Lecture 18

Trickle Irrigation Planning Factors

I. Soil Wetted Area

- Trickle irrigation systems typically apply small amounts of water on a frequent basis, maintaining soil water near field capacity
- But, usually not all of the soil surface is wetted, and much of the root zone is not wetted (at least not by design) by the system
- Recall that the system is applying water to each individual plant using one or more emission points per plant

Widely-Spaced Crops

- These include orchards and vineyards, for example
- According to Keller & Bliesner, for widely-spaced crops, the percent wetted area, P_w, should normally be between 33% and 67%
- The value of P_w from the irrigation system can fall below 33% if there is enough rainfall to supplement the water applied through the trickle system
- Lower values of P_w can decrease the irrigation system cost because less emitters per unit area are required
- Lower values of P_w can allow more convenient access (manual labor & machinery) for cultural practices during irrigation
- Lower values of P_w can also help control weed growth in arid and semi-arid regions, and reduce soil surface evaporation
- Lower values of P_w carry the danger that the soil will dry to dangerously low levels more quickly in the event the irrigation system goes "off-line" for any reason (power failure, broken pipe, pump problems, labor shortage, etc.)
- With lower values of P_w, there is less storage of applied water in the root zone, especially with light-textured soils (sandy soils)
- With tree crops, low values of P_w can lead to "root anchorage" problems, in which root extension is insufficient to support the trees during winds

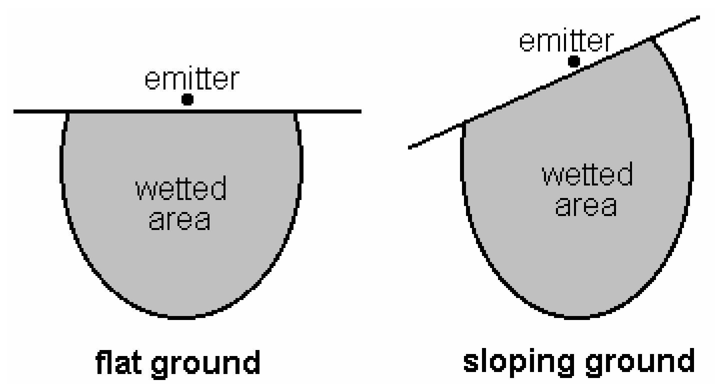
Closely-Spaced Crops

- These include most row crops
- Actual P_w values may be near or at 100% with row crops and subsurface drip irrigation systems (in the USA rows are typically spaced from 30 inches to 60 inches)
- Larger values of P_w usually mean more extensive root development, and enhanced ability for the plant to make use of any rain water that may come
- Figure 19.1 in the textbook shows a generalized relationship between P_w, amount of rainfall, and crop production level – the figure implies that maximum crop yield may be higher under a trickle irrigation system than with other methods

- Figure 19.1 indicates that 100% crop yield might be obtained, in general, with $P_w \geq 33\%$

Wetted Soil Area, A_w

- The wetted soil area, A_w, is not measured at the soil surface, but from a horizontal plane about 30 cm below the soil surface (actually, it depends on root depth and soil type)
- The same is true for P_w
- The reason we are interested in P_w is to calculate the application depth "d_x,” as discussed in the following lecture
- This wetted area is distorted for sloping terrain, but the distortion is uniform for uniform slopes (all other factors being the same)



- Wetted soil area can be estimated from empirical relationships and tables (Table 19.1 in the textbook), but it is best to have site-specific field data in which potential emitters are operated in the design area
- That is, test the emitter(s) and spacings in the field before completing the irrigation system design
- Calculate percent wetted area, P_w, as follows:

$$P_w = 100\left(\frac{N_p S_e w}{S_p S_r P_d}\right), \text{ for } S_e < 0.8w \qquad (333)$$

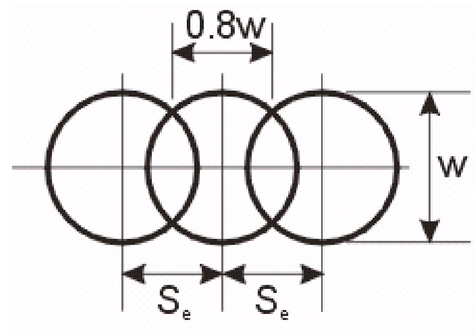
where N_p is the number of emission points (emitters) per plant; S_e is the spacing of emitters along a lateral; w is the wetted width along the lateral; S_p is the spacing of plants along a row; S_r is the spacing between rows; and P_d is the fraction (not percent) of area shaded (see Lecture 19)

- Note that the numerator of Eq. 333 is wetted area, and the denominator is actual plant area
- Note also that some emitters have multiple emission points

- S_e is the spacing between emitters on the lateral; however, if S_e is greater than 0.8w, then use 0.8w instead:

$$P_w = 100\left(\frac{0.8 N_p w^2}{S_p S_r P_d}\right), \text{ for } S_e \geq 0.8w \tag{334}$$

- Note that w is a function of the soil type
- S_e' is the "optimal" emitter spacing, defined as 0.8w
- There are practical limitations to the value of S_e with respect to S_p, otherwise there may not be enough emitters per plant (perhaps less than one)



Continuous wetted strip

- Sample calculation:

  - Suppose $S_r = S_p = 3.0$ m, P_d = 80%, and w = 1.1 m
  - Determine N_p for $P_w \geq 33\%$

$$S_e' = 0.8w = 0.8(1.1) = 0.88 \text{ m} \tag{335}$$

$$0.33 = \frac{N_p (0.88)(1.1)}{(3.0)(3.0)(0.80)} \tag{336}$$

whereby N_p = 2.45. Then,

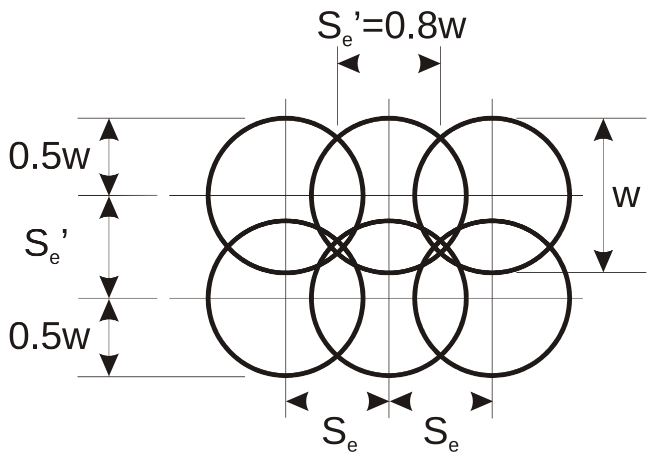
$$P_w = \frac{3(0.88)(1.1)}{(3.0)(3.0)(0.80)} = 0.40 \tag{337}$$

- For double-lateral trickle systems, spaced S_e' apart, P_w is calculated as follows (see Eq. 19.4):

$$P_w = 100\left(\frac{N_p S'_e \left(S'_e + w\right)}{2P_d \left(S_p S_r\right)}\right), \text{ for } S_e \leq 0.8w \tag{338}$$

or,

$$P_w = 100\left(\frac{1.44 w^2 N_p}{2P_d \left(S_p S_r\right)}\right) = \frac{72 w^2 N_p}{P_d \left(S_p S_r\right)}, \text{ for } S_e \leq 0.8w \tag{339}$$



Double laterals

- As in the previous equation, if $S_e > S_e'$, use S_e' instead of S_e in the above equation for double laterals
- In the above equation, the denominator has a "2" because N_p for double lateral systems is always at least 2
- For micro-spray emitters, the wetted area is greater than that measured at the surface (because it is measured below the surface):

$$P_w = 100\left[\frac{N_p\left(A_s + (PS)\dfrac{S_e}{2}\right)}{S_p S_r P_d}\right], \text{ for } S_e \leq 0.8w \tag{340}$$

where A_s is the surface area wetted by the sprayer; and PS is the perimeter (circumference) of the wetted surface area

- In the above equation for P_w, the term in the inner parenthesis is:

$$A_s + (PS)\frac{S_e}{2} = \frac{\pi w^2}{4} + \frac{\pi w S_e}{2} = \frac{\pi w}{2}\left(\frac{w}{2} + S_e\right) \tag{341}$$

where w is the diameter corresponding to A_s, assuming a circular area

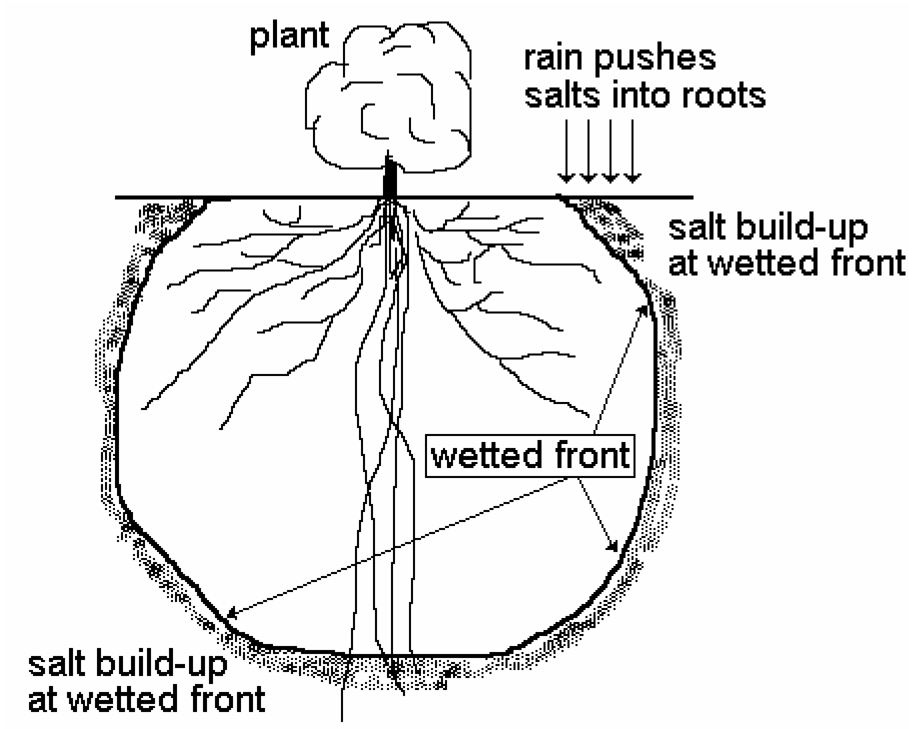
- See Fig. 19.4 on sprayers

Salinity in Trickle Irrigation

I. Salinity in Trickle Systems

- Salinity control is specialized with trickle irrigation because (usually) less than 100% of the area is wetted, and because water movement in the soil has significant horizontal components
- Irrigation water always contains salts, and fertilizers add salt to the crop root zones -- salinity management in the crop root zone is a long-term management consideration with trickle systems, as it is with any other irrigation method
- Salts tend to accumulate, or "build up", at the periphery of the wetted bulb shape under the soil surface

    1. Rain can push salts near the surface down into the crop root area (but a heavy rain can push them all the way through the root zone)
    2. If and when the irrigation system is not operated for a few days, there can be pressure gradients in the soil that pulls salts from the periphery up into the root zone



- The crop is depending on frequent irrigations (perhaps daily) to keep salt build-ups from moving into the root mass
- It may be necessary to operate the trickle system immediately following a light rain to keeps salts away from roots (even if the soil is at field capacity)

- Annual leaching with surface irrigation or sprinklers (on a trickle-irrigated field) may be necessary to clean salts out of the root zone, unless there is a rainy period that provides enough precipitation to leach the soil
- If the irrigation water has high salinity, trickle systems can provide for higher crop production because the frequent irrigations maintain the soil salinity nearer to the EC_w (this is often not the case with sprinklers and surface irrigation systems - salinity concentrates due to ET processes between water applications)

II. Yield Effects of Salinity

- According to Keller, the relative crop yield can be estimated as (Eq. 19.6):

$$Y_r = \frac{Y_{actual}}{Y_{potential}} = \frac{(EC_e)_{max} - EC_w}{(EC_e)_{max} - (EC_e)_{min}} \qquad (342)$$

- This is the relative crop yield (or production) in terms of soil water salinity only
- EC_w is the electrical conductivity of the irrigation water
- $(EC_e)_{max}$ is the zero yield point, and $(EC_e)_{min}$ is the 100% yield threshold value
- $(EC_e)_{max}$ may be as high as 32, and $(EC_e)_{min}$ can be as low as 0.9
- This is based on the linear relationship between relative yield and salinity as adopted years ago by FAO and other organizations
- Of course, calculated Y_r values must be between 0 and 1

- Salinity of the soil extract, EC_e, is measured by taking a soil sample to the laboratory, adding pure water until the soil is saturated, then measuring the electrical conductivity -- most published crop tolerance and yield relationships are based on the EC_e as a standard reference
- Crops don't instantly die when the salinity approaches $(EC_e)_{max}$; the osmotic potential increases and roots cannot extract the water that is there
- There can also be specific toxicity problems with minerals at high salinity levels
- According to Allen, the relative yield will be near 100% for EC_w less than about $2(EC_e)_{min}$, provided that frequent irrigations are applied (maintaining salinity concentrations in root zone)

III. Leaching Requirement

- According to Keller & Bliesner, the leaching requirement under a trickle system in an arid or semi-arid region does not consider effective rainfall (arid regions often have more serious salinity problems, but tropical regions are also subject to salinity in low areas)

- Look at Eq. 19.7:

$$LR_t = \frac{EC_w}{EC_{dw}} \tag{343}$$

where LR_t is the leaching requirement under trickle irrigation (fraction); and EC_{dw} is the electrical conductivity of the “drainage water”, which means the water that moves downward past the root zone

- EC_{dw} can be replaced by $2(EC_e)_{max}$ for daily or every-other-day irrigations (keep water moving through the root zone), still obtaining $Y_r = 1.0$

$$LR_t = \frac{EC_w}{2\left(EC_e\right)_{max}} \tag{344}$$

IV. Allen’s Equation for LR_t

- R.G. Allen suggests a more conservative equation for calculating the leaching requirement under trickle irrigation:

1. For continuous trickle system operation (daily or once every two days), the soil water in the root zone is maintained near field capacity, which can be taken as approximately 50% saturation (θ_v) for many soils. Thus,

$$EC_e = 0.5 EC_{soil} \tag{345}$$

(recall that EC_e is measured after adding distilled water to the soil sample until it is saturated)

2. Suppose the average EC_{soil} is taken as ($0.667EC_w + 0.333EC_{dw}$). Then, for 100% relative yield at field capacity:

$$\left(EC_e\right)_{min} = 0.5\left(0.667EC_w + 0.333EC_{dw}\right) \tag{346}$$

solving for EC_{dw},

$$EC_{dw} = 6\left(EC_e\right)_{min} - 2EC_w \tag{347}$$

3. Substitute this last equation into Eq. 19.7 from the textbook to obtain:

$$LR_t = \frac{EC_w}{6\left(EC_e\right)_{min} - 2EC_w} \tag{348}$$

this is similar to the leaching requirement as calculated for sprinkler irrigation in Eq. 3.3 (coefficients 5 and 1 instead of 6 and 2), except that $(EC_e)_{min}$ is for 100% yield rather than 10% reduction in yield