Spatial Estimation Of Evaporation And Its Potential For Water Resources Management

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Another project sponsored by www.wrc.org.za

Introduction

Hydrological **process** studies (field-scale disaggregating)

Paired catchment studies (large scale integrating)

1935: Start of hydrological research in SA
Establishment of long-term paired catchment studies
Assess afforestation (later also agriculture) on streamflow

1970-1997: Tools to estimate impact of afforestation on streamflow
Nänni curves (Nänni, 1970)
Van der Zel curves (Van der Zel, 1990)

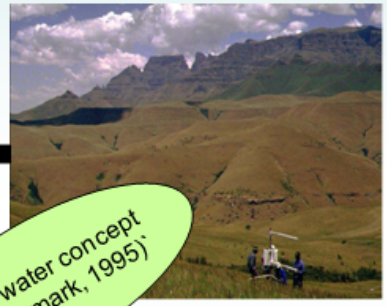
1990: Evaporative losses using micrometeorological techniques

CSIR curves (Scott and Smith, 1997) Gush tables (Gush et al., 2002) informed by evaporation research

Mid 1990's: Process studies assessing full hydrological water balance, Focus: Evaporation

Early 2000: Introduction of scintillometry
~2004: Remote sensing based techniques

1932: Discontinuing afforestation within 20m of riparian zone
1969: Soil Conservation act
1972: Afforestation Permit System (APS) under Forestry Act of 1968

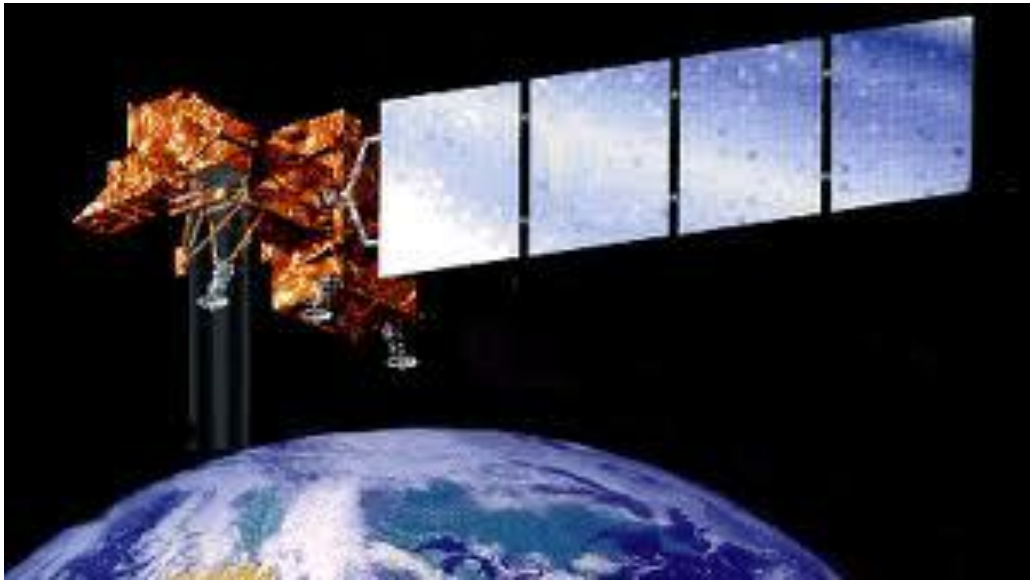


Green water concept (Falkenmark, 1995)

1998: National Water Act of South Africa
1999: Streamflow reduction activities licensing

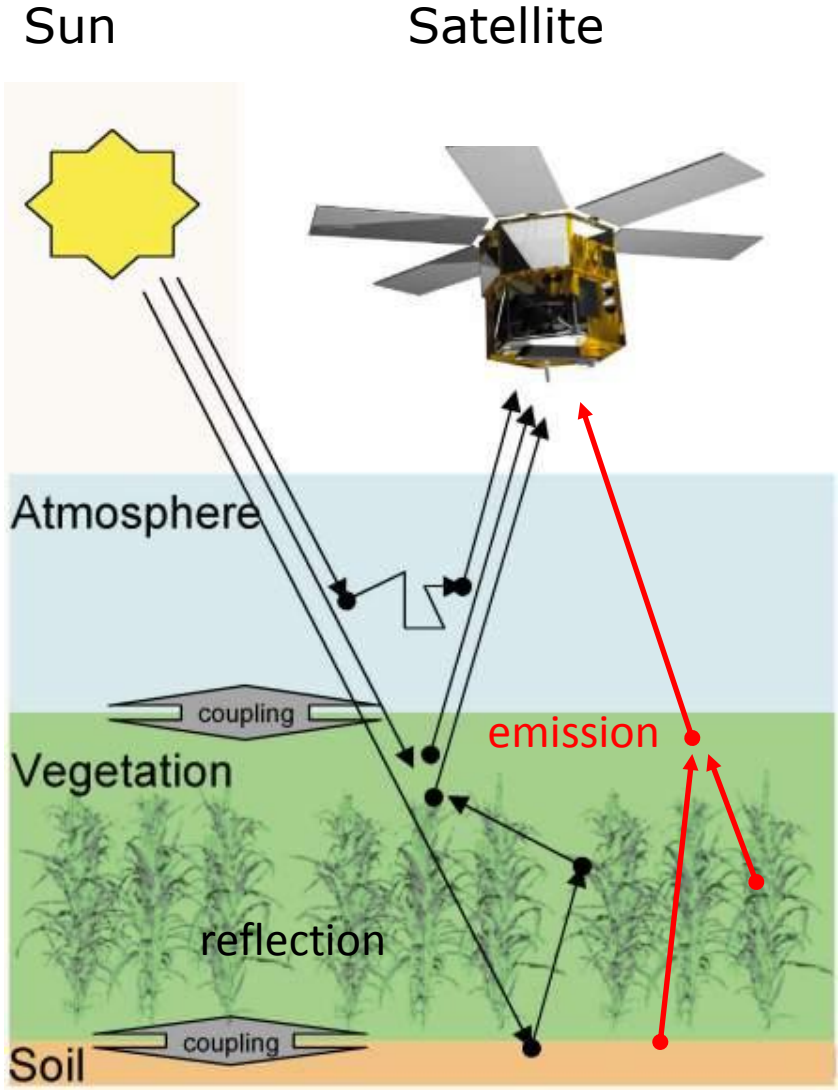
Integrated Land and Water Resources Management

What is remote sensing?



- "Remote sensing is the science of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted Electromagnetic energy (and processing, analyzing, and applying that information)"

Electromagnetic spectrum

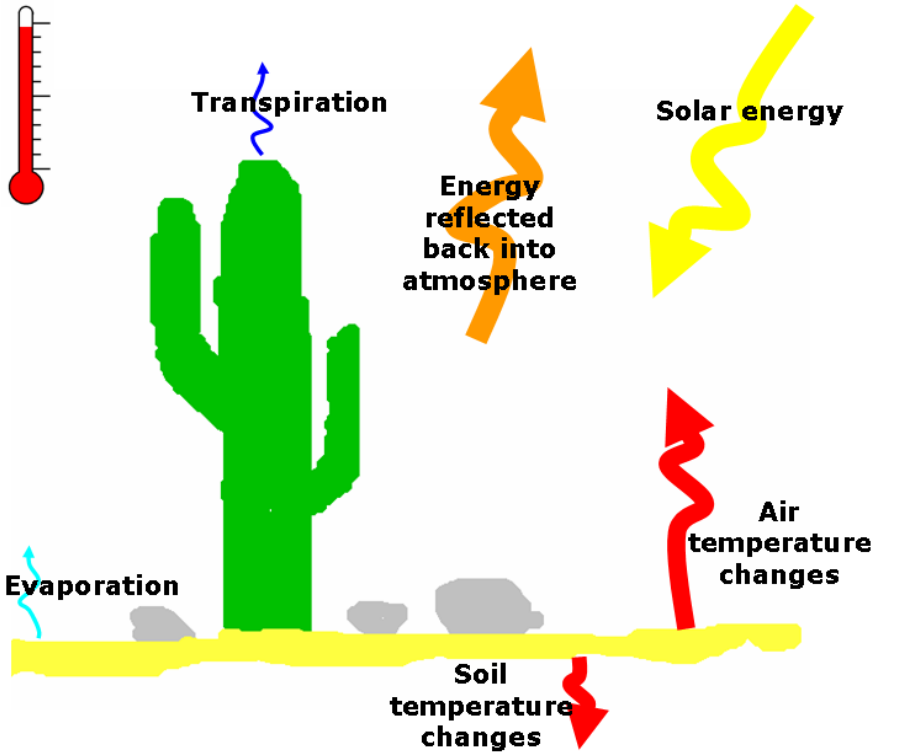


Two main sources of electromagnetic radiation

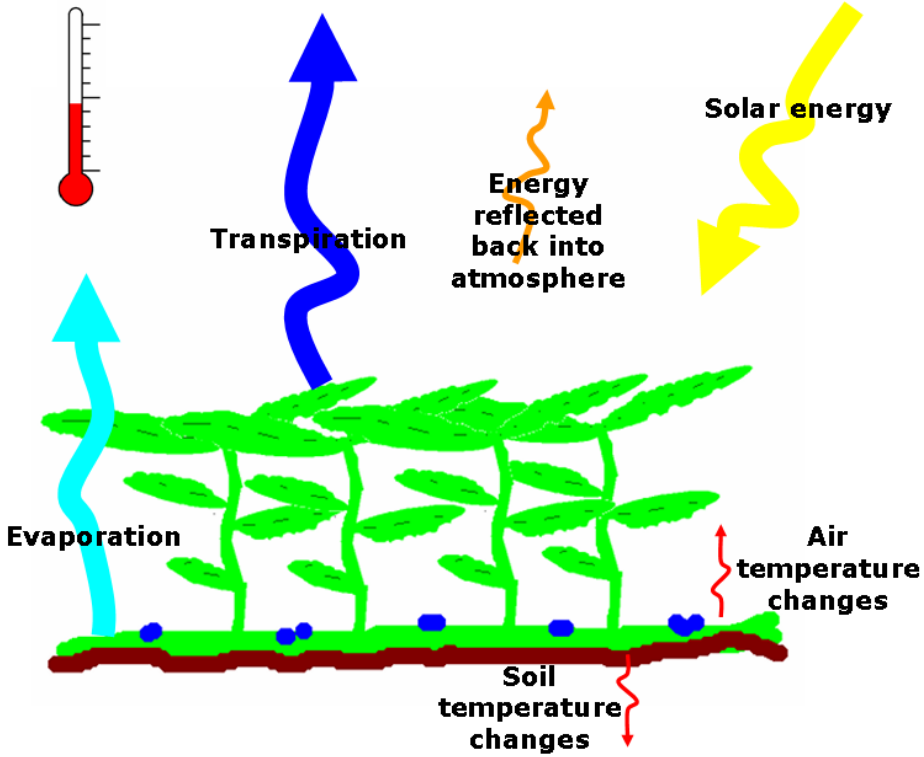
1. **Sun**
   - Visible (VIS)
   - Near-infrared (NIR)
   - Shortwave-infrared (MIR)
   - "Shortwave radiation" (0.1 to 3 μm)
   - Surface albedo (0.1 to 3 μm)
2. **Earth**
   - Thermal-infrared: 8 to 14 μm
   - "Long wave radiation" (5 to 50 μm)

Total evaporation

Surface energy balance



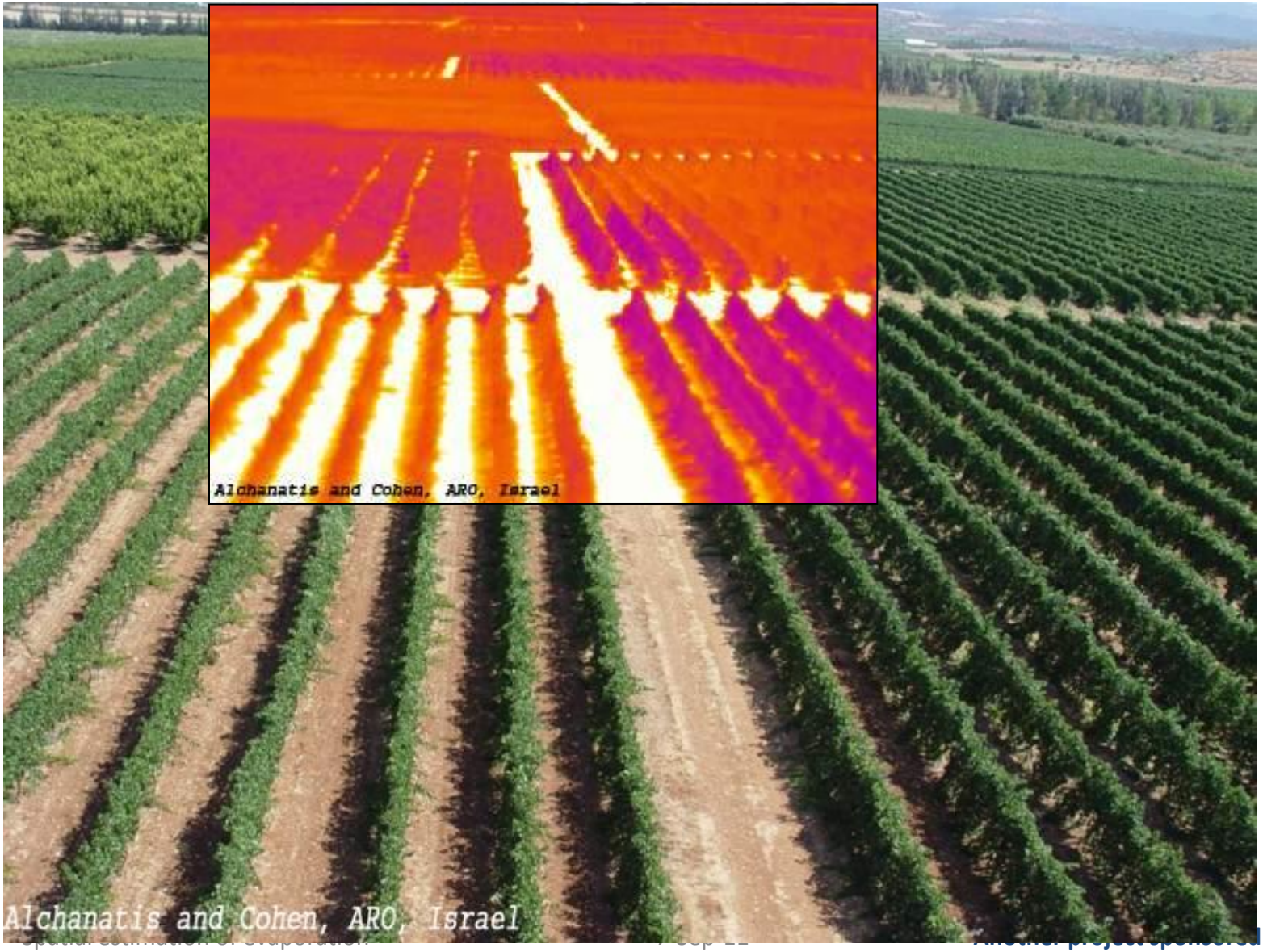
Dry surface



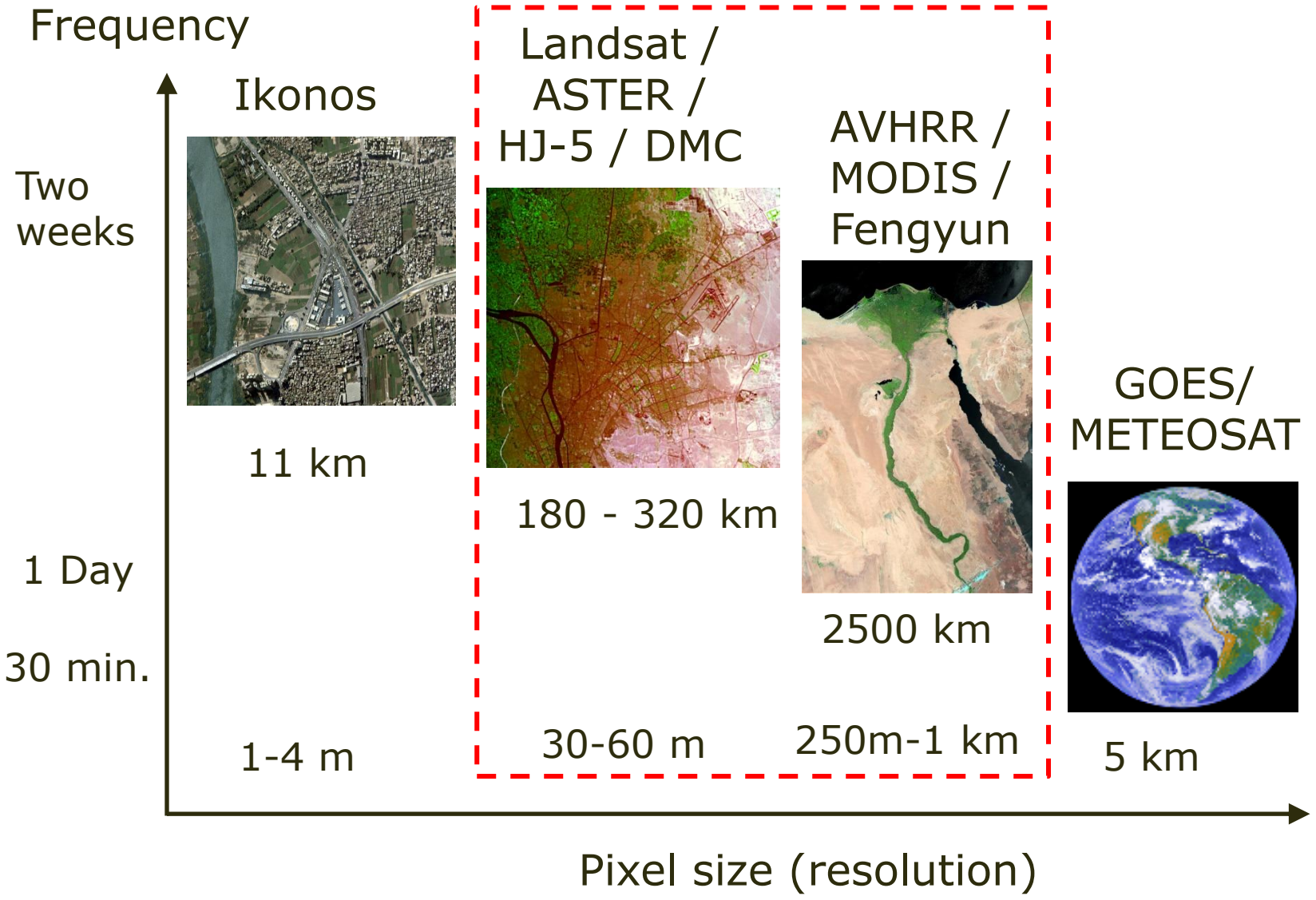
Wet surface

The thermal sensor is a tool of geo-scientist to measure the health of vegetation in full analogy with the thermometer of a doctor measuring the health of his patient (Anderson, 2008 EOS AGU Newsletter)

Thermal imaging

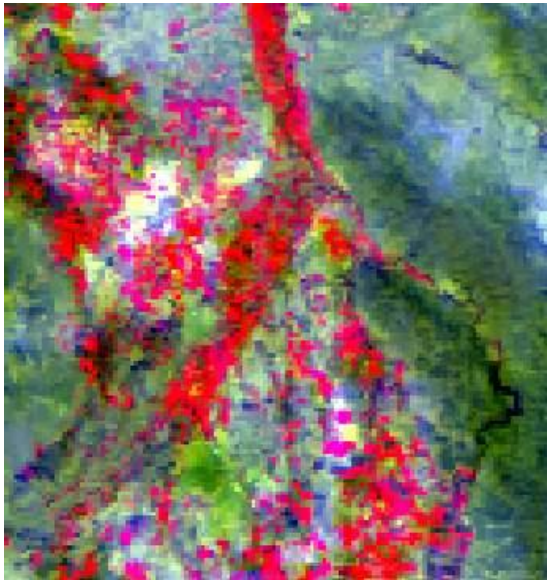


Spatial scales

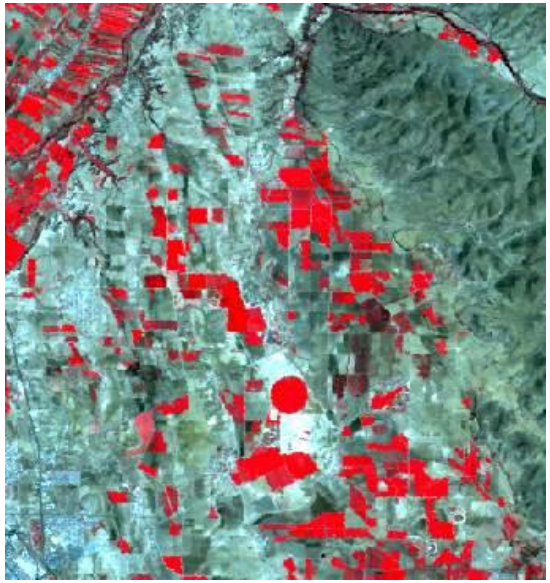


Spatial scales

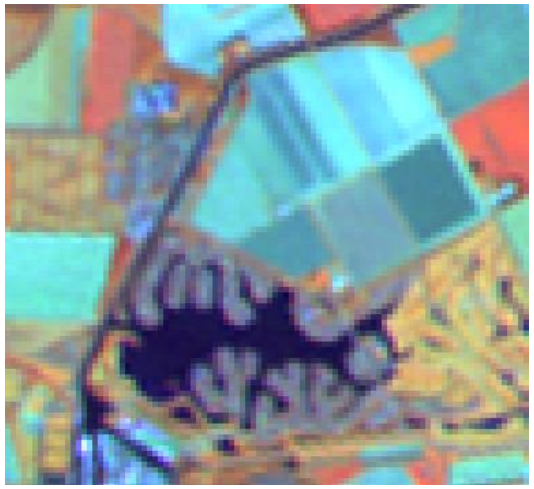
MODIS 250 m

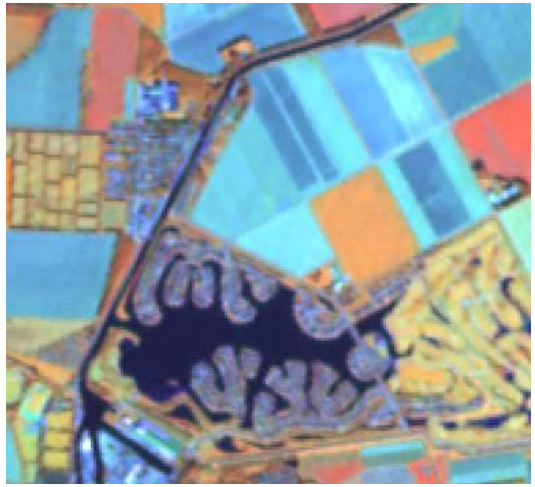


Landsat / HJ 30m



Landsat 30m





SPOT 10m

Combining remote and ancillary data

Water resources management

- Assessing available methods [WRC]
- Characterising entire water balance [WRC]
- Application related to total evaporation, rainfall and soil moisture
  - Land use impacts (Irrigated agriculture) [WCPDA]
  - Operational data use (Irrigated agriculture, CMA's) [WCPDA, WRC]
  - Land use change impacts (Invasive Alien Plants) [WFW]
  - Flood forecasting [WRC]
- In Space (Field → farm → catchment → province)
- Time (Historic → Current → Future)

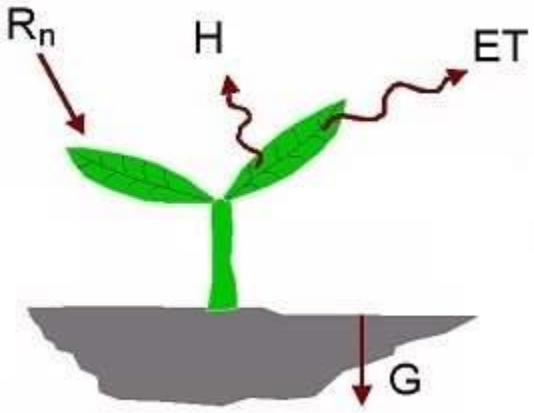




Example 1 – Evaluation of available methods (Jarmain et al., 2009 - WRC report 1751-1-09)

Remote sensing approaches for Evaporation estimation – after Verstreaten et al. (2008)

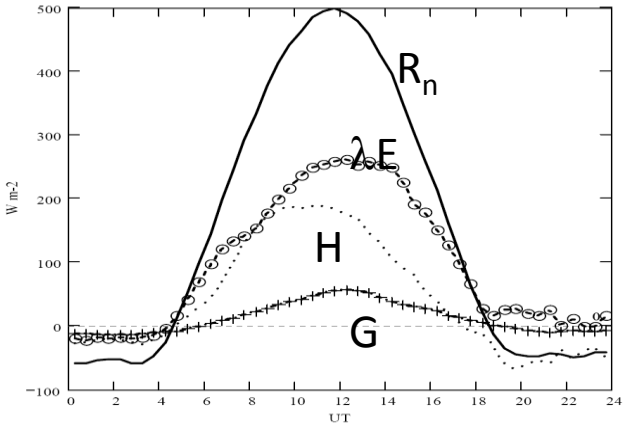
Approach	Models	EO inputs
Parameterise surface energy balance	SEBAL, SEBS, S-SEBI, TSEB, METRIC	Ts, NDVI, α
Penman-Monteith based	Trapezoidal, Promet, Granger	Ts, VI (SAVI or NDVI), α
Water Balance based	SWAP, Price	Ts, VI, α
VI/LST based	Nagler, Jackson	Ts, EVI



Simplified energy balance

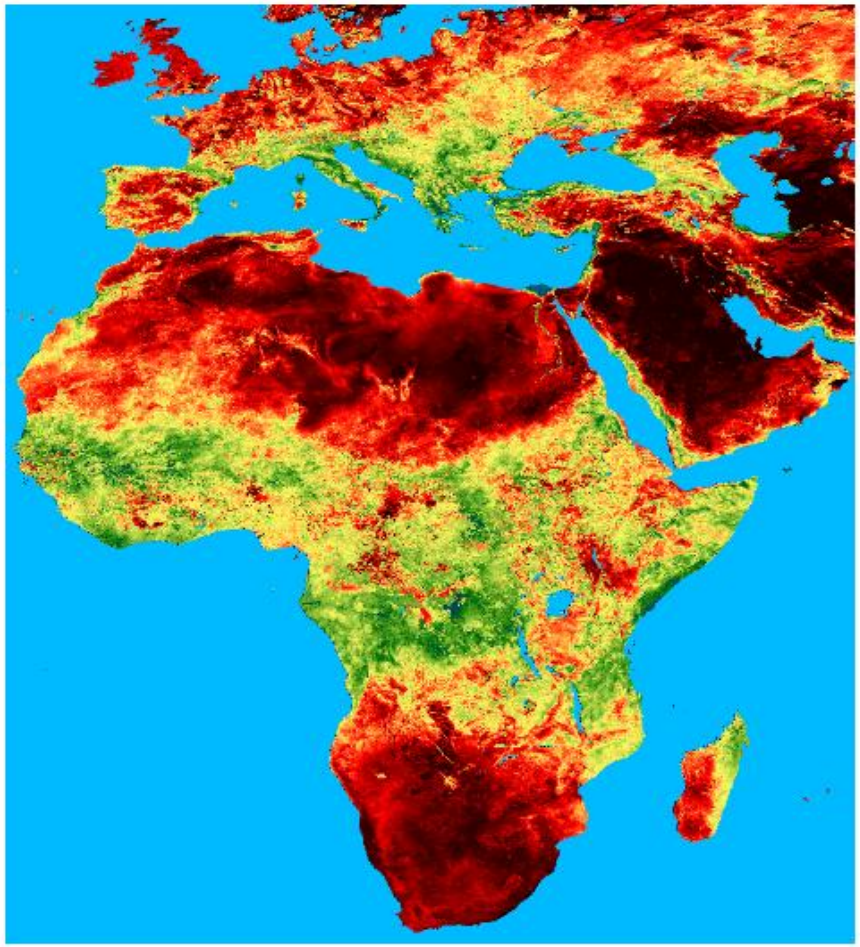
$R_n = H+G+\lambda E$

$\lambda E \leftrightarrow ET$



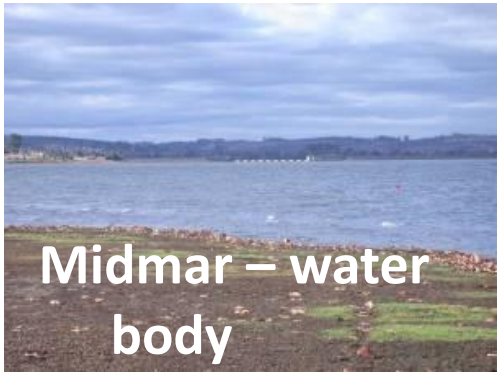
Example 1 - On-line evaporation examples

Actual evapotranspiration field: 11 - 20 August 2011



- http://www.ears.nl/evapotranspiration_field.php

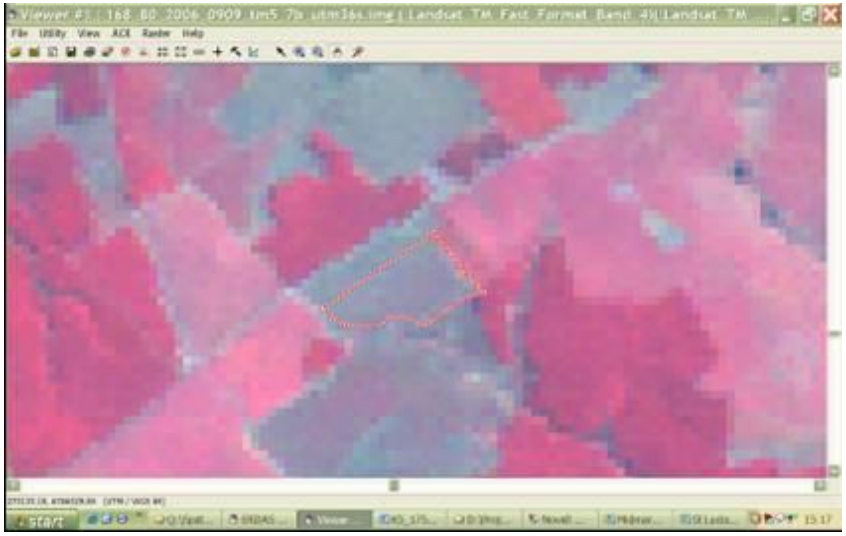
Example 1 – Models, land uses

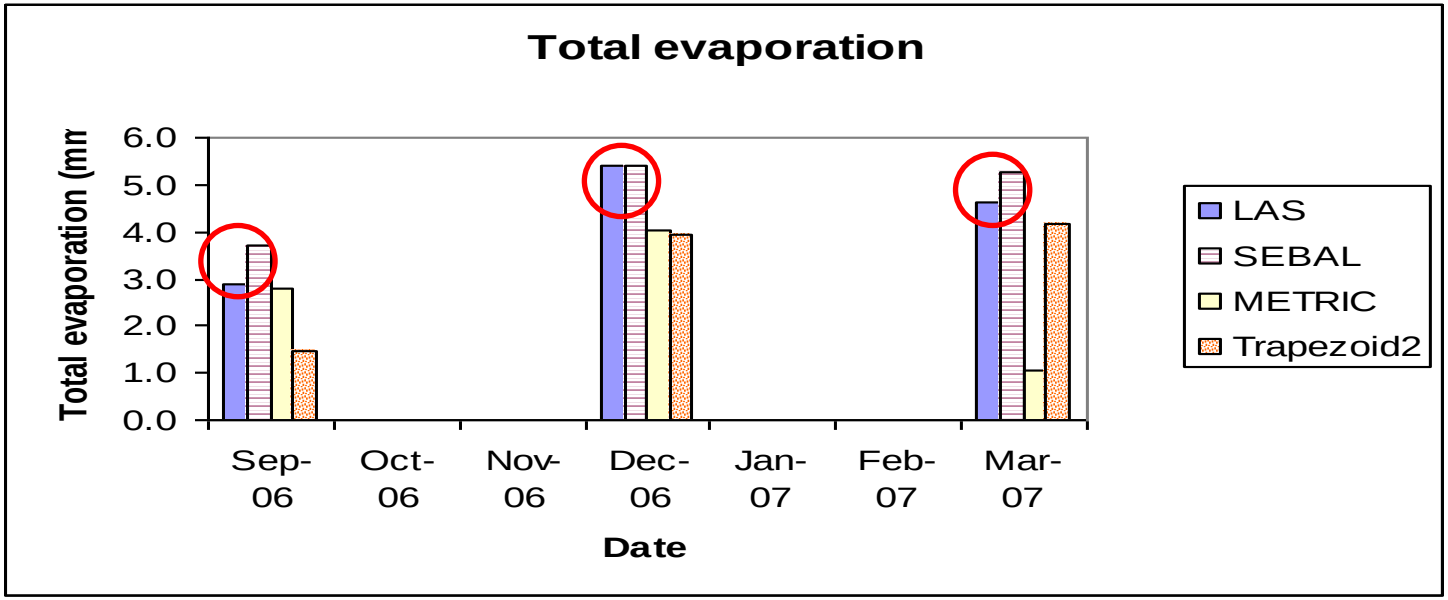


MODELS evaluated:

- SEBAL
- METRIC
- SEBS
- VITT (Trapezoid)

Example 1 – Total evaporation





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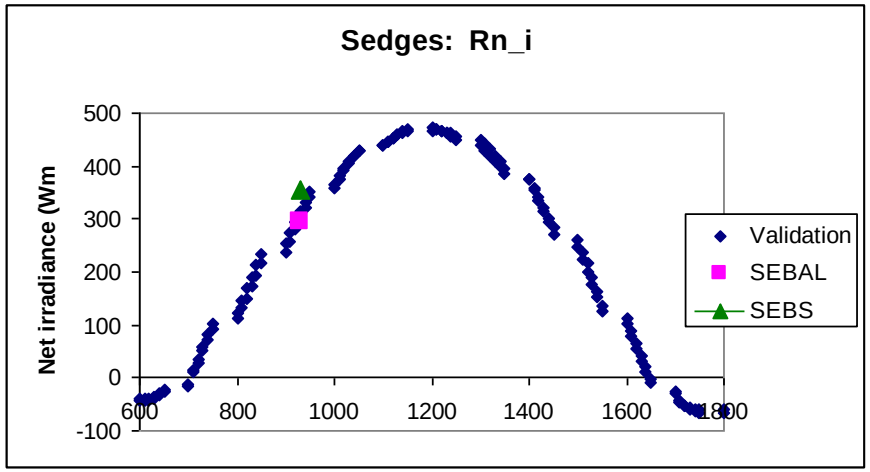
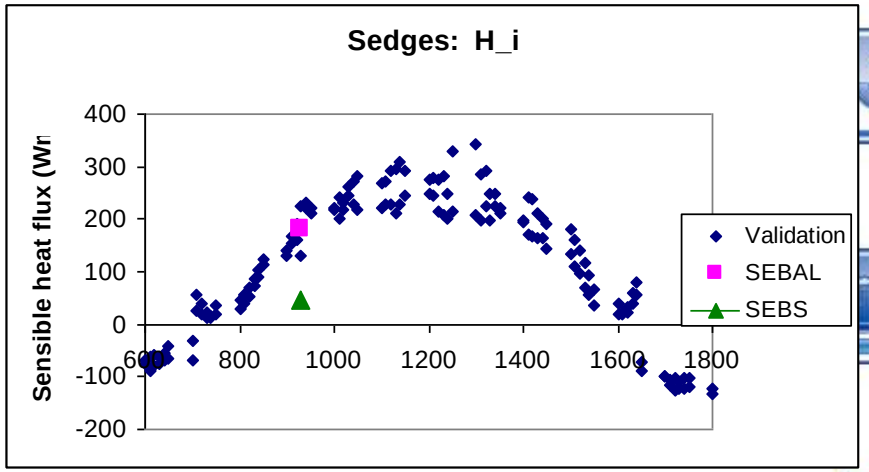
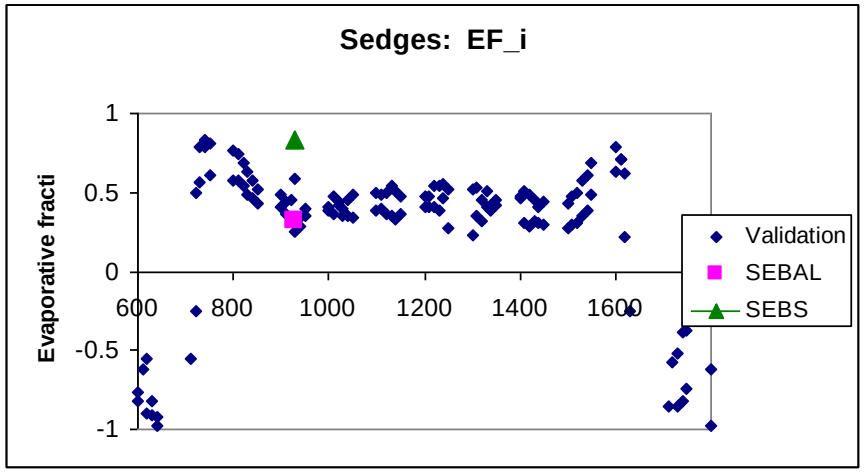
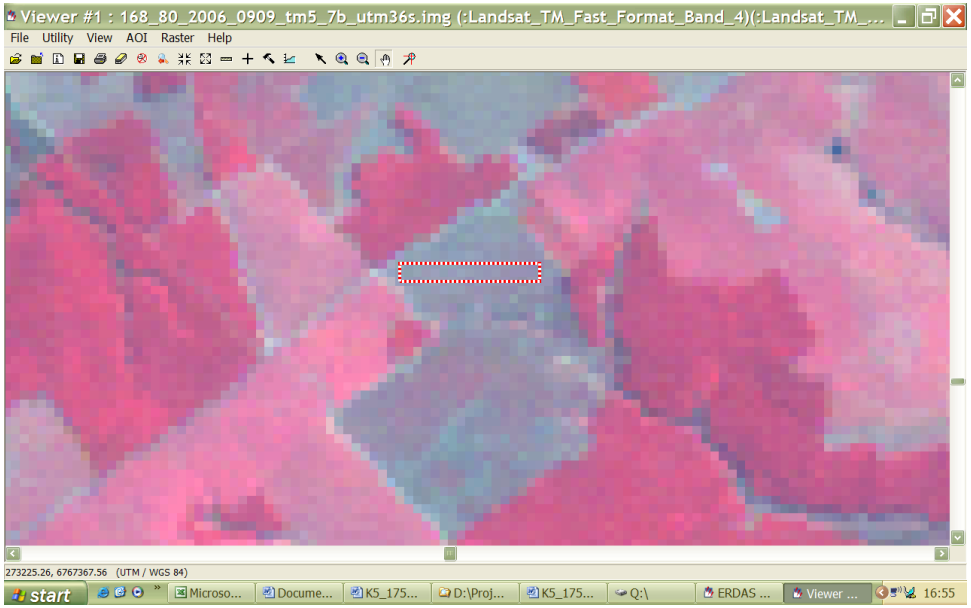






Example 1 – Evaluation of available methods (Jarmain et al., 20009 - WRC report 1751-1-09)



CONCLUSIONS

- ET estimation is a challenge
- RS based methods hold great potential
  - SEBAL performed in general best
  - Energy balance vs. ET (Day vs. Period)
- Hardly any operational examples for field scale

Combining remote and ancillary data

Water resources management

- Assessing available methods
- Characterising entire water balance
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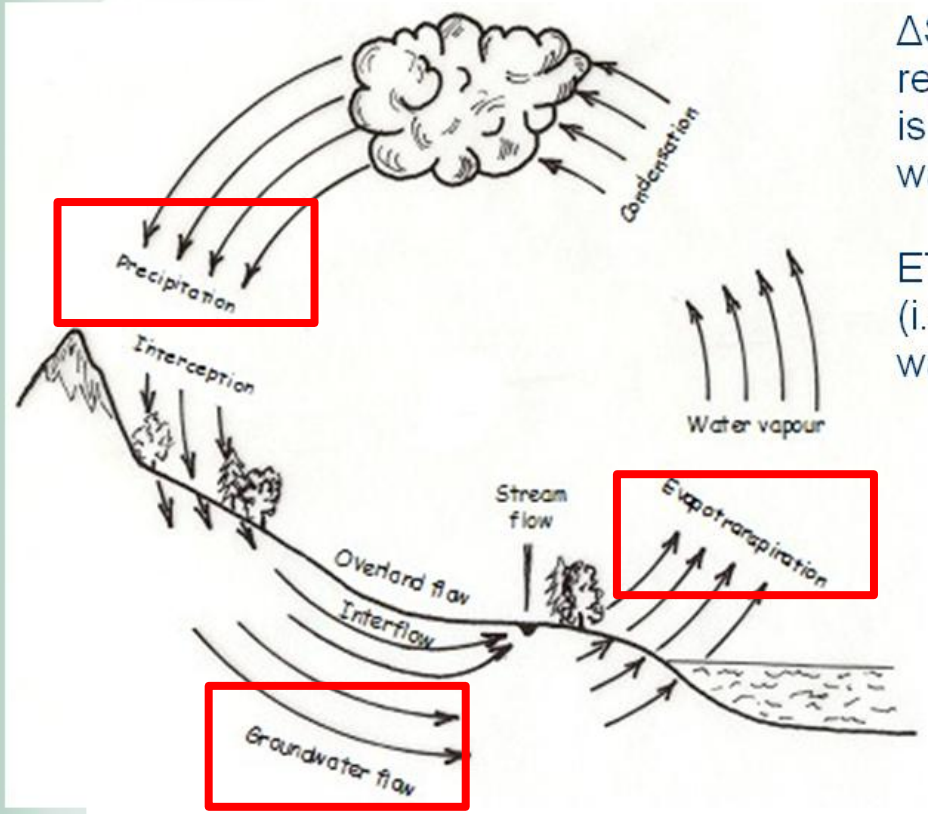
Example 2 – Resource assessment (Gibson et al., 2009 - WRC report 690-1-09.)



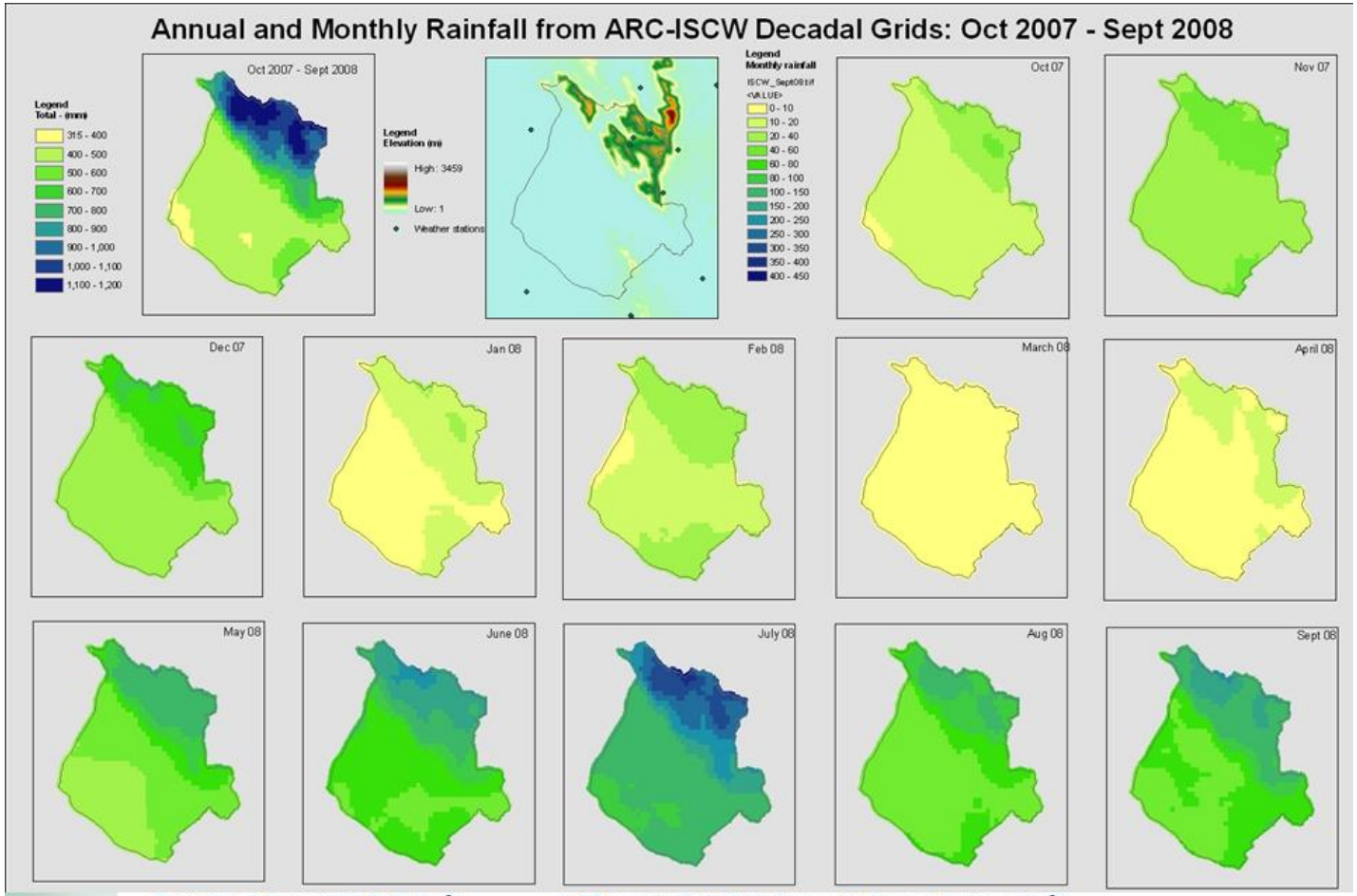
ΔS for a catchment represents whether there is a deficit or surplus of water for the catchment

ET for an irrigated region (i.e. crop) represents water use.

ΔS= change in storage
P = precipitation
ET = evapotranspiration
Re = recharge
RO = runoff

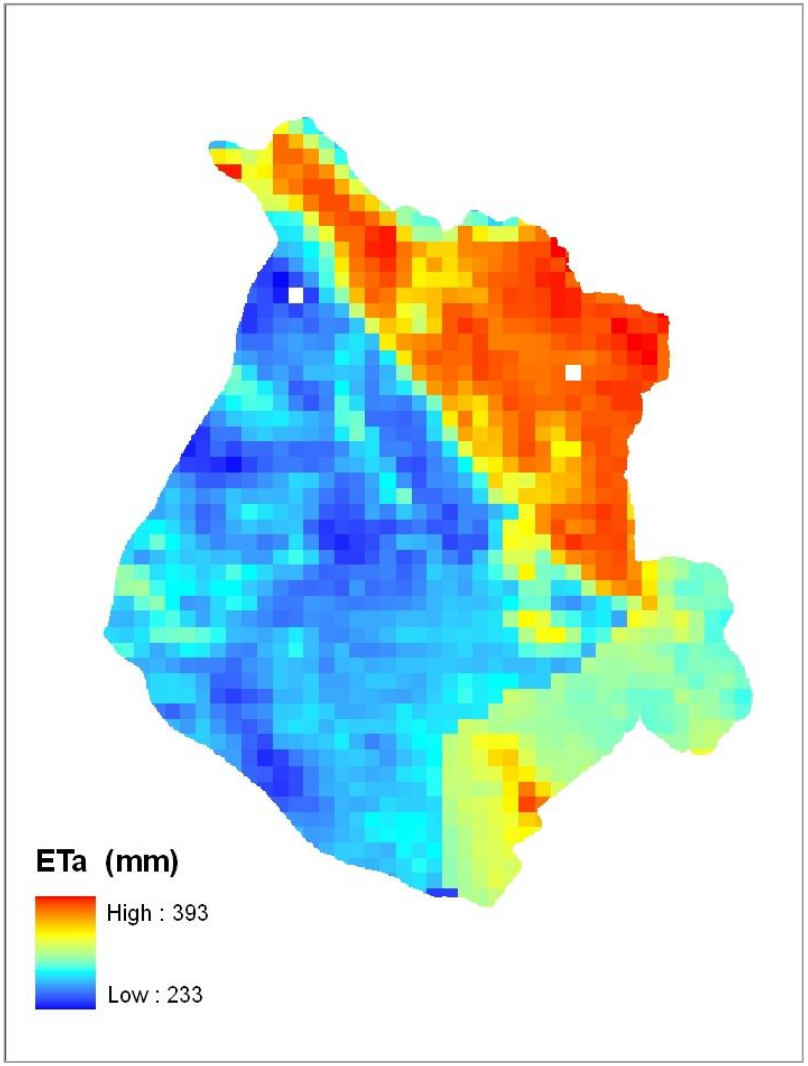
$$\Delta S = P - ET - Re - RO$$

Example 2 – Rainfall



Total volume rainfall (m^3) = Mean rainfall (m) x catchment area (m^2)
= 0.61224 x 1 260 372 503
= 771 650 461 m^3
= 0.771 km^3

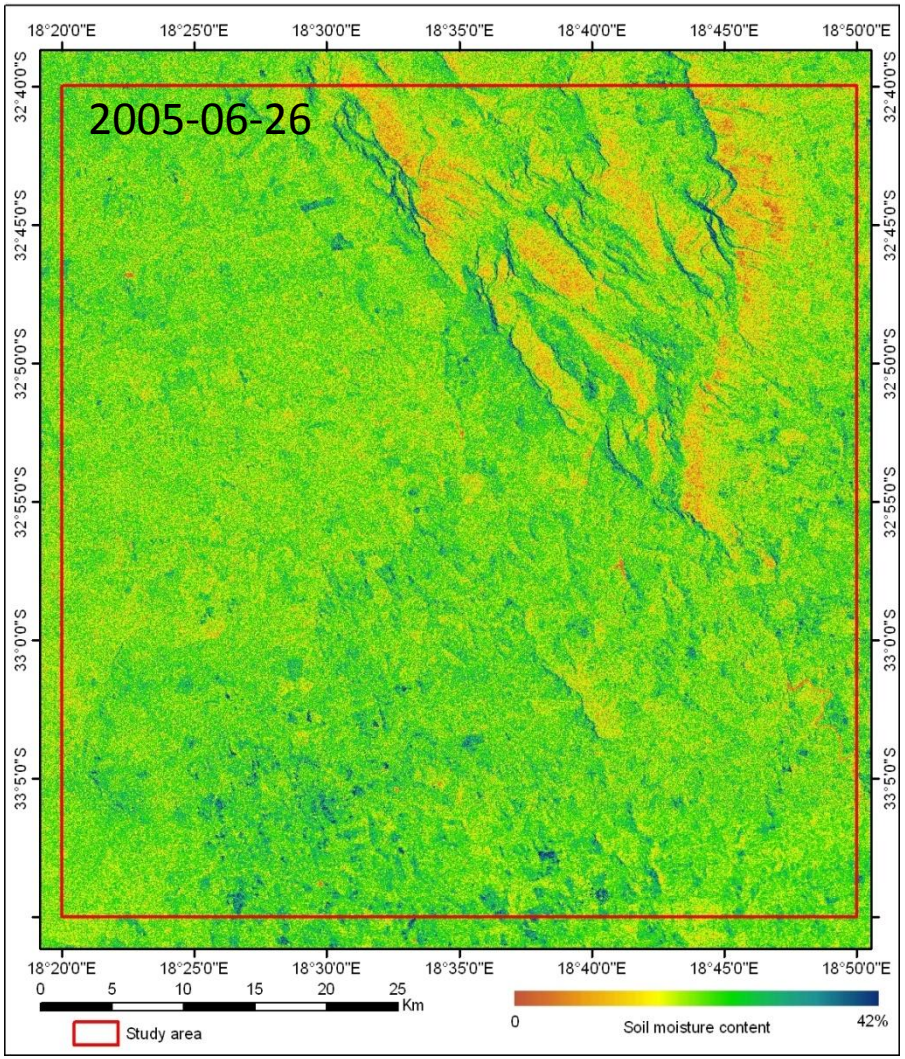
Example 2 – Total evaporation



Total evaporation

- SEBS model with MODIS data

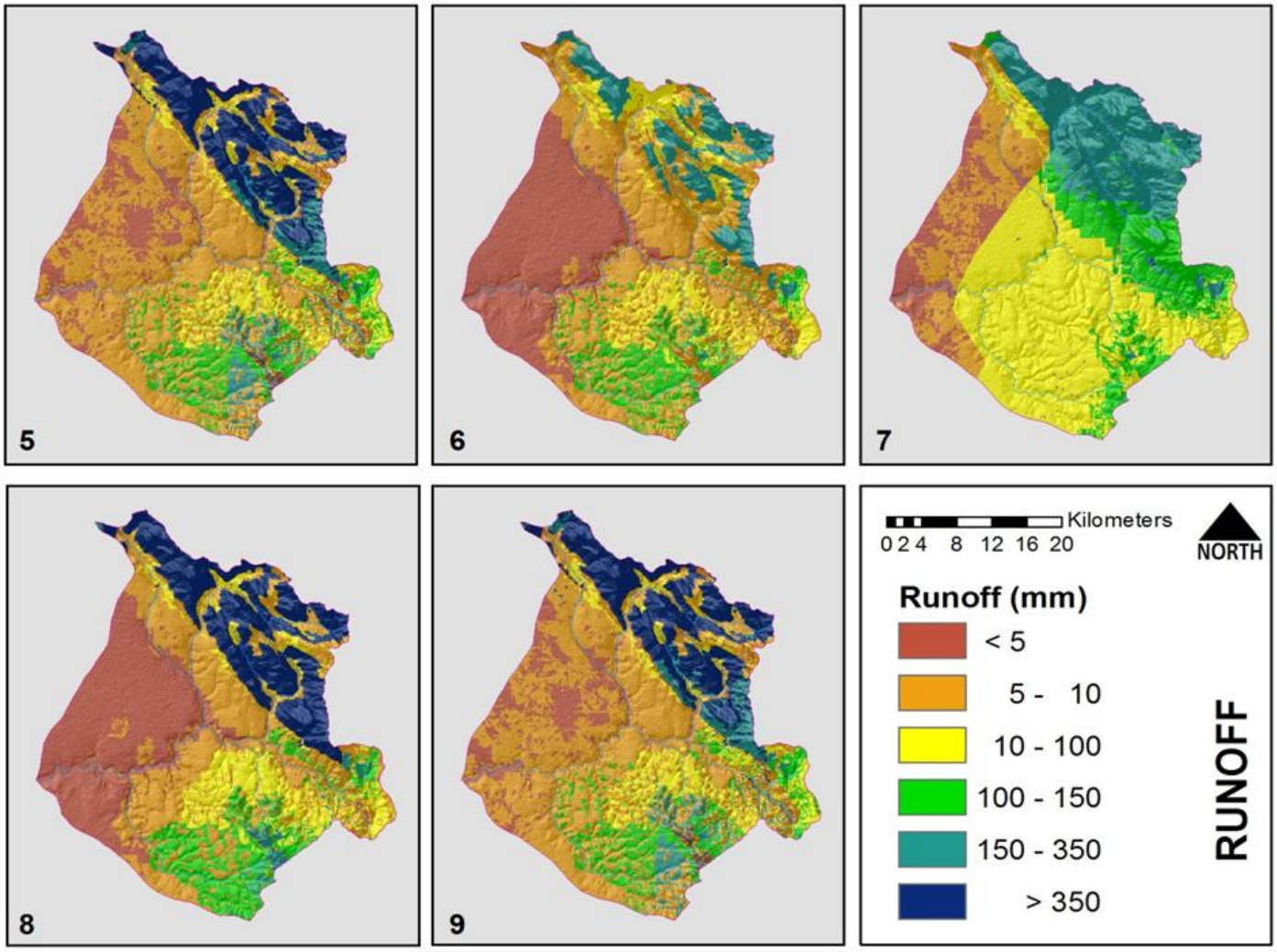
Example 2 – Soil moisture



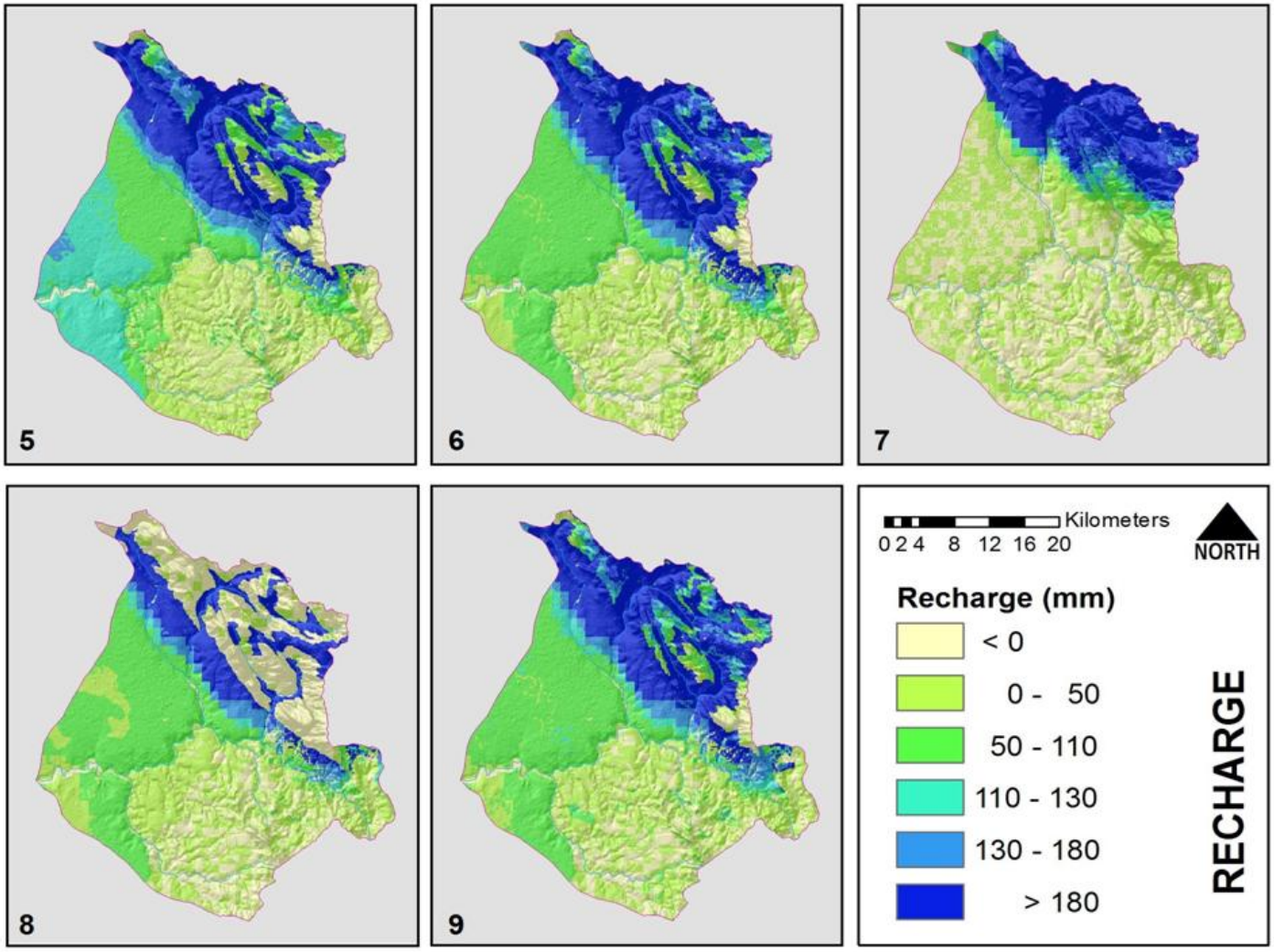
Soil moisture

- Linear regression models and multiple polarization models applied for soil moisture quantification
- Data: Envisat dual polarization and ALOS polarimetric

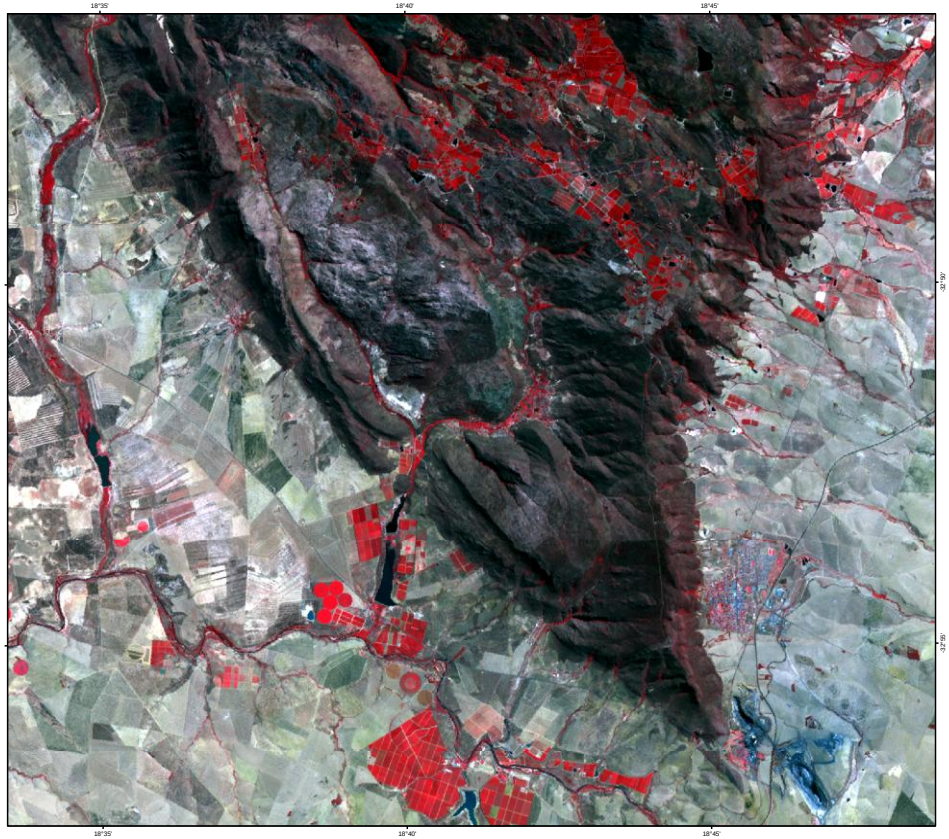
Example 2 – Runoff



Example 2 – Recharge



Example 2 – Resource assessment



CONCLUSIONS

- Great challenge
  - Models available but often untested in SA
  - Data generated requires validation
  - Integrating point and spatial data sources

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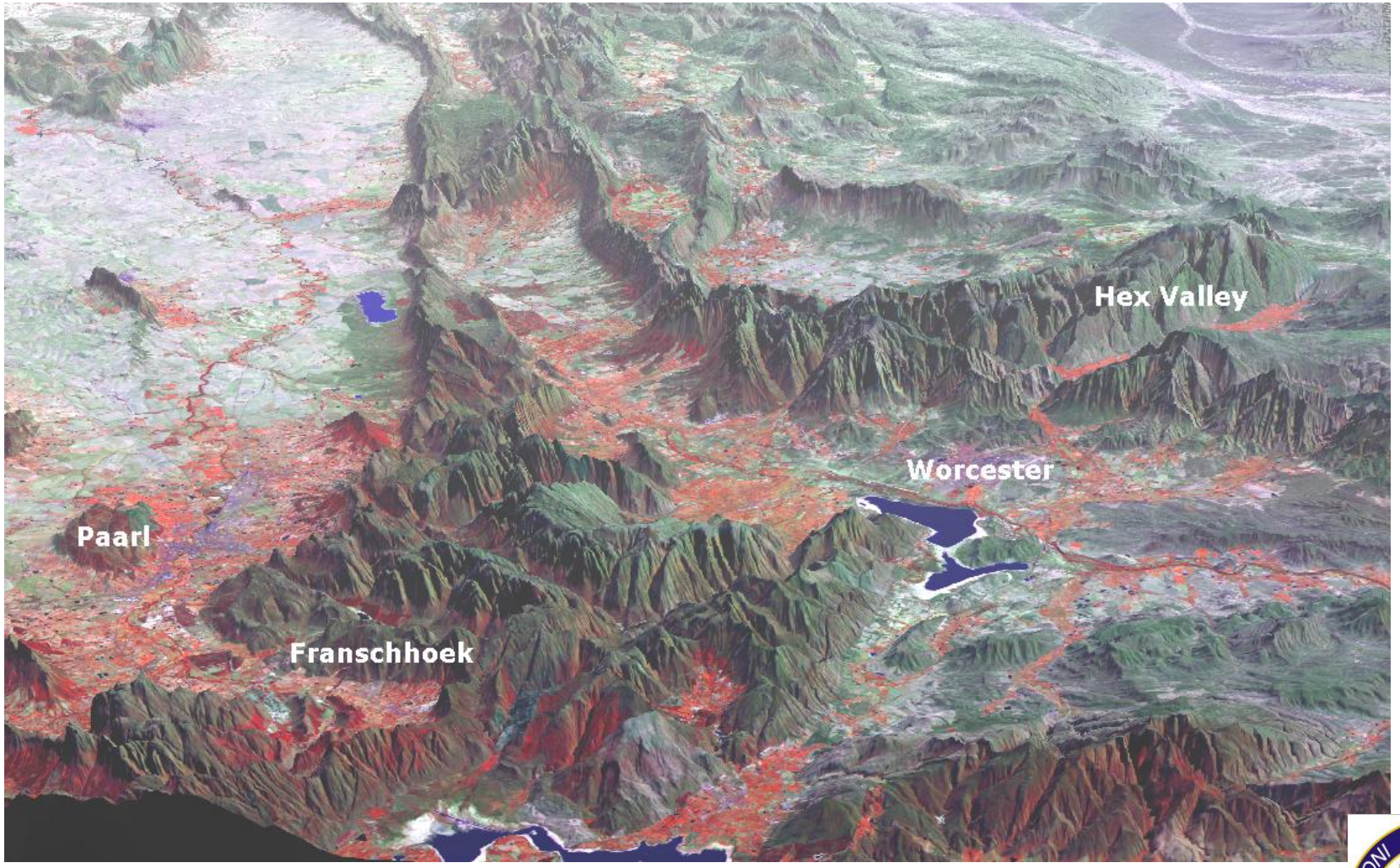
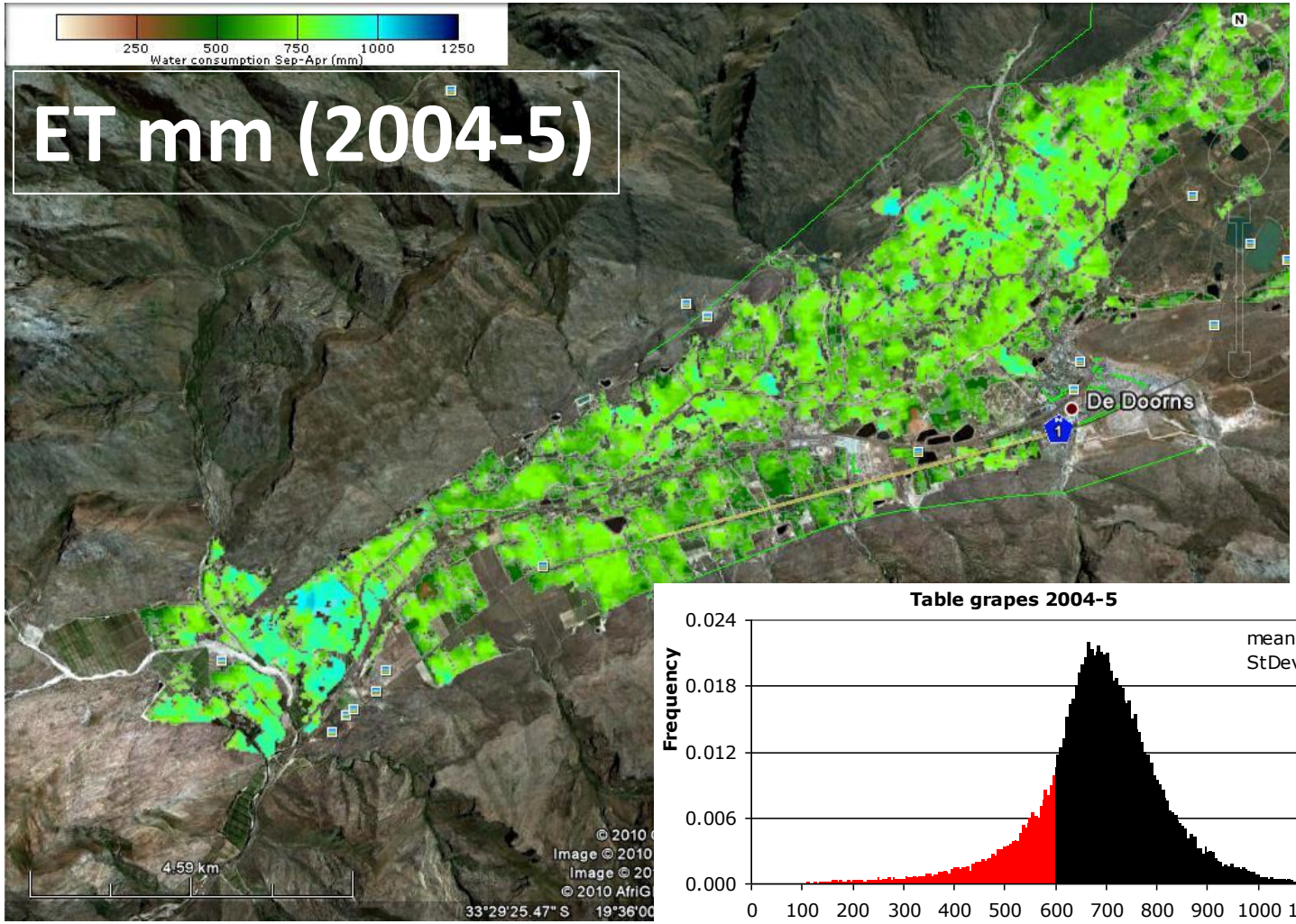
Example 3 – Total evaporation and water use efficiency (Klaasse et al., 2008)



Example 3 – De Doorns valley

Example 3 – Total evaporation



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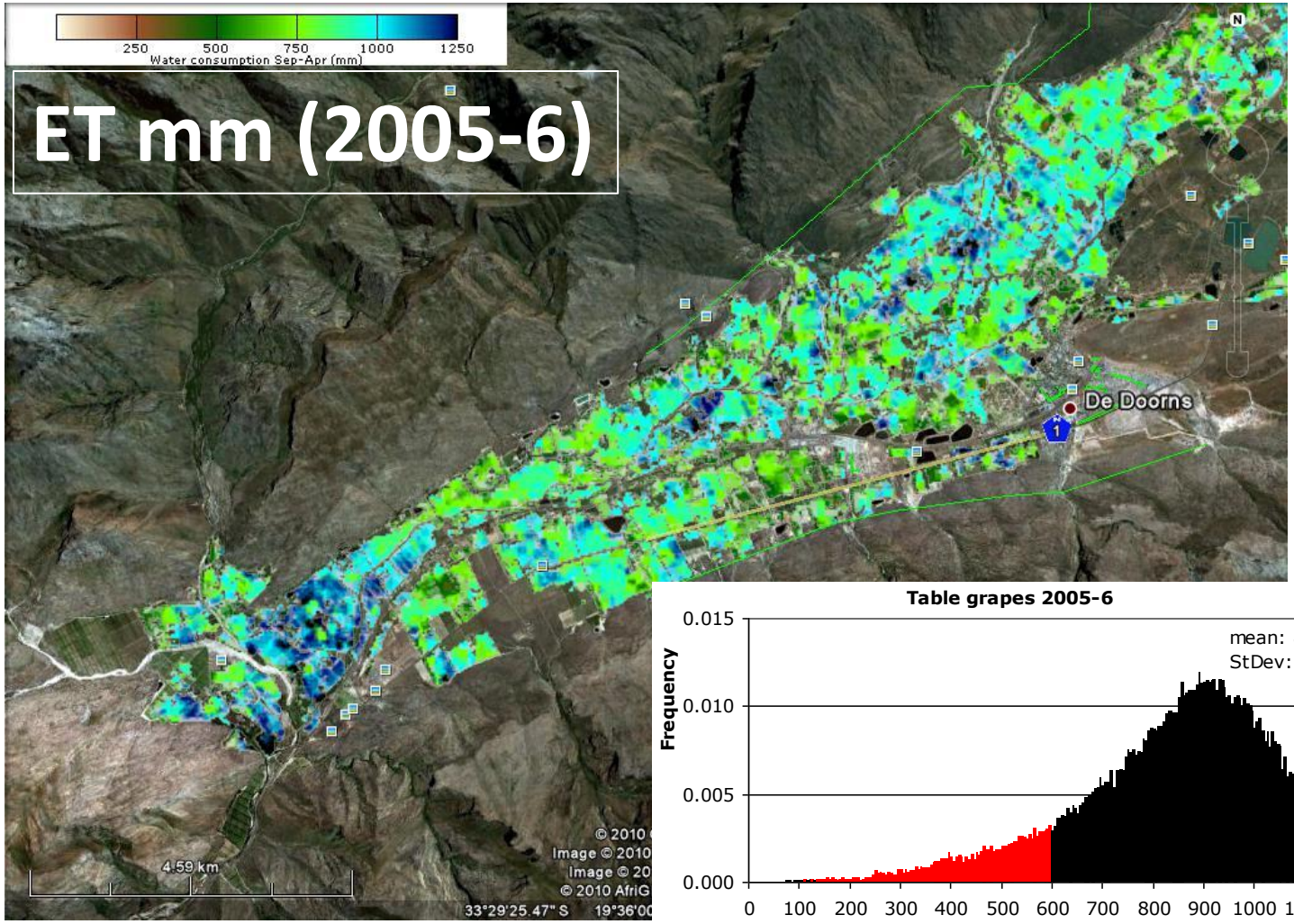

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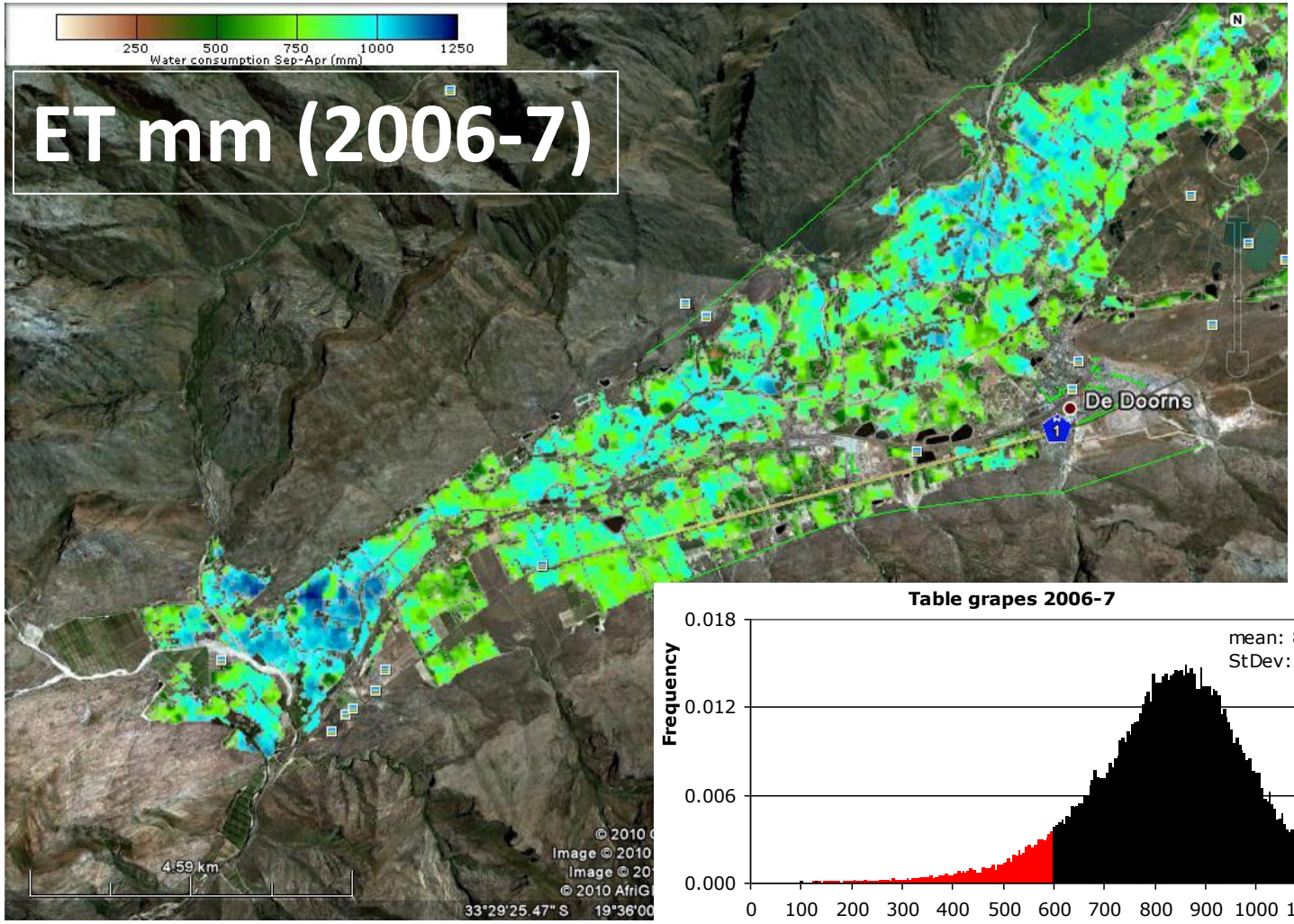

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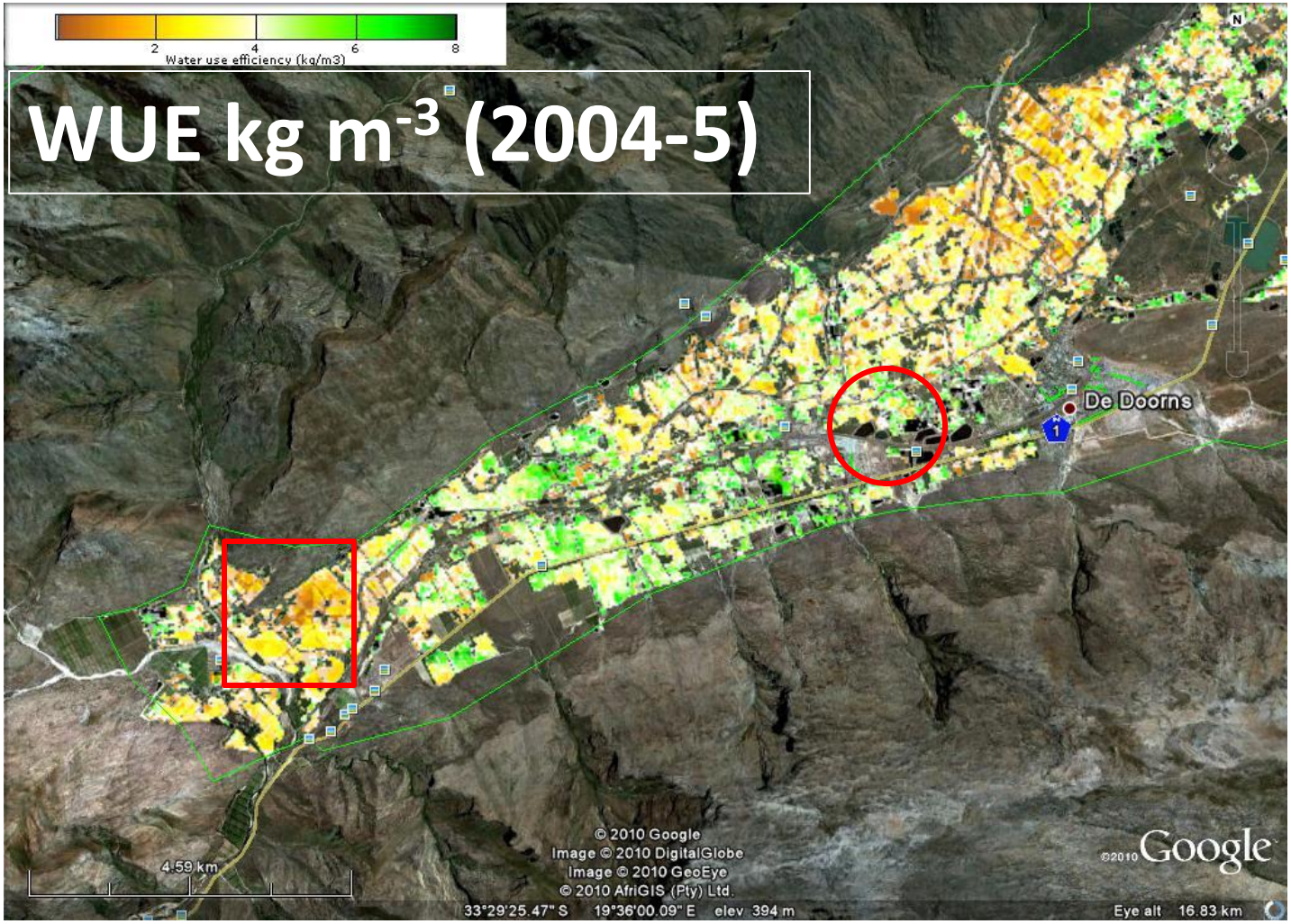
Example 3 – De Doorns valley

Example 3 – Water use efficiency



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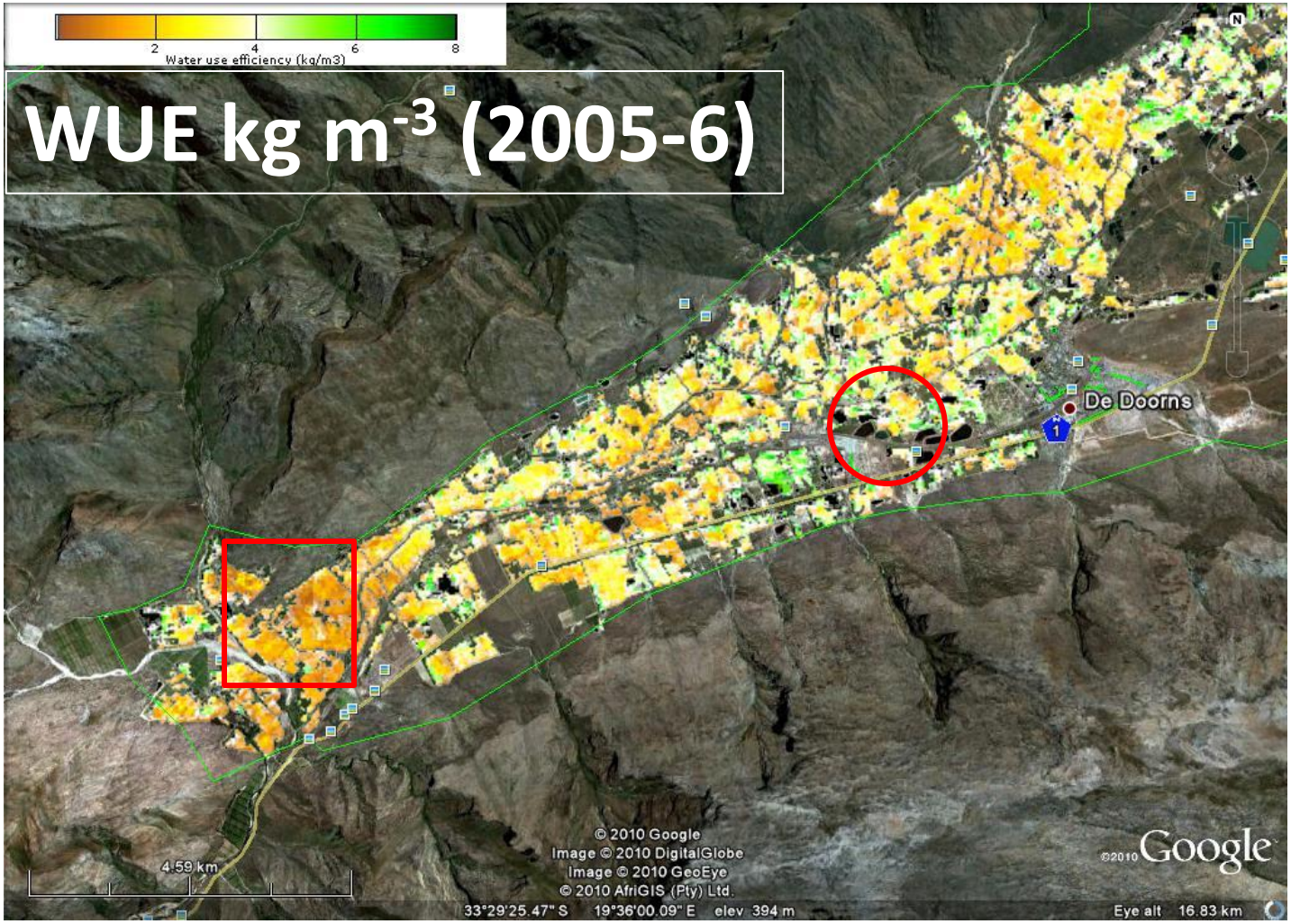

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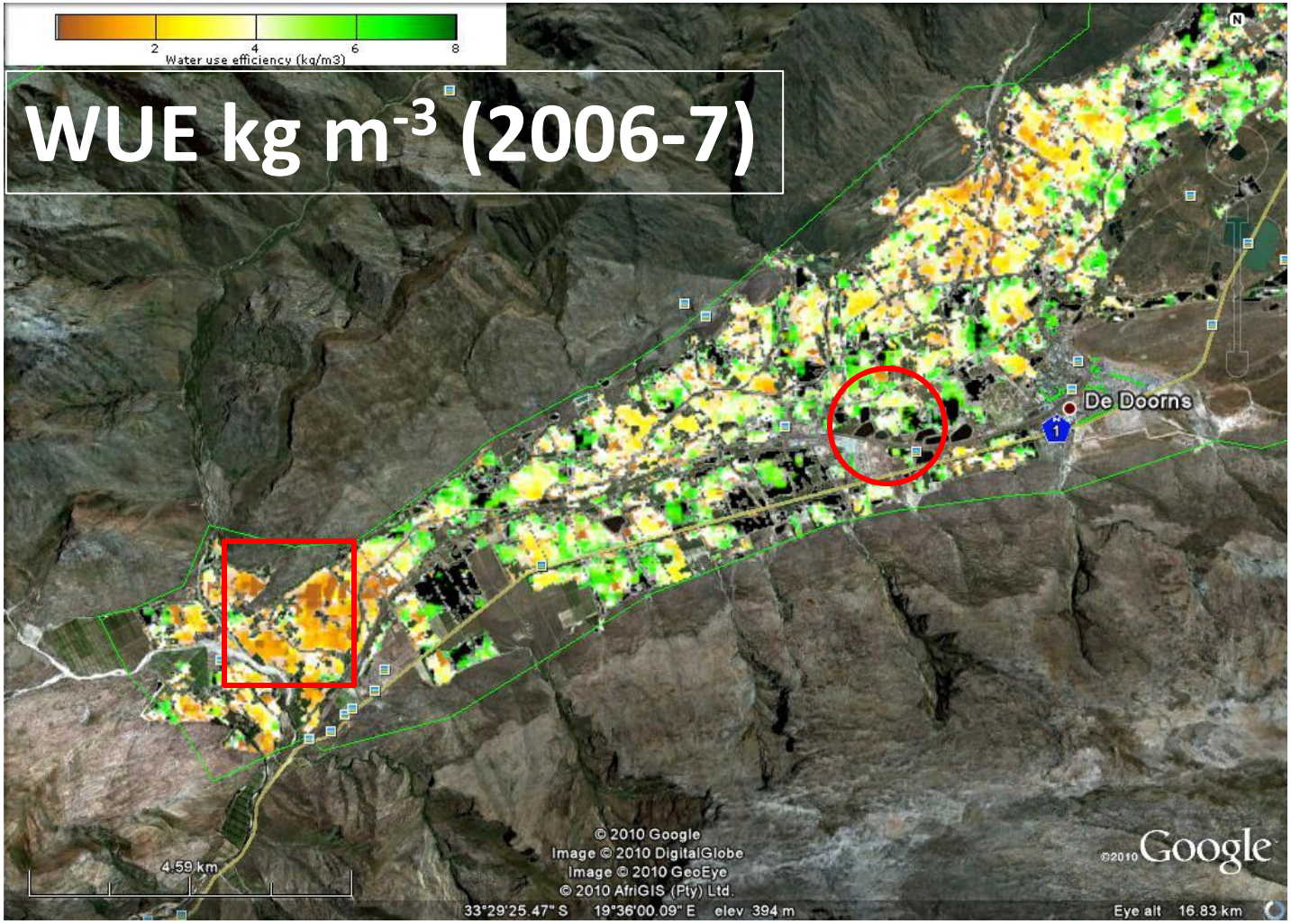
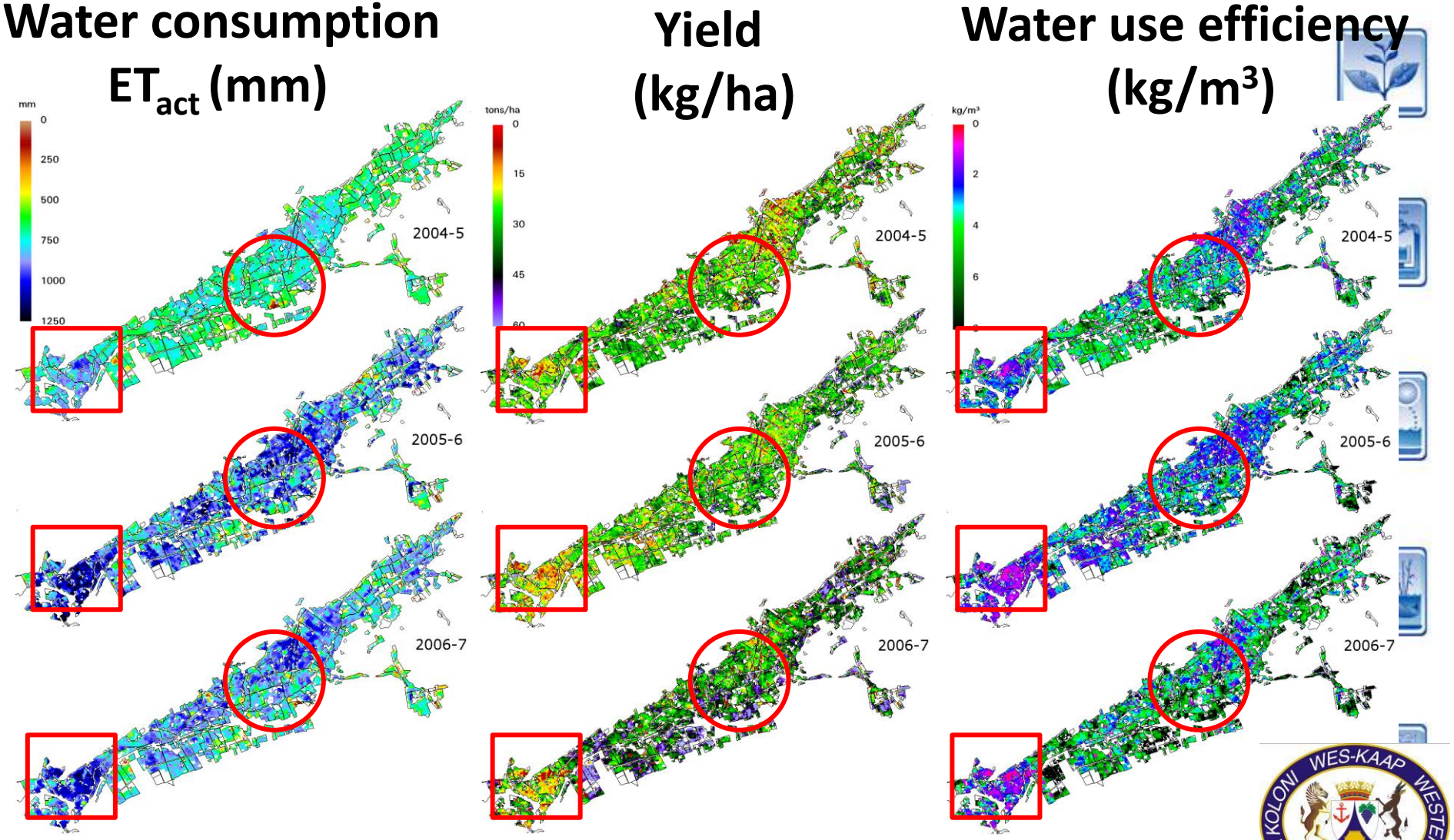


Example 3 – Total evaporation and water use efficiency (Klaasse et al., 2008)



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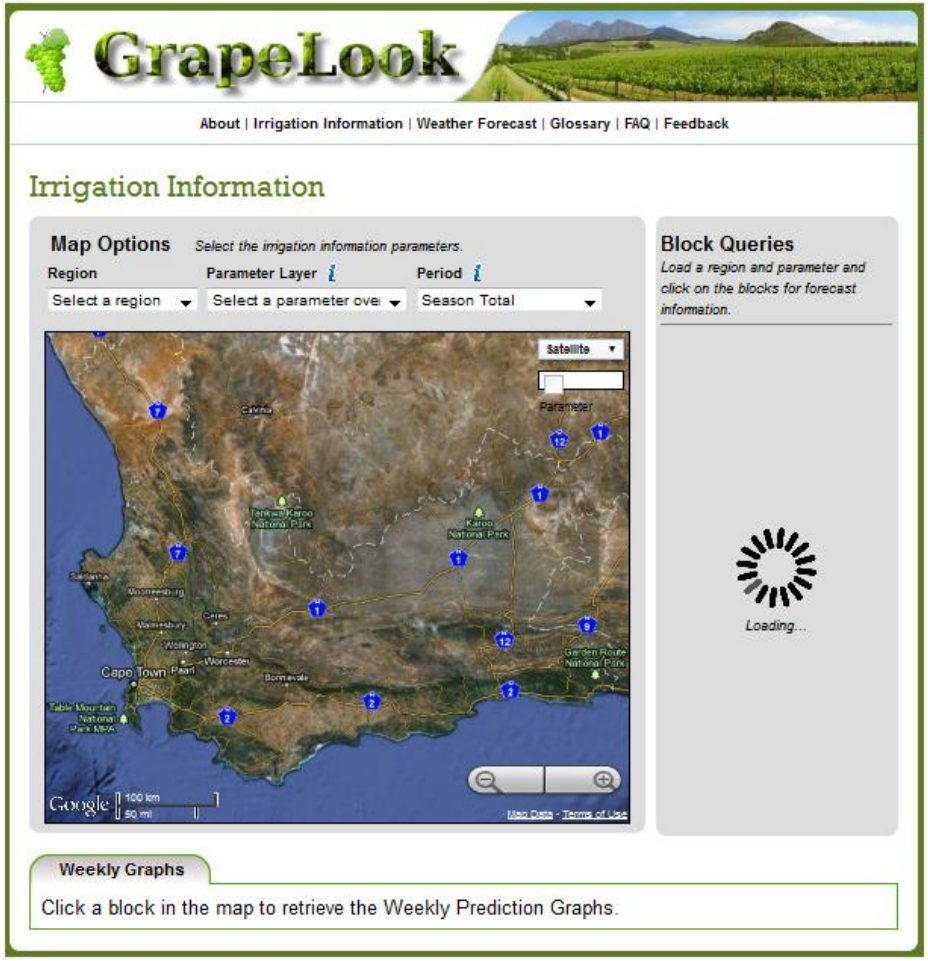
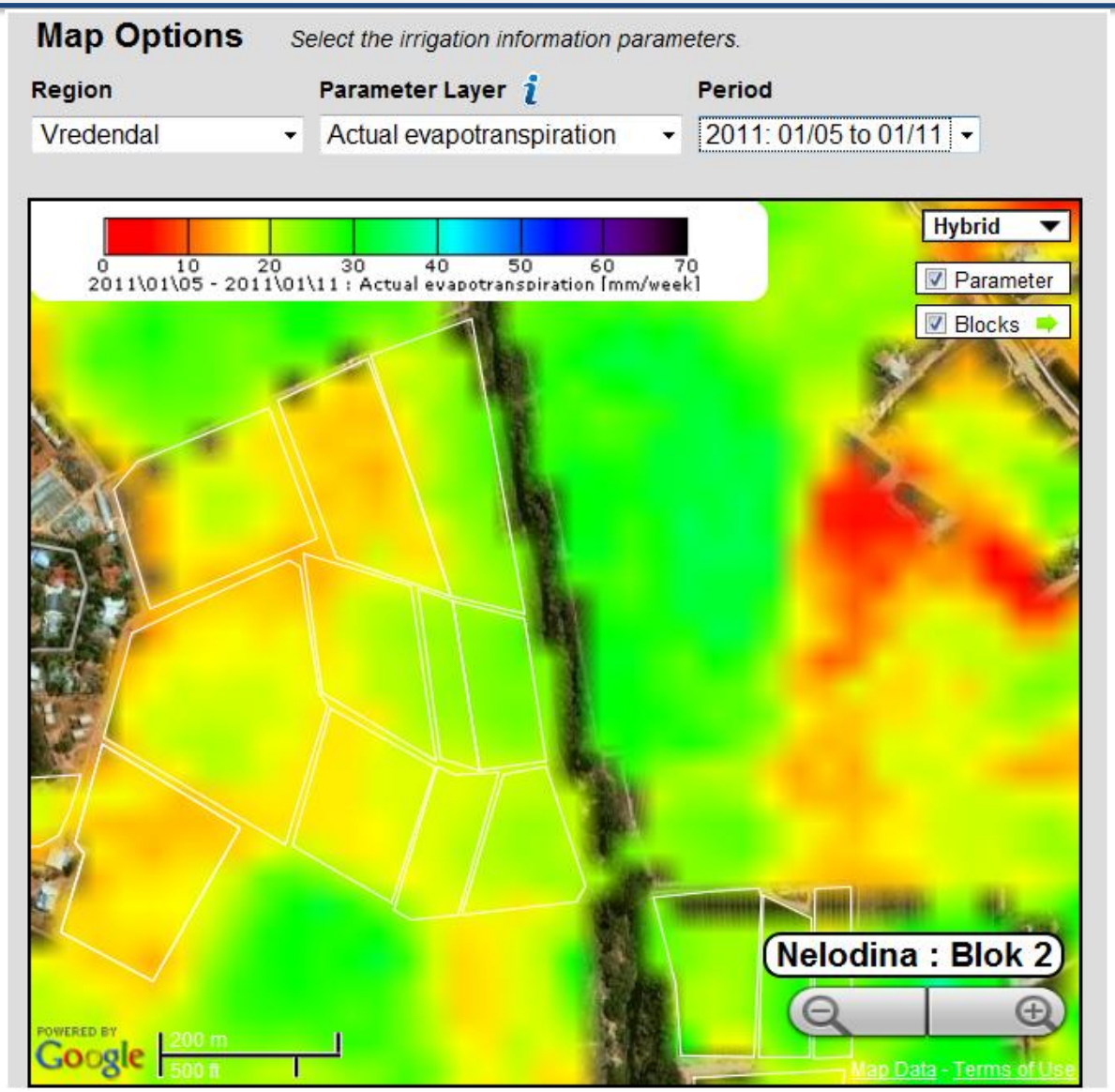
Example 4 – Total evaporation (operational) (Jarmain et al., 2011)



- Grape producing areas of Western Cape
- Near-real time (weekly updates)
- Weekly maps (SEBAL)
  - Water
  - Growth
  - Nutrients
- Forecasts (IrriLook)
  - Soil moisture
  - Irrigation requirements

- www.grapelook.co.za

Example 4 – Actual evapotranspiration



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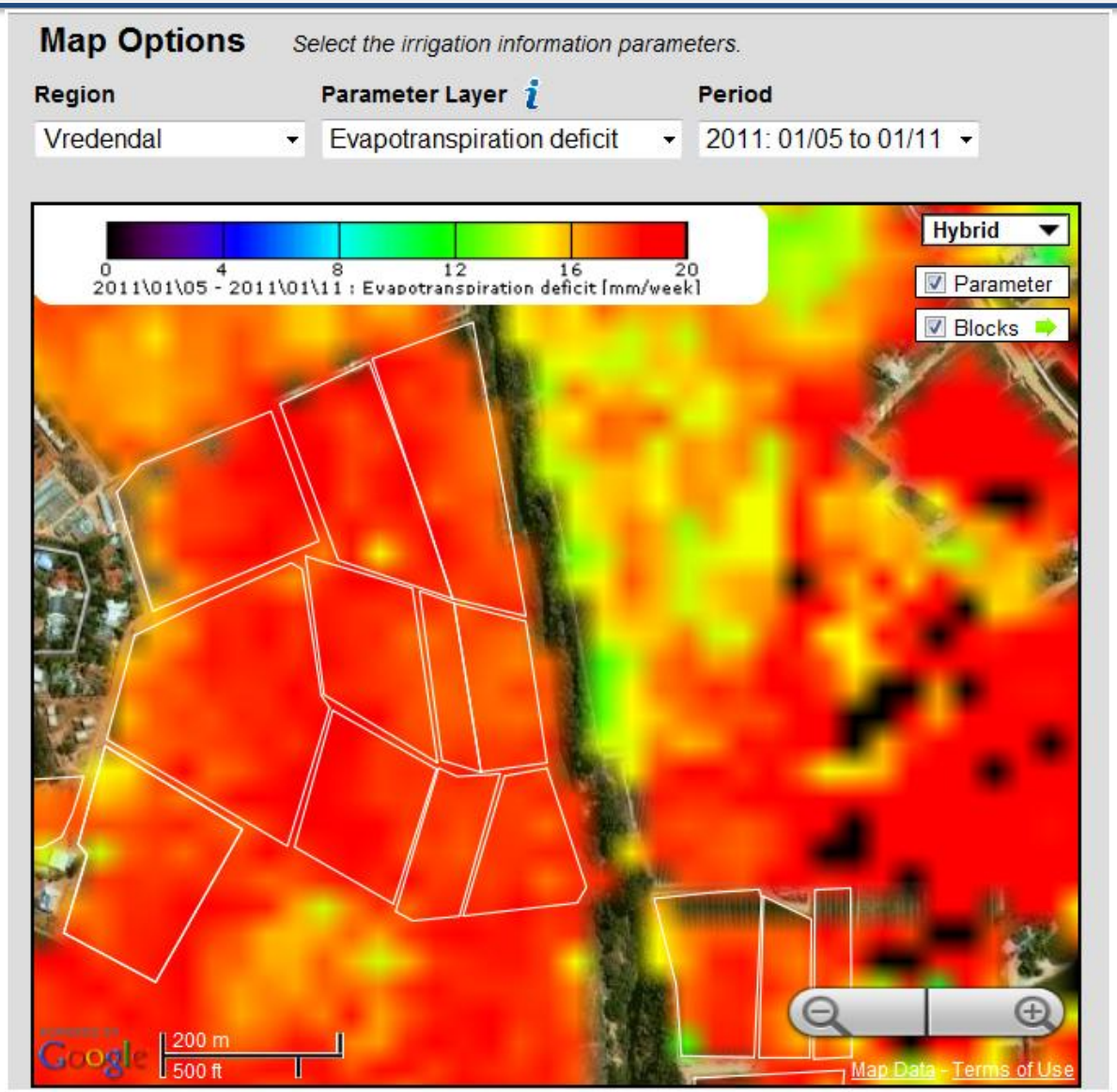
Example 4 – Evapotranspiration deficit



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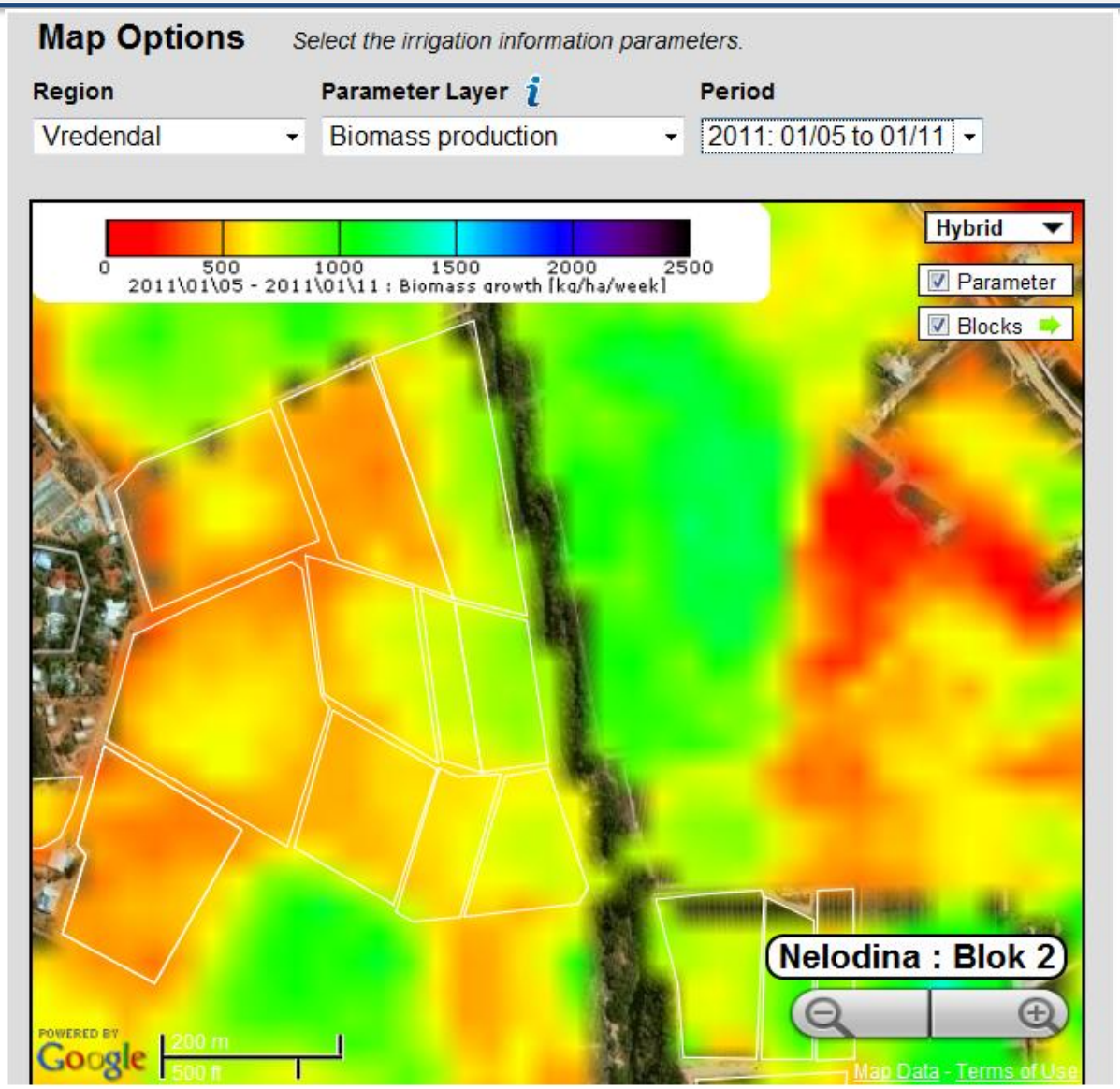
Example 4 – Biomass production



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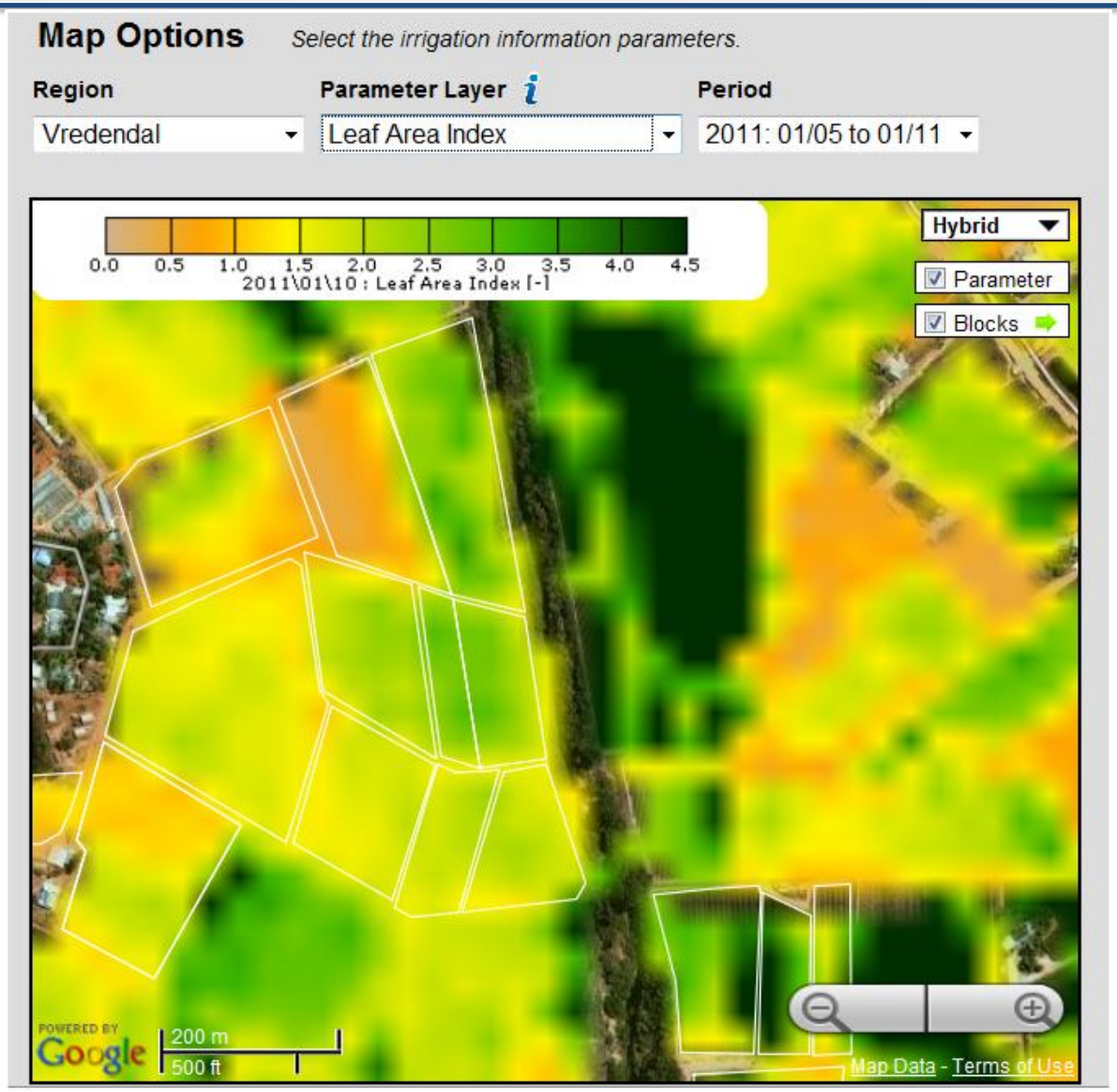
Example 4 – Leaf area index



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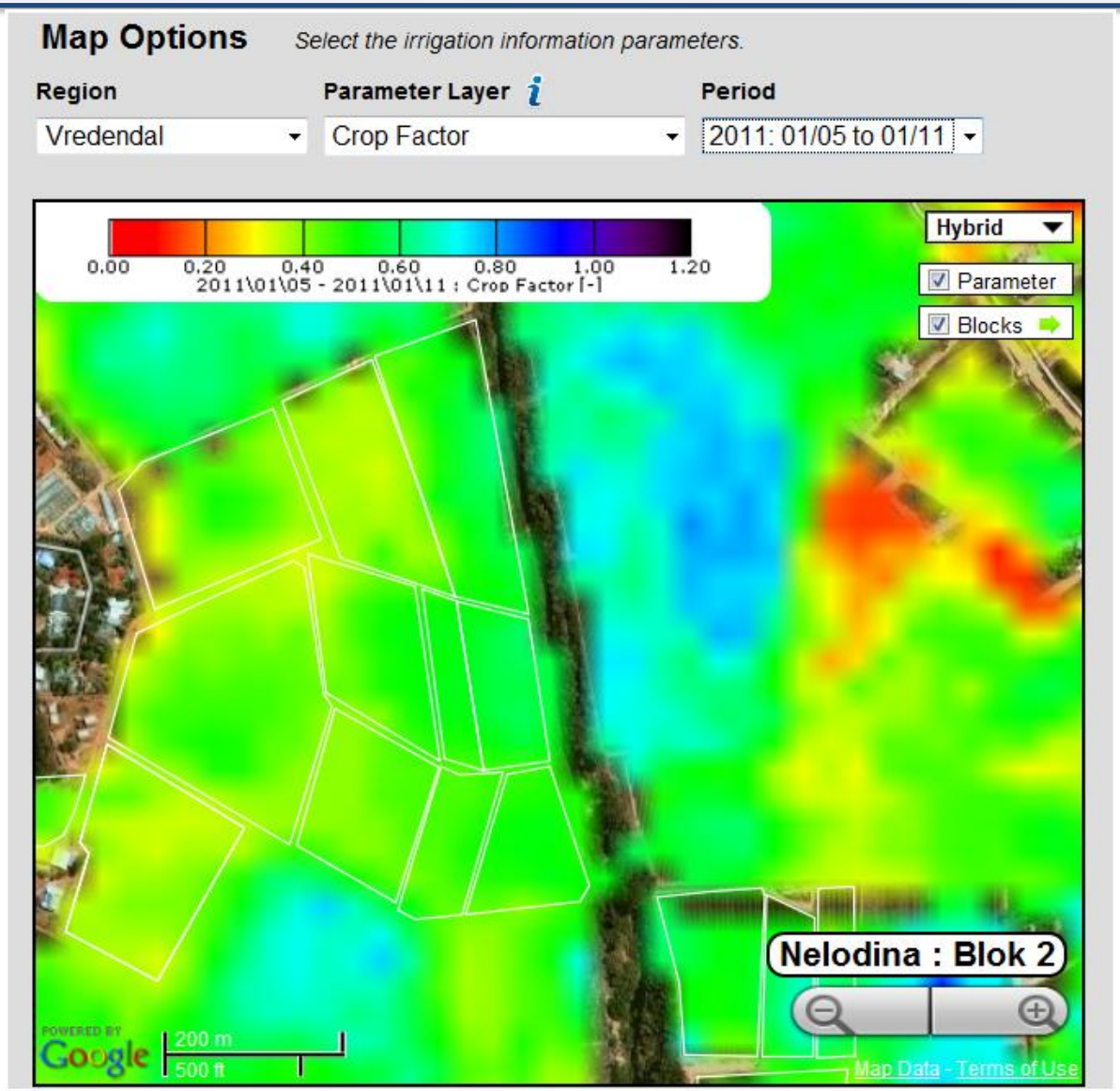
Example 4 – Crop factor $k_c k_s$



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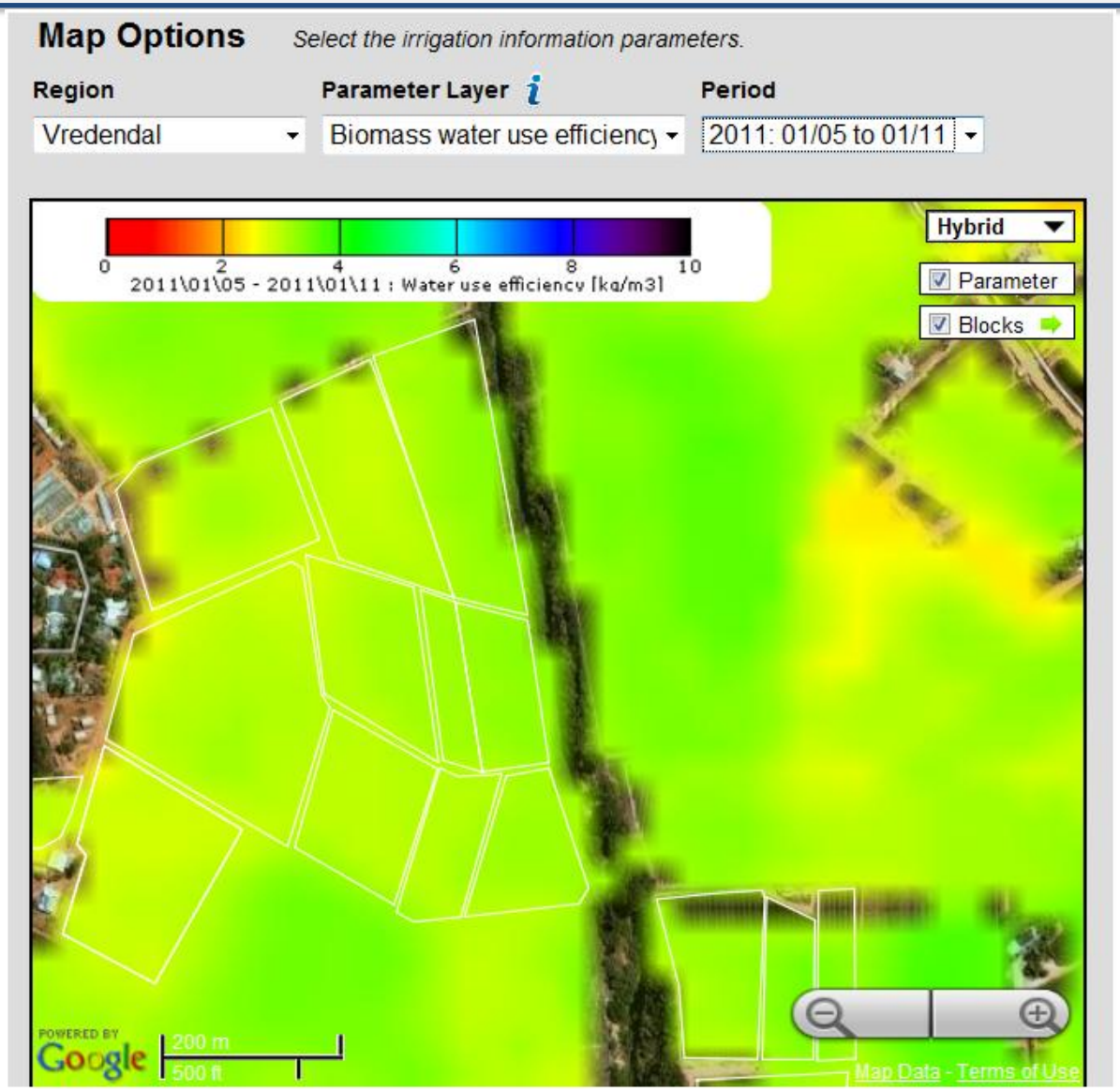
Example 4 – (Biomass) water use efficiency



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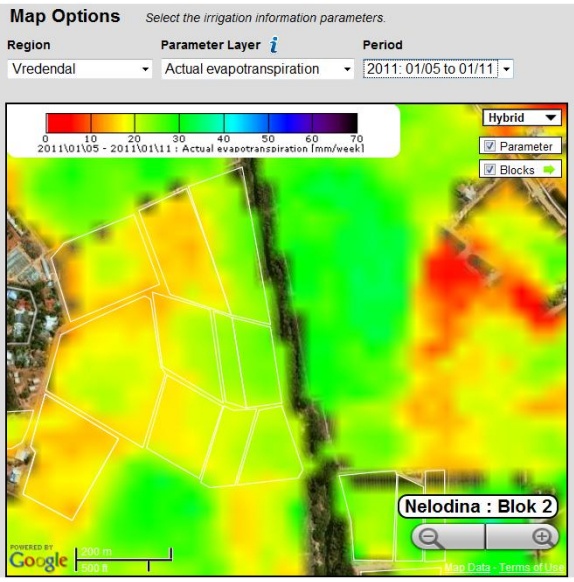
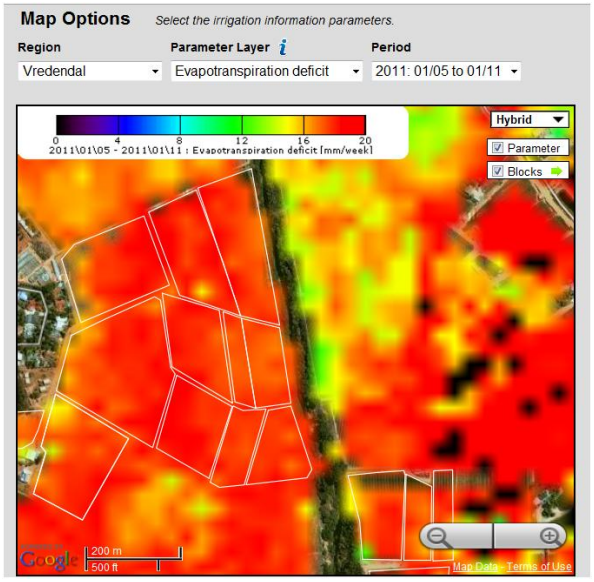
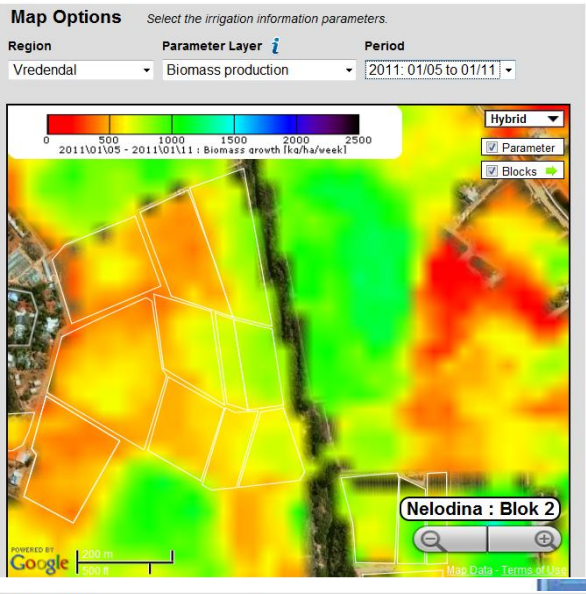
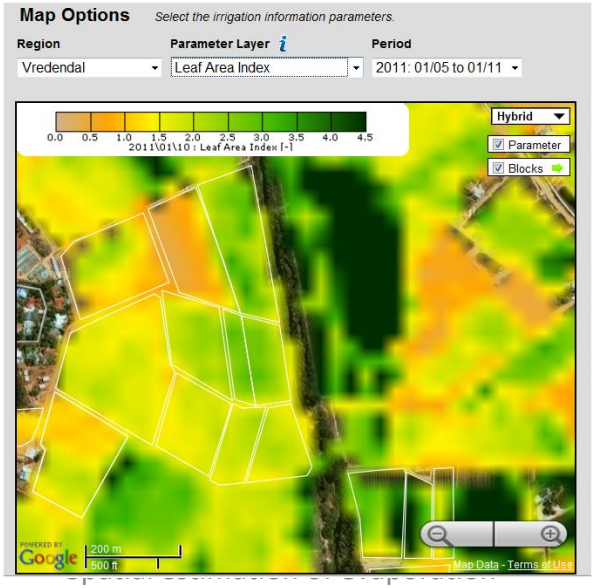
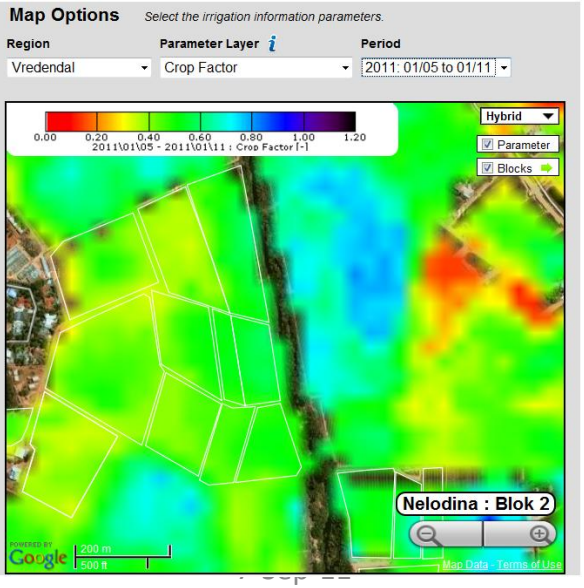
Example 4 – Weekly data maps (operational)

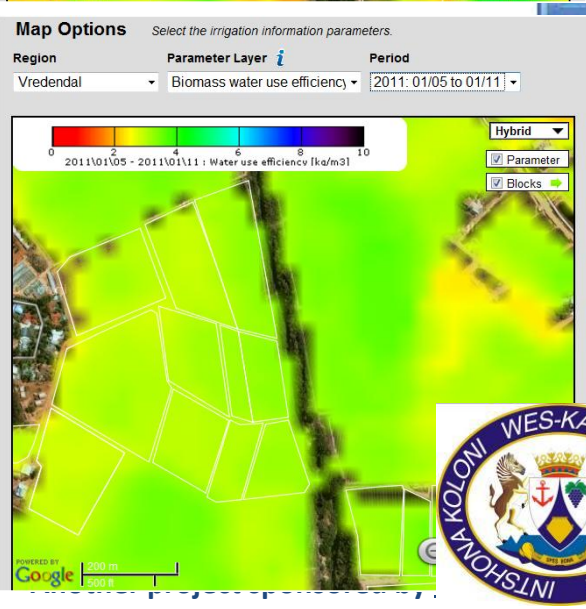




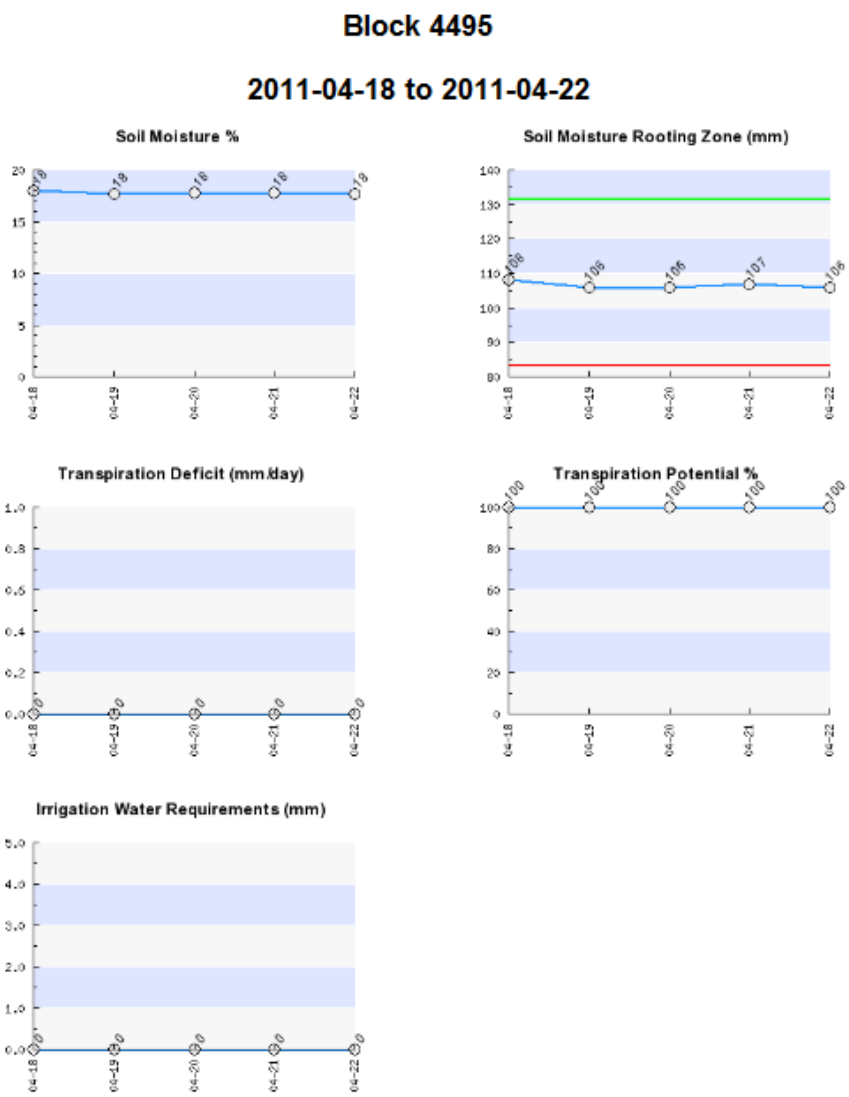


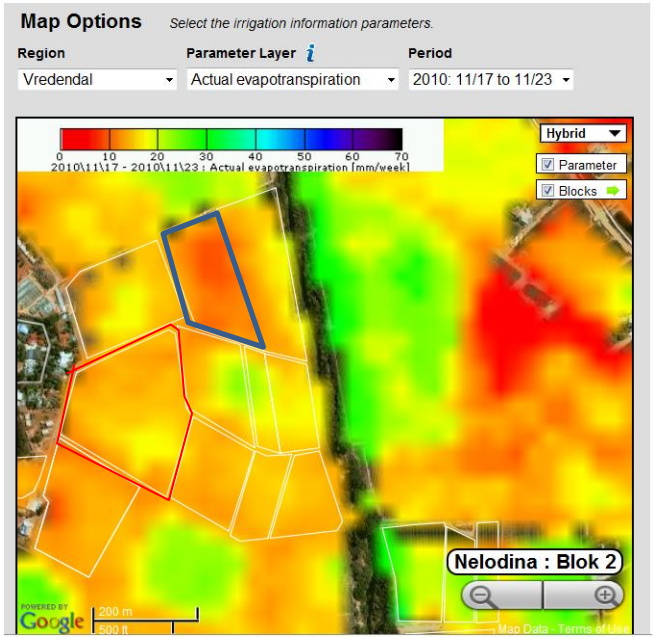






Example 4 – Total evaporation (operational) (Jarmain et al., 2011)





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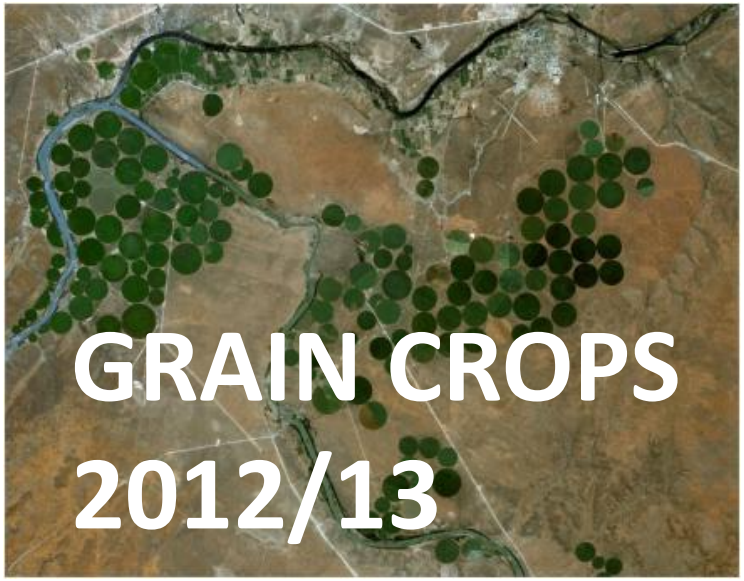
Example 5 – Total evaporation (operational) (K5/2079)

- Water use efficiency of irrigated agricultural crops determined with satellite imagery

Example 5 – Total evaporation (operational) (K5/2079)



- **Accuracy** of SEBAL estimates
- Show **uses** of spatially explicit data
- Develop to **operational application**
- **Capacity** building

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Example 5 – Total evaporation (operational) (K5/2079)

- Pilot study 1 - Irrigated sugarcane in Incomati catchment
- Linked to EU WATPLAN project
- Data delivery from 1 October 2011 (12 months)
- Data maps of ET, ET deficit, Biomass, Rainfall, Rainfall *minus* ET

Example 5 – Total evaporation (operational) (K5/2079)

- Pilot study 2- Irrigated grain crops in Vaal / Orange catchments
- Data maps of ET, ET deficit, Biomass, Rainfall, Rainfall *minus* ET
- Further development of data and applications

Combining remote and ancillary data

Water resources management

- Assessing available methods
- Characterising entire water balance
- Application related to total evaporation, rainfall and soil moisture
  - Land use impacts (Irrigated agriculture)
  - Operational spatial use (Irrigated agriculture, CMA's)
  - Land use change impacts (Invasive Alien Plants)
  - Flood forecasting
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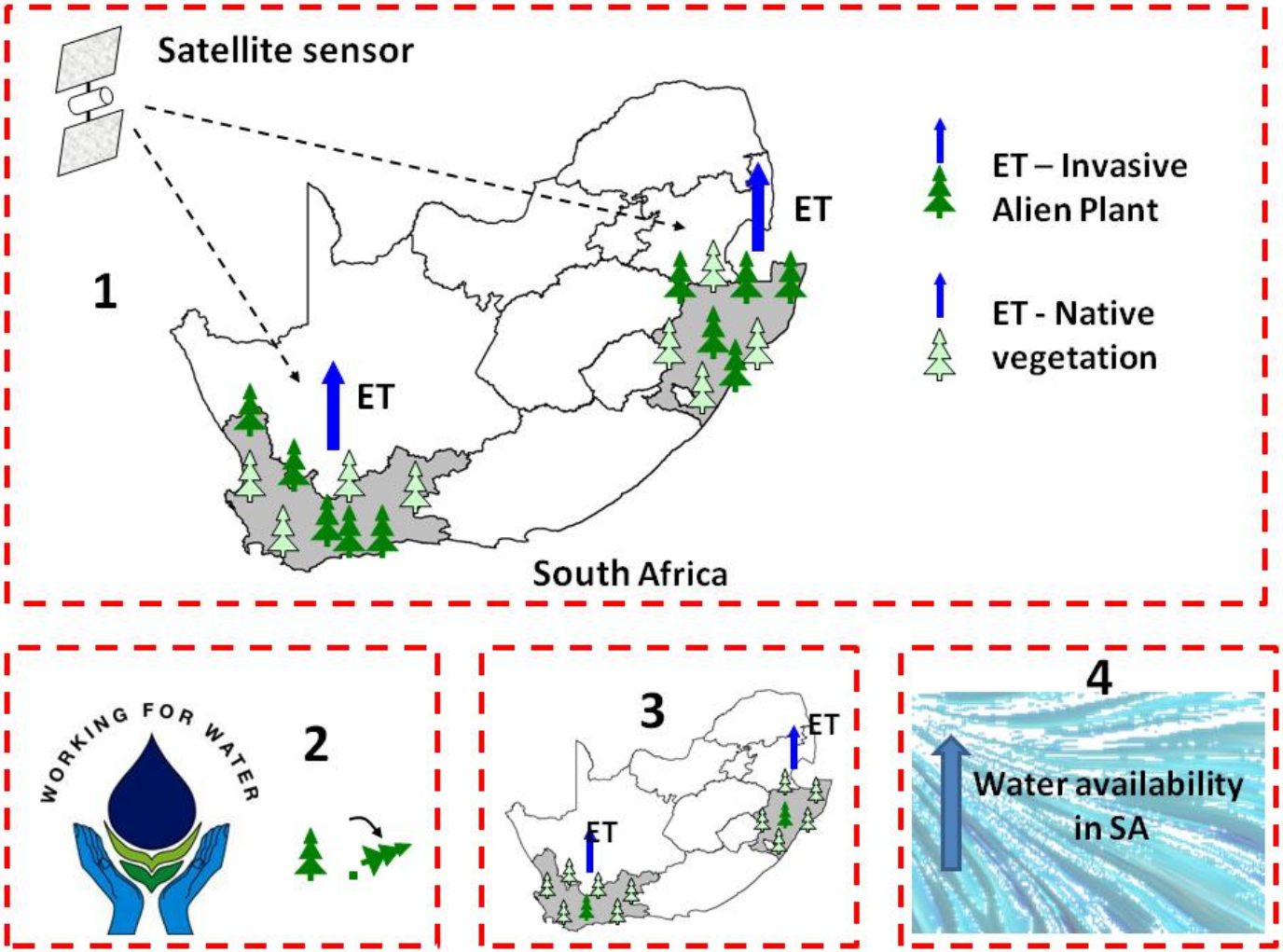
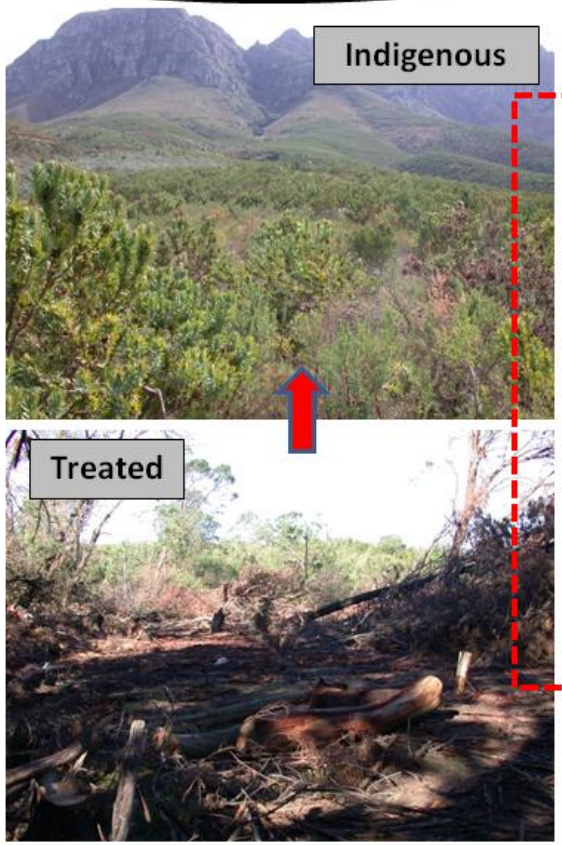
Example 6 – Total evaporation of IAPs (Meijninger and Jarmain, in prep.)

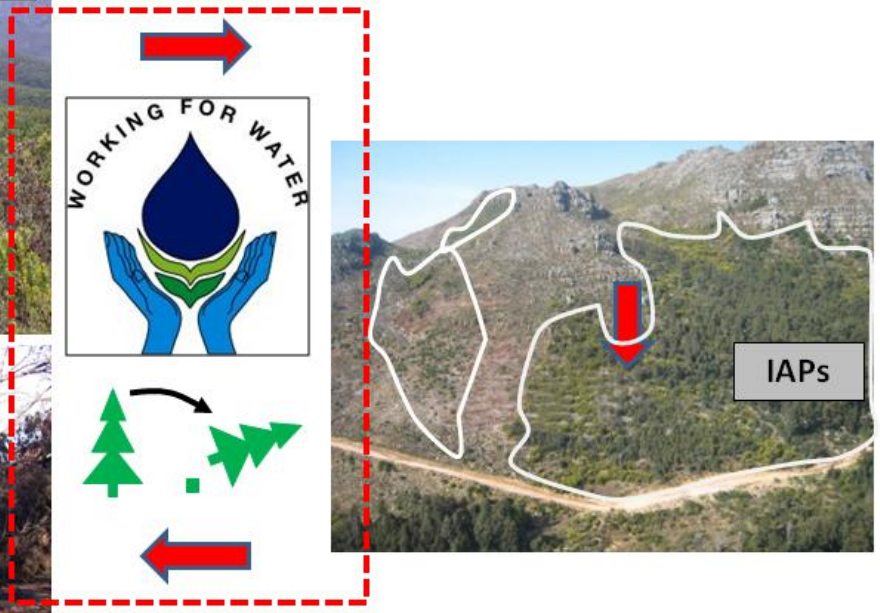


Example 6 – Total evaporation of IAPs (Meijninger and Jarmain, in prep.)

Invasive Alien Plant (IAP)

non-indigenous species….adversely affect…. hydrology

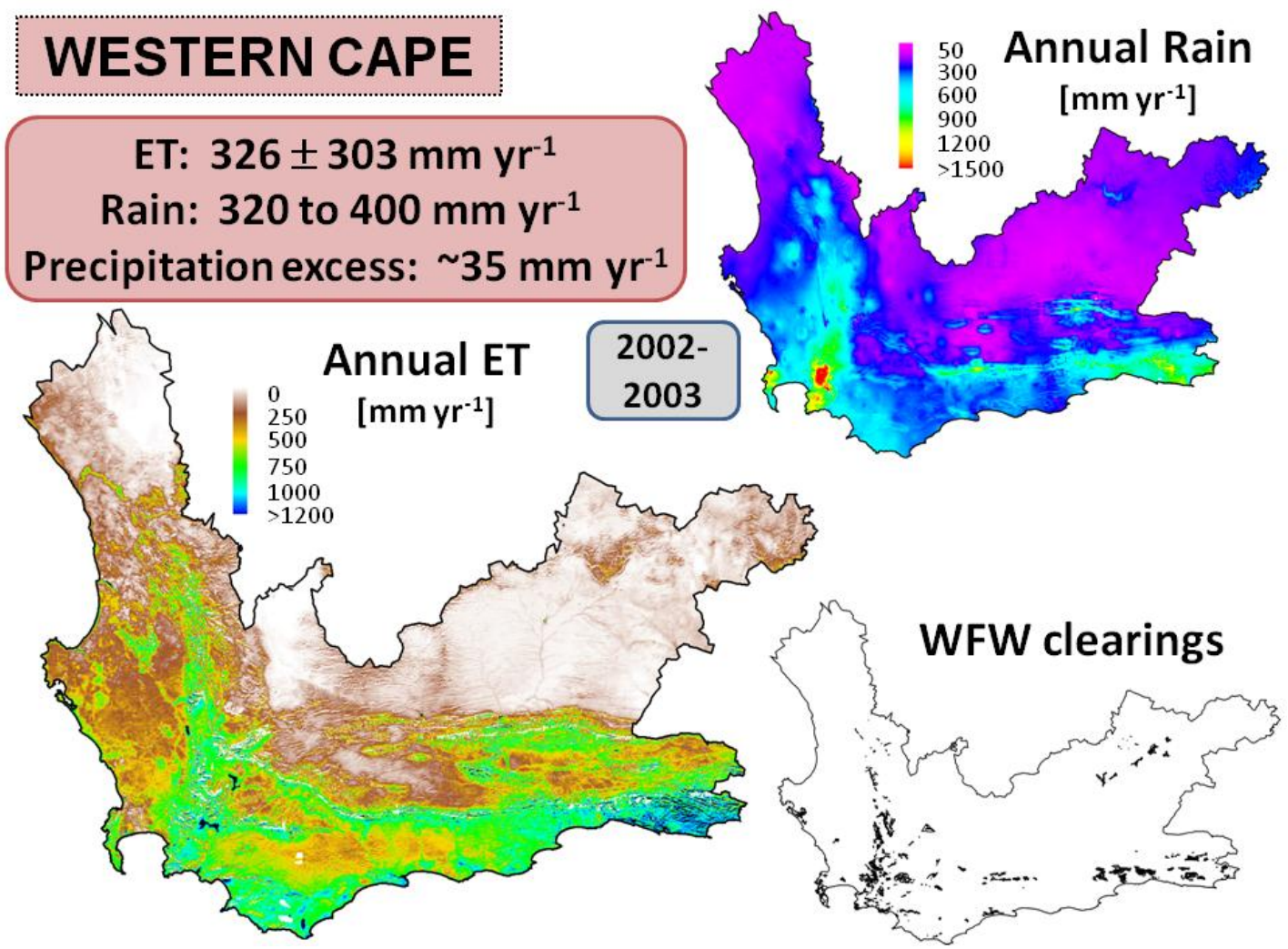




Total evaporation (ET)

sum of water lost from a surface…. transpiration by vegetation, soil evaporation or evaporation of intercepted water

Example 6 – Total evaporation of IAPs (Meijninger and Jarmain, in prep.)



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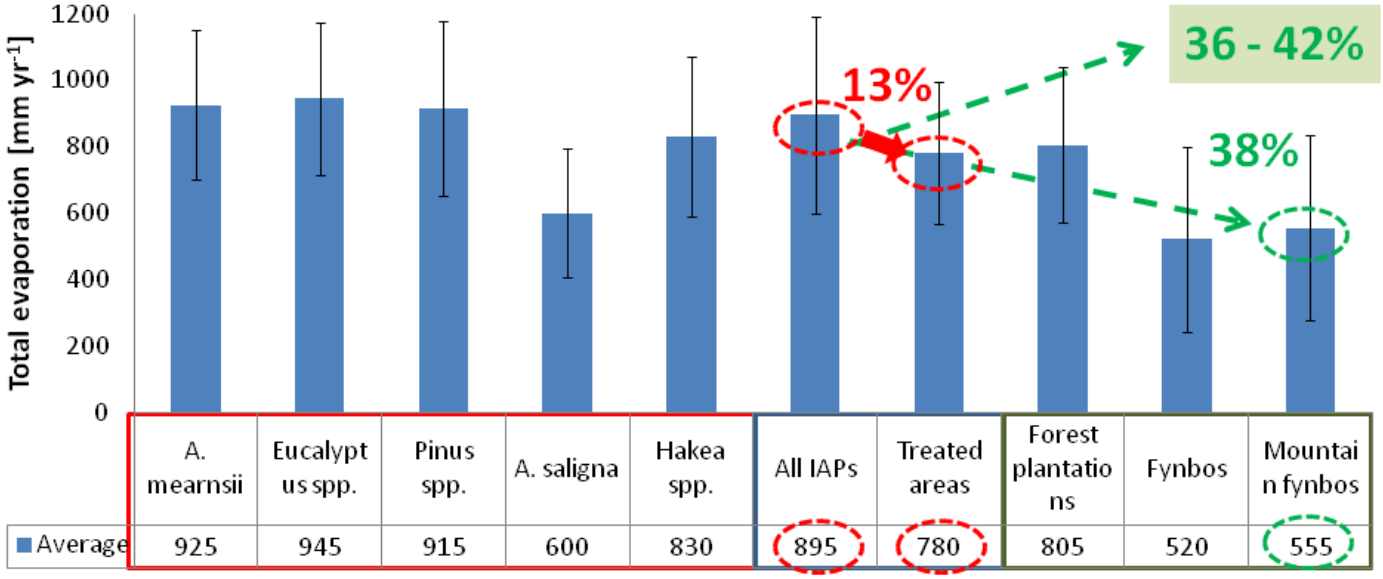
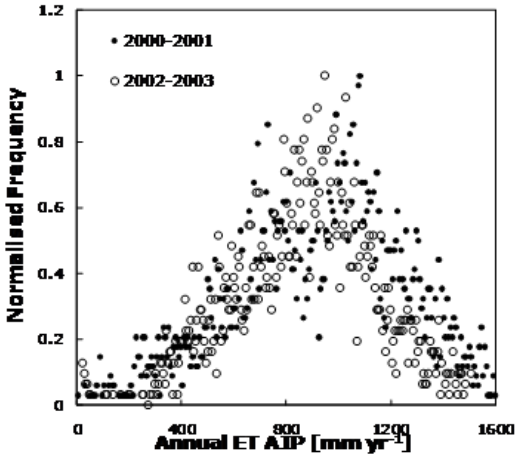
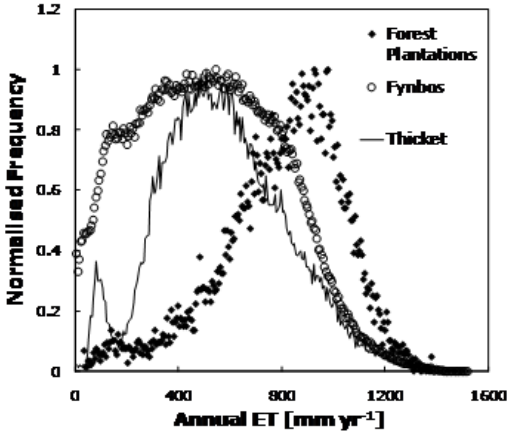


WESTERN CAPE

TOP 5 IAPs ~72%





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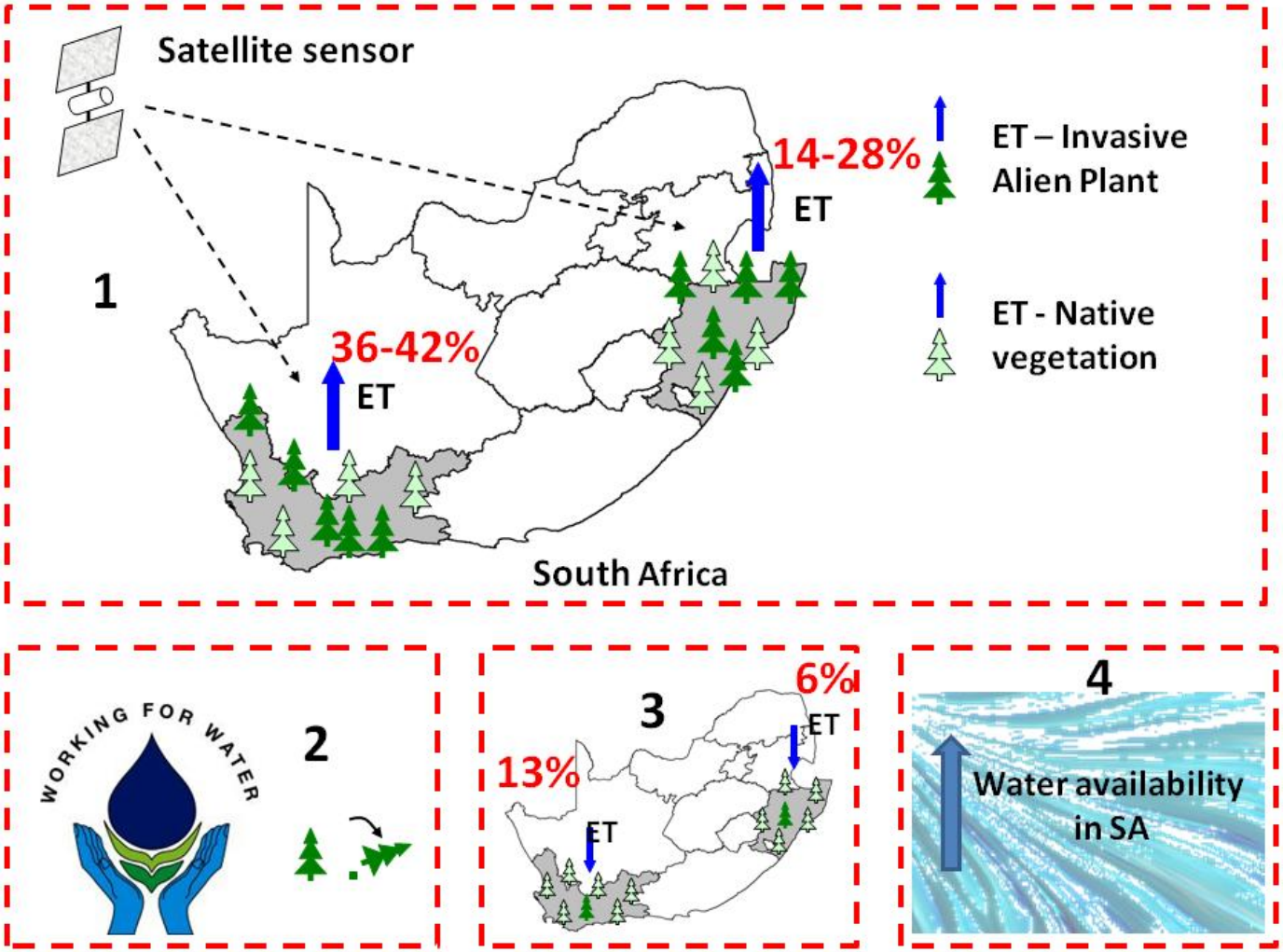

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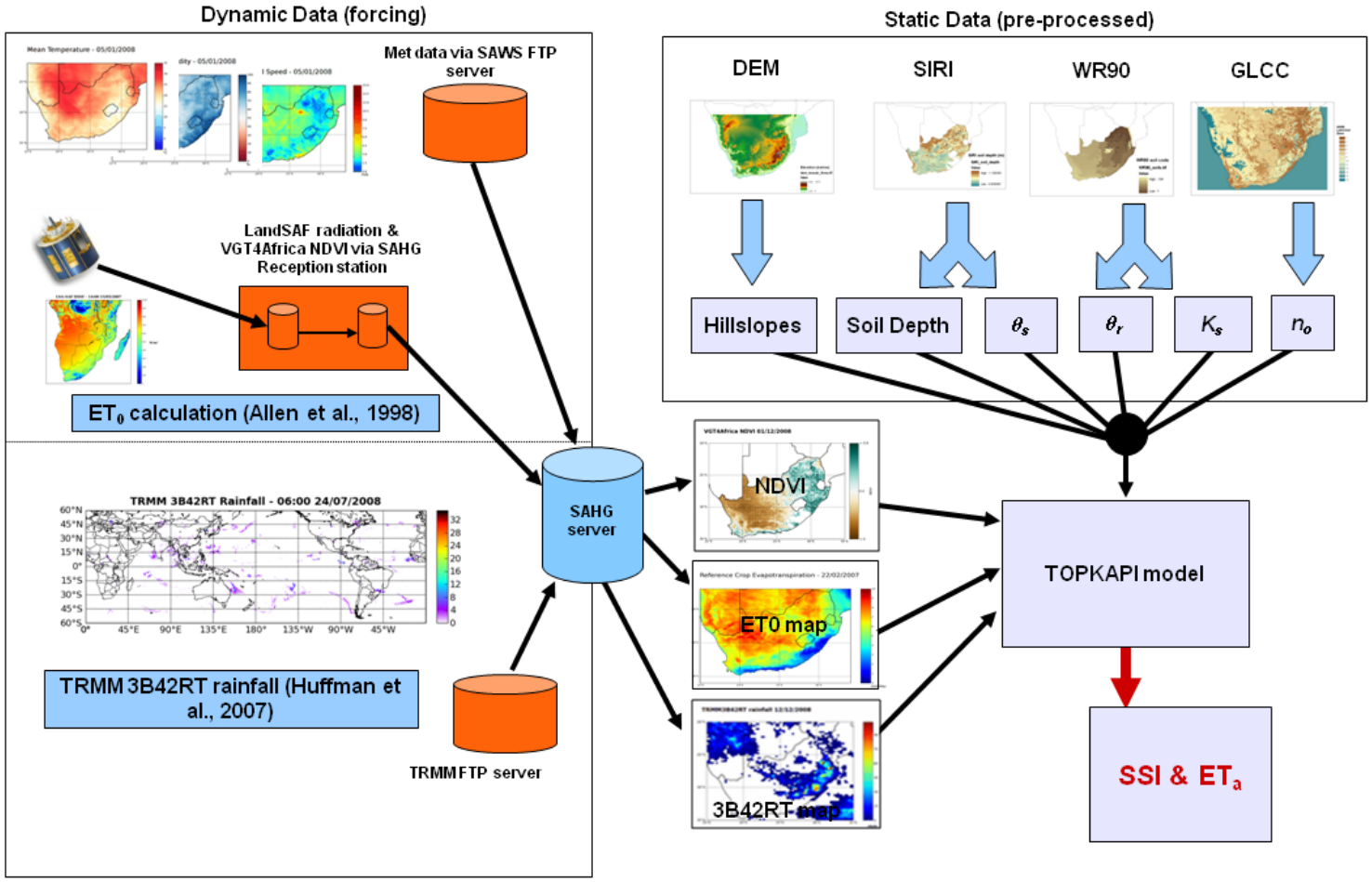
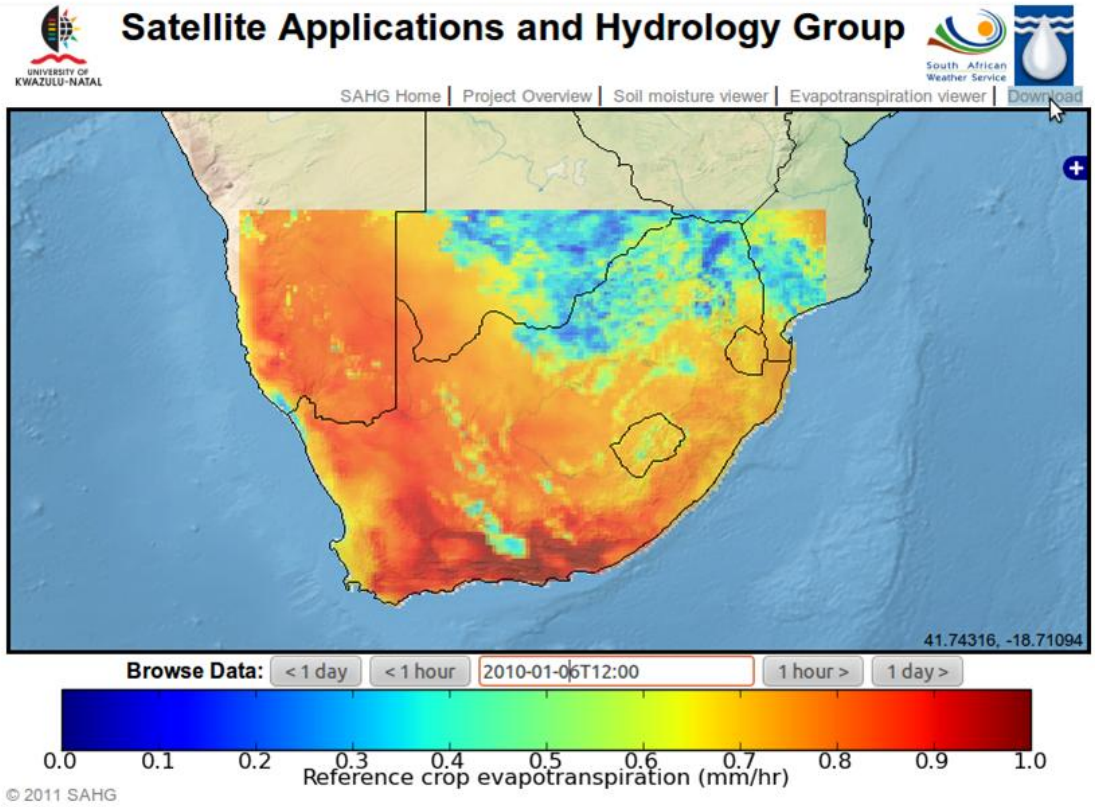
Example 7 – Soil moisture (Pegram et al., 2011 - WRC report 1683-1-11, K5-2024 HYLARSMET)



Example 7 – Reference evapotranspiration (ET_o)

Hourly ET_0 at 0.11° on the web

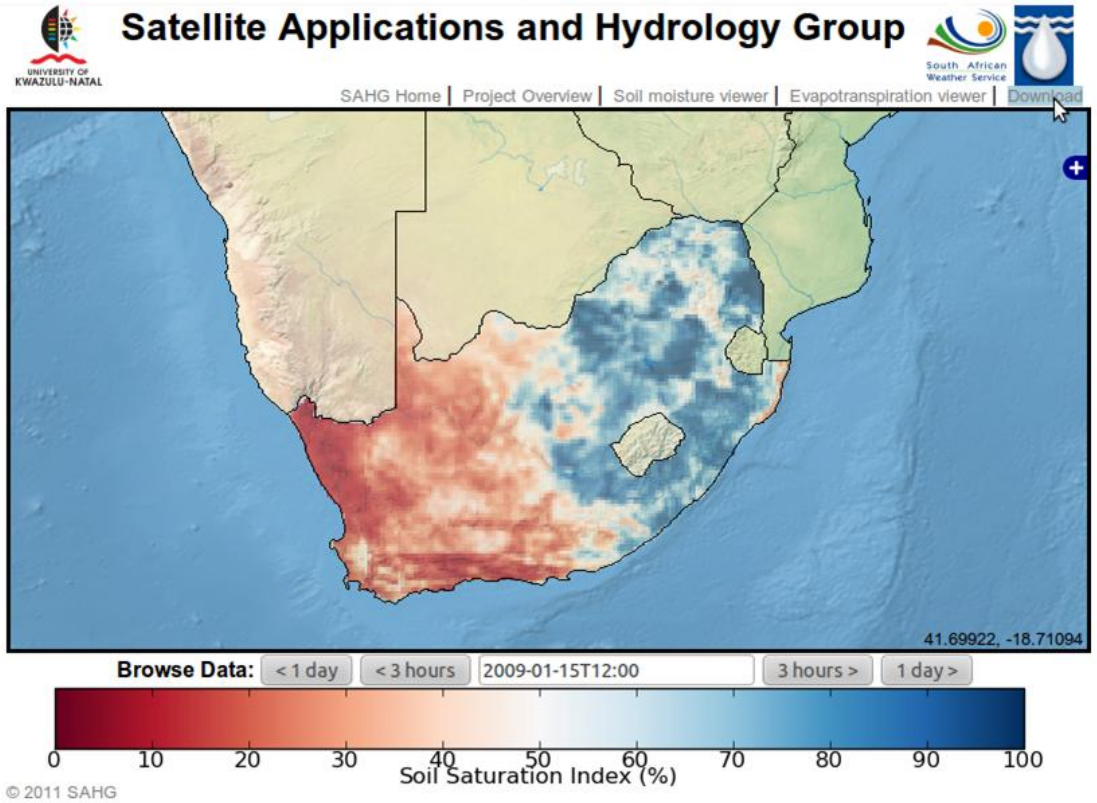


http://sahg.ukzn.ac.za

~11 km x 11 km

Example 7 – Soil Saturation Index (SSI)

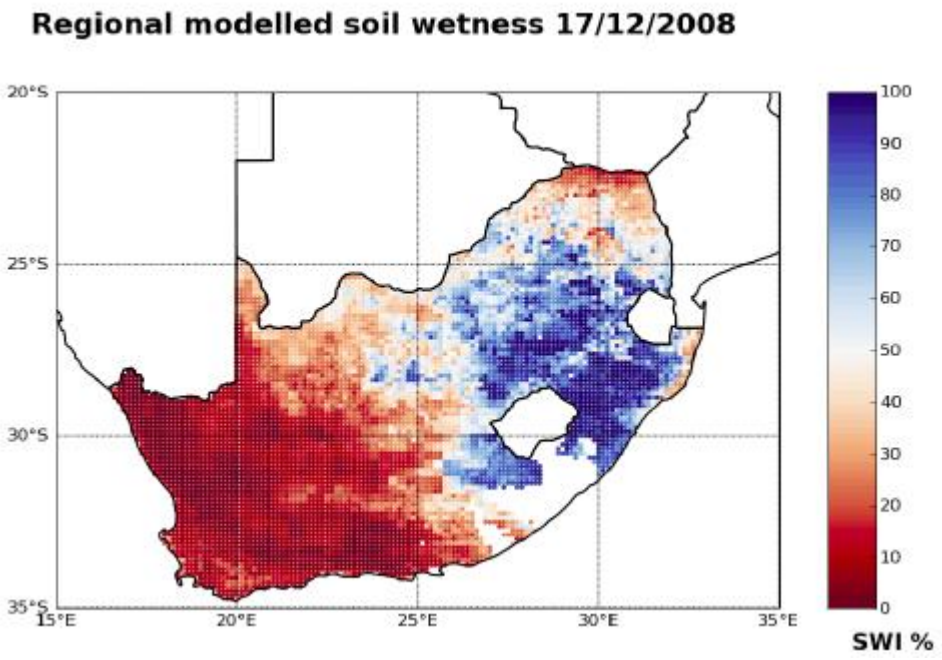
3-hourly SSI at 0.125° on the web



http://sahg.ukzn.ac.za

~12.5 km x 12.5 km

Example 7 – Soil moisture (Pegram et al., 2011 - WRC report 1683-1-11, K5-2024 HYLARSMET)



CONCLUSION

- The soil moisture modelling approach hold promise
  - initial inter-comparisons with other estimates (remote sensing),
  - requires validation against observed data
- High frequency, continuous information
  - Flash flood forecasting

Concluding remarks





Remote sensing data for Water resources management

- WRC has been instrumental in evaluating new technologies and data applications
- Many developments (local, international) anticipated
  - Satellites, integration of data
- Numerous potential applications
  - Historic and operational
- Benefits
  - Space (Field → Farm → Catchment → Provincial)
  - Time (Historic → Current → Future)

Acknowledgements

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