Dept. Hydrology and Hydraulic Engeneering

VRIJE UNIVERSITEIT BRUSSEL (VUB)

Water and Energy Fluxes in a Riparian Wetland

- Estimation of Evapotranspiration by Application of the SEBAL Methodology for the Doode Bemde Wetland, Belgium -

Okke BATELAAN, Hung L.Q. and Verbeiren B.

Email: batelaan@vub.ac.be

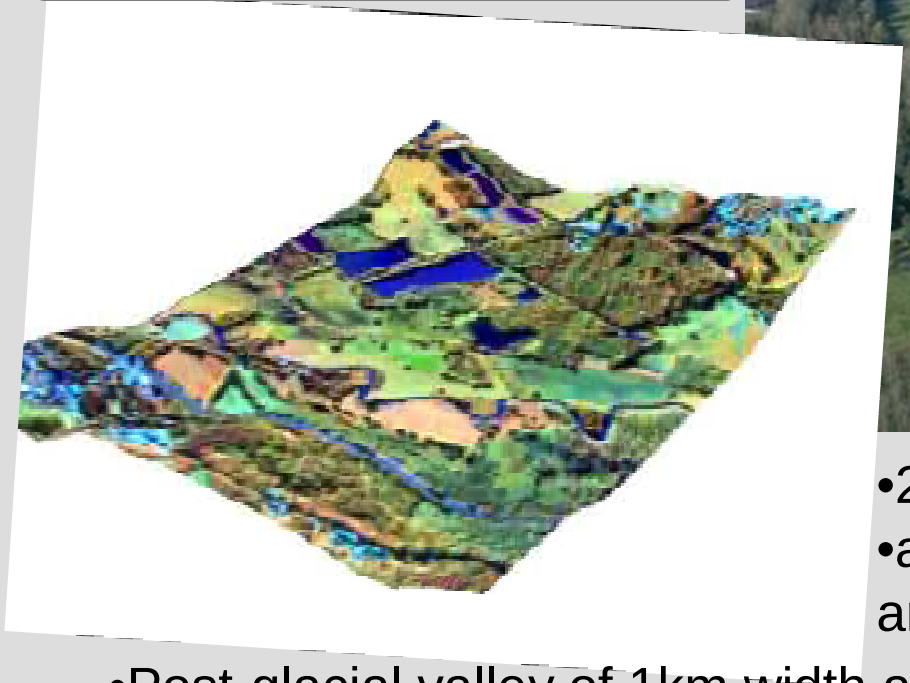
AIRBORNE IMAGING SPECTROSCOPY WORKSHOP, BRUGES 8 OCTOBER 2004

OBJECTIVES

Exploration of contribution of airborne imaging spectroscopy for ecohydrology:

1. Analysis and mapping of **MOISTURE GRADIENTS**
2. **PHREATOPHYTES** mapping
3. Estimation of **EVAPOTRANSPIRATION** of riparian vegetation

STUDY AREA



- 21 ha nature reserve ‘Doode Bemde’
- alluvial floodplain backswamp wetland area, along Dijle River
- Post-glacial valley of 1km width and 40m depth.
- Vegetation: fen meadows
- Flooded yearly by overbank flow and GROUNDWATER DISCHARGE

CAMPAIGNS 2002 AND 2003

	Campaign 2002	Campaign 2003
Flight date	3pm, 13 September	12pm, 16 June
Sensors	CASI - SWIR	CASI - ATM
	Field measurements: spectroradiometer, sunphotometer, gps,… for geo- atmospheric correction of images	

	CASI 2	SWIR	Thermal
Spectral bands	96	160	1
Spectral range (nm)	400 - 960	850 - 2500	10750
Spatial resolution (m)	2.4	2.4	2
Campaigns	2002-2003	2002	2003

HYDROLOGICAL FIELD CAMPAIGN

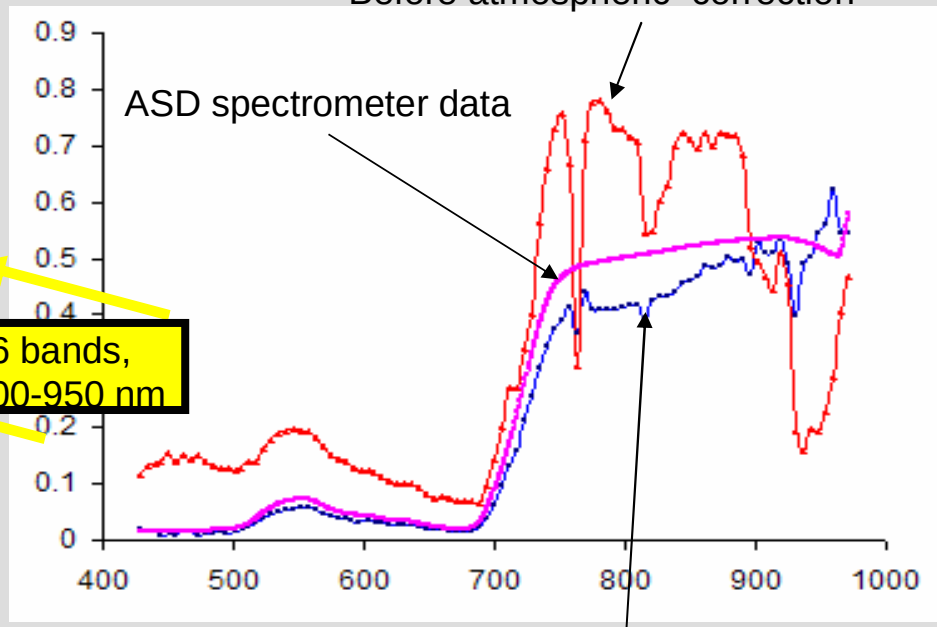
- Measurements (at 60 locations)
  - Soil moisture (probe & gravimetric)
  - Soil temperature and conductivity (EC)
  - Vegetation temperature & height
- Spectral characteristics 10 vegetation targets (spectroradiometer)
- Stage rivers, ditches
- Groundwater levels, 200 piezometers

DATA CALIBRATION

- Radiometric correction
- Geometric correction
- Atmospheric correction
- EFFORT polishing

CASI Spectral Cube - Color composite R:G:B
677, 540, 462 nm

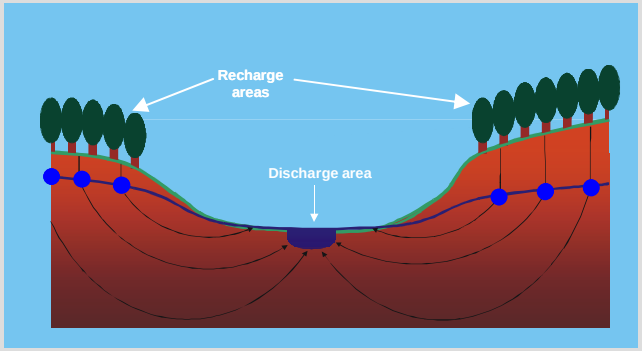
96 bands,
400-950 nm

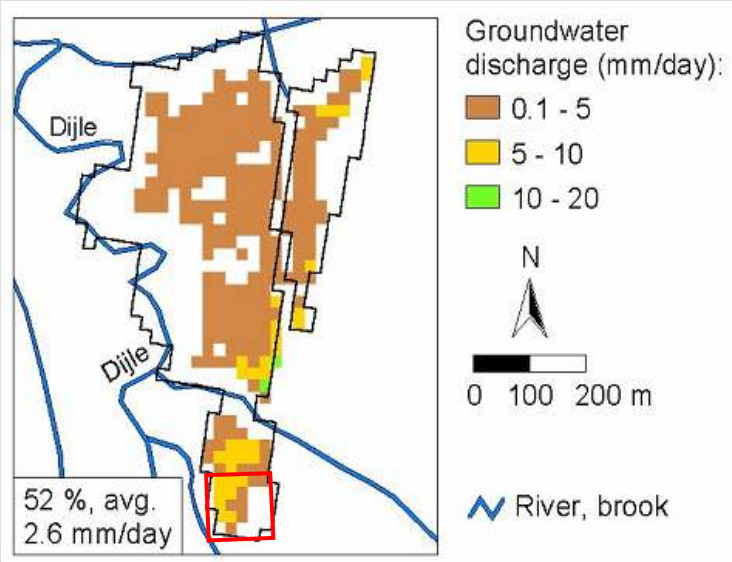


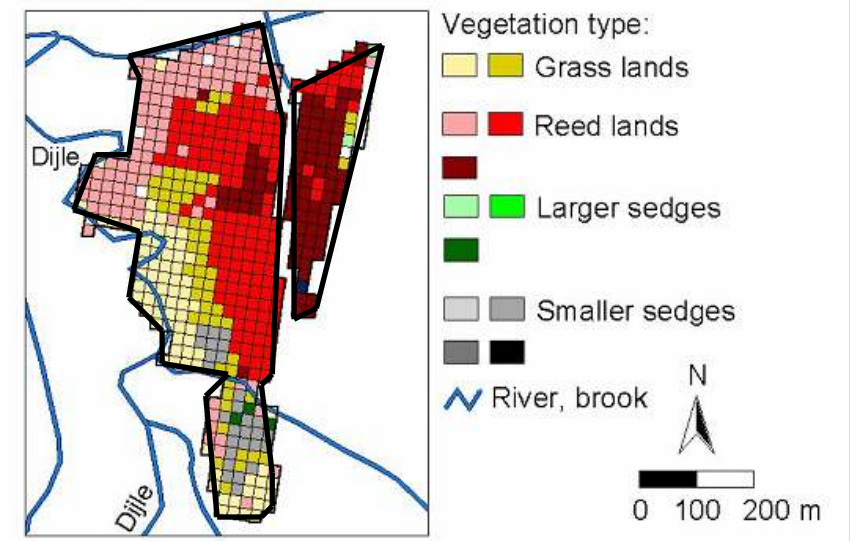
100 by 100 m fen
meadow

GROUNDWATER MODELING

- Recharge/discharge (moisture gradient)
- Complex patterns (interaction of regional groundwater flow, soil, vegetation, topography, …)
- Numerical groundwater models
- Groundwater flow and -levels, discharge maps
- Input for ecological analysis & models



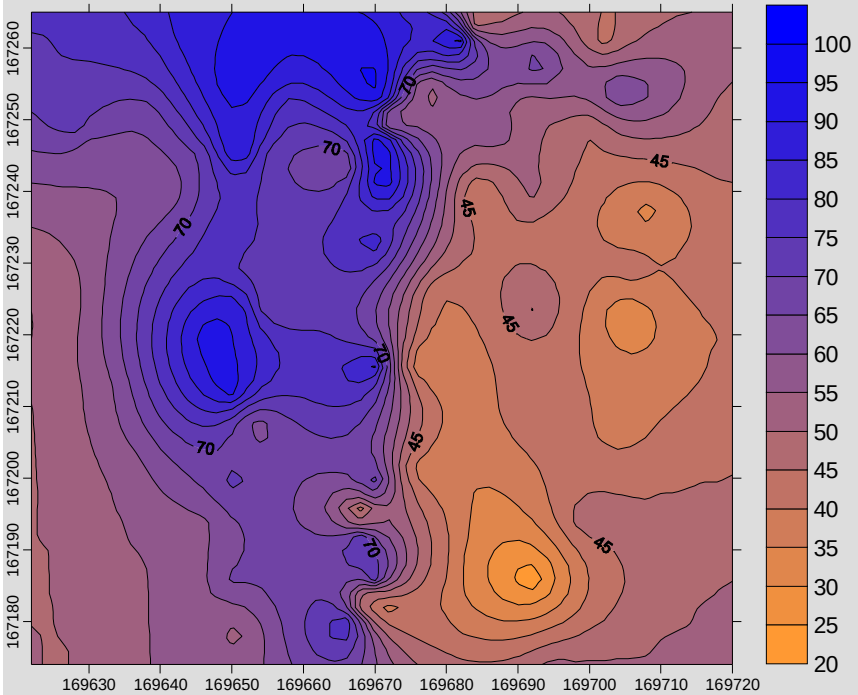




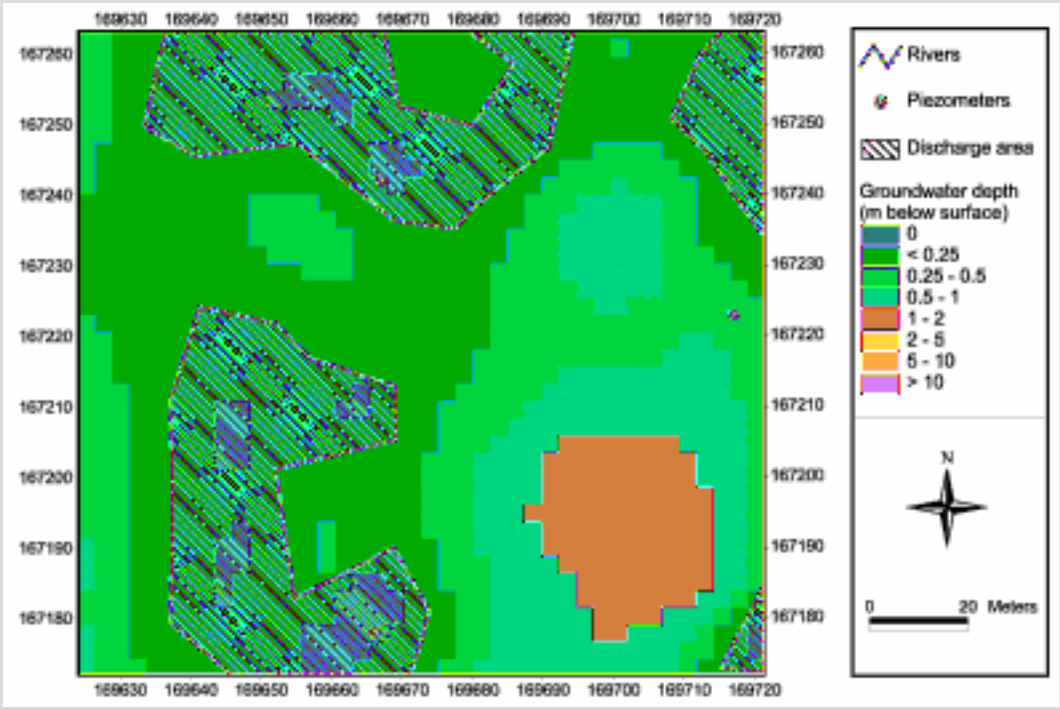
SOIL MOISTURE

Theta probe

- 85 measurements at 1 parcel (grass field)

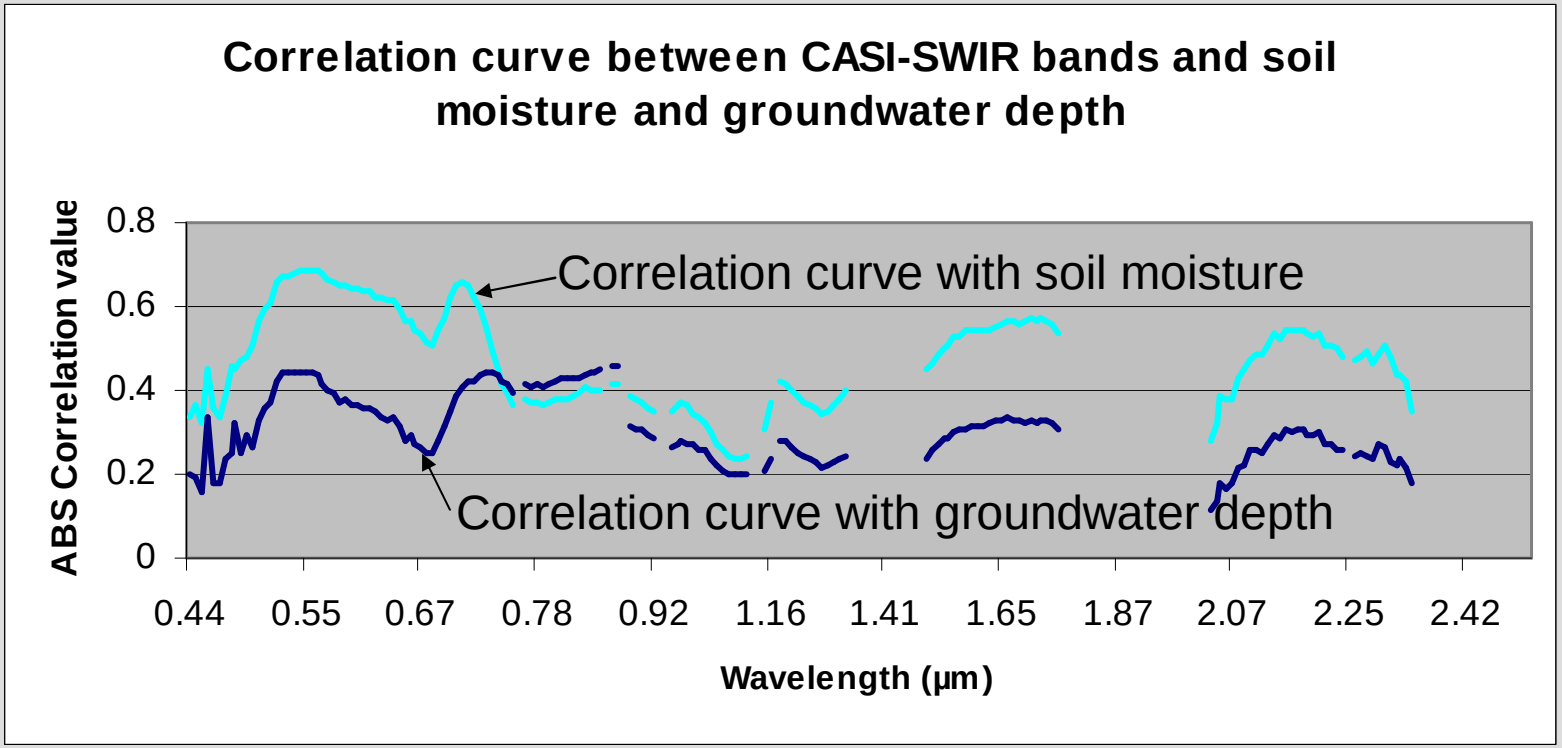


Kriged soil moisture 2002 (%)



Ground water depth (m)

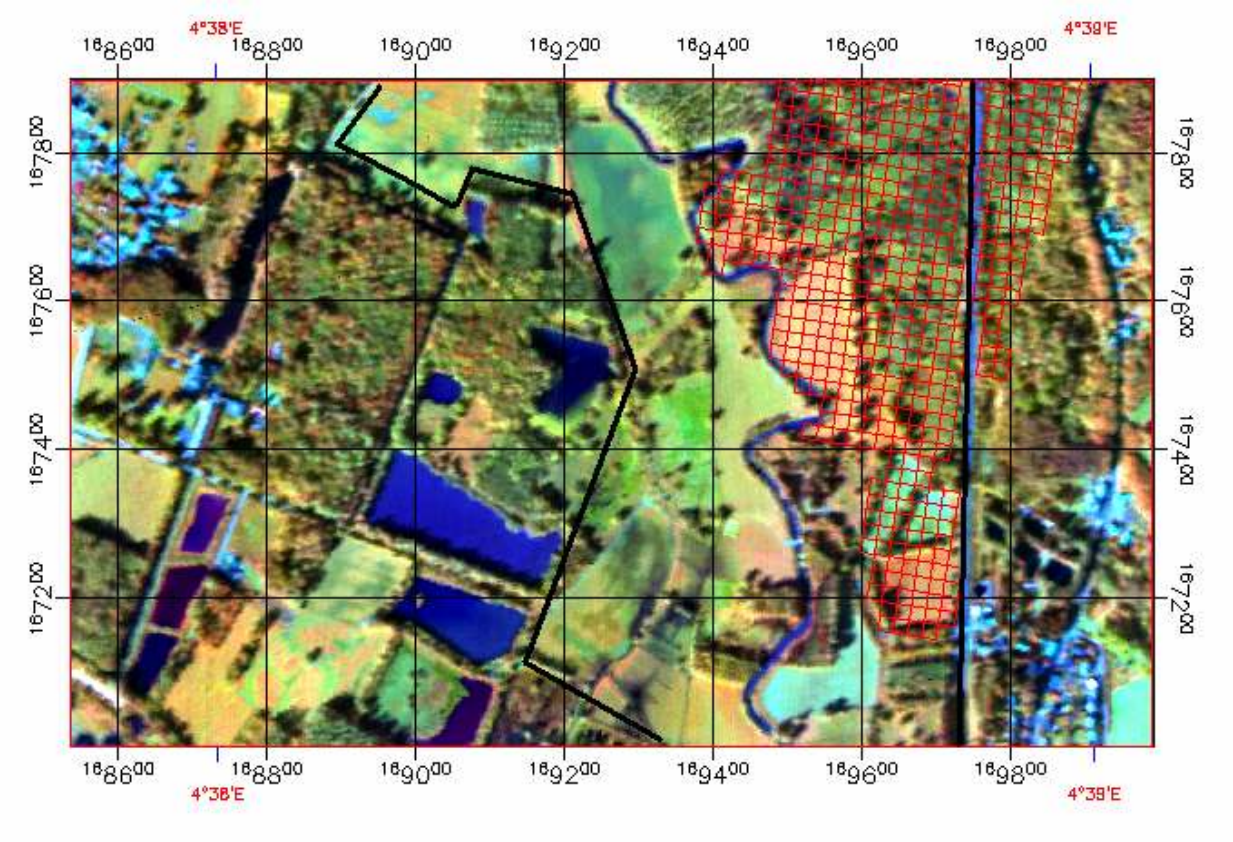
HYPER RS versus WETNESS



The highest correlation at 0.569 µm: **R^2=0.69** => normalised image: **0.73**

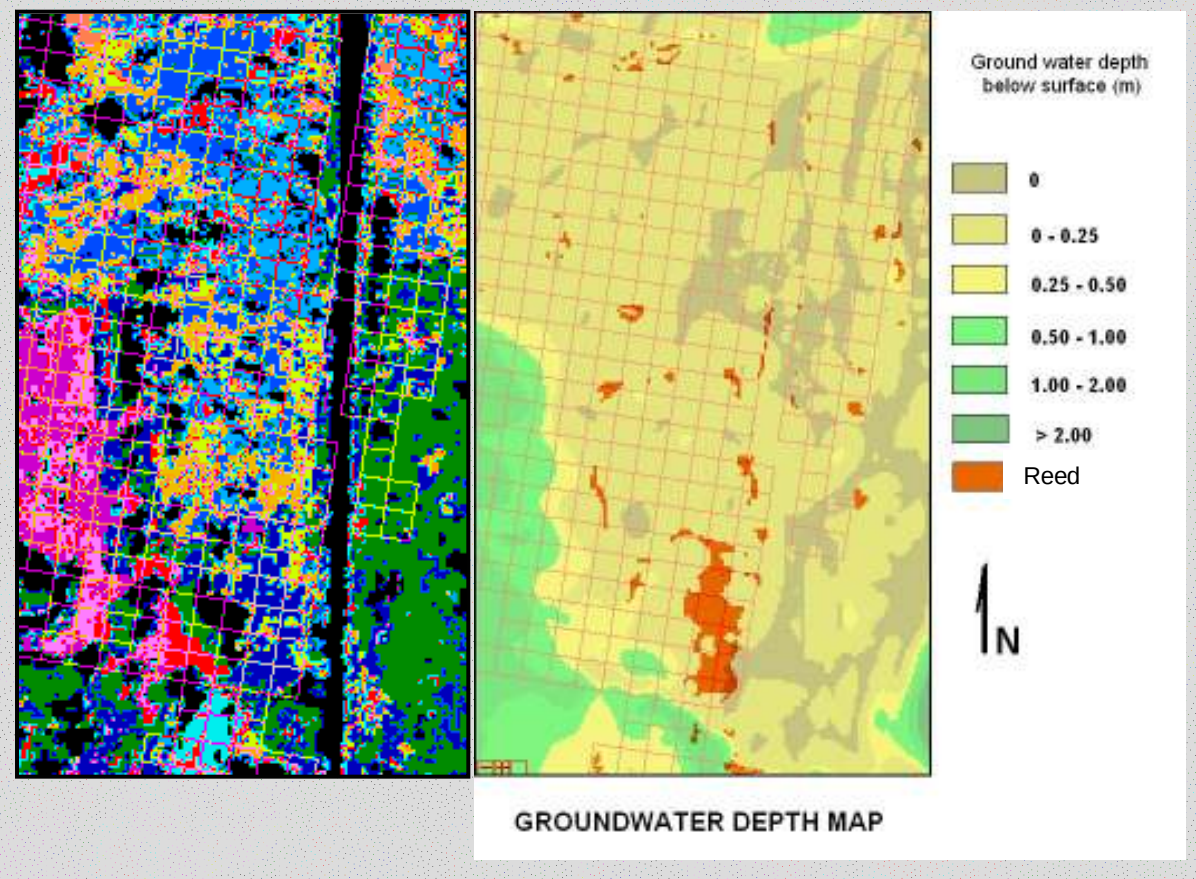
Logistic regression **0.79**

PHREATOPHYTES



-Phreatophytes are indicators of groundwater (soil) wetness
-Mapping of 45 phreatophyte species, 7 vegetation types, 20 by 20m grid (De Becker et al., 1999)
-4 abundance classes: 1= 0-25%, 2=25-50%, 3=50-75%, 4=75-100%.

PHREATOPHYTES MAP

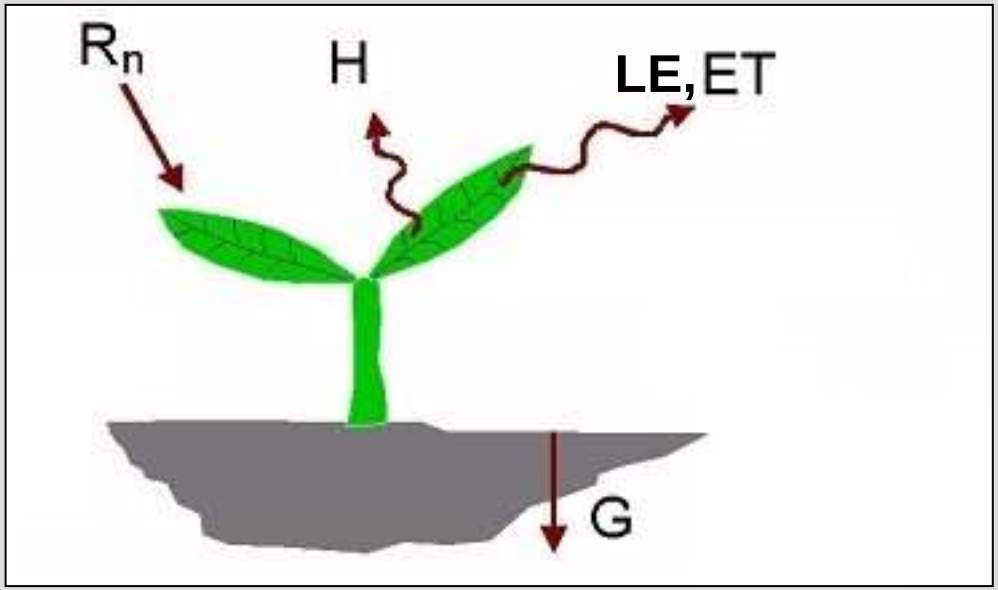


EVAPOTRANSPIRATION

- **SEBAL model - S**urface **E**nergy **B**alance **A**lgorithm for **L**and (Bastiaanssen, 1995).
- An image-processing and GIS model (ILWIS 3.2 and AHAS 1.3) comprised of 25 computational steps for complete radiation and energy balance and resistances for momentum, heat and water vapour transport (ETact).
- Regional scale application:
  - + Applied for NOAA-AVHRR imagery
  - + Applied for Landsat (Allen 2001, 2003)
  - + Suggested for ASTER imagery
- Key input data for SEBAL consists of spectral radiance in the visible, near-infrared and thermal infrared part of the spectrum.
- Objective: testing of SEBAL ET estimation methodology with spatially high resolution hyperspectral imagery (CASI) and thermal data from the ATM sensor.

SURFACE ENERGY BALANCE

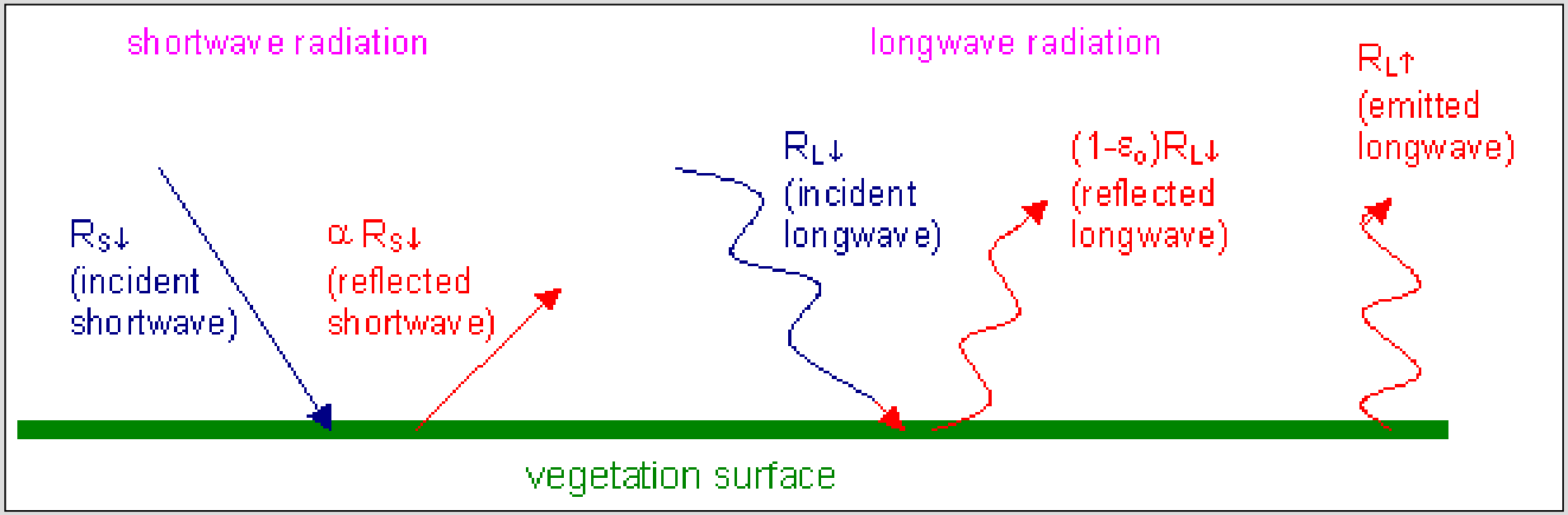
Evapotranspiration is accompanied by a transfer of latent heat.



$$ET = Rn - G - H$$

- LE is the latent heat flux [W/m^2] → **ET**,
- Rn is the net radiation flux at the surface [W/m2],
- G is the soil heat flux [W/m^2], and
- H is the sensible heat flux to the air [W/m2].

Rn NET RADIATION FLUX AT SURFACE



$$R_n = R_{s\downarrow} - \alpha R_{s\downarrow} + R_{L\downarrow} - R_{L\uparrow} - (1-\varepsilon_0)R_{L\downarrow}$$

- $R_{S\downarrow}$ is the incoming short-wave radiation [W/m2],
- α is the surface albedo [-],
- $R_{L\downarrow}$ is the incoming long wave radiation [W/m2],
- $R_{L\uparrow}$ is the outgoing long wave radiation [W/m2], and
- ε_0 is the surface thermal emissivity [-].

ET TEMPORAL MAPPING

- Conversion of instantaneous latent heat flux into daily LE_{24} values by holding the evaporative fraction, EF [-], constant:

$$EF = LE/ (Rn - G)$$

$$LE_{24} = EF\ Rn_{24}$$

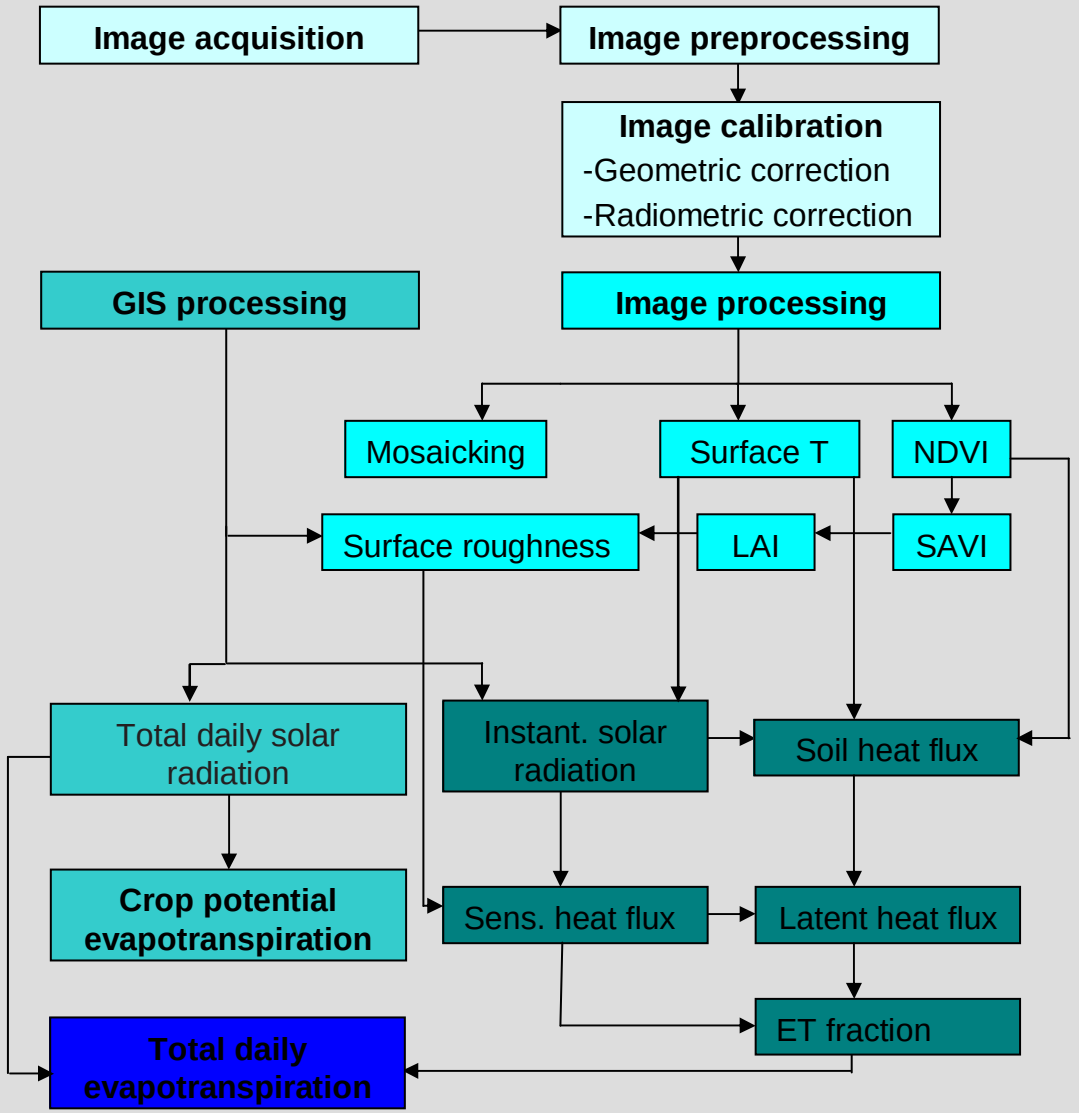
- Surface resistance, r_s [s/m] from inversion of the Penman-Monteith eq.

$$LE_{24} = (s_a\ Rn_{24} + \rho_a c_p\ \Delta e/r_a) / (s_a + \gamma\ (1 + r_s/r_a))$$

  - s_a is the slope of the saturated vapour pressure curve [mbar/K],
  - $\rho_a c_p$ is the air heat capacity [J/m^3 K],
  - Δe is the vapour pressure deficit [mbar],
  - r_a is the aerodynamic resistance [s/m] and
  - γ is the psychrometric constant [mbar/K].

- For all days without imagery, LE_{24} is calculated with determined r_s map and Penman-Monteith. The total ET_{act} for any given period can now be derived by adding up the daily LE_{24} estimates.

SEBAL PROCEDURE



APPLICATION

SEBAL was applied to Doode Bemde, concentration on wet meadow

- For calibration surface and temperature ground truth was available
- Surface temperature map was extracted from the ATM image

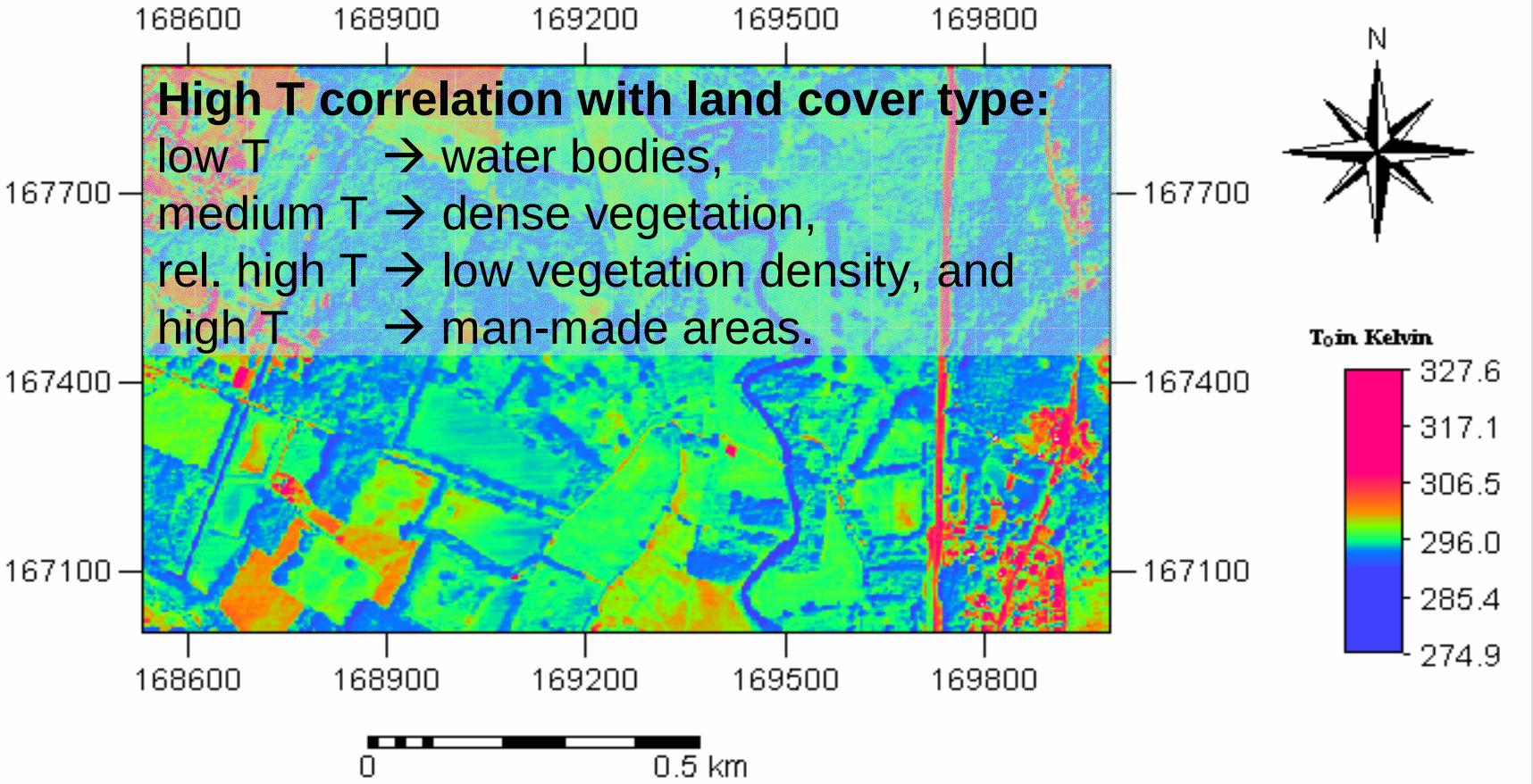
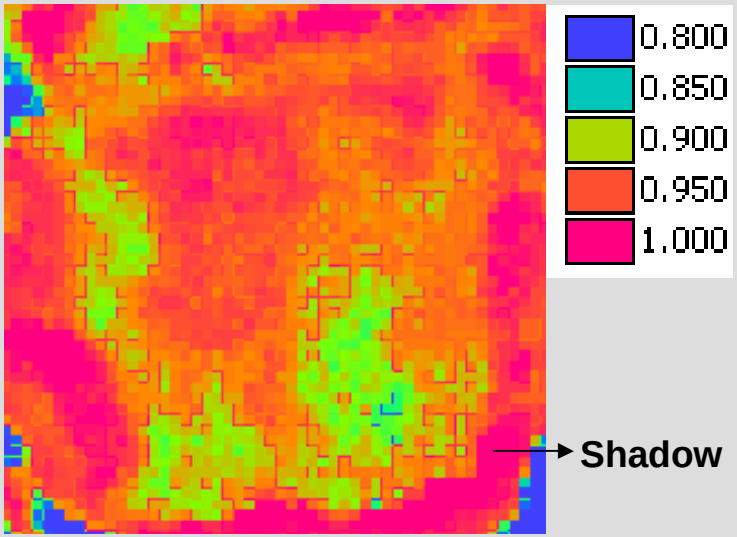
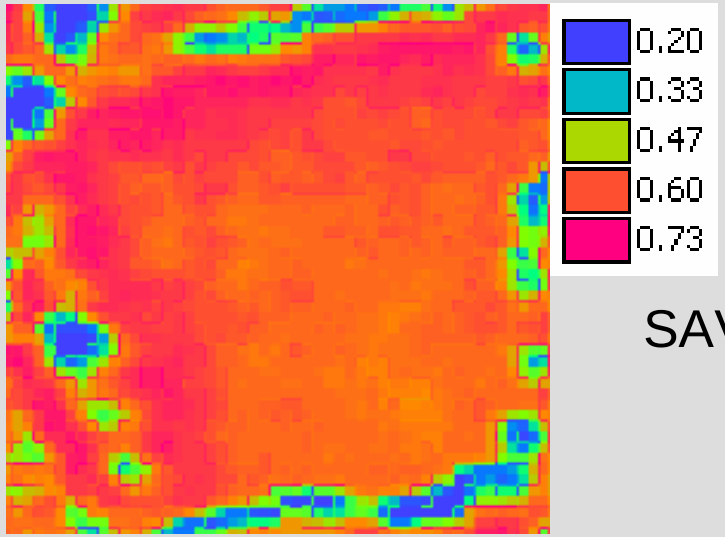


IMAGE PROCESSING-FEN MEADOW

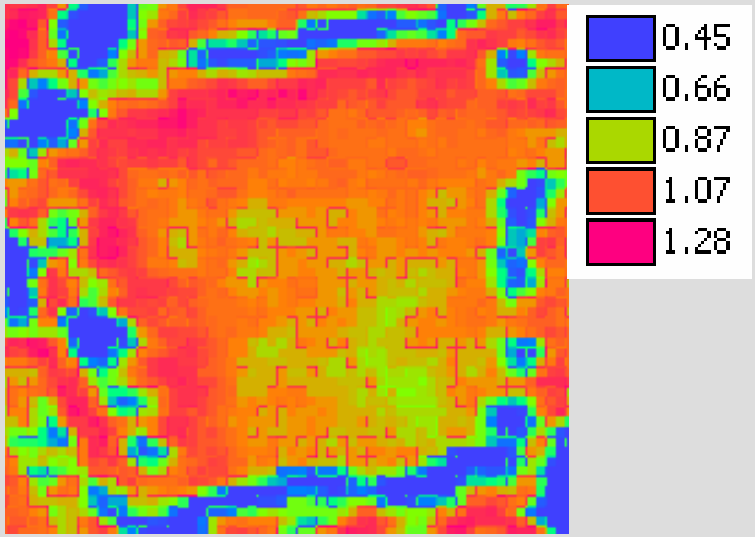
NDVI

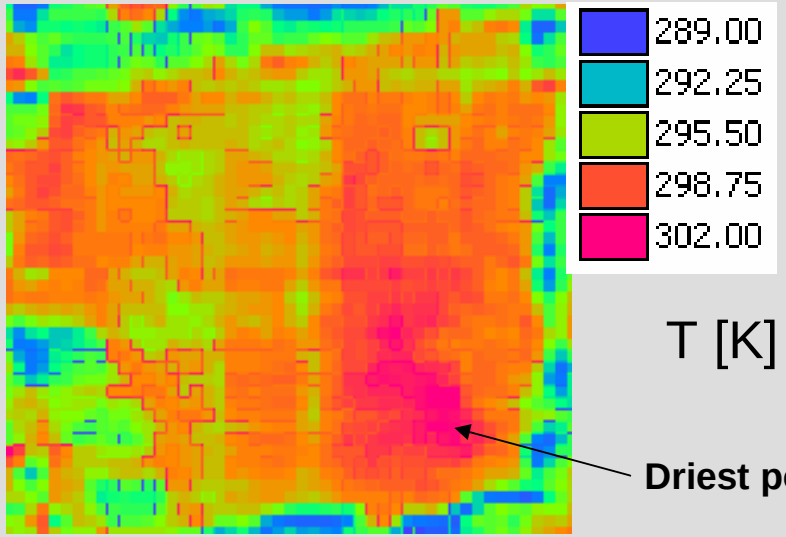




SAVI

LAI

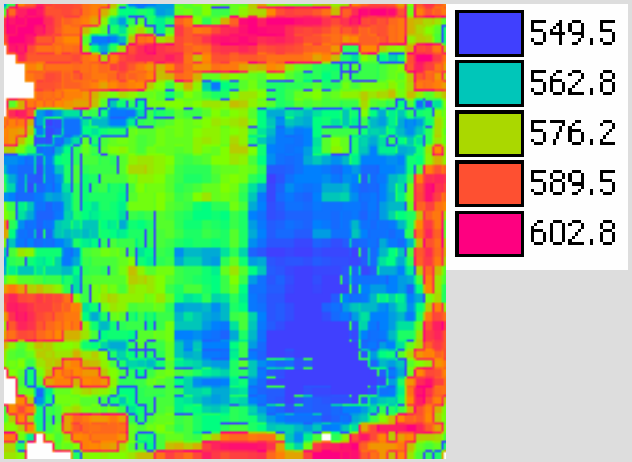




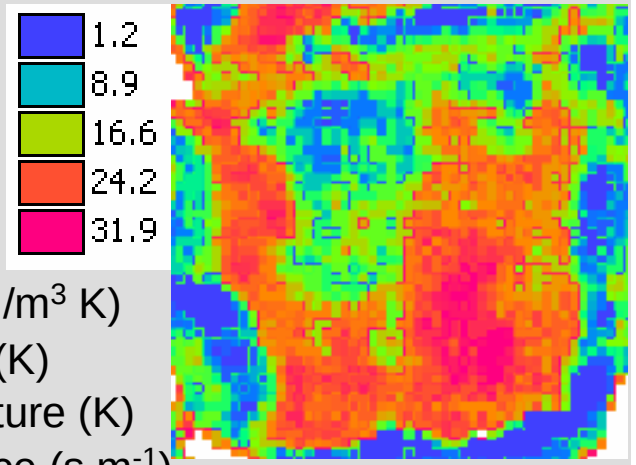
T [K]

ENERGY FLUXES

Instantaneous net radiation (W/m^2)



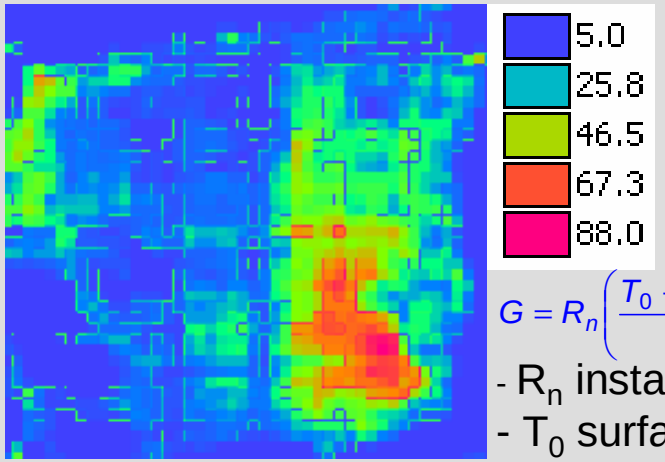
Sensible heat flux (W/m^2)



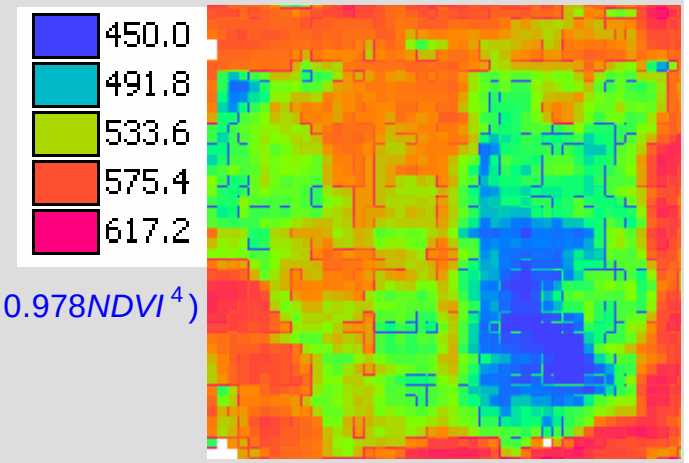
$$H = \rho_a c_p ((T_0 - T_a)/r_a)$$

- $\rho_a c_p$ air heat capacity (J/m^3 K)
- T_0 surface temperature (K)
- T_a atmosphere temperature (K)
- r_a aerodynamic resistance (s m^{-1})

Soil heat flux (W/m^2)



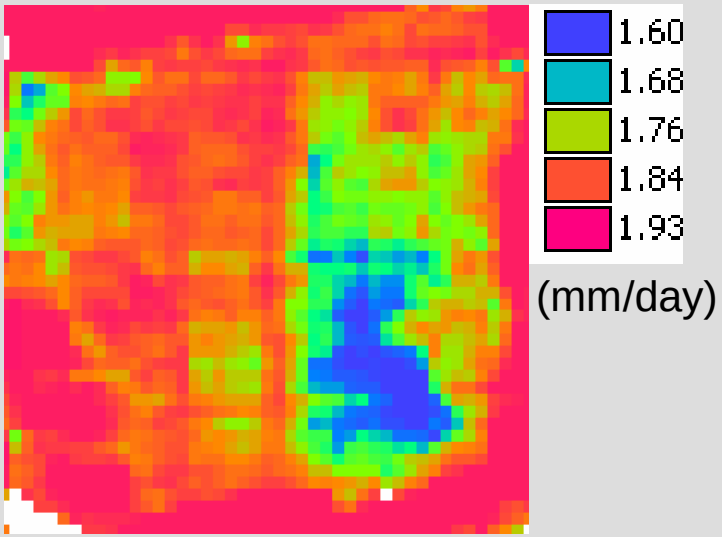
Latent heat flux (W/m^2)



$$G = R_n \left(\frac{T_0 - 273}{r_0} \right) \left[0.0032(c_1 r_0) + 0.0062(c_1 r_0)^2 \right] (1 - 0.978 NDVI^4)$$

- R_n instantaneous net radiation (Wm^{-2})
- T_0 surface temperature (K)
- r_0 surface broadband albedo
- NDVI normalized vegetation index
- C_1 albedo conversion factor

DAILY EVAPOTRANSPIRATION



- ET ranges from 1.6 to 2.0 mm/day.
- Relatively low estimate vs Penman-Monteith (~3.5 mm/day) for the whole Doode Bemde.
- Fen meadow enclosed by high trees, causing low wind velocity, which reduces turbulent upward transport of latent heat.
- Additionally the soil moisture content is also lower than in many other parts of the wetland areas in Doode Bemde due to the fact that the grass field is located on the foot of the valley flank.

CONCLUSIONS

- IS of phreatophytes can serve as proxy for soil moisture and groundwater gradients in riparian areas.
- Soil moisture and energy fluxes (ET) can be obtained for specific riparian condition from CASI + ATM.
- Evapotranspiration varies considerably over short distances in dependence of a complex set of landscape, ecological and hydrometeorological factors.
- High spatially resolution distributed evapotranspiration knowledge is therefore essential in estimating surface and groundwater balances and for better understanding of site specific ecohydrological relationships.

Thanks!