Detecting and Mapping Soil Salinity

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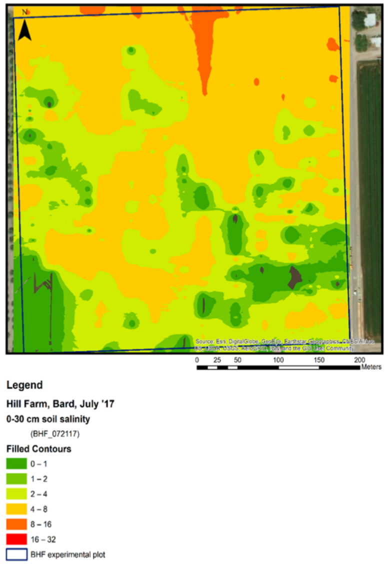
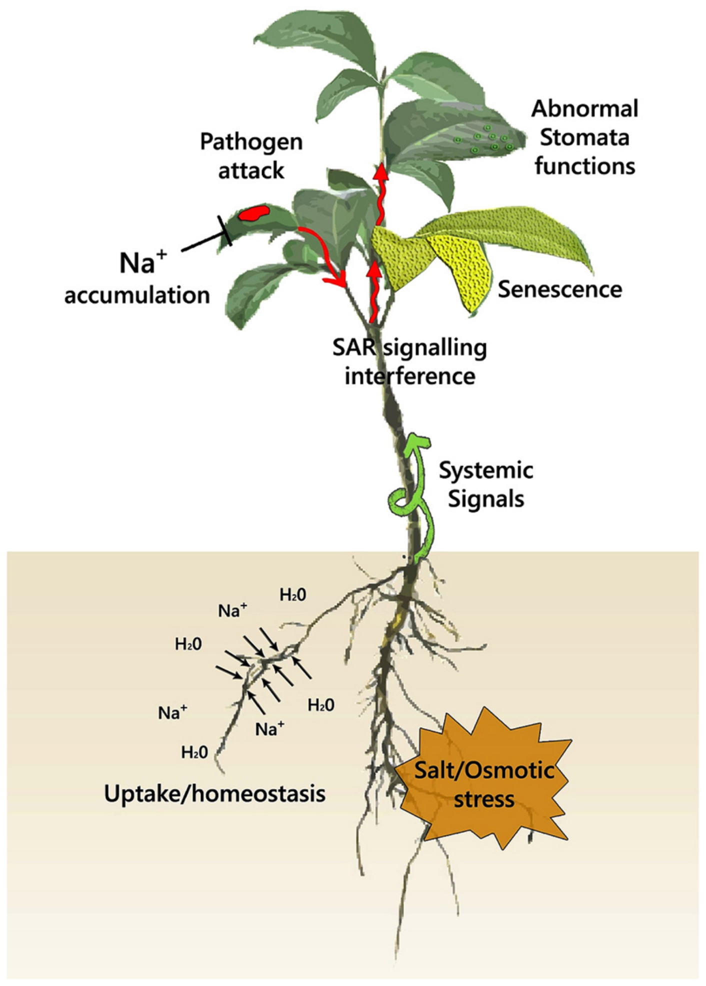
University of Arizona



Salt Effects on Plants

- Excess soluble salts can be harmful to plant growth because:
  - Salts lower the osmotic potential energy of soil water. Water is less available to plants.
  - Some soluble salt ions can have specific toxic effects on plants, such as:
    - Na^+, Cl^- , H_3BO_3

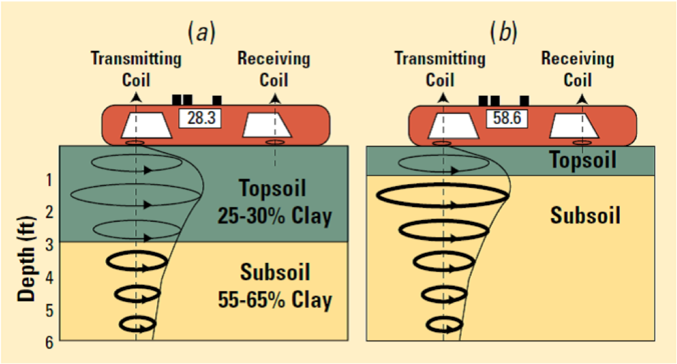


Sodium

- Sodic soils typically:
  - Are poorly-aggregated (sodium disperses clays)
  - Have slow rates of water infiltration
  - Have a pH of 8 or above . This is due to the presence of soluble Na_2CO_3.

$$SAR = \frac{(Na^{+})}{\sqrt{(Ca^{2+}) + (Mg^{2+})}}$$

EM 38 Electromagnetic conductance



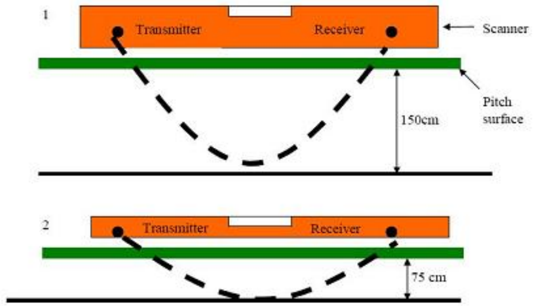
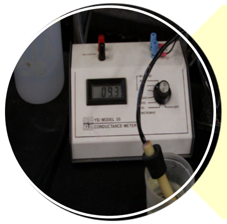


Figure 2.1 EMI scanner in vertical orientation (1) and Horizontal orientation (2)

Types of Electrical Conductivity



EC_{iw} - electrical conductivity of the irrigation water

EC_{e} - electrical conductivity of the saturated soil paste extract

EC_{a} - apparent electrical conductivity of bulk soil

$$ECa = \frac{(\theta ss + \theta s)^2 ECsECss}{(\theta ssECws) + (\theta wsECs)} + (\theta w - \theta ws)ECwc$$

Rhoades et al. 1989

The ESAP software package currently contains five programs:

- ESAP-RSSD
  Designed to generate optimal soil sampling designs from bulk soil electrical conductivity survey information
- ESAP-Calibrate
  Designed to estimate both stochastic (regression model) and deterministic (soil theory based) calibration equations; i.e., the equations which you will ultimately use to predict the spatial values of one or more soil variables from your EM survey data.
- ESAP-SaltMapper
  Used to produce high quality 1-D or 2-D graphical output of your EM survey data and/or predicted soil variables. This software can also be used to map out the locations of tile lines in saline fields, using EM survey data.
- ESAP-SigDPA
  Signal Data pre-processing software for managing raw Conductivity/GPS data file.
- ESAP-DPPC Calculator
  Used to convert insertion four-probe conductivity data into soil salinity estimates.

Program Flowchart

(input data)

conductivity survey data

↓

(input data)

ESAP-RSSD calibration sample data

↓ ↓

(output data) → **ESAP-Calibrate**

*.svy data file

↓ ↓

↓

↓ (input / output data)

↓ *.pro data file

(output data)

↓ *.prd data file

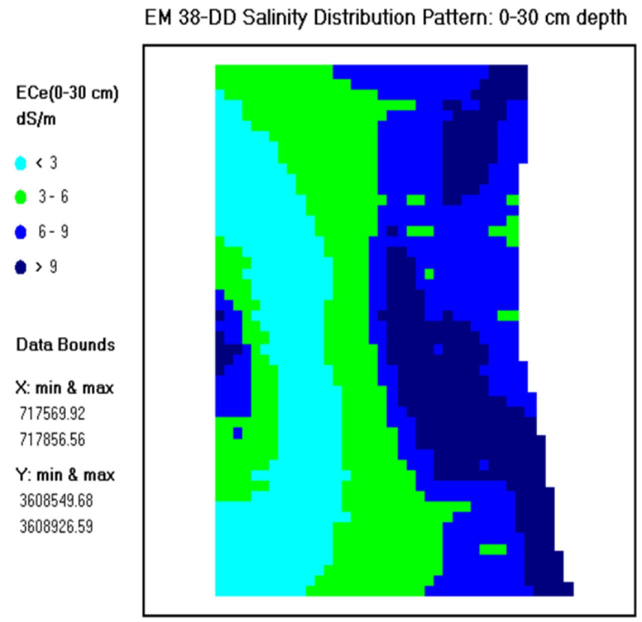
↓ ↓

↓ ↓

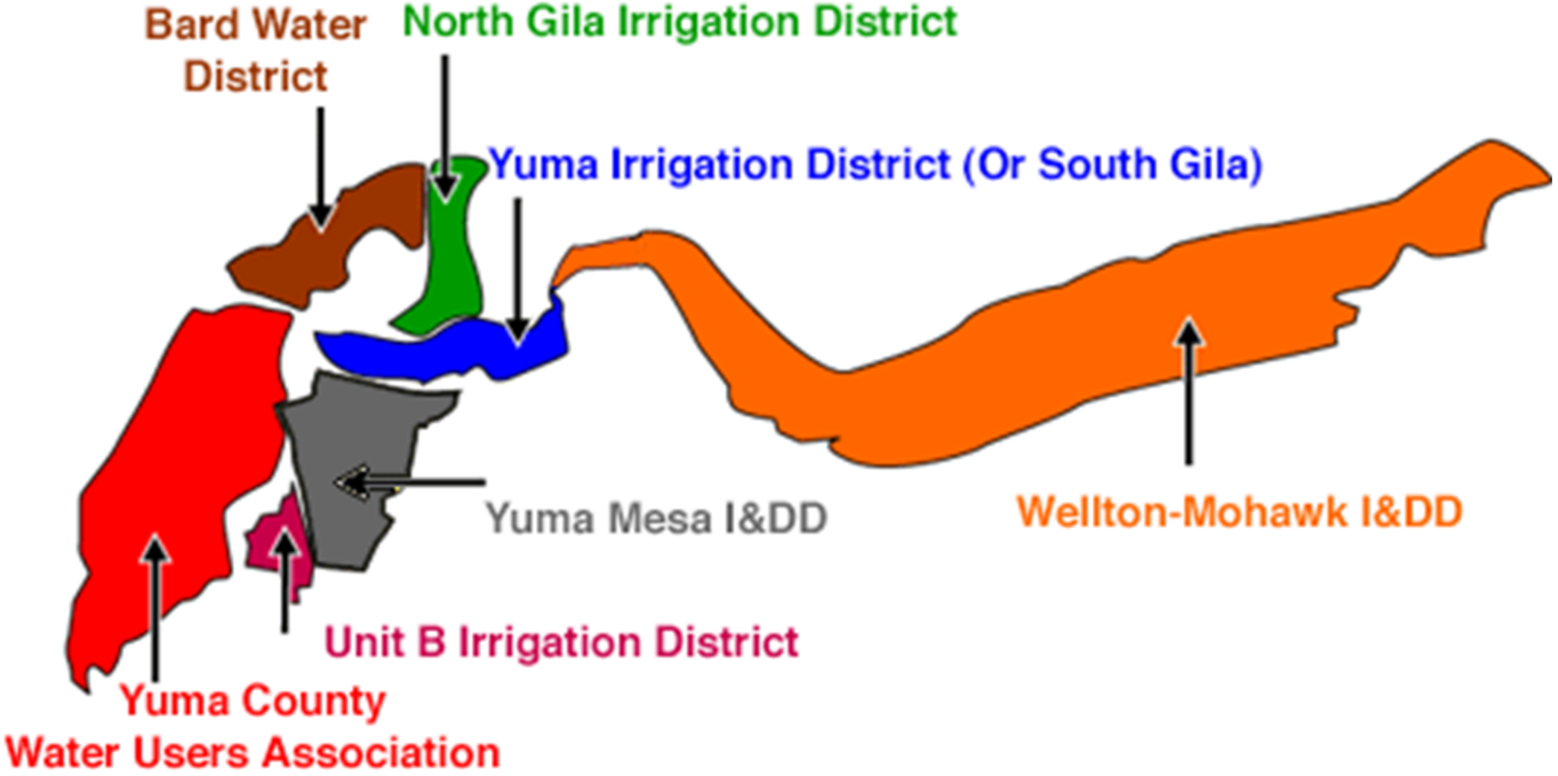
ESAP-SaltMapper

↓ ↓

(output)




BARD IRRIGATION DISTRICT
NORTH GILA VALLEY IRRIGATION & DRAINAGE DISTRICT
YUMA IRRIGATION DISTRICT
YUMA COUNTY WATER USERS ASSOCIATION
COLORADO RIVER
YUMA MESA IRRIGATION & DRAINAGE DISTRICT
UNIT B IRRIGATION & DRAINAGE DISTRICT
N

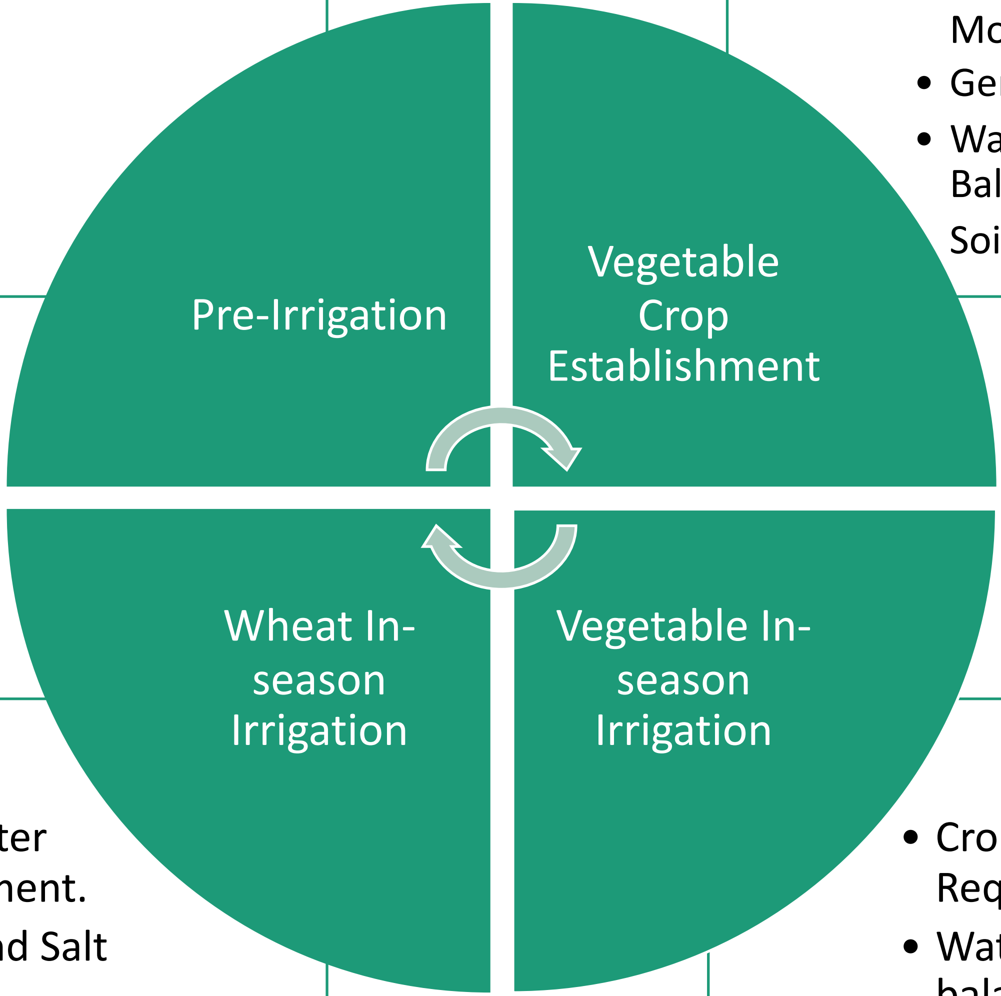

Bard Water District
North Gila Irrigation District
Yuma Irrigation District (Or South Gila)
Yuma Mesa I&DD
Wellton-Mohawk I&DD
Unit B Irrigation District
Yuma County Water Users Association

Cropping System

- Water and Salt Balance.

- Climate Modification
- Germination
- Water and Salt Balance

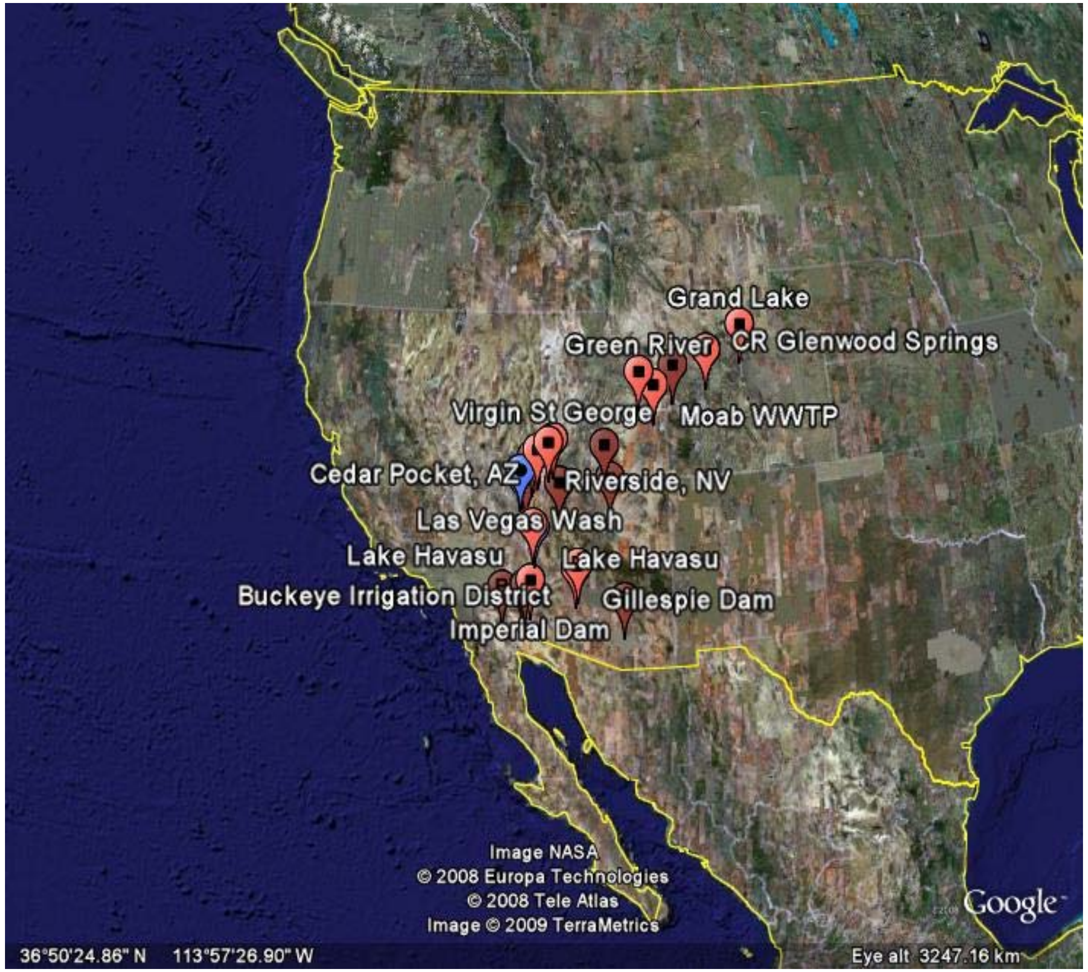
Soil Refill

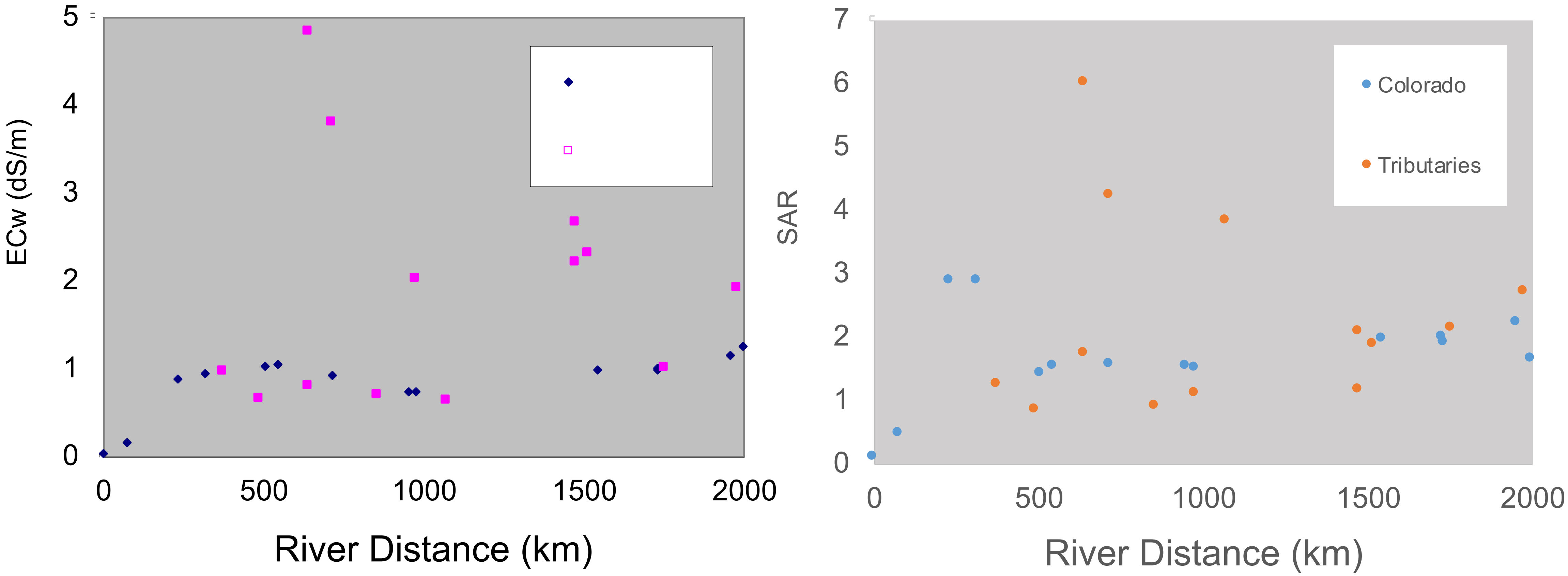


- Crop Water Requirement.
- Water and Salt Balance

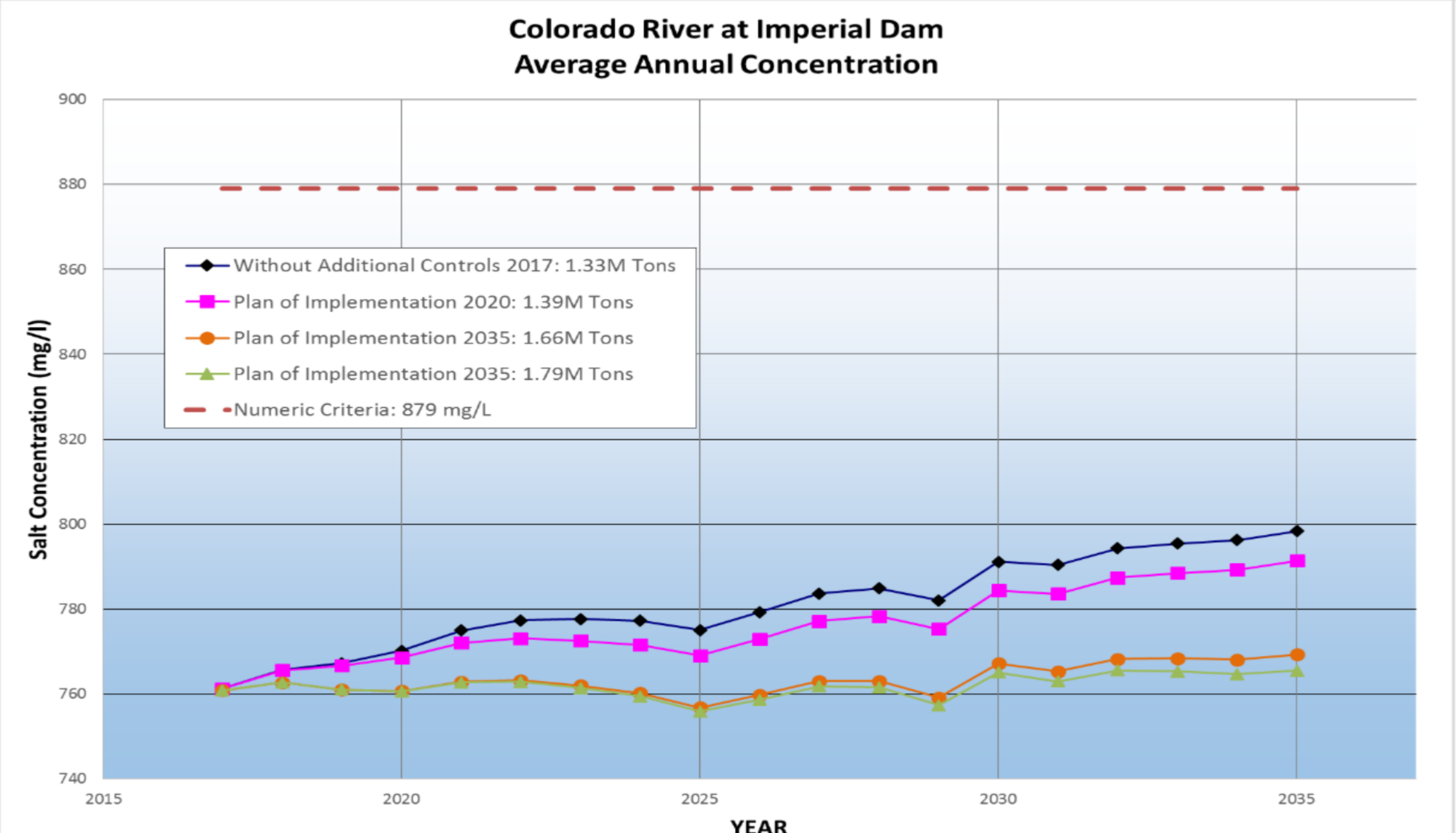
- Crop Water Requirement.
- Water and salt balance.





Grand Lake
Green River
CR Glenwood Springs
Virgin St George
Moab WWTP
Cedar Pocket, AZ
Riverside, NV
Las Vegas Wash
Lake Havasu
Lake Havasu
Buckeye Irrigation District
Gillespie Dam
Imperial Dam
Image NASA
© 2008 Europa Technologies
© 2008 Tele Atlas
Image © 2009 TerraMetrics
36°50'24.86" N 113°57'26.90" W
Eye alt 3247.16 km
Google

ECw (dS/m)
0
1
2
3
4
5
0
500
1000
1500
2000
River Distance (km)
SAR
0
1
2
3
4
5
6
7
Colorado
Tributaries
0
500
1000
1500
2000
River Distance (km)


Colorado River at Imperial Dam
Average Annual Concentration
Salt Concentration (mg/l)
900
880
860
840
820
800
780
760
740
2015
2020
2025
2030
2035
YEAR
Without Additional Controls 2017: 1.33M Tons
Plan of Implementation 2020: 1.39M Tons
Plan of Implementation 2035: 1.66M Tons
Plan of Implementation 2035: 1.79M Tons
Numeric Criteria: 879 mg/L

Leaching Requirement

- Definition: The percentage of water applied that must move below the root zone to control salt buildup.
- Equation:

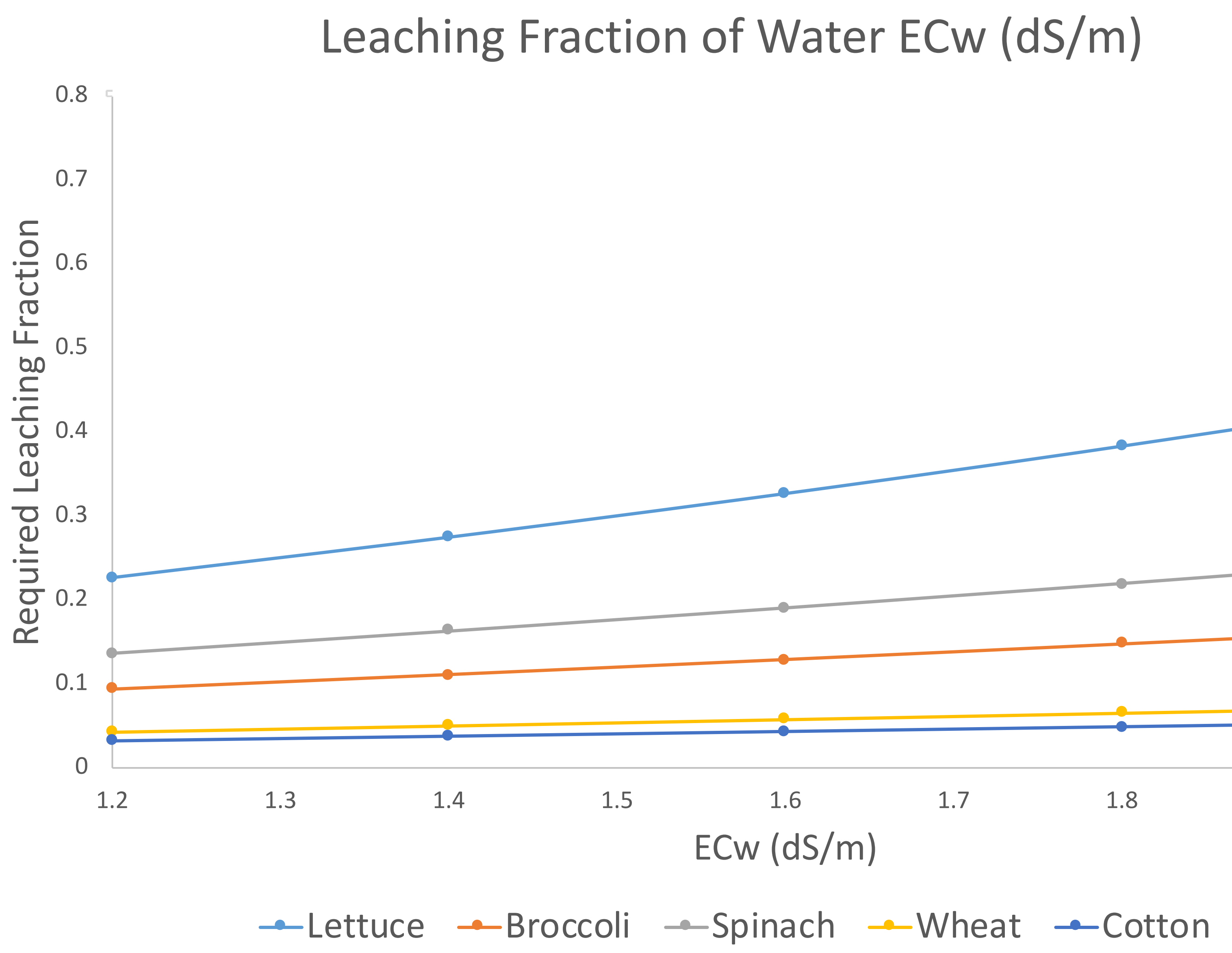
$$LR = \frac{(EC_w)}{5(EC_e) - EC_w}$$

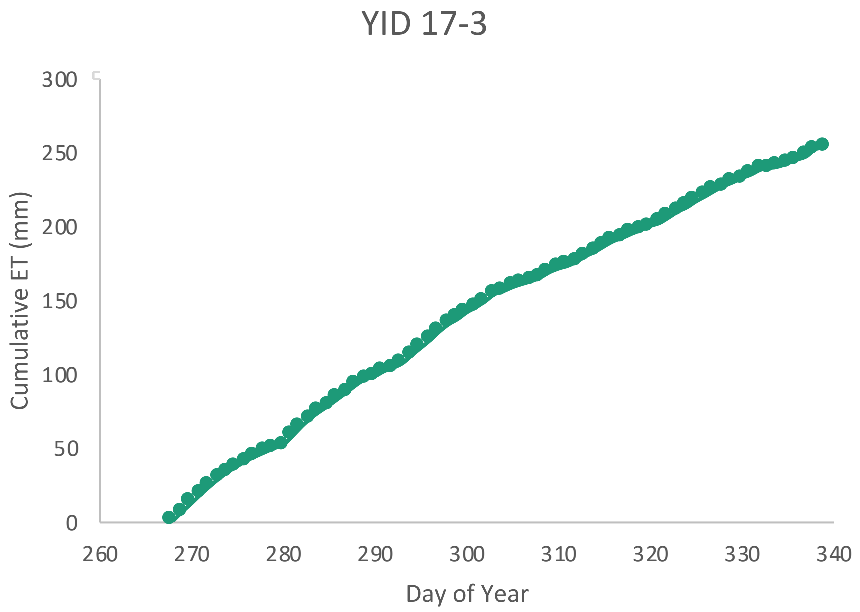
Salinity ions

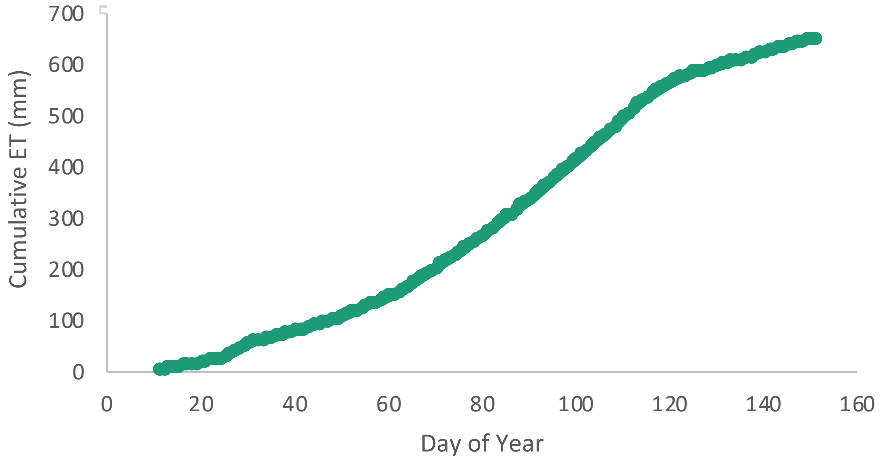
Ion	Irrigation Water mg/L	Soil Water (mg/L)
Ca	71	255
Mg	32	60
K	7	51
Na	135	268
Cl	135	485
NO3	5	88
SO4	222	267
CO3	145	334

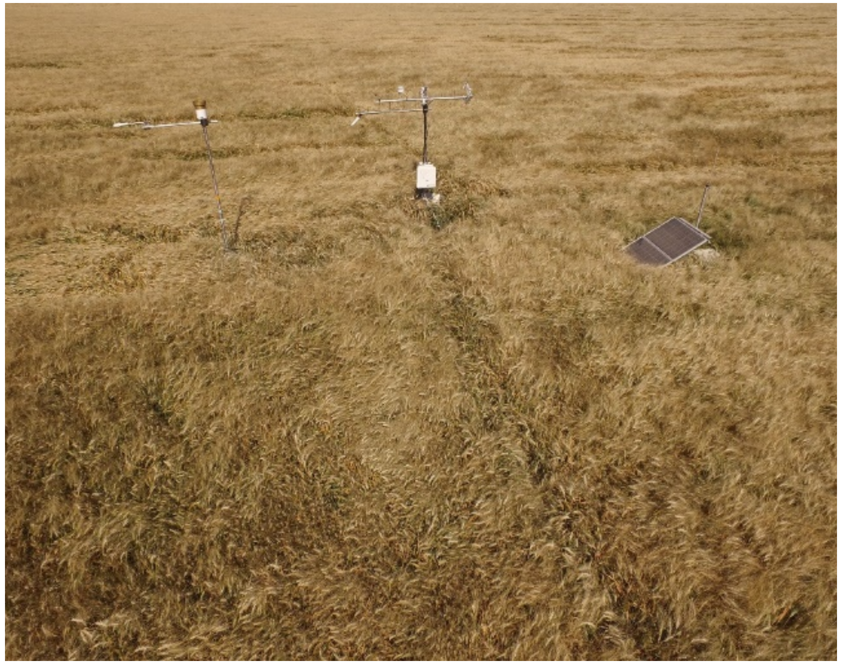
Saturation Indices for Mineral Species

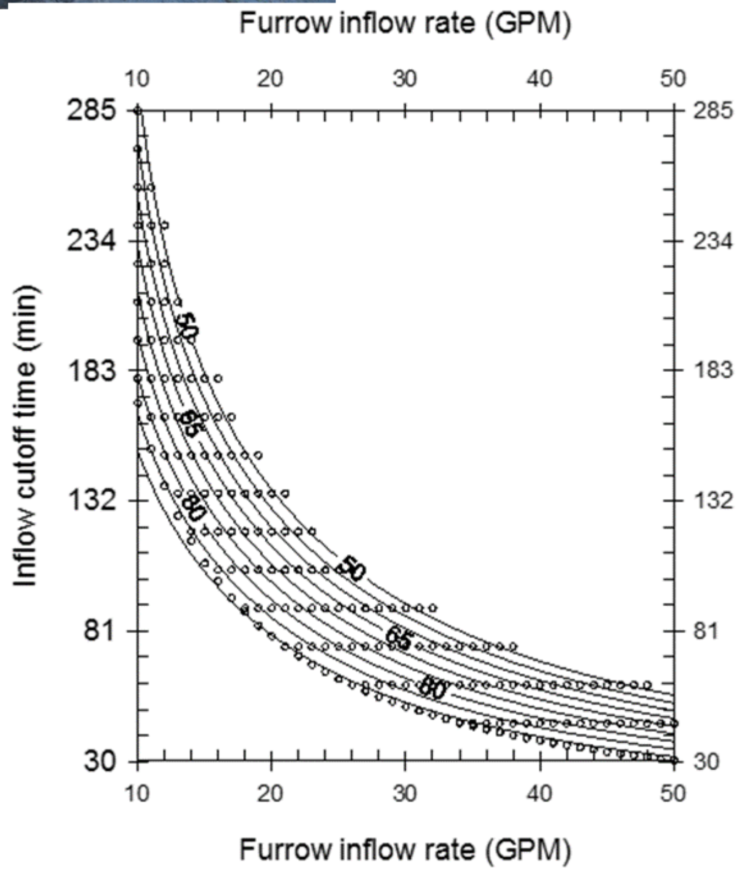
Mineral	Log IAP-log Ks
Argonite	0.733
Calcite	0.877
Dolomite (disordered)	0.889
Dolomite (ordered)	1.439
Gypsum	-0.826
Vaterite	0.310
KCl	-6.392

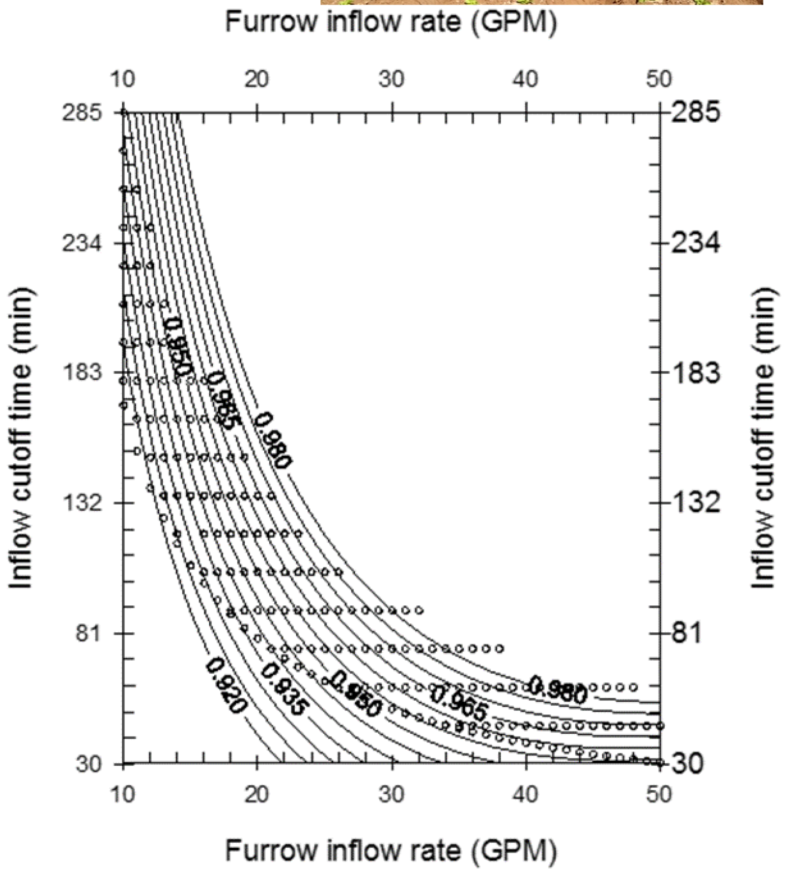

Leaching Fraction of Water ECw (dS/m)
Required Leaching Fraction
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2
ECw (dS/m)
Lettuce
Broccoli
Spinach
Wheat
Cotton


YID 17-3
Cumulative ET (mm)
300
250
200
150
100
50
0
260
270
280
290
300
310
320
330
340
Day of Year

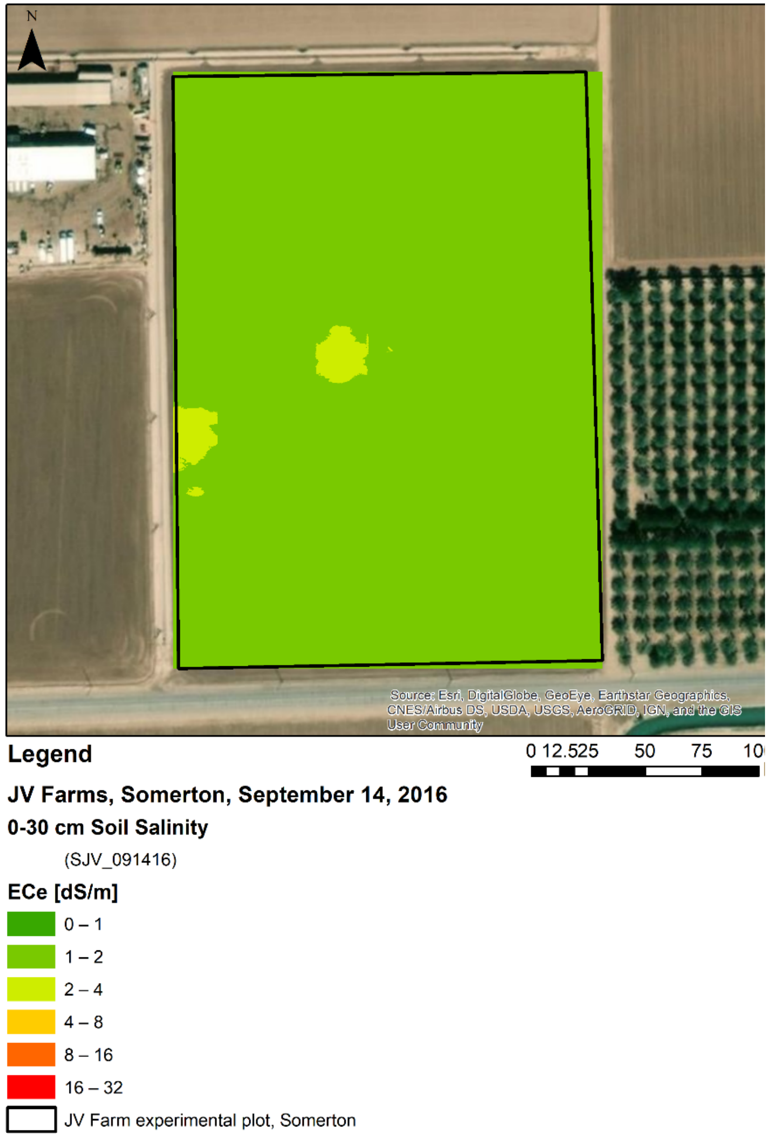

Cumulative ET (mm)
700
600
500
400
300
200
100
0
0
20
40
60
80
100
120
140
160
Day of Year

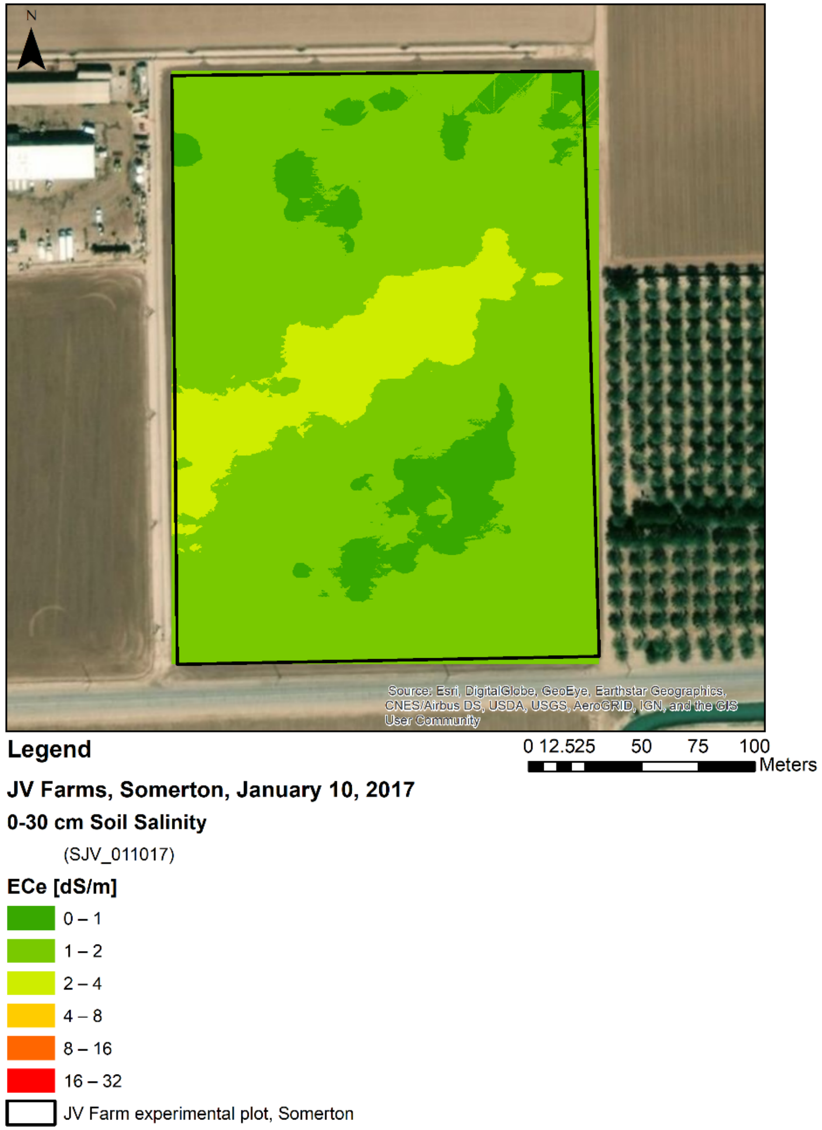


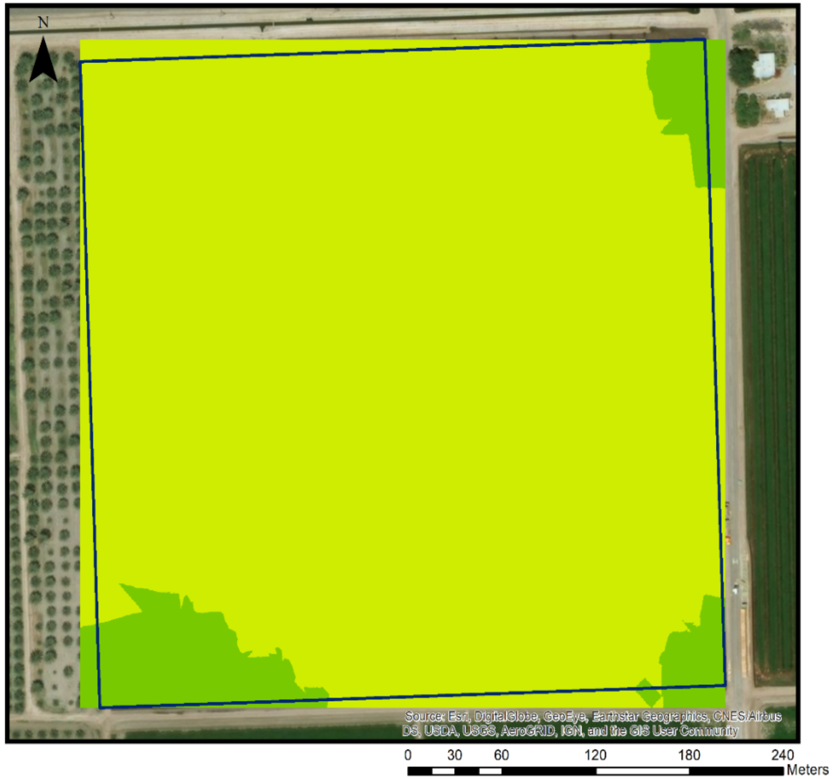




Application efficiency (Ea; left) and low-quarter distribution uniformity (DU_{lq} ; right) expressed as a function of furrow inflow rate and cutoff time


N
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Legend
0 12.525 50 75 10
JV Farms, Somerton, September 14, 2016
0-30 cm Soil Salinity
(SJV_091416)
ECe [dS/m]
0 – 1
1 – 2
2 – 4
4 – 8
8 – 16
16 – 32
JV Farm experimental plot, Somerton


N
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Legend
0 12.525 50 75 100
Meters
JV Farms, Somerton, January 10, 2017
0-30 cm Soil Salinity
(SJV_011017)
ECe [dS/m]
0 – 1
1 – 2
2 – 4
4 – 8
8 – 16
16 – 32
JV Farm experimental plot, Somerton



Legend

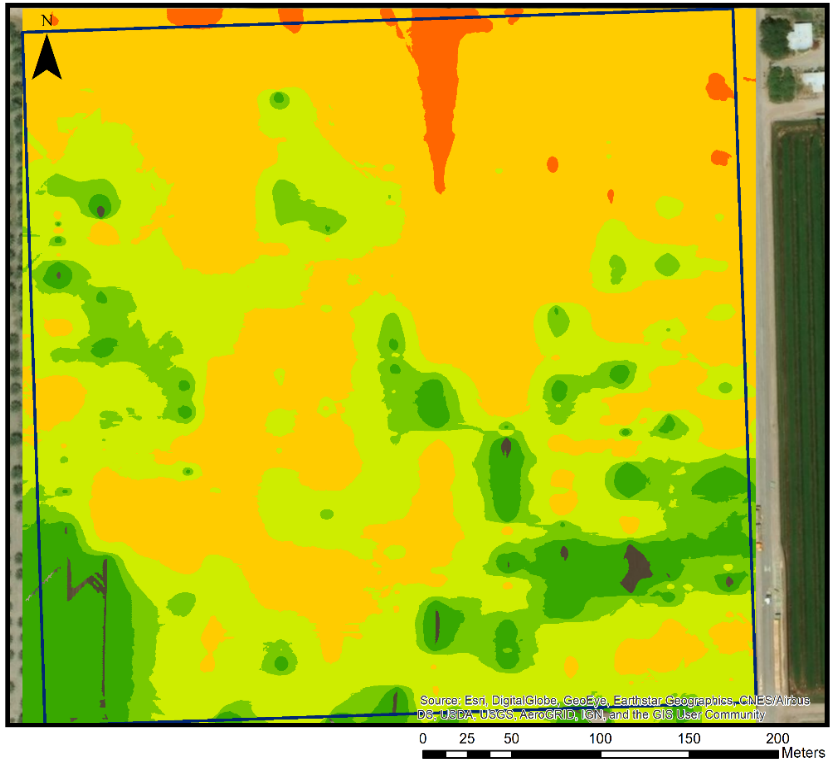
Hill Farm, Bard, December '16

0-30 cm soil salinity

(BHF_122116)

Filled Contours

- 0 – 1
- 1 – 2
- 2 – 4
- 4 – 8
- 8 – 16
- 16 – 32
- BHF experimental plot



Legend

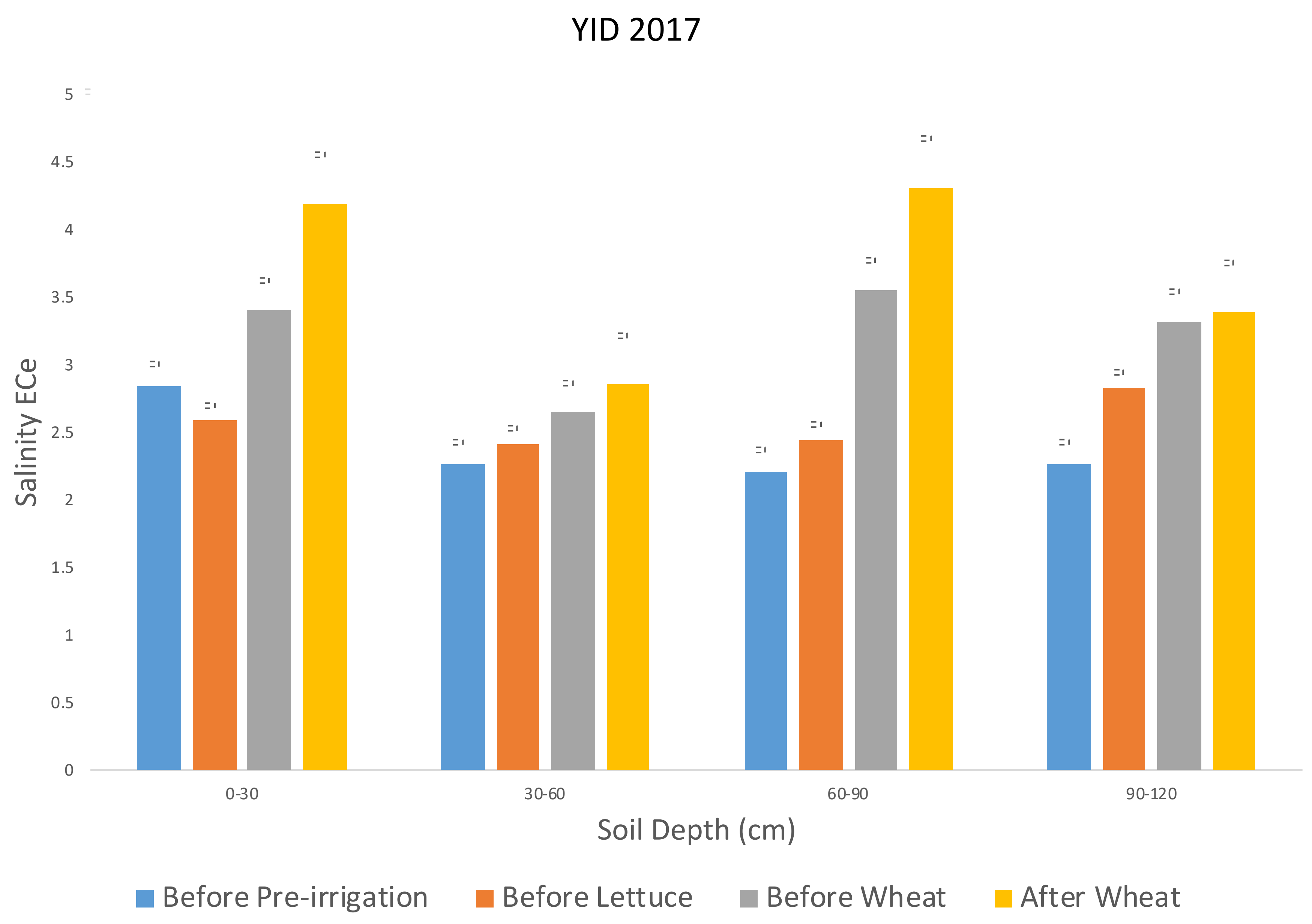
Hill Farm, Bard, July '17

0-30 cm soil salinity

(BHF_072117)

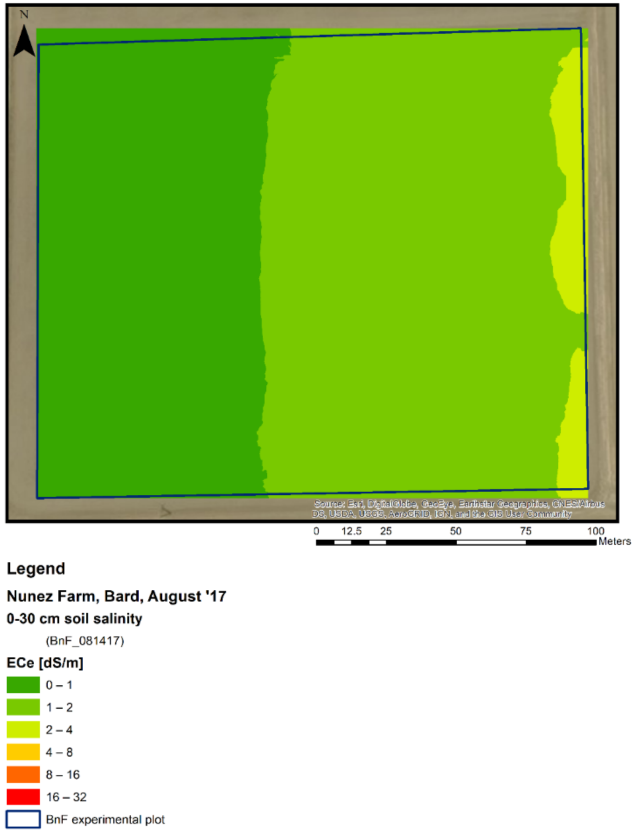
Filled Contours

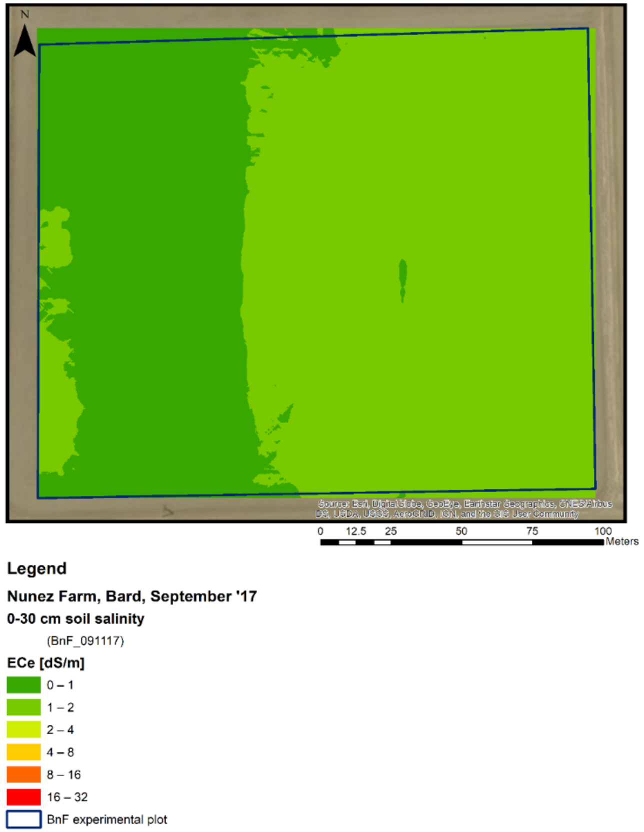
- 0 – 1
- 1 – 2
- 2 – 4
- 4 – 8
- 8 – 16
- 16 – 32
- BHF experimental plot

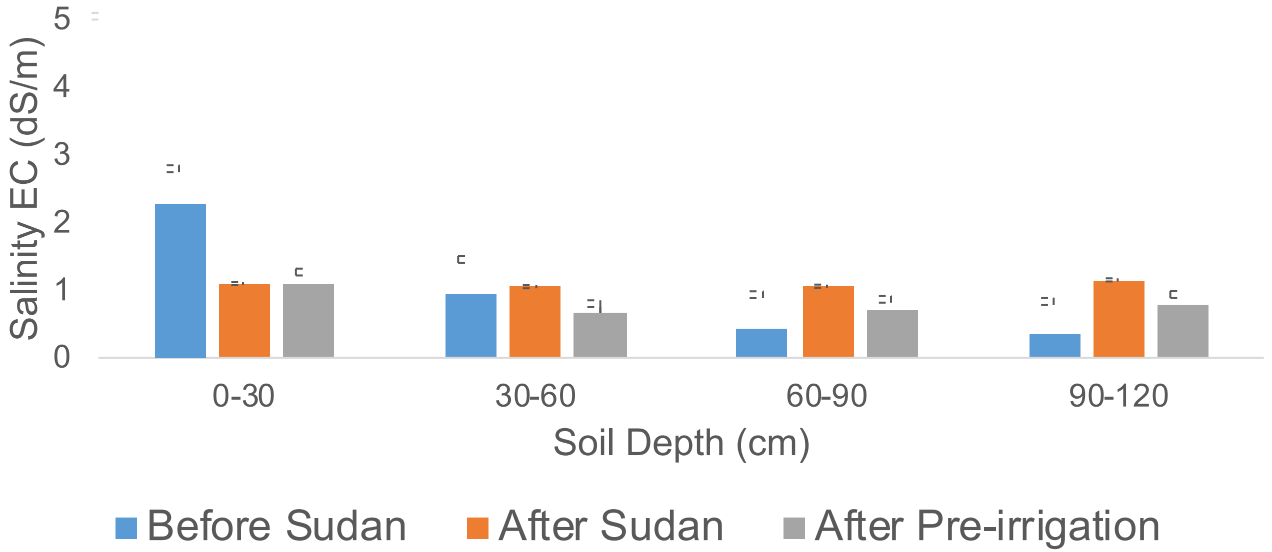


YID 2017
Salinity ECe
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0-30
30-60
60-90
90-120
Soil Depth (cm)
Before Pre-irrigation
Before Lettuce
Before Wheat
After Wheat

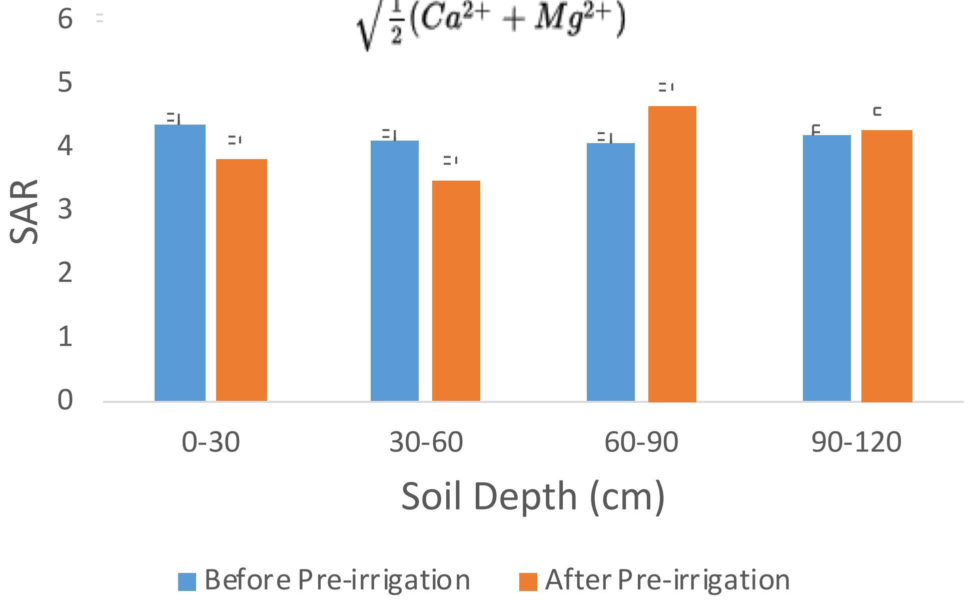

N
0 12.5 25 50 75 100
Meters
Legend
Nunez Farm, Bard, March '17
0-30 cm soil salinity
(BnF_032217)
ECe [dS/m]
0 – 1
1 – 2
2 – 4
4 – 8
8 – 16
16 – 32
BnF experimental plot

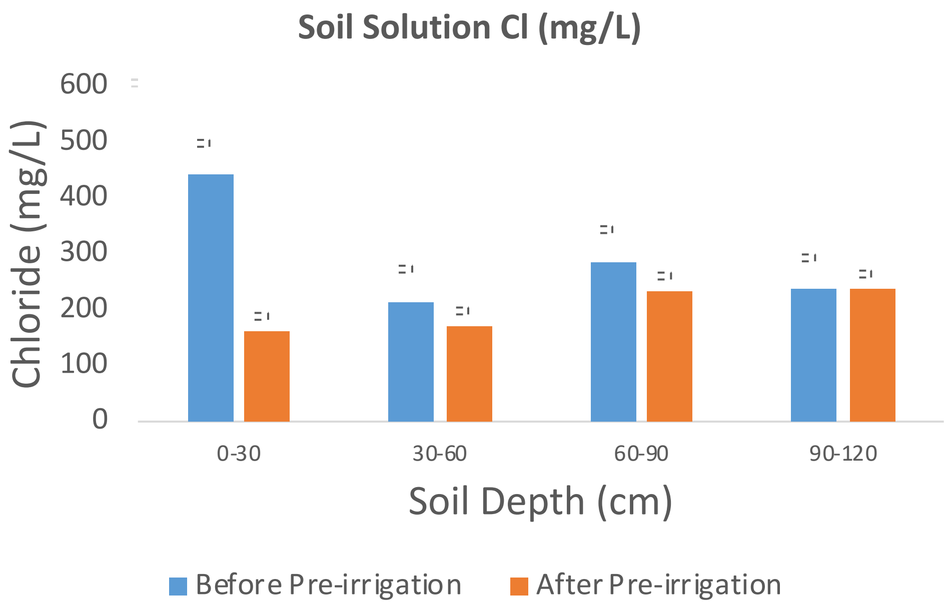

N
0 12.5 25 50 75 100
Meters
Legend
Nunez Farm, Bard, August '17
0-30 cm soil salinity
(BnF_081417)
ECe [dS/m]
0 – 1
1 – 2
2 – 4
4 – 8
8 – 16
16 – 32
BnF experimental plot

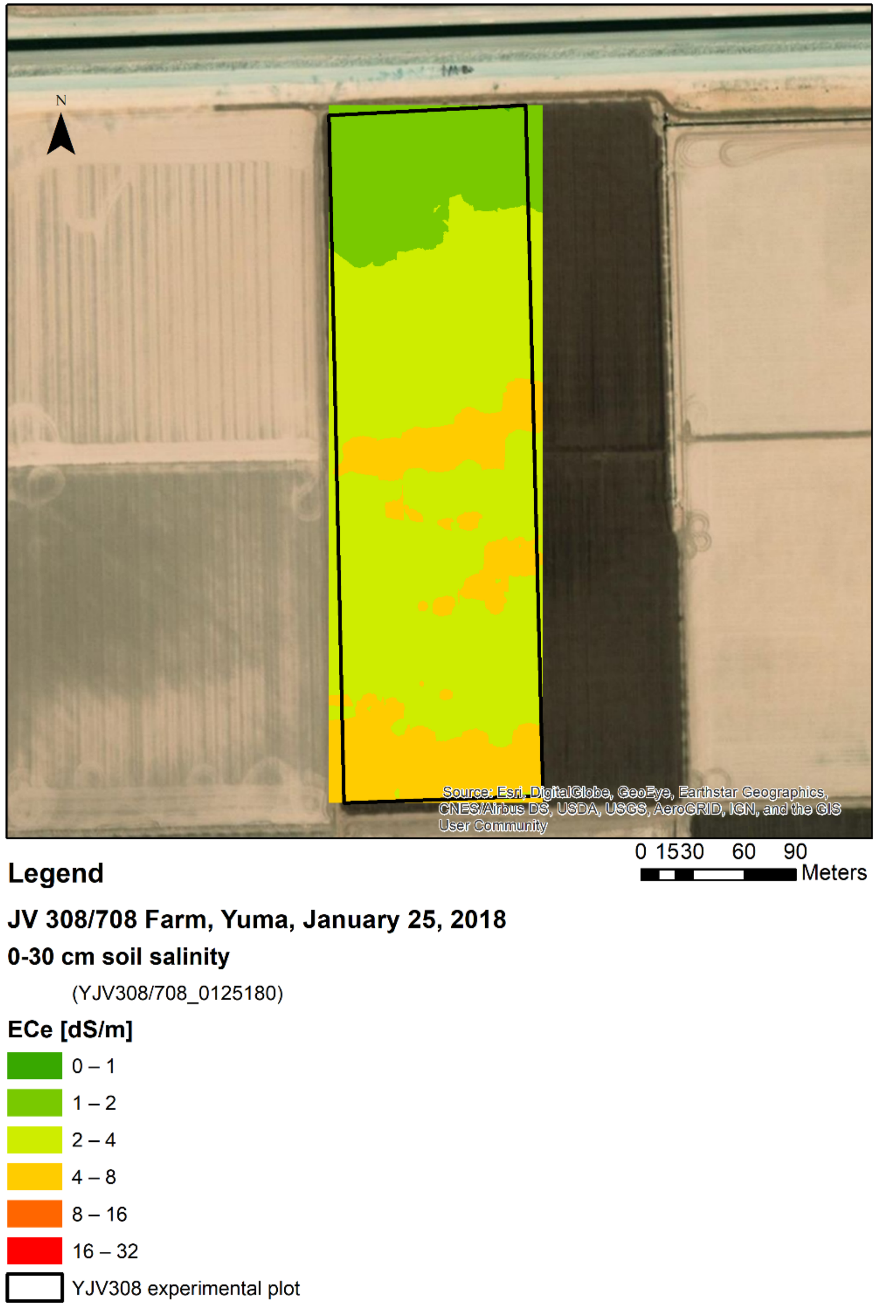

N
0 12.5 25 50 75 100
Meters
Legend
Nunez Farm, Bard, September '17
0-30 cm soil salinity
(BnF_091117)
ECe [dS/m]
0 – 1
1 – 2
2 – 4
4 – 8
8 – 16
16 – 32
BnF experimental plot

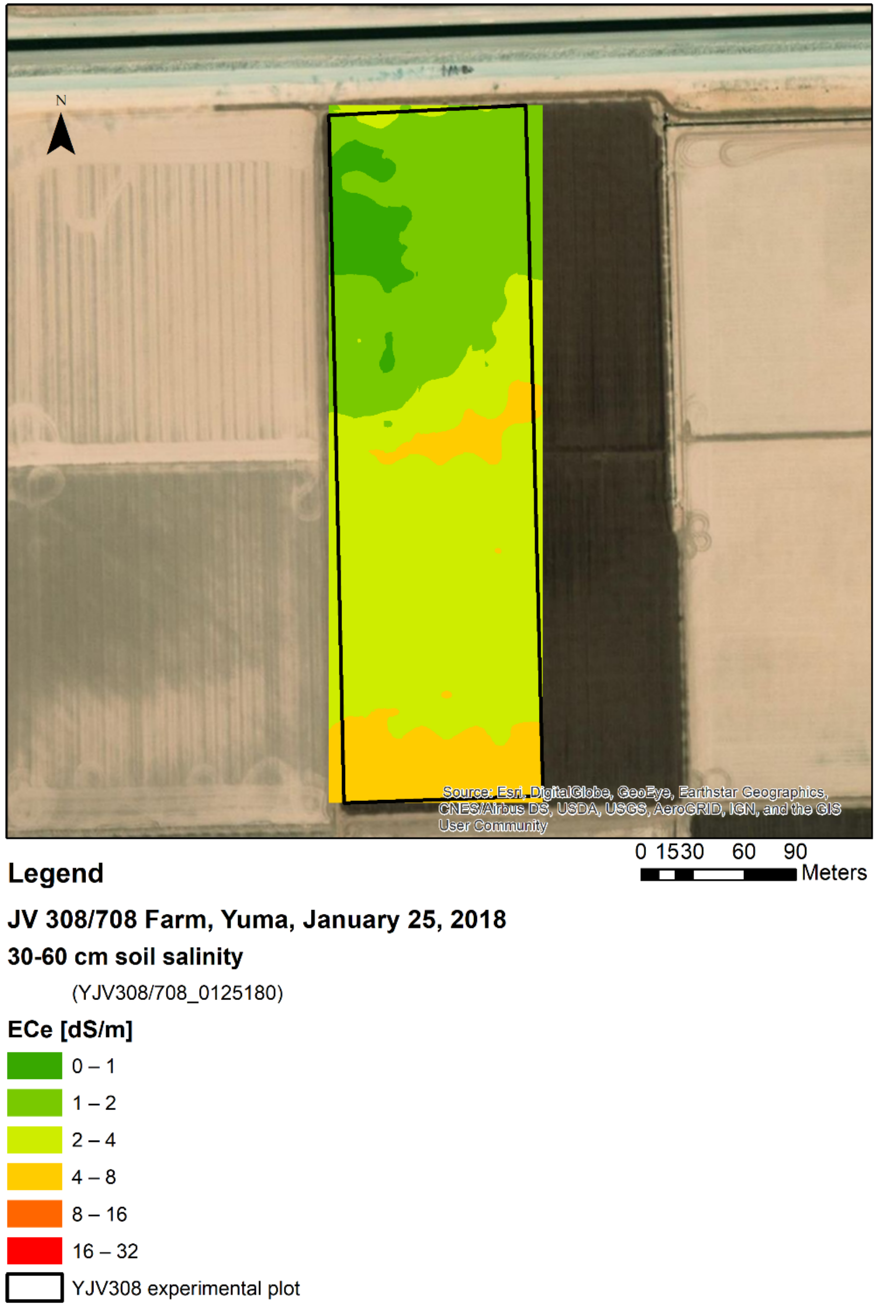

Salinity EC (dS/m)
5
4
3
2
1
0
0-30
30-60
60-90
90-120
Soil Depth (cm)
Before Sudan
After Sudan
After Pre-irrigation

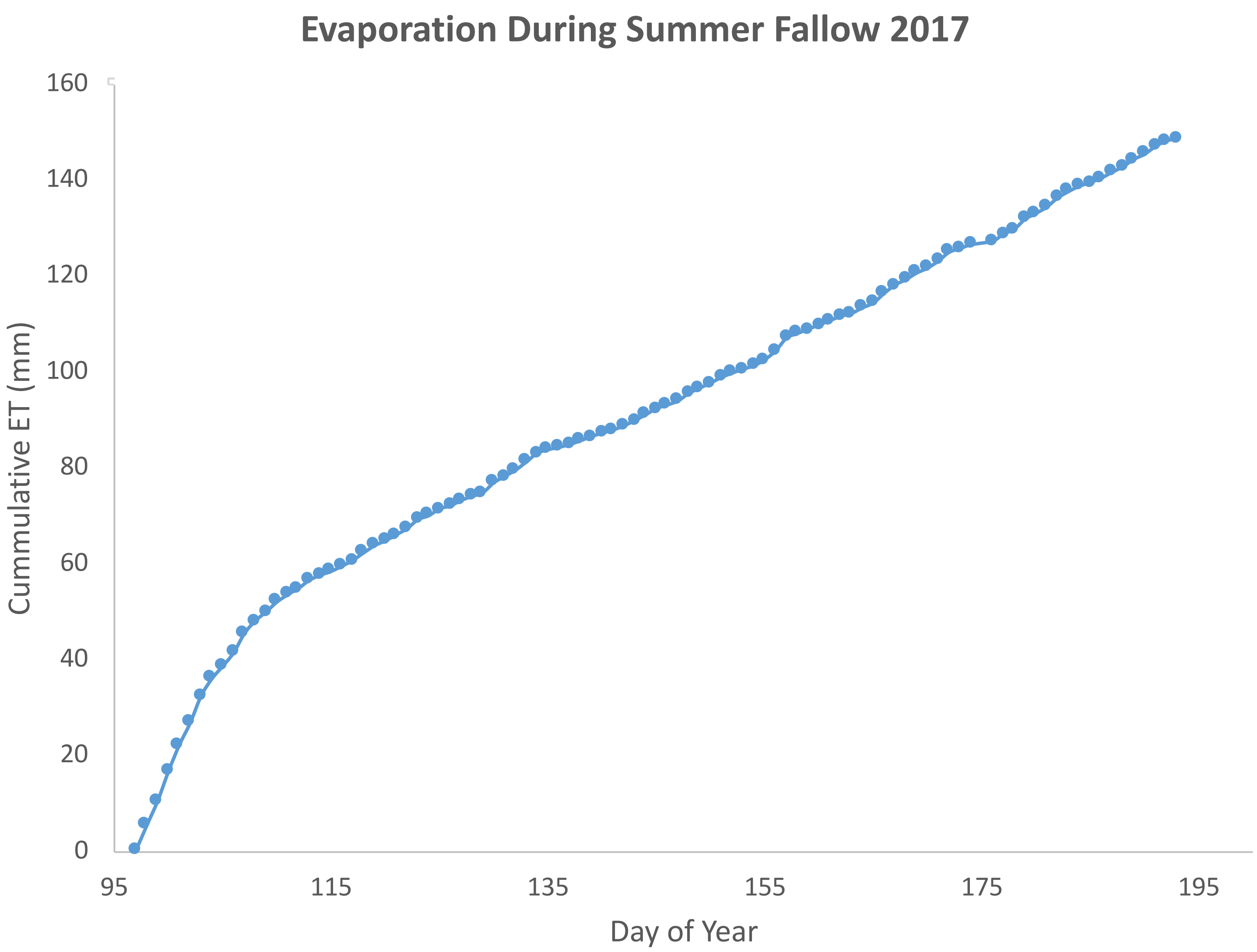
$$\mathrm{SAR} = \frac{Na^{+}}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

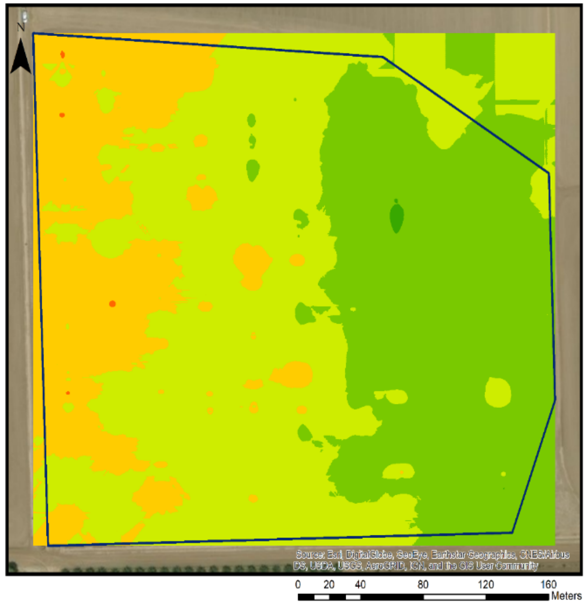





N
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
0 15 30 60 90
Meters
Legend
JV 308/708 Farm, Yuma, January 25, 2018
0-30 cm soil salinity
(YJV308/708_0125180)
ECe [dS/m]
0 – 1
1 – 2
2 – 4
4 – 8
8 – 16
16 – 32
YJV308 experimental plot


N
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
0 15 30 60 90
Meters
Legend
JV 308/708 Farm, Yuma, January 25, 2018
30-60 cm soil salinity
(YJV308/708_0125180)
ECe [dS/m]
0 – 1
1 – 2
2 – 4
4 – 8
8 – 16
16 – 32
YJV308 experimental plot


Evaporation During Summer Fallow 2017
Cummulative ET (mm)
0
20
40
60
80
100
120
140
160
95
115
135
155
175
195
Day of Year



Legend

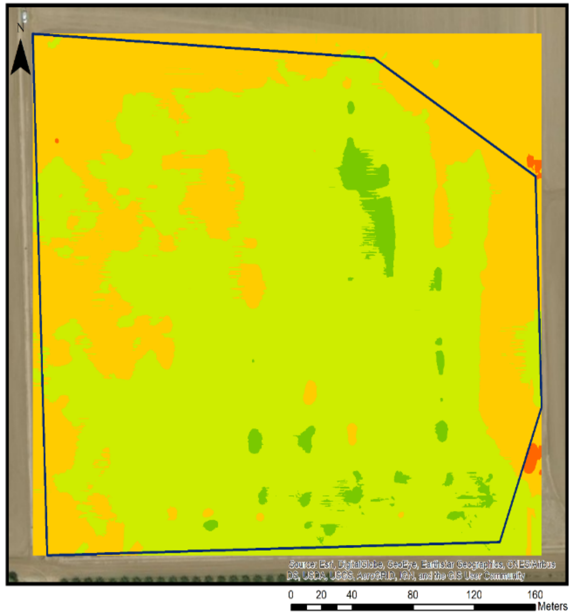
Carol Land Farm, Bard, March '17

0-30 cm soil salinity

(BCL_032217)

ECe [dS/m]

- 0 – 1
- 1 – 2
- 2 – 4
- 4 – 8
- 8 – 16
- 16 – 32
- BCL Experimental Plot



Legend

Carol Land Farm, Bard, August '17

0-30 cm soil salinity

(BCL_081417)

ECe [dS/m]

- 0 – 1
- 1 – 2
- 2 – 4
- 4 – 8
- 8 – 16
- 16 – 32
- BCL Experimental Plot

Legend

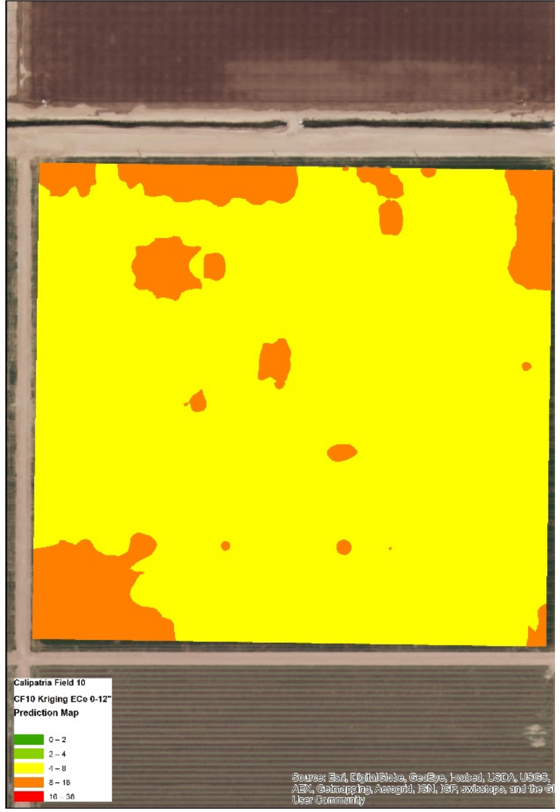
Carol Land Farm, Bard, September '17

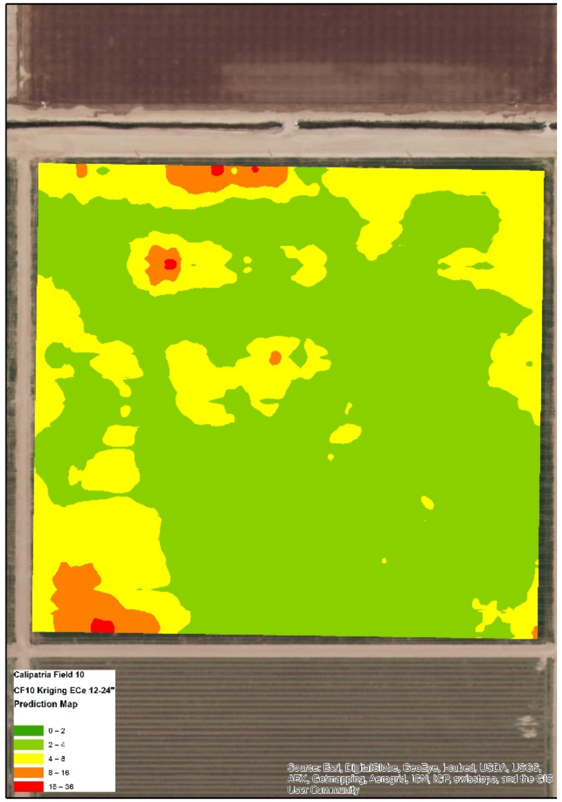
0-30 cm soil salinity

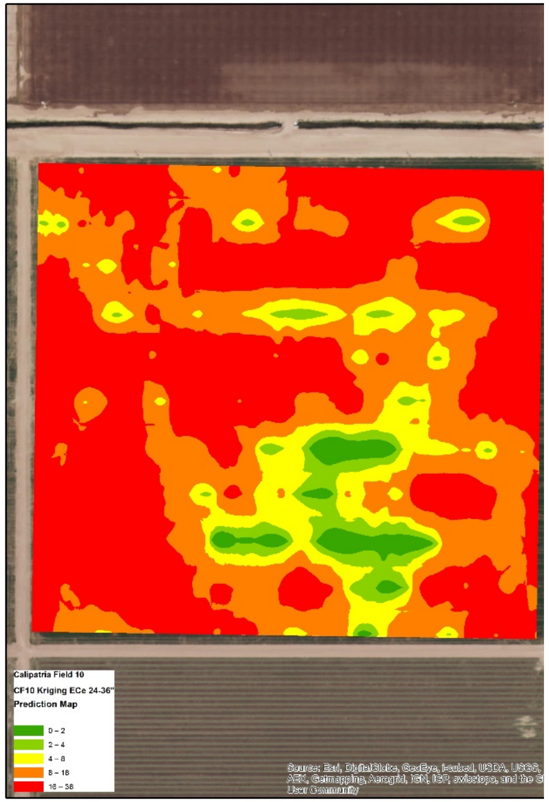
(BCL_091117)

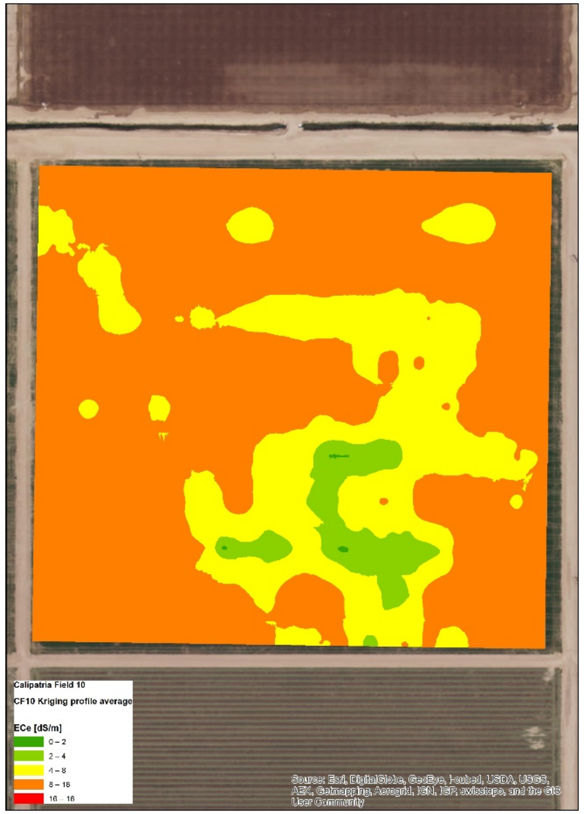
ECe [dS/m]

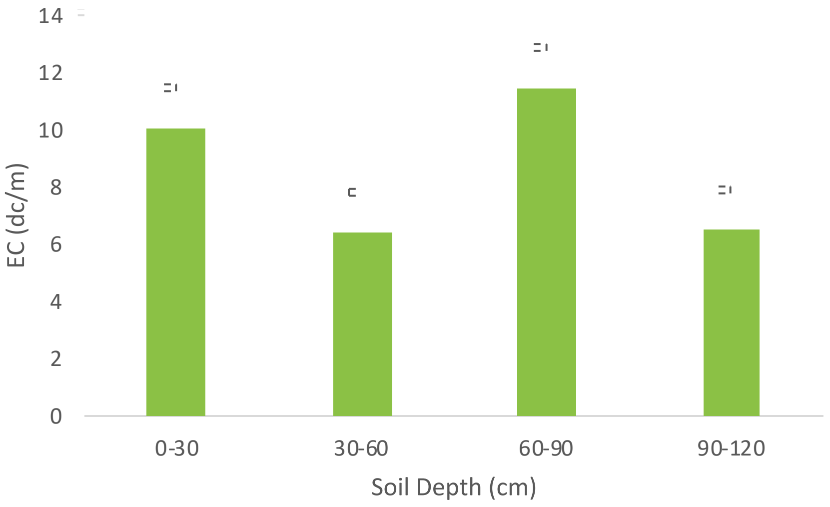
- 0 – 1
- 1 – 2
- 2 – 4
- 4 – 8
- 8 – 16
- 16 – 32
- BCL Experimental Plot


Calipatria Field 10
CF10 Kriging ECe 0-12"
Prediction Map
0 – 2
2 – 4
4 – 8
8 – 16
16 – 36
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community


Calipatria Field 10
CF10 Kriging ECe 12-24"
Prediction Map
0 – 2
2 – 4
4 – 8
8 – 16
16 – 36
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community


Calipatria Field 10
CF10 Kriging ECe 24-36"
Prediction Map
0 – 2
2 – 4
4 – 8
8 – 16
16 – 36
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

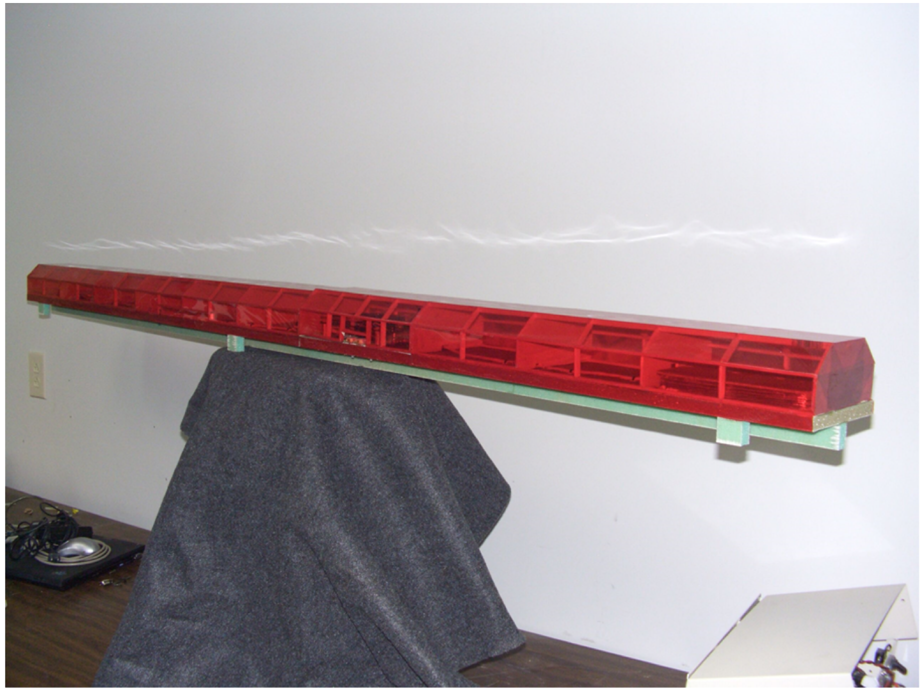

Calipatria Field 10
CF10 Kriging profile average
ECe [dS/m]
0 – 2
2 – 4
4 – 8
8 – 16
16 – 16
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community


14
12
10
8
6
4
2
0
EC (dc/m)
0-30
30-60
60-90
90-120
Soil Depth (cm)

Emerging Technologies


Geophex Ltd

GEM-2S



Remote sensing is a viable tool for mapping soil salinity in agricultural lands

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Zhi "Luke" Wang, California State University, Fresno

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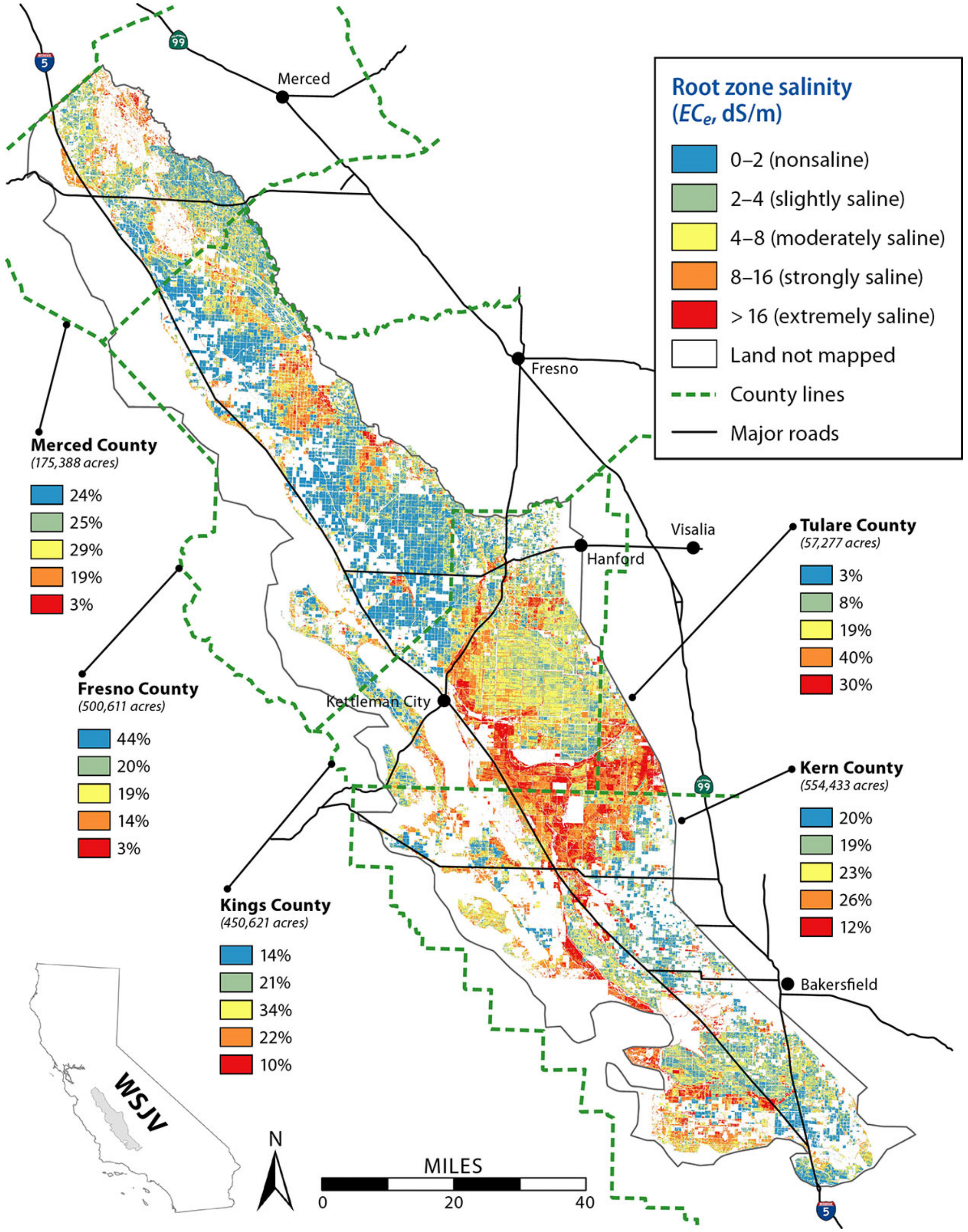


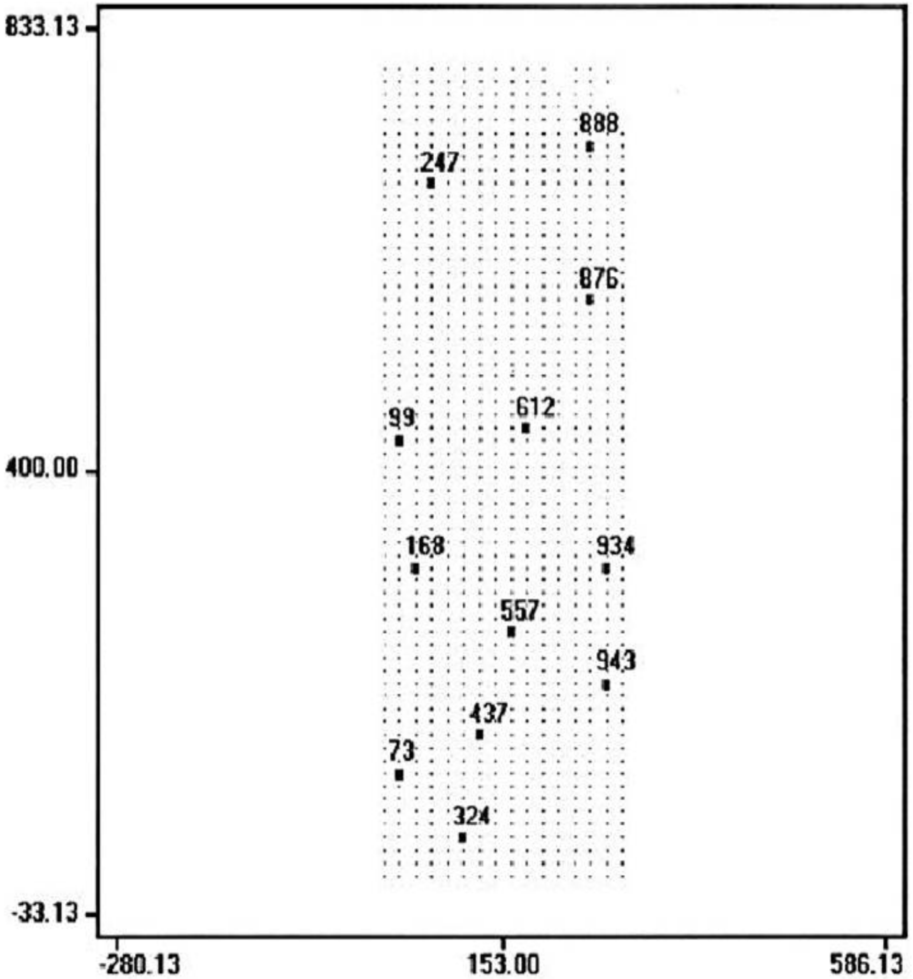
Lower Colorado Region Salinity Assessment Network (LCRSAN)

- Demonstrate new technology and expertise for soil salinity management,
- Assist water districts and action agencies with programs for implementing improved soil salinity management practices, and support continued development of software and tools for soil salinity management.

Possibilities

- Irrigation Districts
- Cooperatives
- Retail Service Providers

Technology already deployed in variable rate fertilizer application services



Summary

- Salinity monitoring challenges in irrigated soils of the southwestern United States will increase.
- User-friendly salt monitoring technologies using conductance are available.
- Existing and emerging technologies in monitoring salinity will have to be further exploited for continued sustainability.