Principles of Irrigation Management in the United States

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Outline

- Methods of Applying Water
  - Irrigation Systems
  - Irrigation Uniformity
- Timing and Amount of Irrigation
  - Recharge Storage Capacity
  - Irrigation Uniformity

Outline (continued)

- Salinity Factors
  - – Steady-state Analyses
  - – Transient-state Models
  - – Rainfall Effects
  - – Irrigation Frequency
- Irrigation – Fertilizer – Chemical Transport Interactions
- Efficient Use of Irrigation Water
- Economic Irrigation Efficiency
- Conclusions

Irrigation Systems

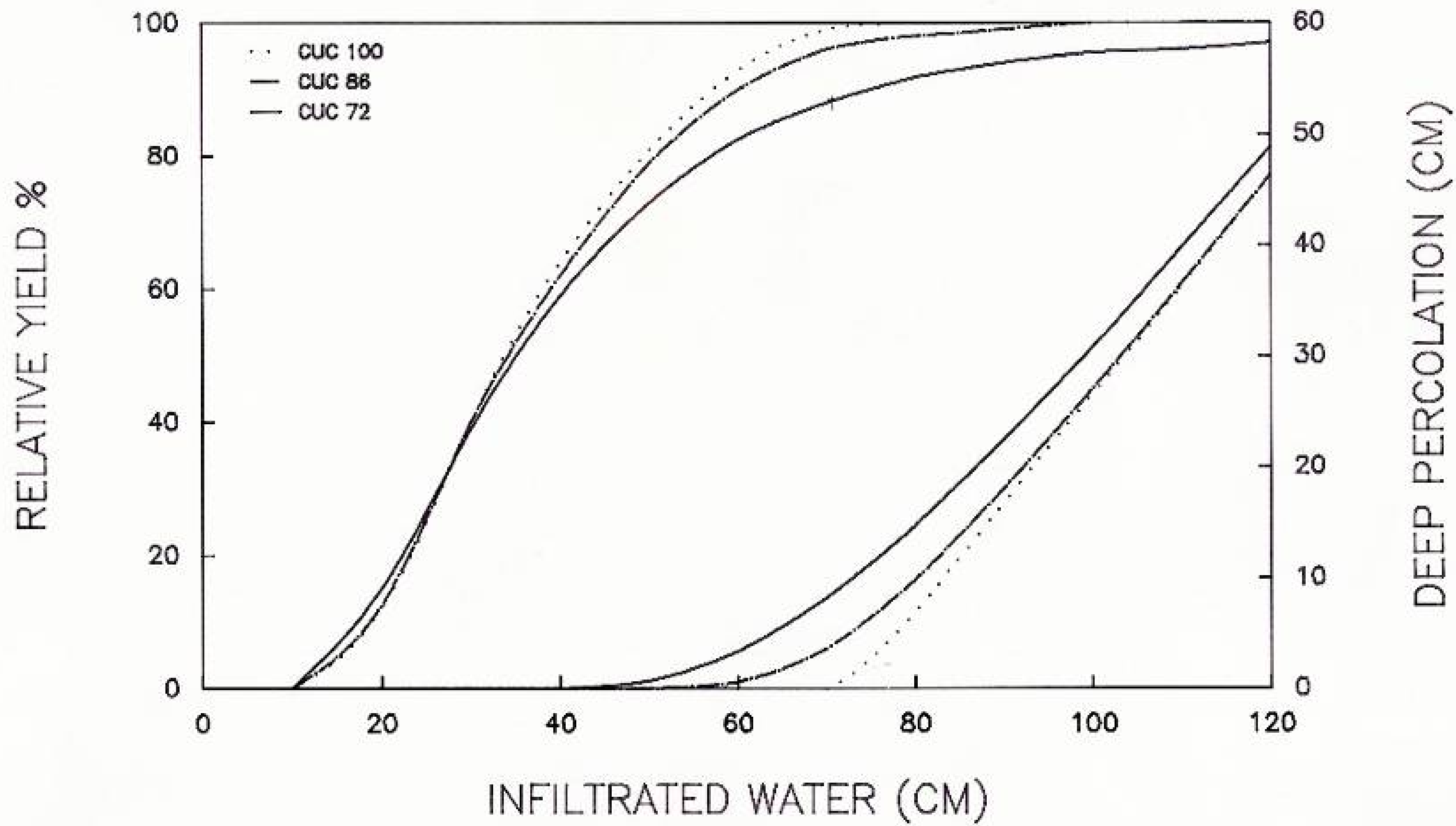
Pressurized

Water delivered through pipes under pressure and discharged through outlets such as sprinkler heads or drip emitters

Non-pressurized

Water delivered and allowed to flow across the field

Irrigation Uniformity



CUC 100
CUC 86
CUC 72
RELATIVE YIELD %
DEEP PERCOLATION (CM)
INFILTRATED WATER (CM)
0
20
40
60
80
100
120
10
30
50

Measuring Uniformity

- Sprinklers
  - Catch-cans (size dependent)
  - Wind
- Furrow
  - Opportunity time
  - Soil variability
- Root system effects

Cannot compare uniformity numbers for different irrigation systems

Usually –

micro-irrigation > sprinkler (except wind) > surface irrigation

Irrigation Scheduling

- Time and amount to irrigate
- ET since last irrigation
  - Climate
  - Soil-water monitoring

$$ET = K_{cr}\ ET_o$$

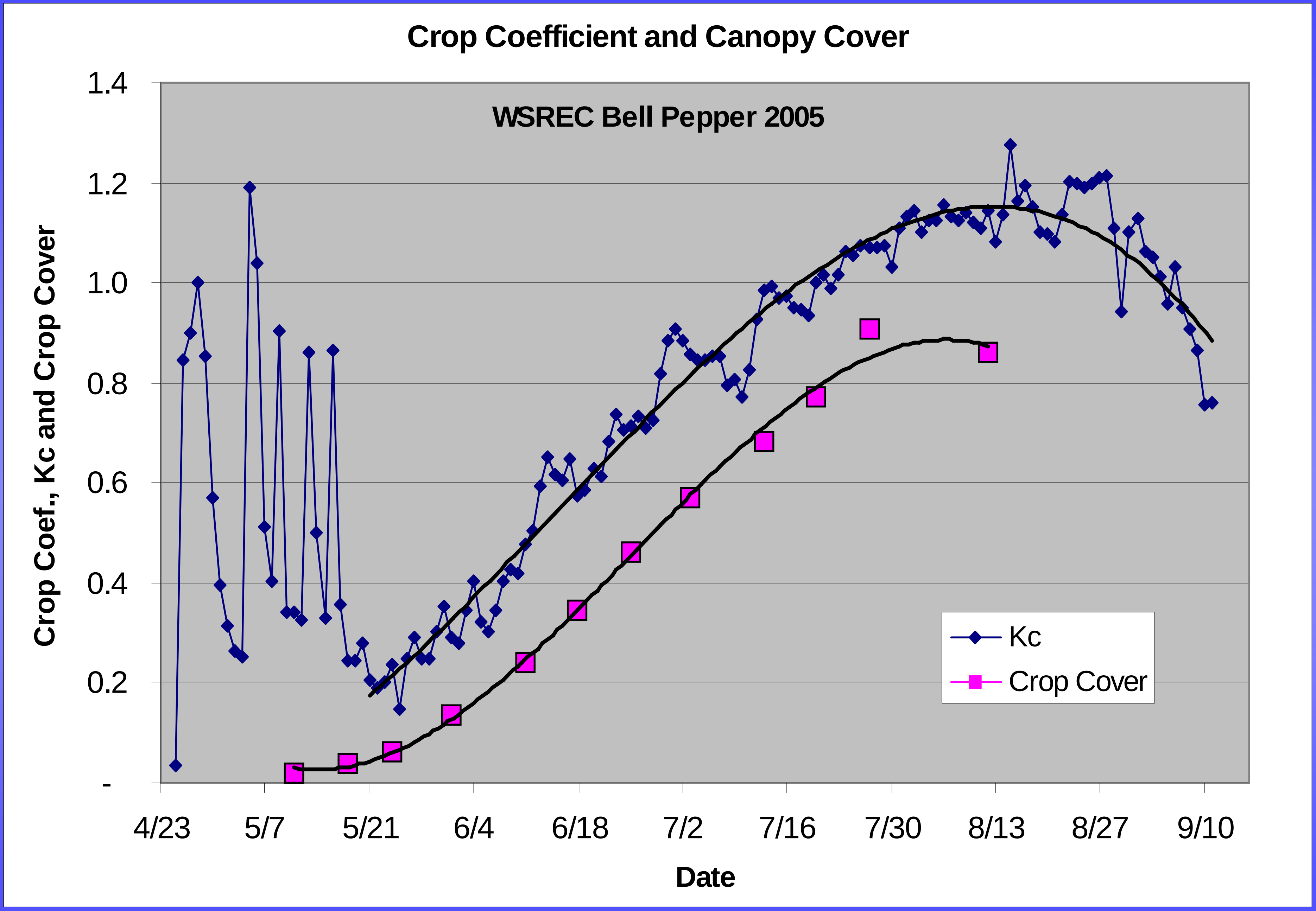


Figure courtesy of Trout and Johnson

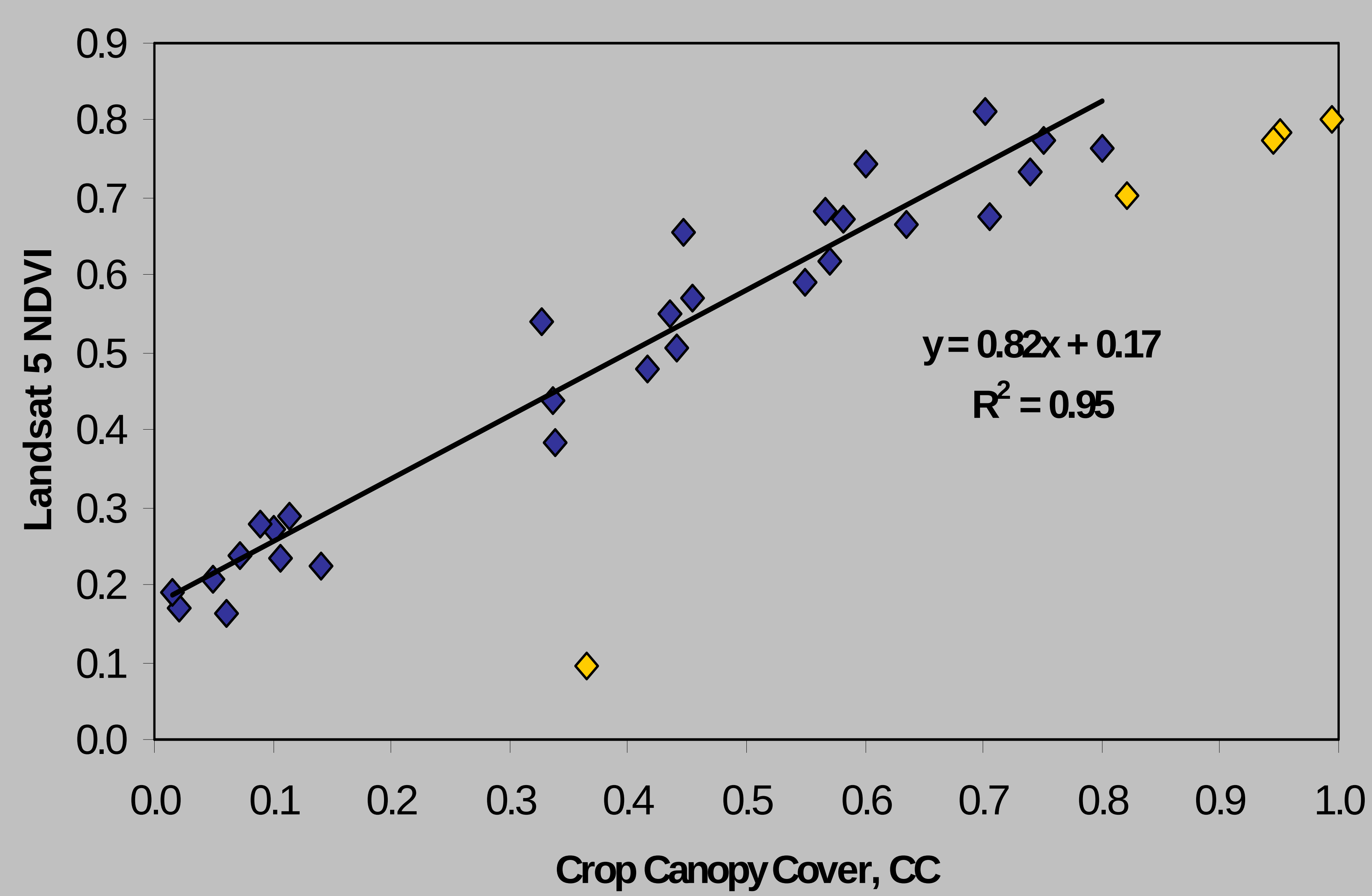
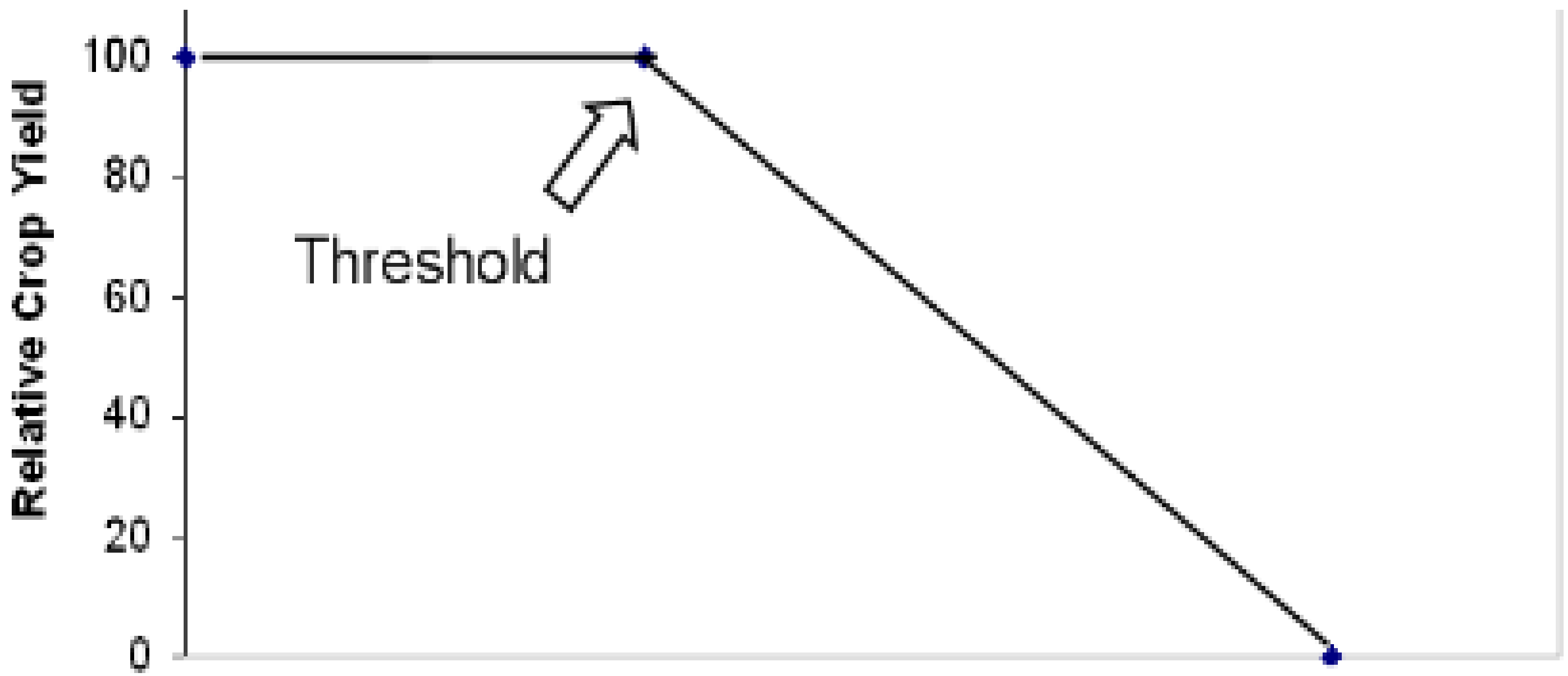


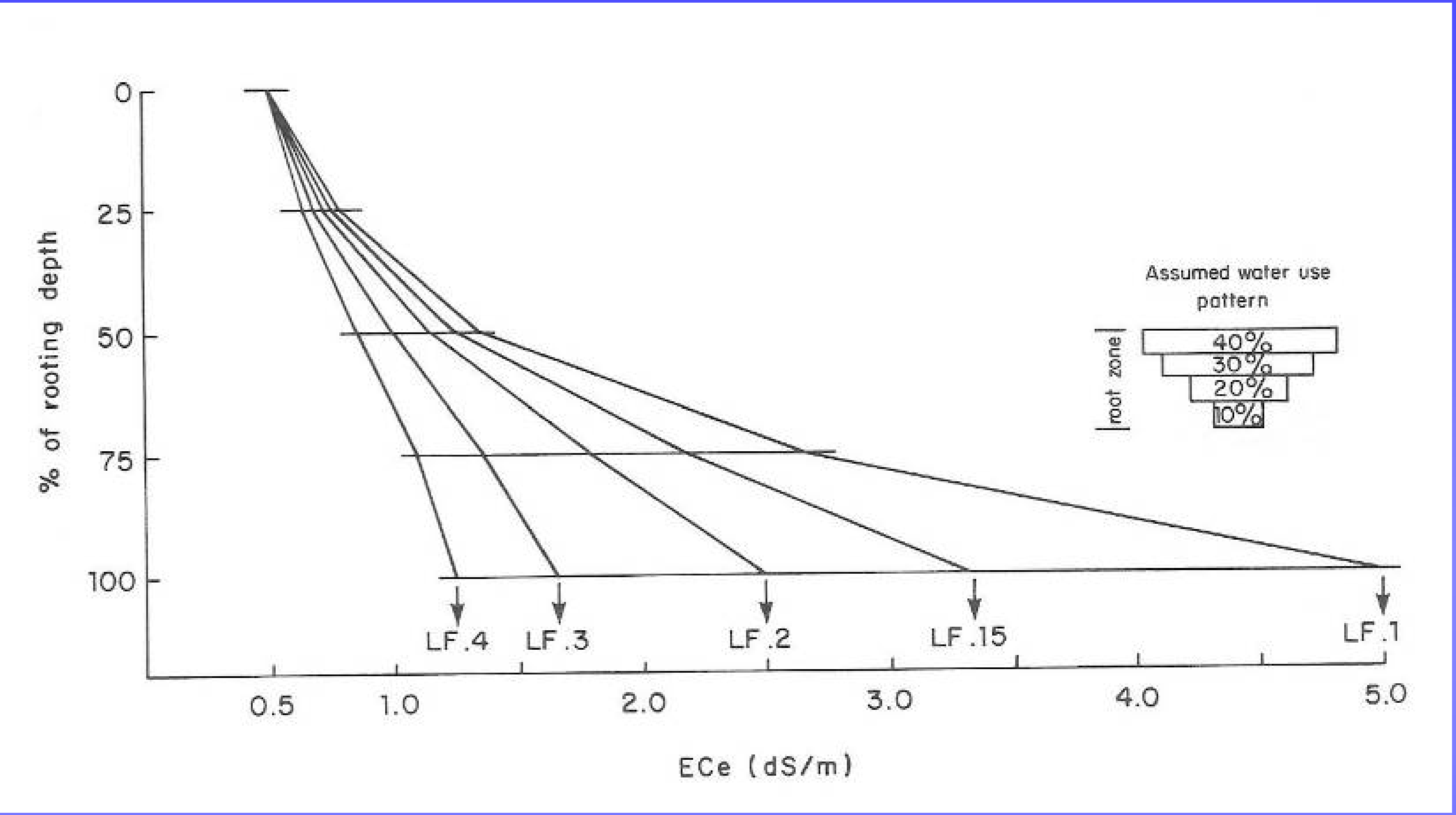
Figure courtesy of Trout and Johnson

Maas and Hoffman Salt Tolerance Coefficients



Ave. root zone ECe

Assume ECsw = 2ECe

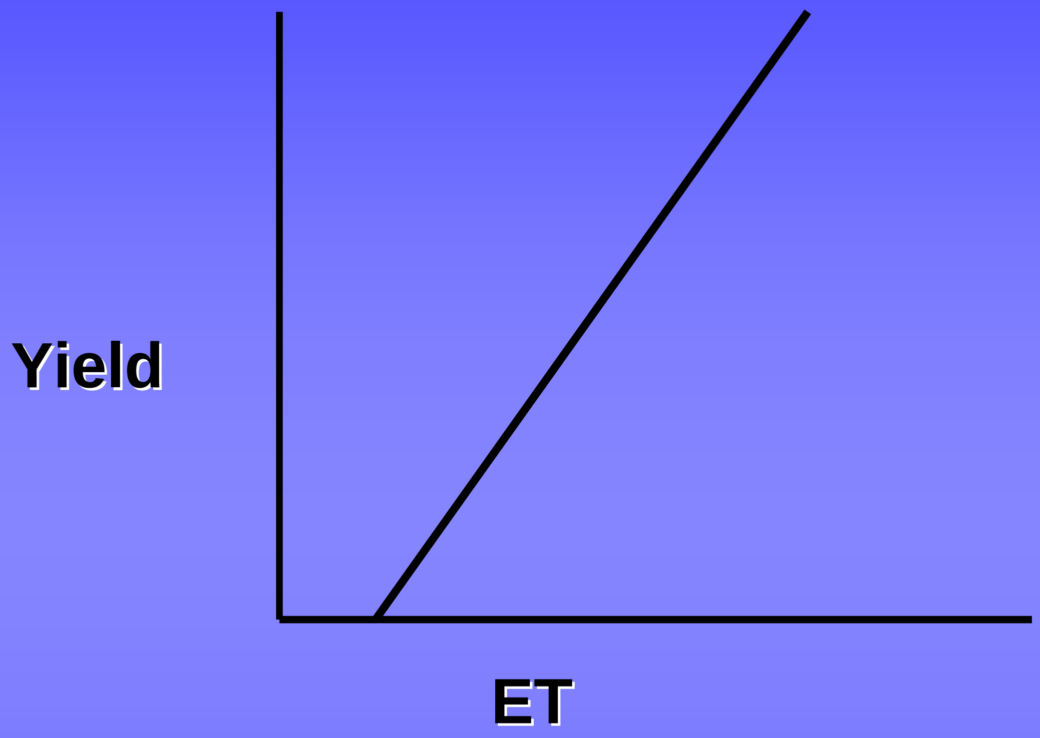


Salinity profile expected to develop after long-term use of water of EC_w = 1.0 dS/m at various leaching fractions (LF). (From Ayers and Westcot, 1985.)

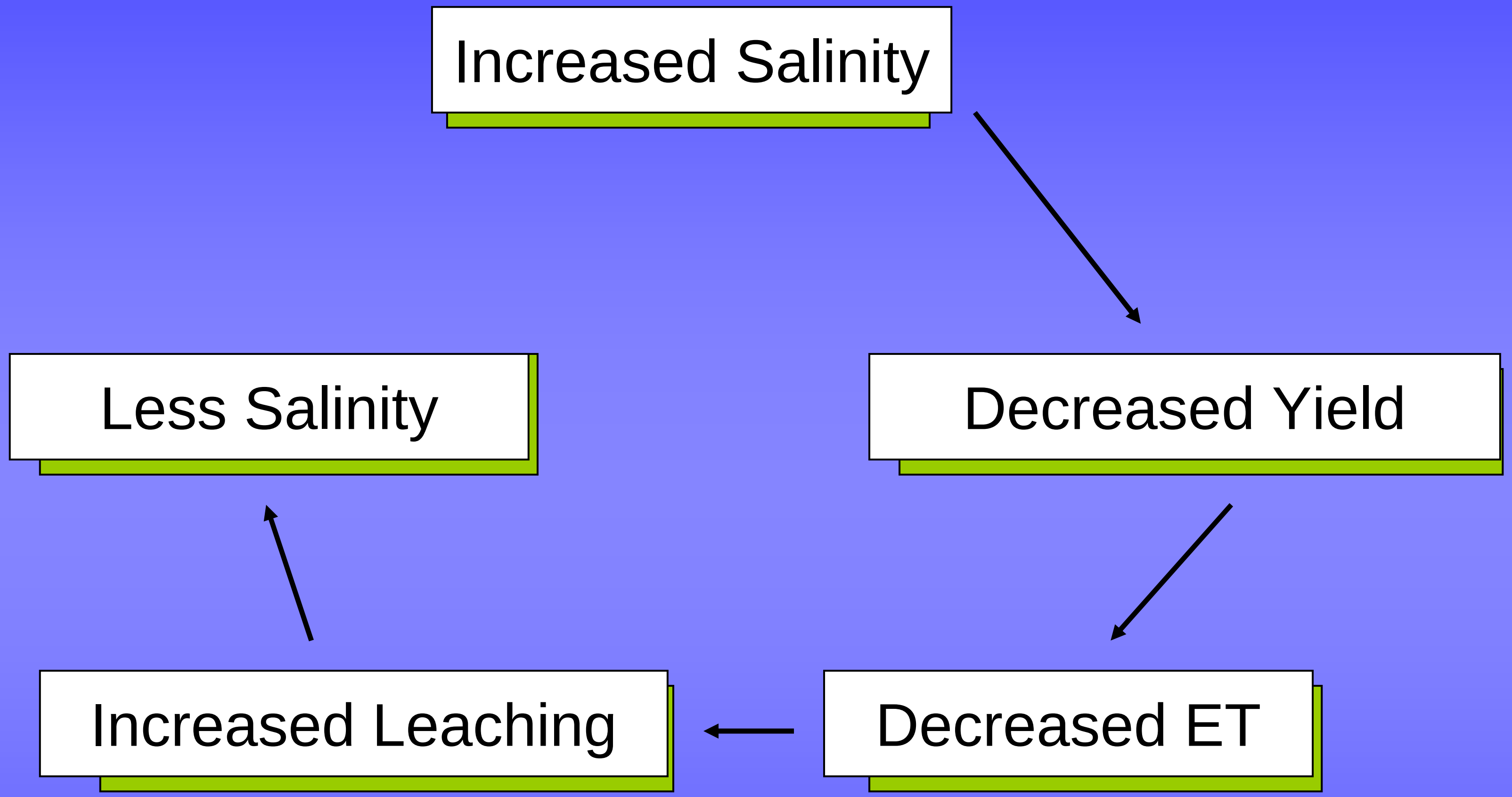
Irrigation water quality required to grow crops based on FAO guidelines

LF	C_f	EC_e^*= 1.0 dS/m	EC_e^*= 2.0 dS/m
.05	3.2	.31	.62
.10	2.1	.48	.96
.15	1.6	.62	1.24
.20	1.3	.77	1.54
.25	1.2	.83	1.86
.30	1.0	1.00	2.00
.40	0.9	1.11	2.22
.50	0.8	1.25	2.50

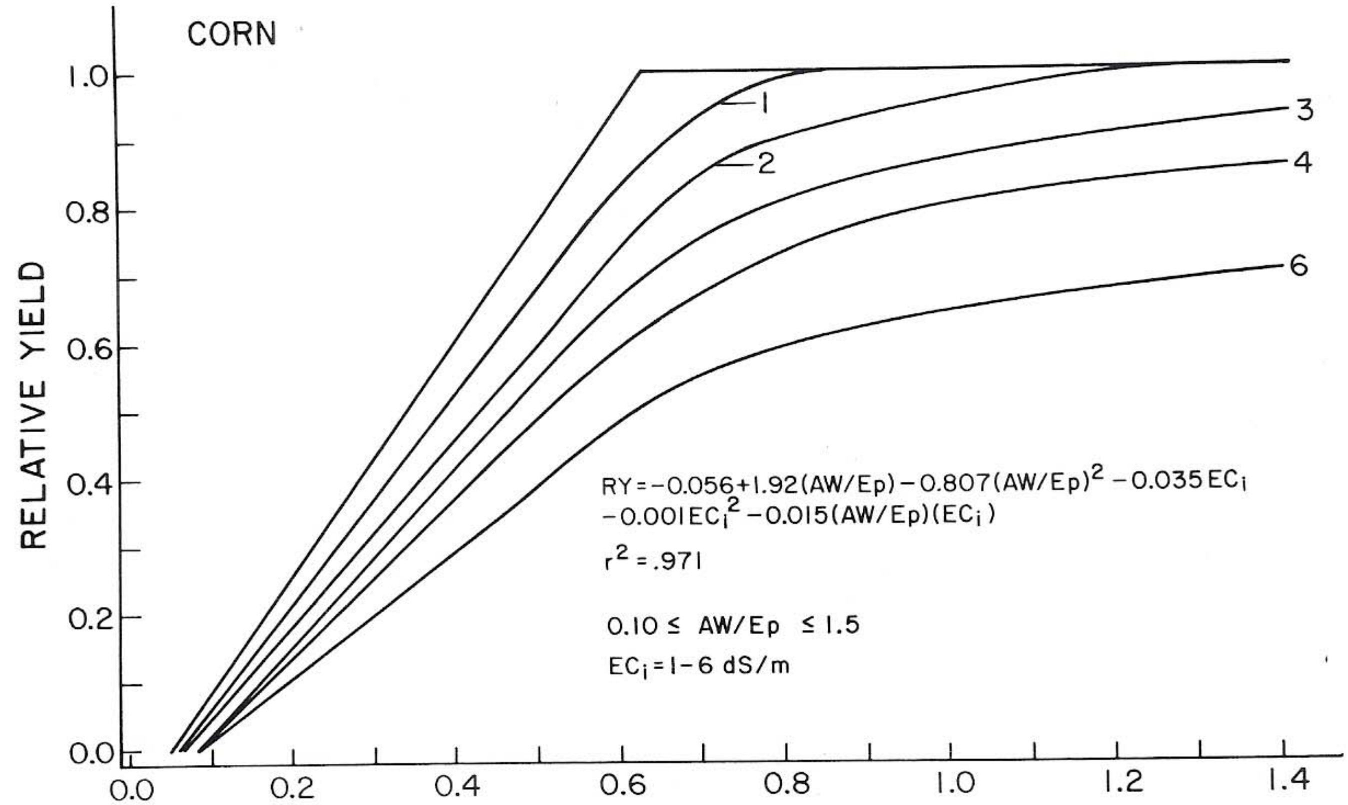
LF is leaching fraction; C_f is (ave EC_e)/EC_i; EC_i is irrigation water salinity; EC_e is EC of saturated soil extract; EC_e^* is threshold salinity tolerance.

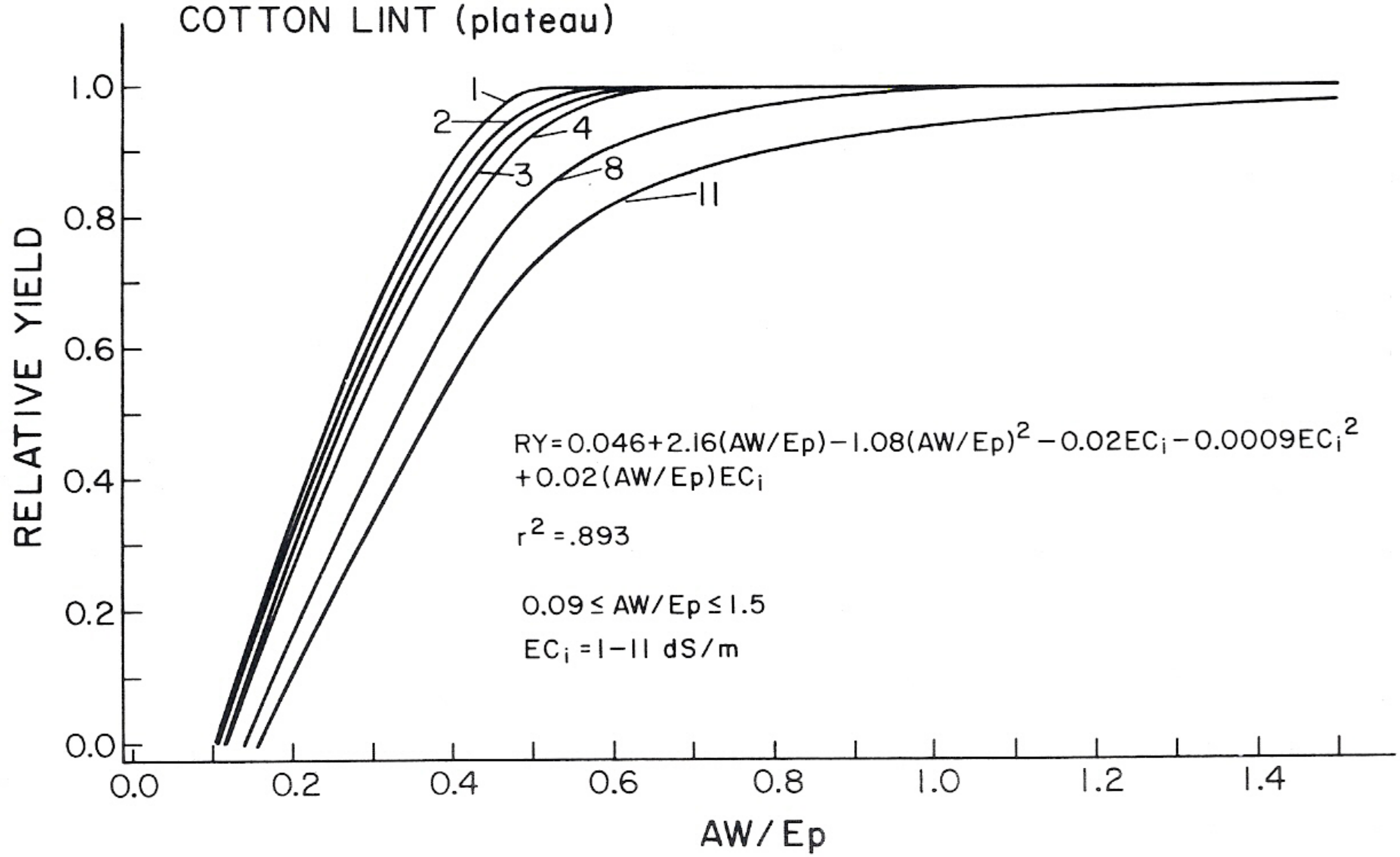


ET is a function of climate, crop, and <u>also</u> plant growth.



Increased Salinity
Decreased Yield
Decreased ET
Increased Leaching
Less Salinity


CORN
RELATIVE YIELD
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1
2
3
4
6
RY=-0.056+1.92(AW/Ep)-0.807(AW/Ep)^2 -0.035 EC$_i$
-0.001EC$_i^2$ -0.015(AW/Ep)(EC$_i$)
r^2 =.971
0.10 ≤ AW/Ep ≤ 1.5
EC$_i$=1-6 dS/m


COTTON LINT (plateau)
RELATIVE YIELD
AW/Ep
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1
2
3
4
8
11
RY=0.046+2.16(AW/Ep)−1.08(AW/Ep)^2−0.02EC$_i$−0.0009EC$_i^2$
+0.02(AW/Ep)EC$_i$
r^2=.893
0.09≤AW/Ep≤1.5
EC$_i$=1−11 dS/m

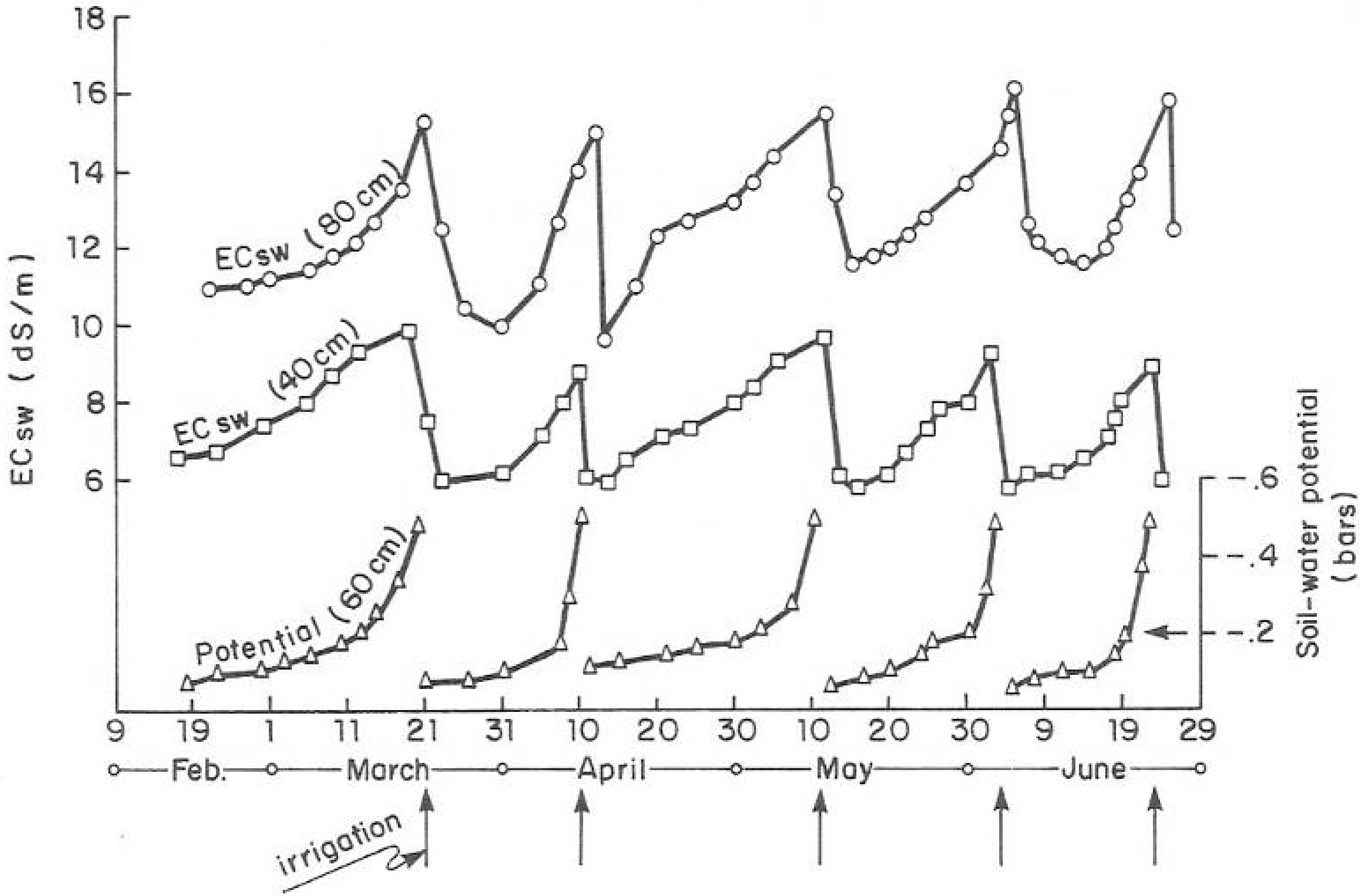


Fig. 4 Change in salinity of soil-water (EC_{SW}) between irrigations of alfalfa due to ET use of stored water (Rhoades 1972)

Transient-state models

Water flow

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left[K(\theta)\frac{\partial h}{\partial z} + K(\theta) \right] - S$$

θ is volumetric soil-water content

z is soil depth

K is hydraulic conductivity

h is soil-water pressure head

S is root water uptake term

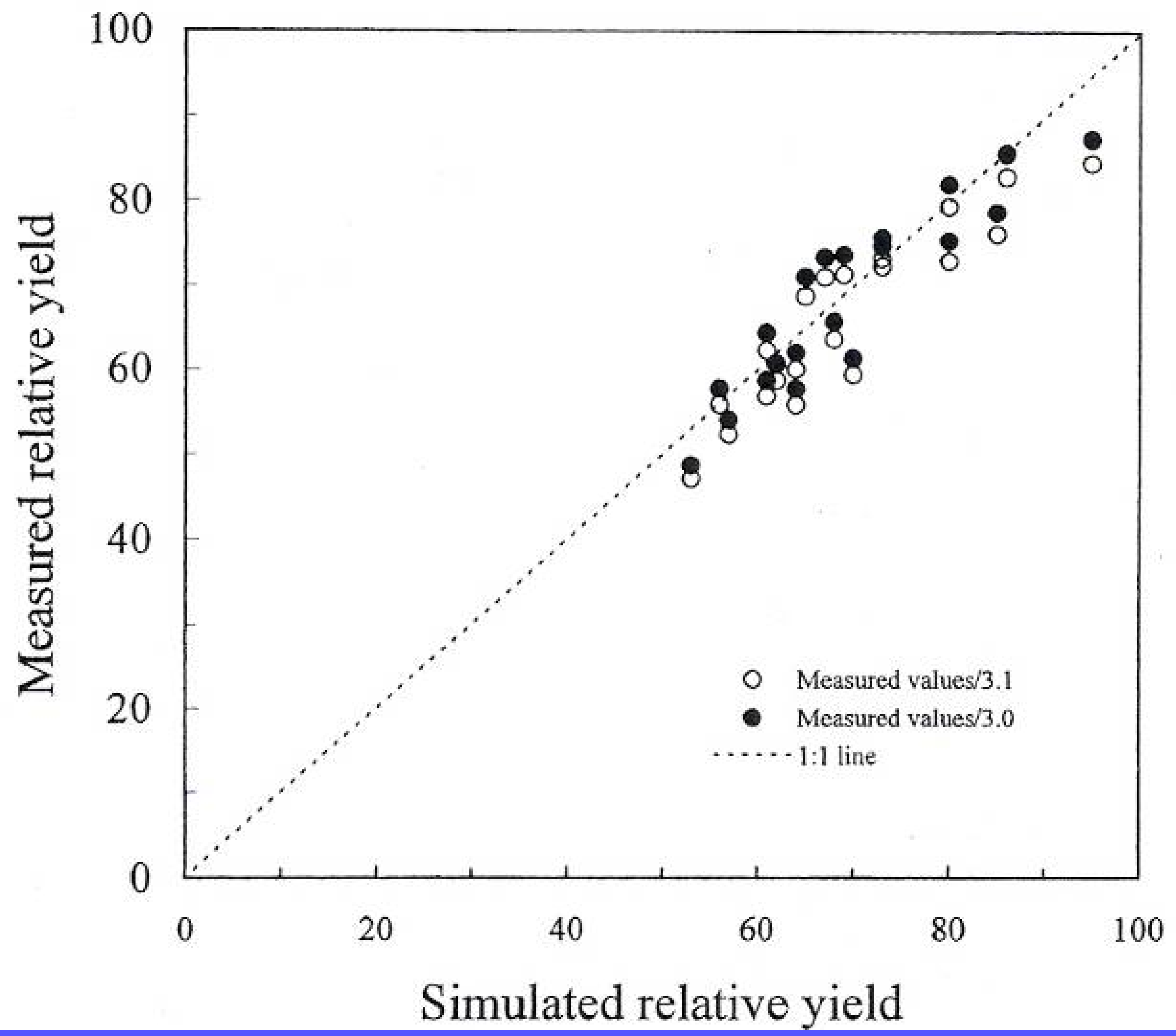
Salt transport

$$\frac{\partial(c\theta)}{\partial t} = \frac{\partial}{\partial z}\left[\theta D \frac{\partial c}{\partial z} - qc\right]$$

- c is salt concentration
- D is dispersion coefficient
- q is volumetric water flux

ENVIRO-GRO MODEL

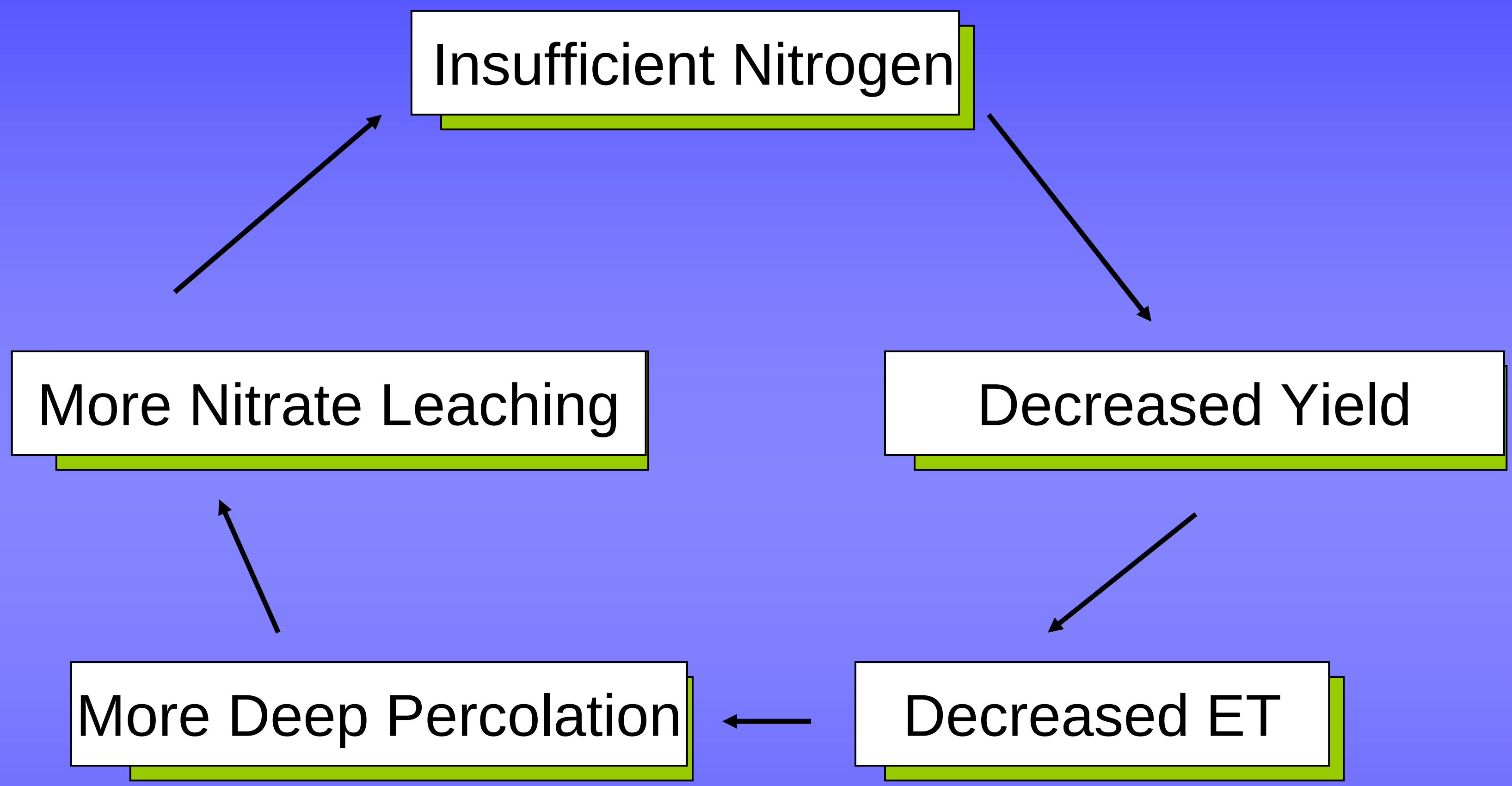
- Transient-state model
- Allows adjustment of ET for plant growth
- Allows extra water uptake from root zone where water is adequate to compensate for zones where water stress occurs

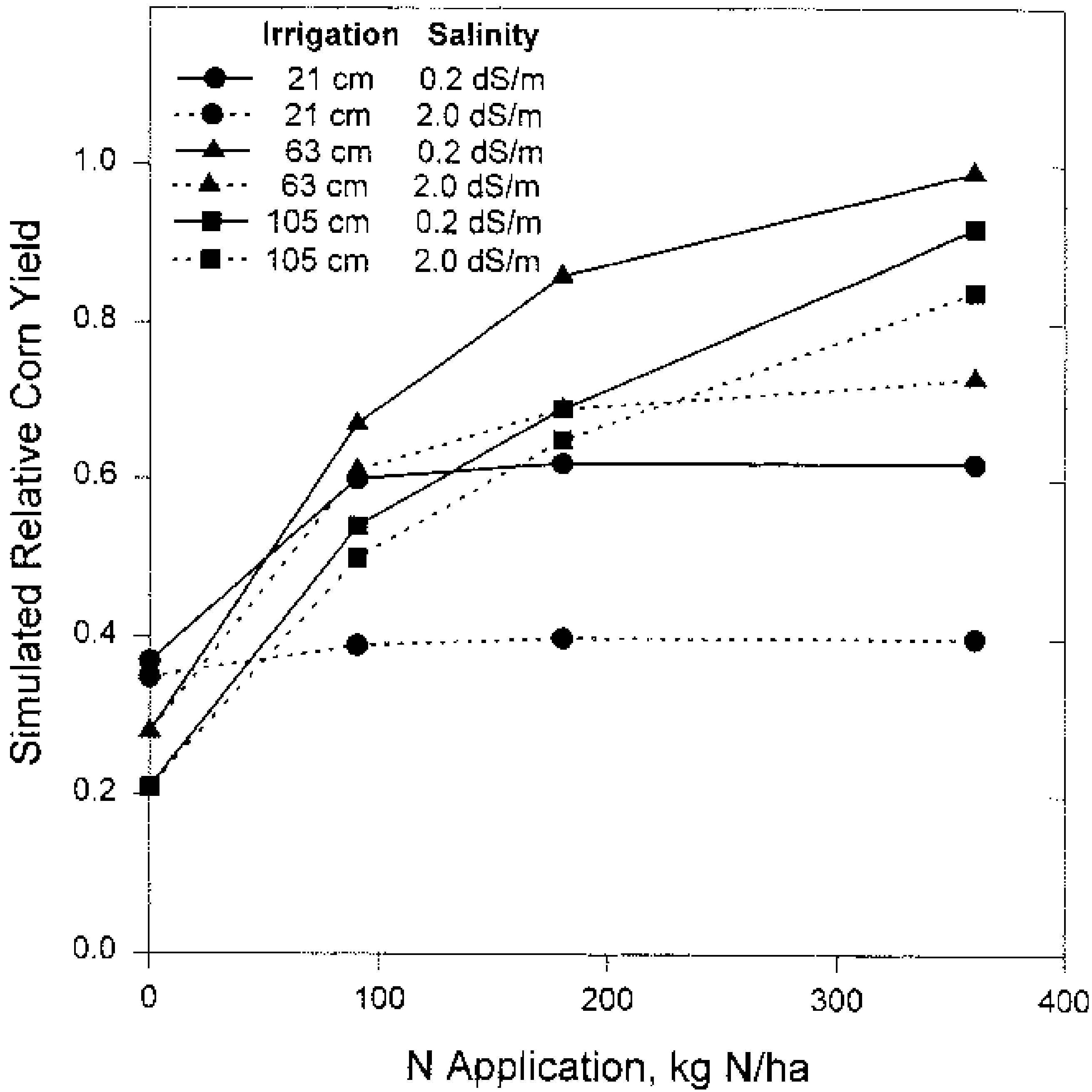

100
80
60
40
20
0
Measured relative yield
0
20
40
60
80
100
Simulated relative yield
Measured values/3.1
Measured values/3.0
1:1 line

Present guidelines for managing saline irrigation waters, based on steady-state analyses,

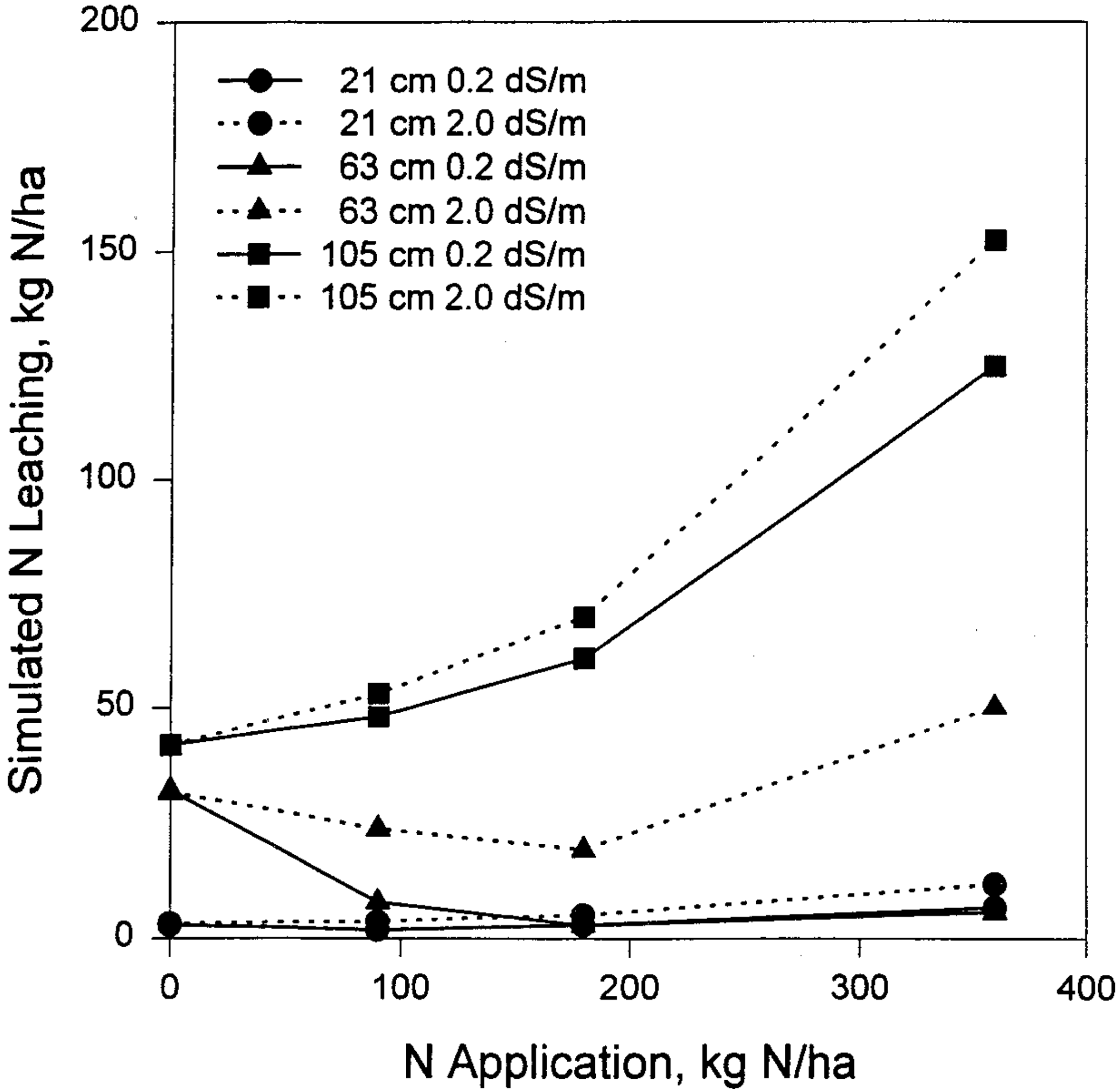
overestimate leaching requirement, and

underestimate yields that can be achieved with saline waters

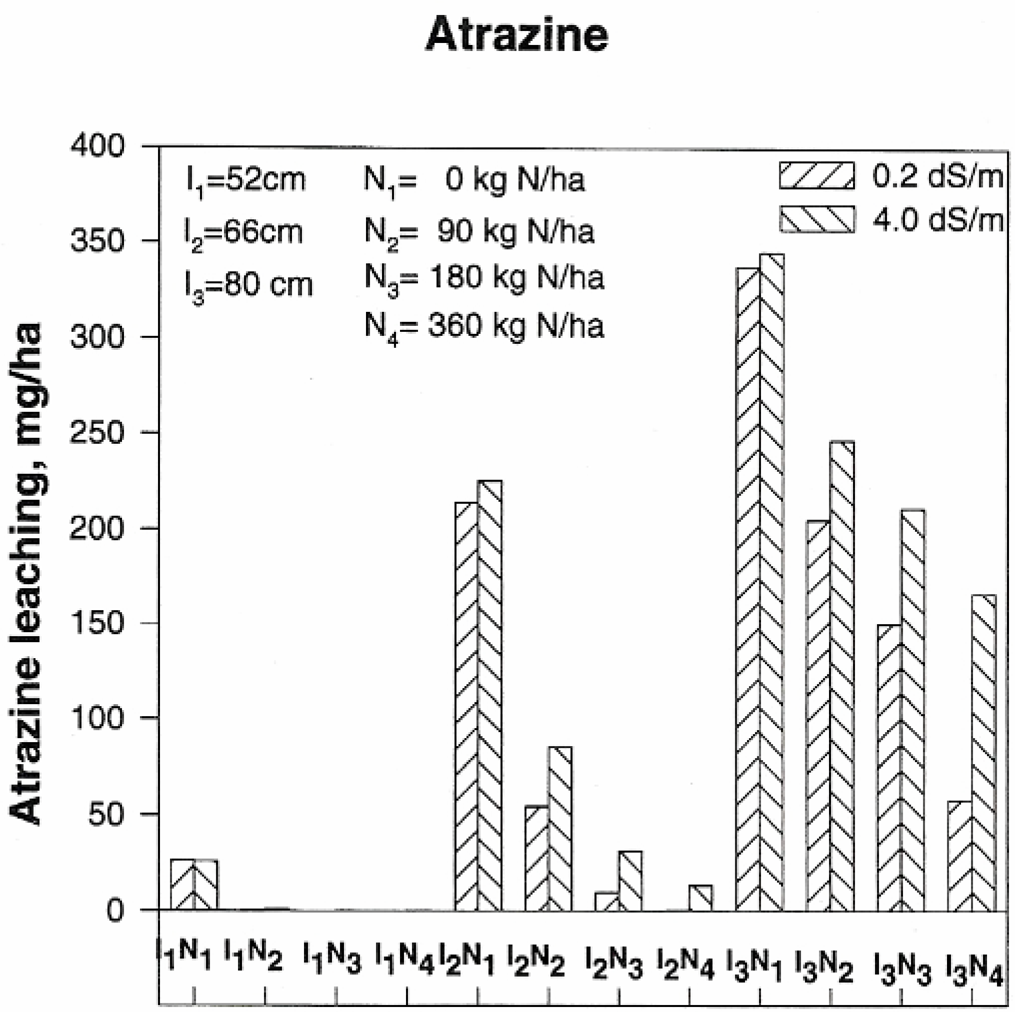

Insufficient Nitrogen
Decreased Yield
Decreased ET
More Deep Percolation
More Nitrate Leaching



Irrigation Salinity
21 cm 0.2 dS/m
21 cm 2.0 dS/m
63 cm 0.2 dS/m
63 cm 2.0 dS/m
105 cm 0.2 dS/m
105 cm 2.0 dS/m
Simulated Relative Corn Yield
0.0
0.2
0.4
0.6
0.8
1.0
0
100
200
300
400
N Application, kg N/ha



21 cm 0.2 dS/m
21 cm 2.0 dS/m
63 cm 0.2 dS/m
63 cm 2.0 dS/m
105 cm 0.2 dS/m
105 cm 2.0 dS/m
Simulated N Leaching, kg N/ha
200
150
100
50
0
0
100
200
300
400
N Application, kg N/ha



Atrazine
Atrazine leaching, mg/ha
400
350
300
250
200
150
100
50
0
I1=52cm
I2=66cm
I3=80 cm
N1= 0 kg N/ha
N2= 90 kg N/ha
N3= 180 kg N/ha
N4= 360 kg N/ha
0.2 dS/m
4.0 dS/m
I1N1
I1N2
I1N3
I1N4
I2N1
I2N2
I2N3
I2N4
I3N1
I3N2
I3N3
I3N4

Efficiency is ratio of terms x 100

ET/AW

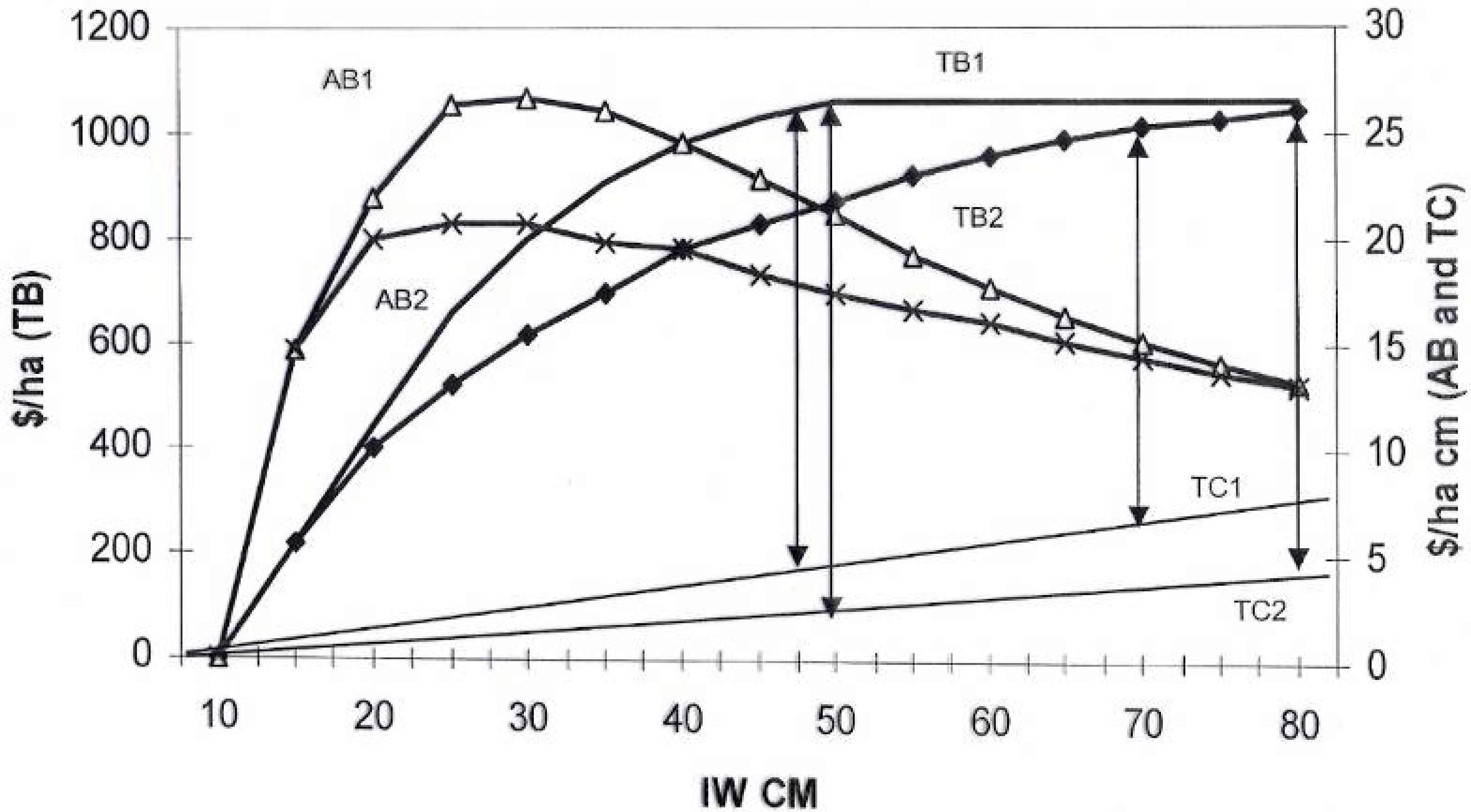
- Sometimes AW is applied water including runoff.
- Sometimes it is applied water minus runoff.

Beneficial Use/AW

- Beneficial use could be ET plus leaching requirement.

High efficiency number is <u>not</u> always better than a lower number.

Economic Irrigation Efficiency


1200
1000
800
600
400
200
0
$/ha (TB)
30
25
20
15
10
5
0
$/ha cm (AB and TC)
10
20
30
40
50
60
70
80
IW CM
AB1
AB2
TB1
TB2
TC1
TC2

Misunderstanding and confusion on water use efficiency has led to:

1. Overly-negative attitude on farm irrigation management
2. Highly inflated expectations that water conserved from agriculture can be used to offset increased urban demand