitrate Become a Problem?

- In nature, nitrogen cycles through soil, water, and plants at low concentrations.
- Agriculture requires high N input to produce profitable crops.
- California agriculture has a long history of N use, with cropped acreage, N fertilization rates, dairy production, and irrigated land increasing in the last 50 years.
- **Inefficiency** of irrigation and N application leads to nitrate leaching losses.

- *Note:* The natural background concentration of nitrogen cycling though soil, water, and plants is about 2 ppm (2mg/L).

Where is Nitrogen Coming From in California



Data from Salinas Valley and Tulare Lake Basin

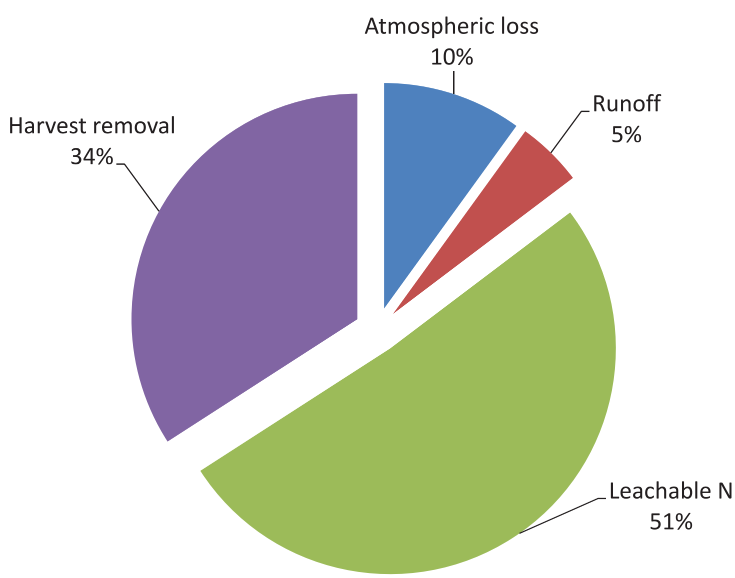
Notes:

- *Figure:* This information is from “Addressing Nitrate in California’s Drinking Water,” linked below. The researchers determined the sources and fates of cropland-applied nitrogen in the Salinas Valley and Tulare Lake Basin. They accounted for all the sources of nitrogen inputs applied in one year in the study areas. More than half of the inputs by mass are from synthetic fertilizer, plus a third from dairy manure, accounting for 86% of total nitrogen inputs.

- Addressing Nitrate in California’s Drinking Water:
- http://groundwaternitrate.ucdavis.edu/files/138956.pdf

- Please note theses data are from Salinas and Tulare Lake Basin and are not necessarily representative of all California.

Of the Total N Inputs Where is Nitrogen Going in California?



Data from Salinas Valley and Tulare Lake Basin

Notes:

- *Figure*: In a mass balance model, the mass of the inputs must equal the mass of the outputs. By estimating the amount of total nitrogen exported in the harvested portion of the crop as well as nitrogen lost to the atmosphere by denitrification, volatilization, and surface runoff, the remaining nitrogen is assumed to have leached below the crop root zone. In these cases, 51% of nitrogen was available to leach to groundwater.
- Please note theses data are from Salinas and Tulare Lake Basin and are not necessarily representative of all California.

Dealing with Nitrate Pollution

- No inexpensive method exists to remove nitrate once it is in water

- Source control: More efficient use of fertilizers and fertilizer products

    - By accounting for all the sources of nitrogen in the system leads to more efficient use of nitrogen and fertilizer products.
    - Sources of nitrogen:
        - Mineralization of organic nitrogen to mineral form
        - Residual soil nitrogen
        - Nitrogen in irrigation water
        - Nitrogen fertilizers

Nitrate -----What is the Problem?

- Nitrate in Drinking Water
    - Federal/CA Maximum Contaminant Level is 45 ppm NO_3 (10 ppm NO_3–N).

    - Concentrations in drinking water of some CA aquifers exceed this level.

    - CA State Water Resources Control Board noted that 8% of drinking water wells exceed the nitrate threshold.

- *Note*: The Maximum Contaminant Level (MCL) amount was determined by US EPA to "…to prevent methemoglobinemia in infants, the most sensitive health endpoint in children."

Measuring Nitrate and Nitrate-N Concentrations

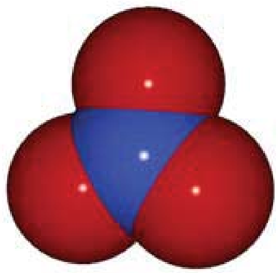
Maximum contaminant levels

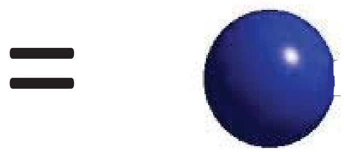
Measuring **Nitrate**:

45 ppmNO_3 (measure **N + O**)

Measuring **Nitrate-N**:

10 ppm NO_3^--N/ (measure **N** only)





Notes:
- When Nitrate concentration is measured in nitrate-N (NO3--N), only the nitrogen is measured.
- When Nitrate concentration is measured in nitrate (NO3-), nitrogen and oxygen are both measured.
- The two maximum contaminant levels are the same – only difference is the mg/L is the weight on N + O_3 versus N only .
  - A factor of about 4.5
  - 62.0049 / 14.0067 = 4.427

Nitrogen in Crop Production Systems

The Nitrogen Cycle

Section 2

Nitrogen Cycle- mineralization and nitrification

Soil Organic Matter

↓ Mineralization

Ammonium NH_4^+

↓ Nitrification

Nitrate NO_3^-

Notes:

- Mineralization of organic matter to ammonium
- Nitrification of ammonium to nitrate
- Uptake by microbes them upon death back to OM
- Process: mention this is the microbe N cycle the start at mineralization then click to next slide for the definition

Mineralization:

A microbial process of conversion of ***organic*** *N* to plant available ***inorganic*** *form* -- ammonium (NH_4^+)

Soil Organic Matter

↓ Mineralization

Ammonium NH_4^+

↓ Nitrification

Nitrate NO_3^-

Notes:

- Mineralization of organic matter to ammonium
- Process: discuss mineralization then next slide for nitrification

Nitrification:

A microbial process of conversion of ammonium (NH_4^+) to nitrate (NO_3^-)

Soil Organic Matter

↓ Mineralization

Ammonium NH_4^+

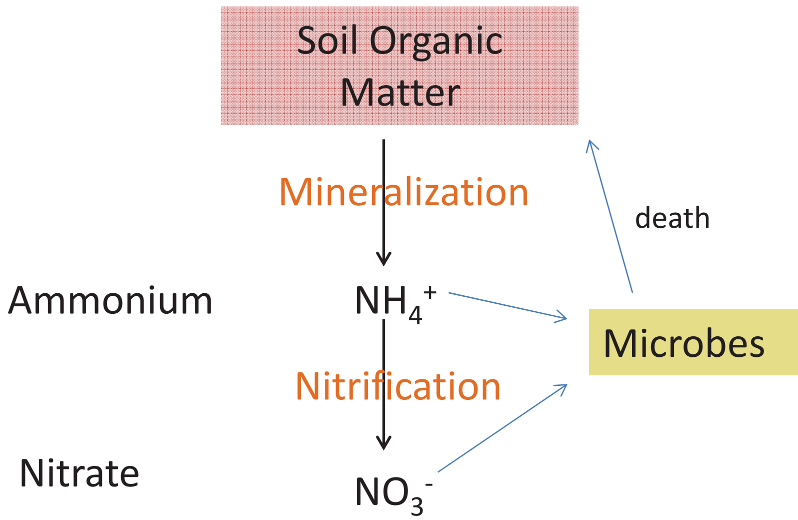
↓ Nitrification

Nitrate NO_3^-

Notes:

- Nitrification of ammonium to nitrate

Nitrogen Cycle- microbe cycle

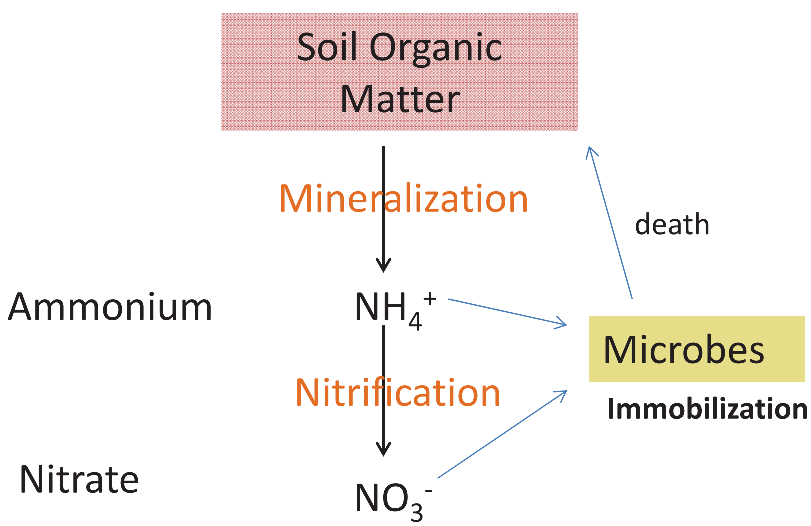


Note:

- Uptake of ammonium and nitrate by microbes then upon death back to organic matter

Immobilization:

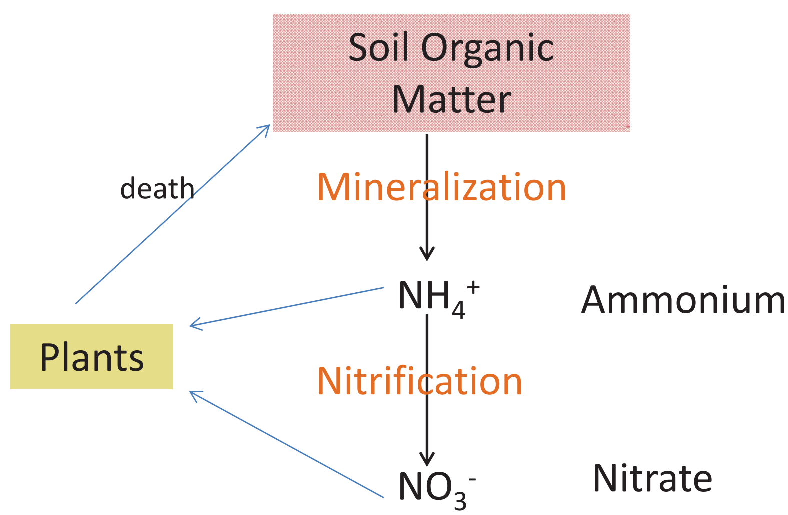
Microbes incorporate *mineral N from soil solution* into organic compounds in cells-- Inverse of mineralization



Notes:

- Microbe uptake of N is very efficient – so efficient that microbes will immobilize available soil N and plant uptake will be limited
- When the microbes die if carbon is available more microbes thrive until the carbon reduces and N become available for plant uptake
- Microbes hold N as they decompose SOM then release mineral N as they die as the carbon source is mineralized.
- When adding an organic source to the soil that has high carbon and low nitrogen, available mineral N is taken up by the microbes reducing soil available mineral N.

Nitrogen Cycle- plant cycle



Notes:
- Mineralization of organic matter to ammonium
- Nitrification of ammonium to nitrate
- Uptake by plants and upon death back to organic matter

Nitrogen Cycle- losses

Atmosphere

Soil Organic Matter

NH^3 Ammonia

Mineralization

Ammonium NH_4^+ → Volatilization

Nitrification

Nitrate NO_3^-

Nitrogen Cycle- losses

Atmosphere

Soil Organic Matter

Atmosphere

NH^3 Ammonia

Mineralization

N_2 N gas
N_2O Nitrous Oxide

NH_4^+ → Volatilization

Nitrification

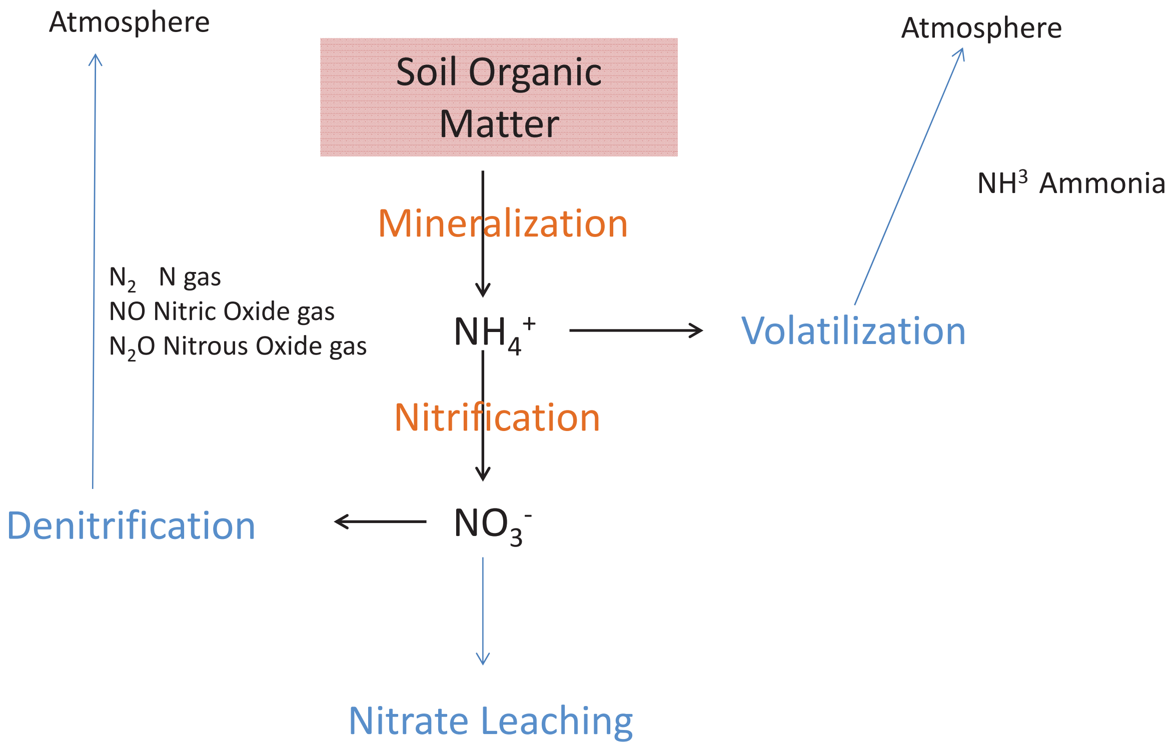
Conditions that increase denitrification:
Low oxygen in soil (near soil water saturation) and a carbon source

Denitrification ← NO_3^-

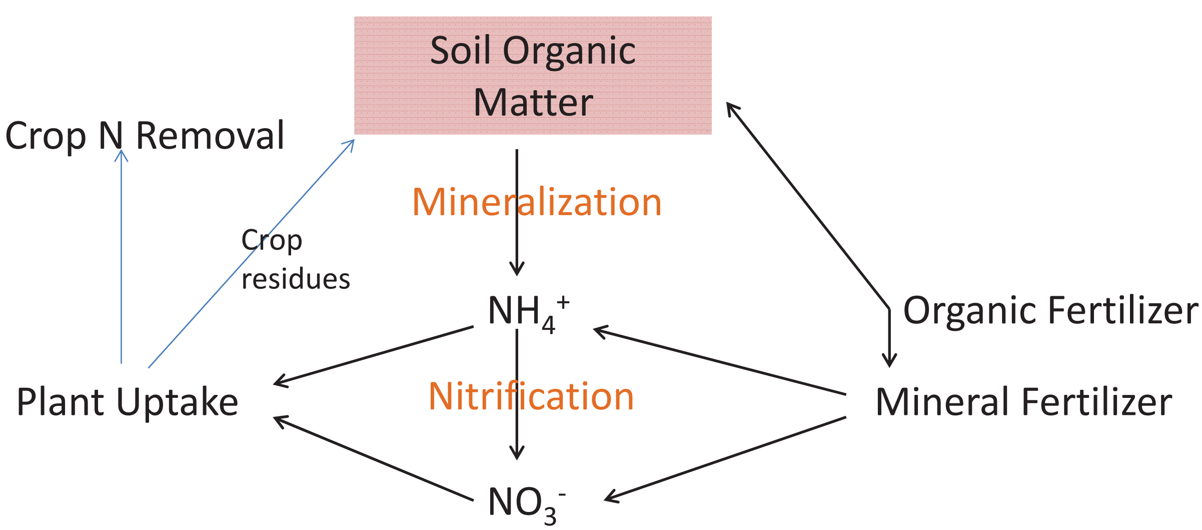
Notes:

- Denitrification generally proceeds through some combination of the following intermediate forms:
  NO3⁻ → NO2⁻ → NO + N2O → N2 (g)

Nitrogen Cycle- losses



Nitrogen Cycle- fertilizer and crop removal



Nitrogen in Soil Organic Matter and Microbes

- Soil organic matter stores soil carbon and nutrients in the soil.
  - Holds nutrients from leaching
- The process of N release is driven by microbes
  - Carbon and nutrients are taken up as microbes grow then released as mineral N upon death(mineralization).

Notes:

- SOM stores soil carbon and nutrients
  - Carbon acts as a food source for microbial populations
  - N is alternately taken up as microbes grow and released as they die
  - The majority of soil organic matter is recalcitrant and does not interact with N. It is the small fraction of organic matter that is soluble that can interact with N and is hence most important.
- The process of N release is driven by microbe populations
  - Release carbon and nutrients for their growth
  - Mineral N is produced

Mineralization-- Organic N to Mineral N

- **Carbon/Nitrogen ratio** of organic materials is one of the main factors controlling mineralization rates.

- Environmental conditions, **tillage**, **temperature**, and **moisture** strongly positively influence mineralization rates.

Note: Mineralization is a particularly relevant component of the N cycle when a grower has or adds large amounts of SOM.

The Process of Organic Decomposition in Soils

- **Composition** of Plant Residues
  – Crop and plant residues (cover crop, compost and animal manure) are the primary source of soil organic matter.
  – Organic materials contain a different carbon containing compounds depending on crop / residue type and age.

Organic compounds ease of decomposition

1. Sugars, Starches, and simple proteins	Rapid decomposition
2. Crude proteins	↕
3. Hemicellulose	
4. Cellulose	
5. Fats and waxes	
6. Lignins and phenolic compounds	Very slow decomposition

(Elements of the Nature and Properties of Soils, 3/e by N. Brady and R. Weil)

Notes:

- Organic matter added to the soil decomposes, releasing N as it does.
- Rate of decomposition depends on the composition of the organic matter. The boxed portion of the slide shows the relative rates of decomposition of different forms of organic matter.
- Faster decomposition means faster release of N.

Immobilization

- **Carbon/Nitrogen ratio** of organic materials is one of the main factors controlling immobilization rates.
- If C:N ratio is high microbes have priority in using available mineral N until decomposition of SOM declines to about 20:1 C:N

Factors Controlling Decomposition and Mineralization Rates

Table 11.2
Typical Carbon and Nitrogen Contents and C/N Ratios of Some Organic Materials

Organic material	% C	% N	C/N
Spruce sawdust	50	0.05	600
Newspaper	39	0.3	120
Wheat straw	38	0.5	80
Corn stover	40	0.7	57
Maple leaf litter	48	1.4	34
Rotted barnyard manure	41	2.1	20
Bluegrass from fertilized lawn	42	2.2	20
Broccoli residues	35	1.9	18
Young alfalfa hay	40	3.0	13
Hairy vetch cover crop	40	3.5	11
Digested municipal sewage sludge	31	4.5	7
Soil microorganisms			
Bacteria	50	10.0	5
Fungi	50	5.0	10
Soil organic matter			
Average forest O horizons	50	1.3	45
Average forest A horizons	50	2.8	20
Mollisol Ap horizon	56	4.9	11
Average B horizon	46	5.1	9

(Elements of the Nature and Properties of Soils, 3/e by N. Brady and R. Weil)

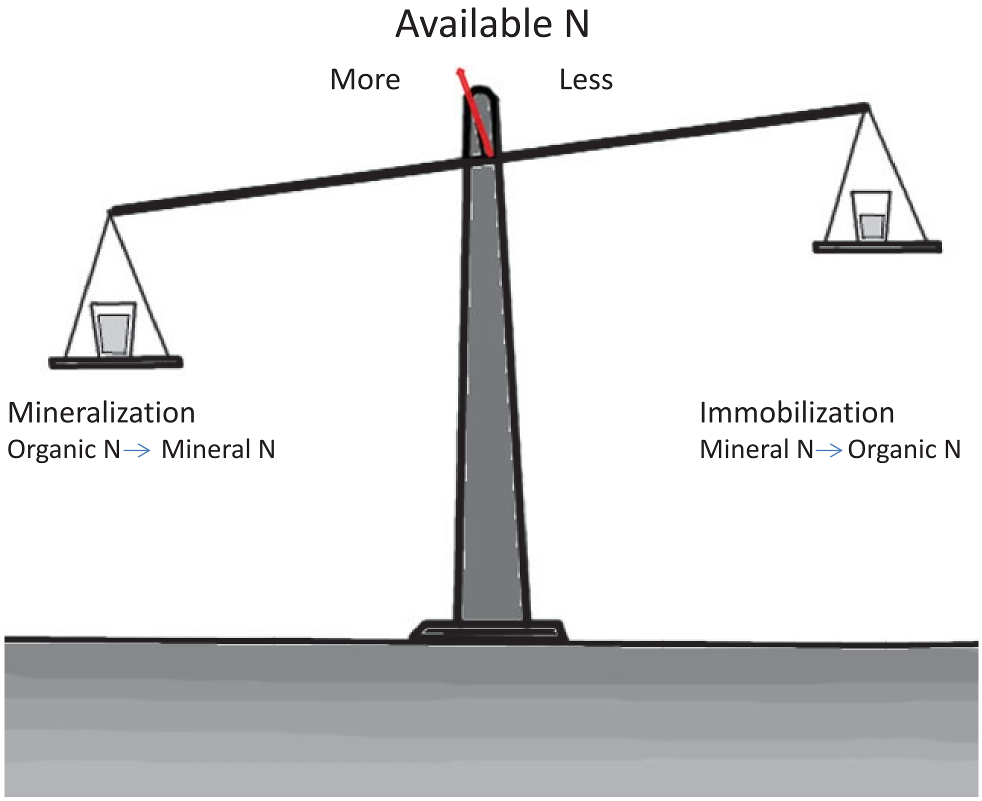
Generally:

- **A C:N ratio** of 20:1 (2% N) is the dividing line between mineralization (immediate release) and immobilization (N binding and subsequent release).
- The higher the C:N ratio the slower decomposition and mineralization occur
- Most N in added materials will ultimately become available, though it may take several years.
- Anaerobic conditions will lead to very slow mineralization.

Notes:

- With a large C:N ratio Microbes take N for growth holding N unavailable
- As decomposition continues the C:N ratio narrows
  - At about 20:1 N becomes available for plant use

Balance of mineralization and immobilization determines the amount of available N in the soil at any given time



Notes:

- This balance depends on the activity level of soil microbes. Microbial population growth is influenced by temperature and moisture, but is mostly limited by amount of carbon in soil. When carbon is added to soil, microbes are able to take up more N to make proteins, increasing immobilization and decreasing mineralization.

- **Mineralization** - process of conversion of organic N to plant available inorganic forms

- **Mineralization** - amine (R-NH_2) groups in SOM hydrolyzed to release ammonium (NH_4^+)
  - Heterotrophic microbial process
  - Rate depends on temperature and moisture
  - Most ammonium eventually oxidized to nitrate

- **Immobilization** - microbes incorporate mineral N from soil solution into organic compounds in cells
  - Reverse of mineralization

Fates of Ammonium After Mineralization

- Plant uptake
- Incorporated into Microbes
- NH_4^+ ions
  - Adsorbed on negatively charged clay surfaces
- Ammonia volatilization
- Converted to nitrate (nitrification)

Notes:

- Vermiculite clays expand when wet and contract when they dry trapping NH_4^+ ions between the clay plates.
- The release back to the soil solution is very slow.
- Ammonium produced by mineralization or added directly to the soil has one of several fates, including binding directly to soil at **cation exchange sites (CEC)** or being lost to **volatilization**.

Ammonia Volatilization

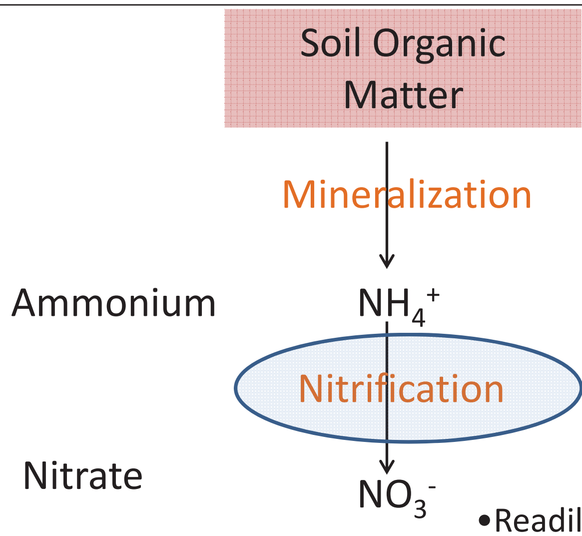
- **The loss of gaseous NH_3 to the atmosphere**

  - Conditions that favor volatilization with:
    - Fresh manures
    - Ammonia injections
    - Urea
    - UAN
      - » Lack of incorporation
      - » Dry soil
      - » Coarse-textured soils (sandy)
      - » High pH soils/water

Note about volatilization: Ammonia gas (NH3) can be present in fresh manures and anhydrous ammonia injections, and is also a breakdown product of urea and UAN. In gas form, it is easily lost to volatilization. Typically, soil moisture is adequate to rapidly convert NH3 (ammonia), to $NH4^+$ (ammonium), preventing volatilization. However, in dry soil, especially when coarse-textured and high pH, NH3 volatilization can be significant (up to 30%).

Nitrification:

A microbial process of conversion of ammonium (NH_4^+) to nitrate (NO_3^-)



•Readily available for plant uptake

•Prone to loss by leaching (- charge) and denitrification

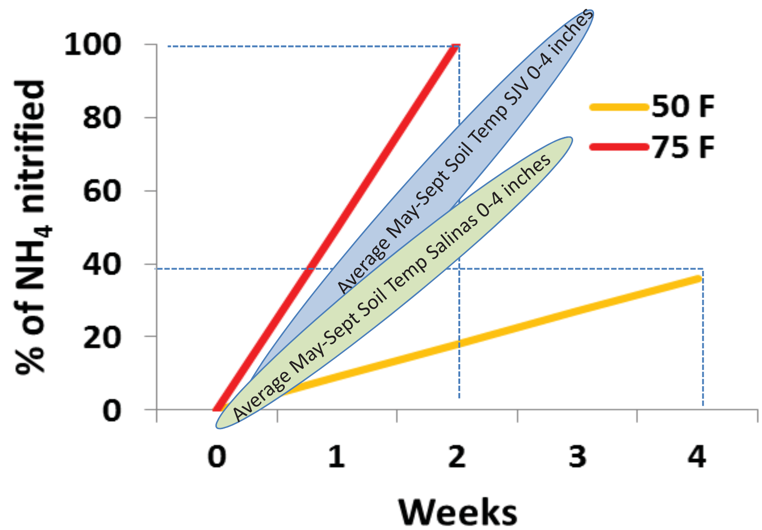
Ammonium is oxidized to Nitrate by bacteria in two steps for the purpose of the microbes obtaining energy

Notes:

- This is the most relevant component of the soil N cycle for California agriculture
- Nitrification is the biochemical oxidation of ammonium to nitrate that occurs in warm, moist, well aerated soils
- Nitrosomonas is a heterotrophic bacterium that converts ammonium to nitrite.
- Nitrobacter is an autotrophic bacterium that oxidizes nitrite to nitrate. The final product is nitrate, which is readily available for plant uptake.

Nitrification: How Quickly Does it Occur?

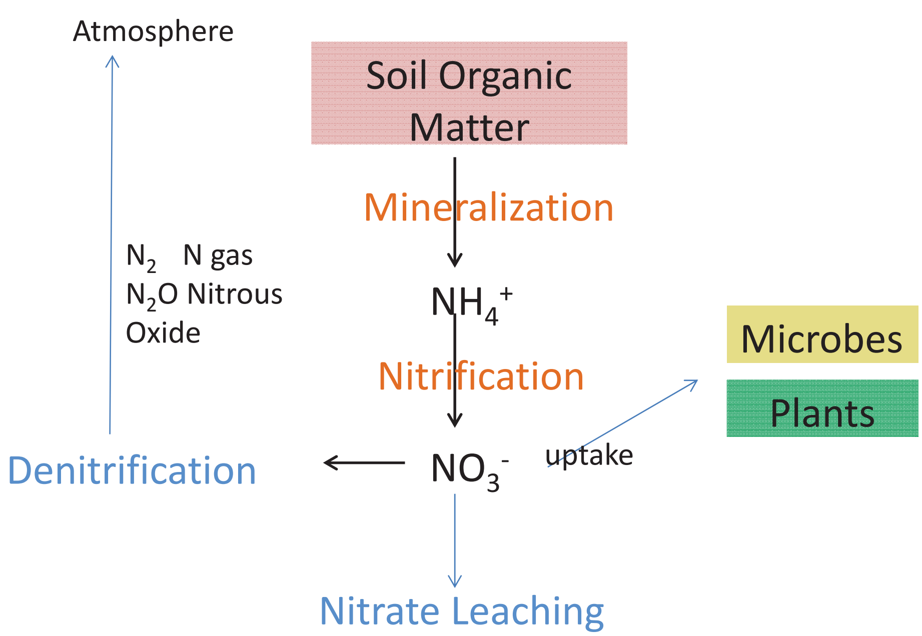
Nitrification rate governed by temperature and adequate moisture:



(Adapted from Western Fertilizer Handbook)

Figure: Estimate of nitrification rates in California soils (San Joaquin and Salinas Valleys), depending on soil temperature.
Mention average of 50% in 1-2 weeks

Fate of Nitrate (NO_3^-)



Notes:

- This is the most difficult component of the cycle to manage because it has the highest potential for loss through **leaching** and **denitrification**.
- Point out that NO3 can be used by plants and microbes or be lost to denitrification or leaching

Why Does Nitrate Leach?

- Nitrate (NO_3^-) is negatively charged, so it is not held by the soil particles which are also negatively charged.
- Because it may be applied in excess
- Because water management is inadequate
- Because timing of application does not match crop demand

Notes:
- Water management inadequate = excess irrigation
- Timing does not match crop leaves excess N available for leaching

Nitrate Leaching Principles

For nitrate leaching to occur:

Nitrate must be present in the soil

Soil must be permeable for water movement

Water must be moving through the soil

Denitrification: Loss of N to atmosphere

Atmosphere

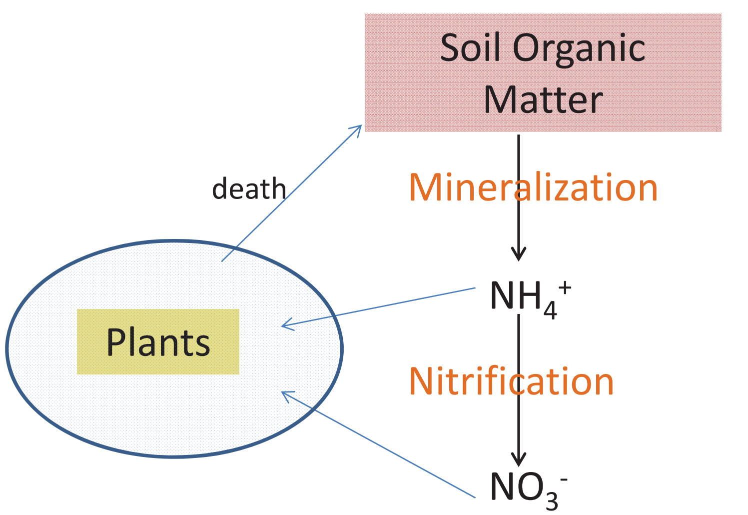
Anaerobic reduction of $NO_3 \rightarrow N_2O$ and N_2 gas

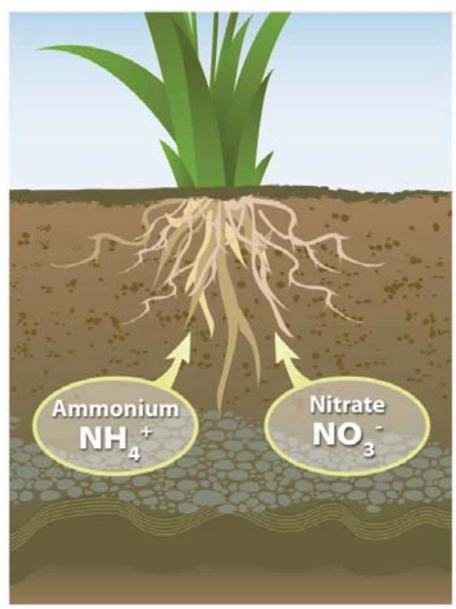
- Occurs under warm, anaerobic conditions
- Most significant in wetlands and rice paddies
- Less significant in well-drained soils
- In irrigated agriculture, N_20 production is sporadic.

Most N loss occurs during a brief period when the soil is warm, wet, and high in nitrate (i.e. fertigation).

Note: The chemical formula shows denitrification, the reduction of nitrate to nitric and nitrous oxide gasses, and dinitrogen gas, all of which can volatilize off the field. This conversion occurs in the presence of an available C source for anaerobic, heterotrophic bacteria that use the N in nitrate as an electron acceptor.(for energy)

Nitrogen Uptake by Plants





Plants take up N in the form of ammonium (NH_4^+) and Nitrate (NO_3^-).

Ammonium is only available in soils for short periods of time until converted to nitrate

Note: Plants vary in the type of nitrogen uptake preference however, ammonium is only available in soils for short periods of time until converted to nitrate. Therefore on a whole the most taken up form is nitrate.

Nitrogen Assimilation

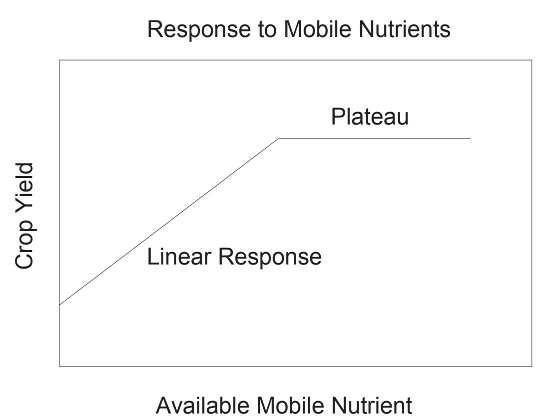
- All N sources must be first converted to Amino Acids which is an energy expensive process

Therefore:

Plants only assimilate the needed amount plus a small amount of “luxury consumption”.

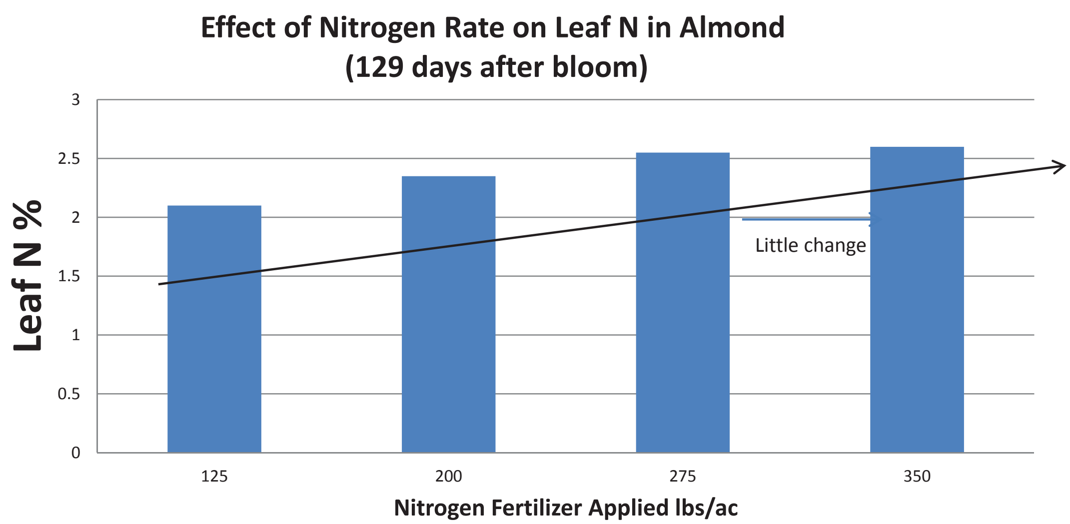
Nitrogen

- Plants require greater amounts of nitrogen than any other mineral nutrient.
- Nitrogen availability generally limits crop productivity until adequacy is reached where productivity does not further increase.



Notes:
- Fertilization past a level of adequacy does not increase productivity.
- The goal is to consider all sources of nitrogen (soil residual, irrigation water, and applied fertilizers) at appropriate times and rates to maximize nitrogen use efficiency and reduce the leaching potential.

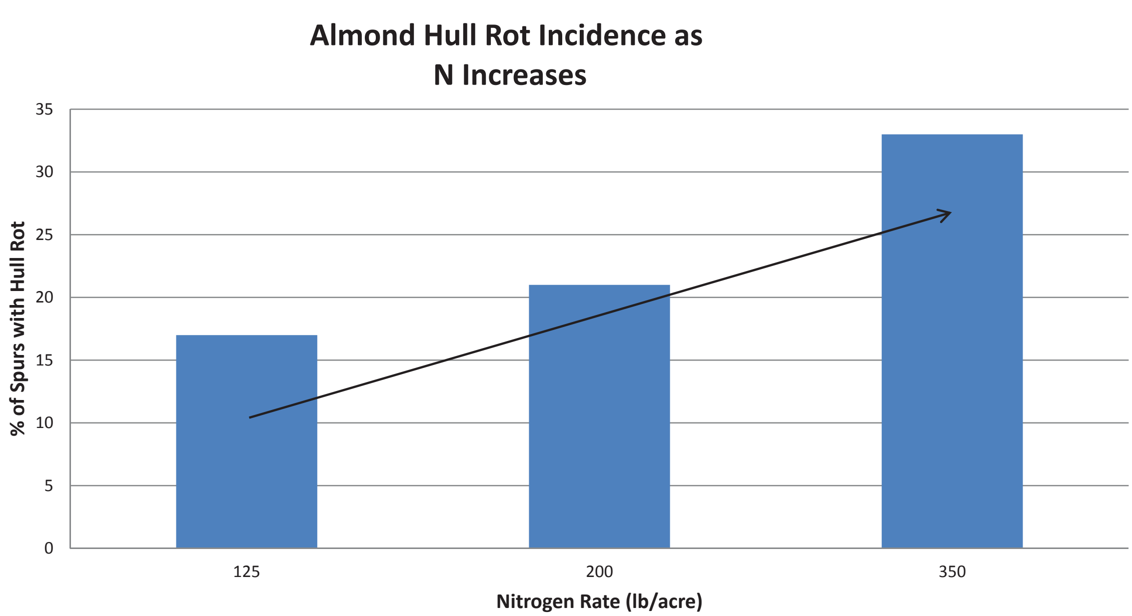
Nitrogen in Plants: N in Excess of Demand is Inefficiently Used



From Muhammad, 2013

Figure: This example from a high-yield almond orchard illustrates the phenomenon described in the previous slide. At the highest level of N applied, no significant additional N was taken up by the plant compared to the second-highest application level. This treatment level is considered excessive, as we can be sure that N remains in the soil.

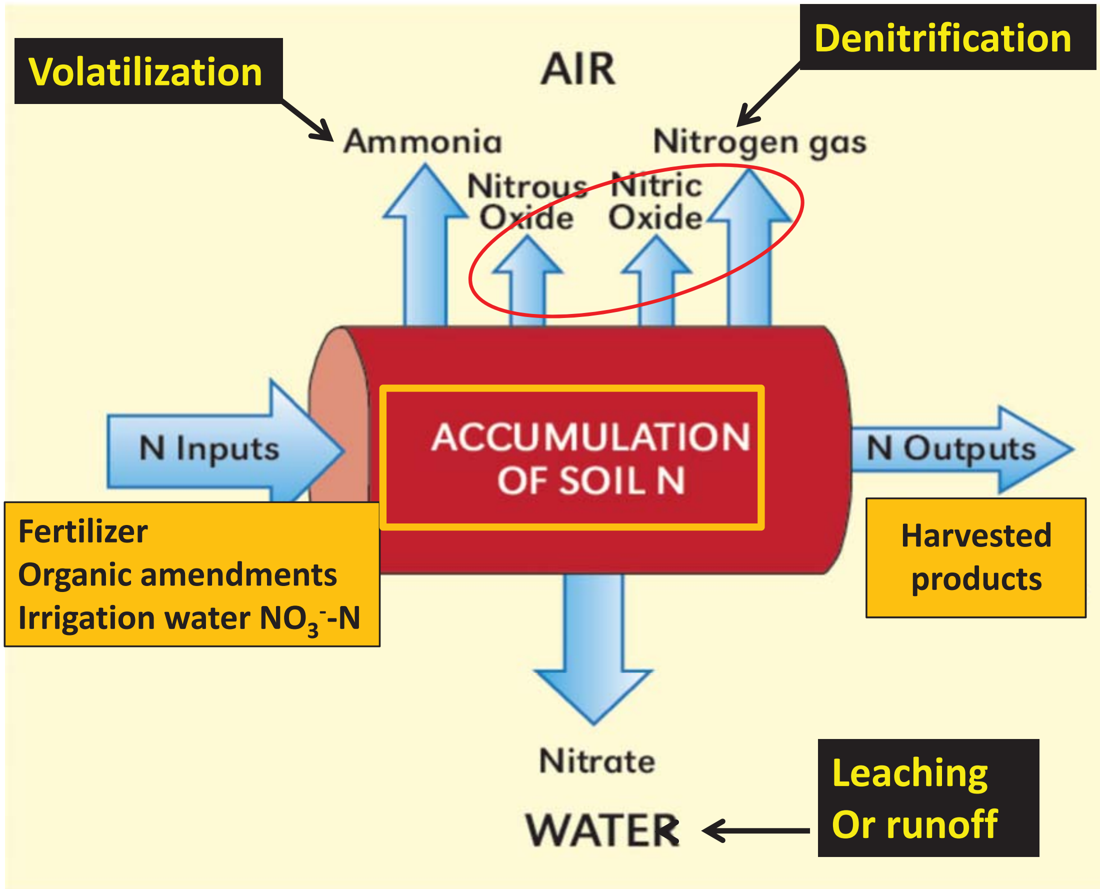
Nitrogen in Plants: Excess N Example



(Elana Peach-Fine, MSc. 2013

Figure: Excess N can have negative consequences for plants. Here excess N resulted in increased incidence of hull rot. The exact mechanism is unknown, but rot may be related to N-induced changes in plant defense against fungal invasion.

N Loss Pathways Summary:



Notes:

- Which N loss pathways are most significant in fruiting crop systems?
  - Volatilization: This is a very minor component for coastal row crop production but can be a problem for Central Valley cereal crops
  - Denitrification: This is a minor consideration for Central Valley conditions. However, for growers applying dairy waste products or furrow irrigating, denitrification can be significant.
  - Leaching/Runoff: Will depend on the magnitude of N accumulation in soil, which varies based on use or absence of tillage. Many tile-drainage tests indicate that N leaching is significant.
- Note that mineral nitrogen carried forward from one crop to another leads only to short-term N buildup in soil. It is not equivalent to long-term accumulation of organic form N bound up in soil. Because of the reliance upon tillage in these systems, there is not likely very much accumulation of organic form N in soil.

Nitrogen Fertilizers and Management

Section 3

Formulations

Management / Use Efficiency

Nitrogen Fertilizers Groups -- with examples:

1. Ammonium-forming fertilizers:
- Anhydrous ammonia
- Urea

2. Ammonium fertilizers :
- Ammonium sulfate
- Ammonium/phosphorus combinations (MAP, DAP, 10-34-0)

3. Nitrate fertilizers :
- Potassium nitrate
- Calcium nitrate (CN-9)

4. Combination fertilizers:
- Ammonium nitrate
- Urea-ammonium nitrate (UAN) solutions
- Calcium ammonium nitrate (CAN-17)

5. Organic materials:
- Manure and other animal byproducts
- Compost

Notes:

- More about each type of fertilizer covered in this module:
  - Those that form Ammonium (NH4+) on reaction with soil moisture or by urease conversion
  - Ammonium-containing materials
  - Nitrate-containing materials
  - Materials that have a combination of N forms (ammonium and nitrate)
  - Organic materials that release mineral N over time, through soil microbial activity

Ammonium-forming Fertilizers

- **Anhydrous ammonia**

Anhydrous ammonia application to soil *or water*:

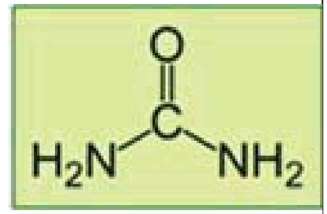
$NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$

pH ↑

Soil applied
In moist soil instantly converted
Water run
Converted to NH_4^+

Note: Anhydrous ammonia is the cheapest N source, but using it efficiently is not easy. When it contacts irrigation water or moist soil, it forms ammonium and hydroxyl ions, raising the pH around the site of application.

Ammonium-forming Fertilizers



Urea

- Highly soluble, uncharged, moves freely with water
  - Not as easily as negatively charged NO_3^-
- Enzymatic hydrolysis produces NH_4^+

$$\text{Urea} + 2\,H^+ \xrightarrow{\text{urease}} 2NH_4^+ + HCO_3^-$$

Ammonium Bicarbonate pH ↑

Note: Urea is an organic molecule with two N groups attached to a carbon atom. It requires the action of the soil enzyme urease to break it down, forming NH4+ and bicarbonate. Bicarbonate increases soil pH. Initial urea hydrolysis is to increase pH. In total after the NH4 is converted to NO3 the over all reaction is to decrease pH

Ammonium-forming Fertilizers:

Urea hydrolysis occurs rapidly:

$$\text{Urea} + 2\,H^+ \xrightarrow{\text{urease}} 2NH_4^+ + HCO_3^-$$

In a few days conversion complete

Rate of hydrolysis …
- Increases as temperature increases
- Decreases as concentration increases

(Broadbent et al., Proc. SSSA 22:303-307, 1958)

Figure: The rate at which urea is broken down by urease depends on both the concentration of urea applied, and the soil temperature. However, except for in very cold soils uncommon to California, urea incorporated into soil is normally converted to ammonium-N within a few days of application.

Ammonium Fertilizers

- **Ammonium sulfate [$(NH_4)_2SO_4$]**

- **Ammonium/phosphorus combinations**
  - Monoammonium phosphate (MAP)
  - Diammonium phosphate (DAP)
  - Ammonium polyphosphate (10-34-0)

- Ammonium fertilizers:
  - Are *temporarily* resistant to leaching

    Until converted to nitrate

Note: Though these forms are temporarily resistant to leaching, this timeframe is likely as short as a matter of days during the summer.

However, they will attach to the soil particles near the surface in the 1st irrigation. Upon conversion they will move with the water front in the 2nd irrigation.

Nitrate Fertilizers

- Potassium nitrate
- Calcium nitrate (CN-9)

Nitrate is negatively charged and moves with the water front

Combination Fertilizers

- **Ammonium nitrate (NH_4NO_3)**
- **Calcium ammonium nitrate** (CAN-17)
  - 32% of N as ammonium, 68% as nitrate
- **Urea ammonium nitrate (UAN) solutions**
  - 50% of N as urea, 25% ammonium, 25% nitrate
  - different concentrations (UAN-28, UAN-32, etc..)

Notes:

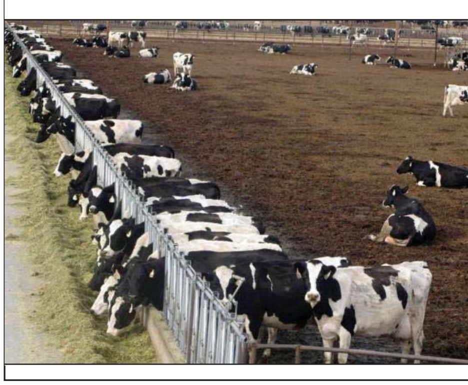
- Combination fertilizers are heavily used by horticultural crops in California. They act mainly as nitrate fertilizers within days of application.
- The fate of ammonium is the same as ammonium forming fertilizers based on the % ammonium.
- Combination fertilizers can provide a rapidly availability of nitrate and a continued supply as the ammonium is converted to nitrate.

Organic Materials

- **Manure and other animal byproducts**
- **Cover crop, Compost and green waste**

- Contain both:
  - Mineral N (immediately available) NH_4 and NO_3
  - Organic N (slowly available after microbial conversion)

Mineralization rate is dependent on C:N ratio, temperature and moisture content



Notes:

- Organic materials differ from mineral fertilizers mostly by the rate at which the N content mineralizes, becoming plant-available.
- A wide range of organic materials are applied to fields in California, and the differing characteristics (most notably N content, and C:N ratio) impact N availability.

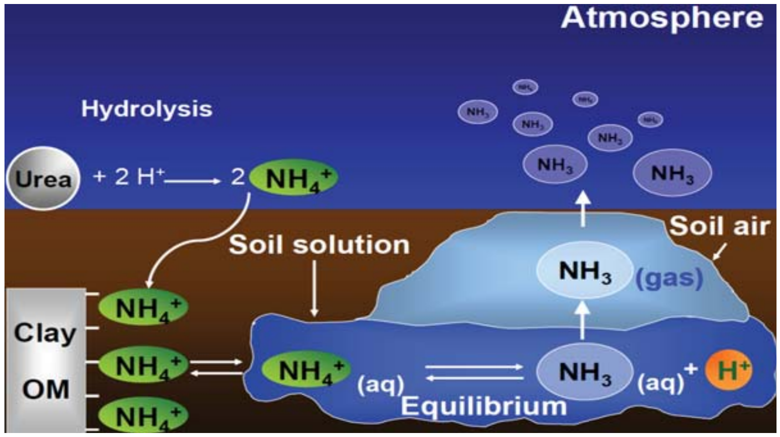
Nitrogen Transformations:

Volatilization and Denitrification

Management considerations to improve Nitrogen Use Efficiency

Volatilization

- **The loss of gaseous NH_3 to the atmosphere**



When is volatilization most significant?

- Soil injection of anhydrous ammonia, poorly sealed
- Anhydrous ammonia injection into irrigation water
- Loss from urea after hydrolysis, before nitrification
- Loss from urea after surface application w/o irrigation or rainfall

Notes:

- In the liquid phase of the soil (the soil solution), or in irrigation water, there is an equilibrium between NH4+ (which is not volatile) and NH3 (which is);
- the NH3 can diffuse out of the solution and be released to the atmosphere. Anhydrous ammonia and urea are most prone to volatilization.
- Higher pH soils have higher rates

Volatilization: Corn/Ammonia Example

Anhydrous ammonia application impacts solution pH

Site	pH irrig water	pH irrig water + AA
1	7.3	9.9
4	7.8	10.0
5	7.4	10.0
6	7.1	9.0
9	7.3	10.1
12	7.3	9.2
13	7.8	10.2

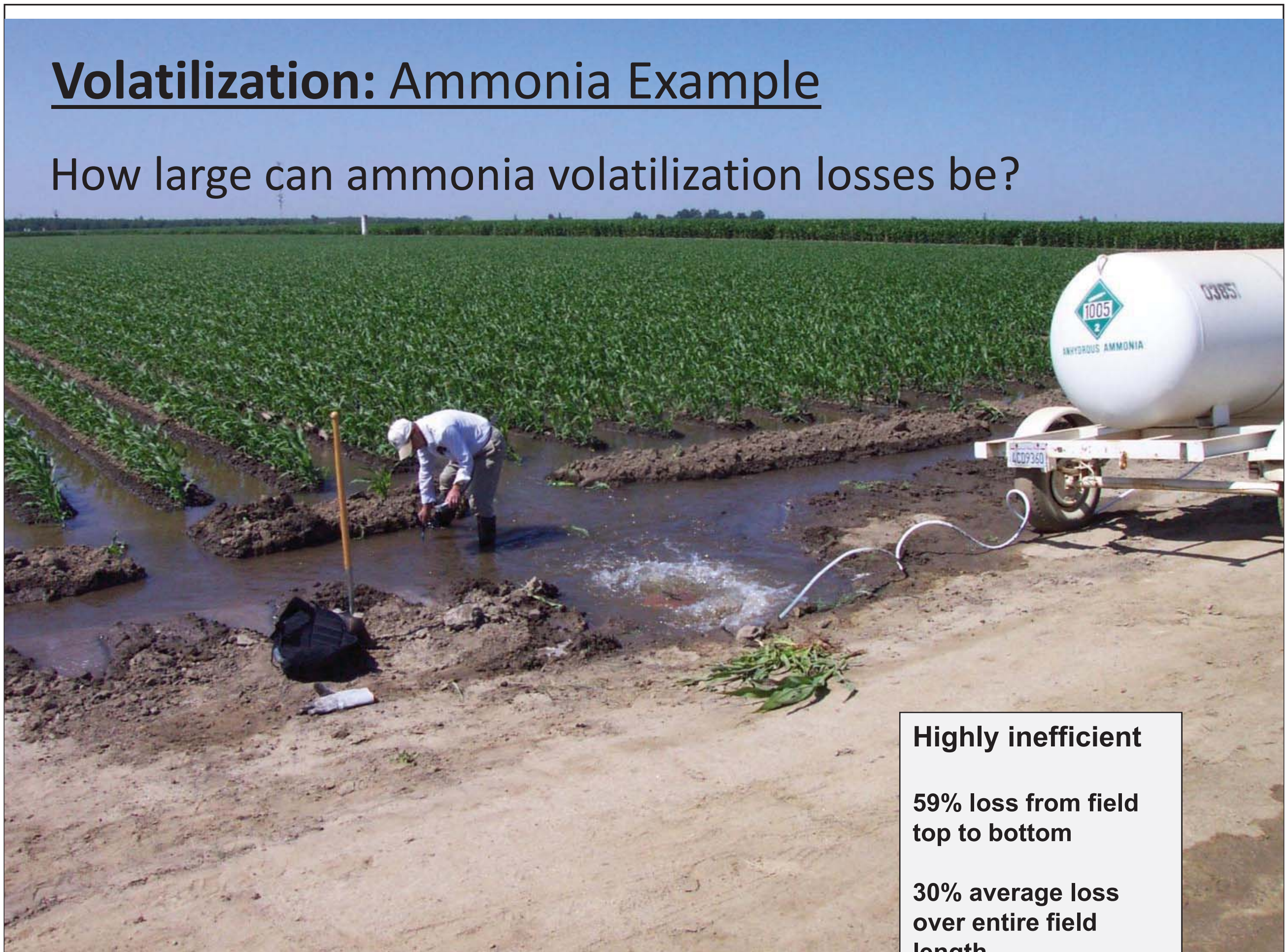
pH 9 = loss 30%

(Anhydrous ammonia injection into irrigation water
Tulare Co. 2008 – C. Frate and J. Deng)

Table: In this example from Tulare County, ammonia was run into furrow irrigated silage corn. In all cases the rise in water pH was substantial, well into the range where large volatilization losses would be expected.

Volatilization: Ammonia Example

How large can ammonia volatilization losses be?



Highly inefficient

59% loss from field top to bottom

30% average loss over entire field length

Notes:

- To quantify ammonia volatilization from water-run anhydrous ammonia, UC Davis agronomist Dr. Stu Pettygrove and farm advisors conducted trials in furrow-irrigated fields. Anhydrous ammonia was injected at the head ditch and then sampled down the length of the furrow.

- *Figure:* Ammonium-N concentration decreased significantly down the furrow at all fertigation events. Ammonium concentrations declined by more than 50% down the length of the furrow; when evaluated on a whole-field basis, ammonia volatilization averaged about **30% of applied N**. Beyond this significant N loss, the uniformity of N application was very poor.

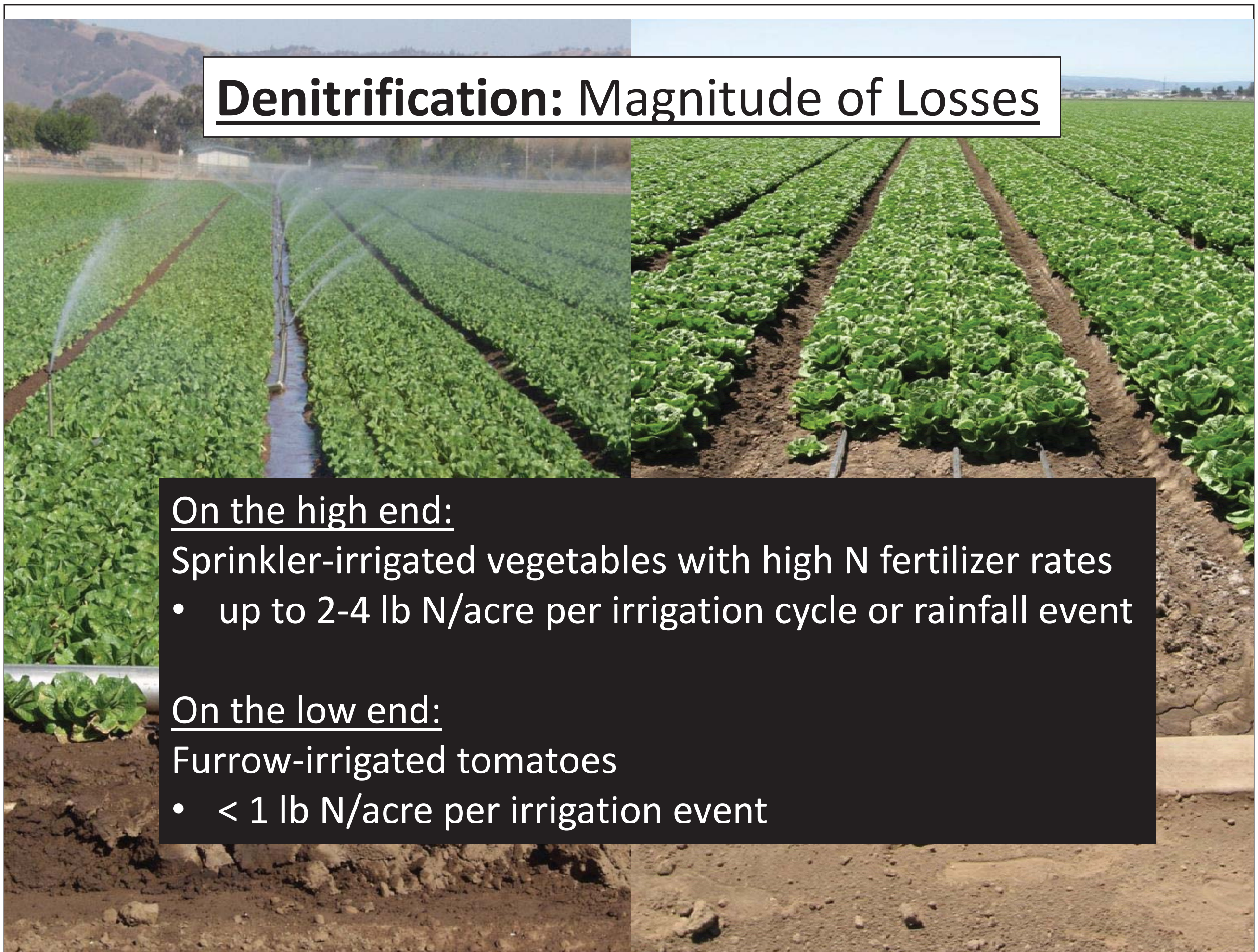
Volatilization: Urea

30% loss in 14 days without rainfall or irrigation

Factors that increase volatilization :

- Surface application without incorporation or irrigation
- High temperature
- High wind speed
- Low soil buffering capacity
- Hi pH soils

Note: When urea is surface-applied and not incorporated, volatilization losses can be high, particularly in the presence of the listed factors. For example, landing on moist soil or drawing dew can cause urea pills to hydrolyze. This raises their surrounding pH, increasing volatilization in the manner described. Urea volatilization can be agronomically significant.



Notes:

- On the high end: This 1970s study indicated that denitrification accounted for a significant fraction of applied N. In some fields, these losses added up to more than 100 lbs N/acre annually. However, that cropping system was ideal for denitrification, with high N application rates and frequent, saturating irrigation events. (Ryden and Lund, SSSAJ 44:505-511, 1980)

- The upper limit of this study is unlikely under most field conditions because 1) the switch to drip irrigation means less field saturation and 2) most fields receive much less N than the 600 lbs/acre applied annually in some of these monitored fields.

- In the past five years, intensive effort has been made to quantify nitrous oxide emissions in irrigated fields. Based on that work, and the assumption that N_2O represents 10% of total N emissions from denitrification, denitrification appears to account for < 30 lb N/acre per season for most irrigated crops in California. Exceptions to this rule would be sprinkler-irrigated vegetables and furrow-irrigated forage crops that receive heavy applications of animal manure. (Burger et al., Biol. Fert. Soils 42:109-118, 2005)

Denitrification:

- For multiple crops and irrigation types (furrow and drip)—

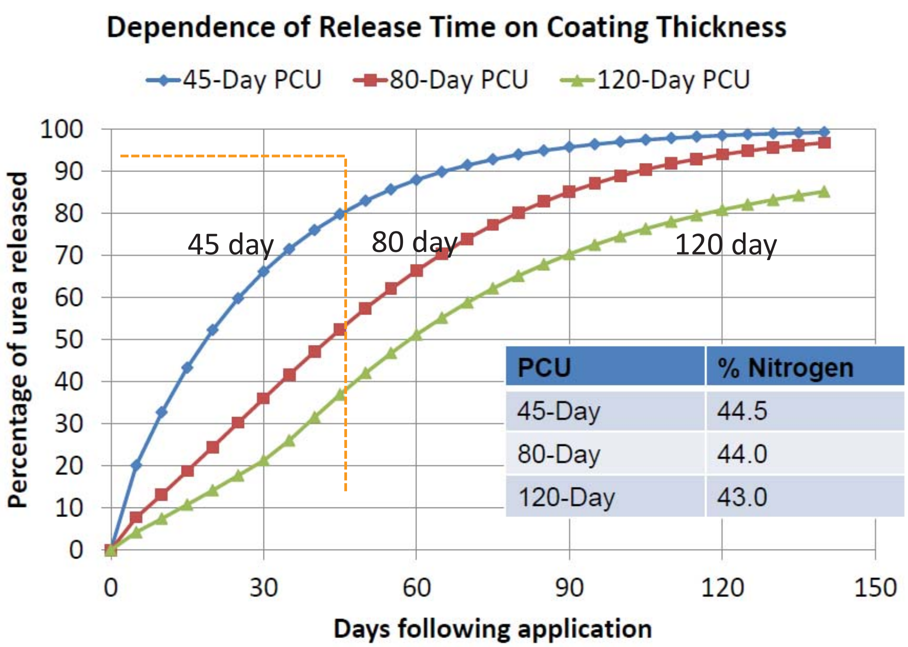
Nitrogen losses from volatilization tend to fall between 1 lb and 30 lb per acre per year.

- Conditions that favor denitrification:
  - High nitrate concentration
  - Saturated soil
  - Adequate carbon source

Manipulating N Transformations for Improved N Efficiency

Controlled Release Fertilizers

Release rating is based on time to release 80% of N at a standard temperature:



PCU	% Nitrogen
45-Day	44.5
80-Day	44.0
120-Day	43.0

- *Figure*: Here, the release times of three polymer-coated urea fertilizers are compared. The fertilizers have coatings of different thicknesses, shown in the table as the slightly lower N content of the 120-day material compared to those with more rapid release; the thicker the coating, the slower the release rate. These release ratings are only relative, however, as soil temperature also plays a role.

- *Note*: Care is particularly important when dealing with materials with shorter release times because they have thinner coatings.

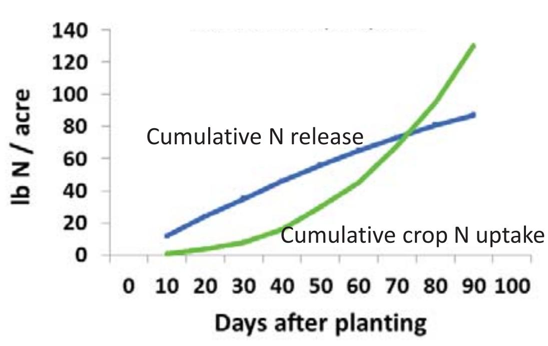
Controlled Release Fertilizers:

Benefits:

- May reduce leaching potential compared to preplant or single sidedress systems
  - weather, soil, and crop factors determine whether this benefit is realized

Drawbacks:

- Higher cost per unit of N
- Match between N release and crop N uptake is often imperfect
  - more appropriate in some cropping scenarios than in others



Notes:

- These products are most effective where fertilization is done by heavy preplant or early season applications, with potential for significant leaching from rain or poorly managed irrigation. Their use was limited by their higher cost per unit N. Recently that price disparity has decreased, and products with thinner coating and faster release time have come on the market.

- *Figure*: Here a problem with controlled release products is illustrated. N release is reasonably linear, but crop N uptake is curvilinear. Efficient use depends on choosing a product with the appropriate release characteristic, applied at the right time.

Summary

- Selecting the appropriate N source for the crop / irrigation management situation can lead to the greatest nitrogen use efficiency.

- Reducing nitrogen losses from:
  – Volatilization
  – Denitrification
  – Leaching

Irrigation and Nitrogen Management

Section 4

Irrigation and Nitrogen Management

Successful nitrogen management depends on efficient irrigation water management:

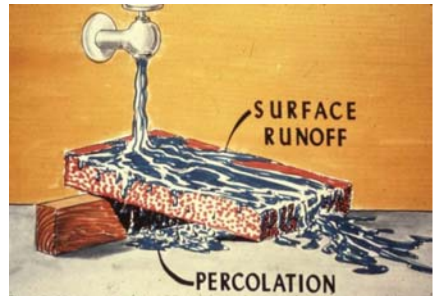
- Nitrate is mobile and moves with water.
- Inefficient irrigation may result in N-deficient crops and potentially add nitrates to groundwater.

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

Notes:

- 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.

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

Note: 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?

Achieving Efficient Irrigation

Where to begin:

- Need to have good information on current irrigation and nutrient management practices.
  - Use readily available info.
    - Fertilizer bills
    - Electricity, fuel, and water bills
    - Production history
- It is especially important to know the current irrigation water applications. How much? When?

Notes:

- 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.

Note: 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.

Notes:

- 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.

- <u>When</u>: 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. There are also services available to provide expertise along with the equipment. 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.

Notes:

- <u>How much</u>: 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.

- 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

Notes:

- 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

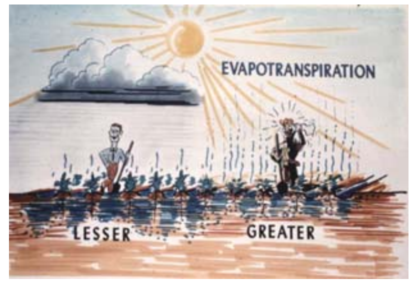
- Methods tend to be **labor intensive** – working toward automation

- 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)

Note: 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).

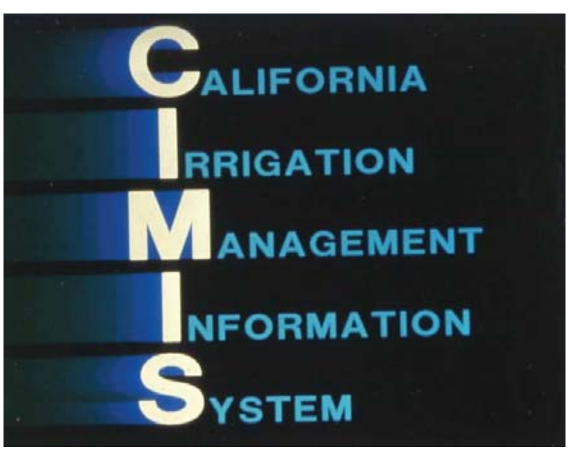


Notes:
- Climatic conditions, especially solar radiation, drive plant water use (Evapotranspiration or ET). Crop ET can be calculated by modeling the relationship between weather conditions and plant water use. Information from calibrated models is then made available to agricultural and urban water 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**

$$ET_c = ET_o \times k_c$$

Notes:

- 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.

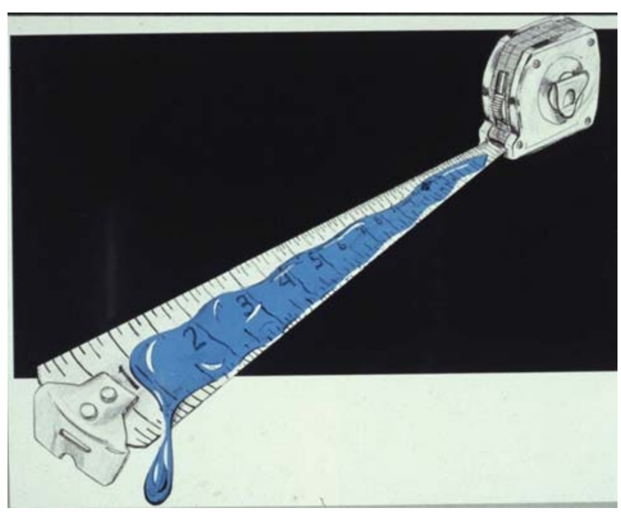
Note: Like the other approaches - soil moisture and plant monitoring - there are challenges to estimating ET_C. Models rely on weather measurements taken in irrigated grass pastures to predict reference crop ET_O. Then ET_O is multiplied by crop coefficients (K_C) to compute ET_C. K_C values depend on 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.

Note: 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.

Notes:

- 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

Notes:

- 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.

Notes:

- ***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.
- 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)

$$\text{Water Applied (inches)} = \frac{(\text{Flow (gpm)} \div 449) \times \text{Irrigation time (hrs)}}{\text{Acres Irrigated}}$$

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

Example: If irrigation flow to a 20 acre field was 1000 gpm for 9 hours, the applied water would be:

$$\text{Water Applied (inches)} = \frac{(1000 \text{ gpm} \div 449) \times 9 \text{ hrs}}{20 \text{ Irrigated acres}} = 1.0 \text{ inch}$$

Notes:

- ***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.
- 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.

Notes:
- ***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

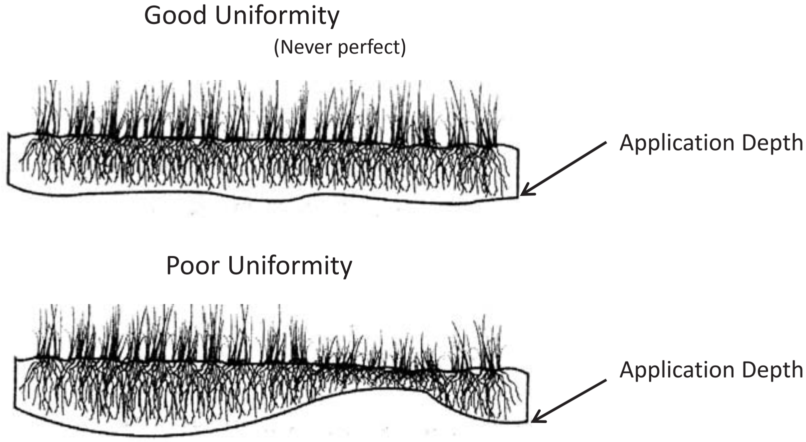
How much water is being applied? Irrigation system evaluation

Water application rate and uniformity

Notes:
- 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



Notes:

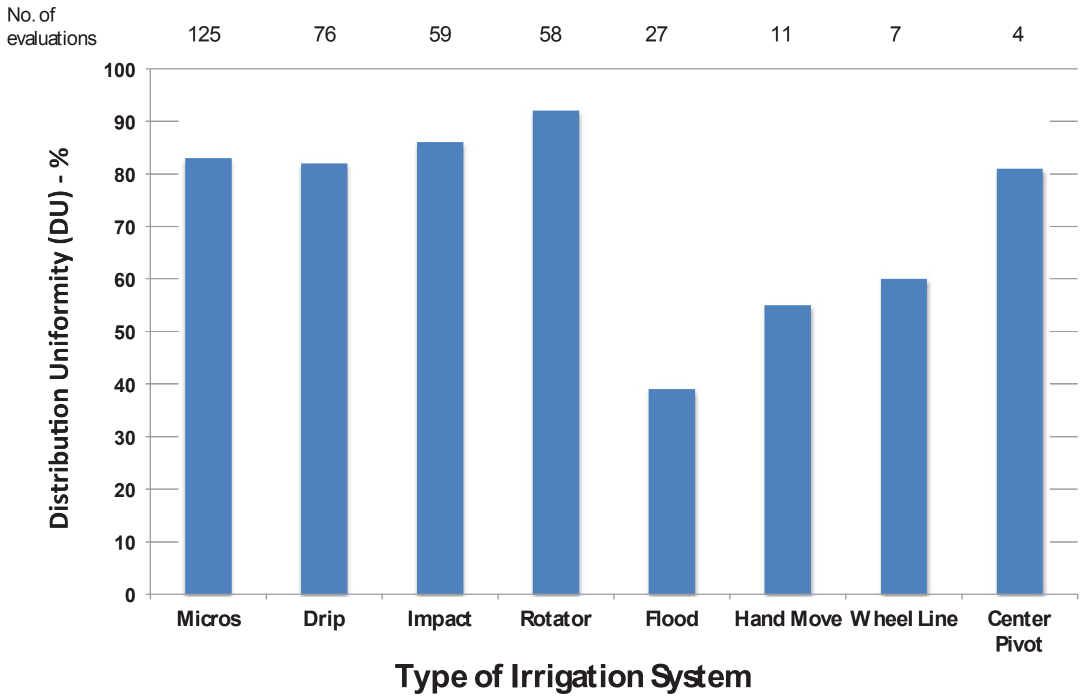
- The second goal is to evaluate how evenly the water is applied, which indicates where in the field lies the greatest leaching risk.

– 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



Field evaluation results from the mobile lab of:

TCRCD Tehama County Resource Conservation District

Notes:

- 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.

- 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.

- 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

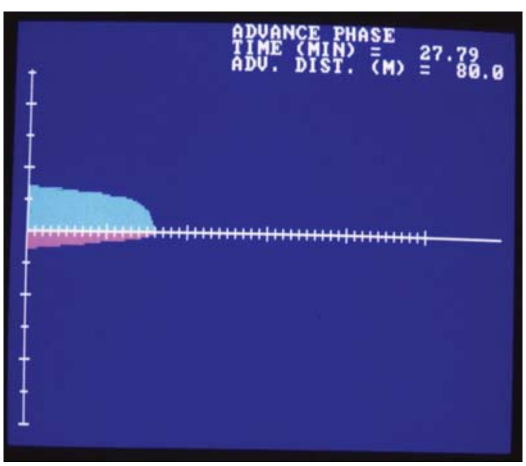
Furrow and border strip irrigation

Notes:

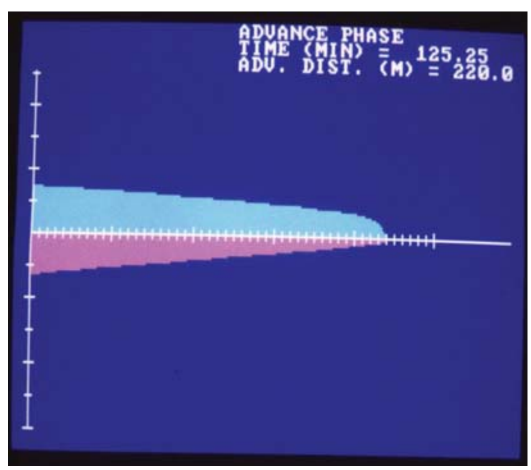
- Surface Irrigation includes furrow and border strip irrigation, also known as flood irrigation or border irrigation. Water advances across the soil surface from one end of the field to the other, and the soil's infiltration rate controls the amount of water applied.

- 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



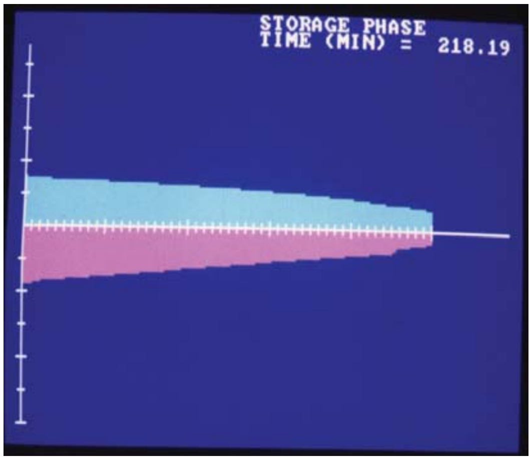
1 Water flows field top to bottom in furrow irrigation. Blue segment represents water on field surface; pink is infiltration.

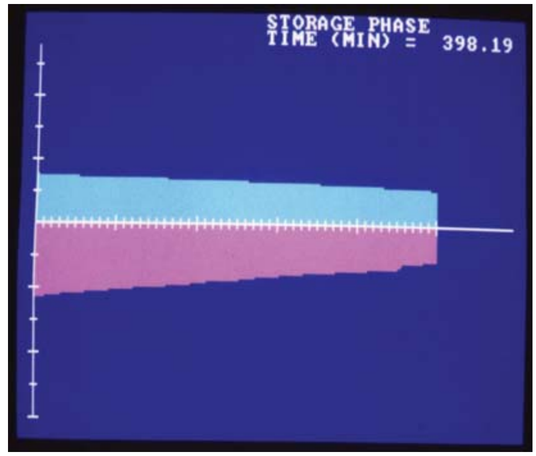


2 More water has infiltrated at field head, where it has been present the longest.

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.





3 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.

4 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

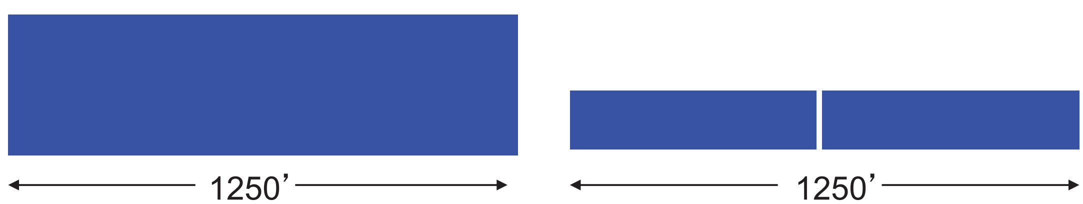
Shortening field length gets water across the field more quickly, resulting in less deep percolation.

Note: 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"**



- *Note:* 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"

Note: 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"

Notes:

- 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.
- 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 Torpedoes

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

Note: A torpedo is a weighted steel cylinder dragged through furrows prior to irrigation. This breaks up the clods and smooths the furrows, allowing water to advance faster, increasing uniformity. Torpedoes are effective when used in fields which have been recently cultivated, but they are not effective after a furrow has been irrigated. 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"**

Notes:

- 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.

Notes:

- 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 tailwater, 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

Notes:

- 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






Note: 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

Note: 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.

Example: The application rate for a sprinkler system with a 24' by 48' spacing and an average nozzle discharge of 1 gpm would be:

$$\textbf{Sprinkler Application Rate (in/hr)} = \frac{\mathbf{96.3 \text{ x } 1.0 \text{ gpm}}}{\mathbf{24' \text{ x } 48'}} = \mathbf{0.084 \text{ in/hr}}$$

Notes:

- 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.

- 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.

Notes:

- 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.

Notes:
- 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:
- Water use (gallons) = Water use (inches) x Plant Spacing (ft^2) x 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

Notes:

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

Notes:

- 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 and microsprinklers 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.

Notes:

- 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.

Notes:

- 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.




Notes:

- 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.

Note: 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

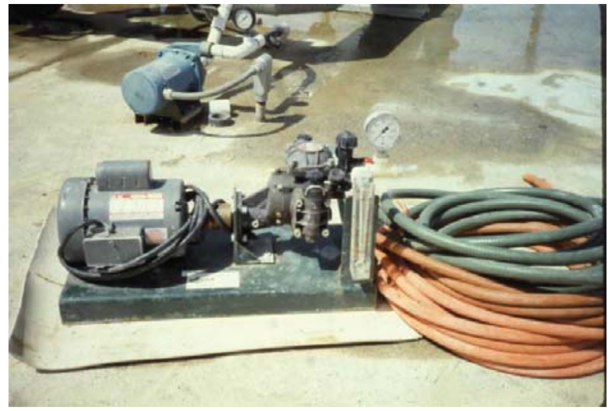
If there are deep percolation losses of irrigation water while fertigating, there is a good chance there will be N losses

Notes:

- 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.



Notes:

- 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, <u>and</u> 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.

Notes:

- *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.

Note: These are tips to consider when it is necessary to leach salts but 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

Note: 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 water status information to understand irrigation needs.
2. Measure applied water.
3. Design and maintain high performing irrigation systems.

Note: 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.

Farm Practices and Nitrogen use Efficiency

Section 5

Integration of N Cycling with Cultural Management

To:
Reduce Nitrogen losses to the atmosphere and leaching
Reduce costs
Reduce environmental impacts

Efficient N Management: Applying the 4 Rs Principle

- Apply the Right Rate
  - Match supply with crop demand (all inputs- fertilizer, organic N, water, soil).
- Apply at the Right Time
  - Apply coincident with crop demand and root uptake.
- Apply In the Right Place
  - Ensure delivery to the active roots.
  - Minimize movement below root zone
- Use the Right Source

The 4 Rs are specific to every individual orchard/field and every year.

Details about each of the 4Rs:

Right Rate:
1. Appropriately assess soil nutrient supply
2. Assess all available indigenous nutrient sources
3. Assess plant demand
4. Predict fertilizer use efficiency

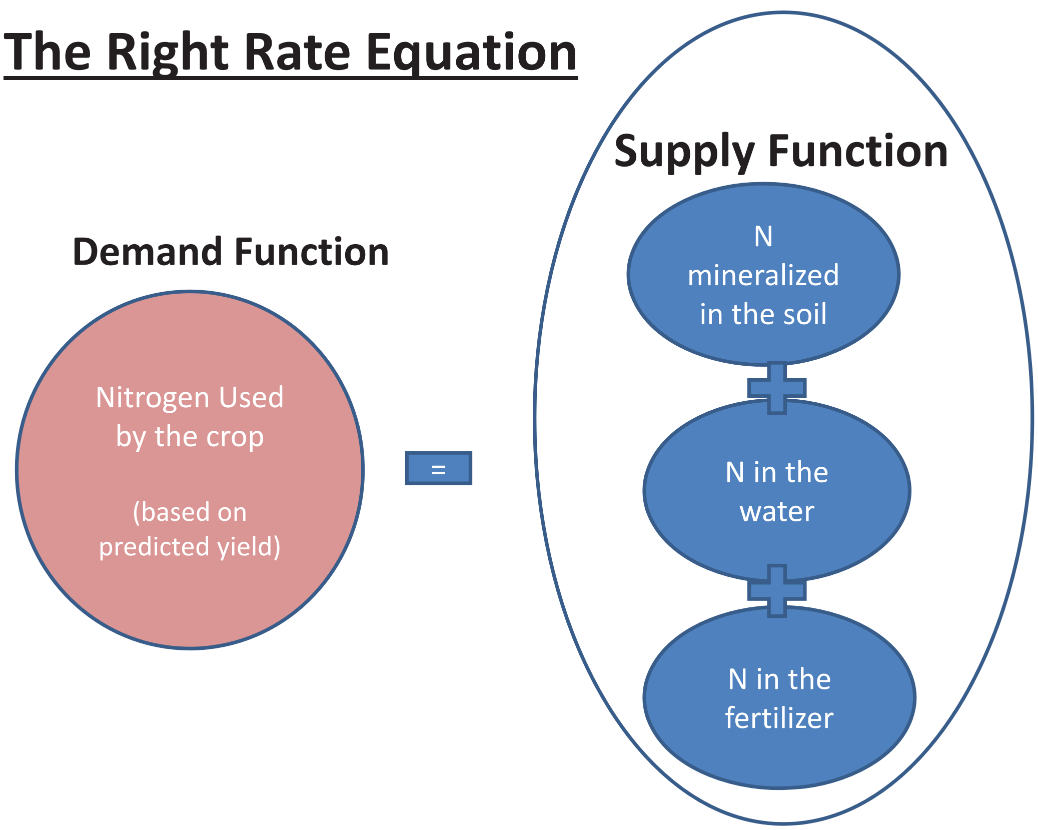
Right Time:
1. Assess timing of crop uptake
2. Assess dynamics of soil nutrient supply
3. Recognize timing of weather factors
4. Evaluate logistics of operations

Right Place:
1. Recognize root-soil dynamics
2. Manage spatial variability
3. Fit needs of tillage system
4. Limit potential off-field transport

Right Source:.
1. Supply in plant available forms
2. Suit soil properties
3. Recognize synergisms among elements
4. Blend compatibility

Note: Information on choosing the "Right Source" will be discussed in Section 3

The Right Rate Equation



Note: Use the right rate equation to avoid excess N, increase nitrogen use efficiency, and increase profitability by accounting for all N inputs.

Crop Nitrogen Demand

- **The amount of nitrogen taken up by the crop**
  - N in the harvested crop and removed form field + N in crop residues
    - Example Wheat:
      - 60 % N in grain
      - 40% N in straw
        - » Significant N left in the field as crop residues
  - N removed in the harvested (removed from field) crop
    - Example Mature walnut orchard:
      - » Includes N in hulls, sticks, and leaves removed from field
        - The bulk of the N is removed from the field at harvest
        - The remainder is cycled in the orchard each year

Note: Use the right rate equation to avoid excess N, increase nitrogen use efficiency, and increase profitability by accounting for all N inputs.

Crop Nitrogen Demand/Supply

- Annual crops:
  - Usually in some sort of crop rotation leaving different amounts and quality of residues each season.
    - Residual N as mineral and organic matter must be considered in the next season's N supply
- Perennial crops:
  - When mature with similar practices each year.
    - Residual N as mineral and organic matter is considered cycled each year and does not need to be considered in the next season's supply

Right Rate: Nutrient Demand in Harvested Crop

Where to get the information

Nutrient removal in harvested portion of crop	Unit	Removal, lb/unit			
		N			
Corn silage	ton	9.7			
Corn grain	ton	23.9			
Tomato	ton	2.5			
Rice grain	bu	0.57			
Wheat grain (winter)	bu	1.16			
Potato tuber	cwt	0.32			

Yield for Corn silage = 30 t/acre x 9.7 lbs N/ton = 291 lbs N /acre
Yield for Corn grain = 6 t/acre x 23.9 lbs N/ton = 143 lbs N /acre
The difference is the amount of N in the stover 148 lbs N / acre

(Modified from: 4R Plant Nutrition: A Manual for Improving the Management of Plant Nutrition, 2012 IPNI)

Notes:

- To look up nutrient demand for the harvested portions of other crops, please visit https://www.ipni.net/app/calculator/home

- This slide makes two points.

1. Nutrient removal rates are available
2. The grain corn example points out that the N **used** for the grain corn is most appropriate while N removed is appropriate for silage corn

- Yield for Corn silage = 30 t/acre x 9.7 lbs N/ton = 291 lbs N /acre
- Yield for Corn grain = 6 t/acre x 23.9 lbs N/ton = 143 lbs N /acre

The difference is the amount of N in the stover 148 lbs N / acre

Right Rate: Nutrient Demand in Harvested Crop Example

Fertilization rates often exceed N demand:

	Typical range (lb N / acre)		
	Seasonal N application	Total crop N uptake	N removal in harvest
Lettuce	120-200	110-140	60-80
Broccoli	150-250	200-300	60-90
Celery	200-300	180-240	120-160
Spinach	120-180	80-110	60-80
Strawberry	160-260	180-200	70-100

Notes:

- *Table*: Application rates for vegetable crops tend to exceed N removal through harvest. Though the total crop N uptake quantities more closely match the amount applied, a large portion will be returned to the field after harvest (ex: broccoli stems, etc..). **So, application should be based on the amount taken up through harvest.**
- The crop residue N must be considered for the following crop.

Right Rate: Nutrient Demand Examples

ALMOND

Nutrient removal per 1000 lb kernels

Nonpareil
- N removal 68 lb per 1000

Monterey
- N removal 65 lb per 1000

Growth Requirement
- Yield 2,000-4,000 = 0 lb N
- Yield 1,000-2,000 = 20 lb N
- Yield <1,000 = 30 lb N

Notes:
- Examples of amount N removed by harvest for some tree crops.
- If yield is unpredictable, begin by using an approximation to determine the first 20% of N needed. Then calculate the remaining fertilization needed after the crop is on the tree, giving a much more accurate estimate of yield for the rest of the season.

PISTACHIO

Kerman:
- N removal 28 lb per 1000*

Growth Requirement:
- On-year: 25 lb N
- Off-year=25-40 lb N

*Dry CPC assessed yield

Walnut

- N removal 19 lb per 1000 lb in shell 8% moisture

Growth Requirement:
- Mature orchard = included in above
- Immature orchard: not as yet available

Right Rate: Methods for Setting Realistic Yield Goals

- Use experience of the potential of a particular field, and then consider environmental conditions.
  - For annuals, weather at planting can have a major effect.
  - For perennials, the past year's yield plus winter and spring weather can be critical.
- Set **target** of 10% above the field's 3-5 year average, excluding years with unusual negative conditions (pests/disease/drought, etc.).

  Estimating too high of a yield can result in early season over application

- Multiple applications combined with in-season tissue and or soil analysis can allow for adjustments

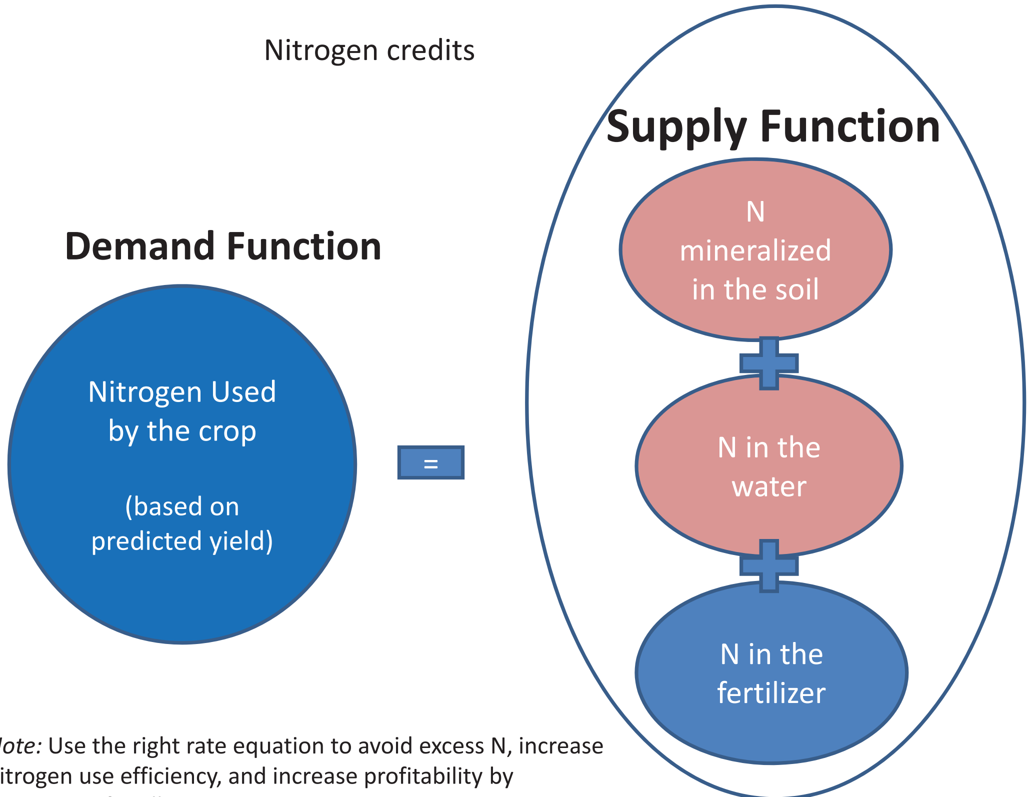
Note: With the more than 100 crops grown in California, it is hard to provide a uniform approach to yield estimation. The best approach is likely to use your own experience to guide you, bearing in mind that getting a yield estimate wrong at the beginning of the year can result in substantial difficulty later in the year.

Calculating Crop N Use

- Nitrogen used per unit of crop yield
- Estimated crop yield
- Example:
- Mature walnuts at 37 lb N per ton
- Yield expected is 3.0 tons/acre
- Result = 111 lb N / acre use

The Right Rate Equation: Supply Function

Nitrogen credits



Note: Use the right rate equation to avoid excess N, increase nitrogen use efficiency, and increase profitability by accounting for all N inputs.

Right Rate 'Supply':

Nutrients in Manures and Composts

	Total N	Inorg N	C: Org N
	lb/ton DM	lb/ton DM	
Fresh Manure	50	4	18
Mech Screen Solids	34	4	30
Coral Scrapings	38	2	13
Compost	44	2	14
Anaerobic Dairy Lagoon Sludge	60	10	11

Notes:

- The inorganic N should be available quickly when the C:N ration is <20
- The organic N will eventually become available, however the rate of mineralization will depend on:
  - C: N ratio 20:1 threshold
  - Temperature
  - Moisture
  - Type of organic material

Right Rate 'Supply':
Nitrogen in Manures and Composts and Cover crops

- Consistent application of manure or the growing of a cover crop allows for easy accounting of N available each year.
  - Dry lbs manure/cover crop/compost x % N
    - If incorporated the efficiency of decomposition and uptake is probably about 70% **over time**
    - **Therefore the N content is used as a N supply**

Right Rate 'Supply':
Nitrogen in Manures and Composts and Cover crops

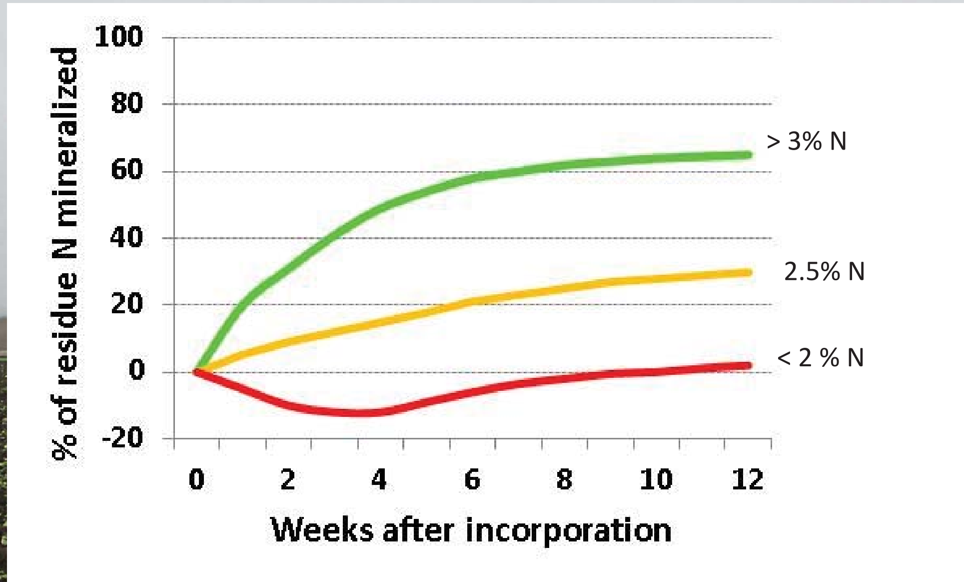
- A single application of manure or the growing of a cover crop is more difficult
- Dry lbs organic amendment x % N x % decomposition
  - If incorporated the efficiency of decomposition and uptake is probably about 70% **over time**.

First year decomposition Rates

Cured compost	5-10%
Dried manure	15-30%

Notes:
- About 70% of the organic N will be mineralized over time– the rest is subject to losses.
- In the first year mineralization is relatively low.

Field-Specific N Management:
Contribution of Crop Residue



In general, more than 90 days after soil incorporation, crop residue N behaves similarly to that of existing soil organic N

Notes:

- Crops vary widely both on the amount of nitrogen typically contained in residue, and in the nitrogen concentration of that residue; both factors profoundly influence the nitrogen contribution to the following crop.
-
- Figure:
- Green = residue of very high N content
- Yellow = residue of intermediate N content
- Red = residue of low N content
-
- These examples show the range of N concentrations, with all high enough to expect rapid mineralization once incorporated. When following a high N concentration crop (ex: lettuce), within several weeks more than half of this N will mineralize and be available. For a crop with a medium N content, you can assume that about 1/3 of its N will eventually become crop-available through mineralization. A crop with a very low N content (ex: cereal grain) will not likely contribute mineralized N to the following crop. These residues may even immobilize N, represented by the negative-sloped portion of the red line, necessitating application of additional N before the following crop.

Mineralizing Soil Organic Matter (SOM)

Contribution of soil N mineralization:

- About 5 % of soil organic matter is organic N
- You can generally count on net mineralization of *at least* 1-2% of soil organic N content during a crop season

20-40 lb N/acre/ % SOM

Notes:

- The final amount is multiplied by whatever % organic matter your soil has, perhaps around 1%. The 1-2% net mineralization figure is for a crop season.
- The example calculation breaks down as 4,000,000 x 5% x 1% x 1-2% = lb N/acre
- In systems where manure and other organic materials are being applied, these portions would be higher. Behavior of N mineralization would also change in a system with very high organic matter content.

Right Rate 'Supply': N in the Soil

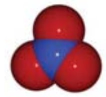
- Especially important for annual crops
- Soil Nitrate Testing at planting or before side-dress is a valuable tool.

Challenges in using these tests:

- Spatial variability – need representative samples
- Turn around time from the lab (there are some quick tests)
- Will the nitrate be there after an irrigation?
- If nitrate is coming from mineralization of an organic source, how much and how quickly will more nitrate be available?

Note: Currently, we do not do soil mineral N tests for perennial crops because the amount of N cycling through from dropped leaves and prunings is such a small percentage of the overall N. This test is much more important for annual crops.

Right Rate ‘Supply’: N in the Water

- Formula for Nitrate: 

  Nitrate concentration (ppm) x inches irrigation applied x **0.052**

- Formula for Nitrate-N: 

  Nitrate-N concentration (ppm) x inches irrigation applied x **0.23**

Example:

Lab reports 10 ppm Nitrate and you apply 36 inches of water
10 x 36 x 0.052 =

Answer = 19 lb N

Lab reports 2.3 ppm Nitrate-N and you apply 36 inches of water
2.3 x 36 x 0.23 =

Answer = 19 lb N

Notes:

- N in water is a free and very readily available nitrogen source.
- Note: The conversion factors .052 and 0.23 are constants used to convert from N concentration in ppm to lbs.
- When Nitrate concentration is measured in nitrate-N (NO3--N), only the nitrogen is measured.
- When Nitrate concentration is measured in nitrate (NO3-), nitrogen and oxygen are both measured.
- The two maximum contaminant levels are the same – only difference is the mg/L is the weight on N and O3 versus N .
  - A factor of about 4.5
  - 62.0049 / 14.0067 = 4.427

The Right Rate Equation: Demand Function

Supply Function

Demand Function

Nitrogen Used by the crop

(based on predicted yield

=

N mineralized in the soil

+

N in the water

+

N in the fertilizer

Note: Use the right rate equation to avoid excess N, increase nitrogen use efficiency, and increase profitability by accounting for all N inputs.

The Right Rate Equation: Demand Function

Supply Function

Demand Function

Nitrogen Used by the crop

(based on predicted yield

=

N mineralized in the soil

+

N in the water

+

N in the fertilizer

Adjust for Nitrogen Use Efficiency

Note: Use the right rate equation to avoid excess N, increase nitrogen use efficiency, and increase profitability by accounting for all N inputs.

Nitrogen Use Efficiency

$$\frac{Output}{Input} = Efficiency$$

1. $$\frac{Lbs\ N\ \textbf{exported}\ from\ the\ field\ in\ crop\ products}{Lbs\ N\ all\ sources} = Nitrogen\ Use\ Efficiency$$

2. $$\frac{Lbs\ N\ \textbf{used}\ by\ the\ crop}{Lbs\ N\ all\ sources} = Nitrogen\ Use\ Efficiency$$

Exported in the crop = Just the exported N from field in crop the other N contained in leaves, prunings etc.. is cycled in field each year

Used = harvested crop + crop residues = incorporated into soil organic matter

All sources of N– fertilizer, mineralized and water sources

Notes:

1. Doesn't include the N used in the crop residues and contribution to SOM. May work with steady state perennials or monoculture.
2. Includes the N used by the crop for harvested and crop residue and contribution to SOM. Works well with annual crop rotations.

Nitrogen Use Efficiency (NUE)

- The highest efficiency is achieved by the best combination of right rate, right time, right place and right source.
  - This requires understanding the dynamics of nitrogen in the soil and the plant

Achievable NUE= 70% (More of a target)

Worldwide NUE = < 50%

Cassman, Kenneth G.; Dobermann, Achim R.; and Walters, Daniel T., "Agroecosystems, Nitrogen-use Efficiency, and Nitrogen
Management" (2002). *Agronomy & Horticulture -- Faculty Publications.* Paper 356.
http://digitalcommons.unl.edu/agronomyfacpub/35

Nitrogen Use Efficiency

- Achieving an NUE of 70 % requires:

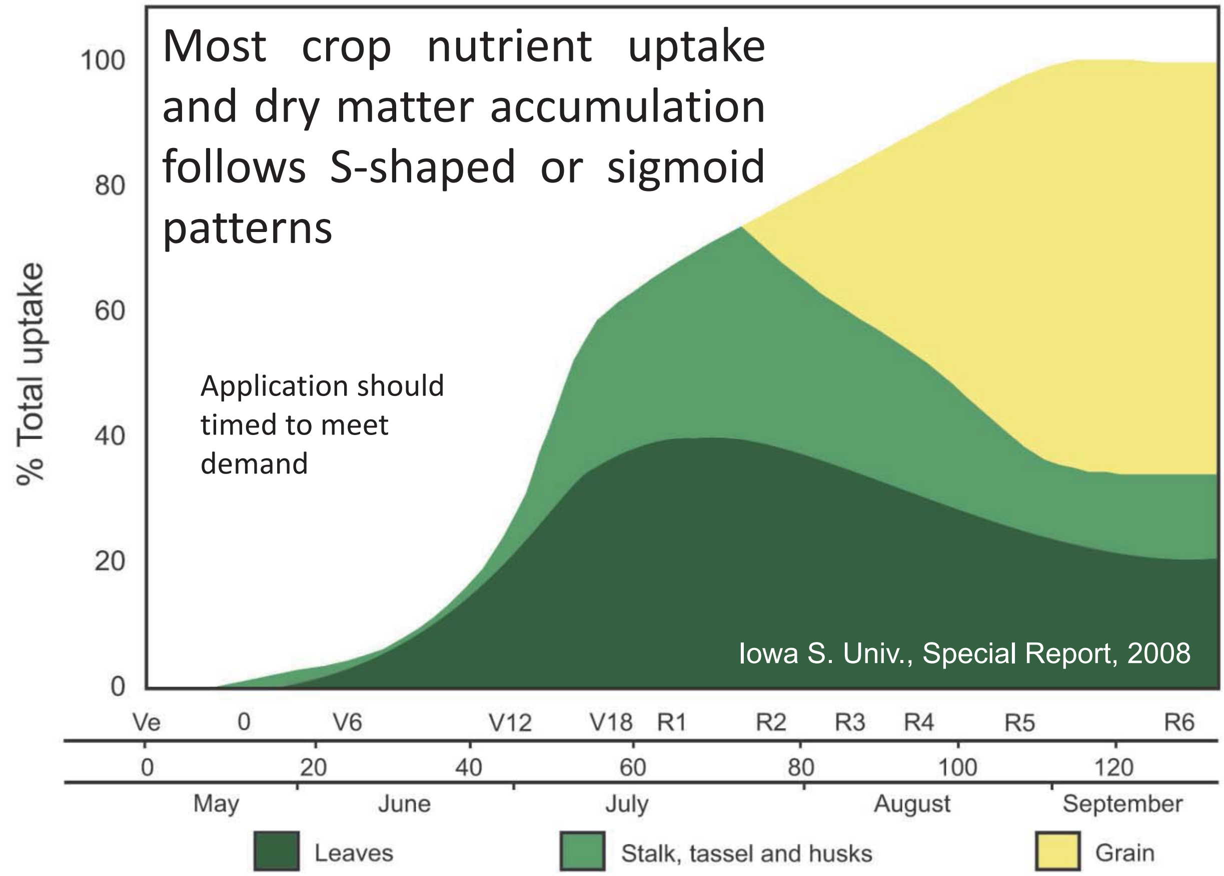
- Management of croplands to minimize Losses:
  - Volatilization
  - Denitrification
  - Runoff
  - Leaching
- Following the 4R's principles

Estimated N Demand

- Crop N use per Acre x Nitrogen Use Efficiency (NUE)

- Walnut:
  - Crop use = 111 lb N/Acre / 0.70 = 159 lbs N/Acre

Right Rate and Timing 'Demand': Corn Example



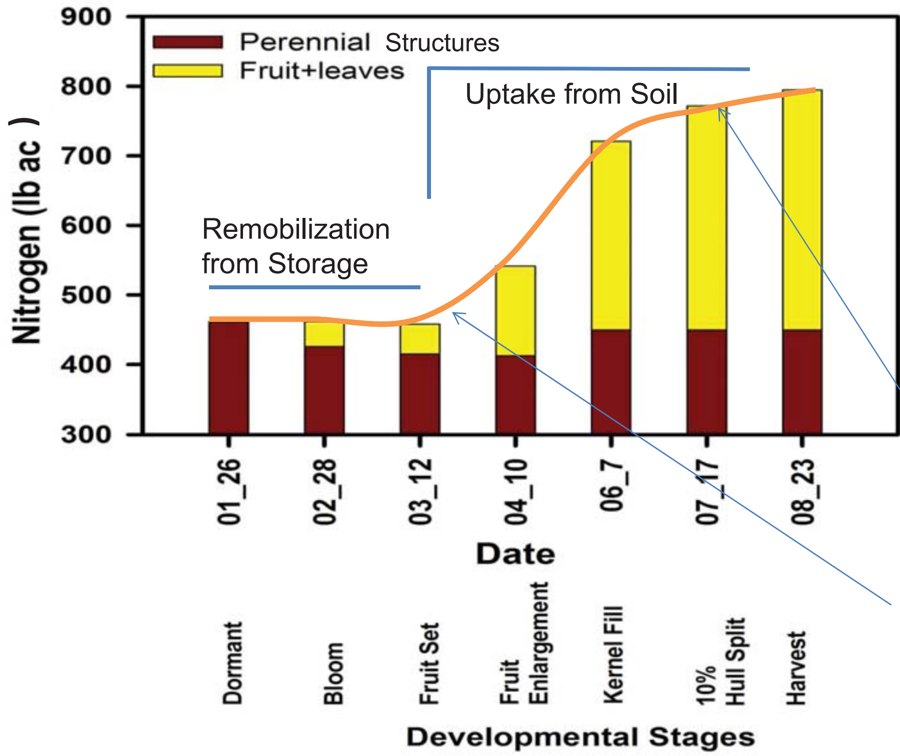
Notes:

- *Figure:* Cumulative corn N uptake divided by plant organ. Nutrient demand is characterized by slow early uptake, increase to a maximum during the rapid growth phase, and decline as the crop reaches flowering and matures. At flowering, N is remobilized from the flowers back in, rather than taken up.

- Demand for N is largely driven by biomass accumulation.

- Nutrient demand per time is related to growth rate; fast growth requires a high rate of N uptake and assimilation.

Right Rate and Timing 'Demand': Almond Example



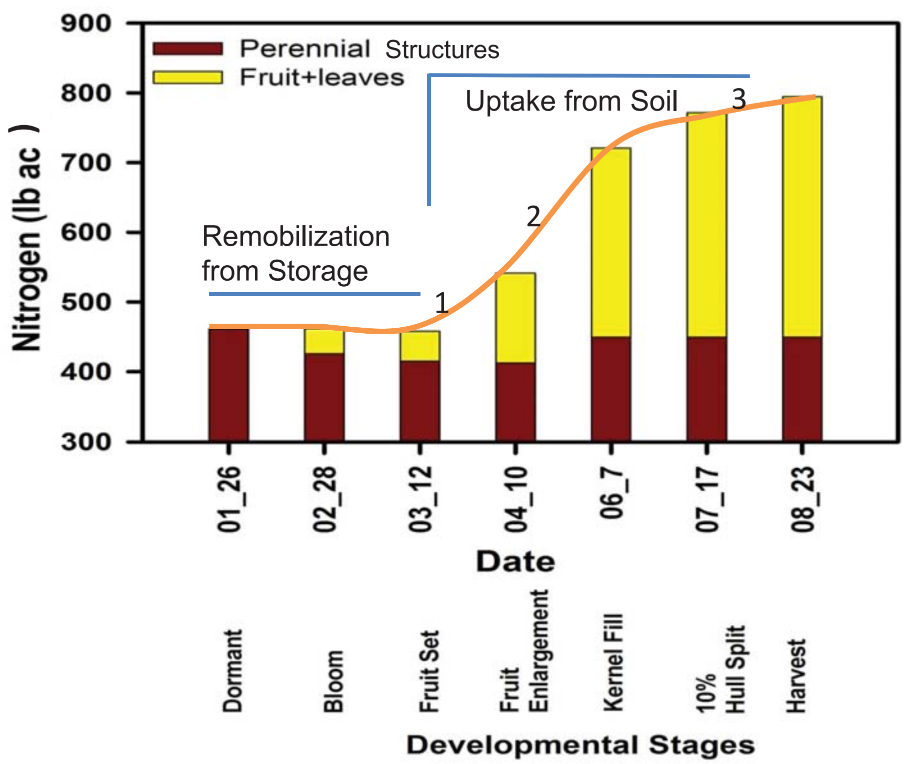
Dark bar height represents the N in perennial tissues (Trunk, branches and roots).

Light bar height represents annual tissues (fruit and Leaves).

From dormancy to mid-March there is very little N uptake.

Uptake commences at mid-leaf out and is essentially complete by hull split.

Right Rate and Timing 'Demand': Almond Example



<u>Recommended N Split:</u>

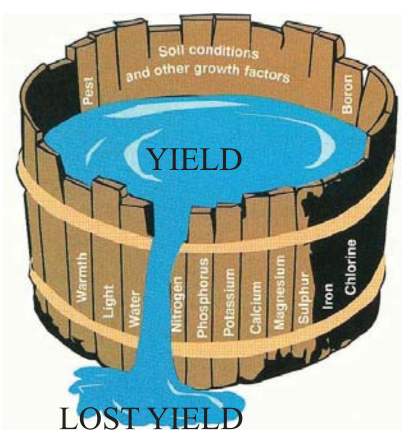
1. 20% Leaf Out-Fruit Enlargement
2. 30% Fruit Enlargement/30% Kernel Fill
3. 20% Hull-split through early Post-Harvest

Notes:

- Figure: This curve represents all N in the orchard, including woody perennial tissues, leaves, and fruit.
- From January through March, the curve is completely flat. Here, N is being remobilized from perennial tissues into fruit and leaves, rather than taken up. This means that any early season application will not be taken up from soil and has the potential to be lost.
- N demand is heavily driven by the amount of nuts on the tree, so rapid uptake from the soil is seen around March and April, with a flattening as the nuts mature.

Right Source: Nutrient Balance

The efficiency of nitrogen will always depend upon the adequacy of all other essential elements and growth conditions.

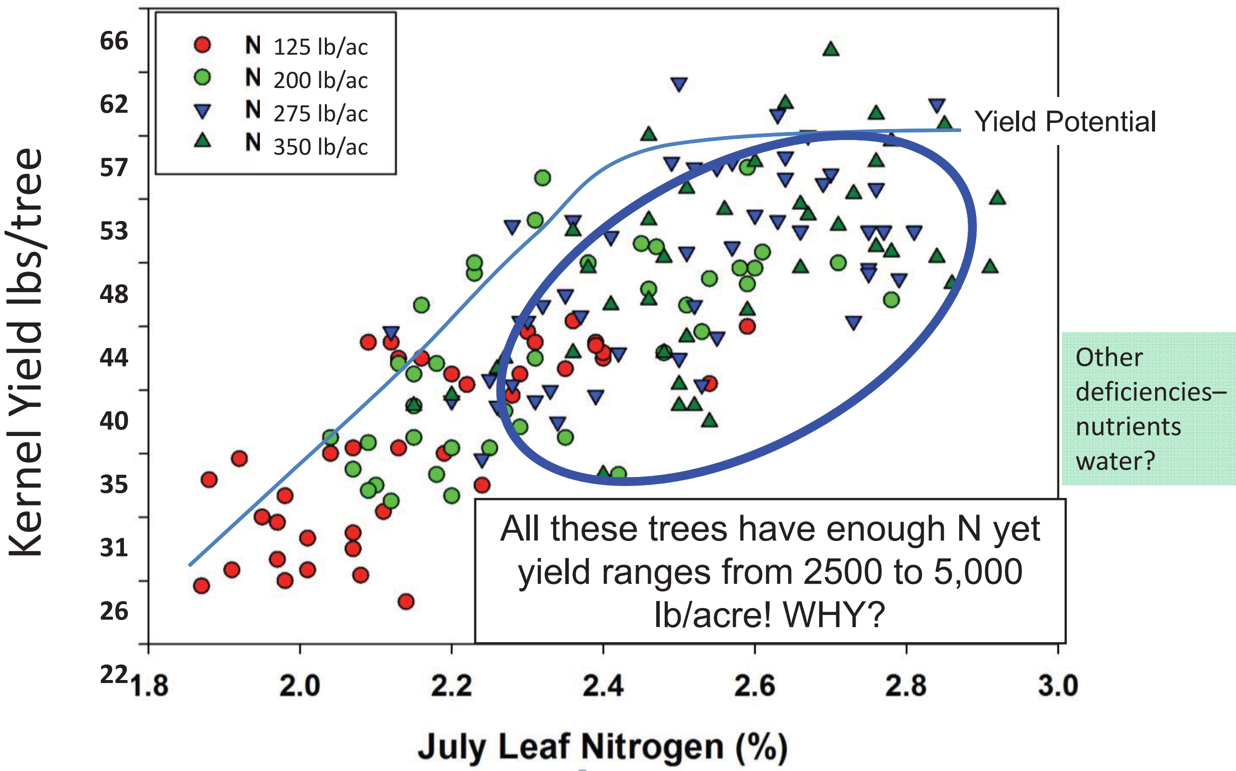


The Law of Minimum
Justus Von Leibig, 1863

If any nutrient is inadequate - Yield is lost AND a response to other elements cannot occur.

If any nutrient is oversupplied - Money is wasted

Right Source: N Management Alone is Not Enough



Notes:

- It is a fundamental law of plant nutrition that the efficiency of one nutrient cannot be optimized without also optimizing the others.

- *Figure:* All trees in the blue circle were given sufficient N, but why is their yield so variable? Another nutrient must be missing that is preventing efficient use of N. Identifying limiting nutrient can help prevent these inefficiencies.

Right Place: Where are the Roots?

How to manage:

for a crop with a 6-inch rooting depth?

How to manage:

for a crop with a 4-foot rooting depth?

Note: The main goal is to keep N in the root zone. If there are only a few fertigation events per year, each one could be large enough to boost soil N concentration above what the plant could take up at the time of the event. When this is the case, it is crucial to keep the N in the root zone for as long as possible to give the plant a chance to catch up.

(Photo's Courtesy Tim Hartz and IPNI)

Right Place: Where Does N Uptake Occur?

Soil and irrigation practices will influence this greatly:

	Depth of Main Root Zone (inches)
Almond	8-23
Apricot	8-16
Cherry	4-16
Peach	0-32
Plum	10-24
Walnut	0-16

Table: Examples of the root zones of some permanent crops.

References:

Almond 8-23 Dziljanov and Penkov 1964b
Apricot 8-16 Ghena and Tercel 1962
Cherry 4-16 Tamasi 1975
Peach 0-32 Dziljanov and Penkov 1964b
Plum 10-24 Tamasi 1973
Walnut 0-16 Kairov et al. 1977
(Adapted from: Atkinson, 1980. The Distribution and Effectiveness of the Roots of Tree Crops. Horticultural Reviews.)

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.

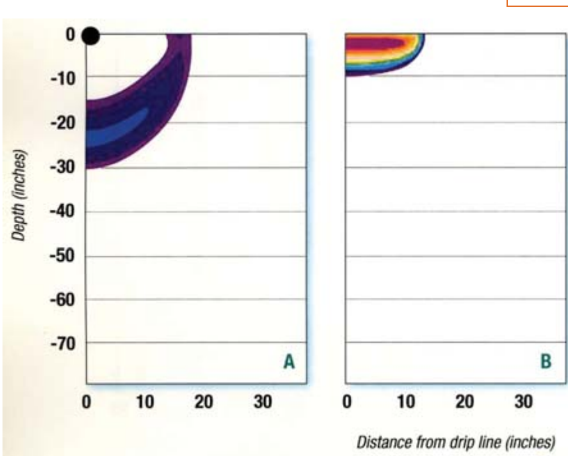
Notes:
- *Left:* A venturi injector with a small pump used to inject fertilizers into pressurized irrigation systems. This eliminates the requirement that the venturi injector be plumbed across a pressure drop. Right: A differential pressure tank used for fertilizer injection. It is difficult to obtain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

Fertigation in Pressurized Systems: Root Zone Targeting Example

When during the irrigation do you inject (for different soil types)?

Surface Drip

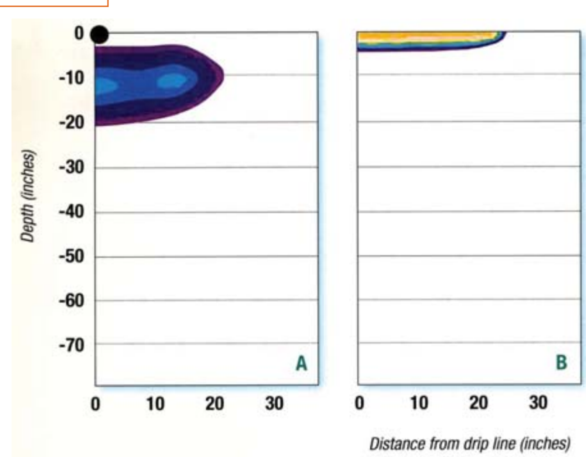
Loam



2 hour injection near start of 27 to 36 hour Irrigation. **N levels elevated at 30 in.**

2 hour injection near end of 27 to 36 hour Irrigation **N confined to top 10 in.**

Silt Loam



2 hour injection near start of 27 to 36 hour Irrigation **N levels elevated at 20 in**

2 hour injection near end of 27 to 36 hour Irrigation **N confined to top 6 in.**

(Blaine Hanson, "Fertigation with Microirrigation")

Notes:

- *Figures:* Distribution of nitrate in soil shortly after application of N fertilizers. Irrigation water and nitrogen fertilizer were applied through surface drip on loam soil (left two figures) and through surface drip on silt loam soil (right two figures). These data sets show that injecting N fertilizers during the latter 1/3 of an irrigation set time yields better placement of N fertilizers and groundwater quality protection. This still leaves adequate time for fertilizer to be distributed uniformly through the system and sufficient time to purge the system of all fertilizer.

- Because of improved abilities to study nitrate movement and heightened scrutiny of nitrogen fertilizer use in CA agriculture, **advice previously given to growers to fertigate toward the middle third of an irrigation event has become outdated**. Research shows this increases the likelihood of nitrate fertilizers percolating below the root zone during subsequent irrigation.

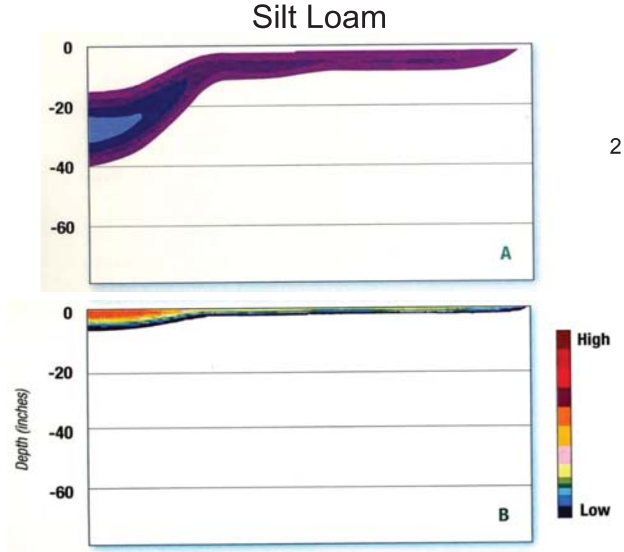
- Is it preferable to apply fertilizers at the beginning, middle, or end of the irrigation set?

Fertigation in Pressurized Systems: Root Zone Targeting Example

When during the irrigation do you inject?

Microsprinklers

Silt Loam



2 hour injection near start of Irrigation

2 hour injection near end of Irrigation

(Blaine Hanson, "Fertigation with Microirrigation")

Notes:

- Fertilizer injections into **microsprinklers** should occur in the latter 1/3 of total irrigation set time.
- *Top Figure:* Nitrate at 40 in. deep in the soil profile shortly after N fertilizer was injected during the first 2 hours of a longer irrigation set.
- *Bottom Figure:* Nitrate confined to a depth of 6 in. when N fertilizer was injected in 2 hours near the end of a longer irrigation set. This, however, raises the question of whether the fertilizer will penetrate deep enough to supply the crop with sufficient N. But with low volume microsprinklers, irrigations occur frequently, so the fertilizer will be moved deeper into the root zone with subsequent irrigations.

Farm Practices and Nitrogen use Efficiency Summary

The highest nitrogen use efficiency is achieved by: the best combination of right rate, right time, right place and right source.

This requires understanding the dynamics of nitrogen in the soil and the plant and irrigation system performance to reduce nitrogen losses

Nitrogen Management Plan

Section 6

A planning document:

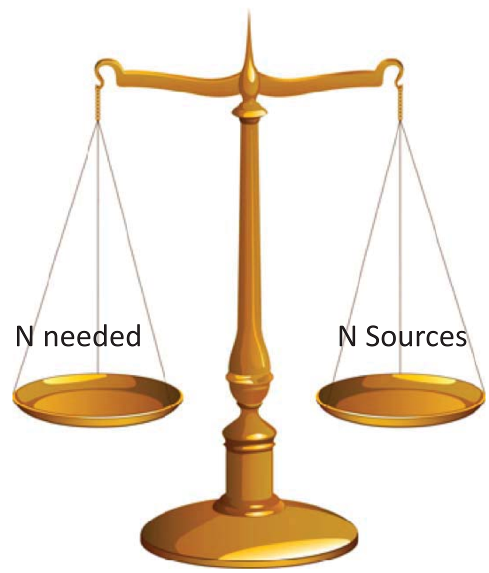
Based on :

Crop

Expected yield

vs

N sources



NITROGEN MANAGEMENT PLAN WORKSHEET

NMP Management Unit: ______________________________

		4. APN(s):	5. Field(s) ID	Acres
1. Crop Year (Harvested):				
2. Member ID#				
3. Name:				

CROP NITROGEN MANAGEMENT PLANNING		N APPLICATIONS/CREDITS	15. Recommended/ Planned N	16. Actual N
6. Crop		**17. Nitrogen Fertilizers**		
7. Production Unit		18. Dry/Liquid N (lbs/ac)		
8. Projected Yield (Units/Acre)		19. Foliar N (lbs/ac)		
9. N Recommended (lbs/ac)		**20. Organic Material N**		
10. Acres		21. Available N in Manure/Compost (lbs/ac estimate)		
Post Production Actuals				
11. Actual Yield (Units/Acre)		**22. Total Available N Applied** (lbs per acre)		
12. Total N Applied (lbs/ac)		**23. Nitrogen Credits (est)**		
13. ** N Removed (lbs N/ac)		24. Available N carryover in soil; (annualized lbs/acre)		
14. Notes:		25. N in Irrigation water (annualized, lbs/ac)		
		26. Total N Credits (lbs per acre)		
		27. Total N Applied & Available		

PLAN CERTIFICATION

28. CERTIFIED BY:	29. CERTIFICATION METHOD	
	30. Low Vulnerability Area, No Certification Needed	
	31. Self-Certified, approved training program attended	
DATE:	32. Self-Certified, UC or NRCS site recommendation	
	33. Nitrogen Management Plan Specialist	

This is a condensed(reduced APN) version for a better fit.

XL NMP Spreadsheet available at : https://www.esjcoalition.org/nCalc.asp

NITROGEN MANAGEMENT PLAN WORKSHEET

NMP Management Unit: ______________________________

1. Crop Year (Harvested):	2015	4. APN(s):	5. Field(s) ID	Acres
2. Member ID#	xxxxxx			
3. Name:	Your Name			

CROP NITROGEN MANAGEMENT PLANNING		N APPLICATIONS/CREDITS	15. Recommended/ Planned N	16. Actual N
6. Crop		**17. Nitrogen Fertilizers**		
7. Production Unit		18. Dry/Liquid N (lbs/ac)		
8. Projected Yield (Units/Acre)		19. Foliar N (lbs/ac)		
9. N Recommended (lbs/ac)		**20. Organic Material N**		
10. Acres		21. Available N in Manure/Compost (lbs/ac estimate)		
Post Production Actuals				
11. Actual Yield (Units/Acre)		**22. Total Available N Applied** (lbs per acre)		
12. Total N Applied (lbs/ac)		**23. Nitrogen Credits (est)**		
13. ** N Removed (lbs N/ac)		24. Available N carryover in soil; (annualized lbs/acre)		
14. Notes:		25. N in Irrigation water (annualized, lbs/ac)		
		26. Total N Credits (lbs per acre)		
		27. Total N Applied & Available		

PLAN CERTIFICATION		
28. CERTIFIED BY:	**29. CERTIFICATION METHOD**	
	30. Low Vulnerability Area, No Certification Needed	
	31. Self-Certified, approved training program attended	
DATE:	32. Self-Certified, UC or NRCS site recommendation	
	33. Nitrogen Management Plan Specialist	

Notes:

- **1.** Enter the **Crop Year** for which this report is based upon.
- The calendar year a crop is harvested.
- Newly planted trees or vines should report amount of nitrogen applied even if not crop is harvested.
- **2**. Enter the membership identification number **(Member ID)** issued by your water quality coalition
- **3**. Enter the **Name** of the person completing the form. This needs to be the owner or manager of the farm or the individual certifying the plan (if certification is necessary).

NITROGEN MANAGEMENT PLAN WORKSHEET

NMP Management Unit: ____________________________

1. Crop Year (Harvested):	2015	4. APN(s):	5. Field(s) ID	Acres
2. Member ID#	xxxx	02-025-016	1	100
3. Name:	Your Name			

CROP NITROGEN MANAGEMENT PLANNING		N APPLICATIONS/CREDITS	15. Recommended/ Planned N	16. Actual N
6. Crop		**17. Nitrogen Fertilizers**		
7. Production Unit		18. Dry/Liquid N (lbs/ac)		
8. Projected Yield (Units/Acre)		19. Foliar N (lbs/ac)		
9. N Recommended (lbs/ac)		**20. Organic Material N**		
10. Acres		21. Available N in Manure/Compost (lbs/ac estimate)		
Post Production Actuals				
11. Actual Yield (Units/Acre)		**22. Total Available N Applied** (lbs per acre)		
12. Total N Applied (lbs/ac)		**23. Nitrogen Credits (est)**		
13. ** N Removed (lbs N/ac)		24. Available N carryover in soil; (annualized lbs/acre)		
14. Notes:		25. N in Irrigation water (annualized, lbs/ac)		
		26. Total N Credits (lbs per acre)		
		27. Total N Applied & Available		

PLAN CERTIFICATION		
28. CERTIFIED BY:	29. CERTIFICATION METHOD	
	30. Low Vulnerability Area, No Certification Needed	
	31. Self-Certified, approved training program attended	
DATE:	32. Self-Certified, UC or NRCS site recommendation	
	33. Nitrogen Management Plan Specialist	

Notes:

- **4.** Enter the Assessor's Parcel Number **(APN).** If field is more than one APN enter both APN's
- **5.** Enter the **Field Identification** (ID) for each unique management unit; the field ID can be an alpha/ numeric, your internal field identifier or the site number used on your pesticide use permit. If the same crop and same nitrogen application is used on more than one field, enter all APN's and/or field numbers where the information applies
- Enter field acres

NITROGEN MANAGEMENT PLAN WORKSHEET

NMP Management Unit: ______________________________

1. Crop Year (Harvested):	2015	4. APN(s):	5. Field(s) ID	Acres
2. Member ID#	xxxx	020-025-016	1	100
3. Name:	Your Name			

CROP NITROGEN MANAGEMENT PLANNING		N APPLICATIONS/CREDITS	15. Recommended/ Planned N	16. Actual N
6. Crop	Walnut	**17. Nitrogen Fertilizers**		
7. Production Unit	tons	18. Dry/Liquid N (lbs/ac)		
8. Projected Yield (Units/Acre)	3.0	19. Foliar N (lbs/ac)		
9. N Recommended (lbs/ac)		**20. Organic Material N**		
10. Acres		21. Available N in Manure/Compost (lbs/ac estimate)		
Post Production Actuals				
11. Actual Yield (Units/Acre)		**22. Total Available N Applied** (lbs per acre)		
12. Total N Applied (lbs/ac)		**23. Nitrogen Credits (est)**		
13. ** N Removed (lbs N/ac)		24. Available N carryover in soil; (annualized lbs/acre)		
14. Notes:		25. N in Irrigation water (annualized, lbs/ac)		
		26. Total N Credits (lbs per acre)		
		27. Total N Applied & Available		

PLAN CERTIFICATION		
28. CERTIFIED BY:	**29. CERTIFICATION METHOD**	
	30. Low Vulnerability Area, No Certification Needed	
	31. Self-Certified, approved training program attended	
DATE:	32. Self-Certified, UC or NRCS site recommendation	
	33. Nitrogen Management Plan Specialist	

Notes:

- **6.** Enter the **Crop** name (almonds, walnuts, table grapes, wine grapes, raisin grapes, watermelons, canning tomatoes, fresh market tomatoes, etc..)
- **7.** Enter the standard **Production Unit.**
- This is the standard unit that is the basis for your nitrogen management planning (tons, pounds, cartons, bales, etc..).
- For irrigated pasture, leave blank and use University of California recommended nitrogen rates needed for desired growth in box 9.
- **8.** Enter your **Projected Yield** per acre for the management unit for the upcoming season. Realistic yield expectations will help guide N management decisions.
  - For irrigated pasture, leave blank and use University of California recommended nitrogen rates needed for desired growth in box 9.

CROP NITROGEN MANAGEMENT PLANNING

9. Enter the amount of **Nitrogen Recommended** (estimated amount needed) to be applied to meet your expected yield. **Use crop recommendations from CDFA, UCCE, NRCS, commodity organizations or site specific knowledge based on previous experience to appropriately estimate the amount of Nitrogen (N) needed.** This should be the same number used in #27, Total N Applied and Available.

NITROGEN MANAGEMENT PLAN WORKSHEET

NMP Management Unit: ______________________________

1. Crop Year (Harvested):	2015	4. APN(s):	5. Field(s) ID	Acres
2. Member ID#	xxxx	020-025-016	1	100
3. Name:	Your Name			
CROP NITROGEN MANAGEMENT PLANNING		N APPLICATIONS/CREDITS	15. Recommended/ Planned N	16. Actual N
6. Crop	Walnut	17. Nitrogen Fertilizers		
7. Production Unit	tons	18. Dry/Liquid N (lbs/ac)		
8. Projected Yield (Units/Acre)	3.00	19. Foliar N (lbs/ac)		
9. N Recommended (lbs/ac)	160	20. Organic Material N		
10. Acres	100	21. Available N in Manure/Compost (lbs/ac estimate)		
Post Production Actuals				
11. Actual Yield (Units/Acre)		22. Total Available N Applied (lbs per acre)		
12. Total N Applied (lbs/ac)		23. Nitrogen Credits (est)		
13. ** N Removed (lbs N/ac)		24. Available N carryover in soil; (annualized lbs/acre)		
14. Notes:		25. N in Irrigation water (annualized, lbs/ac)		
		26. Total N Credits (lbs per acre)		
		27. Total N Applied & Available		

PLAN CERTIFICATION		
28. CERTIFIED BY:	29. CERTIFICATION METHOD	
	30. Low Vulnerability Area, No Certification Needed	
	31. Self-Certified, approved training program attended	
DATE:	32. Self-Certified, UC or NRCS site recommendation	
	33. Nitrogen Management Plan Specialist	

Notes:

- **9.** Enter the amount of **Nitrogen Recommended** (estimated amount needed) to be applied to meet your expected yield. Use crop recommendations from CDFA, UCCE, NRCS, commodity organizations or site specific knowledge based on previous experience to appropriately estimate the amount of Nitrogen (N) needed. This should be the same number used in #27, Total N Applied and Available.

- **10.** Enter total irrigated **Acres** for the management unit covered by each worksheet.

NITROGEN MANAGEMENT PLAN WORKSHEET

NMP Management Unit: ____________________________

1. Crop Year (Harvested):	**2015**	4. APN(s):	5. Field(s) ID	Acres
2. Member ID#	**xxxx**	020-025-016	1	100
3. Name:	Your Name			

CROP NITROGEN MANAGEMENT PLANNING		N APPLICATIONS/CREDITS	15. Recommended/ Planned N	16. Actual N
6. Crop	Walnut	**17. Nitrogen Fertilizers**		
7. Production Unit	tons	18. Dry/Liquid N (lbs/ac)		
8. Projected Yield (Units/Acre)	3.00	19. Foliar N (lbs/ac)		
9. N Recommended (lbs/ac)	160	**20. Organic Material N**		
10. Acres	100	21. Available N in Manure/Compost (lbs/ac estimate)		
Post Production Actuals				
11. Actual Yield (Units/Acre)		**22. Total Available N Applied** (lbs per acre)		
12. Total N Applied (lbs/ac)		**23. Nitrogen Credits (est)**		
13. ** N Removed (lbs N/ac)		24. Available N carryover in soil; (annualized lbs/acre)	0	
14. Notes:		25. N in Irrigation water (annualized, lbs/ac)	20	
		26. Total N Credits (lbs per acre)	**20**	
		27. Total N Applied & Available		

PLAN CERTIFICATION		
28. CERTIFIED BY:	**29. CERTIFICATION METHOD**	
	30. Low Vulnerability Area, No Certification Needed	
	31. Self-Certified, approved training program attended	
DATE:	32. Self-Certified, UC or NRCS site recommendation	
	33. Nitrogen Management Plan Specialist	

Notes:

- **23. Soil Nitrogen Credits** is the estimated amount of nitrogen that will become available for crop uptake during the growing season.

- 24. **Available N Carryover in the Soil** is typically estimated by analyzing a soil sample. This estimate should be reported in pounds per acre available to the crop during the growing season. This is used for annual crops in a rotation or perennial crops with change in practices– i.e. a cover crop the previous year.
- For mature perennial crops with similar practices each year use 0 since it is considered to be at a steady state other than the amount for the crop removed

- 25. **Nitrogen in Irrigation Water** is estimated by analyzing an irrigation water sample to determine the nitrogen content. This estimate should be reported in pounds per acre available throughout the crop season based on the amount of irrigation water applied to the crop if less than ET. If more water applied than ET only use the ET.

- **26. Total N Credits** is the sum of #24 and #25.

- 27. **Total N Applied and Available** is the sum of #22 and #26. This total should be the same number as #12.

NITROGEN MANAGEMENT PLAN WORKSHEET

NMP Management Unit: ______________________________

1. Crop Year (Harvested):	**2015**	4. APN(s):	5. Field(s) ID	Acres
2. Member ID#	**xxxx**	020-025-016	1	100
3. Name:	Your Name			

CROP NITROGEN MANAGEMENT PLANNING		N APPLICATIONS/CREDITS	15. Recommended/ Planned N	16. Actual N
6. Crop	Walnut	**17. Nitrogen Fertilizers**		
7. Production Unit	tons	18. Dry/Liquid N (lbs/ac)	140	
8. Projected Yield (Units/Acre)	3.00	19. Foliar N (lbs/ac)	0	
9. N Recommended (lbs/ac)	160	**20. Organic Material N**		
10. Acres	100	21. Available N in Manure/Compost (lbs/ac estimate)	**0**	
Post Production Actuals				
11. Actual Yield (Units/Acre)		**22. Total Available N Applied** (lbs per acre)	**140**	
12. Total N Applied (lbs/ac)		**23. Nitrogen Credits (est)**		
13. ** N Removed (lbs N/ac)		24. Available N carryover in soil; (annualized lbs/acre)	0	
14. Notes:		25. N in Irrigation water (annualized, lbs/ac)	20	
		26. Total N Credits (lbs per acre)	**20**	
		27. Total N Applied & Available	**160**	

PLAN CERTIFICATION		
28. CERTIFIED BY:	**29. CERTIFICATION METHOD**	
	30. Low Vulnerability Area, No Certification Needed	
	31. Self-Certified, approved training program attended	
DATE:	32. Self-Certified, UC or NRCS site recommendation	
	33. Nitrogen Management Plan Specialist	

Box 8 and 27 should be the same number

Notes:

- **23. Soil Nitrogen Credits** is the estimated amount of nitrogen that will become available for crop uptake during the growing season.
- 24. **Available N Carryover in the Soil** is typically estimated by analyzing a soil sample. This estimate should be reported in pounds per acre available to the crop during the growing season.
- 25. **Nitrogen in Irrigation Water** is estimated by analyzing an irrigation water sample to determine the nitrogen content. This estimate should be reported in pounds per acre available throughout the crop season based on the amount of irrigation water applied to the crop if less than ET. If more water applied than ET only use the ET.
- **26. Total N Credits** is the sum of #24 and #25.
- 27. **Total N Applied and Available** is the sum of #22 and #26. This total should be the same number as #12.

NITROGEN MANAGEMENT PLAN WORKSHEET

NMP Management Unit: ______________________________

1. Crop Year (Harvested):	**2015**	4. APN(s):	5. Field(s) ID	Acres
2. Member ID#	**xxxx**	020-025-016	1	100
3. Name:	Your Name			

CROP NITROGEN MANAGEMENT PLANNING		N APPLICATIONS/CREDITS	15. Recommended/ Planned N	16. Actual N
6. Crop	Walnut	**17. Nitrogen Fertilizers**		
7. Production Unit	tons	18. Dry/Liquid N (lbs/ac)	140	
8. Projected Yield (Units/Acre)	3.00	19. Foliar N (lbs/ac)	0	
9. N Recommended (lbs/ac)	160	**20. Organic Material N**		
10. Acres	100	21. Available N in Manure/Compost (lbs/ac estimate)	**0**	
Post Production Actuals				
11. Actual Yield (Units/Acre)		**22. Total Available N Applied** (lbs per acre)	**140**	
12. Total N Applied (lbs/ac)		**23. Nitrogen Credits (est)**		
13. ** N Removed (lbs N/ac)		24. Available N carryover in soil; (annualized lbs/acre)	0	
14. Notes:		25. N in Irrigation water (annualized, lbs/ac)	20	
		26. Total N Credits (lbs per acre)	**20**	
		27. Total N Applied & Available	**160**	

PLAN CERTIFICATION

28. CERTIFIED BY:	29. CERTIFICATION METHOD	
	30. Low Vulnerability Area, No Certification Needed	
	31. Self-Certified, approved training program attended	
DATE:	32. Self-Certified, UC or NRCS site recommendation	
	33. Nitrogen Management Plan Specialist	

Notes:

- **28.** Place for the signature of person certifying this plan, if required (see definitions in 31-33).
- 29. **Certification Method.** Place an "X" in the box for the method used.
- 30. If a field is in a **Low Vulnerability** area as designated by a Groundwater Assessment Report, no certification of this NMP is necessary
- **31 - 33.** Parcels/Fields that are in designated **High Vulnerability Areas** will need to be certified by a **Nitrogen Management Specialist.** Certification is needed on the Recommended/Planned N plan (column #15) and not for the Actual N (#16). Nitrogen Management
- Specialists include Professional Soil Scientists, Professional Agronomists, Crop Advisors certified by the American Society of Agronomy (and CDFA/California CCA), or Technical Service Providers certified in nutrient management in California by the National Resource
- Conservation Service (NRCS); or other specialist approved by the Executive Officer. Self-Certification is also an acceptable method provided the certifying member has attended an approved training course

Nitrogen Summary Report ***Following*** the crop season

Coalition will summarize and report the crop yield and N applied by crop within a township.
No individual farm data will be included.

NITROGEN MANAGEMENT PLAN WORKSHEET

NMP Management Unit: ____________________

1. Crop Year (Harvested):	**2015**	4. APN(s):	5. Field(s) ID	Acres
2. Member ID#	**xxxx**	020-025-016	1	100
3. Name:	Your Name			

CROP NITROGEN MANAGEMENT PLANNING		N APPLICATIONS/CREDITS	15. Recommended/ Planned N	16. Actual N
6. Crop	Walnut	**17. Nitrogen Fertilizers**		
7. Production Unit	tons	18. Dry/Liquid N (lbs/ac)	160	
8. Projected Yield (Units/Acre)	3.00	19. Foliar N (lbs/ac)	0	
9. N Recommended (lbs/ac)	160	**20. Organic Material N**		
10. Acres	100	21. Available N in Manure/Compost (lbs/ac estimate)	**0**	
Post Production Actuals				
11. Actual Yield (Units/Acre)		**22. Total Available N Applied** (lbs per acre)	**140**	
12. Total N Applied (lbs/ac)		**23. Nitrogen Credits (est)**		
13. ** N Removed (lbs N/ac)	**not required**	24. Available N carryover in soil; (annualized lbs/acre)	0	
14. Notes:		25. N in Irrigation water (annualized, lbs/ac)	20	
		26. Total N Credits (lbs per acre)	**20**	
		27. Total N Applied & Available	**160**	

PLAN CERTIFICATION		
28. CERTIFIED BY:	**29. CERTIFICATION METHOD**	
	30. Low Vulnerability Area, No Certification Needed	
	31. Self-Certified, approved training program attended	
DATE:	32. Self-Certified, UC or NRCS site recommendation	
	33. Nitrogen Management Plan Specialist	

Notes:

- **11. Actual Yield** is the total amount of crop harvested in units per acre.
- This total should be an average of the production from a management unit covered by this Nitrogen Management Plan.
- Compare the Actual Yield to the total amount of N that was available for the crop. Assess if your N applications were appropriate for the yield achieved. Use available resources or site experience to determine the appropriate amount compared to the yield.
- 12. **Total N Applied** is the amount of nitrogen applied in pounds per acre. #12 should equal the total indicated in #27, column #16.
- **13.** A Technical Work Group is in place to develop tools to better estimate nitrogen removal by a crop.
- This information will be used to estimate the amount of **N Removed** each year to assist tracking of Nitrogen after application to a crop.
- Your Coalition will provide you with the most up to date information on how to estimate N removed.
- 14. **Add any Notes** to the worksheet such as information about circumstances faced during the crop season that impact your recommended nitrogen applications #9 such as a larger or smaller crop than projected. Application amounts and timing can be adjusted based upon changing conditions (weather, pest damage, expected yield, etc..).

Walnut Nitrogen Management Planning
A Case Study

Walnut

- Conditions:
  - Mature Walnuts
  - Soil – Clay Loam, 5ft deep over consolidated layer
  - Irrigation water
    - 36 inches / season applied via solid set sprinkler
    - Nitrate from water test = 1.1 ppm Nitrate-N
  - Estimated yield 3.0 tons per acre
  - No organic material applied (manure or composts)
  - Winter cover *crop (peas, beans, vetch, and barley)*

Efficient N Management: Applying the 4 Rs Principle

- Apply the Right Rate
  - Match supply with crop demand (all inputs- fertilizer, organic N, water, soil).
- Apply at the Right Time
  - Apply coincident with crop demand and root uptake.
- Apply In the Right Place
  - Ensure delivery to the active roots.
  - Minimize movement below root zone
- Use the Right Source

The 4 Rs are specific to every individual orchard/field and every year.

Notes:

Following the principles of the 4R's leads to the most efficient use of nitrogen.

Details about each of the 4Rs:

Right Rate:
1. Appropriately assess soil nutrient supply
2. Assess all available indigenous nutrient sources
3. Assess plant demand
4. Predict fertilizer use efficiency

Right Time:
1. Assess timing of crop uptake
2. Assess dynamics of soil nutrient supply
3. Recognize timing of weather factors
4. Evaluate logistics of operations

Right Place:
1. Recognize root-soil dynamics
2. Manage spatial variability
3. Fit needs of tillage system
4. Limit potential off-field transport

Right Source:.
1. Supply in plant available forms
2. Suit soil properties
3. Recognize synergisms among elements
4. Blend compatibility

The Right Rate: Estimate Crop Use

- Nitrogen removed per unit of crop yield
- Estimated crop yield

- Example:
- Mature walnuts N removal I crop + growth at 37 lb N per ton
- Yield expected is 3.0 tons/acre
- Result = 111 lb N / acre use

Note: 37 Lb N per ton includes N required for mature walnut growth

Estimating Demand

- Estimated yield
- Nitrogen removal + growth(lb N/ton)
- Mature walnuts at 37 lb N per ton
- Yield expected is 3.0 tons/acre
- Result = 111 lb N / acre use

- Estimated Nitrogen Use Efficiency (NUE)

Nitrogen Use Efficiency (NUE)

$$\frac{Lbs\ N\ exported\ from\ the\ field\ in\ crop\ products}{Lbs\ N\ all\ sources} = Nitrogen\ Use\ Efficiency$$

- The NUE depends on how closely the 4 R's are followed.
- Best practices can achieve near a 70% NUE
- Most orchards are currently managed at a lower NUE

Estimated Orchard Demand

- Tree N use per Acre / Nitrogen use Efficiency (NUE)
- Tree use = 111 lb N/Acre / 0.70 = 159 lbs N/Acre

Estimating Supply: Credits

- Irrigation Water
- Organic materials (cover crop)

N in the Irrigation Water

- Formula for Nitrate:

  Nitrate concentration (ppm) x inches irrigation applied x **0.052**

- Formula for Nitrate-N:

  Nitrate-N concentration (ppm) x inches irrigation applied x **0.23**

Example:

Lab reports 1.1 ppm **Nitrate- N** and you apply 36 inches of water

1.1 x 36 x **0.23** =

Answer = 9 lb N/ac for the season

Notes:

- N in water is a free and very readily available nitrogen source.
- The conversion factors .052 and .23 are constants used to convert from N concentration in ppm to lbs.
- Use applied water volume if applied water is equal or less than ET. If applied water exceeds ET use ET water volume.

Cover crop

- Peas, beans, vetch, and barley

- 3000 lbs Dry Matter/ cover crop planted acre
- 60 % of total tree acreage planted
- Average of 3000 x 0.60 = 1800 lbs / tree planted acres

- Legumes = 2.8% N   Grasses 1.5% N (average of mix = 2.4% N)
- 1800 lbs x .024 = 43 lb N /ac

N Fertilizer Application

Use – Supply credits = Fertilizer application

159 lb N/acre crop use
- 9 lb N/acre irrigation water supply
- 43 lb N /acre cover crop supply

107 lb N /acre Fertilizer required

The Right Time

- Match the delivery of nitrogen with the tree use
  - Research finds uptake to be steady over the season
- Application Timing
  - 25% in May
  - 25% in June
  - 25% in July
  - 25% in August

N use prior to May fertilization is
from tree storage

The Right Place

- Most walnut roots are in the top 3 feet of soil
- Manage irrigation systems to:
  - Apply irrigation evenly across the orchard
  - Apply the correct amount of irrigation water to prevent leaching and saturated soil conditions
  - Irrigate after dry fertilization to minimize NH_3volatilization
  - Inject liquid fertilizers at a time to position the fertilizer where the root are located

The Right Source

- In orchards, there is no evidence to suggest that any type of N fertilizer delivering the same amount of N can produce higher yields.

- Material selection should be made on costs, application equipment available, and effect on soil chemistry.

NITROGEN MANAGEMENT PLAN WORKSHEET

NMP Management Unit: ____________________________

1. Crop Year (Harvested):	2015	4. APN(s):	5. Field(s) ID	Acres
2. Member ID#	xxxx	020-025-016	1	100
3. Name:	Your Name			

CROP NITROGEN MANAGEMENT PLANNING		N APPLICATIONS/CREDITS	15. Recommended/ Planned N	16. Actual N
6. Crop	Walnut	**17. Nitrogen Fertilizers**		
7. Production Unit	tons	18. Dry/Liquid N (lbs/ac)	140	
8. Projected Yield (Units/Acre)	3.00	19. Foliar N (lbs/ac)	0	
9. N Recommended (lbs/ac)	160	**20. Organic Material N**		
10. Acres	100	21. Available N in Manure/Compost (lbs/ac estimate)	0	
Post Production Actuals				
11. Actual Yield (Units/Acre)		**22. Total Available N Applied** (lbs per acre)	140	
12. Total N Applied (lbs/ac)		**23. Nitrogen Credits (est)**		
13. ** N Removed (lbs N/ac)		24. Available N carryover in soil; (annualized lbs/acre)	0	
14. Notes:		25. N in Irrigation water (annualized, lbs/ac)	20	
		26. Total N Credits (lbs per acre)	20	
		27. Total N Applied & Available	160	

Box 8 and 27 should be the same number

PLAN CERTIFICATION		
28. CERTIFIED BY:	**29. CERTIFICATION METHOD**	
	30. Low Vulnerability Area, No Certification Needed	
	31. Self-Certified, approved training program attended	
DATE:	32. Self-Certified, UC or NRCS site recommendation	
	33. Nitrogen Management Plan Specialist	

Notes:

- **28.** Place for the signature of person certifying this plan, if required (see definitions in 31-33).
- 29. **Certification Method.** Place an "X" in the box for the method used.
- 30. If a field is in a **Low Vulnerability** area as designated by a Groundwater Assessment Report, no certification of this NMP is necessary
- **31 - 33.** Parcels/Fields that are in designated **High Vulnerability Areas** will need to be certified by a **Nitrogen Management Specialist.** Certification is needed on the Recommended/Planned N plan (column #15) and not for the Actual N (#16). Nitrogen Management
- Specialists include Professional Soil Scientists, Professional Agronomists, Crop Advisors certified by the American Society of Agronomy (and CDFA/California CCA), or Technical Service Providers certified in nutrient management in California by the National Resource
- Conservation Service (NRCS); or other specialist approved by the Executive Officer. Self-Certification is also an acceptable method provided the certifying member has attended an approved training course

Silage Corn Nitrogen Management Planning

Corn Silage

- Conditions:
  - Soil– sandy loam
  - Irrigation water
    - 24 inches ETc (crop water use)
    - 34 inches / season applied
    - Water test = 9.0 ppm Nitrate-N
  - Estimated yield 30 tons per acre
  - No organic material applied
  - 1.0% soil organic mater content

Efficient N Management: Applying the 4 Rs Principle

- Apply the Right Rate
  - Match supply with crop demand (all inputs- fertilizer, organic N, water, soil).
- Apply at the Right Time
  - Apply coincident with crop demand and root uptake.
- Apply In the Right Place
  - Ensure delivery to the active roots.
  - Minimize movement below root zone
- Use the Right Source

The 4 Rs are specific to every individual orchard/field and every year.

The Right Rate: Estimate Crop Use

- Nitrogen used per unit of crop yield
- Estimated crop yield

- Example:
- Silage corn 8.3 lbs N / ton
- Yield expected is 30.0 tons/acre
- Result = 249 lb N / acre use

Note: source
Western Fertilizer Handbook, 8th ed.)
"utilized" by the crop

The Right Rate: Estimate Crop Use

For silage and hay crops, the N removed is similar to N "utilized"

SILAGE CORN

From Western Fertilizer Handbook, 8th ed.)
"utilized" **by the crop**
1 ton silage corn– "utilizes" 8.3 lb N
30 T would be 249 lb N

Or you can calculate uptake after the fact to use in the future.

Left Box: Two different book values are provided for silage corn; for this and other reasons, it can be more useful to calculate N requirement based on expected crop uptake; for silage crops this can be done using protein content, a method shown on the next slide.

Estimating Demand

- Estimated yield
- Nitrogen removal (lb N/ton)
- 1 ton corn silage (67%) 8.3 lbs N /acre
- Yield expected is 30 tons/acre
- Result = 249 lb N / acre use

- Estimated Nitrogen Use Efficiency (NUE)

Nitrogen Use Efficiency (NUE)

- *Corn Silage N use per Acre / Nitrogen use Efficiency (NUE)*
- NUE is the amount of nitrogen removed from the field in the crop vs the amount available from all N sources.
- The NUE depends on how closely the 4 R's are followed.
- Best practices using pressurized irrigation may be able to achieve near a 70% NUE
- Most fields are currently managed at a much lower NUE

Estimated Silage Corn Demand

- Corn N use per Acre / Nitrogen use Efficiency (NUE)
- Corn use = 249 lb N/Acre / 0.70 = 356 lbs N/Acre

Note: 70% NUE is optimistic for furrow irrigation

Estimating Supply: Credits

- Available soil N – Soil testing
- Soil organic matter mineralization
- Irrigation Water

Soil Available Nitrogen -- Credit

- Soil test pre plant 52 lb N /acre

Test Description	Result Units
Primary Nutrients	
Nitrate-Nitrogen	26.0 Lbs/AF
Phosphorus-P_2O_5	174 Lbs/AF
Potassium-K_2O (Exch)	1020 Lbs/AF
Potassium-K_2O (Sol)	125 Lbs/AF

Notes:
- Mineral N available in the top 2 feet of soil 2 ft. x 26 lbs/ft = 52 lbs/acre
- The question is whether the N will be in the top 2 ft. when needed.
- Irrigation could move it out of the rootzone for a leaching loss

Mineralizing Soil Organic Matter (SOM)

Contribution of soil N mineralization:

- About 5 % of soil organic matter is organic N
- You can generally count on net mineralization of *at least* 1-2% of soil organic N content during a crop season

20-40 lb N/acre/ % SOM

(30lb N /acre average) for each % SOM = 30 lb N/acre

Notes:

- The final amount is multiplied by whatever % organic matter your soil has, perhaps around 1%. The 1-2% net mineralization figure is for a crop season.
- The example calculation breaks down as 4,000,000 x 5% x 1% x 1-2% = lb N/acre
- in systems where manure and other organic materials are being applied, these portions would be higher. Behavior of N mineralization would also change in a system with very high organic matter content.

N in the Irrigation Water -- Credit

compare ET crop to applied water

ET **corn**: 24 ac-in
Irrigation : 34 ac-in

- If applied > ET, credit only ET ac-in
- If leaching is not significant, credit all or most of the irrigation water nitrate.

Nitrate-N (ppm) x ac-in x 0.23 = lbs N/acre

Example: 24 ac-in x 9.0 ppm Nitrate x 0.23 = 50 lbs N from irrigation N

Notes:

- If more water is being applied than is being evaporated and transpired then some water is leaching. This means the plant is not receiving all N applied, and only the amount of N in ET should be credited. If crop water use and applied water are similar, there is more room for flexibility in the N budget.
- Most of N and water uptake is in the top 2 ft.. for corn. Roots may be found deeper but usually are not doing much
- Depending on location/time of planting/corn variety/weather, ET of corn can range from 21-27 in.

The Right Rate: N Fertilizer Application

Crop use – Supply credits = Fertilizer application

356 lb N/ acre crop use

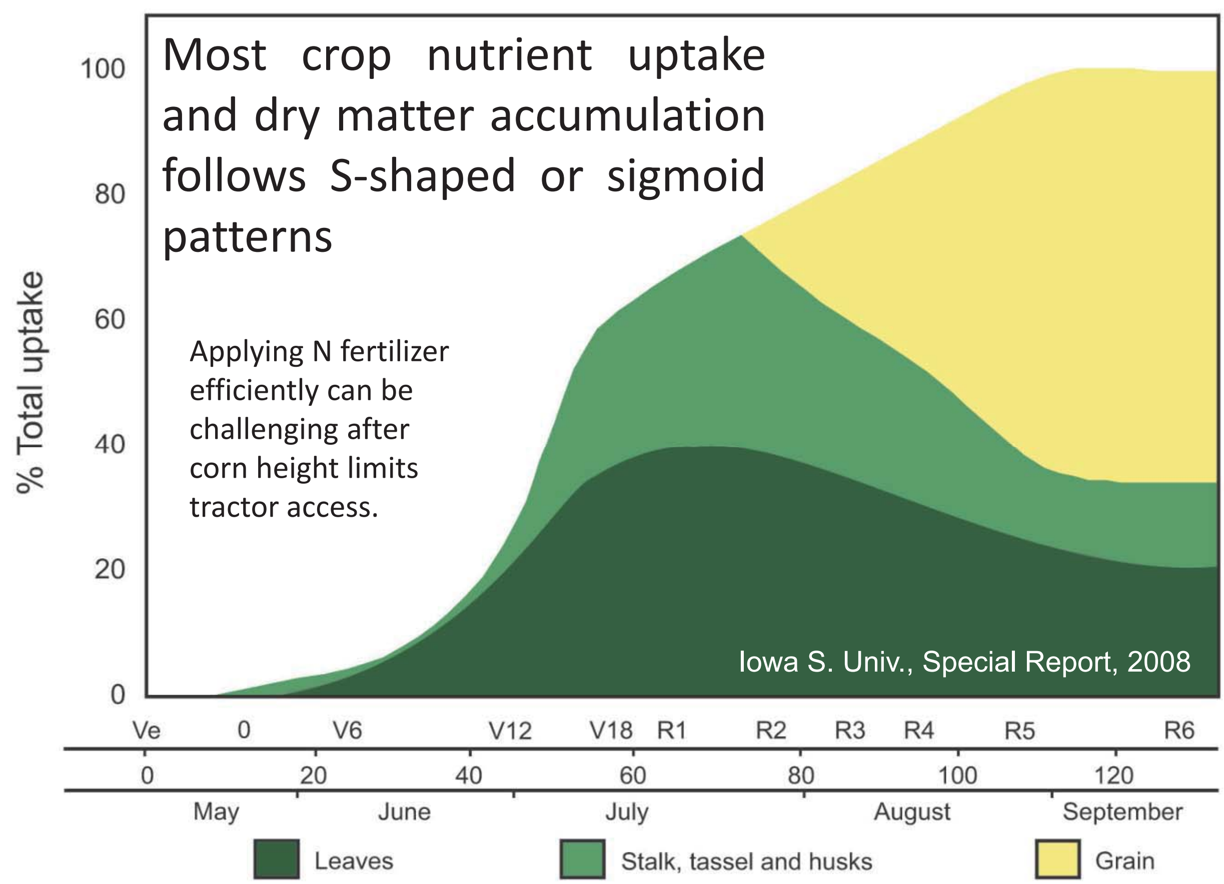
- 52 lb N / acre available soil test

-30 lb N / acre mineralized soil organic matter

-50 lb N/ acre irrigation water supply

224 lb N / acre Fertilizer required

Right Rate and Timing 'Demand': Corn Example



Notes:

- Figure: Cumulative corn N uptake divided by plant organ. Nutrient demand is characterized by slow early uptake, increase to a maximum during the rapid growth phase, and decline as the crop reaches flowering and matures. At flowering, N is remobilized from the flowers back in, rather than taken up.

- Demand for N is largely driven by biomass accumulation.

- Nutrient demand per time is related to growth rate; fast growth requires a high rate of N uptake and assimilation.

NITROGEN MANAGEMENT PLAN WORKSHEET

NMP Management Unit: ____________________________

1. Crop Year (Harvested):	**2015**	4. APN(s):	5. Field(s) ID	Acres
2. Member ID#	**xxxx**	020-025-016	1	100
3. Name:	Your Name			

CROP NITROGEN MANAGEMENT PLANNING	
6. Crop	Silage Corn
7. Production Unit	tons
8. Projected Yield (Units/Acre)	30
9. N Recommended (lbs/ac)	357
10. Acres	100
Post Production Actuals	
11. Actual Yield (Units/Acre)	
12. Total N Applied (lbs/ac)	
13. ** N Removed (lbs N/ac)	
14. Notes:	

N APPLICATIONS/CREDITS	15. Recommended/ Planned N	16. Actual N
17. Nitrogen Fertilizers		
18. Dry/Liquid N (lbs/ac)	225	
19. Foliar N (lbs/ac)	0	
20. Organic Material N		
21. Available N in Manure/Compost (lbs/ac estimate)		
22. Total Available N Applied (lbs per acre)	**225**	
23. Nitrogen Credits (est)		
24. Available N carryover in soil; (annualized lbs/acre)	82	
25. N in Irrigation water (annualized, lbs/ac)	50	
26. Total N Credits (lbs per acre)	**132**	
27. Total N Applied & Available	**357**	

PLAN CERTIFICATION

28. CERTIFIED BY:	29. CERTIFICATION METHOD	
	30. Low Vulnerability Area, No Certification Needed	
	31. Self-Certified, approved training program attended	
DATE:	32. Self-Certified, UC or NRCS site recommendation	
	33. Nitrogen Management Plan Specialist	

Box 8 and 27 should be the same number

Notes:

- Available N = total of soil organic mater mineralization (30 lb N /acre) and available soil N 52 lbs N /acre

- The amount of **Nitrogen Recommended** (estimated amount needed) to be applied to meet your expected yield. Use crop recommendations from CDFA, UCCE, NRCS, commodity organizations or site specific knowledge based on previous experience to appropriately estimate the amount of Nitrogen (N) needed. This should be the same number used in #27, Total N Applied and Available.

Section 7

Resources for Nitrogen Application and Management Practices

Note a full host of resources are available along with all presentation materials and notes at:

http://www.cdfa.ca.gov/is/ffldrs/frep/Outreach_Ed.html

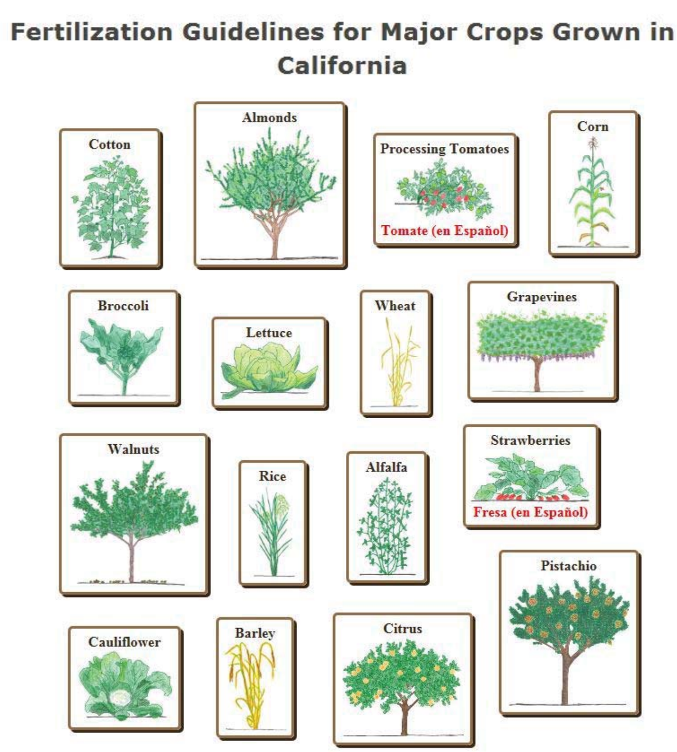
Fertilization Guidelines for Major CA Crops

http://apps.cdfa.ca.gov/frep/docs/guidelines.html

Go here for:

- Application rates & times
- Fertilizer placement
- Fertilizer type
- Deficiencies
- Tissue Analysis

Google:
"CDFA FREP Guidelines"



UC Davis Resources:

Fruit and Nut Research and Information
http://fruitsandnuts.ucdavis.edu/

Grapevines
http://cecentralsierra.ucanr.edu/Agriculture/Viticulture/Grapevine_nutrition/

Almond

http://fruitsandnuts.ucdavis.edu/almondmodels/

Vegetable crops
http://vric.ucdavis.edu/main/veg_info.htm

Go here for:

- Information on biology, fertilization and management of crops
- Links to literature searchable by crop

UC Cooperative Extension Irrigation Management

http://ucanr.edu/sites/irrmgm/

Go here for:

- Introduction to irrigation management

Note: Maintained by Dr. Larry Schwankl, this page contains background information on irrigation management. Covered are topics like dairy irrigation management, fertigation safety, irrigation system maintenance, and drought management.

WATERIGHT

http://www.wateright.org/

Go here for:

- How to get started with irrigation scheduling
- Irrigation scheduling planning tools
- Water and energy management

Note: WATERIGHT is a “multi-function, educational resource for irrigation water management.” The site is aimed at homeowners, commercial turf growers, and agriculture. It houses information on managing irrigation for specific crops, and integrates CIMIS weather forecasts and soil type into its instructions. It is not quite field specific but is a great resource for those advising on new or unfamiliar crops. The site was developed by CSU’s Center for Irrigation Technology, Fresno with support from the US Bureau of Reclamation.

N Removed with Harvested Crops

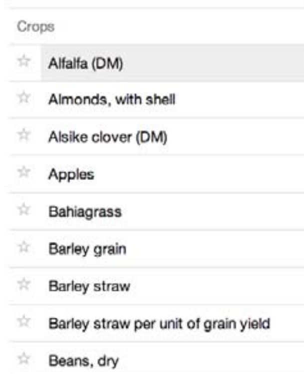
IPNI Crop Nutrient Removal Calculator

https://www.ipni.net/app/calculator/home

Go here for:

- N, P, K harvest removal estimates of field crops
- Multilingual crop nutrient calculator

Note: This tool provides crop nutrient removal estimates for a broad, and continually expanding, list of field crops. Estimates are provided for N, P, and K in the forms of N, P_2O_5, and K_2O. Results are calculated based on user-selected yield goals and can be displayed in either metric or US units.



NRCS Crop Nutrient Tool

http://plants.usda.gov/npk/main

Go here for:

- Elemental N, P, K harvest removal estimates of field crops
- Explanation of how removal calculations are made

Notes:

- A tool for calculating the approximate amount of nitrogen, phosphorous, and potassium that is removed by the harvest of agricultural crops. Based on predicted yield and crop variety, the site gives an estimate of harvest removal of elemental N, P, and K. Also provides links to source material in order to see how the values are calculated.
- Provides estimates of the same nutrients as IPNI but in elemental forms. In order to compare the NRCS's elemental estimates with IPNI's compound estimates, multiply P by 2.3 and K by 1.2.