



# Cálculo de la fracción evaporativa con imágenes MODIS

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# 1. FUNDAMENTOS

La fracción evaporativa (FE) se define como la relación entre el flujo de calor latente (LE) y la energía total disponible (flujo de calor latente+flujo de calor sensible) (Shuttleworth et al., 1989)

$$R_n = LE + H + G$$



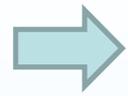
$$FE = \frac{\lambda E}{R_n - G}$$

Hay diferentes métodos para estimar la FE desde satélite (ej: inercia térmica,  $T_{s_{\text{día}}} - T_{s_{\text{noche}}}$ ). Utilizaremos un modelo sencillo semi-empírico que utiliza la relación existente entre la temperatura radiativa de superficie ( $T_s$ ) e índice de vegetación (IV).

A partir de la relación entre  $T_s$  e IV obtendremos el índice de estrés hídrico TVDI y posteriormente la FE.

# Temperature Vegetation Dryness Index (TVDI)

## Indice de vegetación



Respuesta en **IRc** y **rojo** → vigorosidad y salud de la vegetación por cambios en **Hs**

Baja Hs

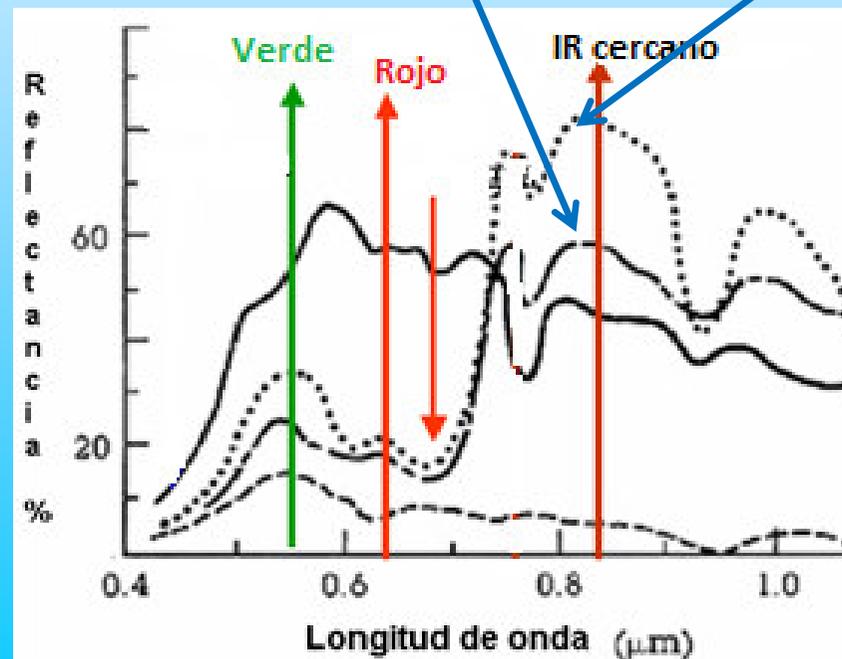


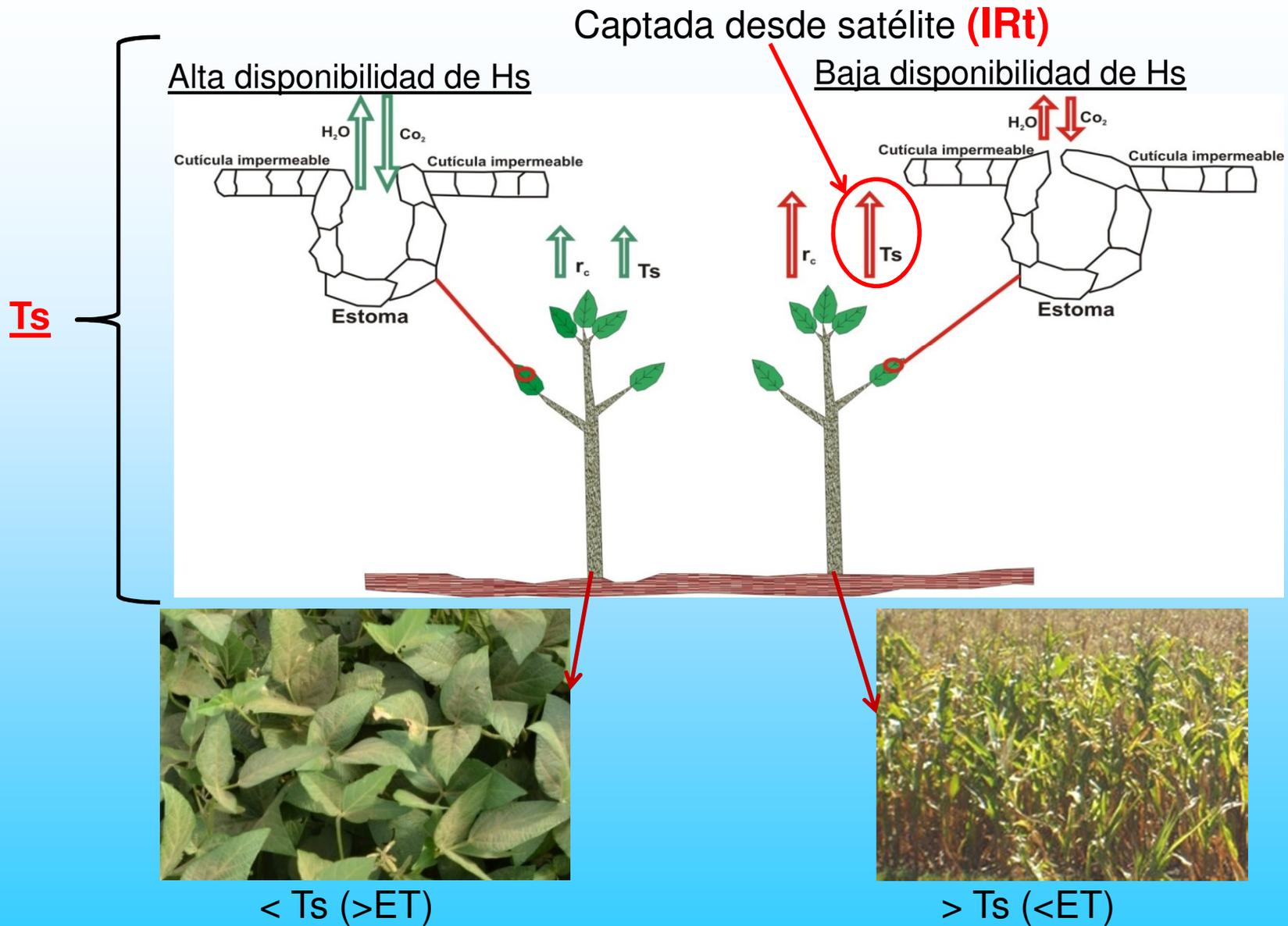
> Ts (<ET)

Alta Hs



< Ts (>ET)



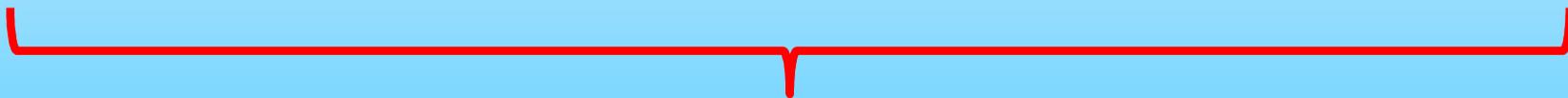


*La humedad del suelo como factor limitante de la evapotranspiración.*

**Índices de vegetación:** muestran los cambios en etapas avanzadas de estrés hídrico.

**Ts es mucho más dinámica,** incrementándose al inicio del estrés.

**Incremento del estrés hídrico**

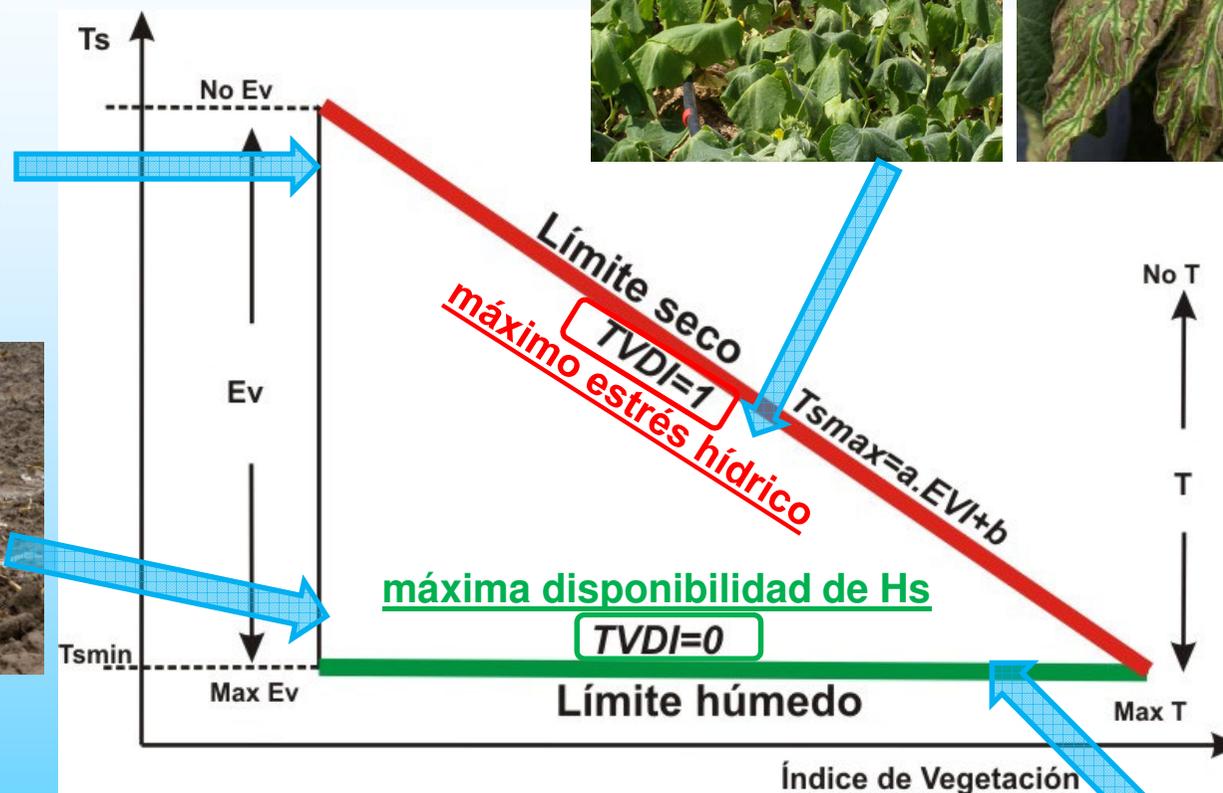


**Ts** aumenta durante todo el proceso



**Índice de vegetación** disminuye en etapas avanzadas

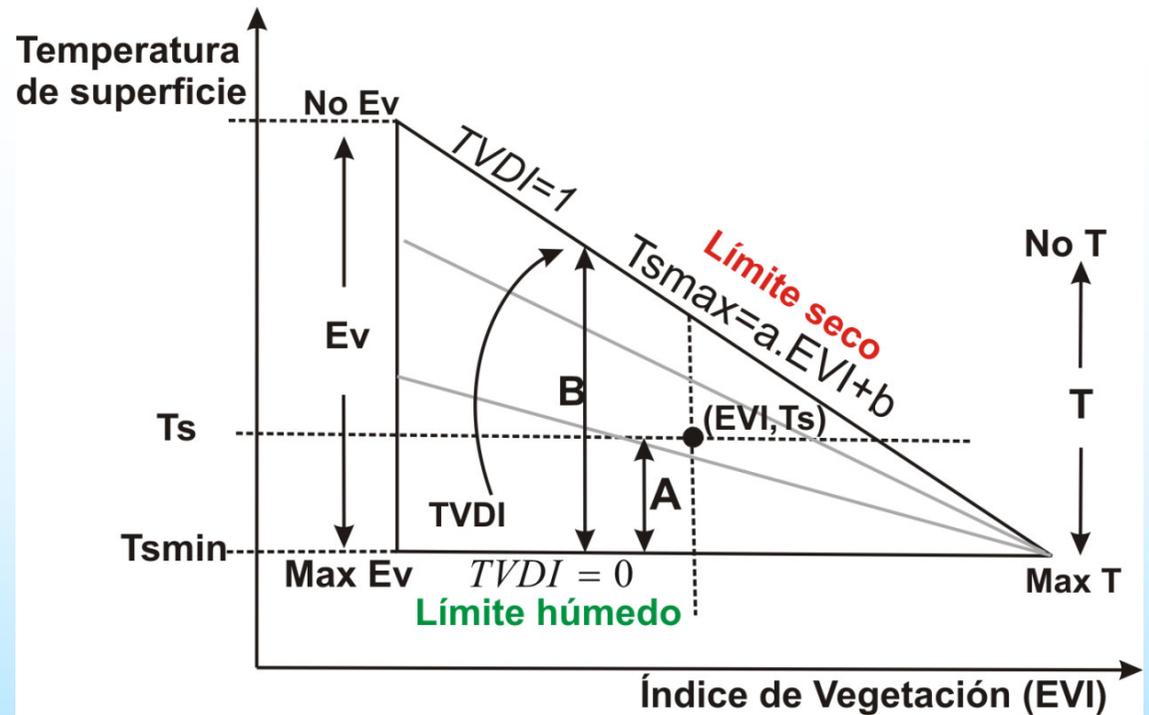
# Triángulo de dispersión Ts e índice de vegetación



*(En áreas con condiciones heterogéneas de grados de cobertura vegetal y humedad del suelo)*



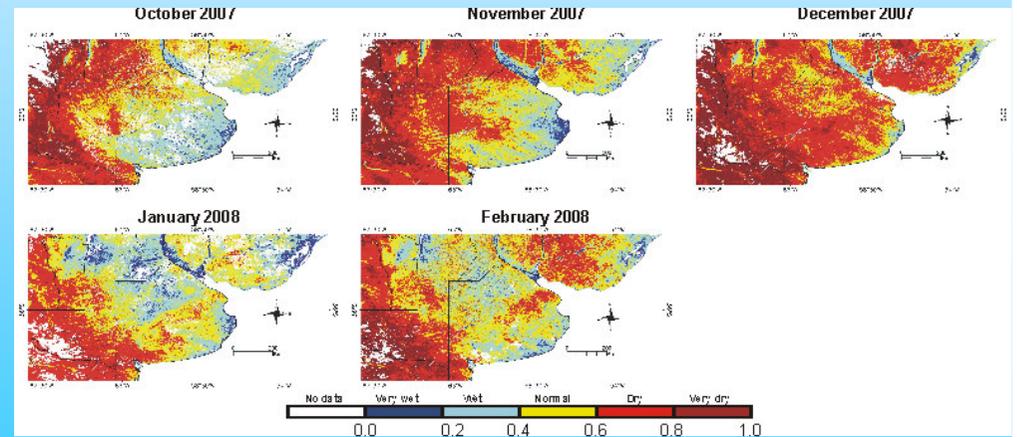
$$TVDI = \frac{T_s - T_{s \min}}{T_{s \max} - T_{s \min}}$$



**T<sub>s</sub>**: temperatura (K) de superficie para un píxel dado;

**T<sub>s min</sub>**: mínima temperatura de superficie en la imagen, definida por el límite húmedo;

**T<sub>s max</sub> = a.EVI + b**: máxima temperatura de superficie de la imagen y se refiere al límite seco del triángulo, definido como una relación lineal entre los datos, donde **a** y **b** son parámetros de la imagen.



Holzman, M.E., Rivas, R. y Piccolo, M.C., 2014. Estimating soil moisture and the relationship with crop yield using surface temperature and vegetation index. International Journal of Applied Earth Observation and Geoinformation, 28: 181-192. ISSN: 0303-2434.

<http://www.sciencedirect.com/science/article/pii/S0303243413001748#>

## Validación del método en la región pampeana

- *Holzman, M.E., Rivas, R. y Bayala, M., 2014. Subsurface soil moisture estimation by VI-LST method. IEEE Geoscience and Remote Sensing Letters, 11 (11): 1951-1955. ISSN: 1545-598X.*

Utilizamos datos diarios MODIS/Aqua de EVI y Ts.

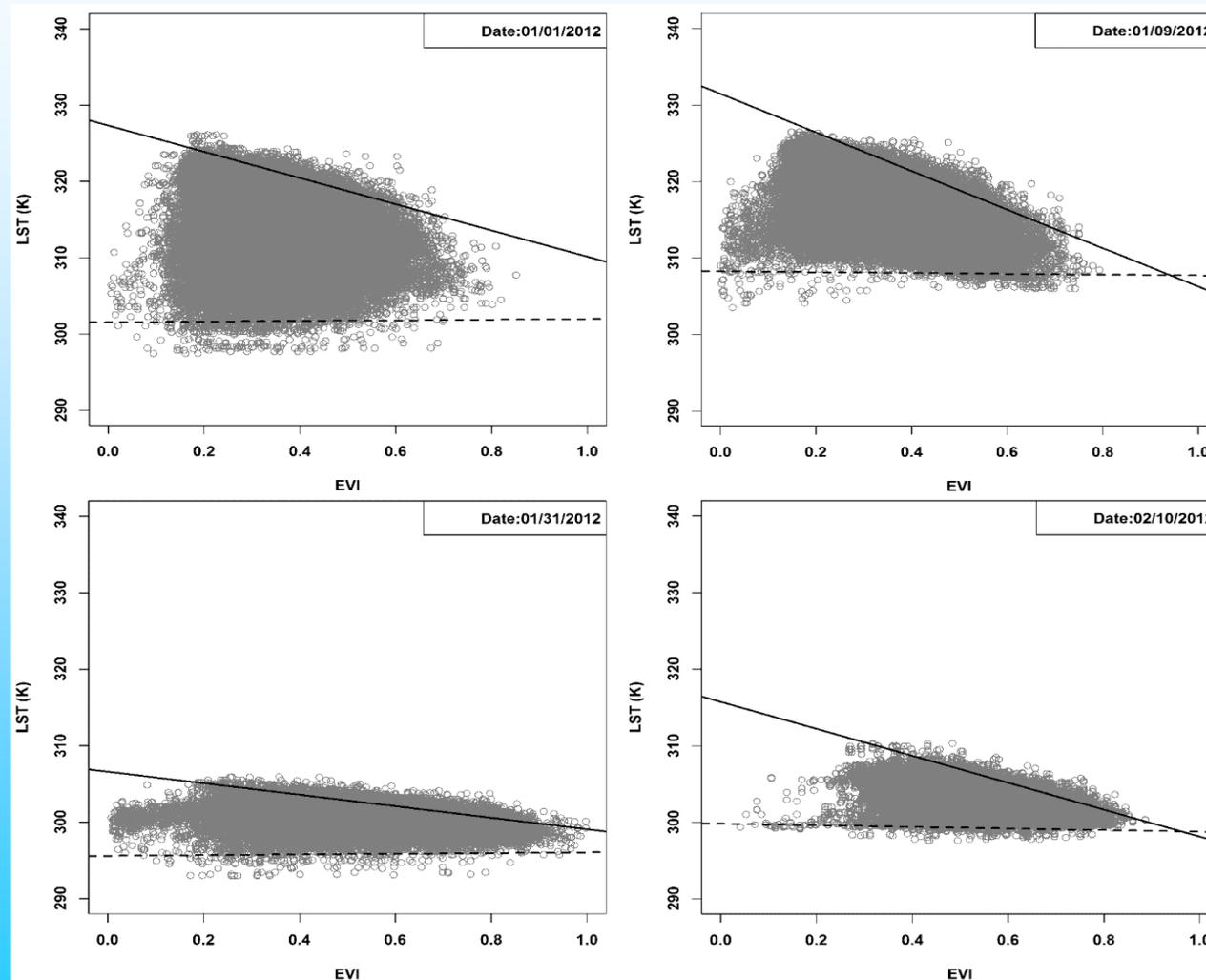
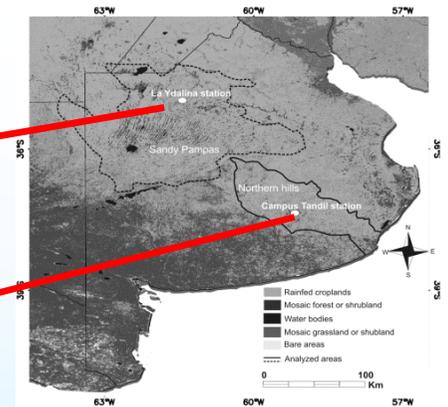
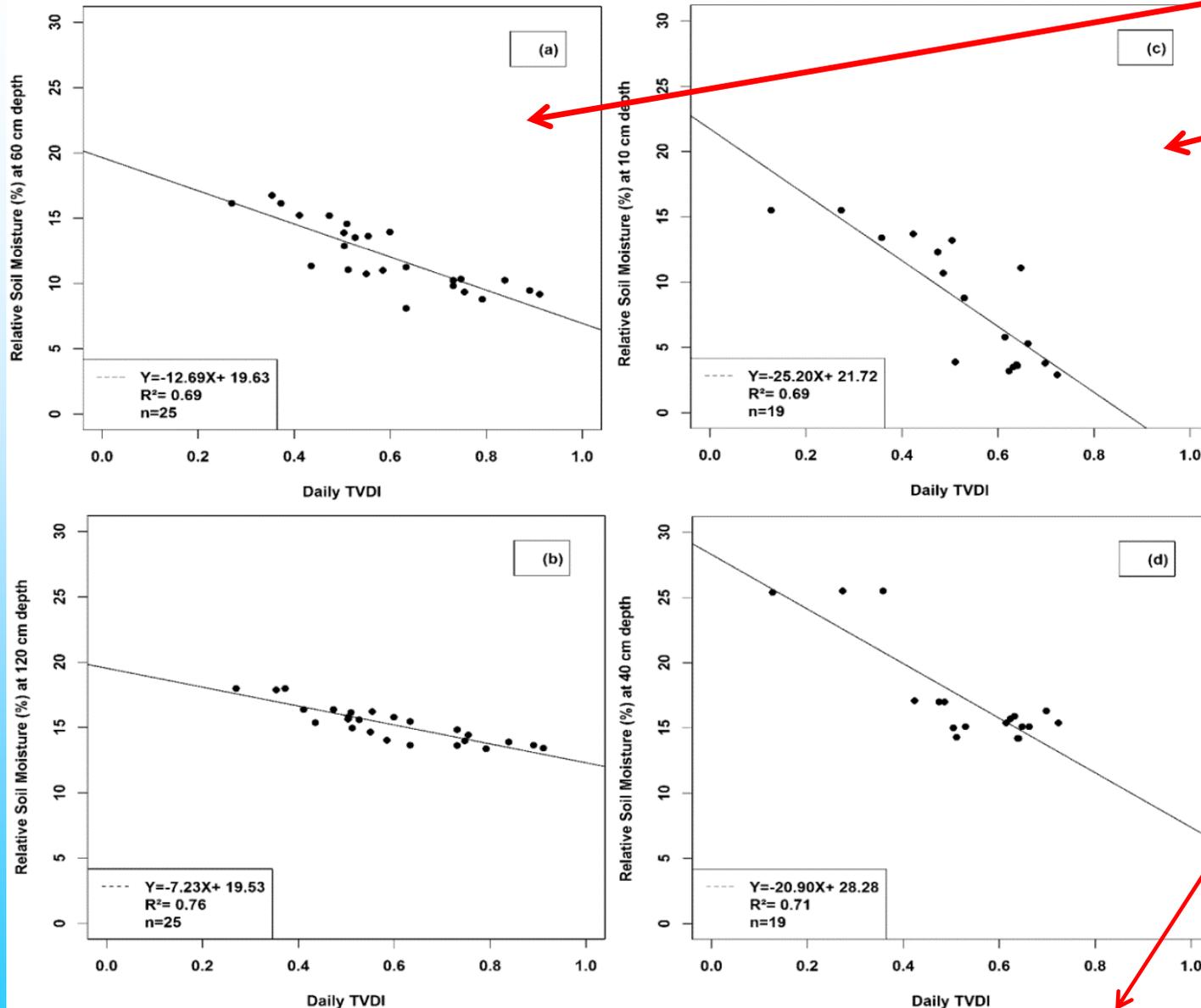


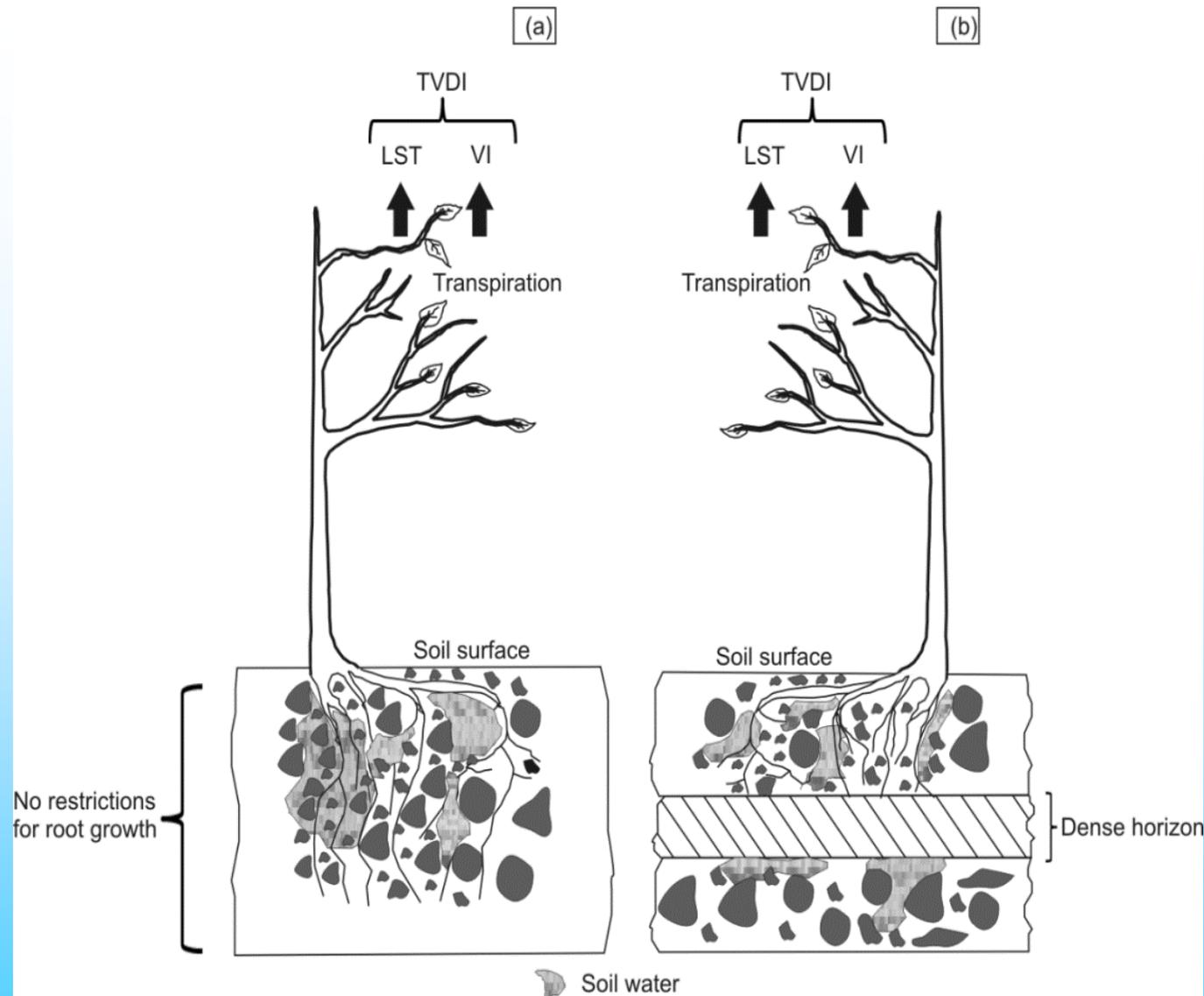
Fig. 4. Scatter plots of EVI and LST for 4 different images of the study period. The extreme dry edge corresponded to 9 January 2012 and wet edge corresponded to 31 January 2012.

# Comparación con la Hs medida a campo.



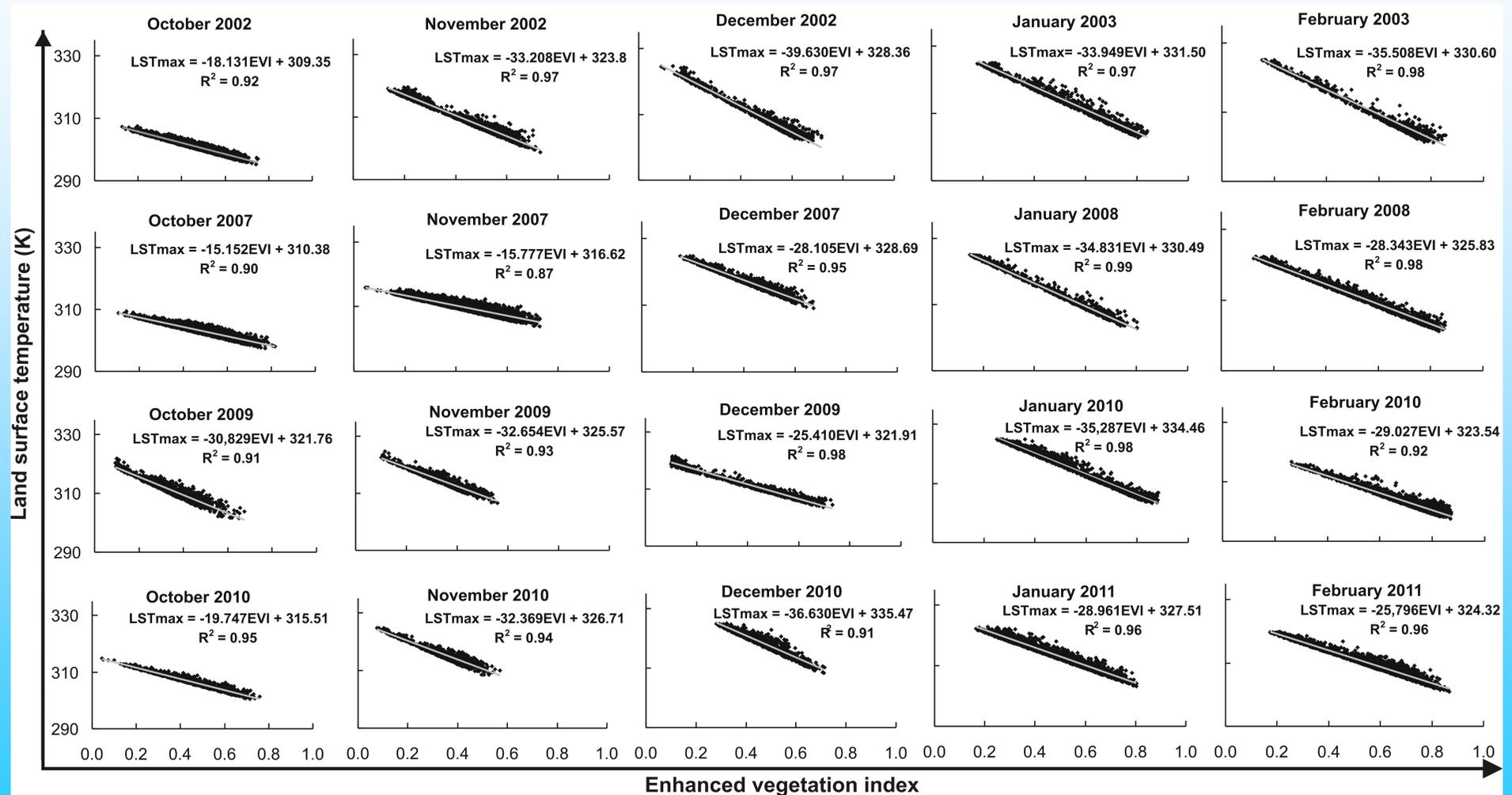
Sin correlación con el sensor a 60 cm

Fig. 5. Relationship between daily TVDI and relative SM at different soil depths in (a) and (b) La Ydalina Station and (c) and (d) Campus Tandil station.

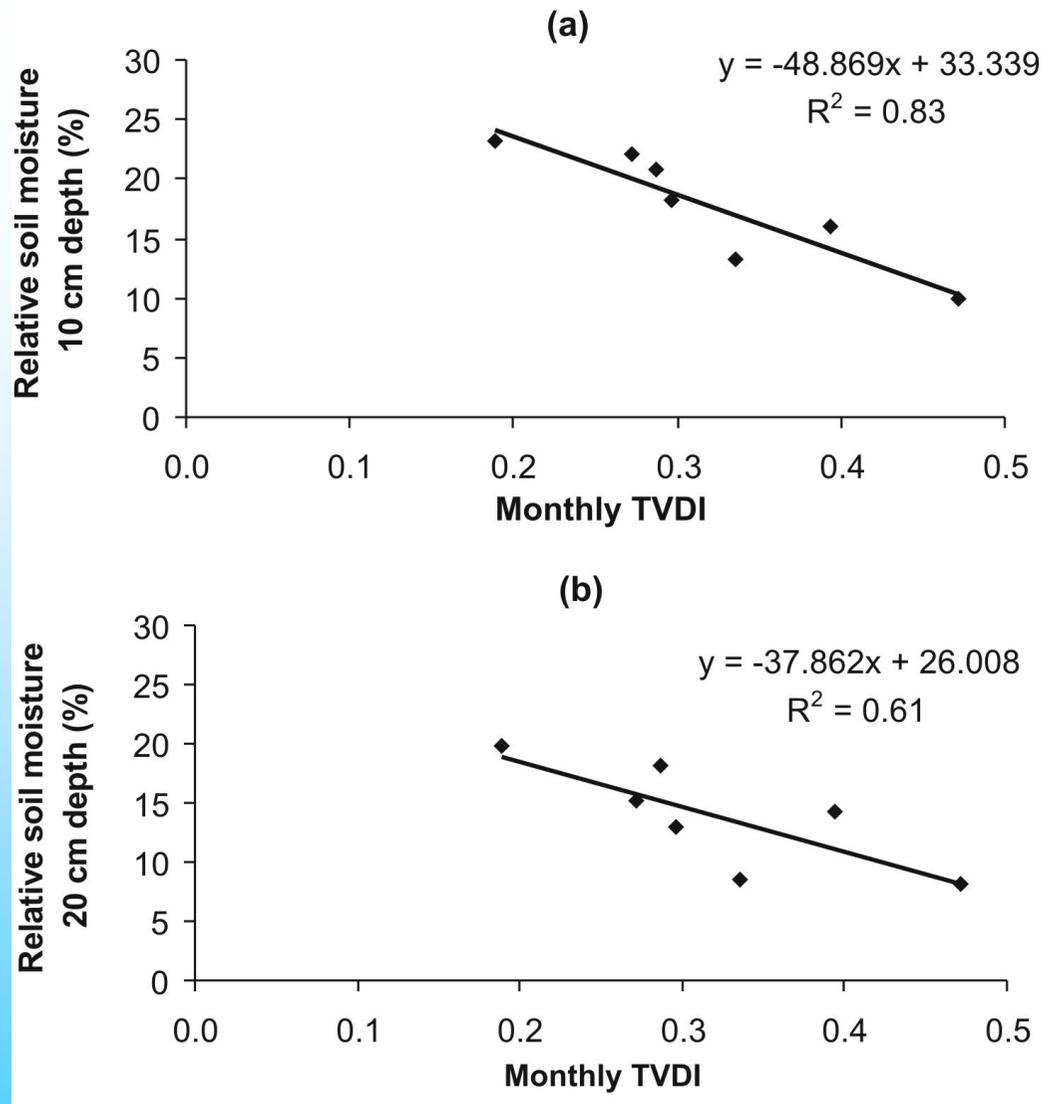


*Fig. 6. Illustration of the relationship between transpiration process and TVDI in (a) deep root system and (b) shallow root system or soils with dense horizon. The TVDI would show subsurface soil water content depending on root system distribution in the soil profile.*

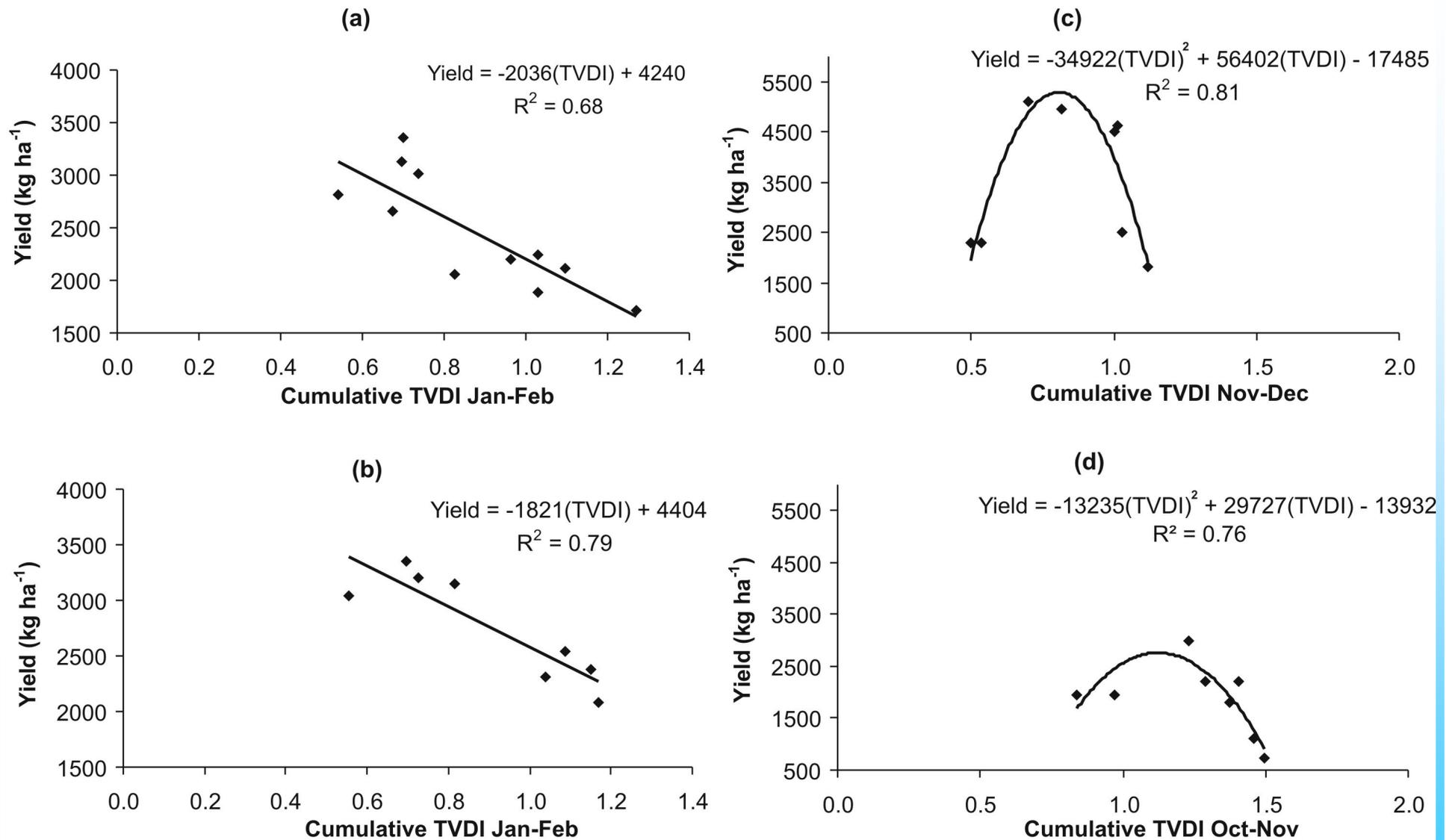
- *Holzman, M.E., Rivas, R. y Piccolo, M.C., 2014. Estimating soil moisture and the relationship with crop yield using surface temperature and vegetation index. International Journal of Applied Earth Observation and Geoinformation, 28: 181-192. ISSN: 0303-2434.*



*Fig. 3. Dry edges from MODIS AQUA over the four study periods.*



*Fig. 5. Scatterplots of corresponding monthly TVDI and soil moisture measurements for Campus Tandil (Northern hills).*



*Fig. 7. Relationship between crop yield and cumulative TVDI of critical growth stage: (a) soybean in Sandy Pampas, (b) soybean in Endorreic Pampas, (c) wheat in Northern hills and (d) wheat in Semi-arid Plains.*

# 1. PRACTICO

El **objetivo** del práctico es calcular la **fracción evaporativa** diaria con imágenes producto MODIS/Aqua a escala regional, a partir del índice de estrés hídrico Temperature Vegetation Dryness Index (**TVDI**). La práctica se realizará con imágenes diarias MODIS/Aqua de temperatura de superficie de 1km (Ts) y reflectancias diarias de 500m.

### **Flujo de trabajo:**

- Descarga de las imágenes producto MODIS/Aqua de índice de vegetación y temperatura de superficie.
- Reproyección de las imágenes.
- Obtención de los diagramas de dispersión Ts/índice de vegetación y de los límites húmedo y seco.
- Cálculo del TVDI en base a los parámetros de los límites anteriores.
- Cálculo de la fracción evaporativa en función del TVDI.

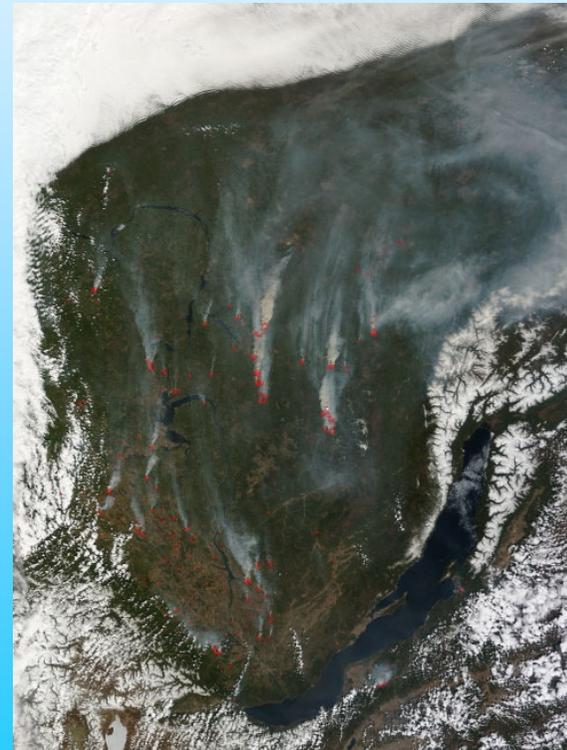
# Productos MODIS

MODIS (MOderate Resolution Imaging Spectroradiometer)

- Es un sensor de 36 bandas (0,4  $\mu\text{m}$  a 14,4  $\mu\text{m}$ )
- Período de revisita: 1 días aprox.
- A bordo del satélite Terra (AM) y Aqua (PM)
- Resolución espacial: 250 m (bandas 1-2), 500 m (bandas 3-7), 1 km (bandas 8-36).



Aqua/MODIS, 1 km



Terra/MODIS, 500 m

<b>Primary Use</b>	<b>Band</b>	<b>Bandwidth<sup>1</sup></b>
<b>Land/Cloud/Aerosols Boundaries</b>	1	620 - 670
	2	841 - 876
<b>Land/Cloud/Aerosols Properties</b>	3	459 - 479
	4	545 - 565
	5	1230 - 1250
	6	1628 - 1652
	7	2105 - 2155
<b>Ocean Color/ Phytoplankton/ Biogeochemistry</b>	8	405 - 420
	9	438 - 448
	10	483 - 493
	11	526 - 536
	12	546 - 556
	13	662 - 672
	14	673 - 683
	15	743 - 753
	16	862 - 877
<b>Atmospheric Water Vapor</b>	17	890 - 920
	18	931 - 941
	19	915 - 965
<b>Surface/Cloud Temperature</b>	20	3.660 - 3.840
	21	3.929 - 3.989
	22	3.929 - 3.989
	23	4.020 - 4.080
<b>Atmospheric Temperature</b>	24	4.433 - 4.498
	25	4.482 - 4.549
<b>Cirrus Clouds Water Vapor</b>	26	1.360 - 1.390
	27	6.535 - 6.895
	28	7.175 - 7.475
<b>Cloud Properties</b>	29	8.400 - 8.700
<b>Ozone</b>	30	9.580 - 9.880
<b>Surface/Cloud Temperature</b>	31	10.780 - 11.280
	32	11.770 - 12.270
<b>Cloud Top Altitude</b>	33	13.185 - 13.485
	34	13.485 - 13.785
	35	13.785 - 14.085
	36	14.085 - 14.385

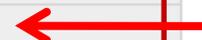
<sup>1</sup> Bands 1 to 19 are in nm; Bands 20 to 36 are in  $\mu\text{m}$

## Productos MODIS

(Fuente: [https://lpdaac.usgs.gov/products/modis\\_products\\_table](https://lpdaac.usgs.gov/products/modis_products_table))

Shortname	Platform	MODIS Data Product	Raster type	Res (m)	Temporal Granularity
<a href="#">MOD13Q1</a>	Terra	Vegetation Indices	Tile	250m	16 day
<a href="#">MYD14A1</a>	Aqua	Thermal Anomalies & Fire	Tile	1000m	Daily
<a href="#">MOD14A1</a>	Terra	Thermal Anomalies & Fire	Tile	1000m	Daily
<a href="#">MYD14A2</a>	Aqua	Thermal Anomalies & Fire	Tile	1000m	8 day
<a href="#">MOD14A2</a>	Terra	Thermal Anomalies & Fire	Tile	1000m	8 day
<a href="#">MYD14</a>	Aqua	Thermal Anomalies & Fire	Swath	1000m	5 min
<a href="#">MYD09CMG</a>	Aqua	Surface Reflectance Bands 1–7	CMG	5600m	Daily
<a href="#">MOD09CMG</a>	Terra	Surface Reflectance Bands 1–7	CMG	5600m	Daily
<a href="#">MYD09GQ</a>	Aqua	Surface Reflectance Bands 1–2	Tile	250m	Daily
<a href="#">MOD09GQ</a>	Terra	Surface Reflectance Bands 1–2	Tile	250m	Daily
<a href="#">MYD09GA</a>	Aqua	Surface Reflectance Bands 1–7	Tile	500/1000m	Daily
<a href="#">MYD09A1</a>	Aqua	Surface Reflectance Bands 1–7	Tile	500m	8 day
<a href="#">MYD17A2</a>	Aqua	Gross Primary Productivity	Tile	1000m	8 day
<a href="#">MOD09A1</a>	Terra	Surface Reflectance Bands 1–7	Tile	500m	8 day
<a href="#">MYD09Q1</a>	Aqua	Surface Reflectance Bands 1–2	Tile	250m	8 day
<a href="#">MOD09Q1</a>	Terra	Surface Reflectance Bands 1–2	Tile	250m	8 day
<a href="#">MCD43B4</a>	Combined	Nadir BRDF-Adjusted Reflectance	Tile	1000m	16 day
<a href="#">MCD43A4</a>	Combined	Nadir BRDF-Adjusted Reflectance	Tile	500m	16 day
<a href="#">MCD43C4</a>	Combined	Nadir BRDF-Adjusted Reflectance	CMG	5600m	16 day
<a href="#">MYD15A2</a>	Aqua	Leaf Area Index - FPAR	Tile	1000m	8 day
<a href="#">MOD15A2</a>	Terra	Leaf Area Index - FPAR	Tile	1000m	8 day

Band	Bandwidth <sup>1</sup>
1	620 – 670 (rojo)
2	841 – 876 (IRc)
3	459 – 479 (Azul)
4	545 – 565 (verde)
5	1230 – 1250 (IRc)
6	1628 – 1652 (IRc)
7	2105 – 2155 (IRc)



<a href="#">MOD15A2</a>	Terra	Leaf Area Index - FPAR	Tile	1000m	8 day
<a href="#">MCD15A3</a>	Combined	Leaf Area Index - FPAR	Tile	1000m	4 day
<a href="#">MOD44W</a>	Terra	Land Water Mask Derived	Tile	250m	None
<a href="#">MYD11C3</a>	Aqua	Land Surface Temperature & Emissivity	CMG	5600m	Monthl
<a href="#">MOD11C3</a>	Terra	Land Surface Temperature & Emissivity	CMG	5600m	Monthl
<a href="#">MYD11B1</a>	Aqua	Land Surface Temperature & Emissivity	Tile	5600m	Daily
<a href="#">MOD11B1</a>	Terra	Land Surface Temperature & Emissivity	Tile	5600m	Daily
<a href="#">MYD11A1</a>	Aqua	Land Surface Temperature & Emissivity	Tile	1000m	Daily
<a href="#">MYD11C1</a>	Aqua	Land Surface Temperature & Emissivity	CMG	5600m	Daily
<a href="#">MOD11C1</a>	Terra	Land Surface Temperature & Emissivity	CMG	5600m	Daily
<a href="#">MOD11A2</a>	Terra	Land Surface Temperature & Emissivity	Tile	1000m	8 day
<a href="#">MYD11C2</a>	Aqua	Land Surface Temperature & Emissivity	CMG	5600m	8 day
<a href="#">MOD11C2</a>	Terra	Land Surface Temperature & Emissivity	CMG	5600m	8 day
<a href="#">MYD11 L2</a>	Aqua	Land Surface Temperature & Emissivity	Swath	1000m	5 min
<a href="#">MCD12Q1</a>	Combined	Land Cover Type	Tile	500m	Yearly
<a href="#">MCD12C1</a>	Combined	Land Cover Type	CMG	5600m	Yearly
<a href="#">MCD12Q2</a>	Combined	Land Cover Dynamics	Tile	500m	Yearly



<a href="#">MCD43B3</a>	Combined	Albedo	Tile	1000m	16 day
<a href="#">MCD43C3</a>	Combined	Albedo	CMG	5000m	16 day
<a href="#">MYD13C2</a>	Aqua	Vegetation Indices	CMG	5000m	Monthly
<a href="#">MOD13C2</a>	Terra	Vegetation Indices	CMG	5000m	Monthly
<a href="#">MYD13C1</a>	Aqua	Vegetation Indices	CMG	5000m	16 day
<a href="#">MOD13C1</a>	Terra	Vegetation Indices	CMG	5000m	16 day
<a href="#">MYD13A3</a>	Aqua	Vegetation Indices	Tile	1000m	Monthly
<a href="#">MOD13A3</a>	Terra	Vegetation Indices	Tile	1000m	Monthly
<a href="#">MYD13Q1</a>	Aqua	Vegetation Indices	Tile	250m	16 day
<a href="#">MYD13A2</a>	Aqua	Vegetation Indices	Tile	1000m	16 day
<a href="#">MOD13A2</a>	Terra	Vegetation Indices	Tile	1000m	16 day
<a href="#">MYD13A1</a>	Aqua	Vegetation Indices	Tile	500m	16 day
<a href="#">MCD43B2</a>	Combined	BRDF-Albedo Quality	Tile	1000m	16 day
<a href="#">MYD11A2</a>	Aqua	Land Surface Temperature & Emissivity	Tile	1000m	8 day
<a href="#">MCD45A1</a>	Combined	Burned Area	Tile	500m	Monthly
<a href="#">MOD11A1</a>	Terra	Land Surface Temperature & Emissivity	Tile	1000m	Daily
<a href="#">MOD44B</a>	Terra	Vegetation Continuous Fields	Tile	250m	Yearly
<a href="#">MOD14</a>	Terra	Thermal Anomalies & Fire	Swath	1000m	5 min
<a href="#">MOD17A3</a>	Terra	Net Primary Productivity	Tile	1000m	Yearly
<a href="#">MCD15A2</a>	Combined	Leaf Area Index - FPAR	Tile	1000m	8 day
<a href="#">MOD13A1</a>	Terra	Vegetation Indices	Tile	500m	16 day
<a href="#">MCD43A3</a>	Combined	Albedo	Tile	500m	16 day
<a href="#">MOD11_L2</a>	Terra	Land Surface Temperature & Emissivity	Swath	1000m	5 min
<a href="#">MOD09GA</a>	Terra	Surface Reflectance Bands 1-7	Tile	500/1000m	Daily

# Nomenclatura de los productos

