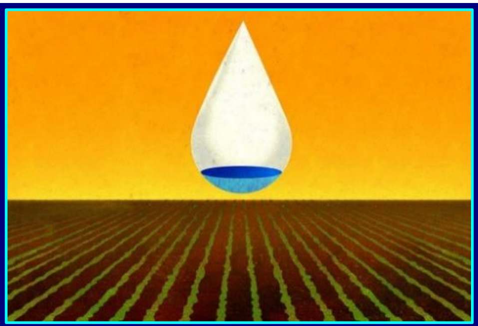

What it takes to be Efficient Irrigators

- from Principles to Practical Implementation -

Workshop on Efficient Water Management for Forage Crops

Tulelake, CA – March 14th, 2024

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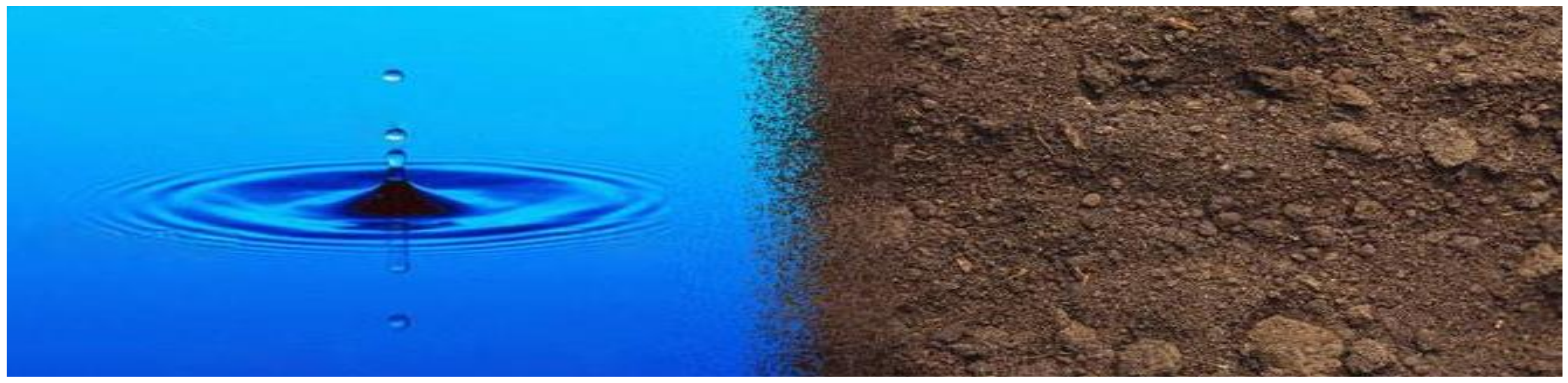
OBJECTIVES

1) Review the Basic Principles of Irrigation Efficiency

2) Why Caring about Being Efficient Irrigators?

3) Provide Information on Water & Energy Requirements

4) Discuss Additional Information for Efficient Irrigation Management



IRRIGATION EFFICIENCY @ FIELD SCALE

What fraction of the total water applied to the field is <u>beneficially</u> used by the crop

$$Irr.Eff. = \frac{Water\ used\ by\ the\ crop\ for\ ET\ +\ Other\ Beneficial\ Uses}{Total\ water\ applied\ onto\ the\ field}$$

Beneficial is the water used for crop production & health

- ✓Transpiration (T) of water through the canopy
- ✓Water used to apply with fertilizers & nutrients, chemicals for pest & weeds control
- ✓Frost Protection & Canopy Cooling
- ✓Leaching salts + Application of amendments (gypsum, humic/fulvic acids etc.)

$$Irr.Eff. = \frac{Water\ used\ by\ the\ crop\ for\ ET + Other\ Beneficial\ Uses}{Total\ water\ applied\ onto\ the\ field}$$

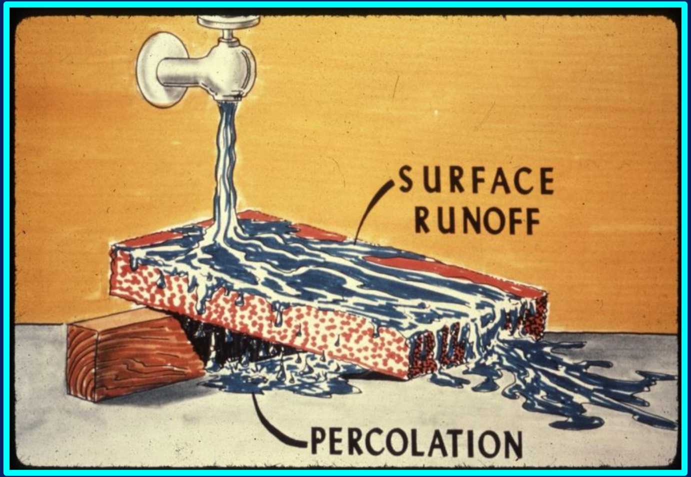
Water Applied to the field

- ✓Replenish Soil Moisture depleted since the last irrigation or rainfall
- ✓Soil Evaporation + Deep Percolation + Surface Runoff + Wind Drift
- ✓Leakages from pipes, canal, ditches + valves/gates stuck-open, wrong commands, operational losses, irrigation over-run, etc.
- ✓Pipe flushing + Screen cleaning & Filters back-flush
- ✓Pipe & Hose chemical injection (keep the pipe system clean and functional)
- ✓Water draining out of pipes and hoses after irrigation shut-off (pulsing on-off)

Application Efficiency (A.E.) vs. Irrigation Efficiency (Irr. Eff.)

Application Efficiency (A.E.) → single irrigation event →

$$A.E. = \frac{\text{Water stored in the soil root zone}}{\text{Total water applied onto the field}}$$



Irrigation Efficiency (Irr. Eff.) → entire irrigation season →

$$I.E. = \frac{\text{Water beneficially used by the crop}}{\text{Total water applied onto the field}}$$

Distribution Uniformity (D.U.) vs. Irrigation Efficiency (Irr. Eff.)

Distribution Uniformity:

Is a number (%) describing how evenly water is distributed across the field

Irrigation Efficiency:

Is the fraction of the applied water that is beneficially used by the crop

EXAMPLE

2 gallons per tree per week in July

The trees will use every drop of the applied water

D.U. = 100%; I.E. = ~100%

200 gallons per tree per week in July

Trees will use only a fraction of the applied water

D.U. = 100%; I.E. << 100%

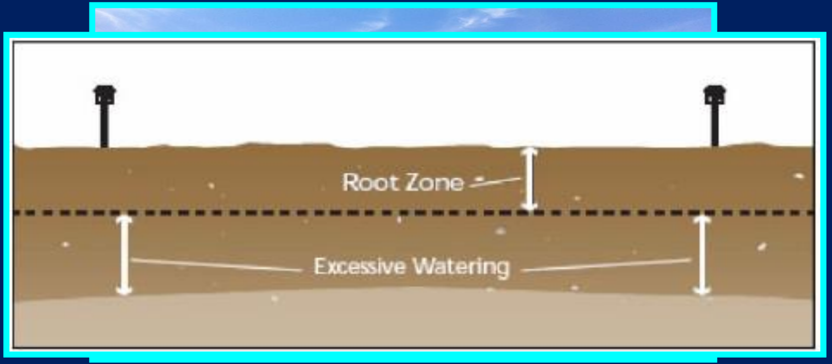
Components of Irrigation Efficiency

Irrigation Application

- ✓Adequacy of application
  (depth or volume infiltrated & stored)
- ✓Application Uniformity (DU)

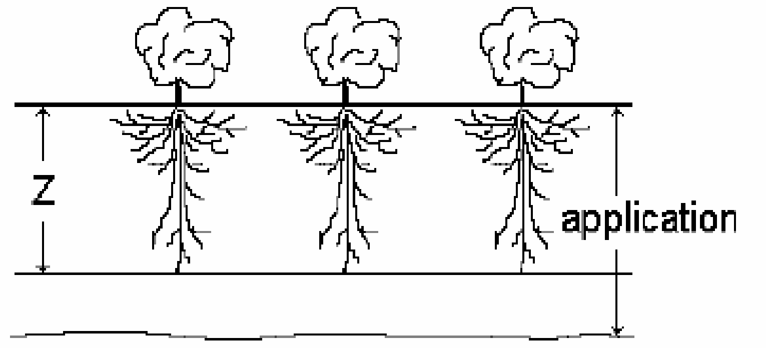
Irrigation Losses

- ✓Soil Evaporation
- ✓Deep percolation
- ✓Runoff
- ✓Wind drift (sprinkler)

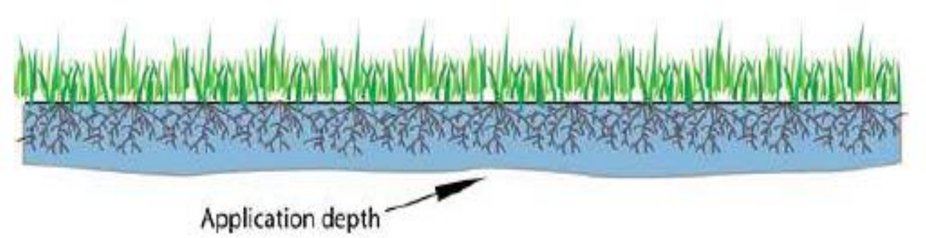


Adequacy of application refers to the depth or volume of water that infiltrates in the root zone, is stored, and is available for plant use (Transpiration)

ADEQUACY OF APPLICATION



Uniform, but average depth applied exceeds the soil water deficit (too much deep percolation)



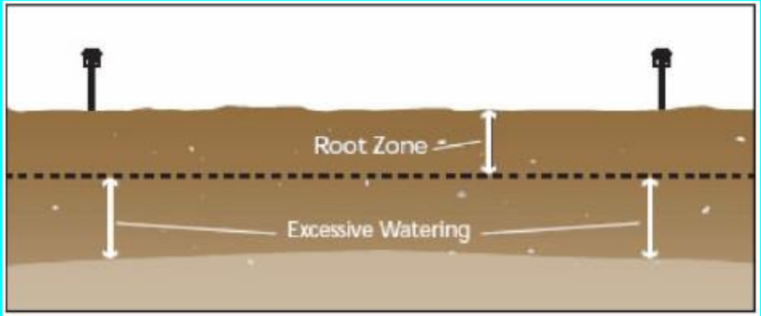


FIGURE 3: Depiction of irrigation resulting in good DU but poor irrigation efficiency

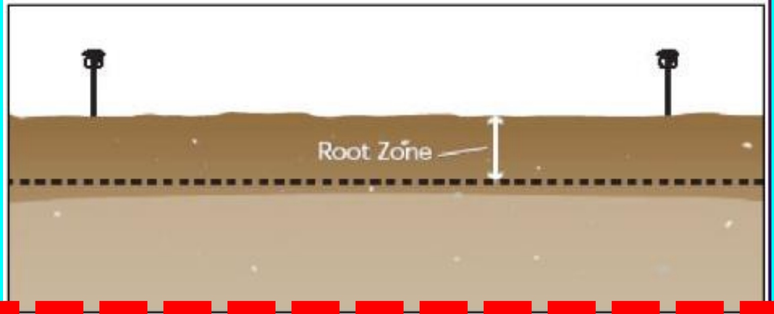
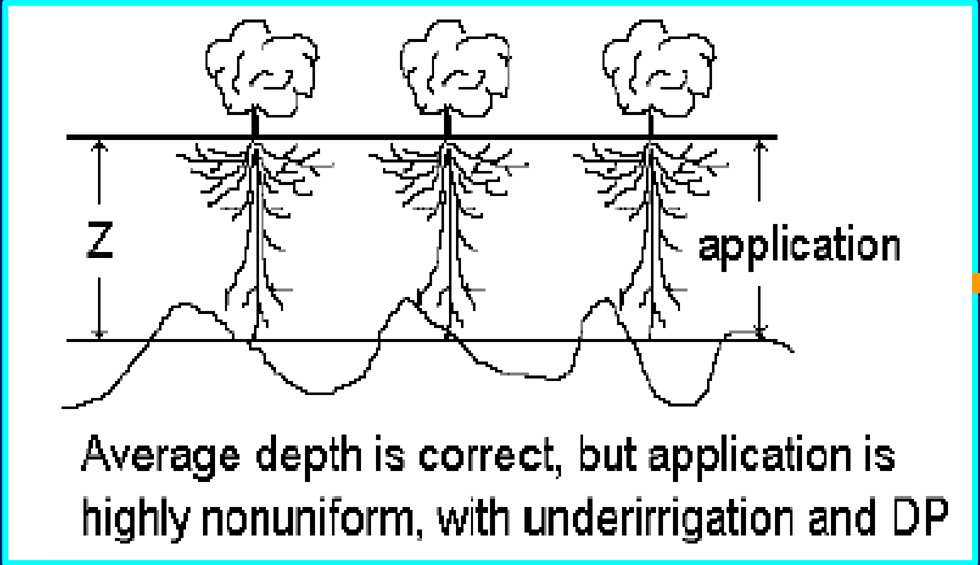


FIGURE 4: Depiction of irrigation sufficiently watering the entire field with good DU and irrigation efficiency

Whether an irrigation is adequate or not depends on the irrigation set-time & soil moisture status/depletion @ irrigation start (irrigation management)

Whether water is distributed evenly across the field or among plants (D.U.) mainly depends on proper system design, operation, and maintenance

UNIFORMITY OF APPLICATION



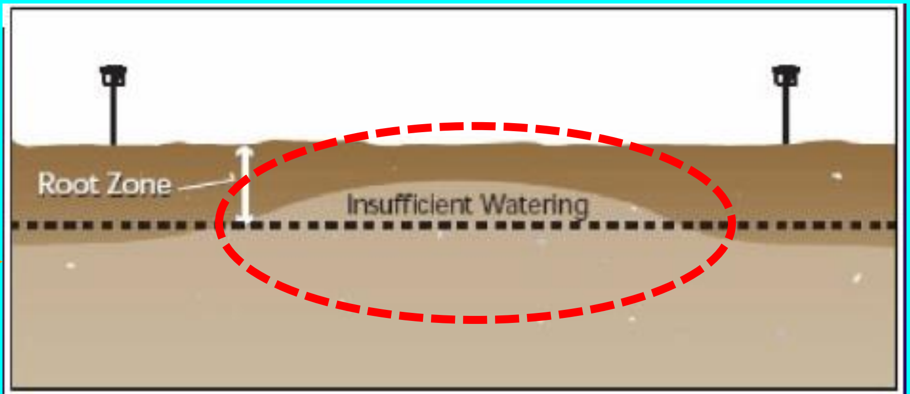


FIGURE 2: Depiction of irrigation resulting in poor DU and insufficient irrigation in parts of the field

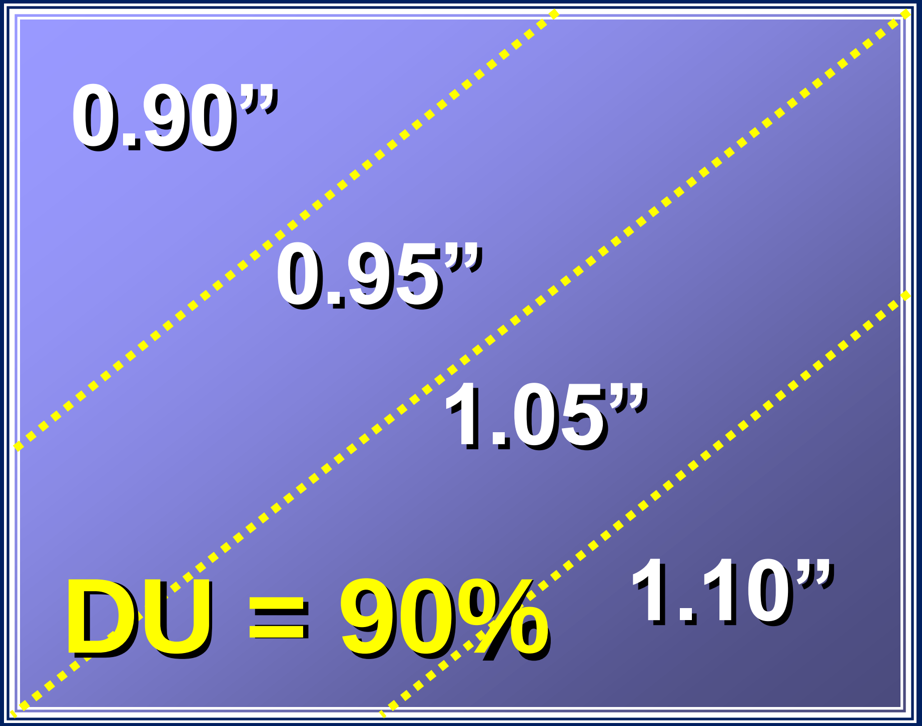
Some parts of the field must be over-irrigated so that the areas receiving less water can be adequately irrigated.

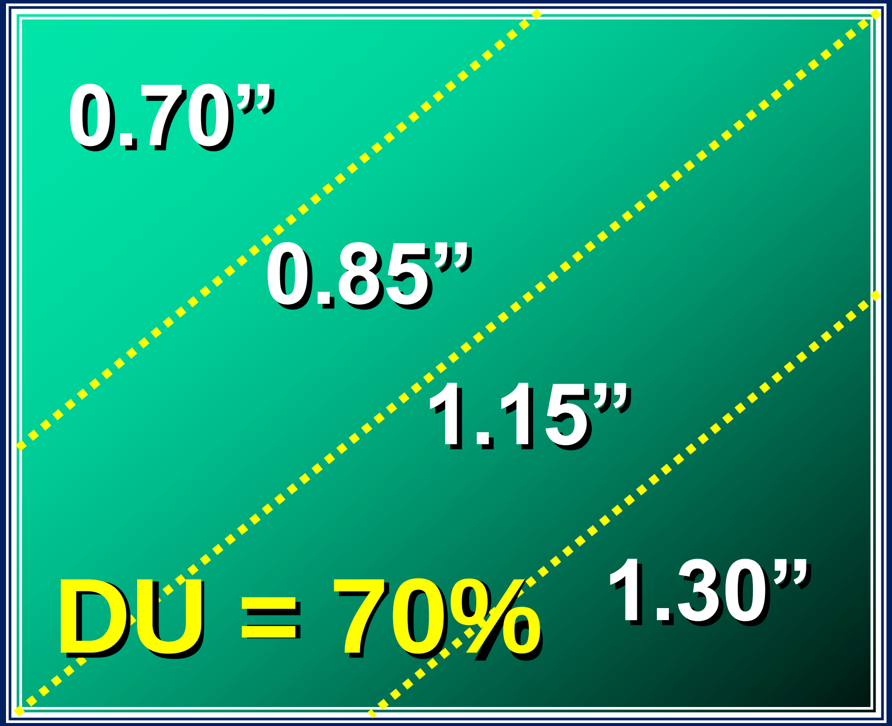
This over-irrigation can cause excessive deep percolation in some areas of the field

Irrigation: Getting It Uniform

$$DU = \frac{\text{Average of low 1/4}}{\text{All Field Average}}$$

Target Application = 1.0 inch





Why caring about being efficient irrigators?

✓REDUCE WATER AND ENERGY BILLS FOR PRODUCING OUR CROPS (sprinkler & micro-irrigation, groundwater pumping)

✓GROW MORE ACREAGE WITH THE SAME WATER/ENERGY OR OBTAIN HIGHER YIELD

✓HEALTHY CROP => LESS WATER-RELATED PROBLEMS (water stress, hypoxia, asphyxia, phytophthora, weeds growth, etc.)

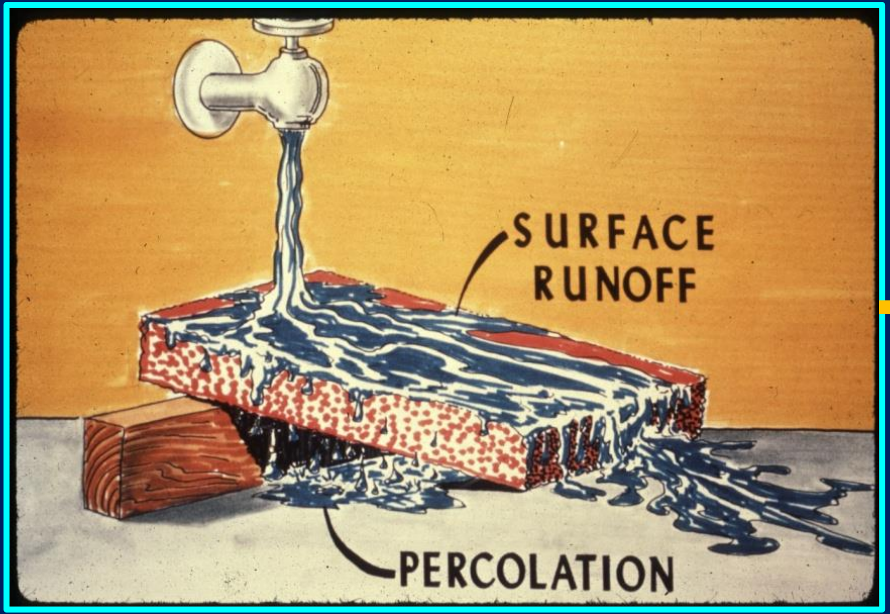
✓BETTER CONTROL ON WATER & NUTRIENTS AVAILABLE IN THE SOIL TO PLANTS

✓COMPLIANCE WITH EXISTING ENVIRONMENTAL REGULATIONS (ILRP, SGMA, AB 589, etc.)




INEFFICIENT IRRIGATION OFTEN LEADS TO:

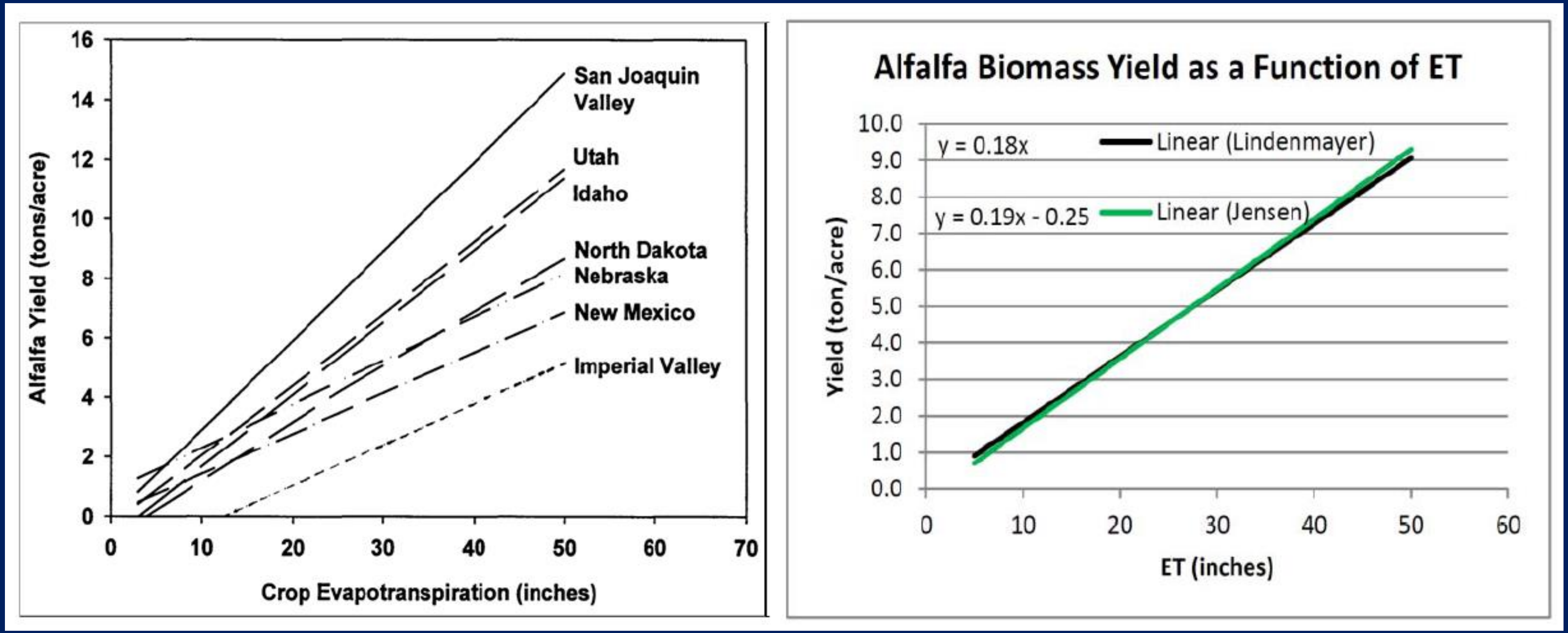
- ✓ **HIGHER COSTS** (labor, water, nutrients, pumping)
- ✓ **CROP YIELD LOWER THAN MAX POTENTIAL** (water stress, water logging, hypoxia, asphyxia, phytophthora)
- ✓ **UNEVEN/SLOW PLANTS DEVELOPMENT & PRODUCTION**
- ✓ **LOSS OF NUTRIENTS, FERTILIZERS, & CHEMICALS/PESTICIDES** (Runoff or Leaching)



Since all the above-ground biomass of forages is harvested, yield is tightly related to actual crop ET

(~ 1:1 relationship)

Inaccurate Water Management (deficit & excess) can strongly impact yield



What really matters for high yield is that there is sufficient soil moisture available to meet and sustain the crop ET

WHAT IT TAKES TO BE EFFICIENT?

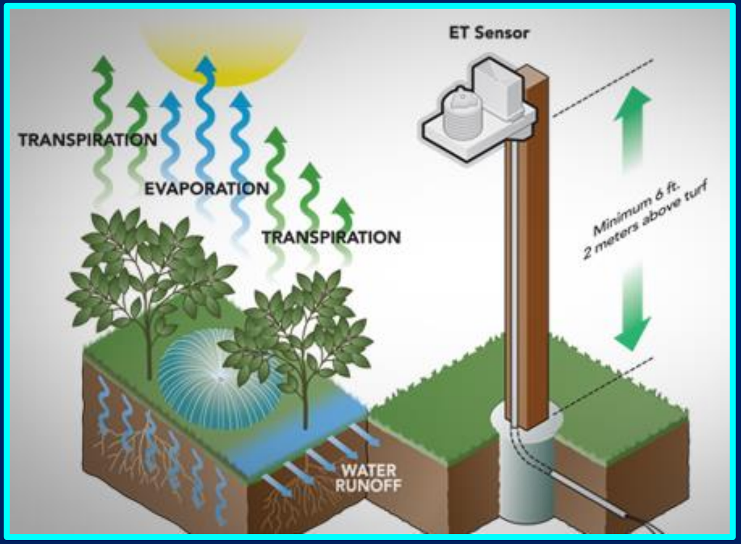
Good System Design
✓Accurate & Skilled
✓Flexible Operation

Proper **Installation**
Regular **Maintenance**
System **Evaluation**

Defined Irrigation Strategy

- Full Irrigation
- Sustained Deficit Irrigation/RDI

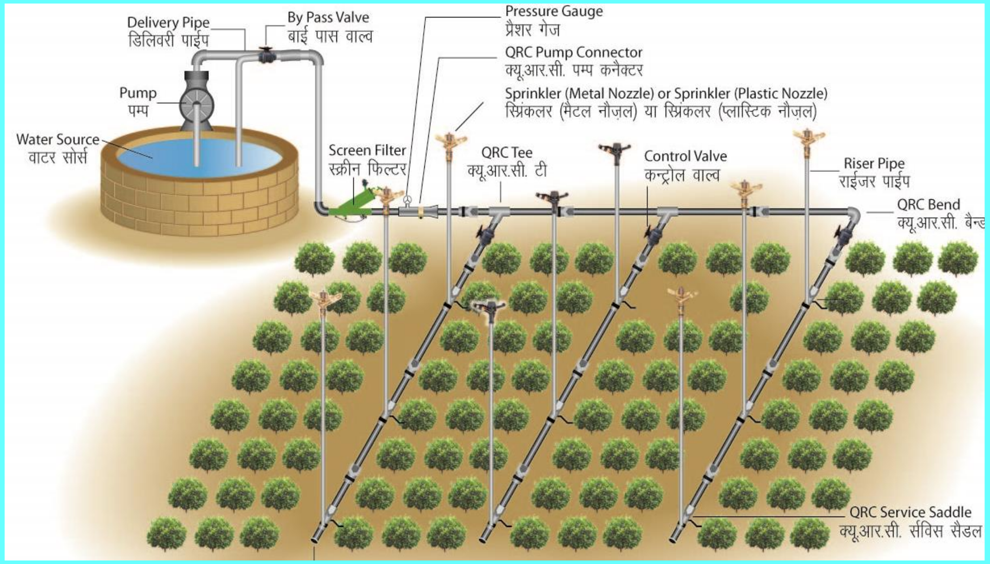
Accurate Irrigation Scheduling & Control + Feedback Collection



DIFFERENCES BETWEEN IRRIGATION METHODS

SURFACE IRRIGATION METHODS

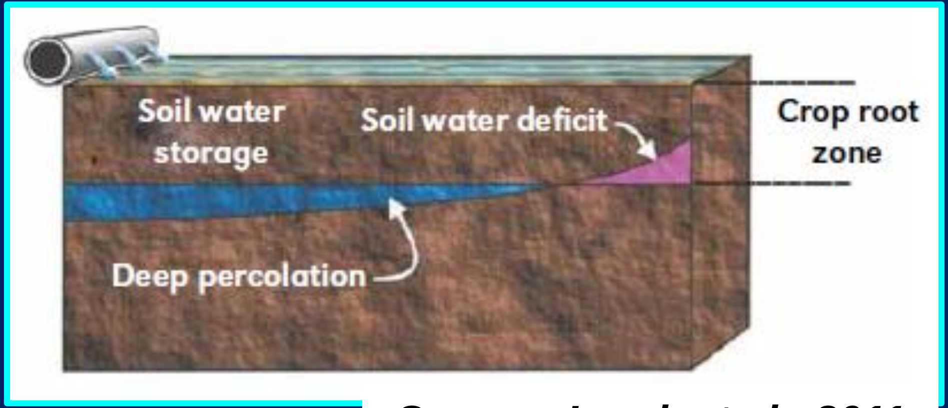
Infiltrated water and DU mainly depend on soil intake rate, flow rate, slope and length of fields (water travels on the ground across the fields)



SPRINKLER & MICRO-IRRIGATION

Infiltrated water and DU mainly depend on system's characteristics (water travels along the pipe system and is discharged in the vicinity of plants)

SURFACE IRRIGATION METHODS



Source: Irmak et al., 2011

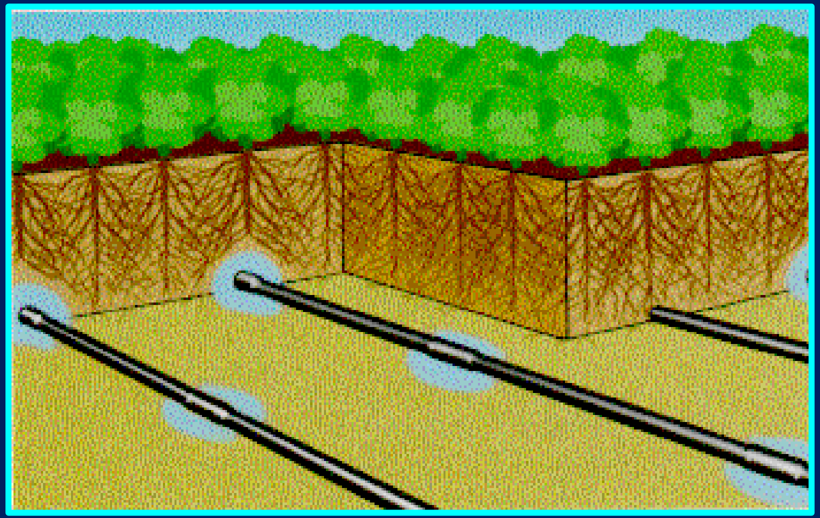
Distribution Uniformity in Space: some areas of the field receive less water than others

Distribution Uniformity in Time: some areas of the field may receive water at much longer intervals than others (may be more subject to water deficit) **=> affecting ADEQUACY**

SPRINKLER & MICRO-IRRIGATION

Water infiltrating the soil mainly depends on system's characteristics
(water travels along the pipe system and is applied in the vicinity of plants)

Distribution Uniformity in Space: some areas may receive less water than others



BEING EFFICIENT IRRIGATORS REQUIRES

KNOWING HOW TO APPLY WATER

In the adequate amount

With the proper Timing, Set-Time & Frequency

With uniform mode

Know the crop water use (ET) since the last irrigation

Know the application rate of your irrigation system

Know the application uniformity (DU)

The adequate amount?

The proper Timing, Set-Time, & Frequency?

How much water has the crop used (ET) since the last irrigation or rainfall?

Operate the irrigation system to apply the adequate amount of water needed in the proper mode

Know the crop water use, ET (in.)

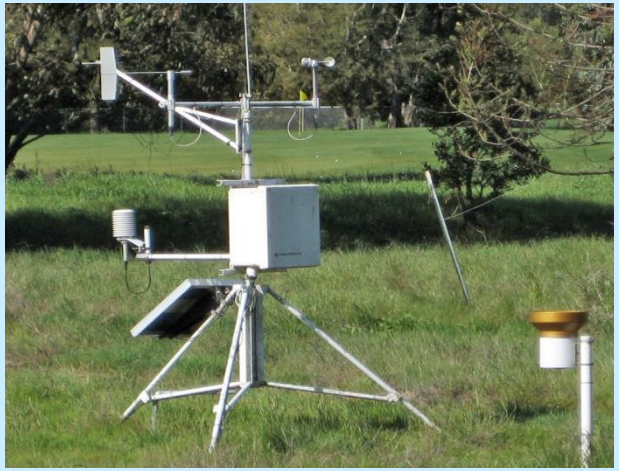
Know the system application rate (in./hr.)

Know the application uniformity, DU (%)

<u>Basic criterion</u> for Irrigation Management:
replenish the amount of water used by the crop (ET_C) since the last irrigation or rainfall, avoiding water logging and losses

Crop ET = Reference ET x Crop Coefficient

$$ET_C = ET_O \times k_C$$



ET of a standard grass surface

- ✓Use historical ETc averages
- ✓Use historical ET_O or real-time ET_O and K_c values

CIMIS and Spatial CIMIS provide daily **ETo** data:
http://wwwcimis.water.ca.gov/

HOW MUCH WATER DOES ALFALFA USE FOR ET ON AVERAGE IN CA OVER THE CROP SEASON?

SITE	SEASONAL ETc (inches)
Intermountain	33-36
Sacramento Valley	44-46
Central Valley	48-52
Desert Areas	58-66

IRRIGATION WATER AMOUNT TO APPLY TO MEET ET

Irrig. Need = [(ETc – Rain)/Eff_{APP}]

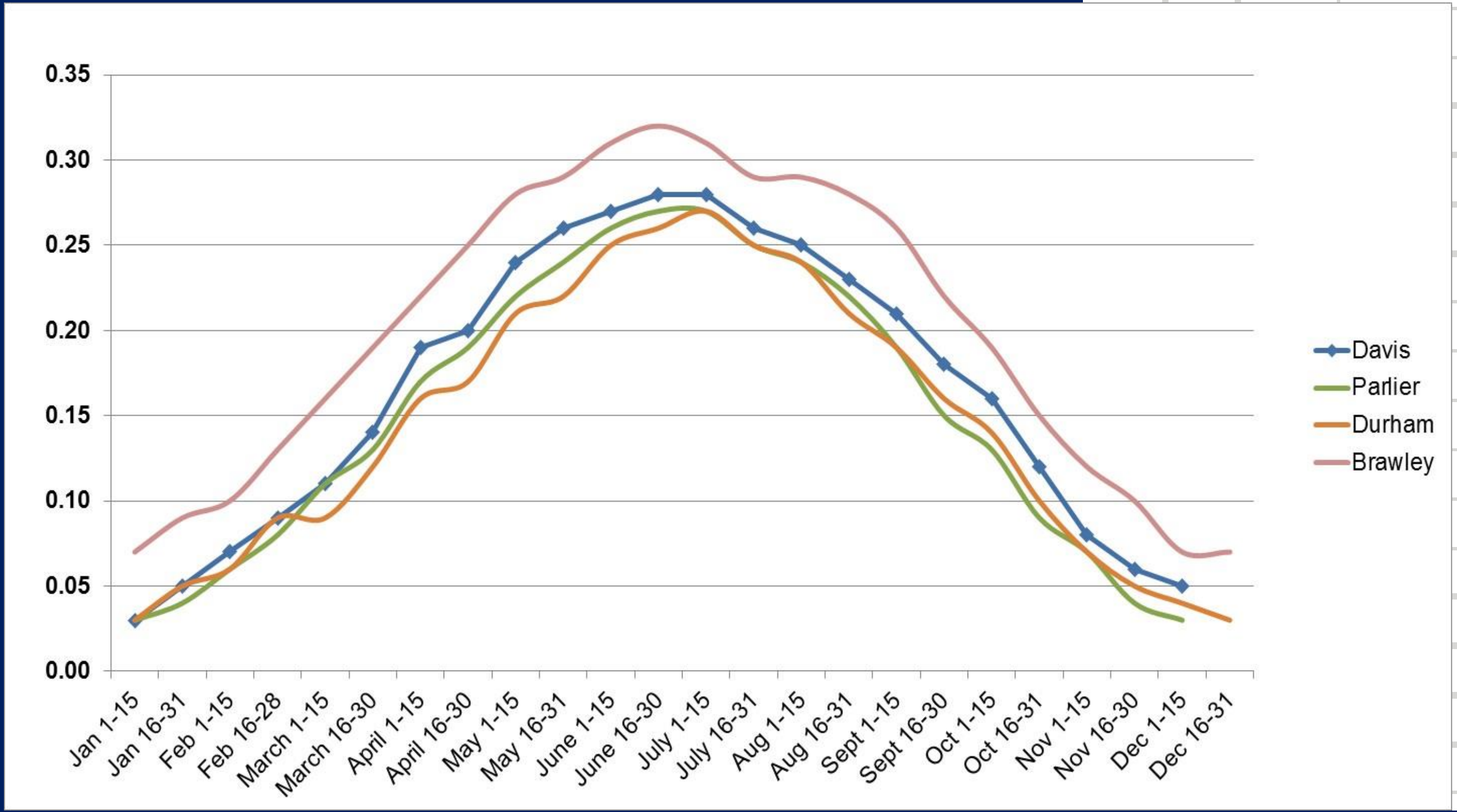
System	$Eff._{APP}$
Surface Irrigation	0.60 – 0.65
Sprinkler	0.70 - 0.75
Micro-sprinkler	0.80 – 0.85
Drip	0.85 – 0.90

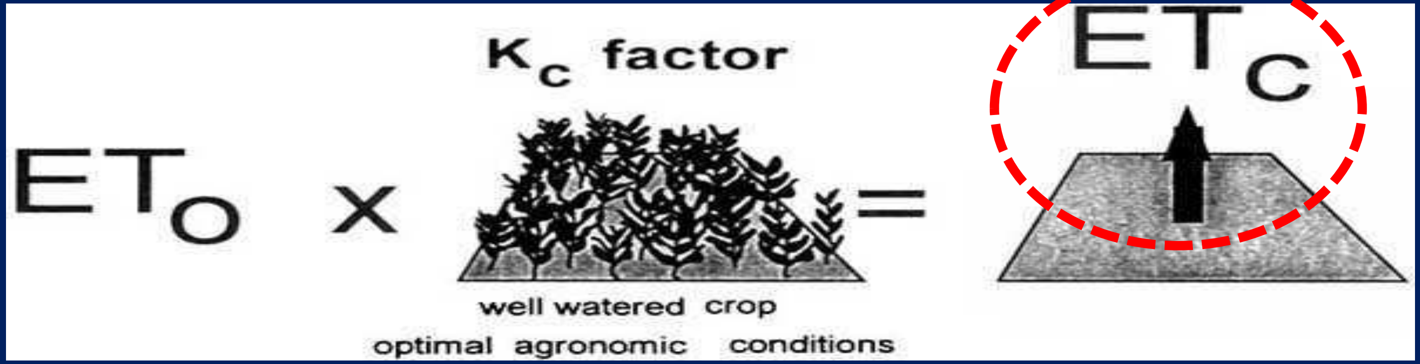
Historical average ET

- ✓ Can be used with minimal errors
- ✓ Convenient to use and allow to develop an irrigation schedule for the entire season

Table 2. Historical alfalfa crop evapotranspiration (inches per day).

		Shafter	Five Points	Parlier	Davis	Nicolaus	Durham	McArthur	Brawley
Jan	1-15	0.03	0.04	0.03	0.03	0.03	0.03	0.02	0.07
	16-31	0.05	0.05	0.04	0.05	0.04	0.05	0.03	0.09
Feb	1-15	0.07	0.06	0.06	0.06	0.06	0.06	0.04	0.10
	16-30	0.09	0.09	0.08	0.09	0.09	0.09	0.07	0.13
Mar	1-15	0.11	0.11	0.10	0.09	0.09	0.09	0.08	0.16
	16-31	0.14	0.15	0.13	0.14	0.12	0.12	0.11	0.19
Apr	1-15	0.19	0.20	0.17	0.18	0.15	0.16	0.14	0.22
	16-30	0.20	0.22	0.19	0.20	0.18	0.17	0.14	0.25
			0.26	0.22	0.23	0.21	0.21	0.18	0.28
			0.27	0.24	0.24	0.21	0.22	0.19	0.29
			0.29	0.26	0.28	0.24	0.25	0.22	0.31
			0.30	0.27	0.29	0.26	0.26	0.25	0.32
			0.30	0.27	0.29	0.26	0.27	0.27	0.31
			0.28	0.25	0.27	0.25	0.25	0.25	0.29
			0.28	0.24	0.26	0.24	0.24	0.25	0.29
			0.25	0.22	0.24	0.21	0.21	0.22	0.28
			0.23	0.19	0.21	0.19	0.19	0.18	0.26
			0.20	0.15	0.18	0.16	0.16	0.14	0.22
			0.17	0.13	0.16	0.13	0.14	0.12	0.19
			0.13	0.09	0.12	0.09	0.10	0.08	0.15
			0.10	0.07	0.09	0.07	0.07	0.05	0.12
			0.07	0.04	0.06	0.05	0.05	0.03	0.10
			0.05	0.03	0.05	0.03	0.04	0.02	0.07
			0.03	0.02	0.04	0.04	0.03	0.02	0.07





Amount of water lost by alfalfa for ET

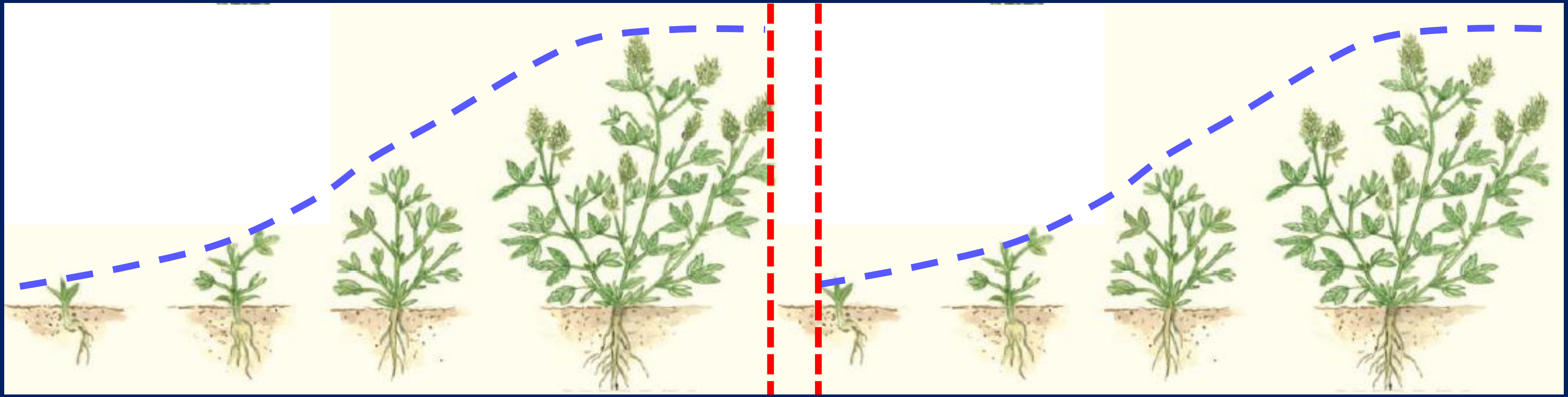
Seasonal Crop Coefficient:

K_c = 0.96 – 0.98 (averaged over the entire crop season)

Within-cycle Crop Coefficients:

$K_c \approx$ 0.35 - 0.40 after cutting until irrigation starts

$K_c \approx$ 1.05 - 1.10 from 2-3 days after irrigation till the next cutting



APPLICATION RATE << SOIL INTAKE RATE (inch/hr.)

System	Appl. Rate (in./hr)	$Eff._A$
Surface Irrigation	0.40 – 0.45	0.60 – 0.65
Drip	0.01 - 0.03	0.70 - 0.75
Micro-sprinkler	0.05 – 0.07	0.80 – 0.85
Sprinkler	0.12 & +	0.85 – 0.90

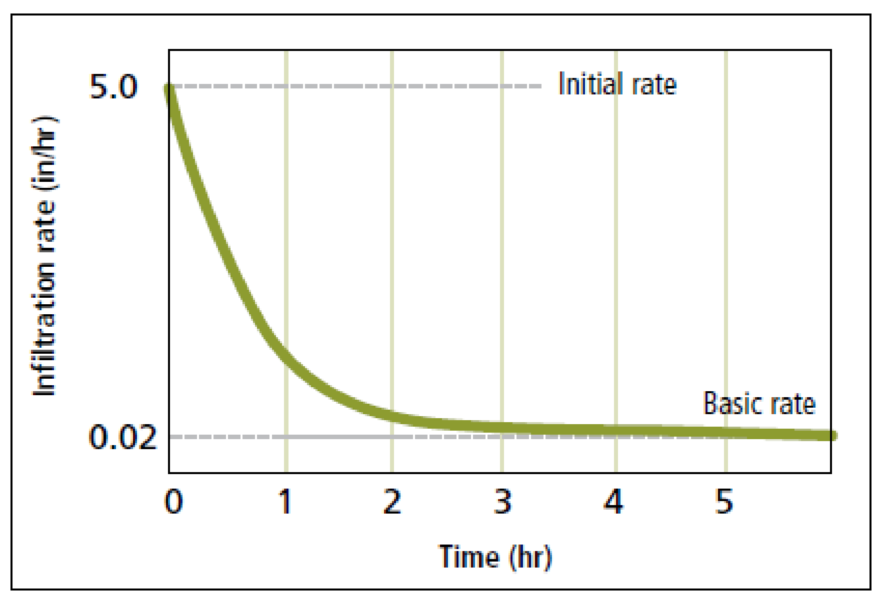


Table 1. Recommended maximum application rates for soils of various textures

Soil type	Maximum application rate (in/hr) at slope		
	0–5%	5–8%	8–12%
coarse sandy soil	1.5–2.0	1.0–1.5	0.75–1.0
light sandy soil	0.75–1.0	0.5–0.8	0.4–0.6
silt loam	0.3–0.5	0.25–0.4	0.15–0.3
clay loam, clay	0.15	0.10	0.08

Source: NRCS 1984.

Range of available water-holding capacity in different soils (inches of water per foot of soil)

Soil texture	Water-holding capacity Range In./ft	Water-holding capacity Average In./ft
1. Very coarse texture—very coarse sands	0.38-0.75	0.50
2. Coarse texture—coarse sands, fine sands, and loamy sands	0.75-1.25	1.00
3. Moderately coarse texture—sandy loams	1.25-1.75	1.50
4. Medium texture—very fine sandy loams, loams, and silt loams	1.50-2.30	2.00
5. Moderately fine texture—clay loams, silty clay loams, and sandy clay loams	1.75-2.50	2.20
6. Fine texture—sandy clays, silty clays, and clays	1.60-2.50	2.30
7. Peats and mucks	2.00-3.00	2.50

NOTE: 1 mm/m = 0.012 in./ft.

Source: Keller & Bliesner, 2000

ENERGY REQUIREMENTS FOR IRRIGATION

It takes 1.37 whp-hr./ac-ft. per foot of lift

(power the pump must provide to lift 1 ac-foot of water by 1 foot)

FUEL SOURCE	PUMP OUTPUT
ELECTRICITY	0.885 whp-hr/kWh
NATURAL GAS (925 BTU)	61.7 whp-hr/MCF
NATURAL GAS (1000 BTU)	66.7 whp-hr/MCF
DIESEL	12.50 whp-hr/gal
PROPANE	6.89 whp-hr/gal

Source of Energy	Energy Units to Lift Water
Electricity	1.55 kWh/ac-ft per foot of lift
Natural Gas (925 BTU)	0.22 MCF/ac-ft per foot of lift
Natural Gas (1000 BTU)	0.20 MCF/ac-ft per foot of lift
Diesel	0.10 Gal/ac-ft per foot of lift
Propane	0.20 Gal/ac-ft per foot of lift

Source: Nebraska Pumping Plant Performance Criteria (NPPPC)

CALCULATION EXAMPLE

Alfalfa ET = 36 inches = 3.0 ft. of water over the crop season

Area = 130 acres

Irrigation methods: Sprinkler (50 psi) VS. Surface Irrigation (5 psi)

Water Lift = 60 ft. (from water table to ground)

$TDH_{SPRINKLER}$: 60 ft. + 50 psi x 2.31 ft./psi = 175 ft.

Total ac-ft. $_{SPRINKLER}$ = 3.0/0.75 = 4.0 ac-ft.

$TDH_{SURFACE}$: 60 ft. + 5 psi x 2.31 ft./psi = 71 ft.

Total ac-ft. $_{SURFACE}$ = 3.0/0.65 = 4.6 ac-ft.

Diesel : 0.10 gal/ac-ft. per foot of lift

Cost of Diesel = $ 5.30 per gallon

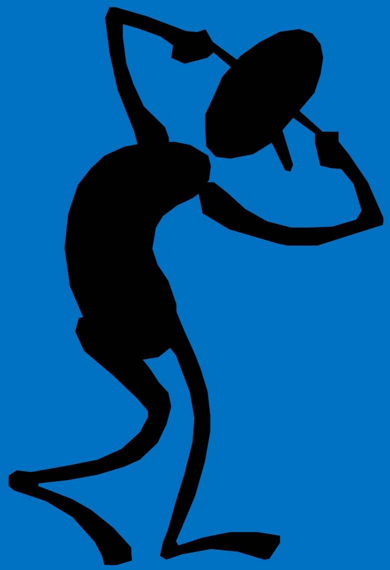
System	$Eff._{APPL.}$
Surface Irrigation	**0.60 – 0.65**
Sprinkler	**0.70 - 0.75**
Micro-sprinkler	**0.80 – 0.85**
Drip	**0.85 – 0.90**

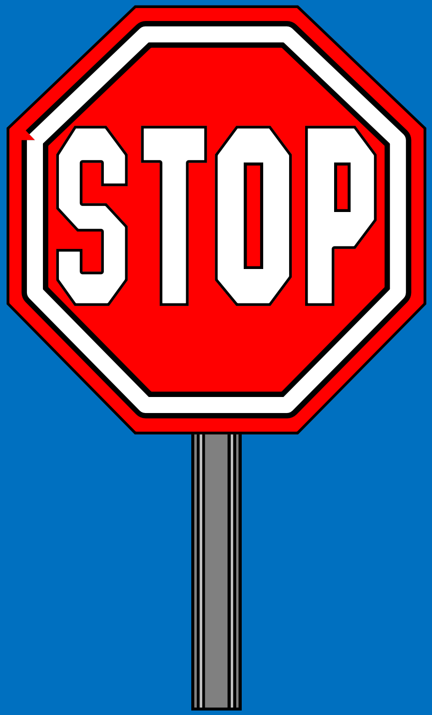
Sprinkler: 130 ac x 4.0 ac-ft. x 175 ft. x 0.10 gal/ac-ft. = 9,100 gal = <u>$48,230</u>

Surface: 130 ac x 4.6 ac-ft. x 71 ft. x 0.10 gal/ac-ft. = 4,246 gal = <u>$22,503</u>

Difference in fuel amount = 9,100 – 4,246 = <u>4,854 gal</u>

Total saving with surface irrigation = 4,854 gal x $5.30/gal = <u>$25,727</u>





THANK YOU !!

QUESTIONS OR COMMENTS?

Cost: $40-60 per acre