



Improving water use for irrigation in Chile

Water Management Research Lines for the Extreme North and Central Area of Chile

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Santiago de Chile, 17 de noviembre 2014



PROCISUR

***Plataforma de Recursos Hídricos
y Tecnología de Riego***



PROCISUR

Cooperative Program for the Technological Development of the Agriculture of the Southern Cone

- Team effort between agriculture research institutes of the southern cone and the Instituto Interamericano de Cooperación para la Agricultura (IICA-BID)

PLATEFORM

Plateform of Water Resources and Irrigation Technology of Procisur

- Activities to reinforce specific projects of the countries
- Equilibrium between countries



General objective

- To contribute to the development, management and sustainability of water resource and the optimization of the irrigation systems in the countries of the Southern Cone.

Irrigated Surface

Procisur

| País | Superficie (ha) |
|-----------|-----------------|
| Argentina | 1.550.000 |
| Bolivia | 150.000 |
| Brasil | 2.920.000 |
| Chile | 1.900.000 |
| Paraguay | 67.000 |
| Uruguay | 218.000 |
| Total | 6.805.000 |

Irrigated surface in Chile



| | Total Superficie regada (há) | Riego Superficial (%) | Riego Tecnificado (%) |
|--------------------------------------|------------------------------|-----------------------|-----------------------|
| XV de Arica y Parinacota | 11.167,86 | 80,47 | 19,53 |
| I de Tarapacá | 1.133,19 | 70,83 | 29,17 |
| II de Antofagasta | 2.295,64 | 98,03 | 1,97 |
| III de Atacama | 19.544,93 | 37,93 | 62,07 |
| IV de Coquimbo | 75.708,62 | 50,76 | 49,24 |
| V de Valparaíso | 86.156,71 | 41,80 | 58,20 |
| Región Metropolitana | 136.732,34 | 66,47 | 33,53 |
| VI de O'Higgins | 210.691,01 | 72,04 | 27,96 |
| VII del Maule | 299.059,80 | 85,55 | 14,45 |
| VIII del Bío-Bío | 166.455,21 | 85,87 | 14,13 |
| IX de La Araucanía | 49.771,45 | 66,76 | 33,24 |
| XIV de Los Ríos | 8.117,00 | 6,01 | 93,99 |
| X de Los Lagos | 4.417,60 | 1,77 | 98,23 |
| XI Aysén | 2.767,35 | 44,34 | 55,66 |
| XII de Magallanes y Antártica | 19.794,20 | 98,21 | 1,79 |
| Total país | 1.093.812,91 | 72,21 | 27,79 |

Research lines

Extreme North of Chile

- ▶ RDI in Olive trees: Commercial fruit size distribution, water savings, sustainability of the water stress irrigation practices.
- ▶ Irrigation water balance under saline water stress in Tomato.
- ▶ Alternative energy for agriculture systems in the Azapa Valley.

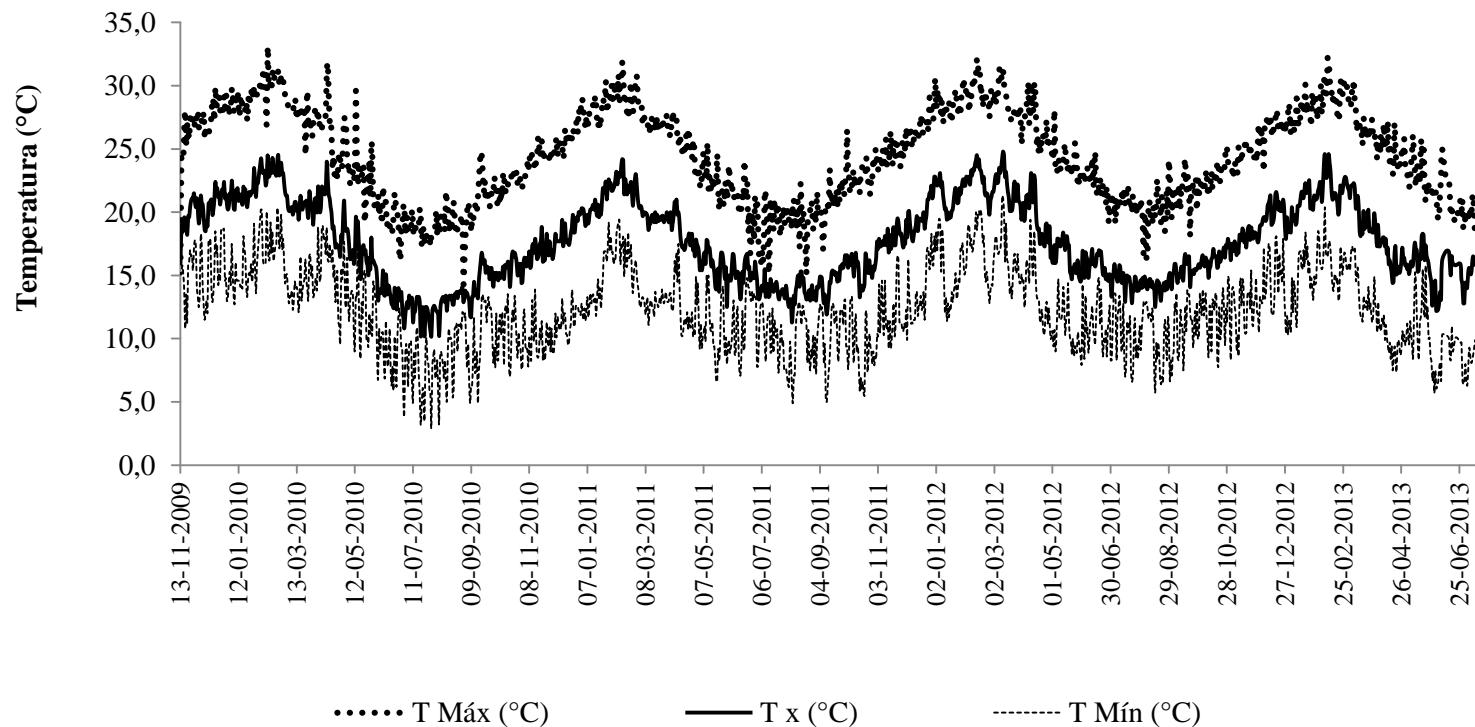
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Weather parameters Azapa Valley



67% R.H. in average.
ET₀ : 4 to 7 mm/day

► RDI and its effect on physiological and productive parameters:

- 100% ET_c
- 80% ET_c
- 60% ET_c
- 40% ET_c



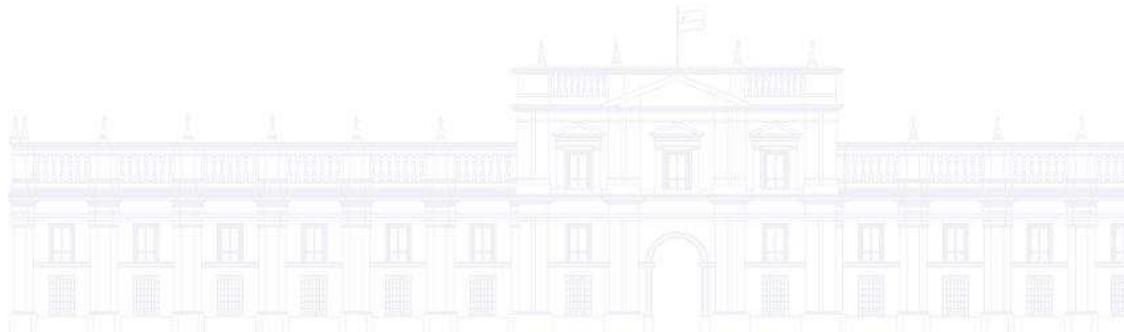
Between pit hardening until olive maturity

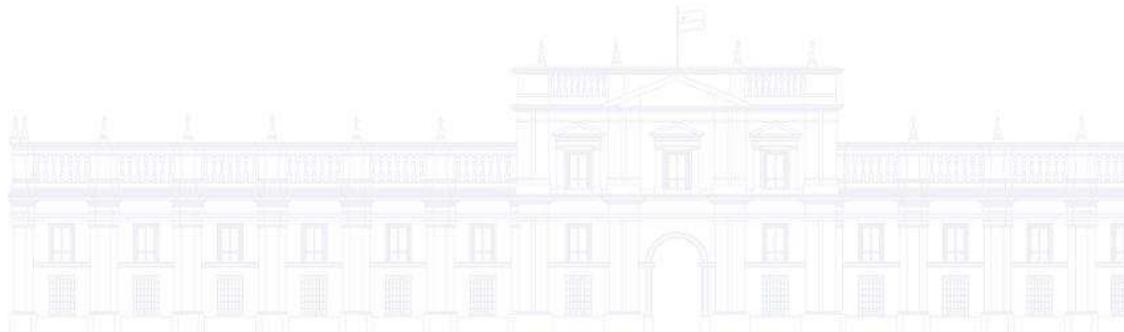
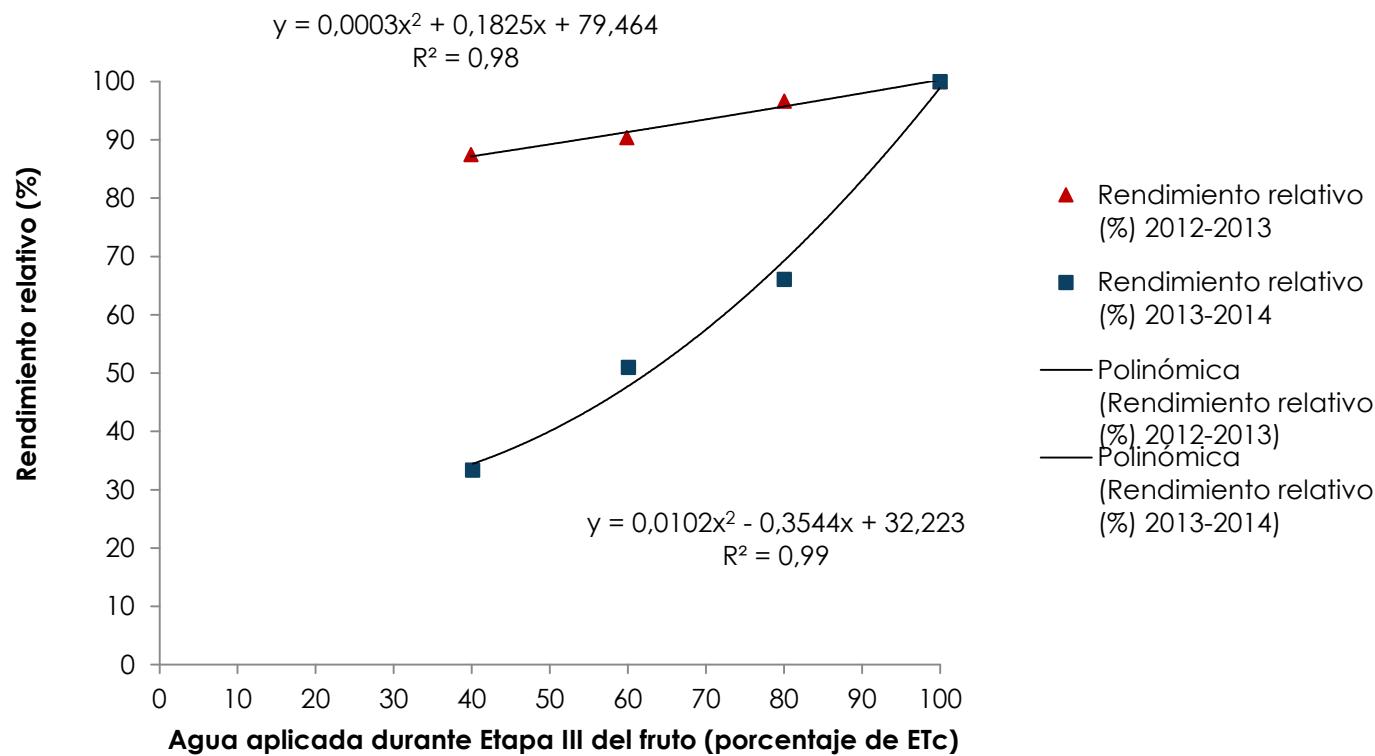


| Etapa fenológica | Mes | Ψ xilemático a mediodía (MPa) | Conductancia estomática (mmol/m² s) | Contenido relativo de agua (%) |
|-------------------------|------------|--|---|---------------------------------------|
| Brotación | Julio | -0,6 a -1,0 | 38,8 | 67,4 |
| | Agosto | | | |
| Floración | Septiembre | | | |
| Etapa I | Octubre | -1,0 a -1,3 | 48,6 | 56,2 |
| | Noviembre | | | |
| Etapa II | Diciembre | -1,4 | 39,2 | 53,3 |
| Etapa III | Enero | -1,4 a -1,8 | 45,6 | 61,3 |
| | Febrero | | | |
| | Marzo | | | |
| | Abril | | | |
| | Mayo | -1,6 a -1,8 | 44,4 | 61,23 |
| | Junio | | | |

Yield (ton/ha) of commercial olives in two seasons.

| Módulo 1 | | Temporada | | |
|----------------|----------------------|-----------|---------|----|
| | | 2012/13 | 2013/14 | |
| T ₀ | 100% ET _c | 2,65 | 7,26 | a |
| T ₁ | 80% ET _c | 3,09 | 2,30 | b |
| T ₂ | 60% ET _c | 1,86 | 2,76 | b |
| T ₃ | 40% ET _c | 1,90 | 3,88 | ab |





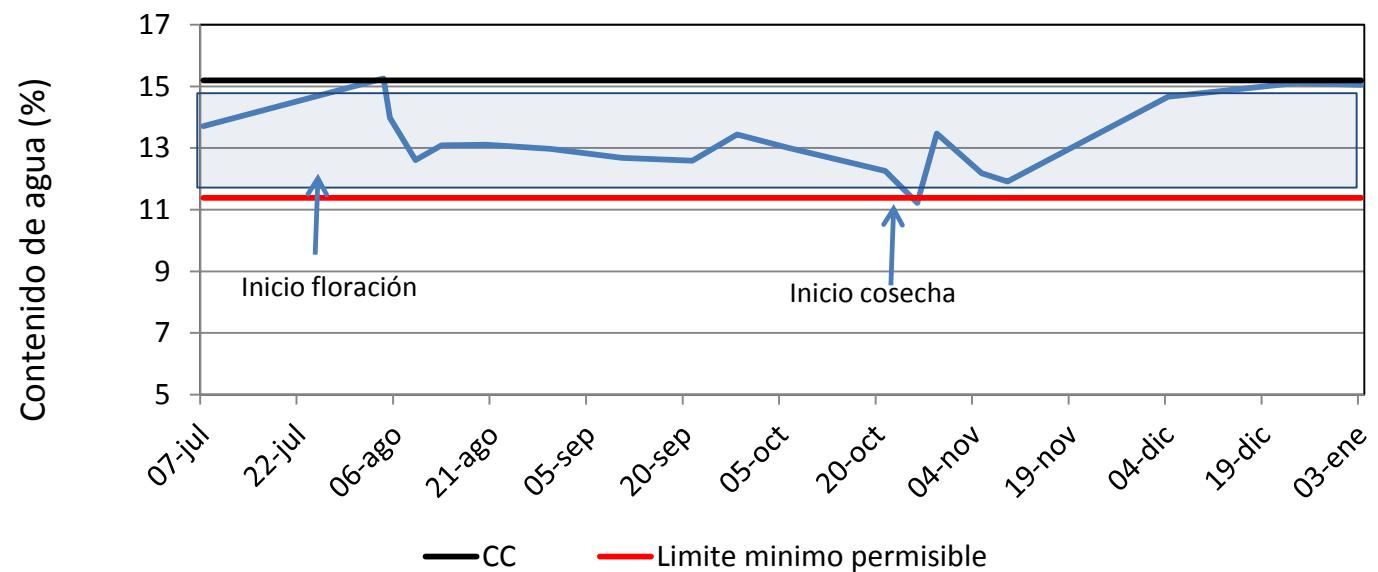
Research lines

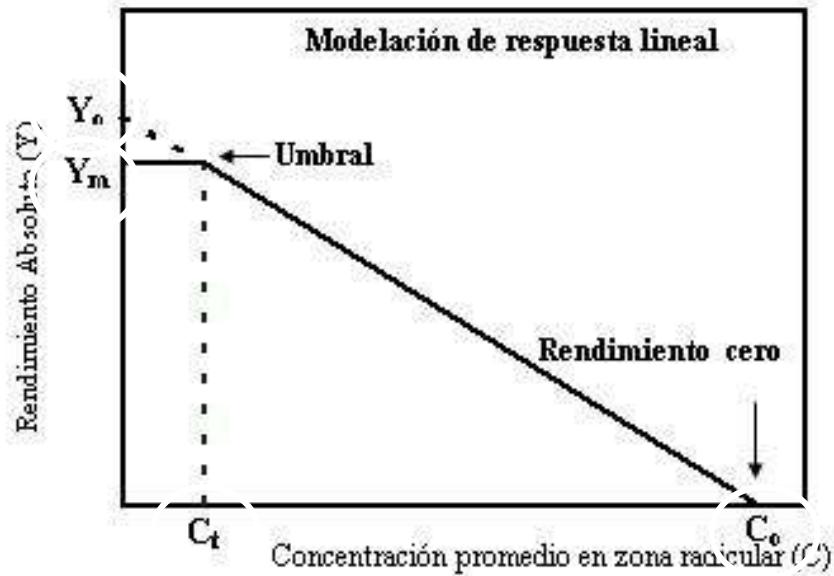
Extreme North of Chile

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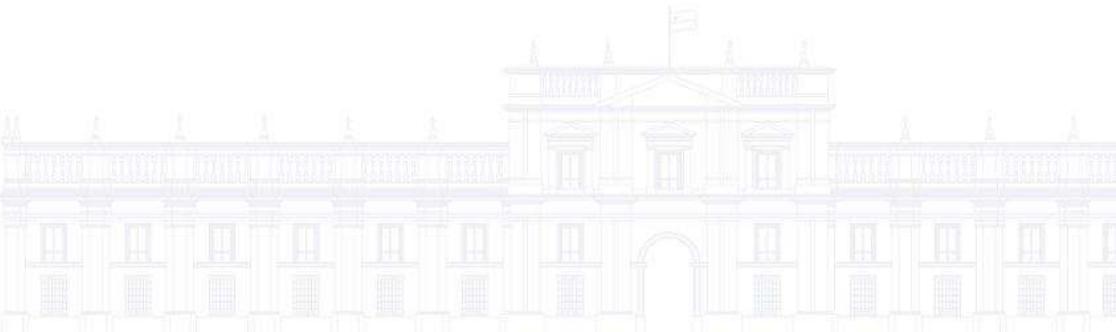
Irrigation Scheduling of Pepper

| Mes | ETo (mm/día) | Kc | ETc (mm/día) | TR (min/día) | TR Aplicado (min/día) |
|------------|-----------------|-----|-----------------|-----------------|--------------------------|
| Junio | 0,56 | 0,4 | 0,22 | 5,6 | 10 |
| Julio | 0,88 | 0,6 | 0,53 | 13,2 | 15 |
| Agosto | 1,01 | 0,9 | 0,91 | 22,8 | 25 |
| Septiembre | 1,31 | 1 | 1,31 | 32,7 | 35 |
| Octubre | 1,85 | 1,1 | 2,04 | 50,9 | 50 |
| Noviembre | 2,09 | 1,2 | 2,51 | 62,6 | 60 |
| Diciembre | 2,13 | 1,2 | 2,56 | 63,9 | 65 |



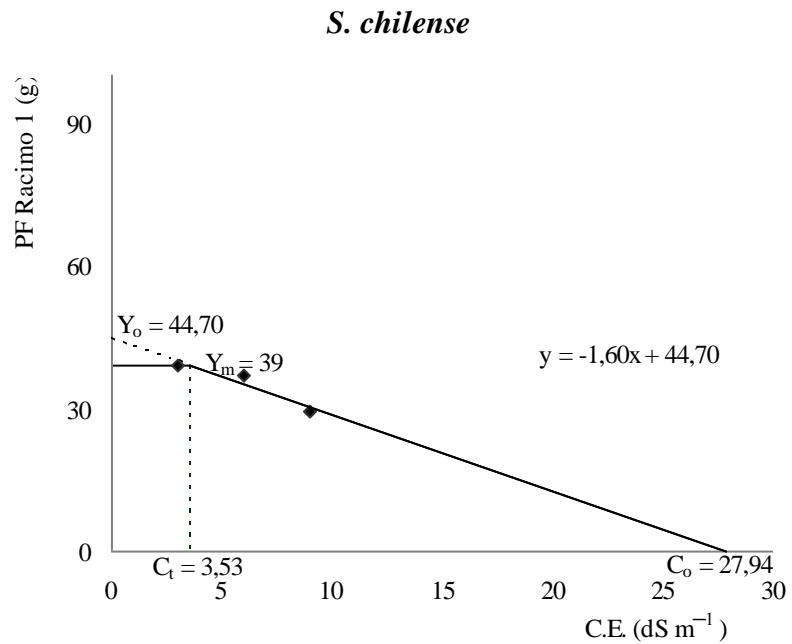
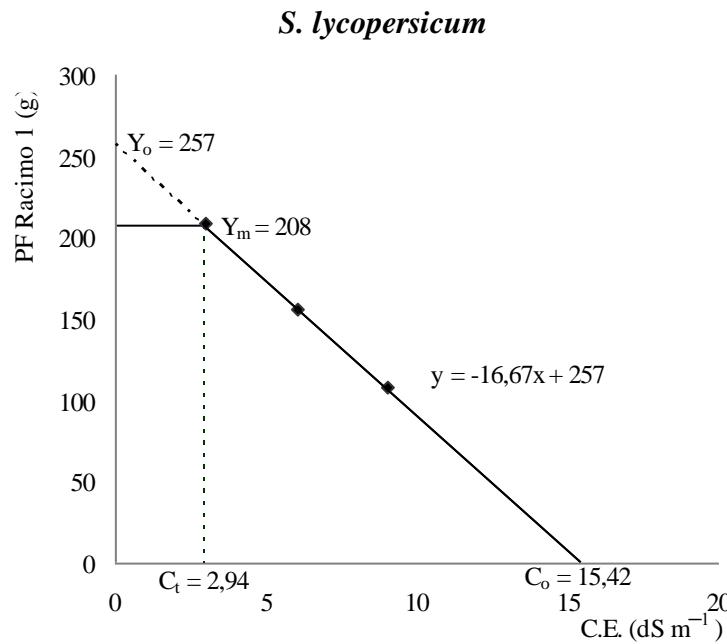


- C_t Concentración umbral. Salinidad máxima sin reducción de rendimiento
- s Pendiente, disminución de rendimiento fraccional por unidad de aumento en la salinidad más allá del umbral
- C_0 Concentración más allá del cual el rendimiento es cero
- Y_m Rendimiento alcanzado en el tratamiento control
- Y_o Rendimiento proyectado sin salinidad.





Fresh mass of the first bunch



| Parámetro | <i>S. lycopersicum</i> | <i>S. chilense</i> |
|-----------|------------------------|--------------------|
| Y_o | 257,00 | 44,70 |
| Y_m | 208,00 | 39,00 |
| C_t | 2,94 | 3,53 |
| C_o | 15,42 | 27,94 |
| s | 16,67 | 1,60 |



Research lines

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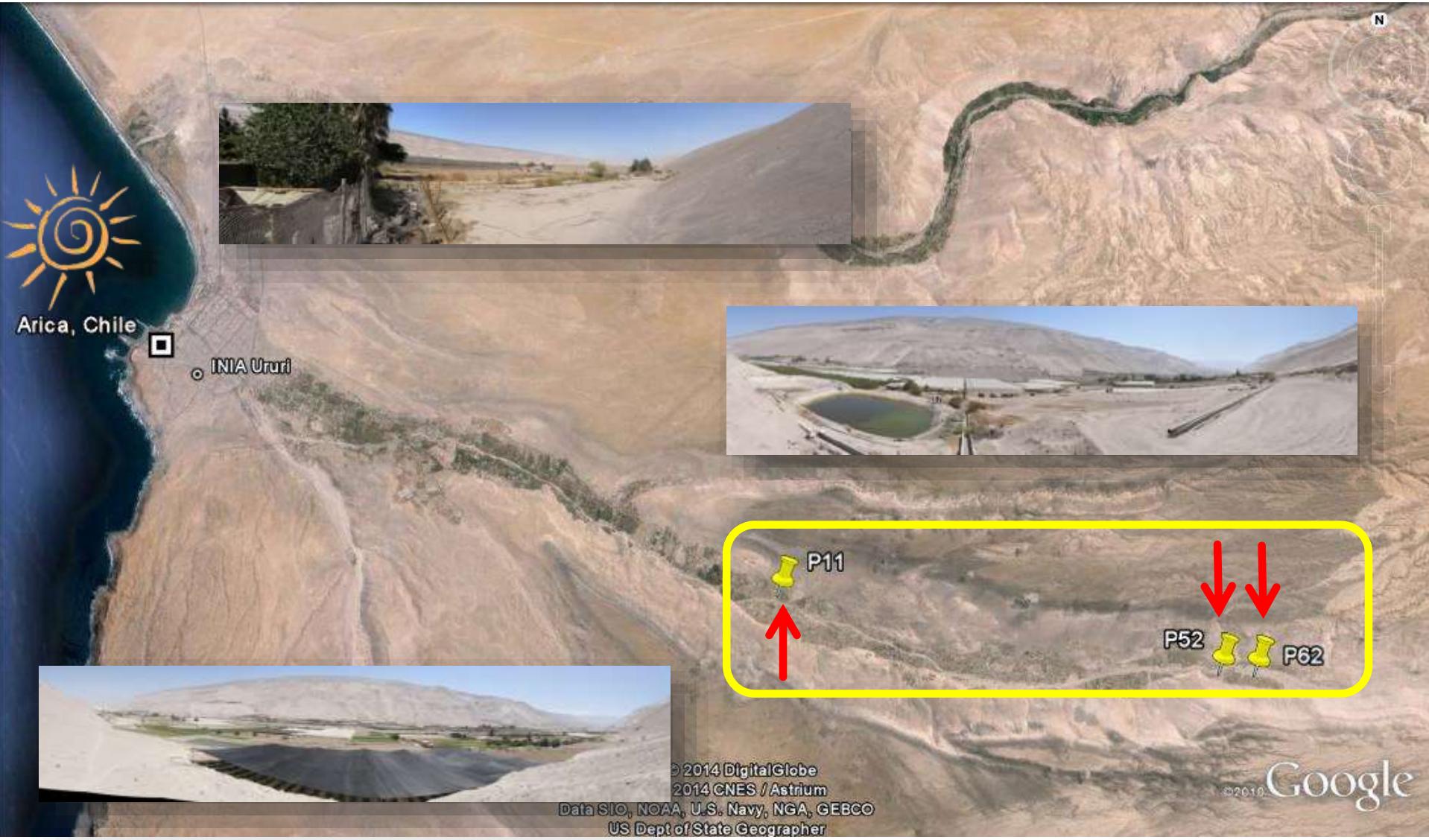
Ministerio de
Agricultura

Gobierno de Chile

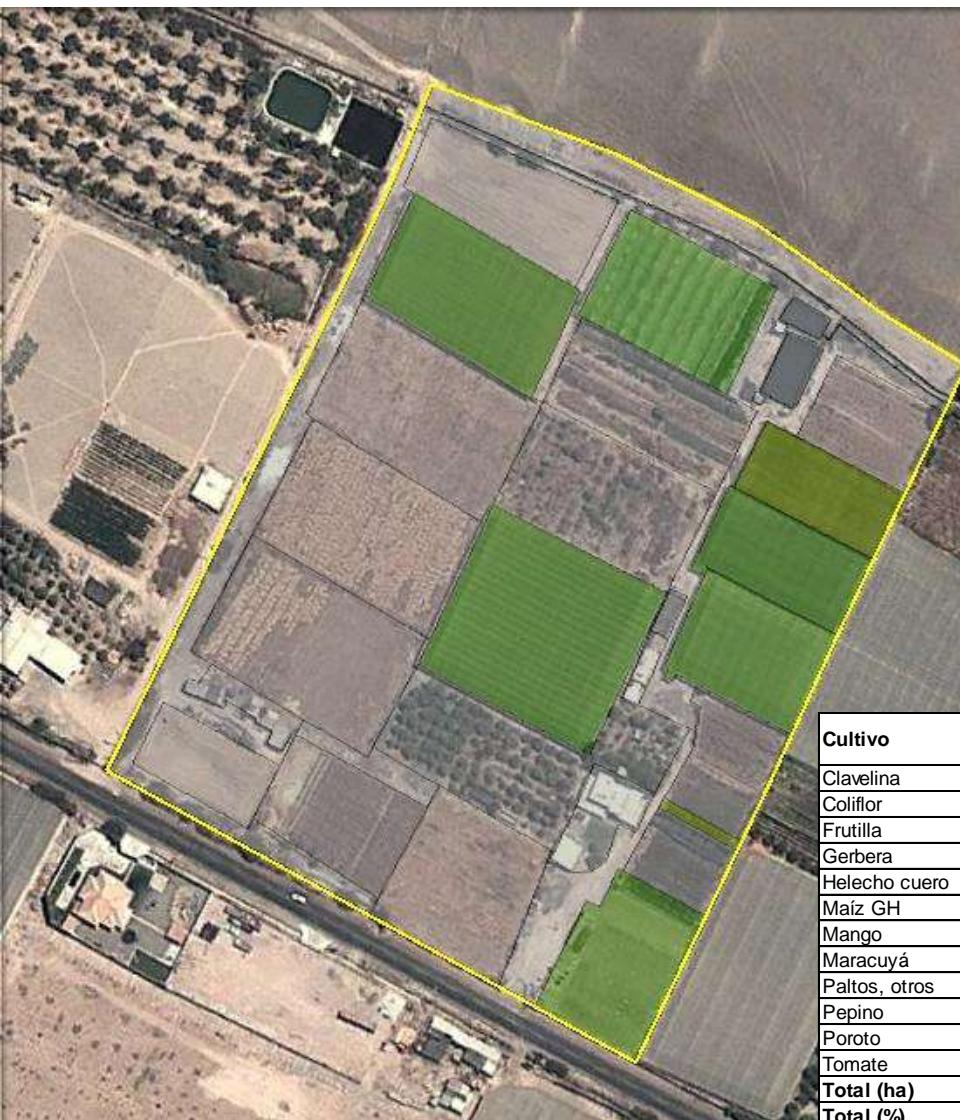


Energía sustentable para
agricultura intensiva bajo
condiciones de zonas áridas y alta
radiación solar

Tres parcelas en el Valle de Azapa.



DIAGNÓSTICO PREDIAL P11



UTM Norte 7.947.765 m, UTM Este 383.225 m, 433 m s.n.m.

| Uso actual del suelo | Superficie (ha) | Participación (%) |
|----------------------|-----------------|-------------------|
| Cultivo | 3,533 | 68,9 |
| Instalaciones | 0,125 | 2,4 |
| Riego | 0,053 | 1,0 |
| Sin uso | 1,415 | 27,6 |
| Total | 5,126 | 100,0 |

| Cultivo | Sistema de producción | | | Total (ha) | Participación (%) |
|-------------------|-----------------------|--------------|--------------|--------------|-------------------|
| | Abierto | Cerrado | Semicerrado | | |
| Clavelina | - | - | 0,126 | 0,126 | 3,58 |
| Coliflor | 0,303 | - | - | 0,303 | 8,57 |
| Frutilla | 0,074 | - | - | 0,074 | 2,10 |
| Gerbera | - | 0,523 | - | 0,523 | 14,81 |
| Helecho cuero | - | - | 0,011 | 0,011 | 0,30 |
| Maíz GH | 1,006 | - | - | 1,006 | 28,47 |
| Mango | 0,285 | - | - | 0,285 | 8,05 |
| Maracuyá | - | 0,382 | - | 0,382 | 10,81 |
| Paltos, otros | 0,244 | - | - | 0,244 | 6,90 |
| Pepino | - | 0,211 | - | 0,211 | 5,98 |
| Poroto | 0,120 | - | - | 0,120 | 3,39 |
| Tomate | - | 0,249 | - | 0,249 | 7,05 |
| Total (ha) | 2,031 | 1,365 | 0,137 | 3,533 | 100 |
| Total (%) | 57,5 | 38,6 | 3,9 | 100 | |

DIAGNÓSTICO PREDIAL P11



La demanda de energía eléctrica existe para:

- 2 motobombas de riego tipo superficial de 2 HP cada uno
- 1 refrigerador
- equipos de música y televisión
- 1 lavadora
- electrodomésticos
- 1 PC con conexión Internet

El suministro de energía eléctrica de Emelari se realiza a través de un empalme en la subestación S/E 354, 10 kVA, a una distancia de 250 metros en dirección oeste.

Número cliente Emelari:
Tarifa:

18,0 kWh/día

1033991
AT4.1

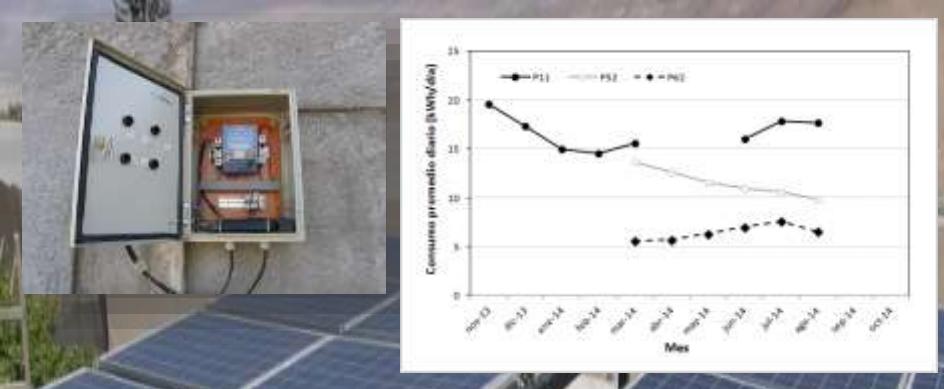
$E_{consumo} = 16,6 \text{ kWh/día}$ | $5 - 26 \text{ kWh/día}$

Gasto medio mensual en electricidad:

\$62.272

DIAGNÓSTICO ENERGÉTICO

Diseño FV - TS



| Parcela | Consumo medio kWh/día | Potencia kWp |
|---------|--------------------------|-----------------|
| P11 | 16,6 | 5 |
| P52 | 11,9 | 4 |
| P62 | 3,2 | 1,5 |

| Parcela | Generador solar | Banco baterías | Inversor |
|---------|--|--|---|
| P11 | 20 * 250 Watt-peak, paneles de 72 celdas, policristalino | Sonnenschein modelo A602/1130, 8 OPzV 960, 24 Volt (12 celdas de 2 Volt), 1105 Ah/C100 | Powerrouter NEDAP PR50SB-BS/S240, 5 kW |
| P52 | 16 * 250 Watt-peak, paneles de 60 celdas, policristalino | Sonnenschein modelo A602/1130, 8 OPzV 960, 24 Volt (12 celdas de 2 Volt), 1105 Ah/C100 | Powerrouter NEDAP PR37SB-BS/S24 3,7 kW, |
| P62 | 6 * 250 Watt-peak, paneles de 72 celdas, policristalino | Victron, gel, 12 Volt, 4 * 220 Ah, 4 en conexión serie, 4 Volt | 48 V, 220 V, 1.500 Watt |

| Parcela | Instalación | Observaciones | Nº pers. peak | Vol equipo (L) | Cantidad | Vol total (L) |
|--------------|-----------------|---|---------------|----------------|----------|---------------|
| P11 | Casa | Vivienda propietario | 6 | 180 | 1 | 300 |
| P52 | Casa 1 | Vivienda propietario y mamá | 3 | 240 | 1 | 660 |
| | Casa 2 | Vivienda hermana propietario | 4 | 180 | 1 | |
| | Baño servicio | Baño mujeres y hombres con WC y duchas para operarios campo | 6 | 240 | 1 | |
| P62 | Casa | Vivienda propietario | 3 | 180 | 1 | 540 |
| | Baño servicio 1 | Baño con WC y ducha para operarios campo | 4 | 180 | 1 | |
| | Baño servicio 2 | Baño mujeres y hombres con WC y duchas para operarios selección | 3 | 180 | 1 | |
| Total | | | | 29 | 8 | 1.500 |

Research lines Central Zone of Chile

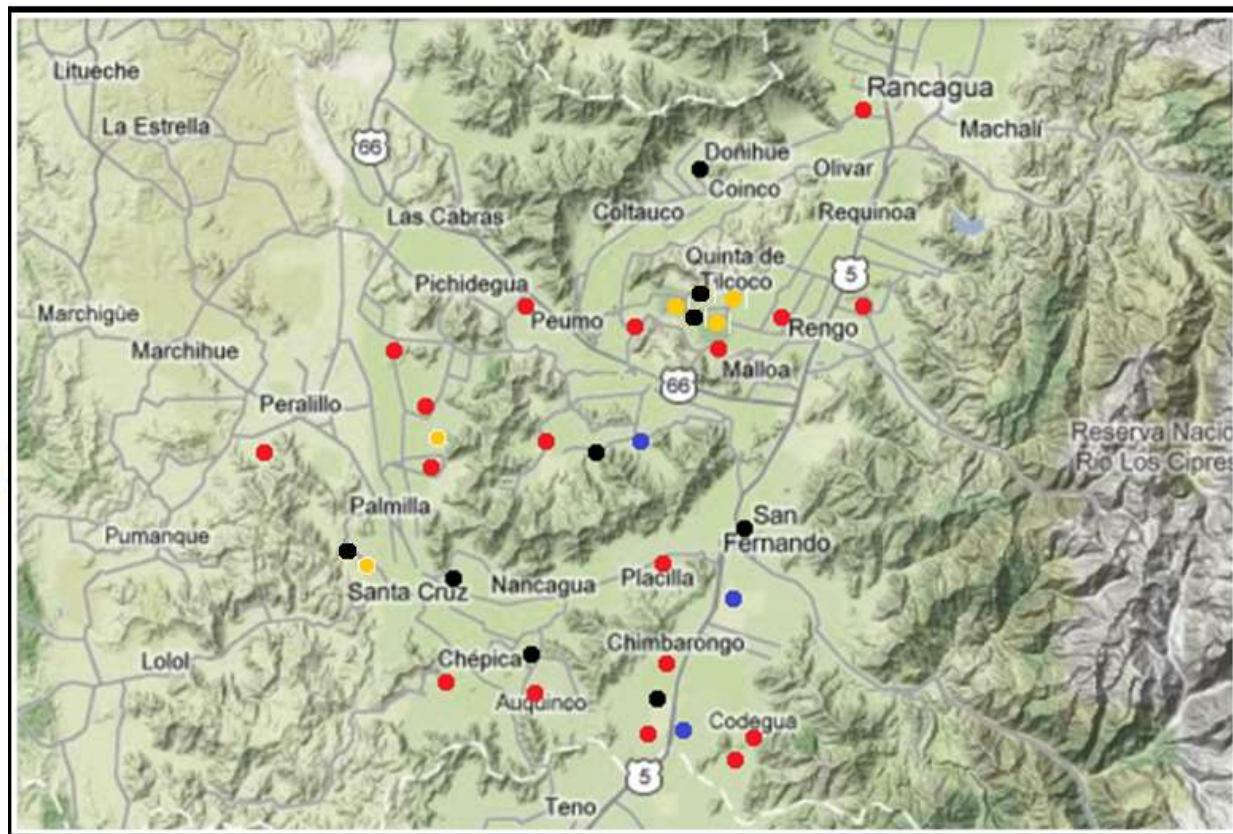
- ▶ Water Footprint of Corn.
- ▶ Irrigation efficiency of furrows combined with surge irrigation.
- ▶ Nitrogen fertigation of furrow/surge irrigation and its effect on Nitrate lixiviation.

Surface and production of Corn in Chile

| Region | Surface (ha) | Production (ton) | Average Yield (qq ha ⁻¹) |
|----------------|-----------------|---------------------|---|
| Coquimbo | 37 | 247 | 66,7 |
| Valparaíso | 1.504 | 16.554 | 143,3 |
| Metropolitana | 15.534 | 162.135 | 132,9 |
| O'Higgins | 55.678 | 655.059 | 136,8 |
| Maule | 49.472 | 429.557 | 126,6 |
| Bío Bío | 19.909 | 250.608 | 133,7 |
| Araucanía | 255 | 2.930 | 130,3 |
| Total Nacional | 142.389 | 1.517.090 | 134 |

Fuente: ODEPA (2013)

Corn > 50.000 ha Región de O'Higgins
Potencial Yield: 16,7 ton/ha
Average Yield: 13,7 ton/ha



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Cuánta agua gastamos



en la producción de los siguientes artículos:

| | |
|----------|-----------------|
| Camiseta | 2.700 lt/unidad |
| Arroz | 3.400 lt/kg |
| Carne | 15.500 lt/kg |
| Manzana | 70 lt/unidad |
| Café | 140 lt/taza |
| Queso | 5.000 lt/kg |
| Cabra | 4.000 lt/kg |
| Pan | 40 lt/rebanada |
| Hoja A4 | 10 lt/unidad |
| Leche | 1.000 lt/litro |
| Pollo | 3.900 lt/kg |
| Té | 30 lt/taza |
| Cerveza | 75 lt/vaso |
| Maíz | 900 lt/kg |
| Oveja | 6.100 lt/kg |
| Trigo | 1.300 lt/kg |
| Cerdo | 4.800 lt/kg |
| Algodón | 11.000 lt/kg |

Litros de agua/unidad de medida

Fuente: Water Footprint

Corn Water Footprint (L/Kg)

| Watershed | Blue Fp. L Kg ⁻¹ | Green Fp. L Kg ⁻¹ | Gray Fp. L Kg ⁻¹ | Total Fp. L Kg ⁻¹ |
|-------------|--------------------------------|---------------------------------|--------------------------------|---------------------------------|
| Chimbarongo | 488,1 | 42,3 | 240,9 | 771,3 |
| Cachapoal | 541,1 | 28,6 | 239,3 | 809,0 |
| Rapel | 541,9 | 49,4 | 235,7 | 827,0 |

En: Osorio U., Alfonso (ed). 2013. Determinación de la huella del agua y estrategias de manejo de recursos hídricos. 211 p. Serie Actas N°50. Instituto de Investigaciones Agropecuarias, Centro Regional de Investigación Intihuasi, La Serena, Chile.

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Soil leveling



Flow control

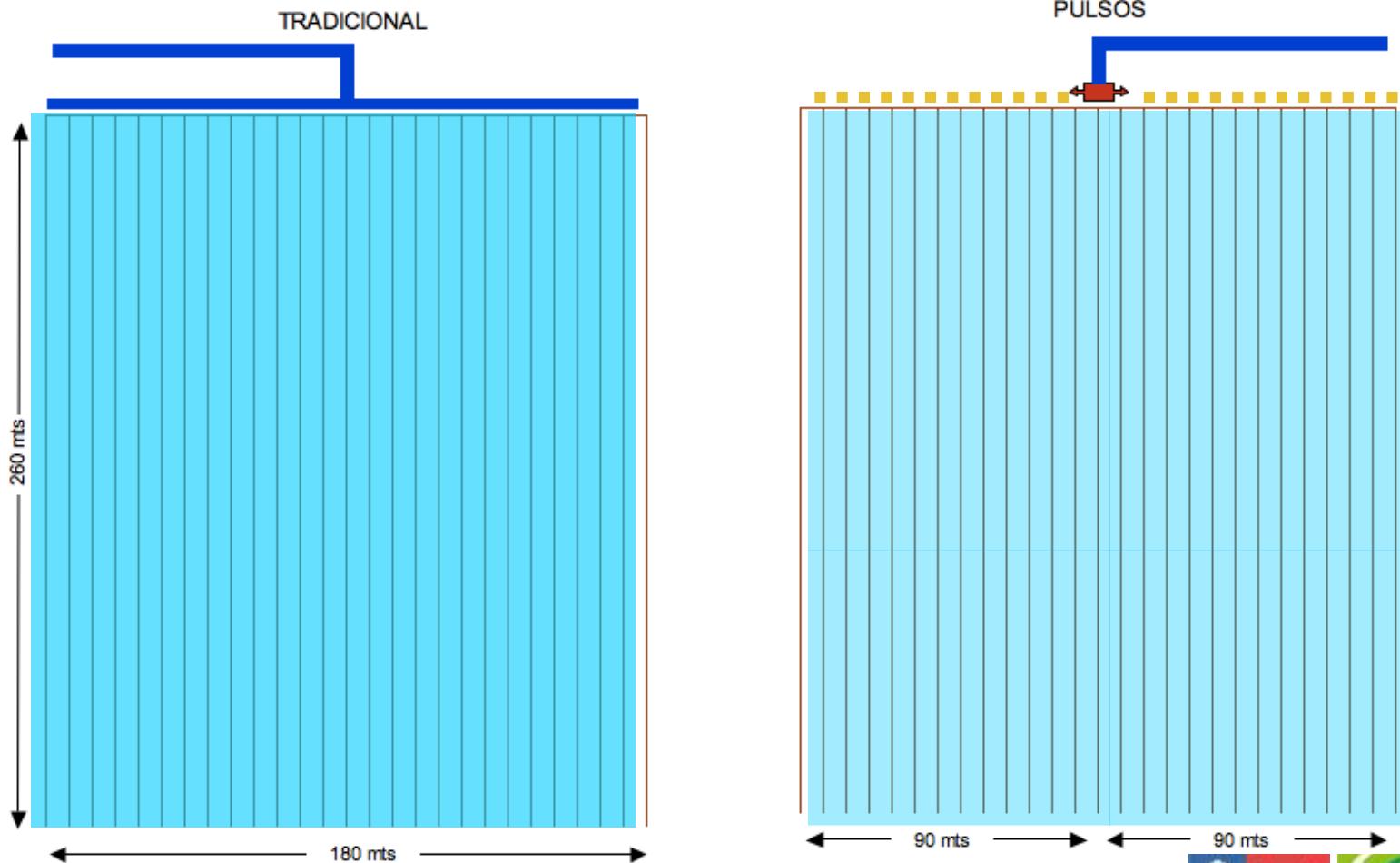




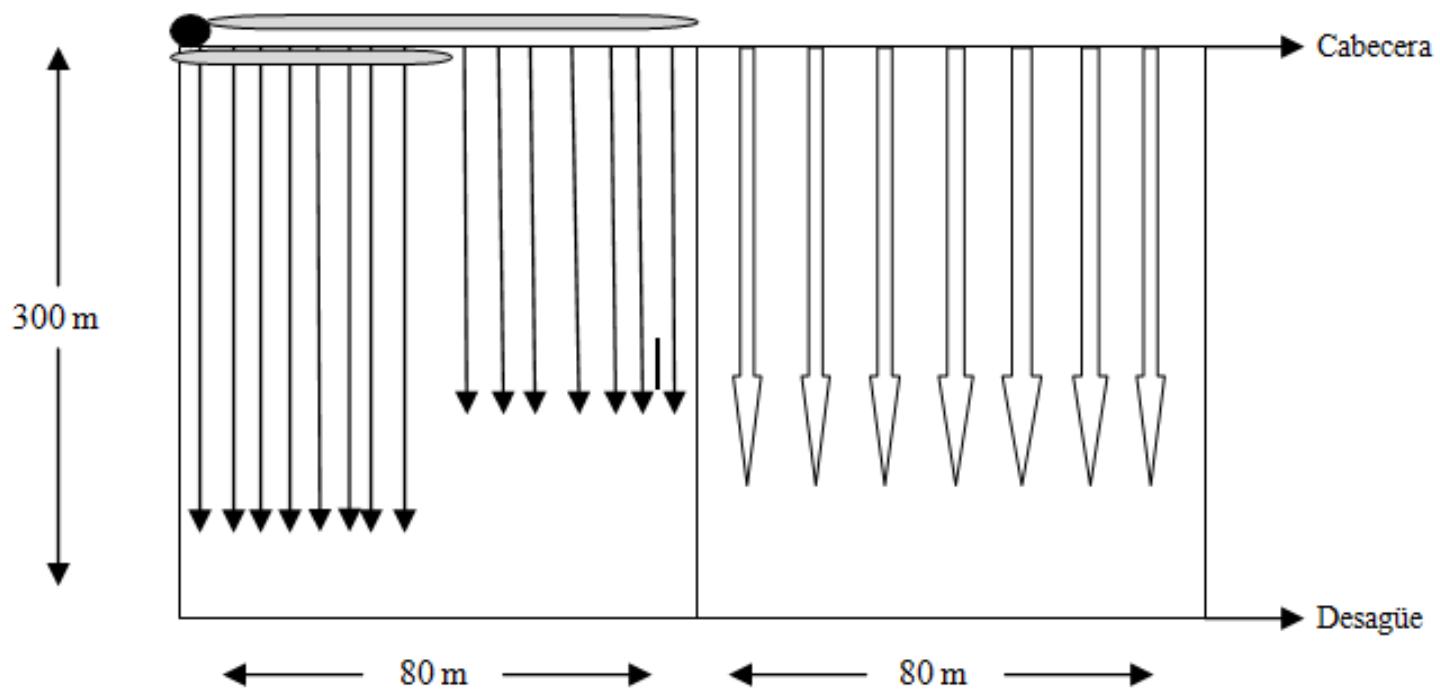
Surge Irrigation Valve and controller



Conventional Furrow v/s Surge Irrigation



Experimental site of 11 ha.





Furrow Irrigation practices



Irrigation times

| Evento | Pulsos de Avance | | | | | Remojo | Total Riego (min) |
|--------|------------------|----|----|----|----|--------|-------------------|
| | P1 | P2 | P3 | P4 | P5 | | |
| 1 | 25 | 36 | 49 | 63 | 76 | 120 | 738 |
| 2 | 36 | 48 | 60 | 72 | -- | 120 | 672 |
| 3 | 36 | 48 | 60 | 72 | -- | 60 | 552 |
| 4 | 25 | 36 | 57 | -- | -- | 90 | 416 |
| 5 | 19 | 27 | 38 | -- | -- | 120 | 408 |
| 6 | 21 | 30 | 42 | -- | -- | 120 | 426 |

Análisis de Merriam–Keller

Lámina de agua a reponer



CropWat 8.0

Clima/ETo.

Precipitación efectiva.

Cultivo.

| Etapas Fenológicas | |
|--------------------|--------------------|
| Etapa | Duración (días) |
| Inicial | 45 |
| Desarrollo | 45 |
| Media | 50 |
| Final | 30 |
| Total | 170 |

→ Kc = 0.25

→ Kc = 1.15

→ Kc = 0.15

Efficiency and Uniformity Evaluation

WinSRFR versión 4.1.2

► *Ventana Start Simulation*

► *Ventana System Geometry*

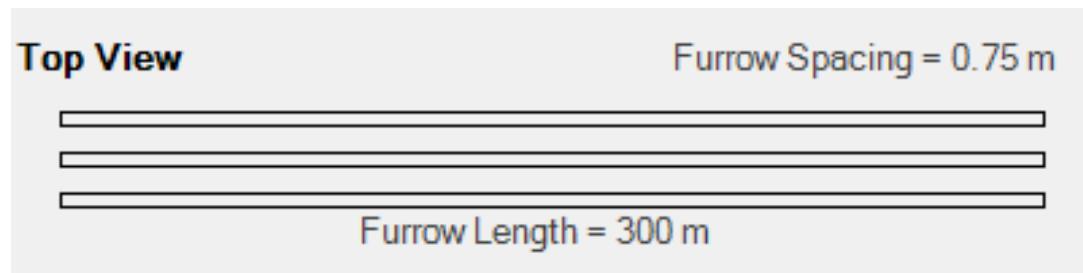
Surco

Longitud

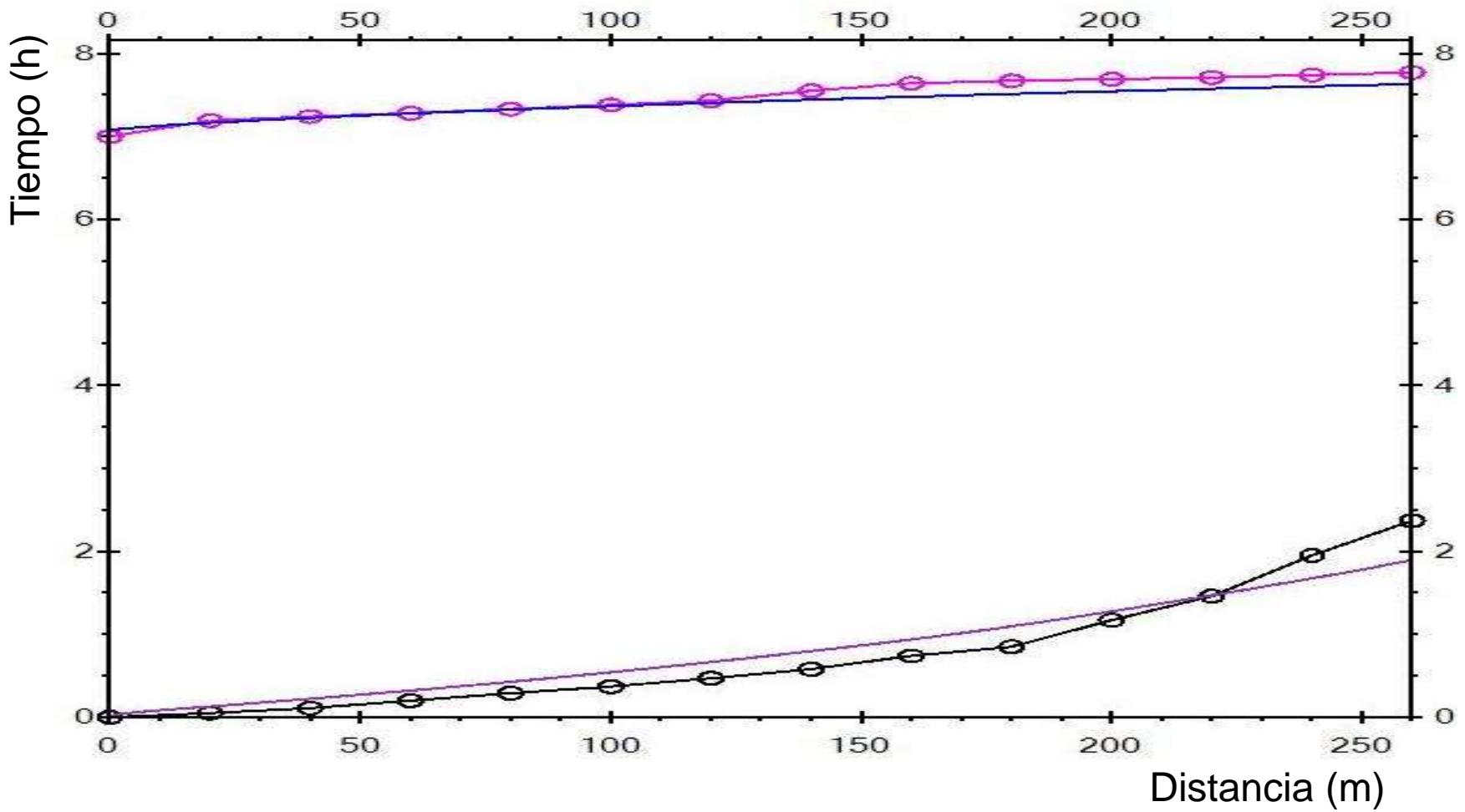
Espaciamiento

Número de surcos por postura

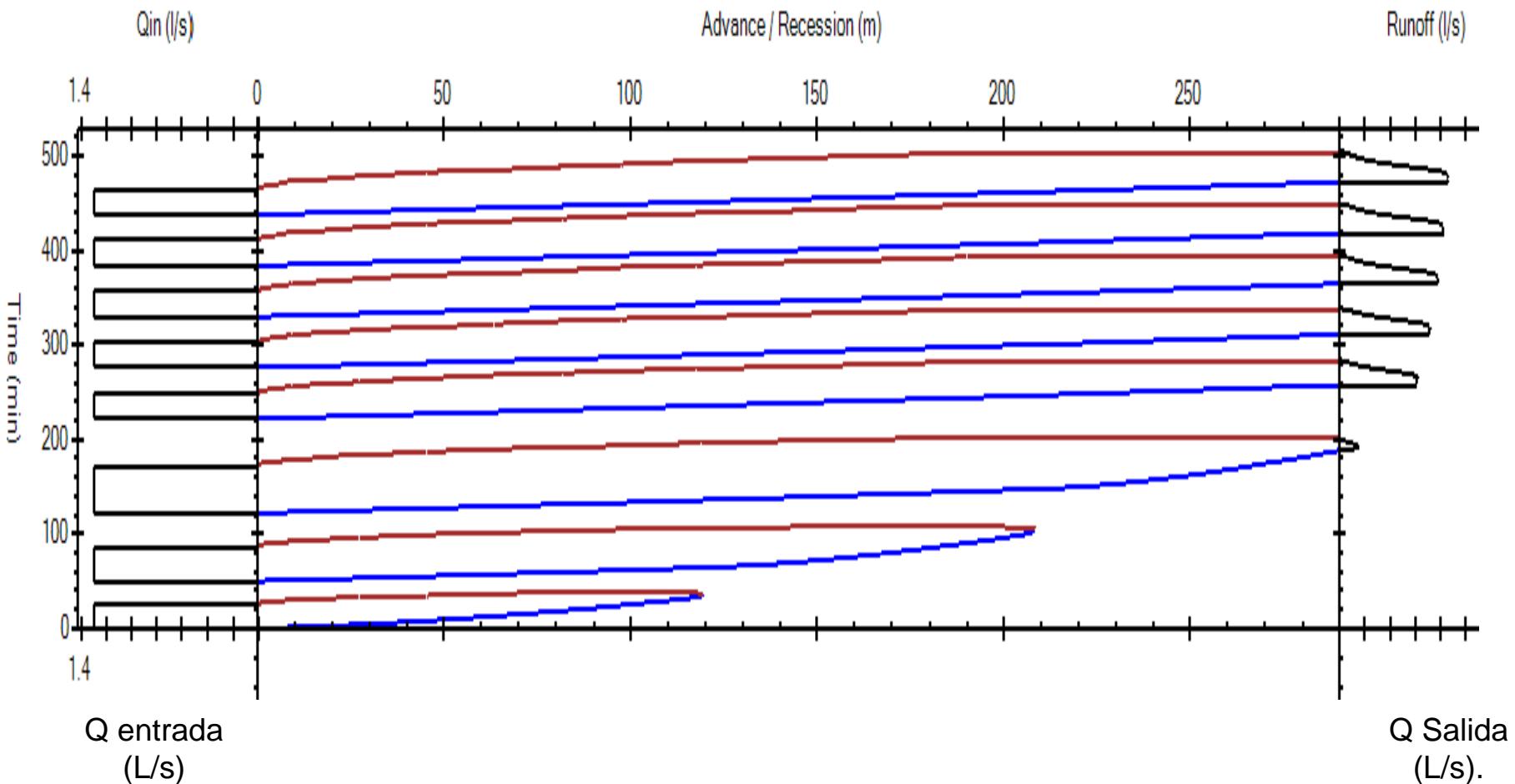
| Evento | Riego Surcos Tradicional (mm) | Riego por pulsos (mm) |
|--------|-------------------------------|-----------------------|
| 1 | 70.3 | 63.1 |
| 2 | 48.6 | 40.4 |
| 3 | 70.5 | 70.9 |
| 4 | 71.7 | 75.5 |
| 5 | 82.2 | 83.5 |
| 6 | 86.9 | 85.8 |
| Total | 430 | 419 |



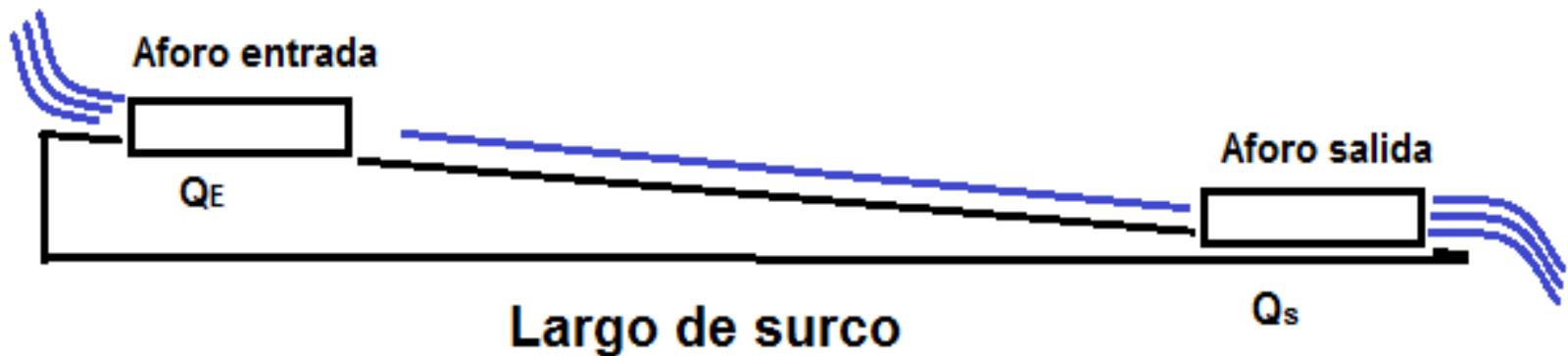
Advance and recession curves



Advance and recession with surge



Water inflow and outflow



Opportunity time

Advance



Recessing



$$To = TR - Ta + Tr$$

En que: To = Tiempo de oportunidad o de contacto (min).

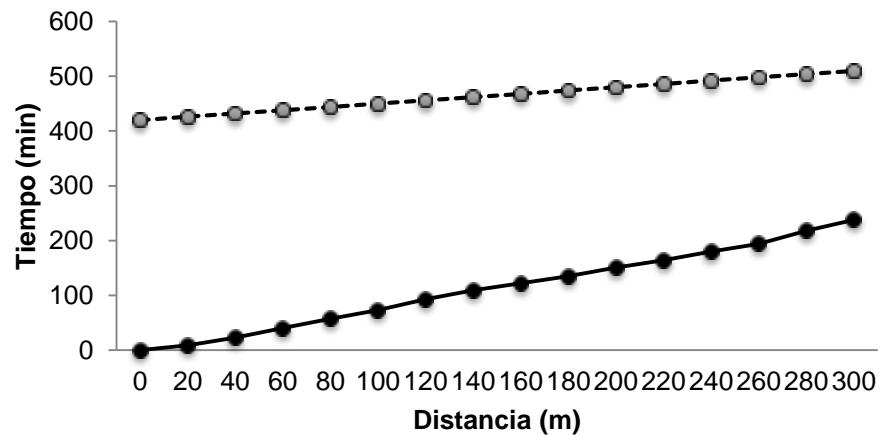
TR = Tiempo de riego (min).

Ta = Tiempo de avance (min).

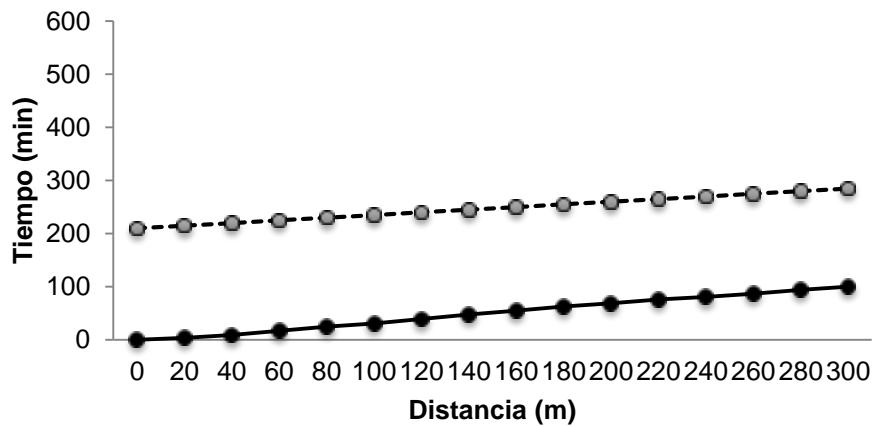
Tr = Tiempo de recesión (min).

Advance and recession traditional furrow

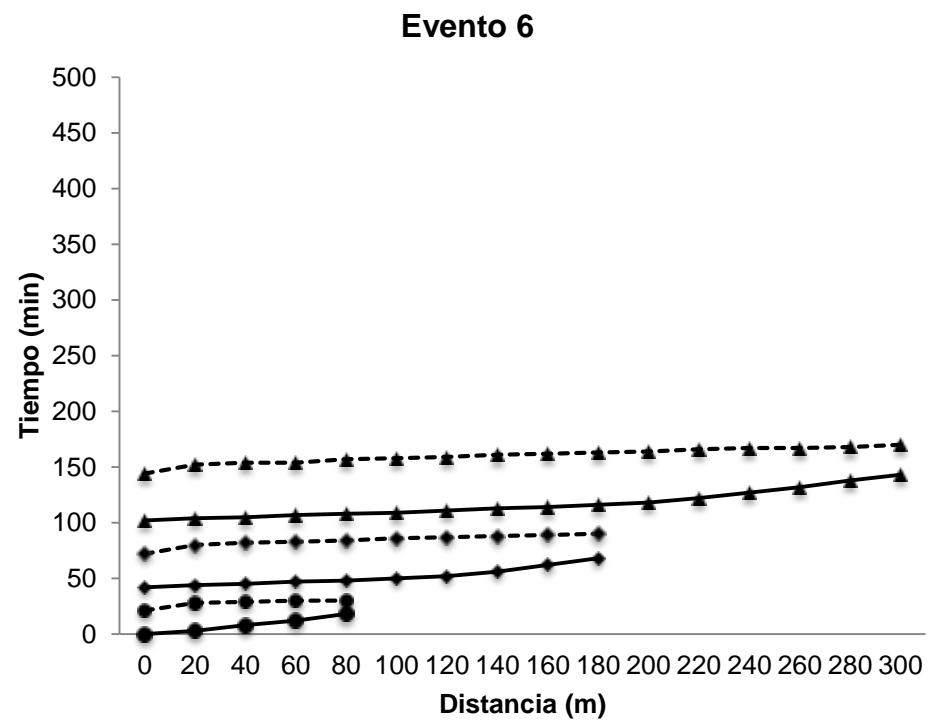
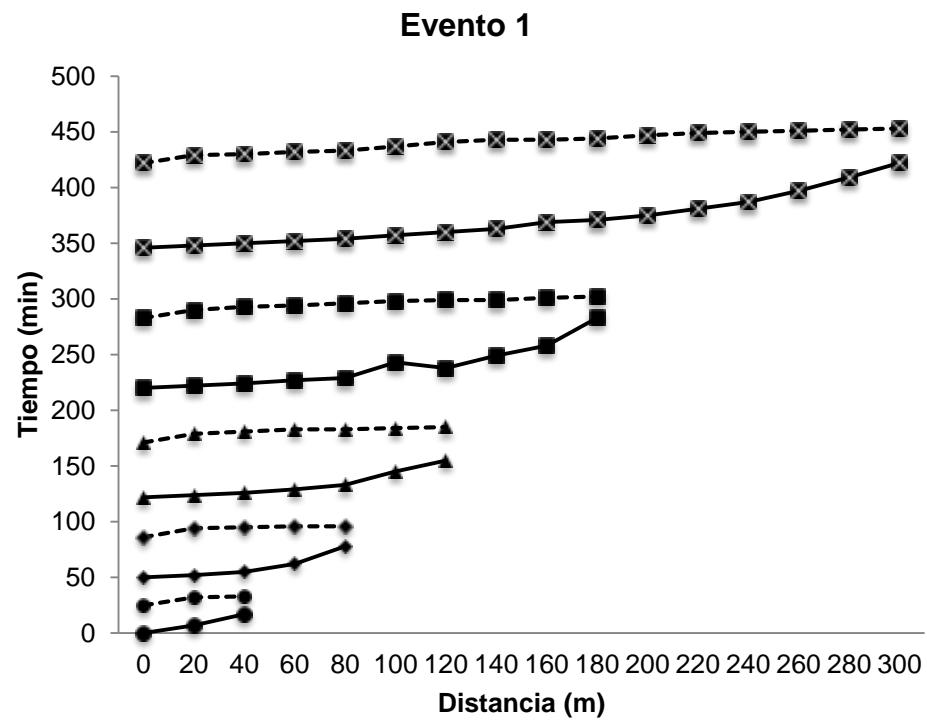
Evento 1



Evento 2



Advance and recession surge



Water Balance

Conventional Furrow

| Período | Riego (mm) | Lluvia Ef. (mm) | ETc (mm) | Esc. Sup. (mm) | Perc. Prof. (mm) |
|------------------|------------|-----------------|----------|----------------|------------------|
| 18 Oct al 9 Dic | 331 | 0 | 70 | 179 | 82 |
| 10 Dic al 23 Dic | 219 | 0 | 49 | 133 | 37 |
| 24 Dic al 6 Ene | 280 | 0 | 70 | 24 | 185 |
| 7 Ene al 17 Ene | 432 | 0 | 72 | 24 | 336 |
| 18 Ene al 30 Ene | 213 | 0 | 83 | 25 | 106 |
| 31 Ene al 14 Feb | 570 | 0 | 87 | 148 | 335 |

Furrow with surge

| Período | Riego (mm) | Lluvia Ef. (mm) | ETc (mm) | Esc. Sup. (mm) | Perc. Prof. (mm) |
|------------------|------------|-----------------|----------|----------------|------------------|
| 18 Oct al 3 Dic | 281 | 0 | 63 | 33 | 186 |
| 4 Dic al 18 Dic | 152 | 0 | 40 | 44 | 68 |
| 19 Dic al 3 Ene | 125 | 0 | 71 | 23 | 31 |
| 4 Ene al 15 Ene | 117 | 0 | 75 | 24 | 18 |
| 16 Ene al 28 Ene | 116 | 0 | 79 | 35 | 3 |
| 29 Ene al 12 Feb | 125 | 0 | 86 | 34 | 5 |

Application Efficiency Clay Loam Soil

Conventional Furrow

| Evento | Ef. Aplicación | Escorrentía | Percolación |
|----------|----------------|-------------|-------------|
| 1 | 21% | 54% | 25% |
| 2 | 22% | 61% | 17% |
| 3 | 25% | 9% | 66% |
| 4 | 17% | 6% | 78% |
| 5 | 39% | 12% | 50% |
| 6 | 15% | 26% | 59% |
| Promedio | 23% | 28% | 49% |

Furrow with Surge

| Evento | Ef. Aplicación | Escorrentía | Percolación |
|----------|----------------|-------------|-------------|
| 1 | 22% | 12% | 66% |
| 2 | 26% | 29% | 45% |
| 3 | 57% | 18% | 25% |
| 4 | 64% | 21% | 15% |
| 5 | 67% | 30% | 3% |
| 6 | 69% | 27% | 4% |
| Promedio | 51% | 23% | 26% |

Furrows with surge



Conventional furrows



Application Efficiency Sandy Loam soil

Riego convencional

| Evento | Ef. Aplicación (%) | Escorrentía (%) | Percolación (%) |
|----------|-----------------------|--------------------|--------------------|
| 1 | 15 % | 37 % | 48 % |
| 2 | 6 % | 37 % | 57 % |
| 3 | 49 % | 44 % | 8 % |
| 4 | 34 % | 45 % | 21 % |
| 5 | 42 % | 38 % | 20 % |
| 6 | 50 % | 41 % | 9 % |
| 7 | 38 % | 38 % | 24 % |
| 8 | 28 % | 26 % | 46 % |
| 9 | 40 % | 38 % | 22 % |
| 10 | 18 % | 44 % | 37 % |
| Promedio | 32 % | 39 % | 29 % |

Riego por pulsos

| Evento | Ef. Aplicación (%) | Escorrentía (%) | Percolación (%) |
|----------|-----------------------|--------------------|--------------------|
| 1 | 21 % | 30 % | 48 % |
| 2 | 44 % | 29 % | 21 % |
| 3 | 85 % | 23 % | 0 % |
| 4 | 76 % | 22 % | 0 % |
| 5 | 69 % | 25 % | 0 % |
| 6 | 80 % | 15 % | 0 % |
| 7 | 75 % | 23 % | 0 % |
| 8 | 70 % | 29 % | 0 % |
| 9 | 77 % | 22 % | 0 % |
| 10 | 63 % | 28 % | 0 % |
| Promedio | 66 % | 25 % | 7 % |

Conventional
Furrow

Furrow with surge



Research lines Central Zone of Chile

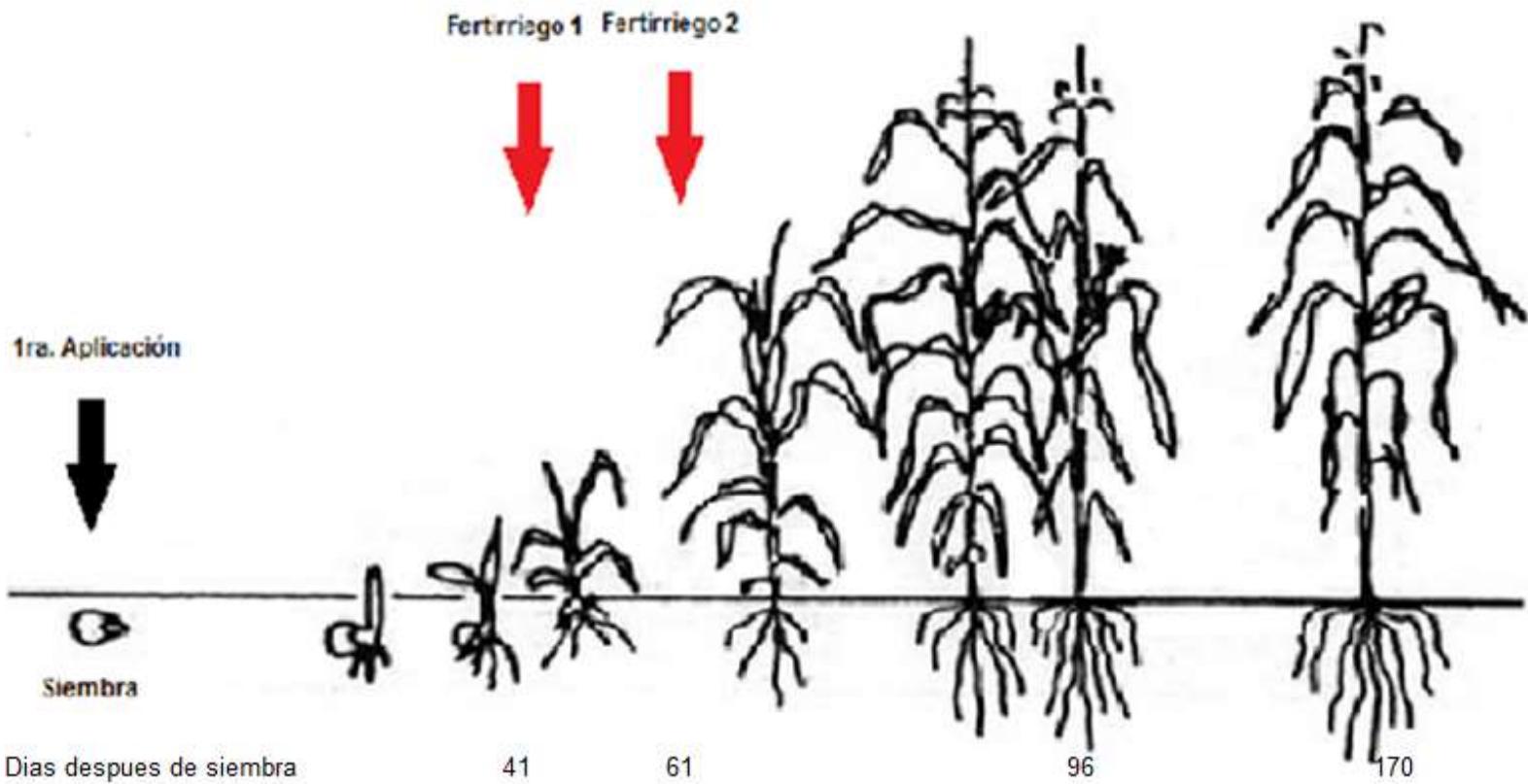
- ▶ Water Footprint of Corn.
- ▶ Irrigation efficiency of furrows combined with surge irrigation.
- ▶ Nitrogen fertigation of furrow/surge irrigation and its effect on Nitrate lixiviation.

► Nitrogen

Rol en las plantas

FERTILIZACIÓN





Grain Yield

