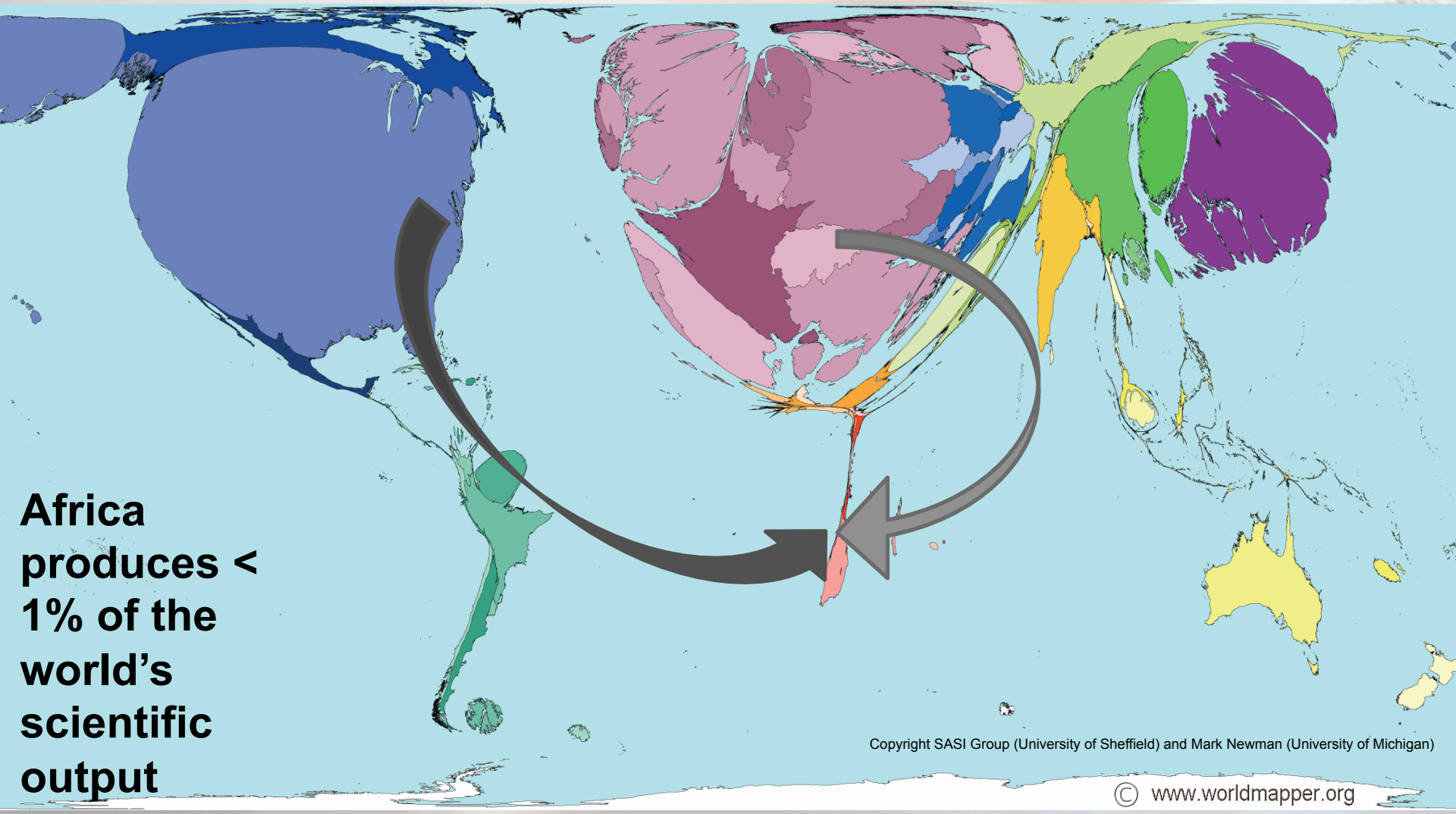
UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

# Land and Water Considerations for Biofuel Feedstock Production

**Graham Jewitt**
**Umgeni Water Chair of Water Resources Management**
**Centre for Water Resources Research**






Africa produces < 1% of the world's scientific output
Copyright SASI Group (University of Sheffield) and Mark Newman (University of Michigan)
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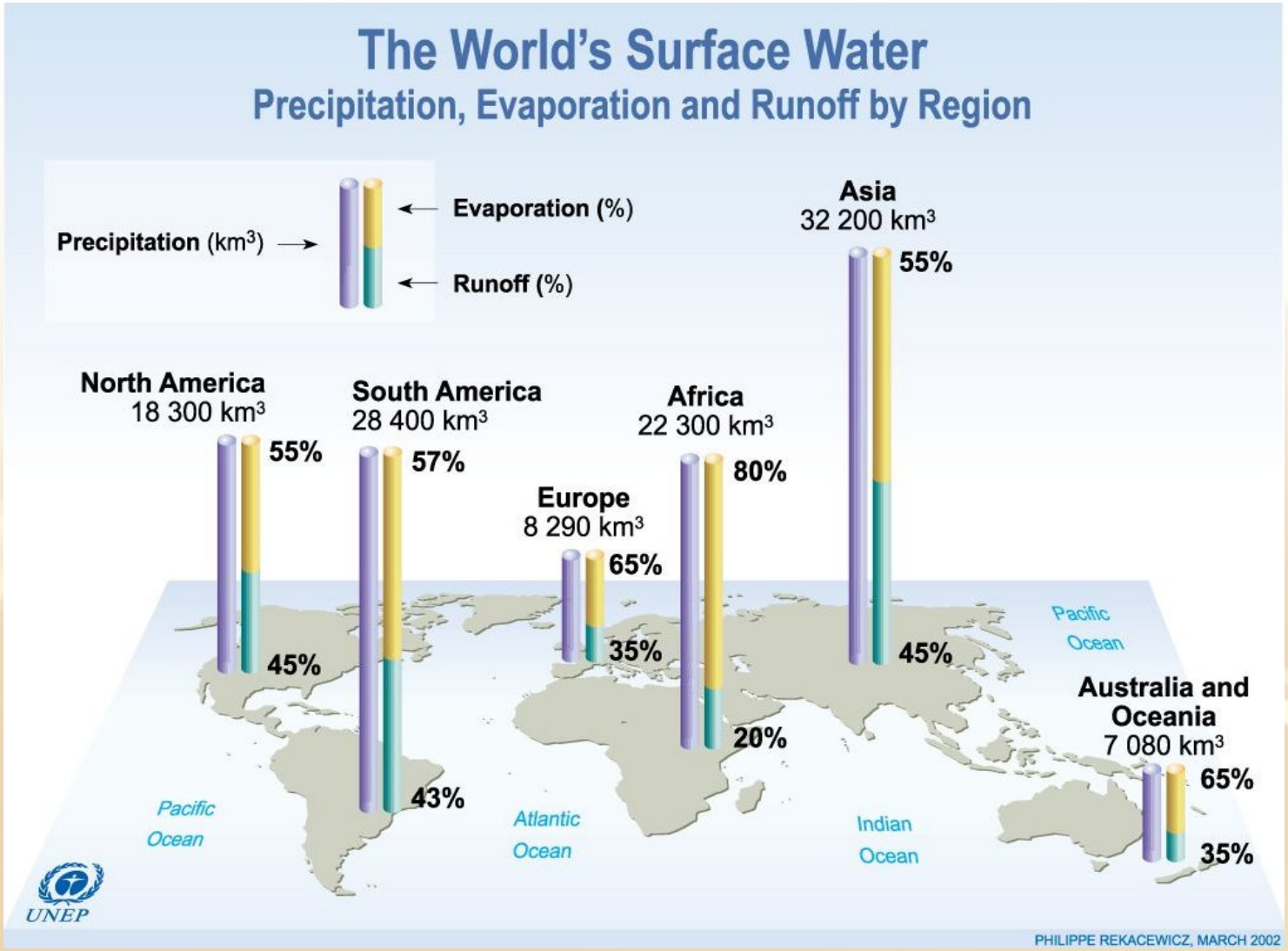
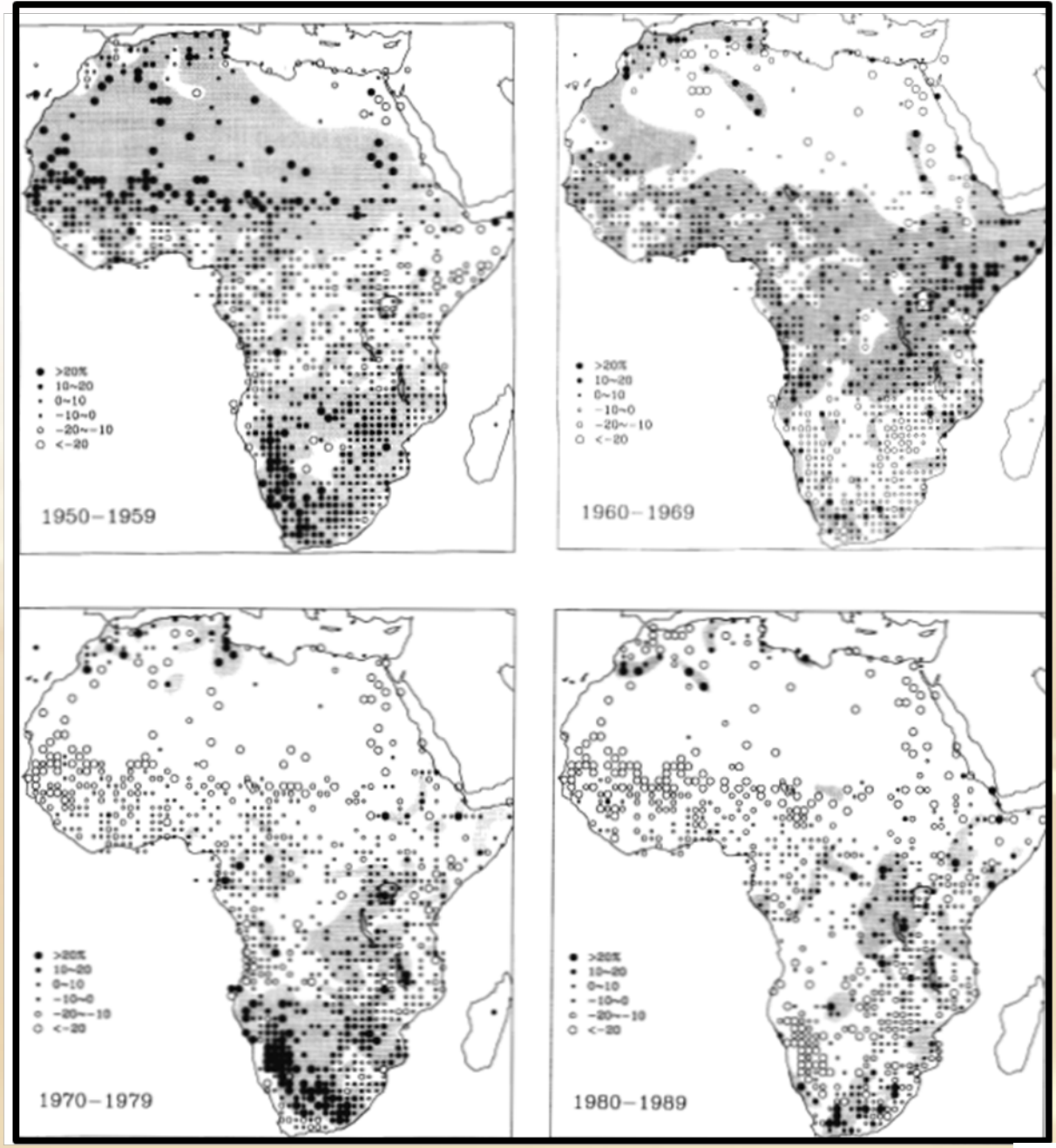
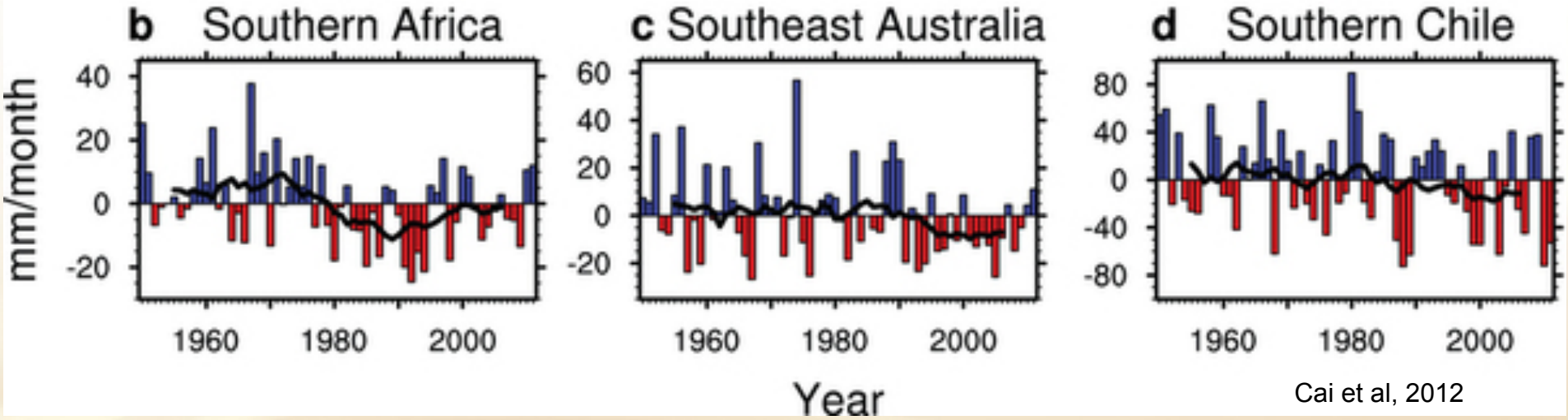



African countries are "hostage to their hydrology
-Low rainfall: runoff ratio
- High variability

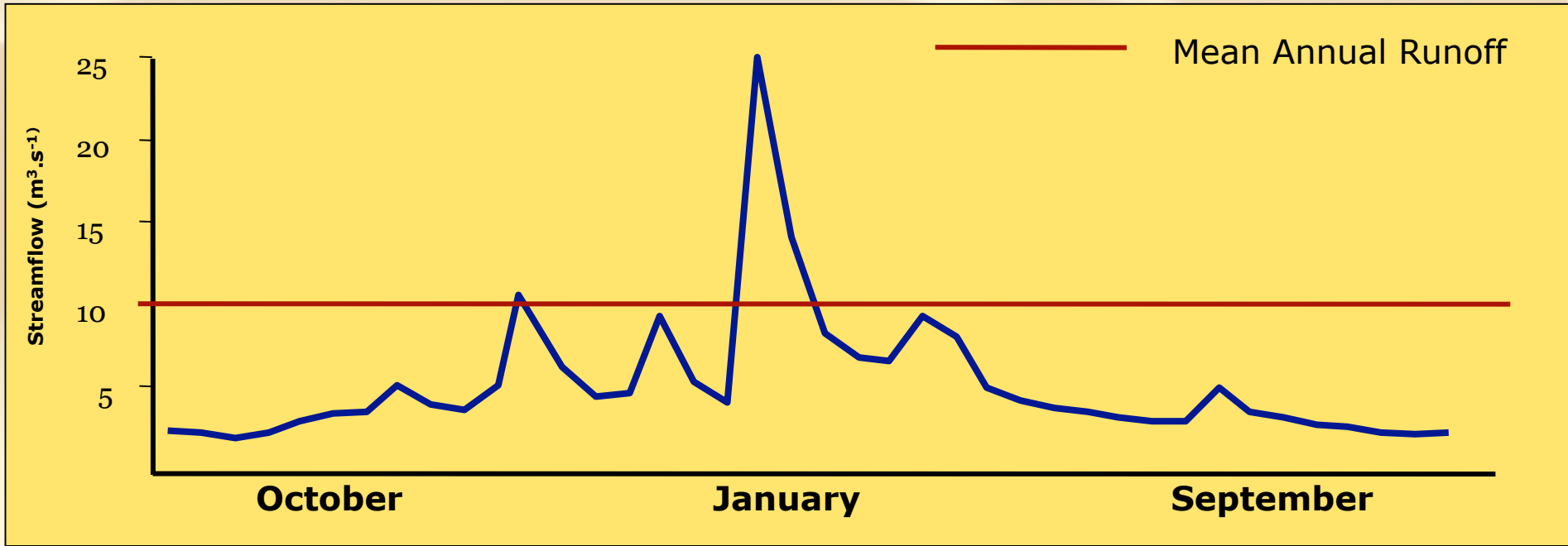
Decadally averaged rainfall anomalies for the 1950', 1960's, 1970's and 1980's in Africa (Nicholson, 2000).



# The Mean is Meaningless




Cai et al, 2012



# Land and Water


MARK EDWARDS, HARD RAIN PICTURE LIBRARY

**Changes in hydrological cycle functioning**

**Water withdrawals**

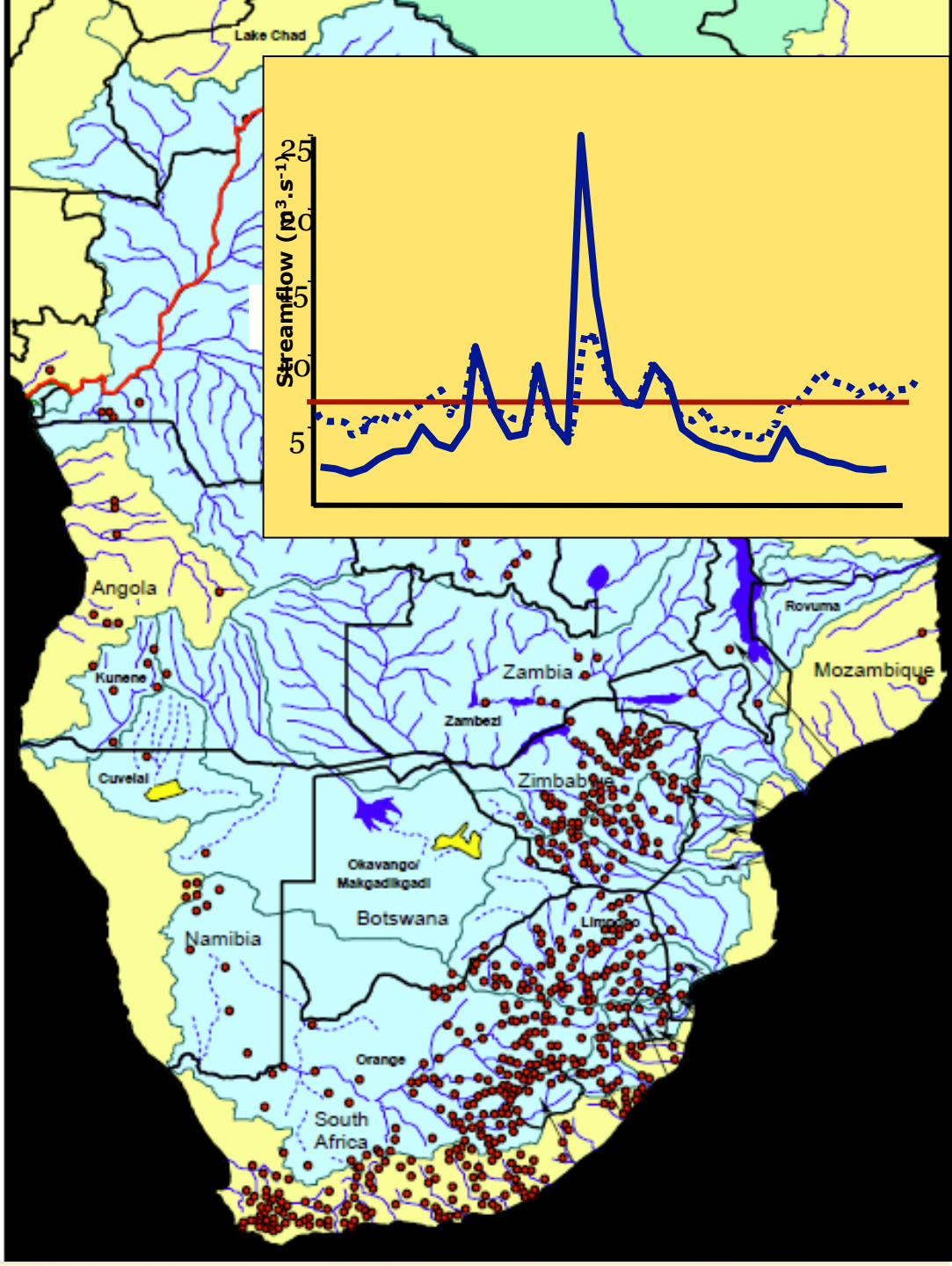
**Storage**

# Large Dams in Southern Africa

N.B. Large dam: Wall height > 15 m and/or Volume > 2 million $m^3$
*(ICOLD, 1999)*

- Africa has a total of 1,269 large dams; 827 (65%) of these are in the SADC countries
- SADC dams hold 37% of Africa's impounded water
- South Africa (#11) and Zimbabwe (#20) are listed amongst the top twenty countries in the world in terms of the numbers of dams built

*Sources: AQUASTAT Database (FAO, 2005); WCD, 2000*



# Land and Water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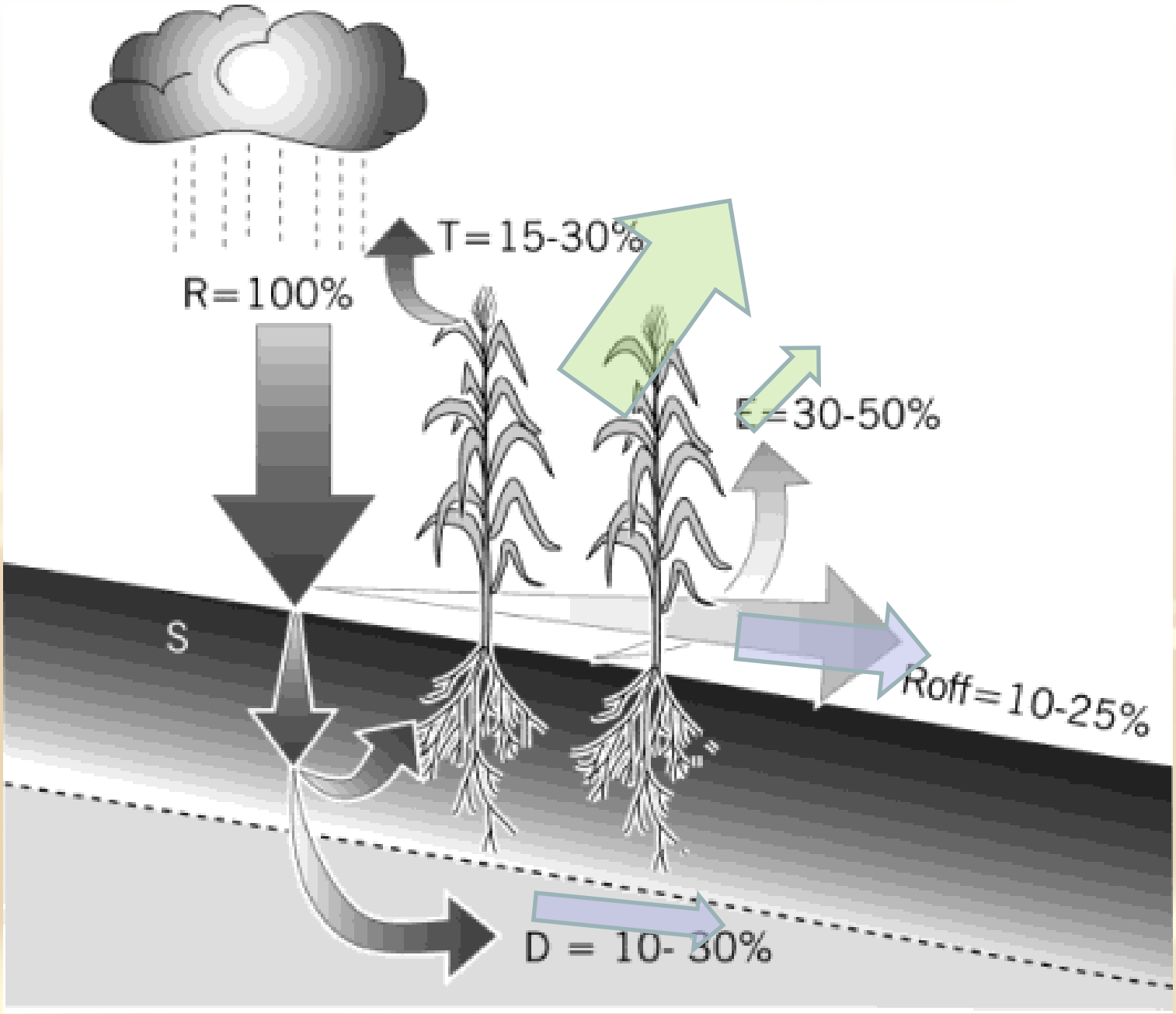
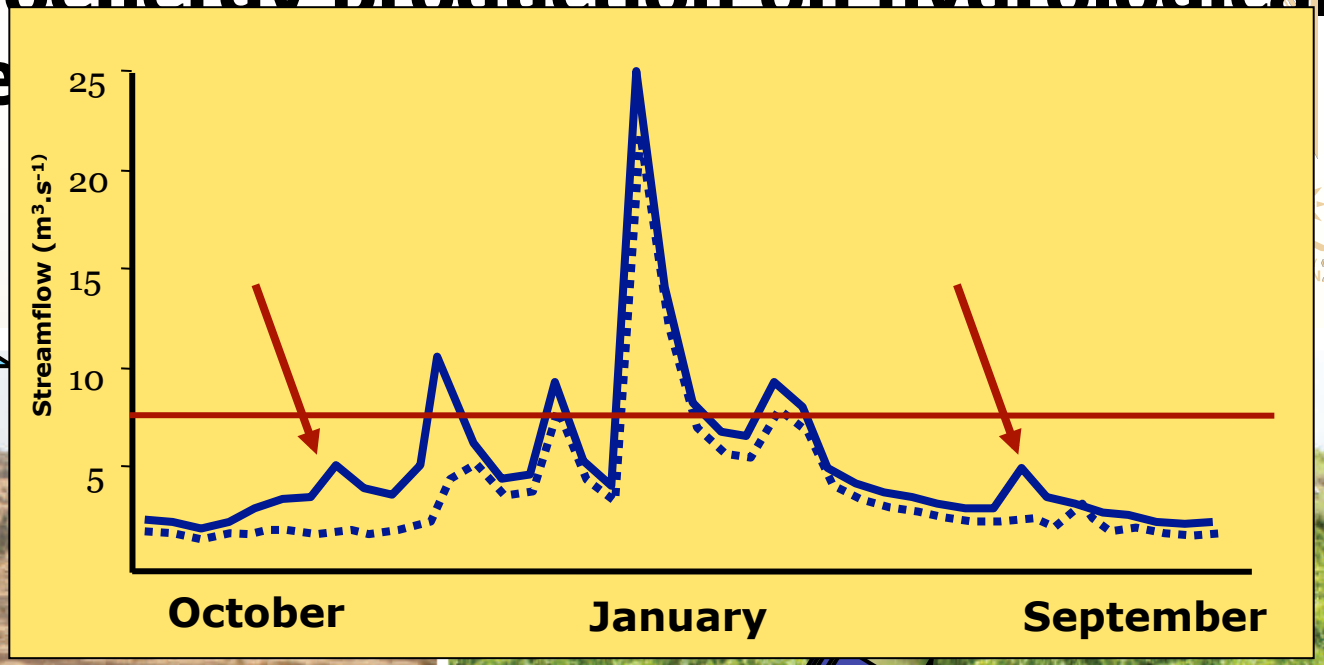
**Changes in hydrological cycle functioning**

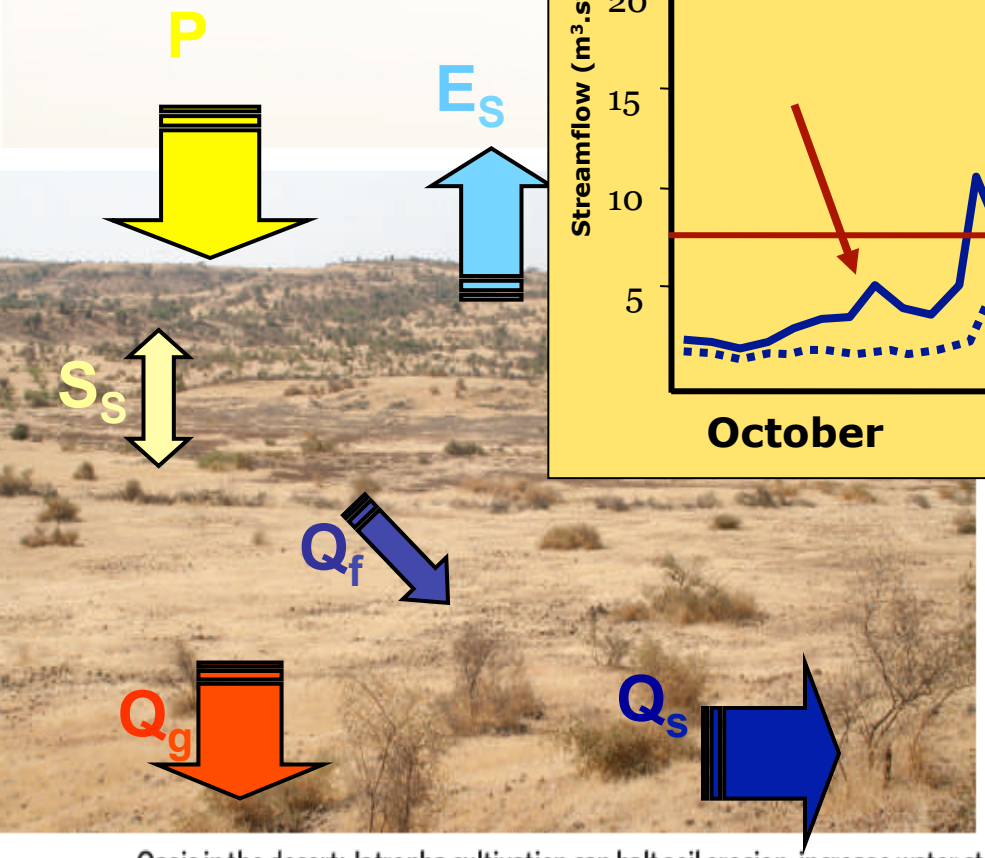
**Water withdrawals**

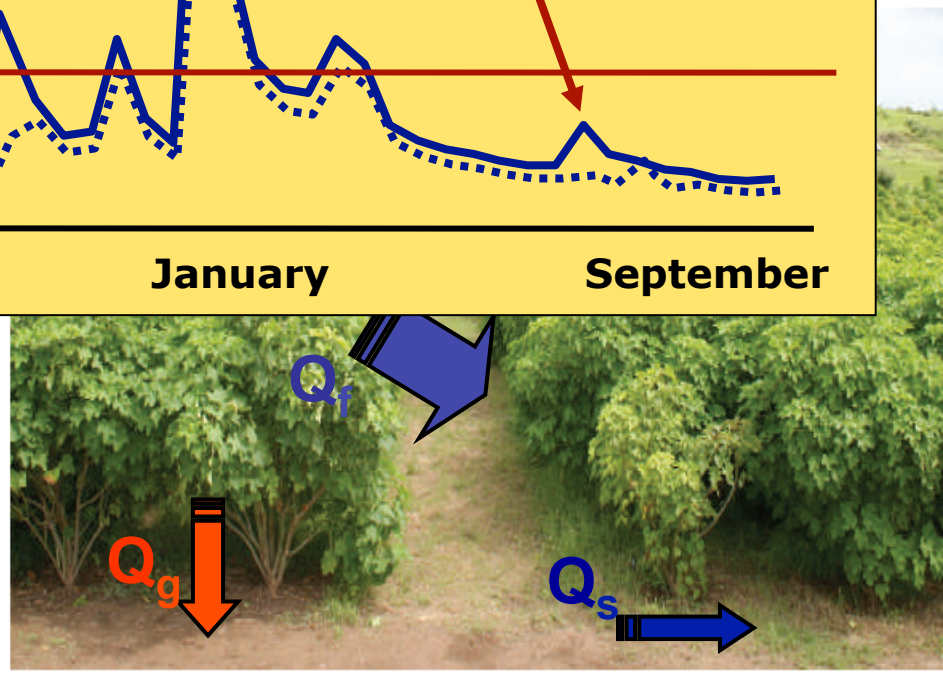
**Storage**


T=15-30%
R=100%
E=30-50%
S
Roff=10-25%
D = 10- 30%

# Impacts of bioenergy production on hydrological processes



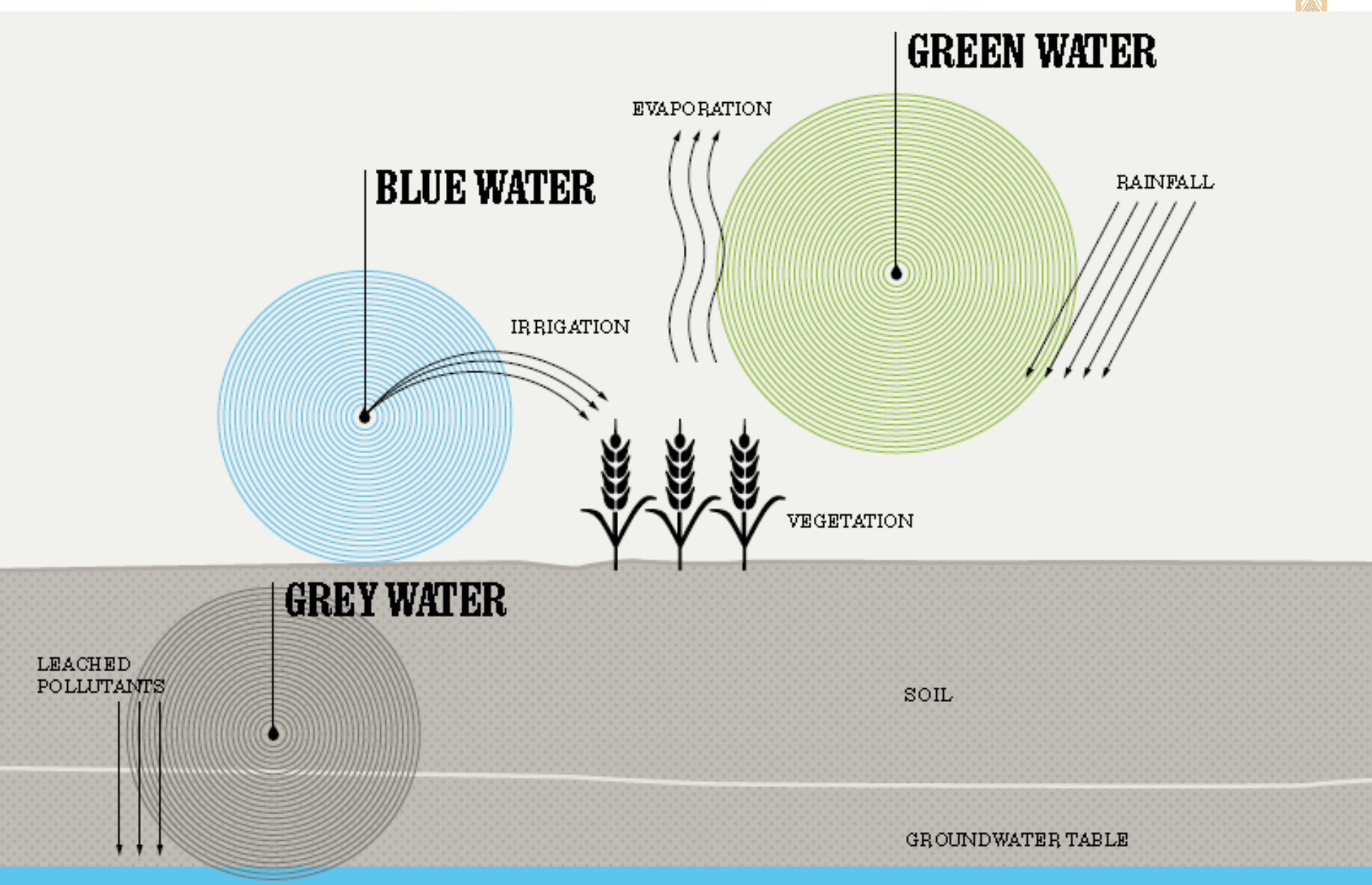




Oasis in the desert: Jatropha cultivation can halt soil erosion, increase water storage in the soil and transform barren expanses into lush, productive land.

**Short-term dynamics (e.g. interception, flood generation) *vs.* long-term dynamics (e.g. groundwater recharge, base flow)**

Picture from Fairless, 2007, *Nature with annotation by Stefan Uhlenbrook*

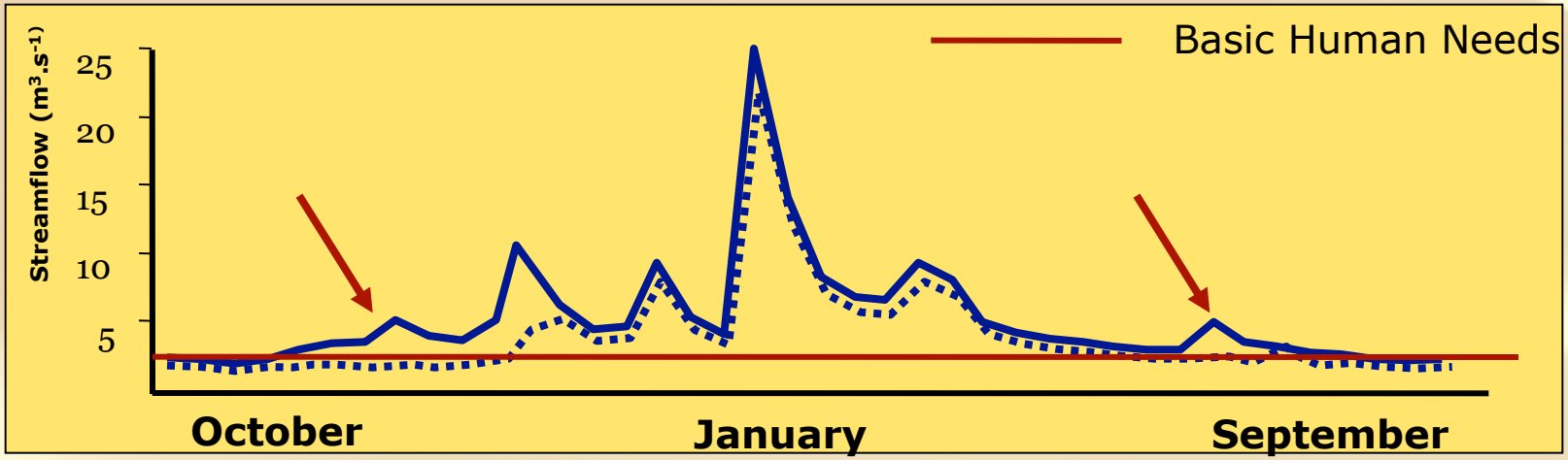


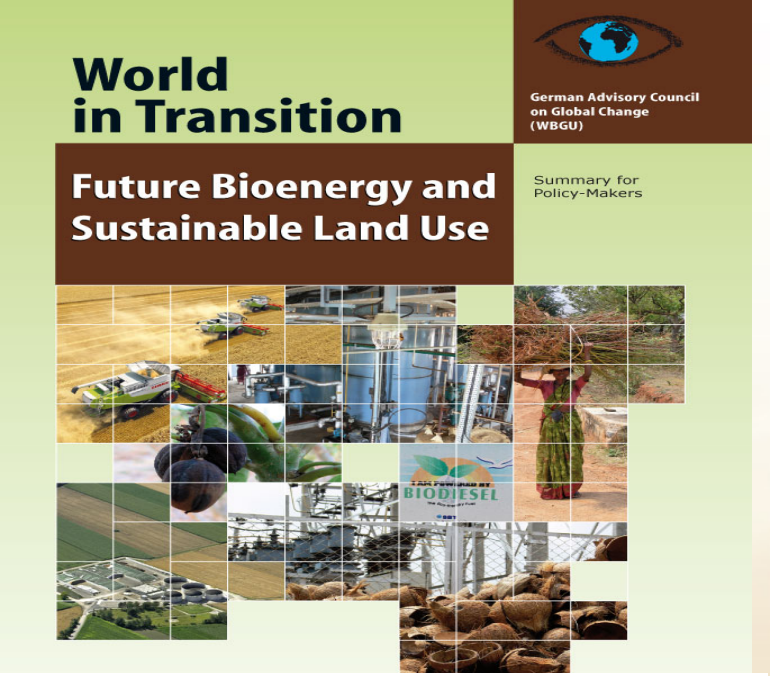

Source: WWF-UK and SABMillar: Water Footprinting

# Impact of Land Use on Freshwater Availability

1 – Grassland Baseline  2 – Forest Baseline

| Land Use | | Impact on Wet Season Recharge | Impact on Onset of wet season flows | Impact on onset of dry season flows | Long term impact on groundwater reserves |
|---|---|---|---|---|---|
| **Plantation Forest** | 1 | Moderate-High | High | High | Moderate-High |
| | 2 | Minor | Moderate | Moderate | Moderate |
| **Sugar Cane (Dryland)** | 1 | Moderate | Moderate | Low | Low |
| | 2 | No Impact | No Impact | No Impact | No Impact |
| **Jatropha (Dryland)** | 1 | Low | Moderate | Low | Low |
| | 2 | No Impact | No Impact | No Impact | No Impact |






UNEP

Öko-Institut e.V.

IEA Bioenergy

THE BIOENERGY AND WATER NEXUS

# Sustainable bioenergy production means understanding Land-Water-Soil interactions

- Many way to consider these:
  - Virtual Water
  - Embedded Water
  - Green Water Flows
  - Water Footprint
- Think scientifically (hydrologically)!
  - Appropriate scale, scope and resolution
  - Spatial and temporal variability
  - Not 1-D
- The South African approach

JEWITT, G. and KUNZ, R. (2011). The impact of biofuel feedstock production on water resources: a developing country perspective. Biofuels, Bioproducts and Biorefining 5, 387-398.

# Biofuels in South Africa

The National Biofuels Industrial Strategy of South Africa (NBIS)

Department of Minerals and Energy (DME, 2007)

2% penetration of biofuel within five years (conservative)

- 400 million liters per year by 2013
- Van Maltitz = 310 000Ha

Biofuel crop production

- Alleviate rural poverty
- Provide economic development

# Policy Approaches from South Africa

- No food crops for biofuels
- No potential invasive plants
- No irrigation of biofuels
- If **dryland** water use is significant – water use license

# Biofuel Production Concerns

**The "food vs. fuel" debate**
- Impact on food supply and food prices (food security)
- Maize (Corn) excluded

**Impacts of large-scale land use change on water resources**
- The irrigation of biofuel crops is not supported

**Transportation of large volumes of biofuel feedstock**
- Local opportunities

**Impacts on biodiversity**
- Monoculture production
- Invasive alien plants

# Biofuels in South Africa

Specified energy crops to be considered (NBIS)

- Sugarcane
- Sugarbeet
- Soybeans
- Canola
- Sunflower

Energy crops that are excluded

- Jatropha (alien invasiveness; moratorium)
- Maize (food security issues)

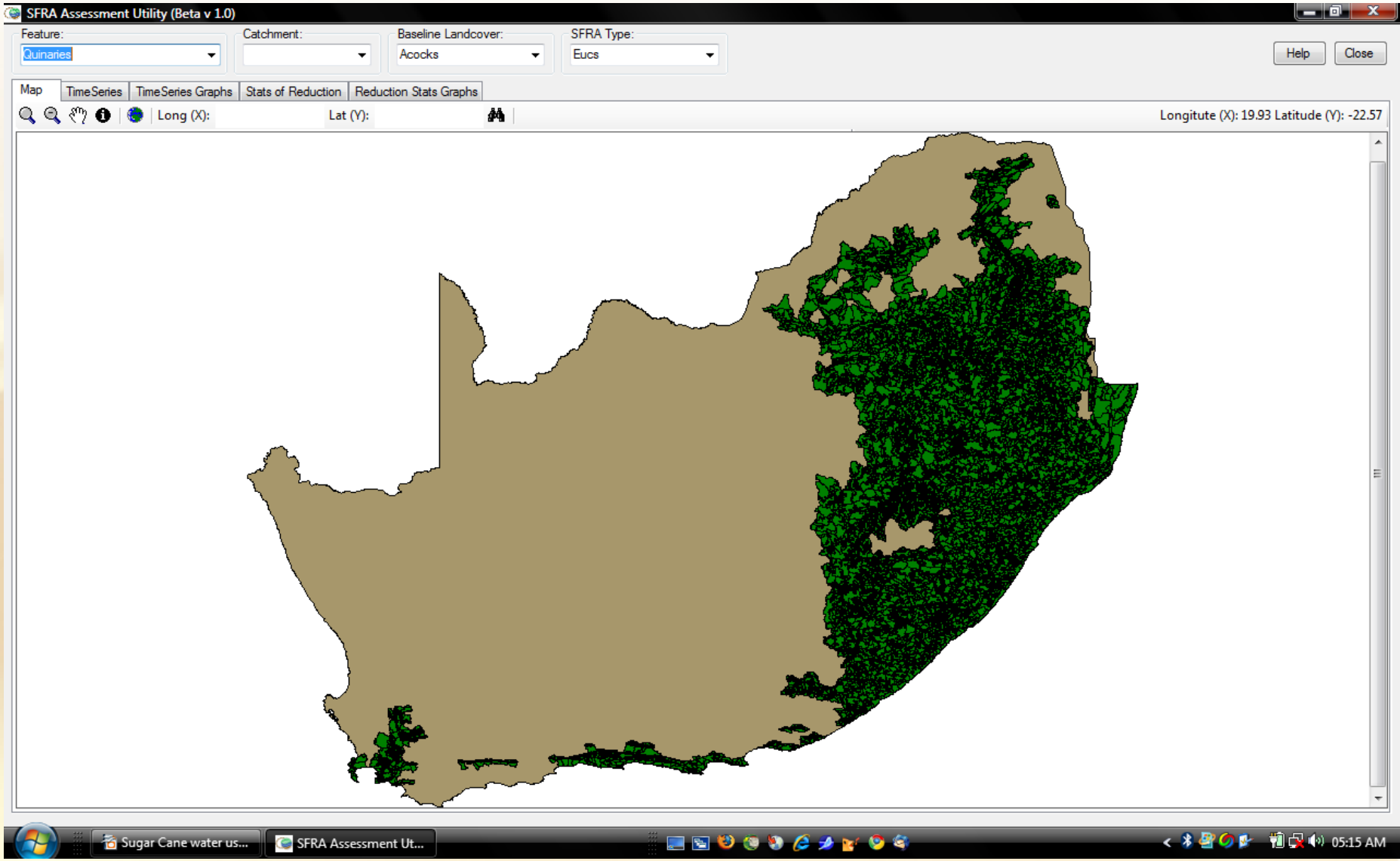
Irrigation of biofuel crops not supported

- Industrial water tariff applied

# South Africa's National Water Act

- **Principle 18**
  - Since many **land uses** have a significant **impact** upon the water cycle, the regulation of land use shall, where appropriate, be used as an instrument to manage water resources within the broader integrated framework of land use management
- A **stream flow reduction activity** is defined as
  - "… any activity (including the cultivation of any particular crop or other vegetation) … [that] … is likely to reduce the availability of water in a watercourse to the Reserve, to meet international obligations, or to other water users significantly" (NWA Section 36(2)).
  - Commercial forestry is a "stream flow reduction activity" (SFRA) and as such must be **licensed** as one of several forms of water use.
- Interest in bioebergy crops as an SFRA
- Optimal growing areas?

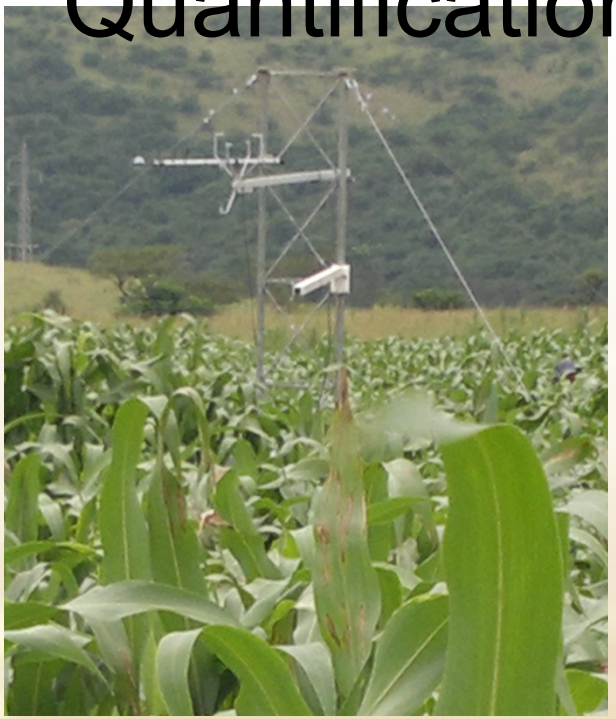
# Land-Water Assessment Utility

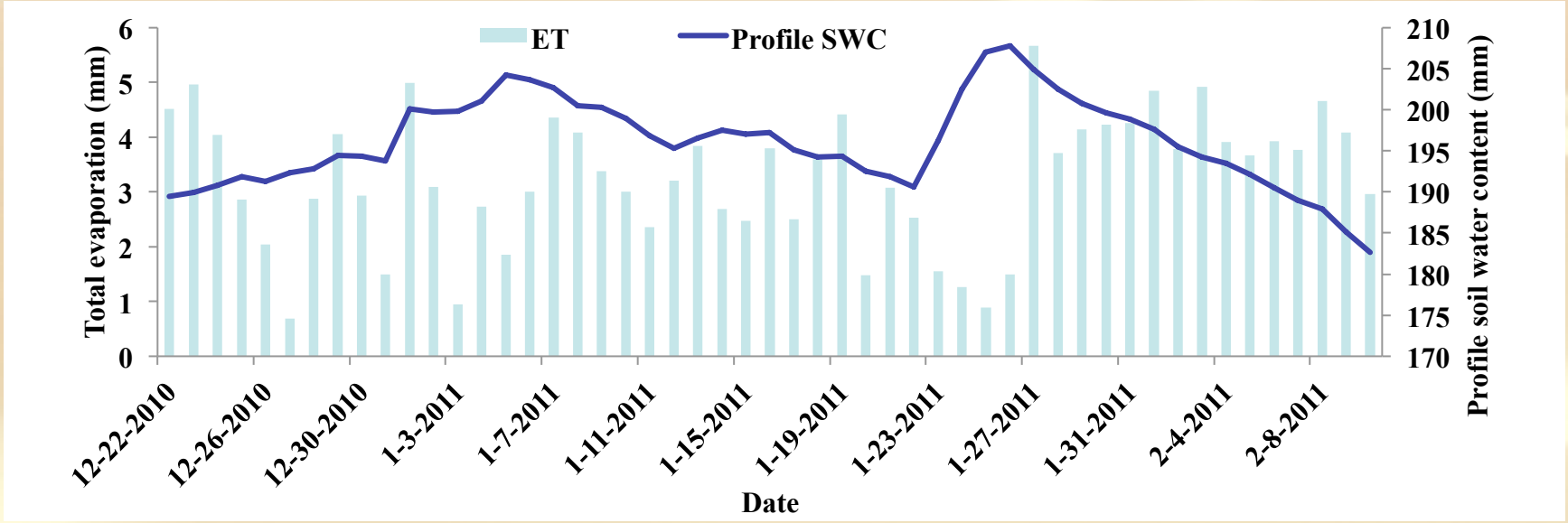



2009/11/28 10:37


FLGS-TDP
DYNAMAX
2009/11/28 11:32

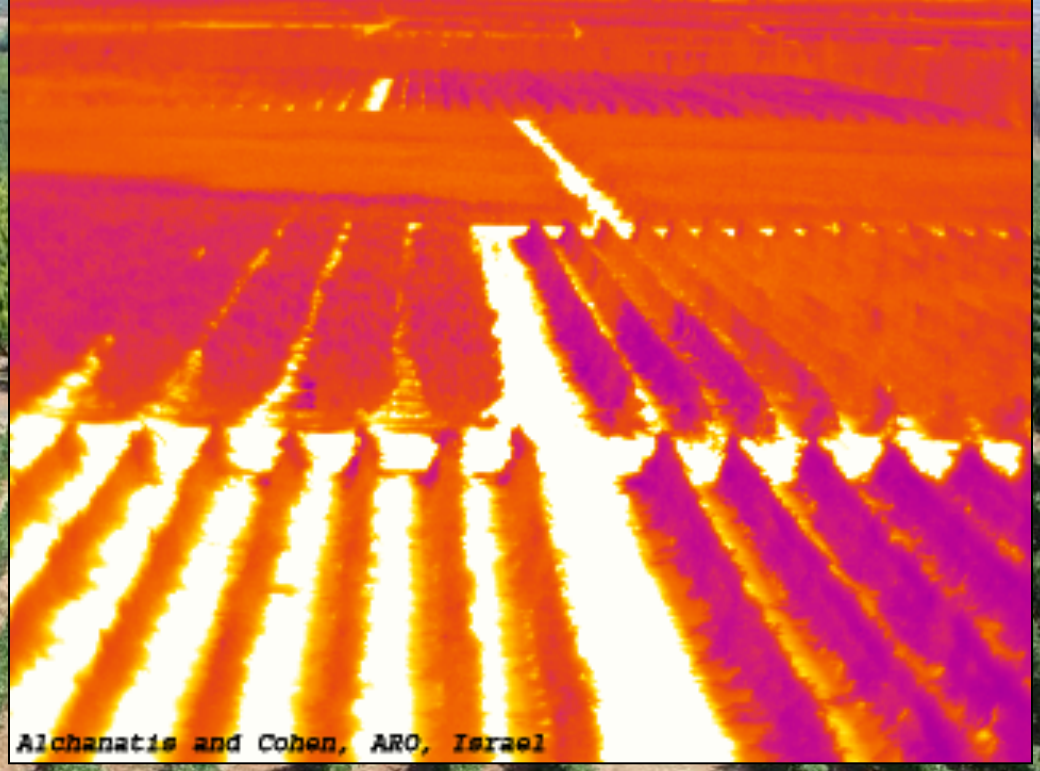
# Quantification of Green Water Flows





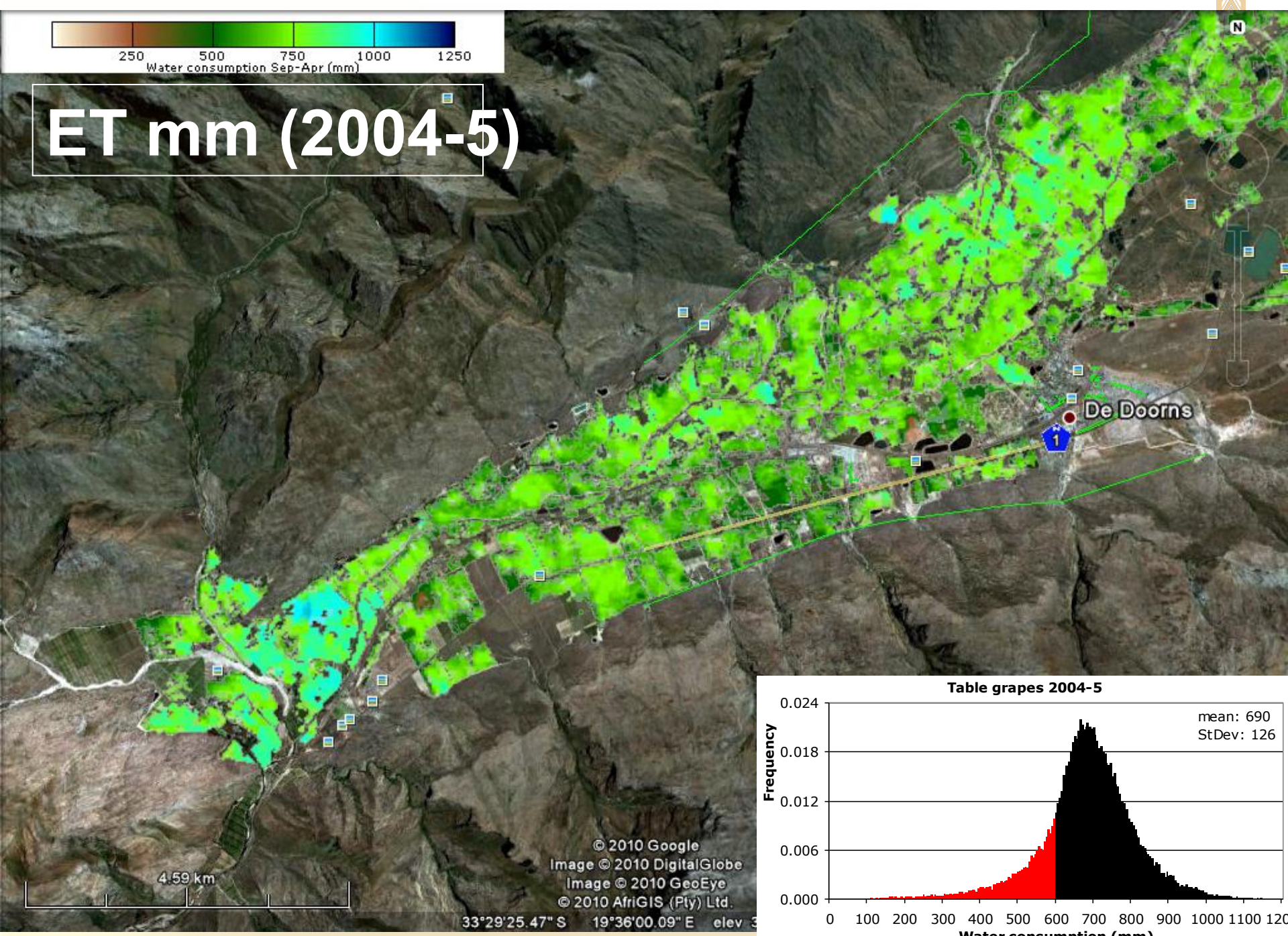
| Date | Oct-04 | Nov-04 | Dec-04 | Jan-05 | Feb-05 | Mar-05 | Apr-05 | May-05 | Jun-05 | Jul-05 | Aug-05 | Sep-05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Equipment** | | | | | | | | | | | | |
| Net Radiometer | | | | | | | | | | | | |
| Scintillometer | | | | | | | | | | | | |
| Hobo Soil Thermocouples | | | | | | | | | | | | |
| MCS Soil Thermometers 1 | | | | | | | | | | | | |
| MCS Soil Thermometers 2 | | | | | | | | | | | | |
| TDR Moisture Sensor | | | | | | | | | | | | |
| Rainfall | | | | | | | | | | | | |
| Reliable Total Evaporation | | | | | | | | | | | | |

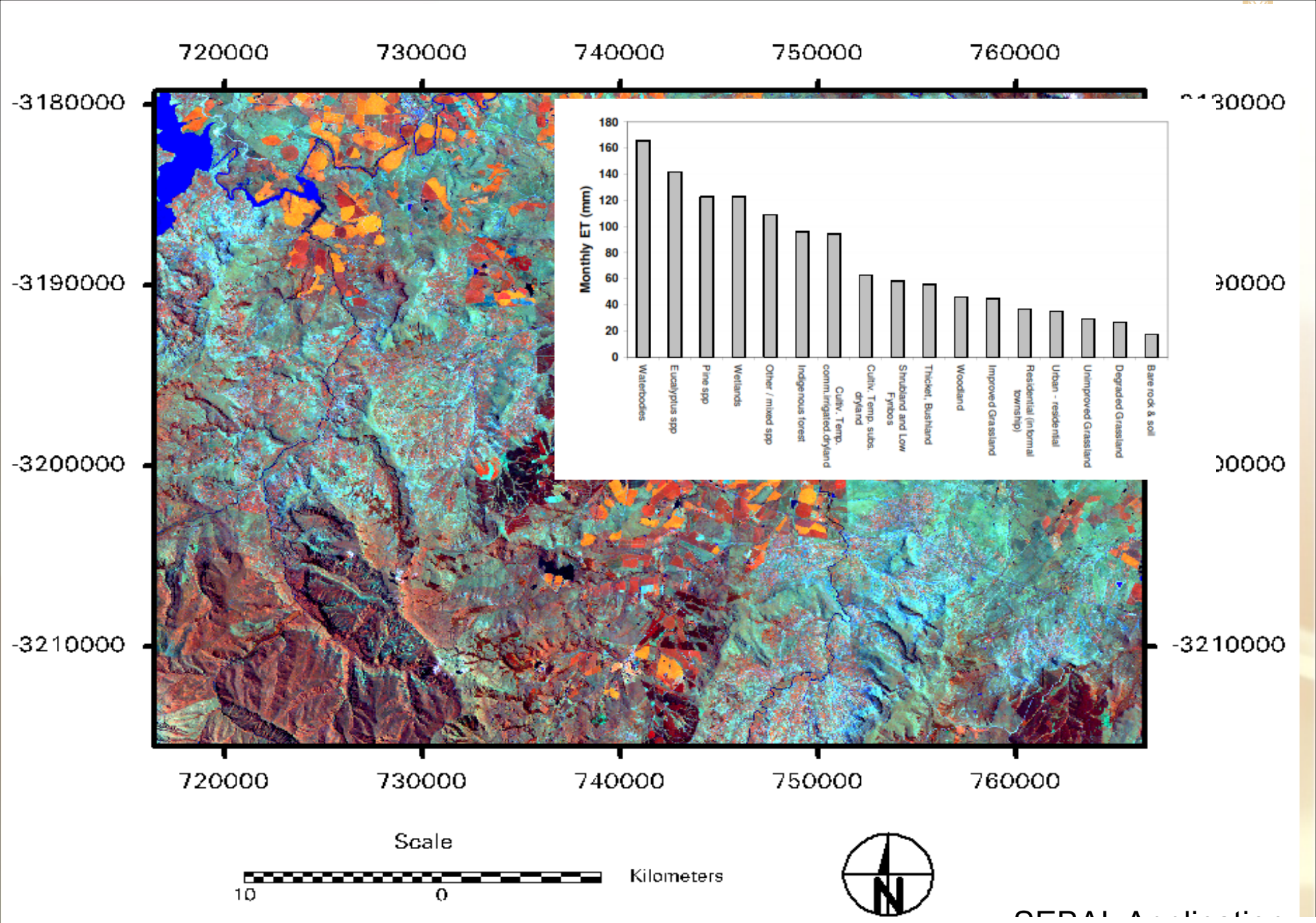
Energy and water balance studies – Sugar Cane



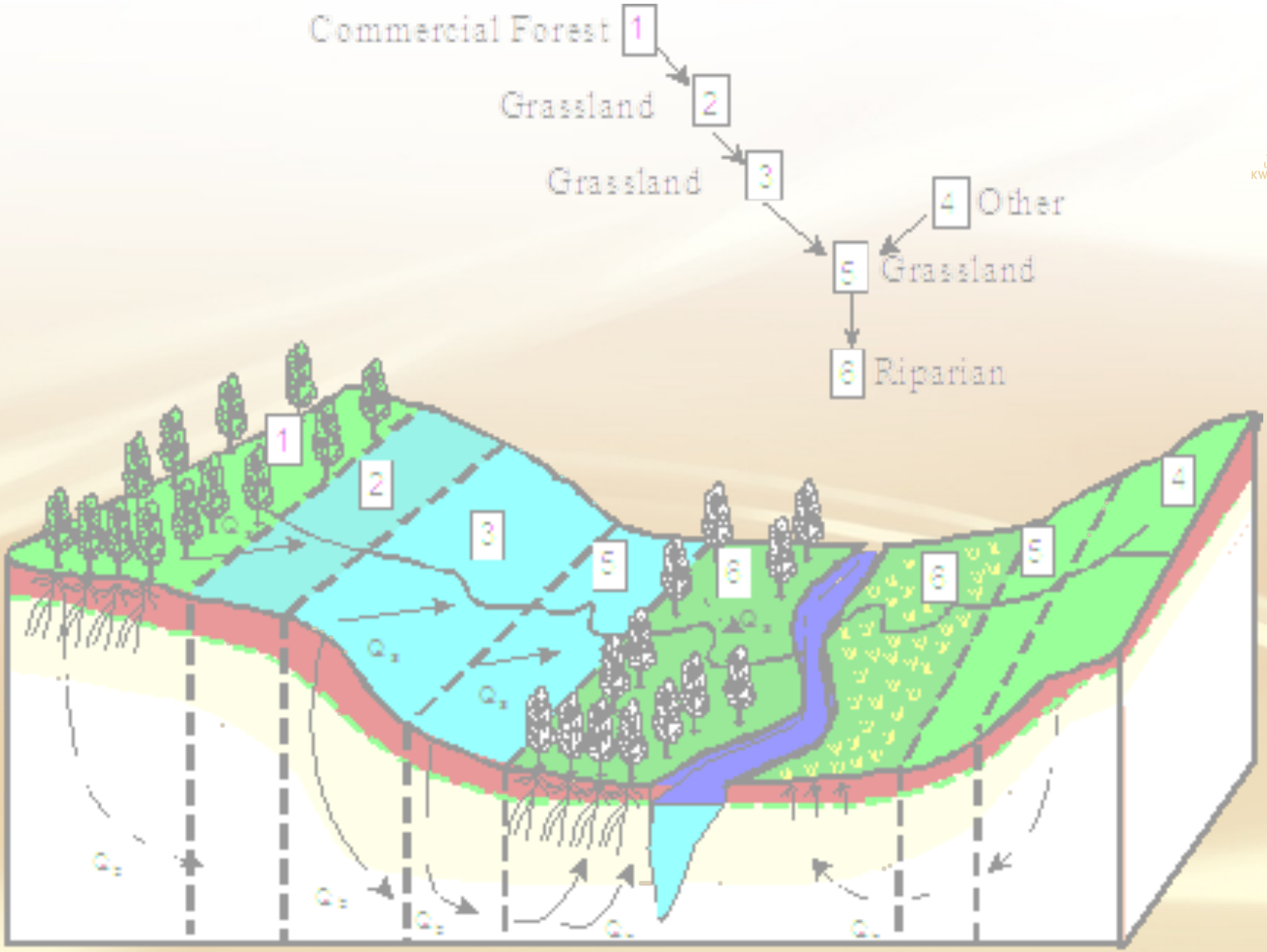

Alchanatis and Cohen, ARO, Israel

Slide: Wim Bastiannsse


250
500
750
1000
1250
Water consumption Sep-Apr (mm)
ET mm (2004-5)
De Doorns
1
N
4.59 km
© 2010 Google
Image © 2010 DigitalGlobe
Image © 2010 GeoEye
© 2010 AfriGIS (Pty) Ltd.
33°29'25.47" S 19°36'00.09" E elev
Table grapes 2004-5
mean: 690
StDev: 126
Frequency
0.024
0.018
0.012
0.006
0.000
0 100 200 300 400 500 600 700 800 900 1000 1100 120
Water consumption (mm)




KONGO, M. V., JEWITT, G.P.W. and LORENTZ, S. A. (2011). Evaporative water use of different land uses in the upper-Thukela river basin assessed from satellite imagery. Agricultural Water Management 98 (11) 1727-1739.

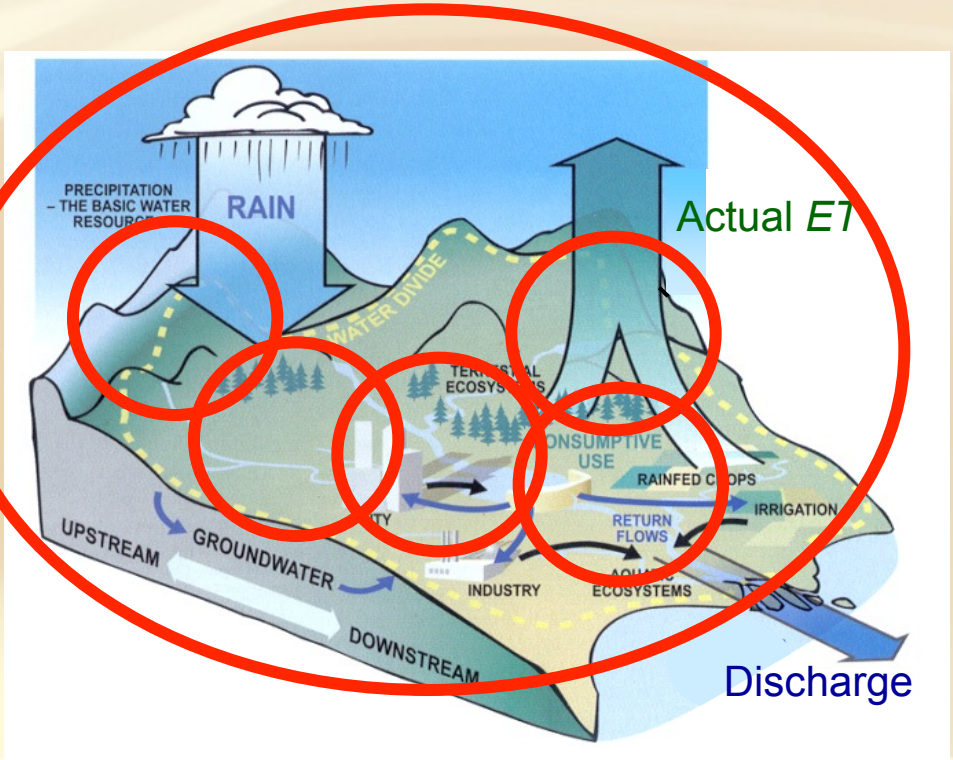

Commercial Forest 1
Grassland 2
Grassland 3
4 Other
5 Grassland
6 Riparian
1
2
3
5
6
6
5
4

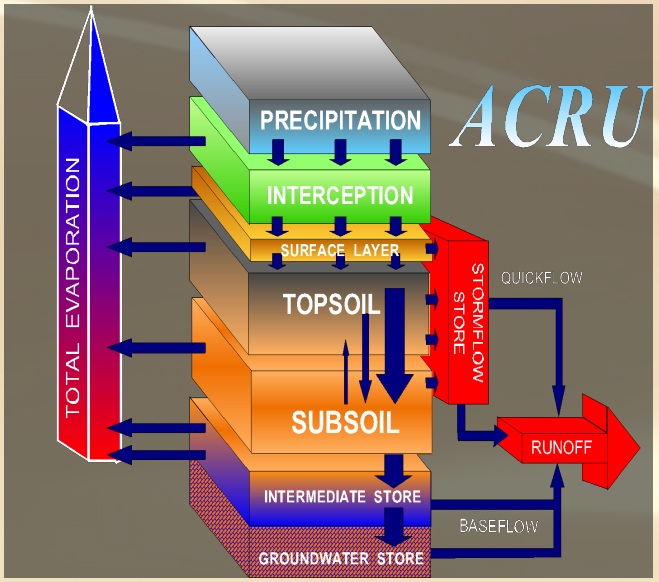
# How could water resources analyses work?

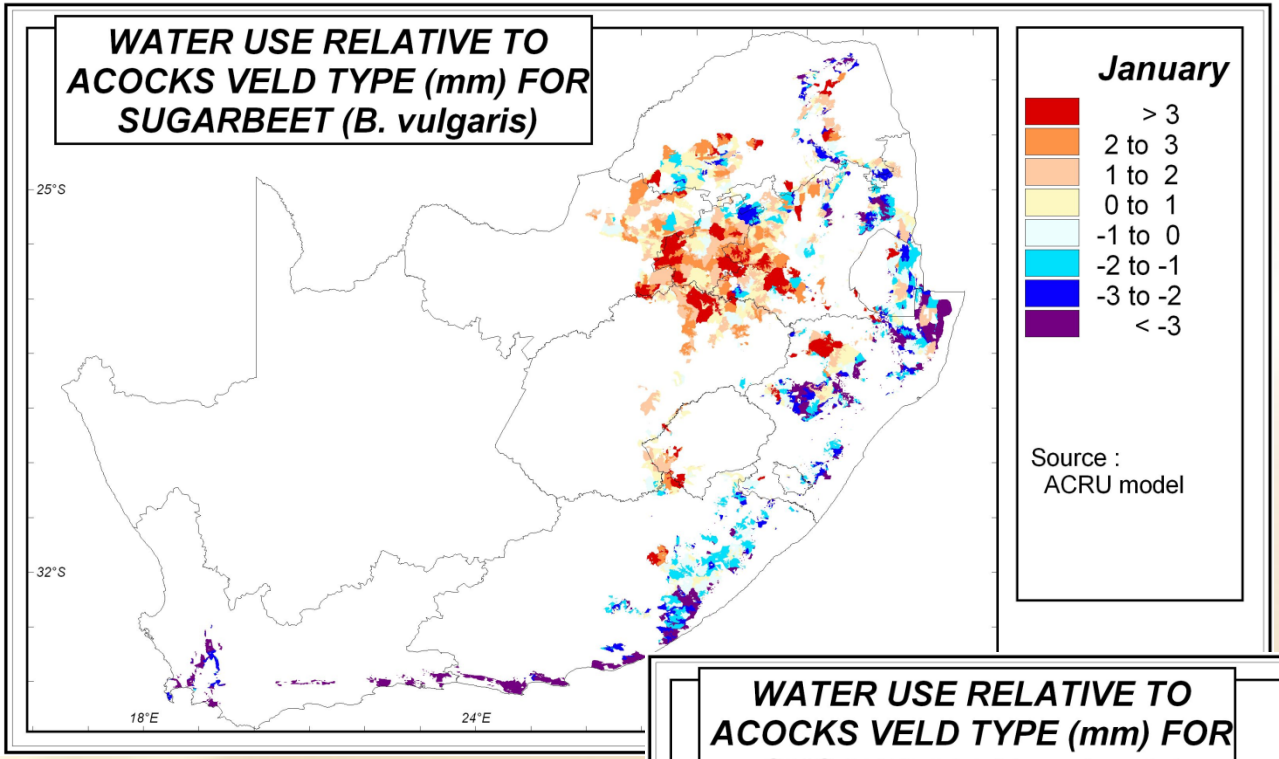
## Water Balance:

$$P = Q + E + dS/dt$$

| | | |
|---|---|---|
| $P$ | : | precipitation [mm $a^{-1}$] |
| $R$ | : | discharge [mm $a^{-1}$] |
| $E$ | : | evaporation [mm $a^{-1}$] |
| $dS/dt$ | : | storage changes per time step [mm $a^{-1}$] |

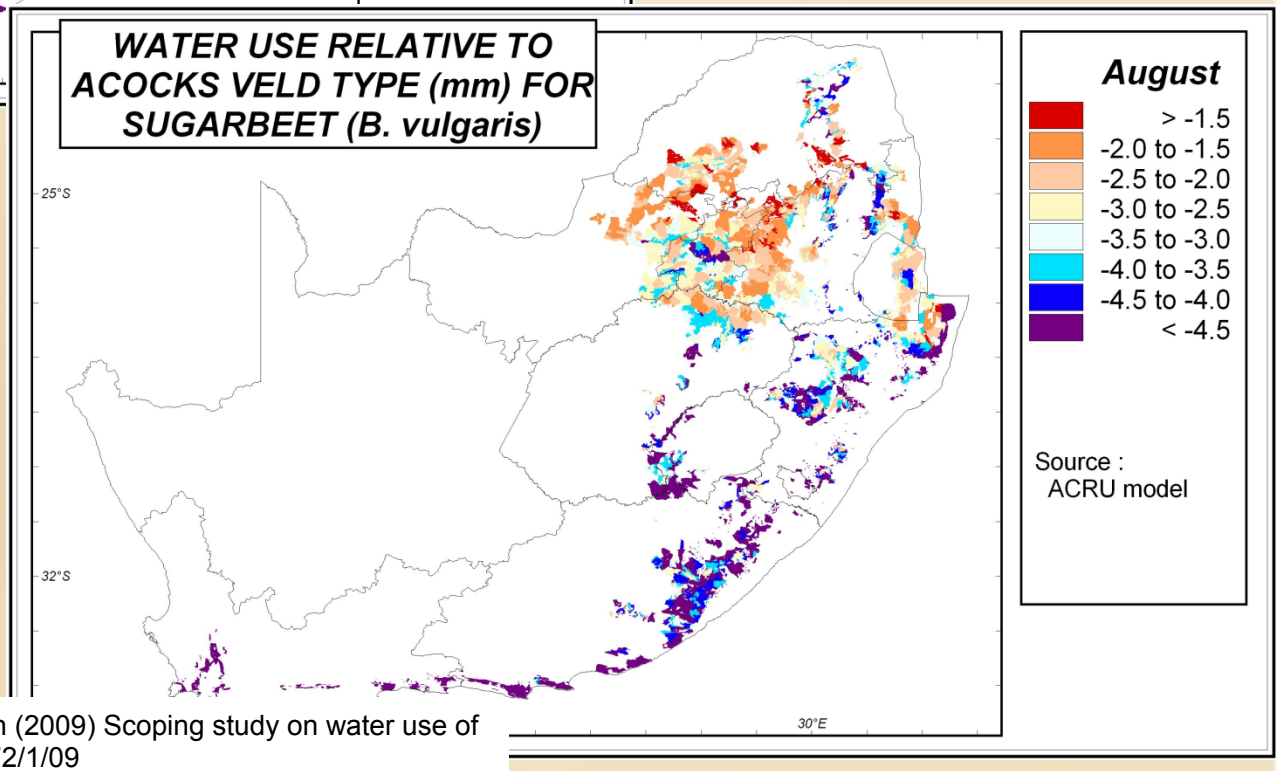





## Seasonal Differences

Crop uses more water than baseline in summer, especially inland areas.



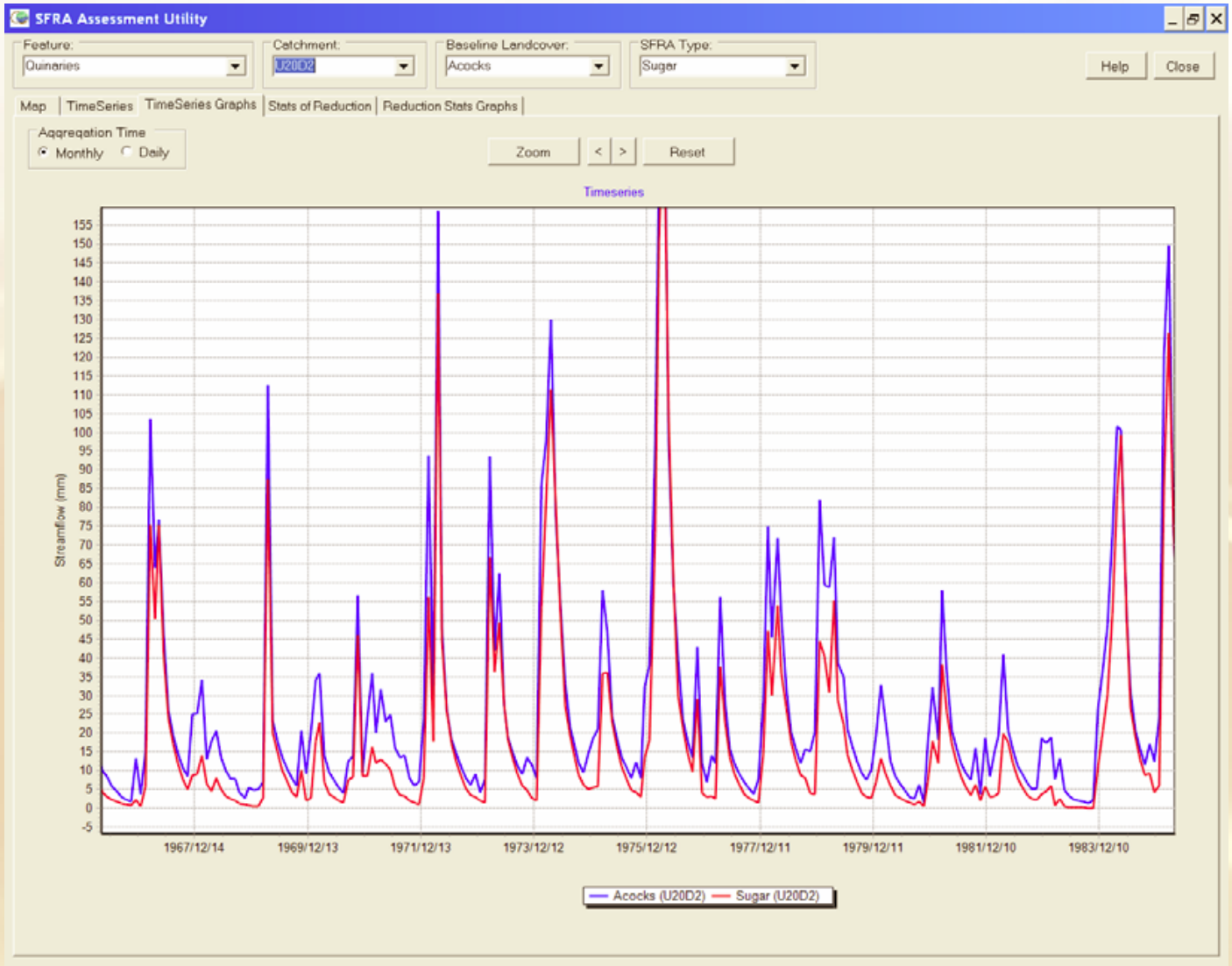

## Seasonal Differences

Crop uses less water than baseline in winter, especially coastal areas.

GPW Jewitt, RP Kunz, HW Wen & AM van Rooyen (2009) Scoping study on water use of crops/trees for biofuels in South Africa WRC - 1772/1/09

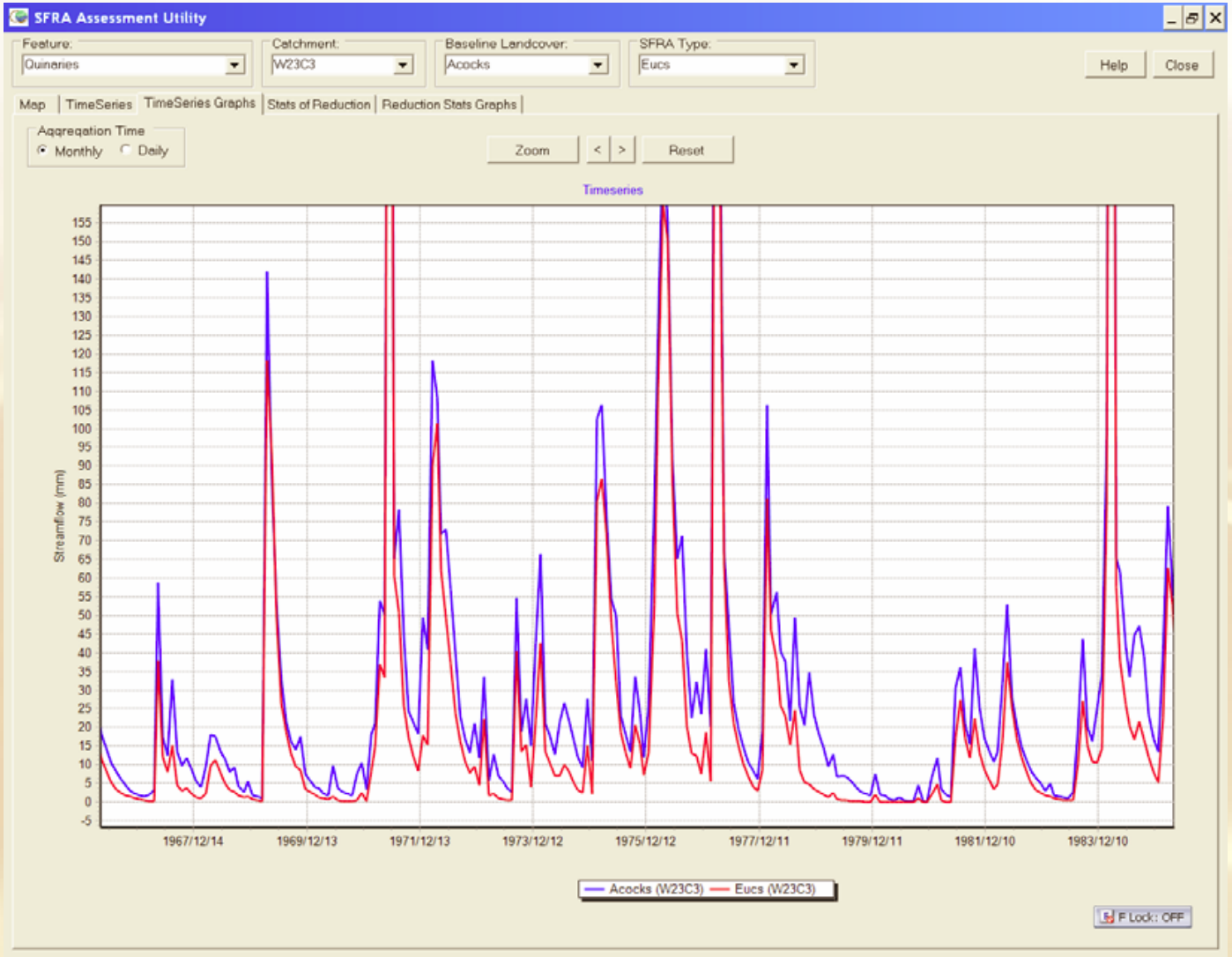
# Streamflow Analysis

KZN Midlands Sugar Cane

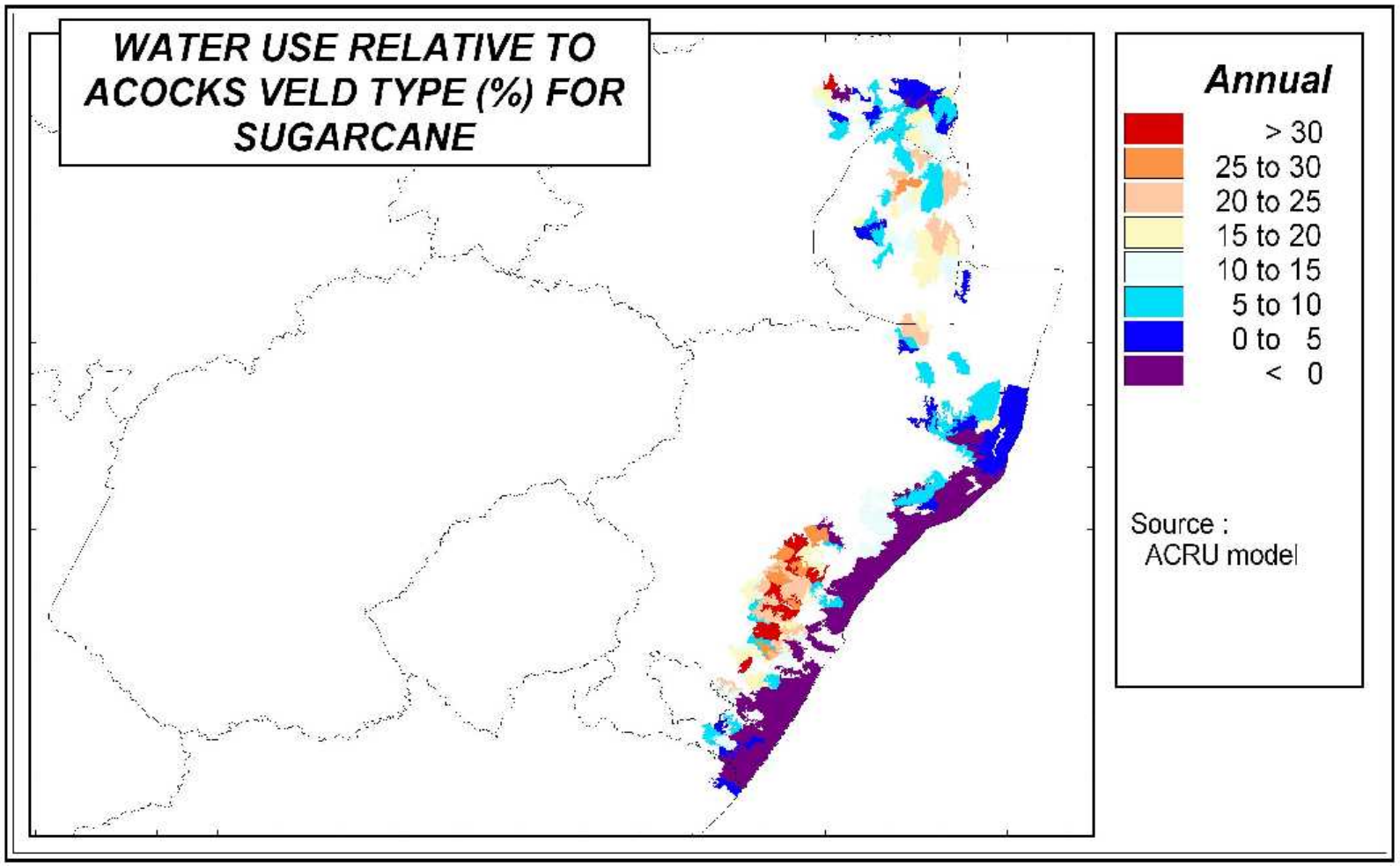


# Streamflow Analysis

North Coast Eucalyptus



# Sugar Cane “Water Use”



# Conclusions

- Highly variable biophysical environment
  - Constraints & Opportunities
- Managing water for sustainability
  - Consider high natural variability
  - Importance of process understanding
- Increasing pressure on land
  - SA example useful worldwide
- Win-Win opportunities do exist
  - Beyond the superficial