

Potencialidades del SENTINEL en la Agricultura de Precisión.

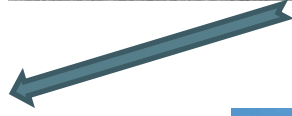
Jose María Terrón López



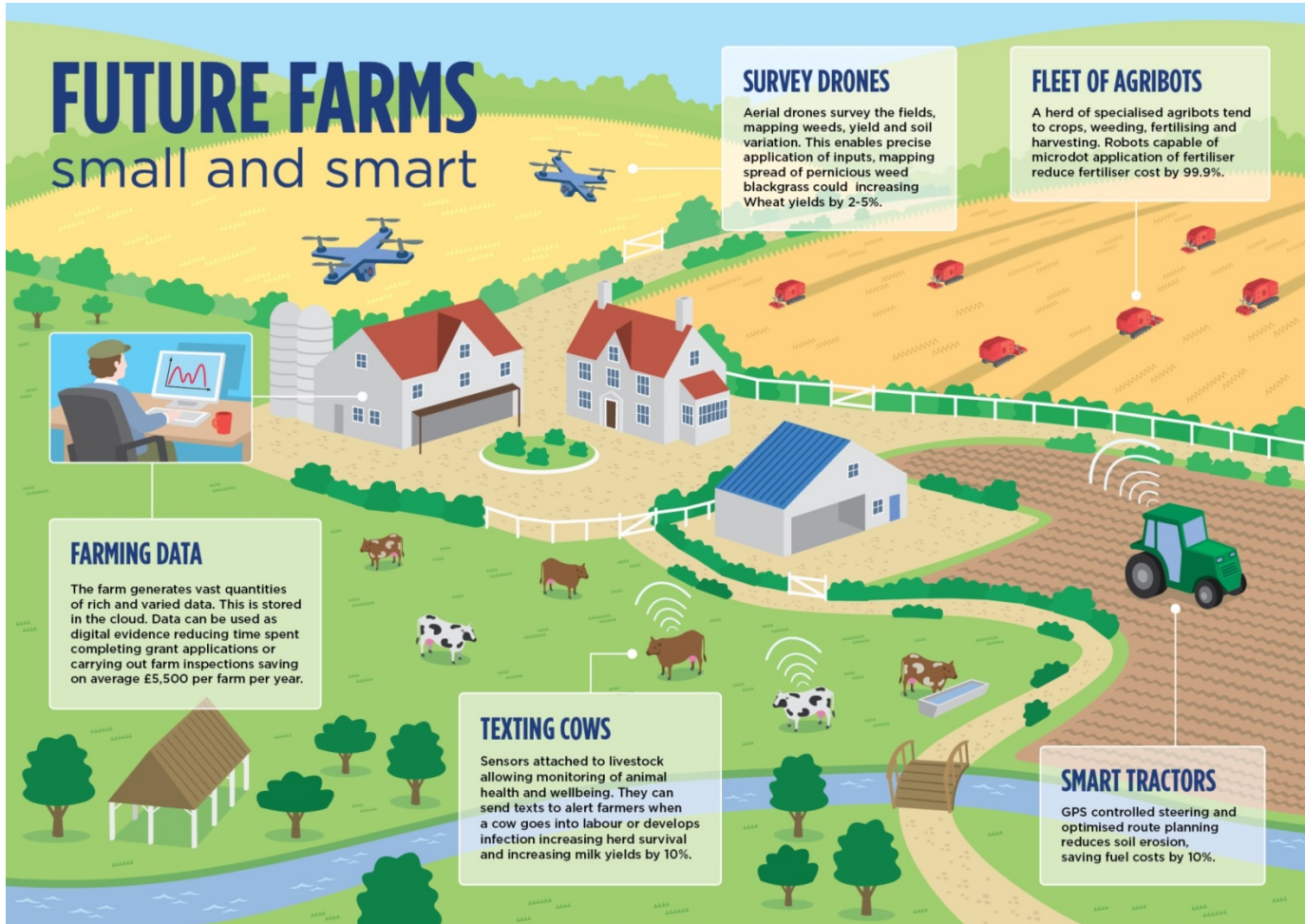
AGRICULTURA DE PRECISIÓN

OBJETIVO:

Gestionar los cultivos teniendo en cuenta la variabilidad espacial de los suelos y del estado de las plantas.

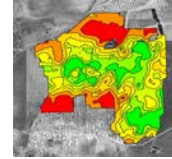


**EL CONCEPTO DE AGRICULTURA INTELIGENTE (SMART FARMING)
 COMBINA EL BIG DATA Y LA AGRICULTURA DE PRECISIÓN.**

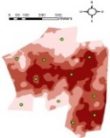


PROCESOS E INTERACCIONES EN LA AGRICULTURA DE PRECISIÓN

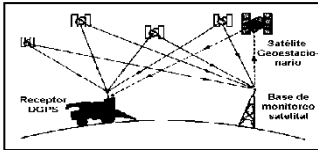
Sensores de CEa y pH



Muestreo de suelos



GPS

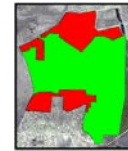


Mapas zonales



Mapas de suelos

Abonado variable



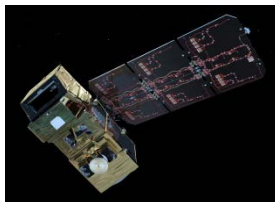
Internet



Agricultura de Precisión



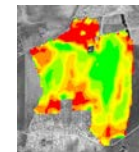
Control de cultivos con sensores de NDVI



S.I.G.



Mapas de producción



Otras aplicaciones: Fitosanitarios, trazabilidad, rentabilidad, etc



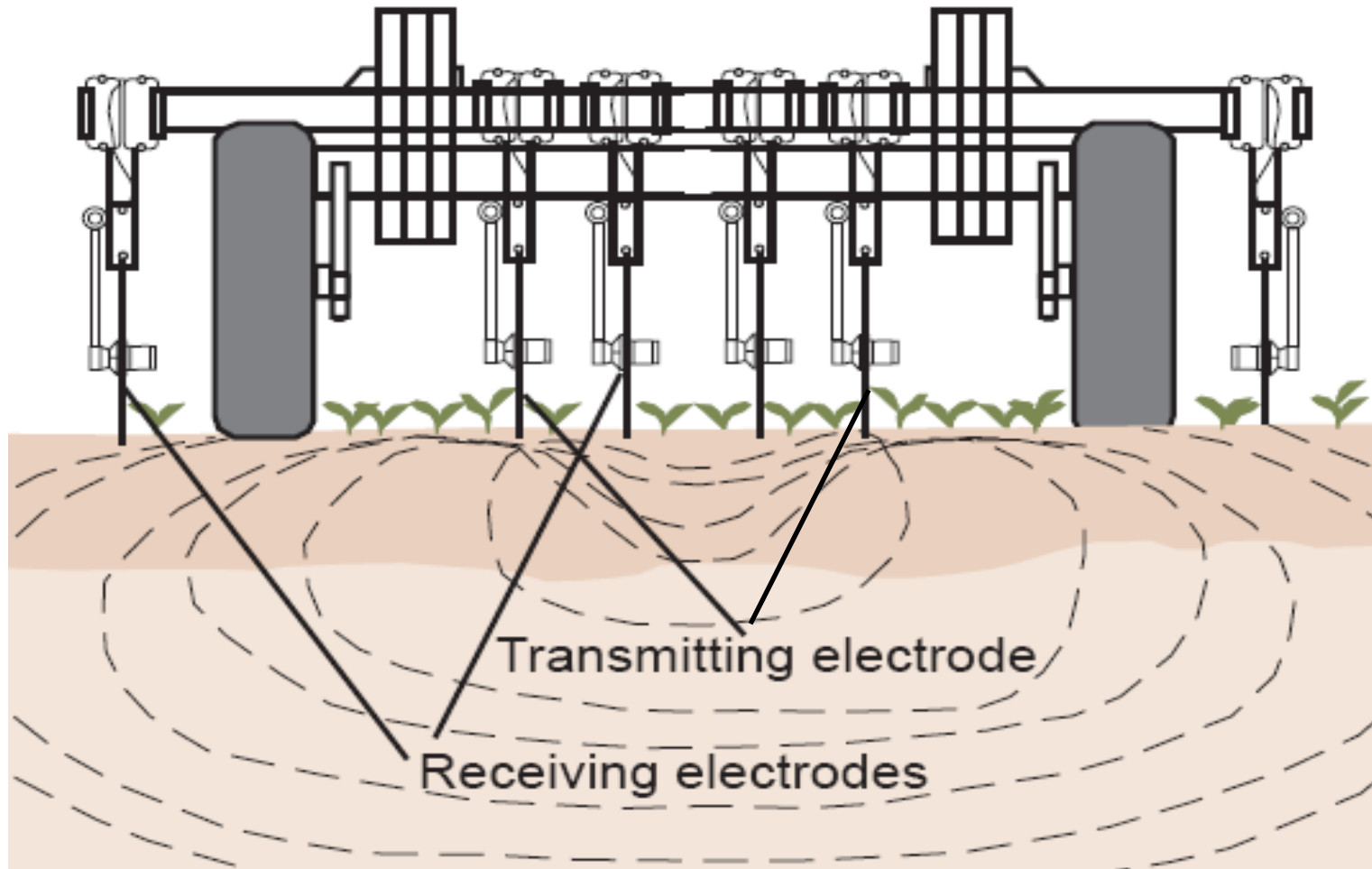


Sensores de Conductividad Eléctrica Aparente del suelo



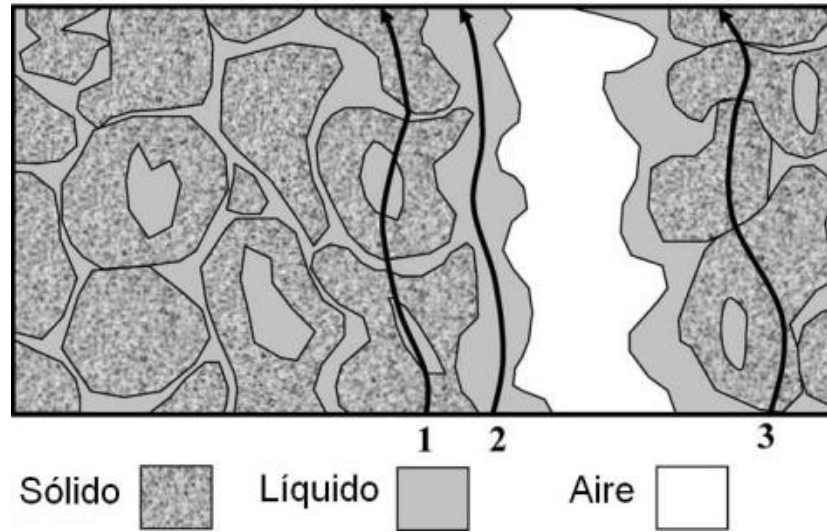


Esquema de distribución de electrodos





Conductividad eléctrica aparente

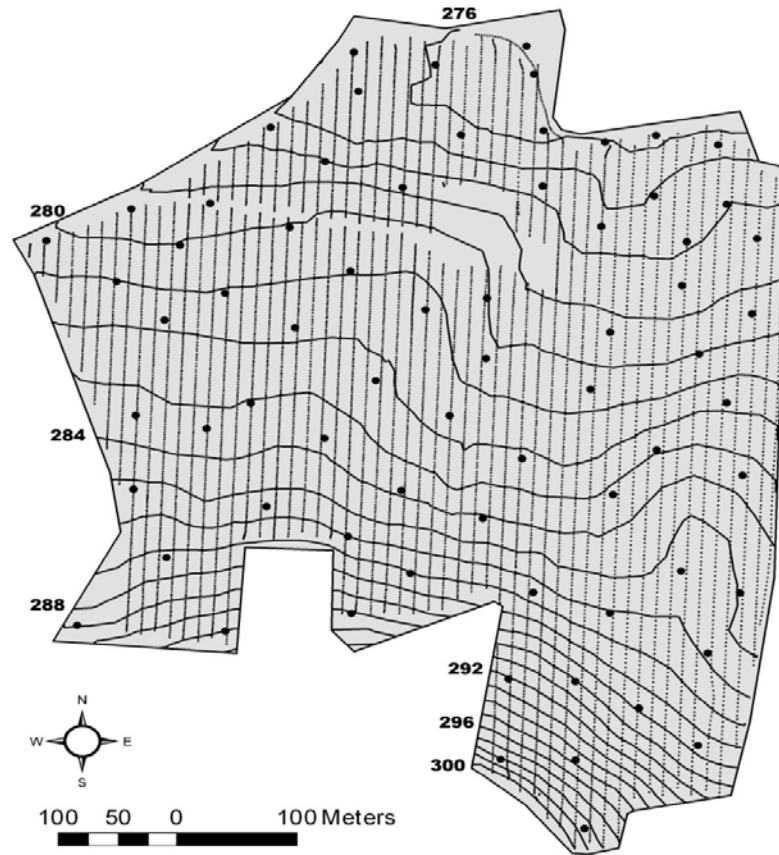


- Textura, especialmente con % arcilla
- Humedad del suelo
- CIC
- Salinidad
- Densidad



Zonificación de suelos

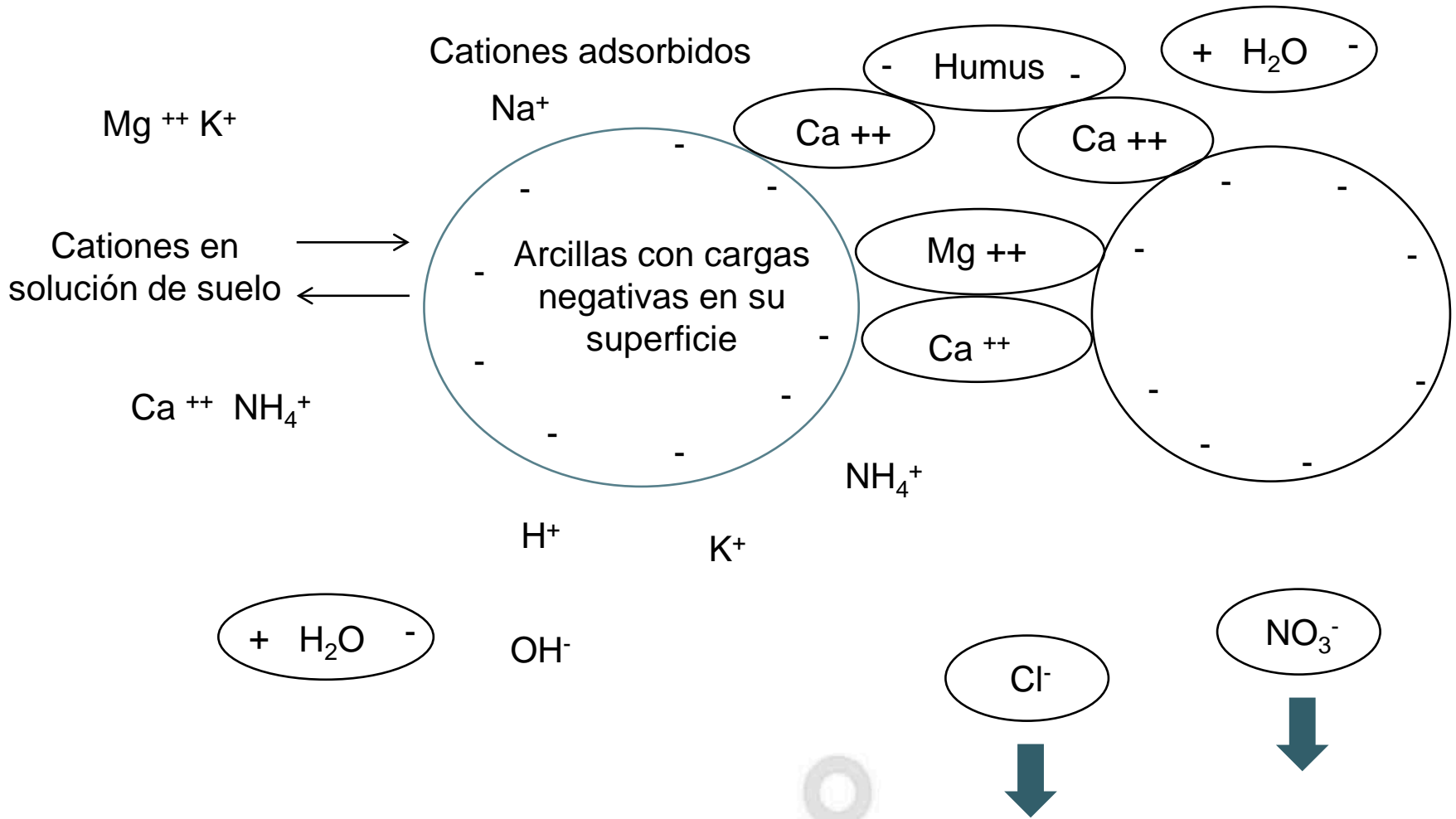
Muestreo de suelos



Matriz de correlación de las propiedades fisico-químicas del suelo

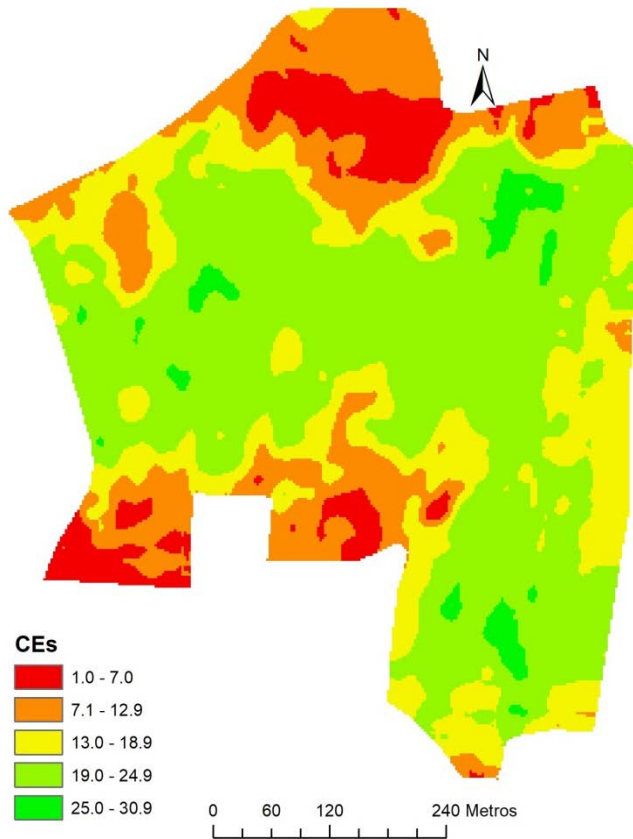
Matriz de correlación entre las propiedades del suelo en el área de estudio

| | Arena gruesa | Arena fina | Limo | Arcilla | pH | CIC | MO | CEe | CEs | CEp | NT |
|--------------|--------------|------------|--------|---------|--------|--------|-------|-------|-------|-------|----|
| Arena gruesa | 1 | | | | | | | | | | |
| Arena fina | 0.968 | 1 | | | | | | | | | |
| Limo | -0.312 | -0.287 | 1 | | | | | | | | |
| Arcilla | -0.857 | -0.869 | -0.195 | 1 | | | | | | | |
| pH | -0.617 | -0.612 | -0.052 | 0.660 | 1 | | | | | | |
| CIC | -0.732 | -0.742 | -0.312 | 0.843 | 0.838 | 1 | | | | | |
| MO | -0.041 | -0.065 | 0.034 | 0.038 | -0.023 | 0.013 | 1 | | | | |
| CEe | -0.294 | -0.276 | -0.077 | 0.322 | 0.300 | 0.435 | 0.102 | 1 | | | |
| CEs | -0.671 | -0.686 | -0.141 | 0.768 | 0.734 | 0.879 | 0.076 | 0.357 | 1 | | |
| CEp | -0.610 | -0.628 | -0.078 | 0.674 | 0.648 | 0.781 | 0.104 | 0.280 | 0.954 | 1 | |
| NT | -0.479 | -0.528 | 0.079 | 0.482 | 0.431 | -0.256 | 0.293 | 0.219 | 0.483 | 0.461 | 1 |

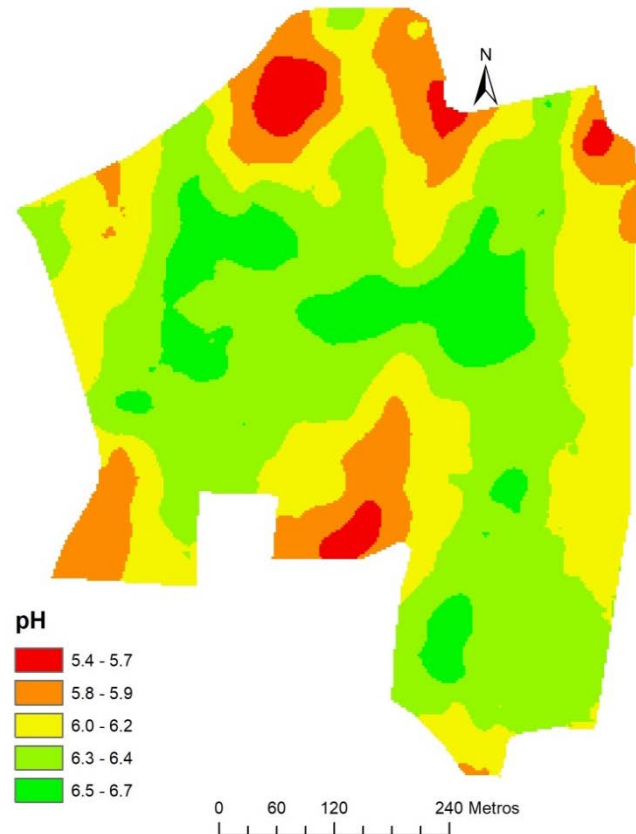


Zonificación de suelos

Mapa de Conductividad Eléctrica Aparente



pH



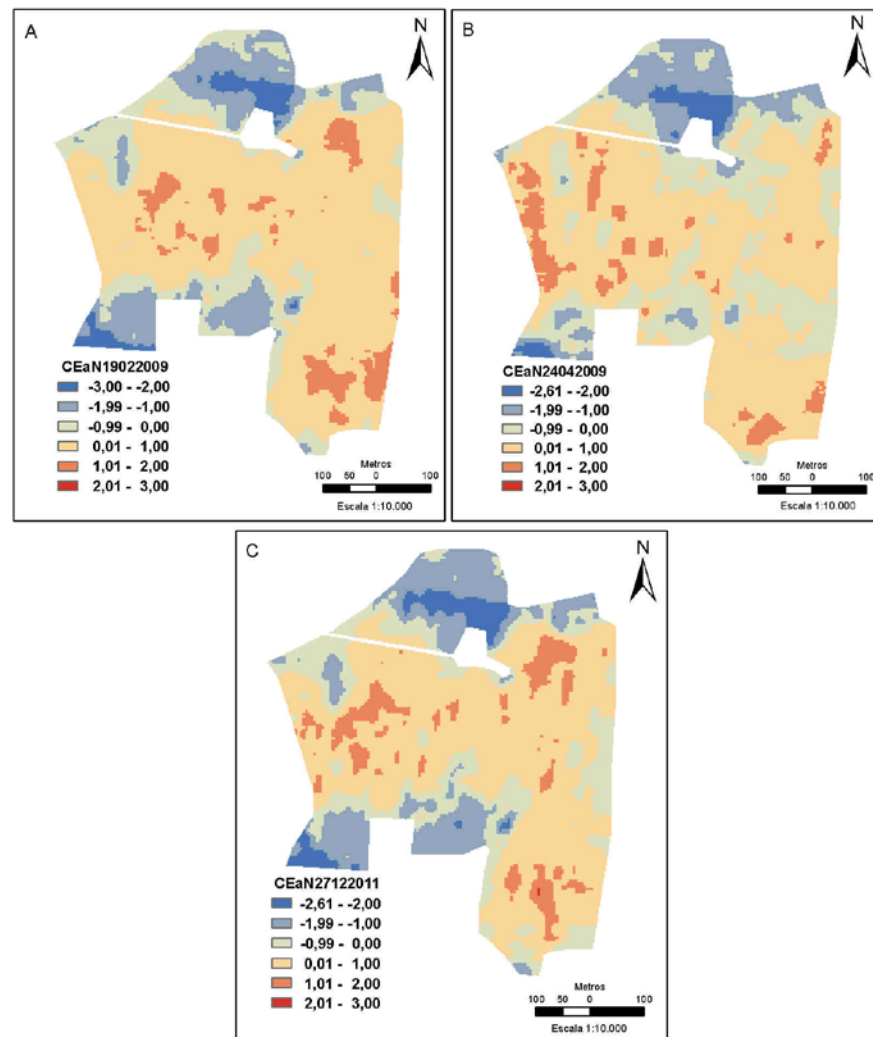
Variabilidad temporal de la conductividad eléctrica aparente superficial, CEs.

Datos de muestreos

| Fecha de muestreo | 19/02/2009 | 24/04/2009 | 27/01/2011 |
|--------------------------|------------|------------|------------|
| Mínimo (mS/m) | 0,50 | 1,20 | 0,50 |
| Máximo (mS/m) | 26,30 | 20,90 | 33,50 |
| Media (mS/m) | 16,14 | 10,63 | 17,56 |
| Desviación típica (mS/m) | 5,84 | 3,59 | 6,22 |
| Mediana (mS/m) | 18,50 | 10,90 | 19,50 |
| Coefficiente de sesgo | -0,79 | -0,22 | -0,76 |
| Curtosis | 2,45 | 2,99 | 2,64 |
| Primer Cuartil (mS/m) | 11,70 | 8,57 | 13,40 |
| Tercer Cuartil (mS/m) | 20,80 | 13,00 | 22,20 |

Datos normalizados

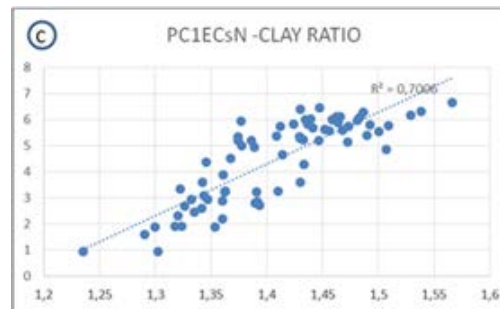
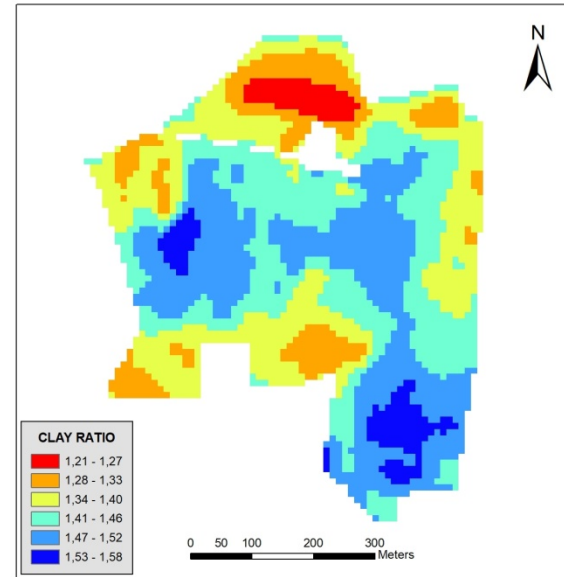
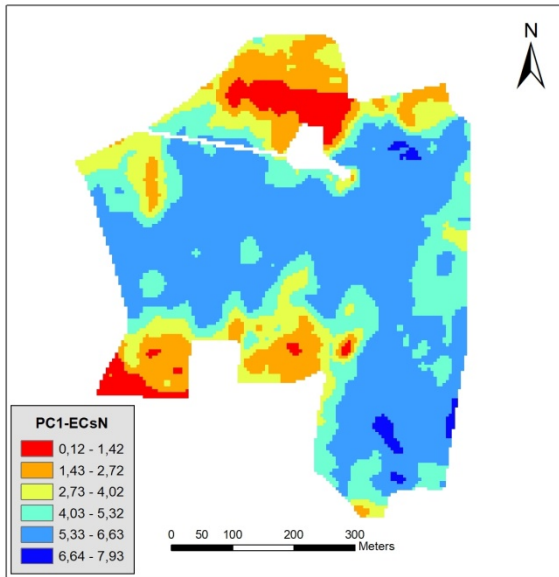
| Fecha de muestreo | 19/02/2009 | 24/04/2009 | 27/01/2011 |
|-----------------------|------------|------------|------------|
| Mínimo | -2,68 | -2,63 | -2,74 |
| Máximo | 1,74 | 2,86 | 2,56 |
| Mediana | 0,40 | 0,07 | 0,31 |
| Coefficiente de sesgo | -0,79 | -0,22 | -0,76 |
| Curtosis | 2,45 | 2,96 | 2,64 |
| 1 Cuartil | -0,76 | -0,57 | 0,67 |
| 3 Cuartil | 0,80 | 0,66 | 0,75 |



Mapas de los muestreos de CEsN.

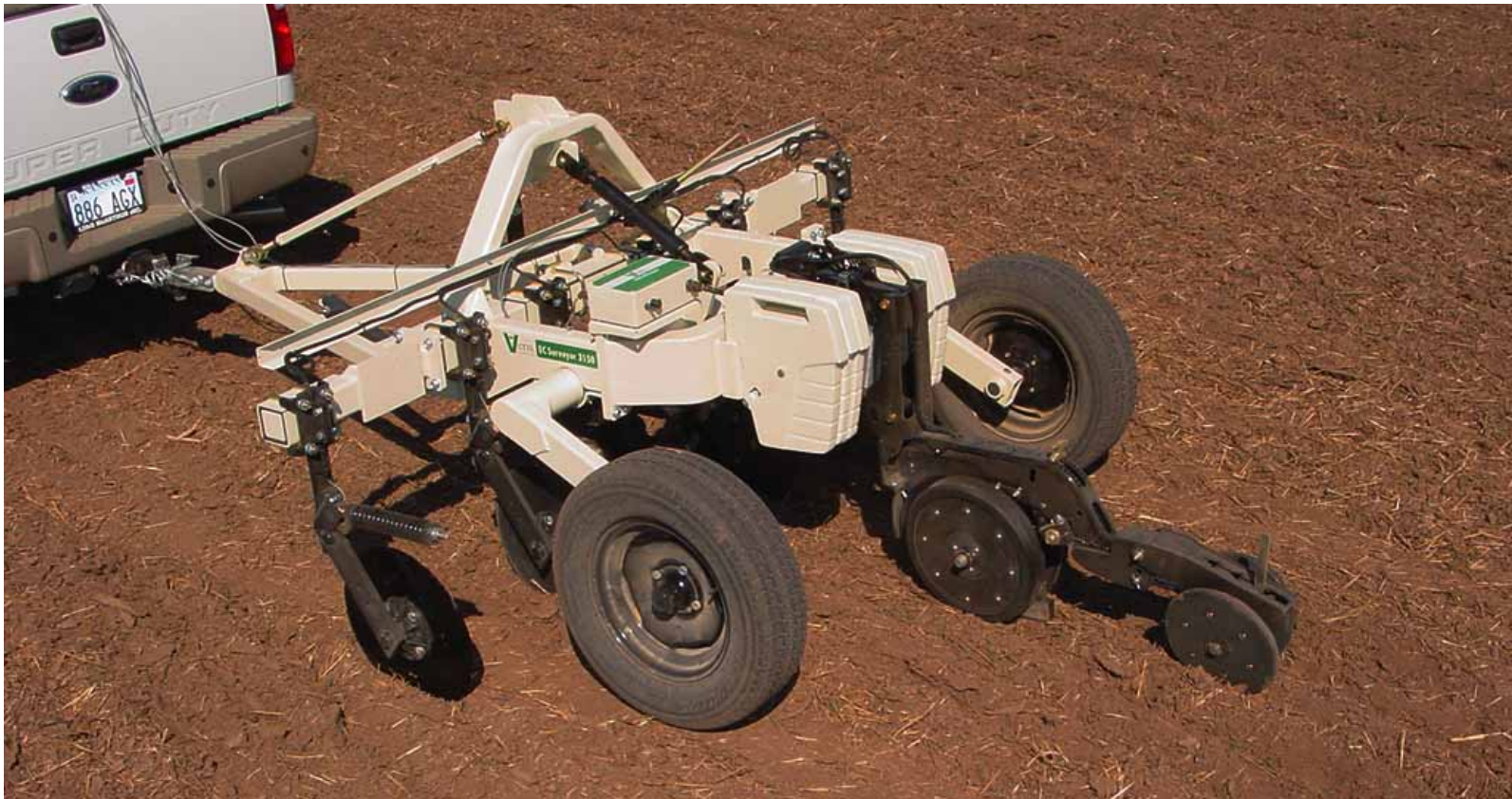
- A) 19/02/2009.
- B) 24/04/2009.
- C) 27/01/2011.

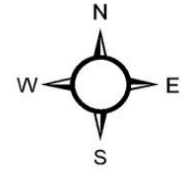
Uso de Clay Ratio SENTINEL para zonificación de suelos



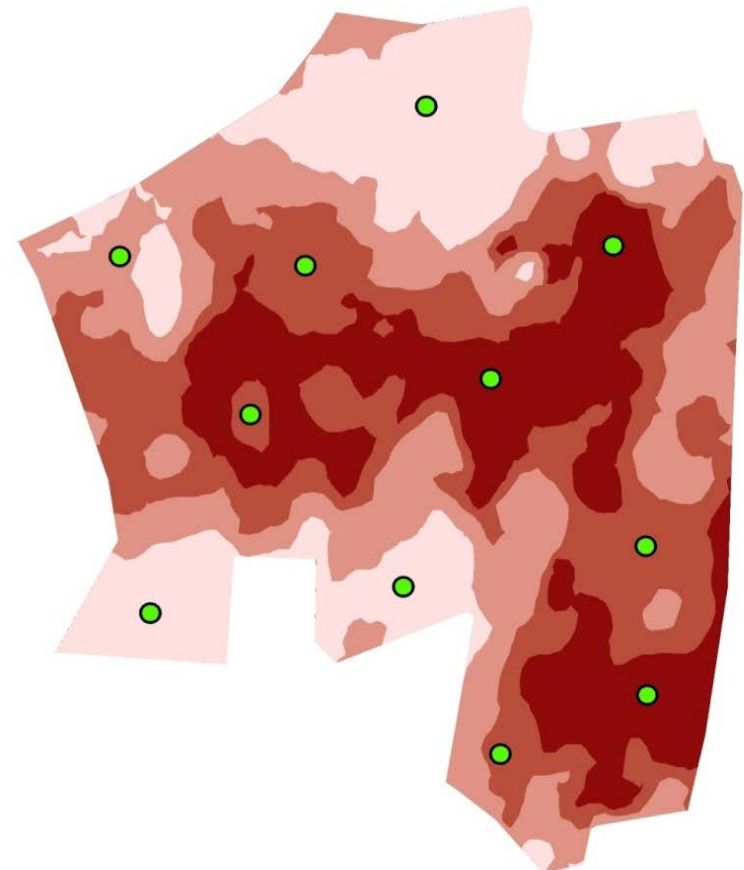


Sensor de Materia Orgánica del suelo



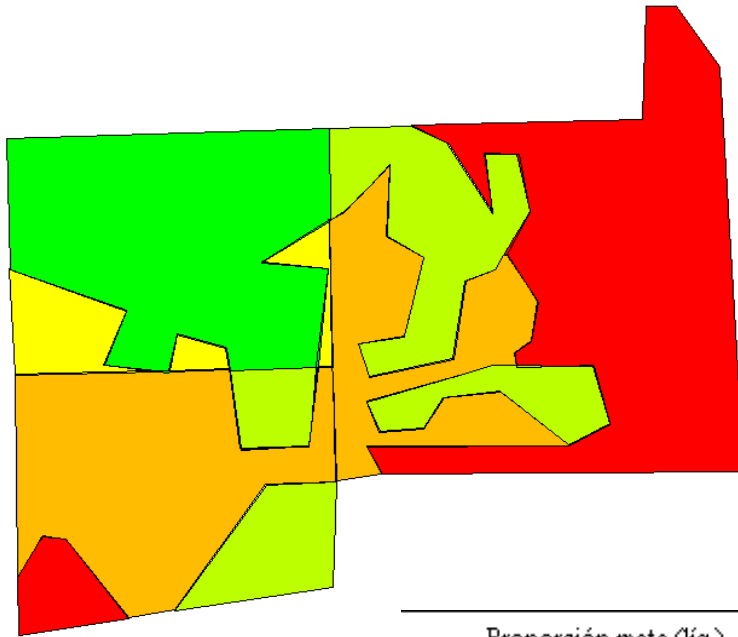


Muestreo dirigido de suelos



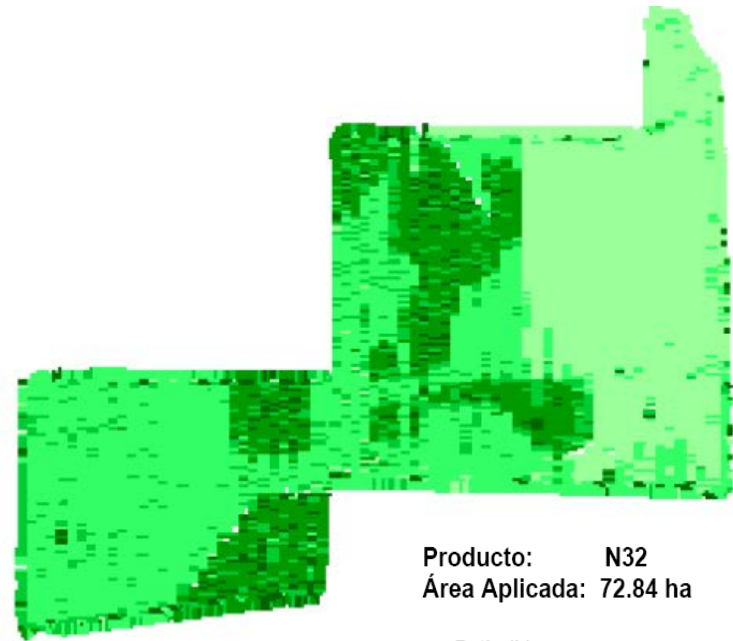


Mapa de prescripción de abonado líquido



| Proporción meta (líq.) (L/ha) | |
|---|------------------|
| ■ | 250.0 (20.24 ha) |
| ■ | 210.0 (16.93 ha) |
| ■ | 170.0 (4.15 ha) |
| ■ | 140.0 (25.95 ha) |
| ■ | 70.0 (28.58 ha) |

Mapa de aplicación de abonado líquido

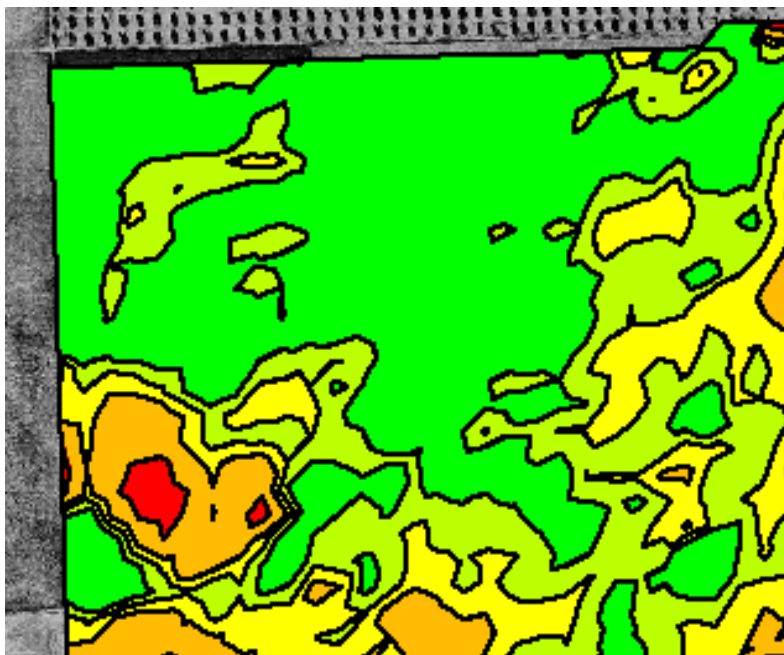


Producto: N32
Área Aplicada: 72.84 ha

| Ratio (L): | |
|--|------|
| ■ | 250 |
| ■ | 210 |
| ■ | 170 |
| ■ | 140 |
| ■ | 70.0 |

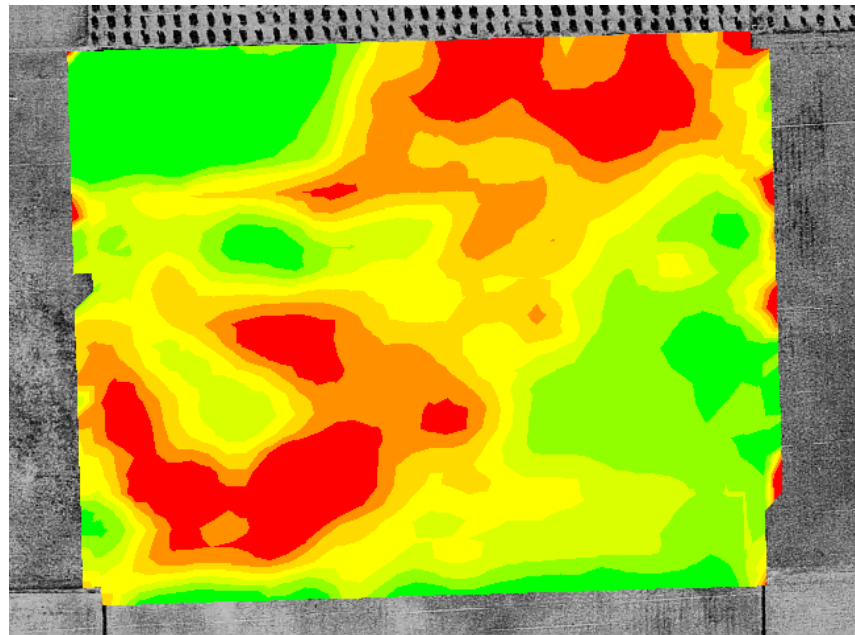


CEa del suelo de 0 a 30 cm (mS/m)



| | |
|---|----------------|
| ■ | 76.16 - 260.51 |
| ■ | 64.61 - 76.16 |
| ■ | 53.20 - 64.61 |
| ■ | 34.50 - 53.20 |
| ■ | 3.00 - 34.50 |

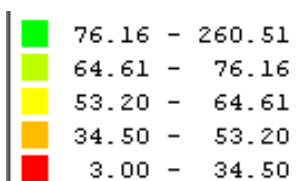
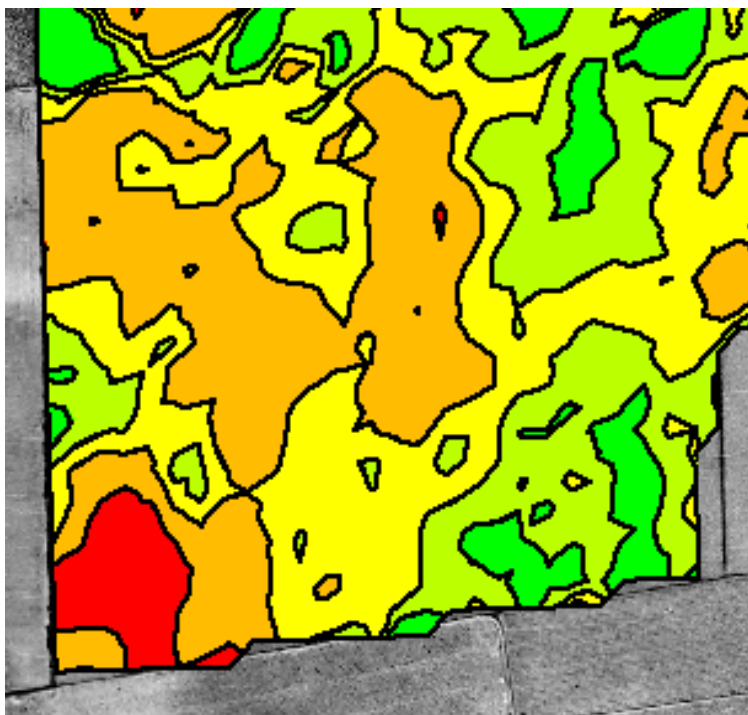
Mapa de rendimiento de triticale



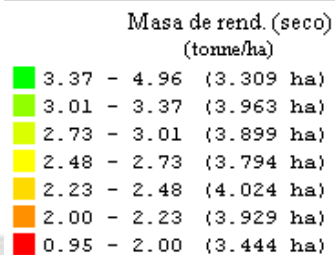
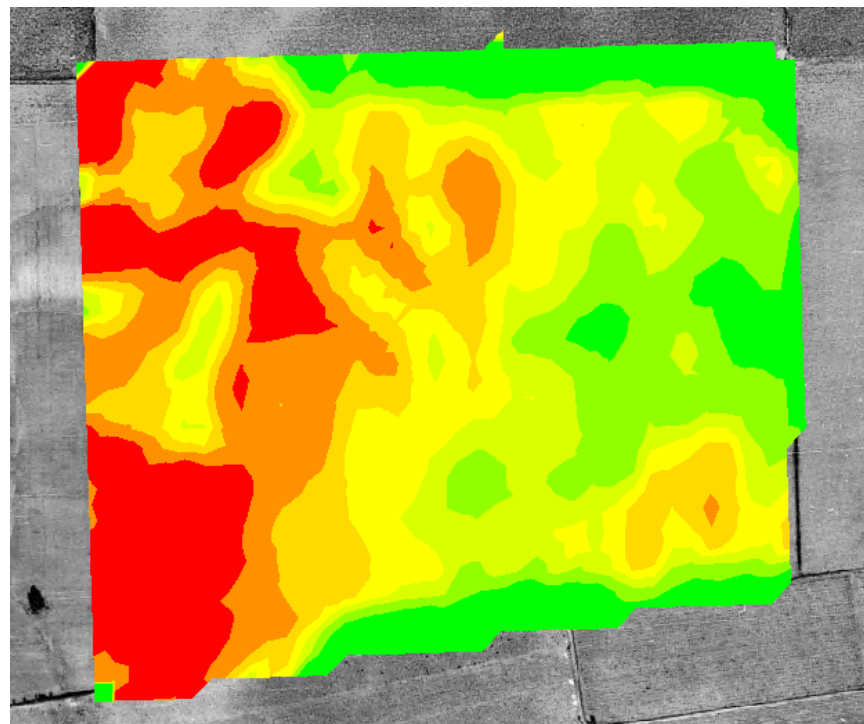
Masa de rend. (seco)
(tonne/ha)

| | |
|---|------------------------|
| ■ | 3.37 - 4.96 (3.309 ha) |
| ■ | 3.01 - 3.37 (3.963 ha) |
| ■ | 2.73 - 3.01 (3.899 ha) |
| ■ | 2.48 - 2.73 (3.794 ha) |
| ■ | 2.23 - 2.48 (4.024 ha) |
| ■ | 2.00 - 2.23 (3.929 ha) |
| ■ | 0.95 - 2.00 (3.444 ha) |

CEa del suelo de 0 a 30 cm (mS/m)



Mapa de rendimiento de trigo



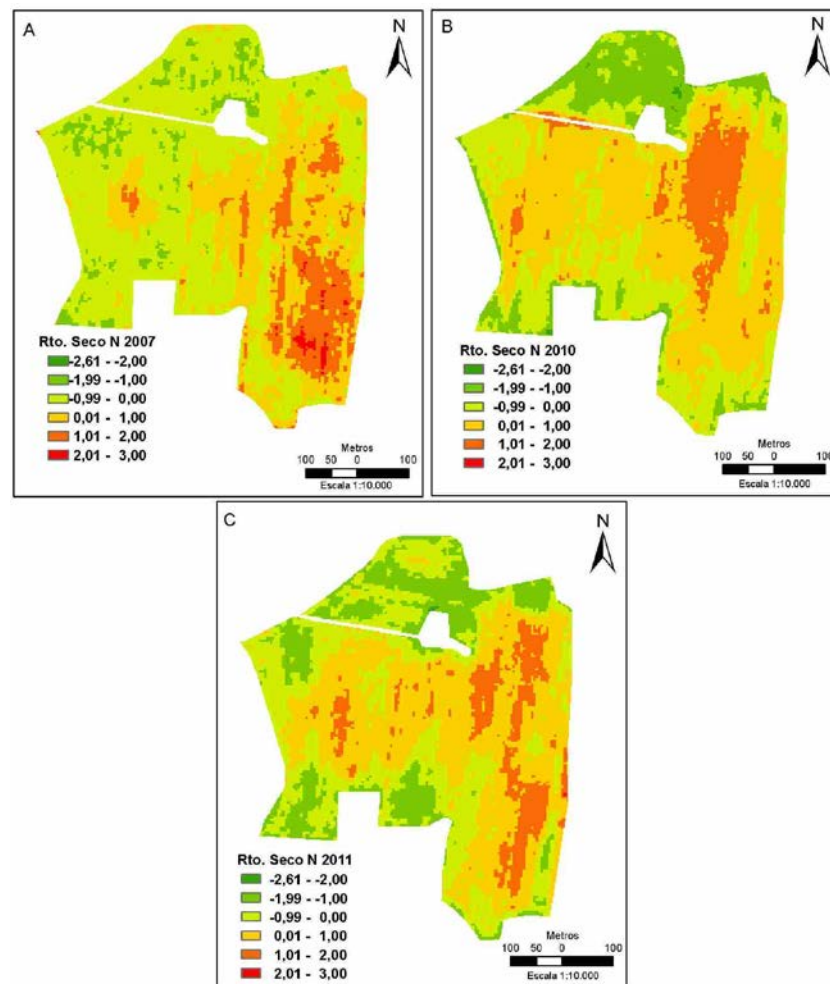
Mapas de producción de girasol

Producciones reales

| Campaña | 2007 | 2010 | 2011 |
|---------------------------|------|-------|-------|
| Mínimo (Tm/ha) | 0,12 | 0,10 | 0,47 |
| Máximo (Tm/ha) | 1,70 | 1,80 | 2,98 |
| Media (Tm/ha) | 0,53 | 0,87 | 1,67 |
| Desviación típica (Tm/ha) | 0,24 | 0,33 | 0,47 |
| Mediana (Tm/ha) | 0,49 | 0,89 | 1,69 |
| Coefficiente de sesgo | 0,93 | -0,13 | -0,02 |
| Curtosis | 4,14 | 2,55 | 2,12 |
| Primer Cuartil (Tm/ha) | 0,34 | 0,64 | 1,27 |
| Tercer Cuartil (Tm/ha) | 0,67 | 1,10 | 2,04 |

Producciones normalizadas

| Campaña | 2007 | 2010 | 2011 |
|-----------------------|-------|-------|-------|
| Mínimo | -1,74 | -2,36 | -2,57 |
| Máximo | 4,80 | 2,86 | 2,81 |
| Mediana | -0,16 | 0,07 | 0,04 |
| Coefficiente de sesgo | 0,93 | -0,13 | -0,02 |
| Curtosis | 4,14 | 2,55 | 2,12 |
| Primer Cuartil | -0,76 | -0,69 | -0,85 |
| Tercer Cuartil | 0,60 | 0,70 | 0,81 |



Mapas del RSN.

A) 2007.

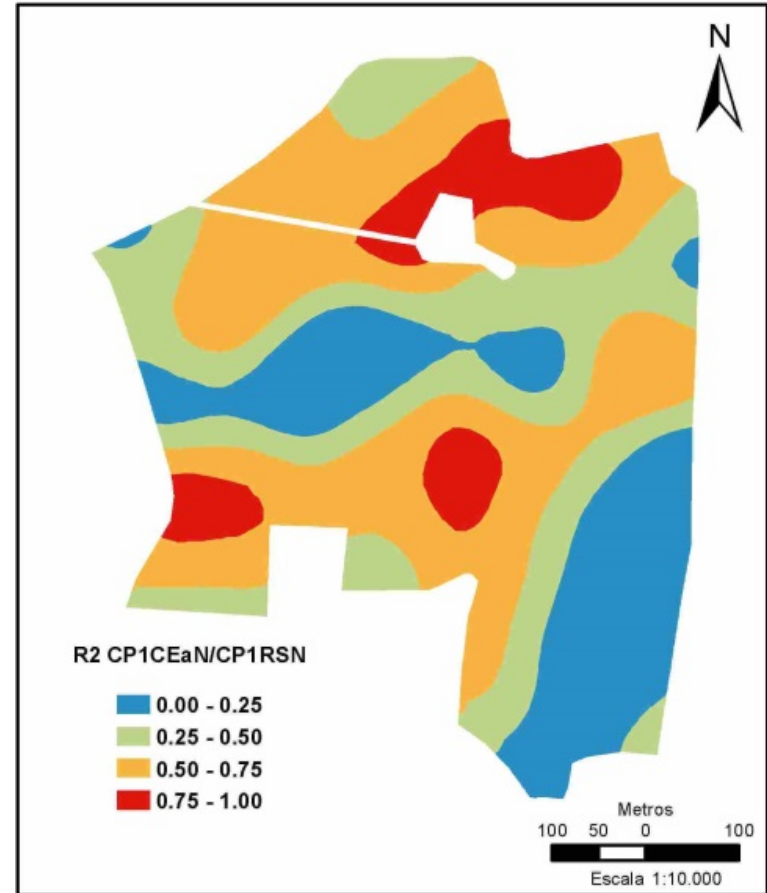
B) 2010.

C) 2011.

Comparación entre CEs y las producciones de girasol

Superficies y porcentajes de ocupación

| R2 local | Superficie (ha) | Ocupación |
|-------------|-----------------|-----------|
| 0,00 – 0,25 | 7,51 | 23,46 % |
| 0,25 – 0,50 | 9,18 | 28,66 % |
| 0,50 – 0,75 | 12,22 | 38,16 % |
| 0,75 – 1,00 | 3,11 | 9,72 % |

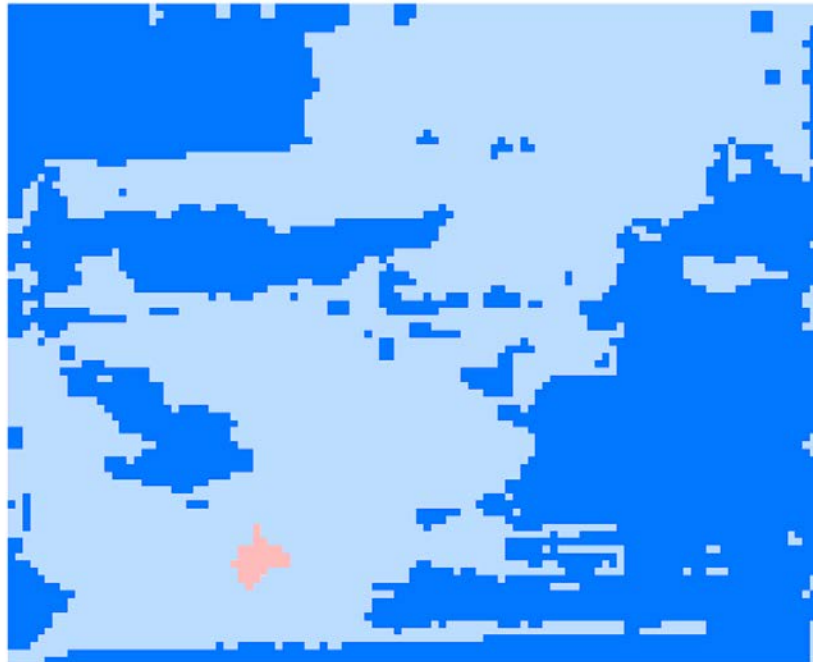


Mapa de coeficiente de determinación R2 entre la CEs, y la producción de girasol.



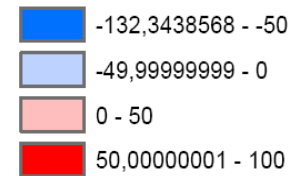


Balance de nitrógeno en triticale



N_triticale.tif

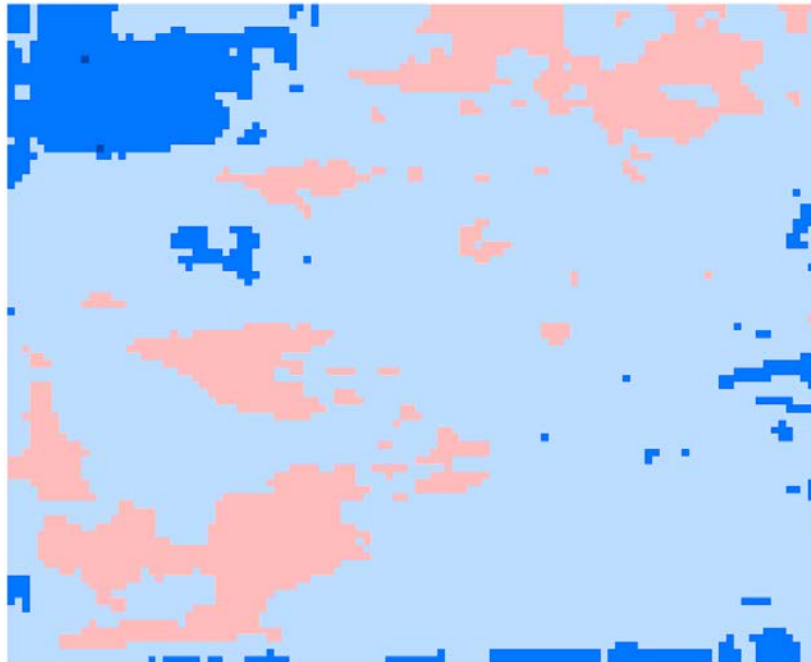
<VALUE>



| | U.F.N | Has |
|--------------|-----------|--------------|
| Déficit | -1.223,88 | 24,39 |
| Superávit | 0,32 | 0,08 |
| TOTAL | | 24,47 |

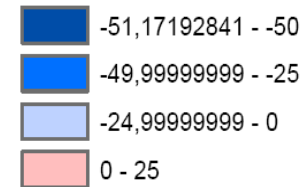


Balance de fósforo en triticales



P_triticales.tif

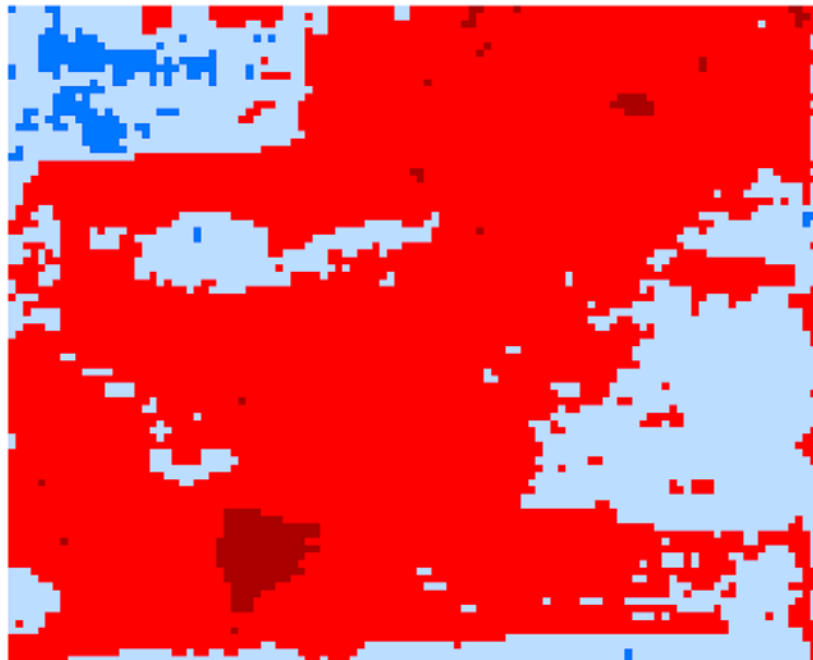
<VALUE>



| | U.F.P ₂ O ₅ | Has |
|-----------|-----------------------------------|-------|
| Déficit | -258,99 | 20,40 |
| Superávit | 14,15 | 4,07 |
| TOTAL | | 24,47 |

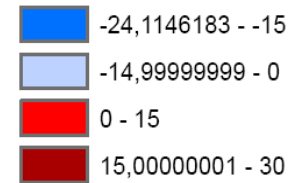


Balance de potasio en triticale



K_triticale.tif

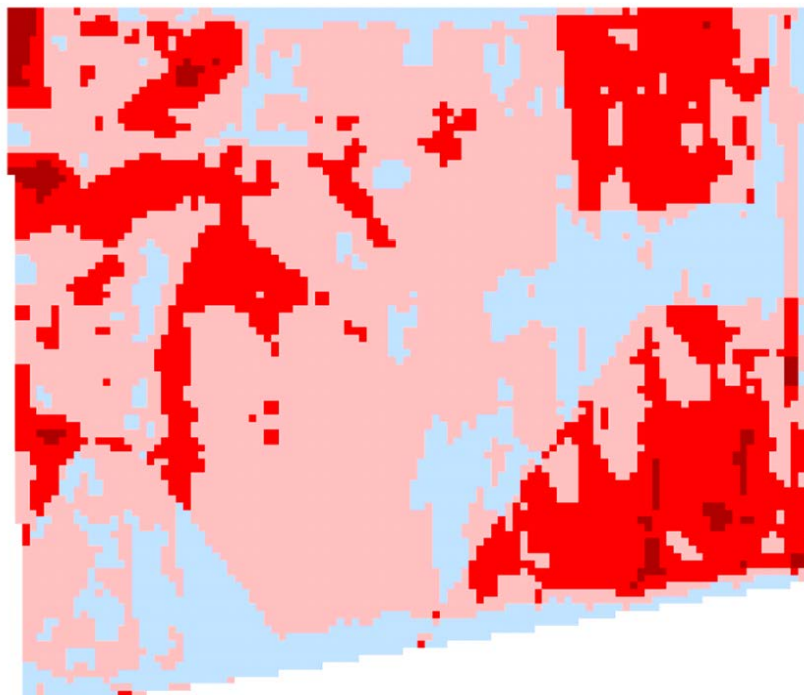
<VALUE>



| | U.F.K ₂ O | Has |
|-----------|----------------------|-------|
| Déficit | -38,80 | 7,09 |
| Superávit | 120,22 | 17,38 |
| TOTAL | | 24,47 |

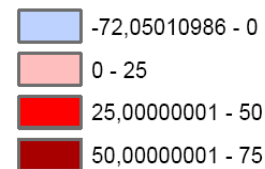


Balace de nitrógeno en trigo



N_trigo.tif

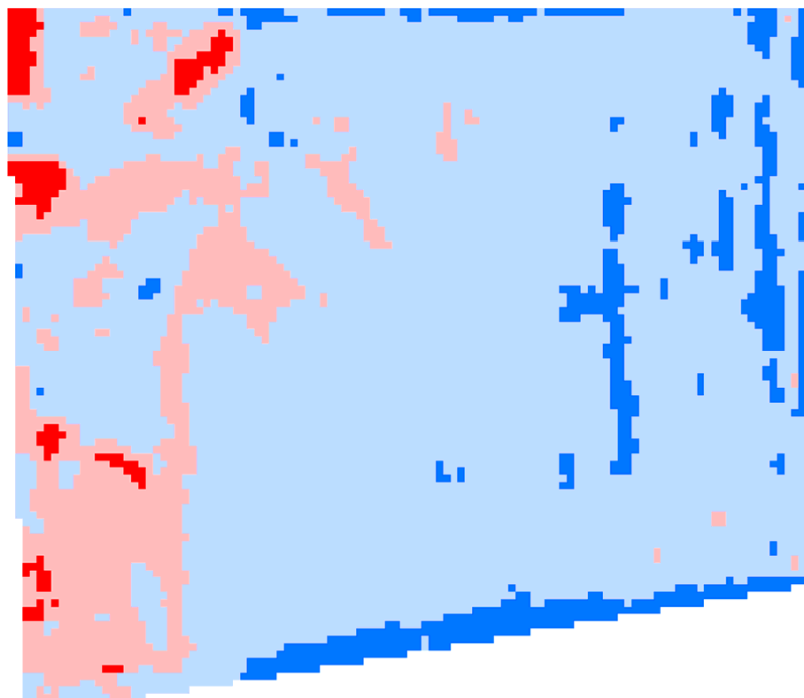
<VALUE>



| | U.F.N | Has |
|--------------|--------|--------------|
| Déficit | -52,02 | 4,9 |
| Superávit | 377,61 | 19,10 |
| TOTAL | | 24,00 |

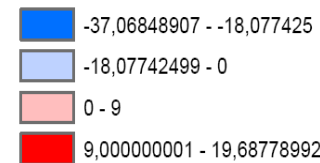


Balance de fósforo en trigo



P_trigo_Clip

<VALUE>



| | U.F.P ₂ O ₅ | Has |
|-----------|-----------------------------------|-------|
| Déficit | -206,46 | 20,18 |
| Superávit | 16,16 | 3,82 |
| TOTAL | | 24,00 |

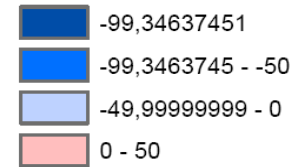


Balance de potasio en trigo



K_trigo_Clip

<VALUE>



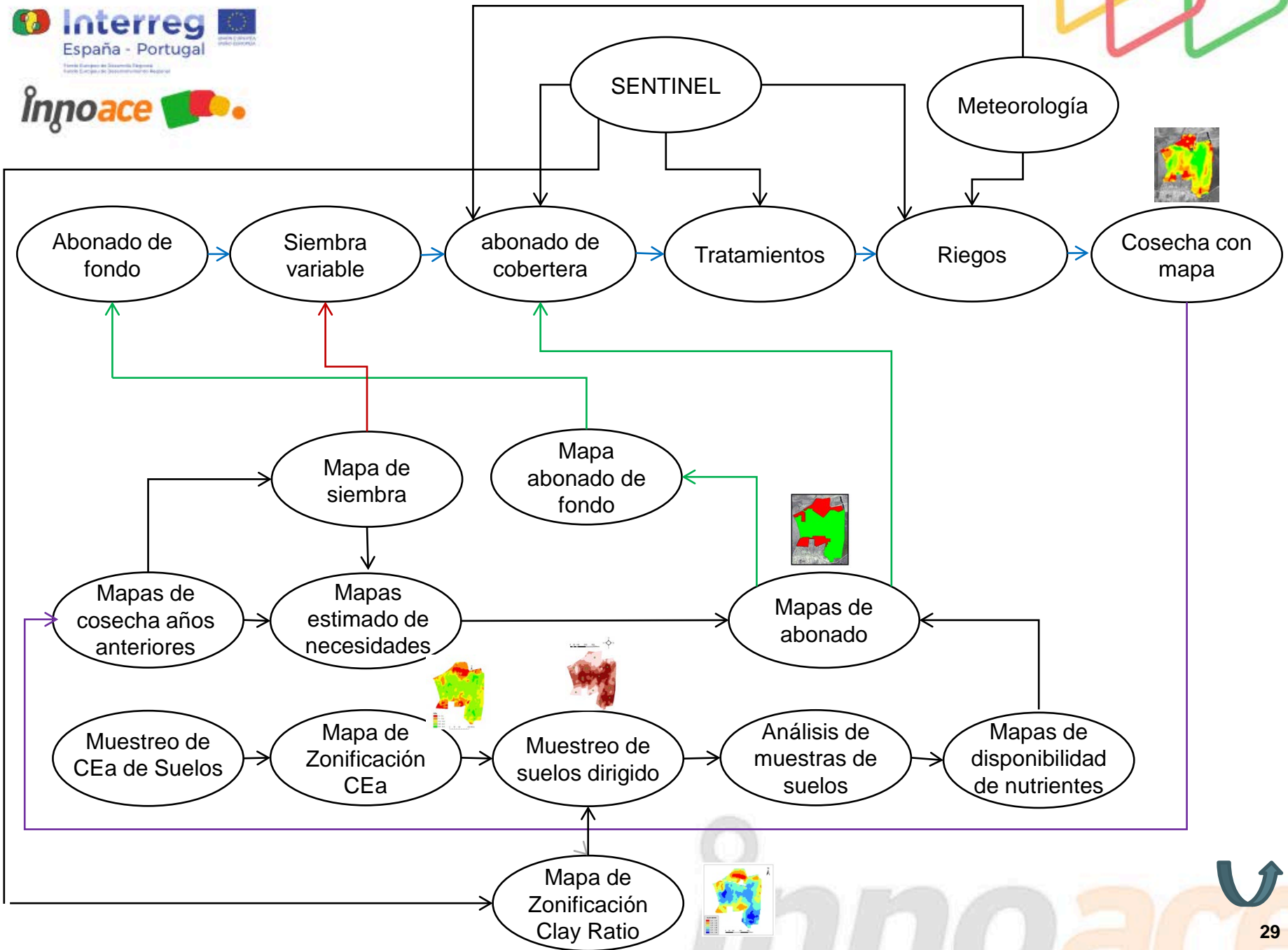
| | U.F.K ₂ O | Has |
|-----------|----------------------|-------|
| Déficit | -1035,39 | 23,93 |
| Superávit | 0,29 | 0,07 |
| TOTAL | | 24,00 |



Tabla Resumen del Balance de Nutrientes

| | N | | P2O5 | | K2O | |
|-----------|-----------|-----------|---------|-----------|-----------|-----------|
| | Déficit | Superavit | Déficit | Superavit | Déficit | Superavit |
| Triticale | -1.223,88 | 0,32 | -258,99 | 14,15 | -38,80 | 120,22 |
| Trigo | -52,02 | 377,61 | -206,46 | 16,16 | -1.035,39 | 0,29 |
| TOTALES | -1.275,91 | 377,93 | -465,45 | 30,30 | -1.074,19 | 120,51 |
| TOTALES | -897,98 | | -435,15 | | -953,68 | |







**Muchas
gracias!**