REMOTE SENSING ESTIMATES OF EVAPOTRANSPIRATION TO ANALYZE ECOHYDROLOGICAL DYNAMICS IN A SEMI-ARID BASIN

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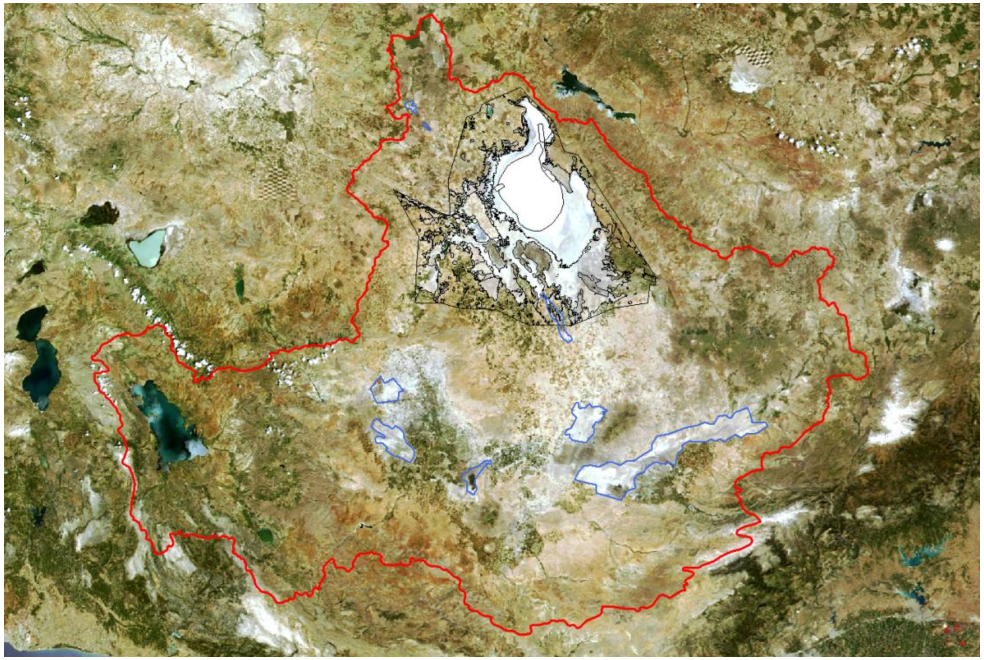

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1. Introduction

1.1. Water Limited Environments

1.2. A regional case (Konya closed basin, Turkey)

1.3. The problem

1.4. The conceptual model

1.5. Objectives

1.1. Water Limited Environments

- **WLE** are generally characterized by low precipitation (***P***), and high potential evapotranspiration (***PET***). (***P***/***PET*** is less than **0.75** according to Parsons and Abrahams, 1994)
- In **WLE,** the total actual evapotranspiration (***ETa***) is usually the major component of the water balance (Lubczynski, 2008).
- **WLE** include arid, semi-arid and some sub-humid regions.
- Demand and pressure on the limited water resources are usually high.
- Adaption to water stress by natural vegetation: large variability of transpiration and water use efficiency.





1.2. A regional case (Konya closed basin, Turkey)

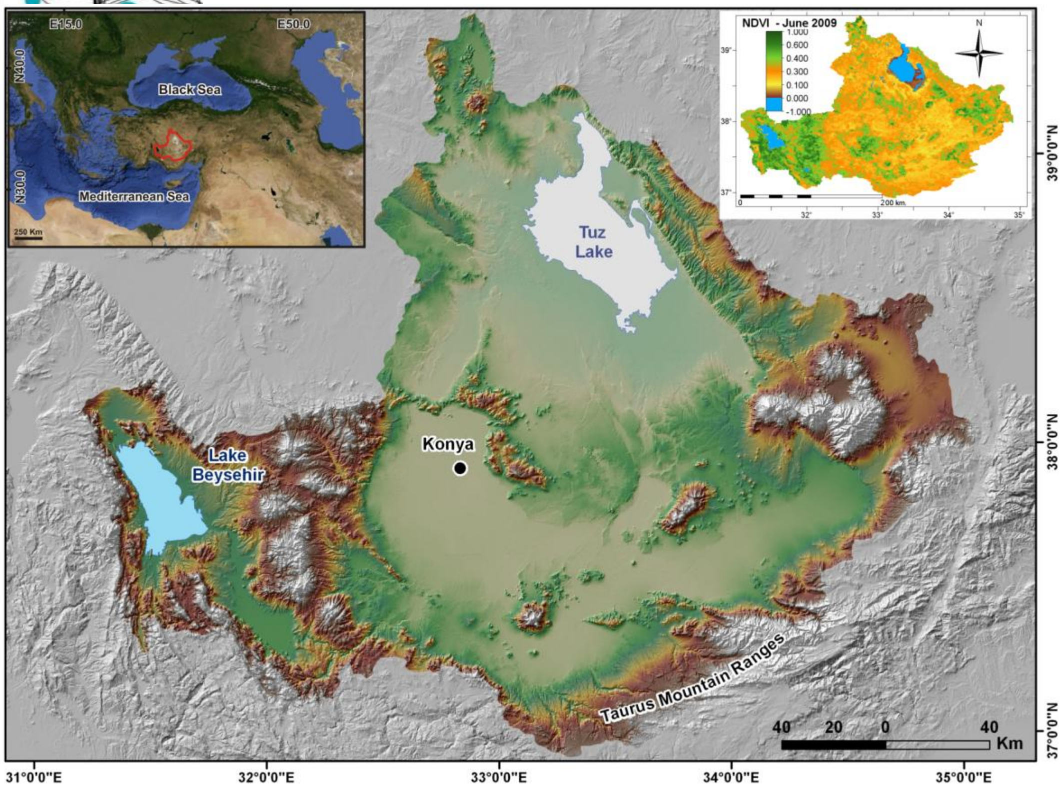

Fig. 1. Location, DEM and NDVI of the Konya Closed Basin (KCB).

The Konya closed basin, Turkey:

Elevation: 900 – 3.534 m.a.s.l.

Surface area: 54.000 km^2

Climate: Arid to semi-arid

P ≈ 350 mm/year

PET ≈ 1400 mm/year

P/PET ≈ 0.25

Land cover: shows a strong contrast b/w intensively irrigated agricultural lands and the sparse steppe areas.

Water resources:

Groundwater (GW) is the main source for irrigation. Also, the discharge of GW feeds the hyper-saline Tuz Lake and GW dependent wetlands in the mid & downstream.

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1.3. The problem: Depletion of GW resources

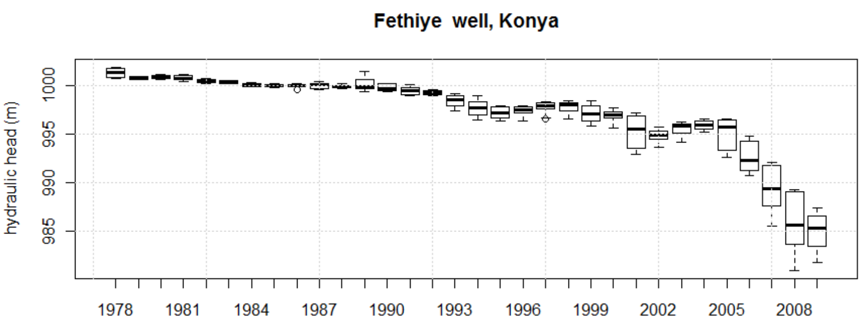


Fig. Long term GW head changes

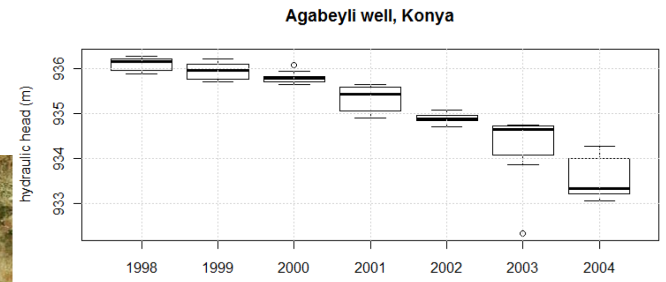


Fig. GW head changes in time

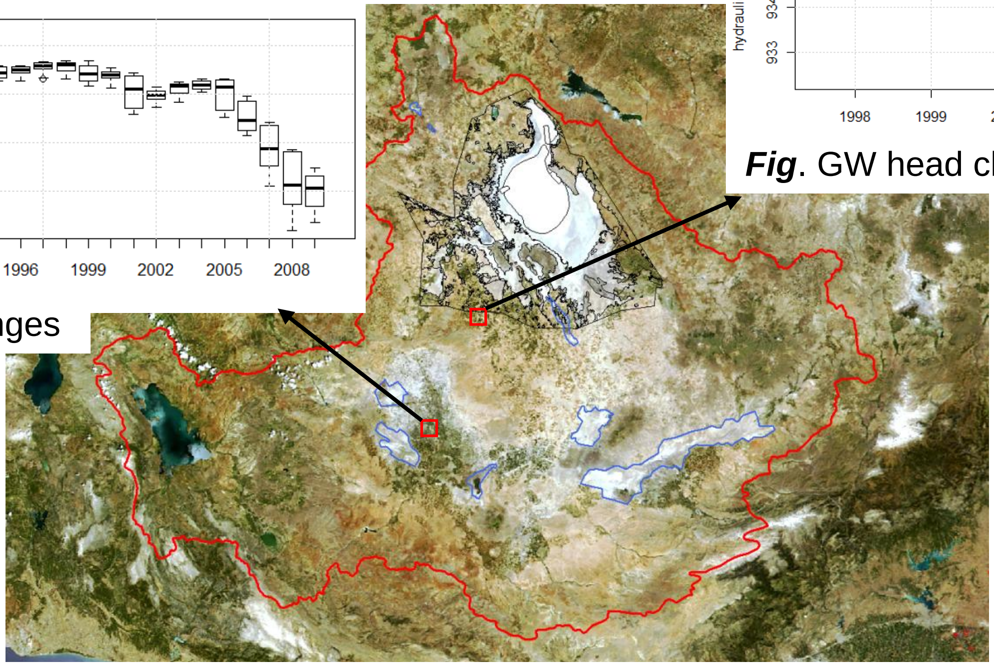


Fig. 2. A true color MODIS image (2004). The polygons are indicating mid and downstream Wetlands or important nature areas

1.4. The conceptual model

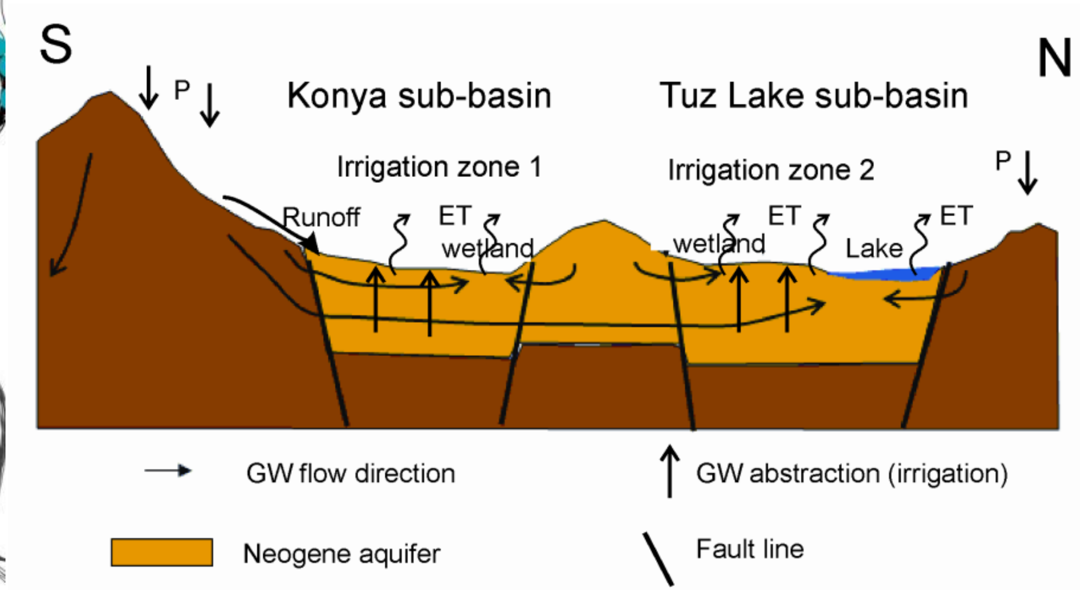


Fig. 3. A conceptual model of hydrological fluxes in KCB. *(Modified from the MSc thesis of Win Naing, 2011)*

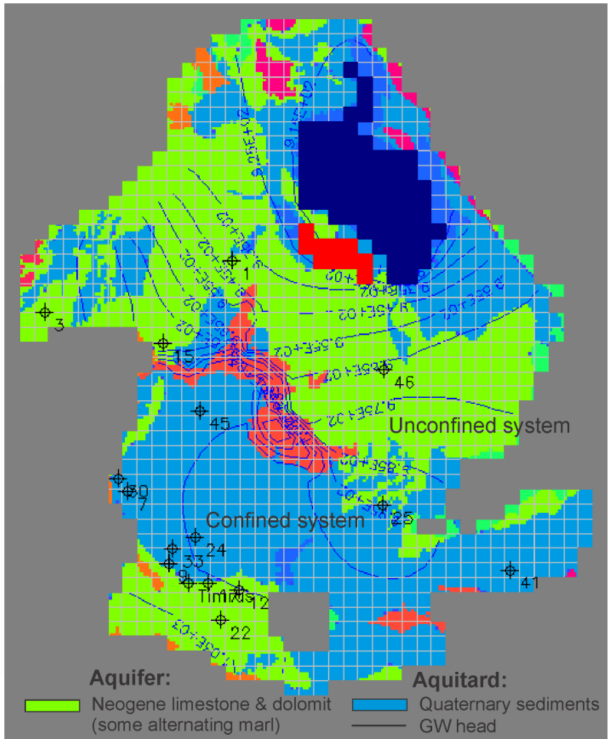
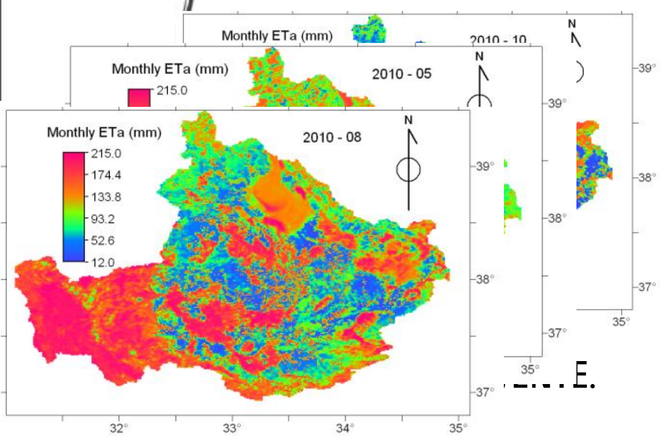


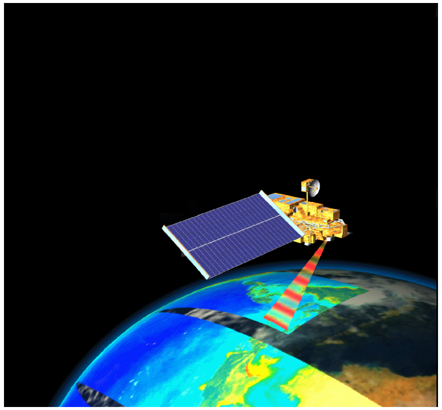
Fig. 4. Aquifers and GW flow systems in KCB. *(Modified from the MSc thesis of Win Naing, 2011)*

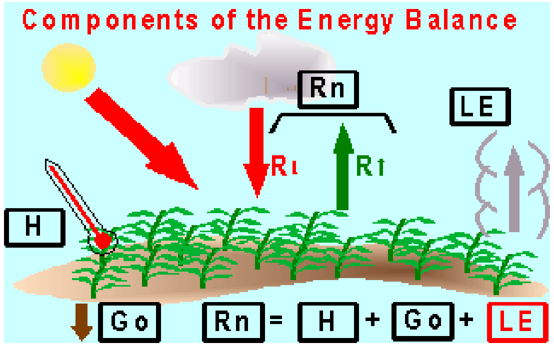
1.5. Objectives

- This research aims at analyzing the ecohydrological dynamics in a semi-arid region through long term time-series of *ET*, as it is the main outflux from the hydrological system.
- How?

  A Remote Sensing based, systematic and consistent tool to quantify spatio-temporal ET with good accuracy.







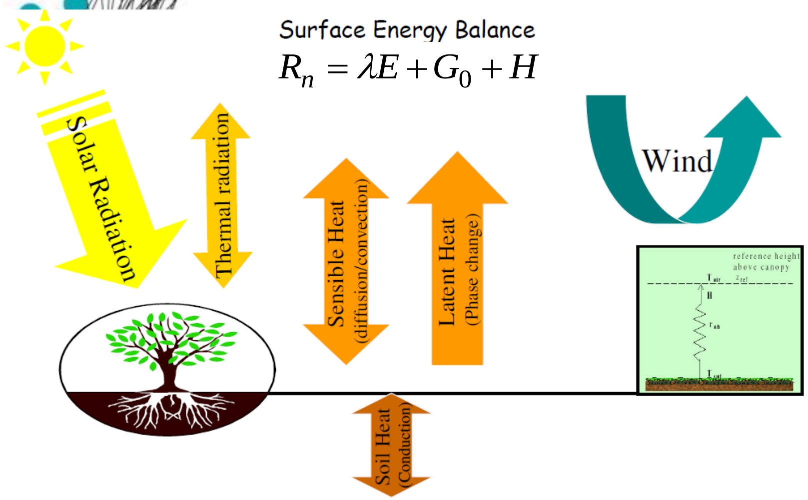
2. Methods

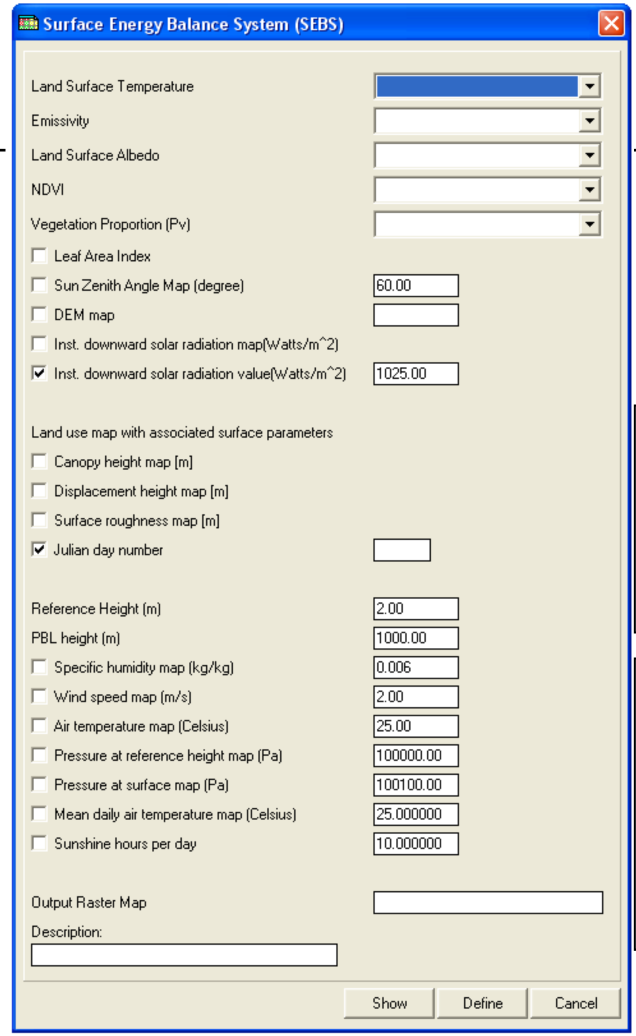
2.1. SEBS for spatio-temporal ET

2.2. Building time-series of ET

* A paper is to be submitted soon regarding validation and accuracy of ET by SEBS in drylands, which is titled "*An operational integration of soil moisture into SEB models for improving evapotranspiration estimation in sparsely vegetated drylands*"

2.1. Surface Energy Balance System (SEBS), Su (2002)



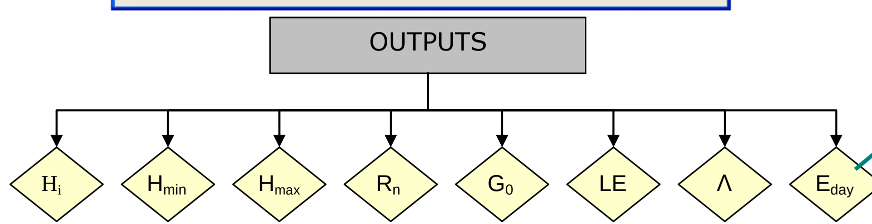


RS data:
MODIS visible, near-infrared and thermal bands

Surf. roughness:
- Field data or,
- Land use map or,
- Vegetation indices

Meteorology Data
(air temperature, wind speed, pressure, sun hours)

- RS based SEBS (Su, 2002) enable a spatially and temporally distributed ET calculation from plot to regional, continental and global scale.
- SEBS combines optical and thermal RS with meteorological data to calculate the turbulent heat fluxes.
- SEBS calculate latent heat flux (the energy for evaporation) as the residual of the energy balance equation.



Daily ET

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2.2. How to build a consistent ET time series?

Daily ET → Upscale → 10-daily ET → Upscale → Monthly ET

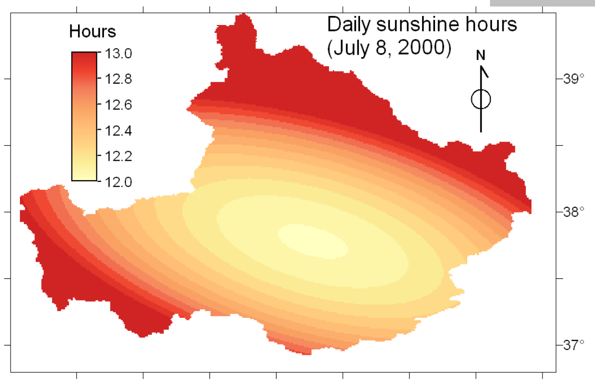
ET is limited by ***Energy demand*** and ***Water availability*** (Parlange & Albertson 1995; Wang et al, 2006)

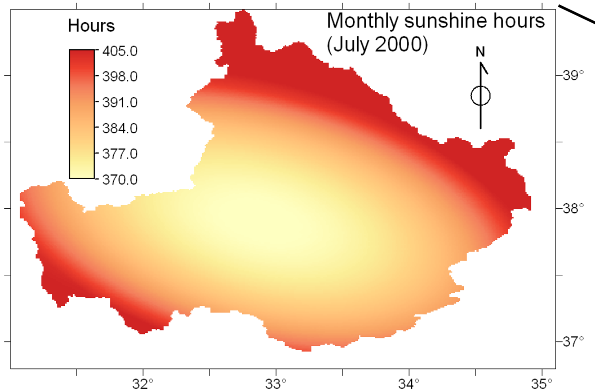
$$\lambda E = \psi \left[A \frac{\Delta}{\Delta + \gamma} (R_n - G) + B \frac{\gamma}{\Delta + \gamma} f(u) (e_a^* - e_a) \right]$$

Energy needed for ET

Available energy

Vapor deficit (water limitation)





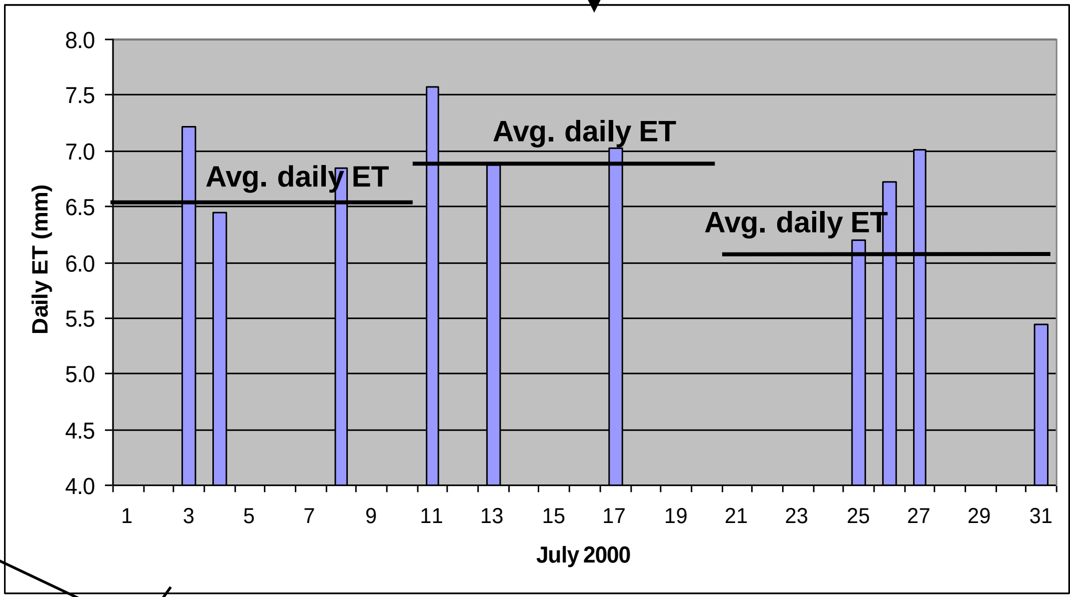
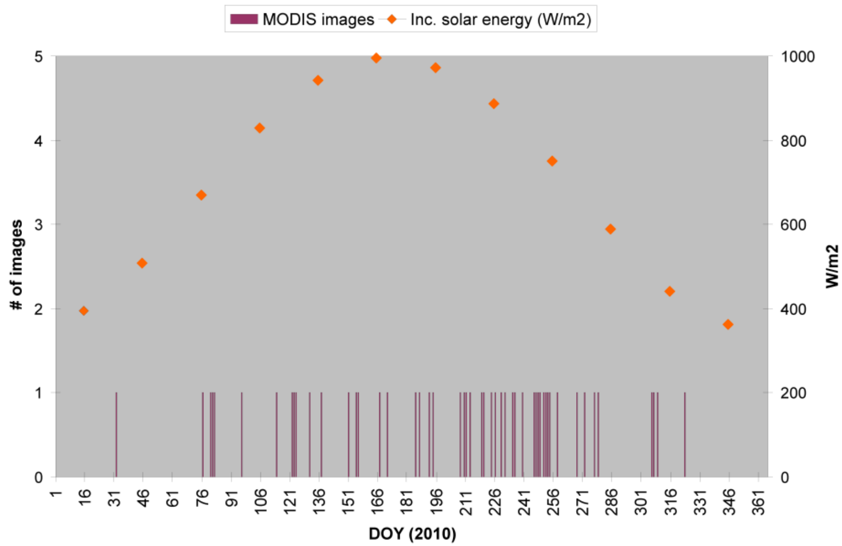
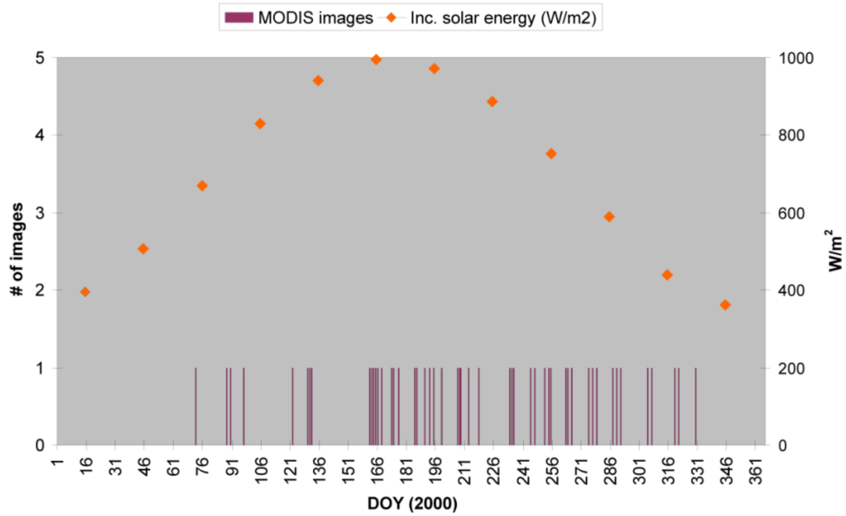


Fig. Distribution of daily ET calculated by SEBS at a pixel.

$$10.dailyET = Avg.dailyET \times \frac{Total.10.daily.sunhours}{Avg.daily.sunhours}$$

2.2. ET time series – RS image availability





	# of Cloud free MODIS (Terra) images
2010	**51**
2002	**31**
2000	**50**

* Radiation curve was used to scale ET in winter months (Dec, Jan, Feb)

3. Results

3.1. Time series of monthly ET

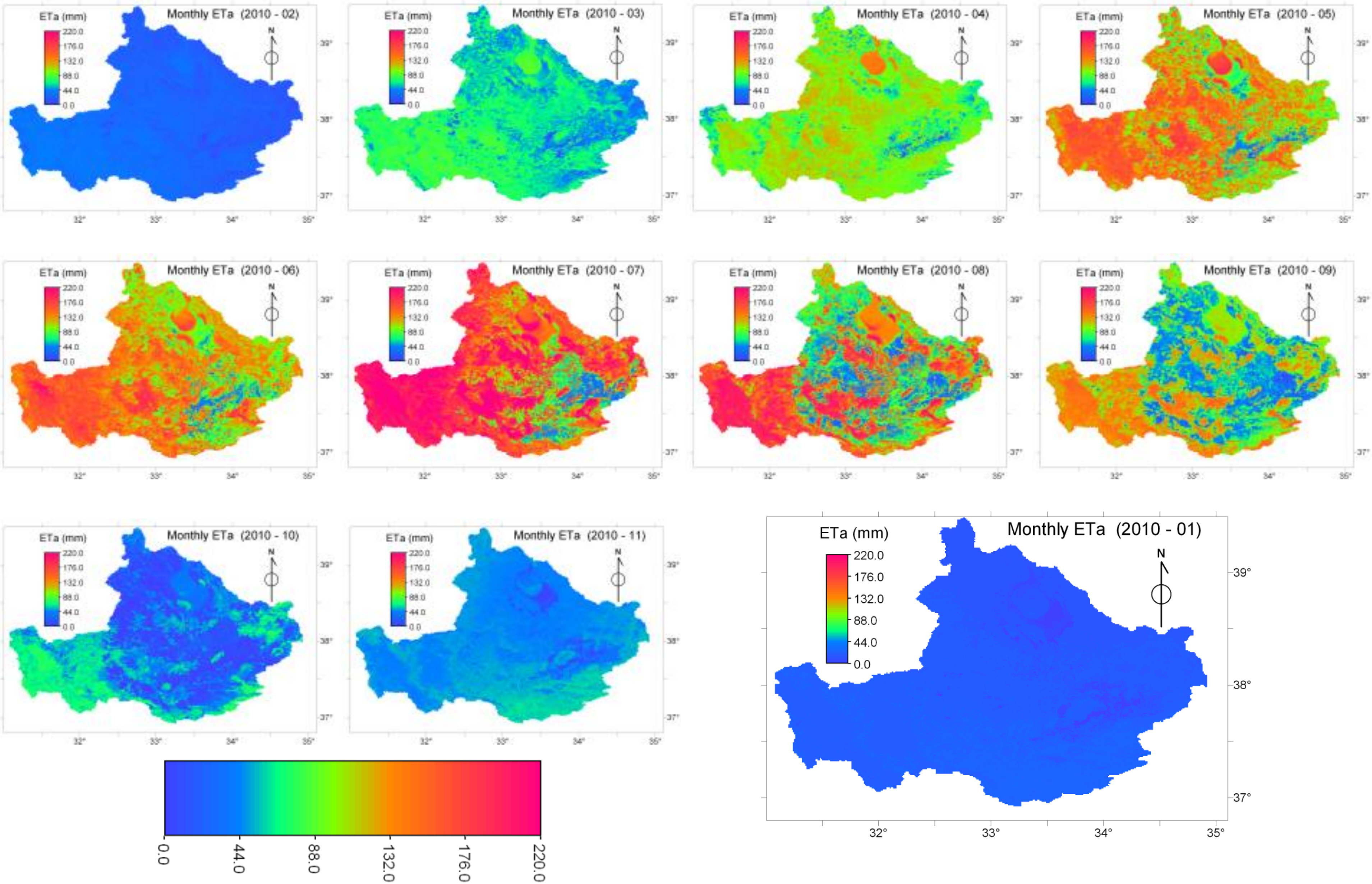
3.2. Changes in Yearly ET

3.3. Changes in the wetlands

3.4. Ecological GW demand

3.5. Adaptations of natural vegetation

3.1. Time series of monthly ET



3.2. Changes in Yearly ET

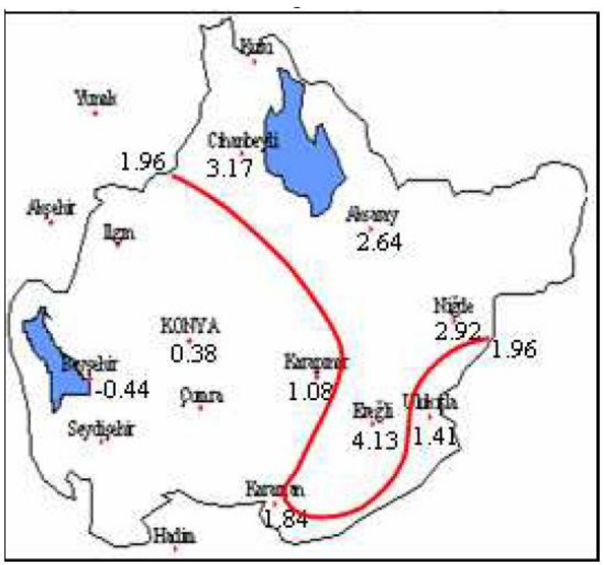
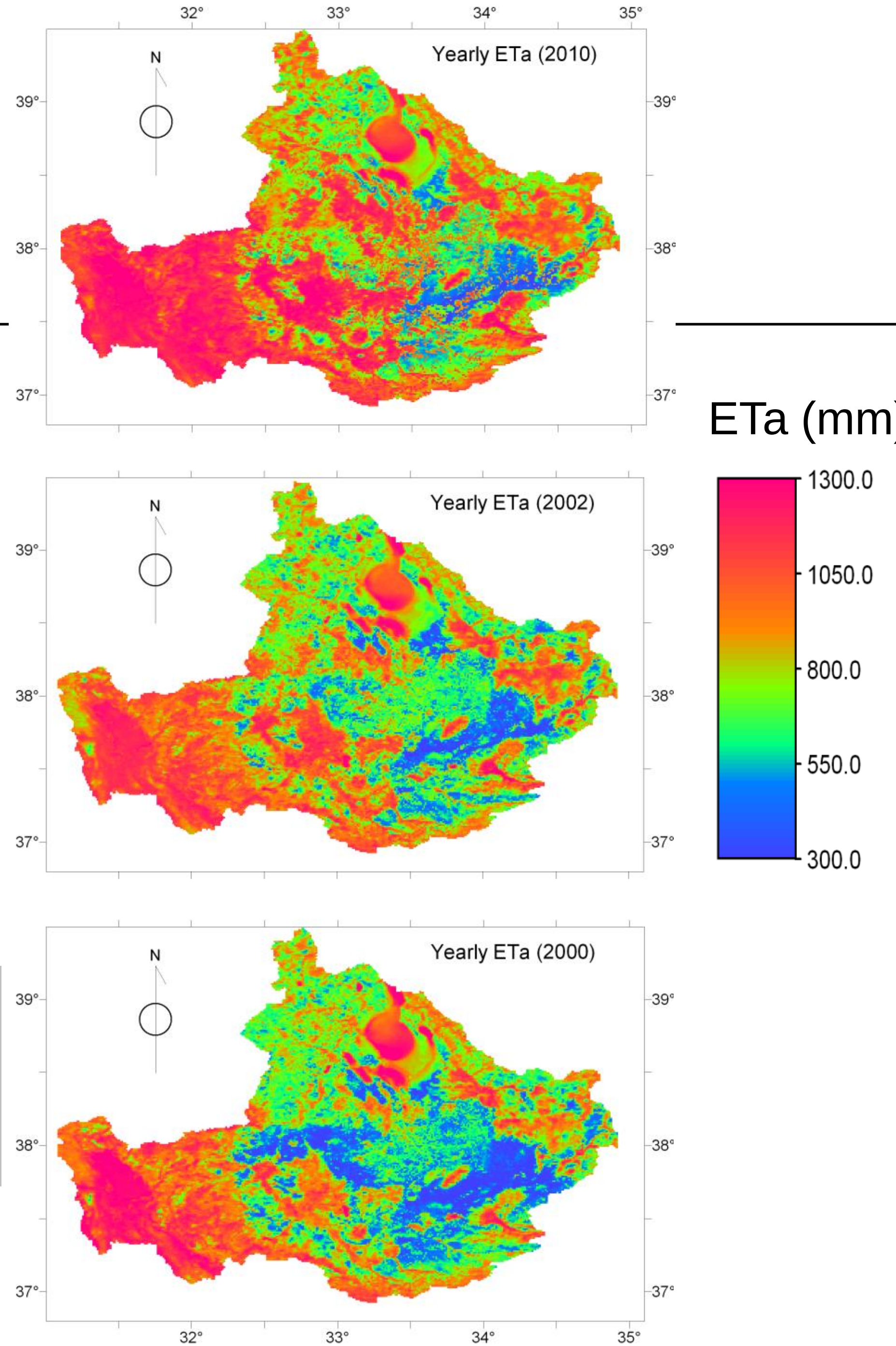
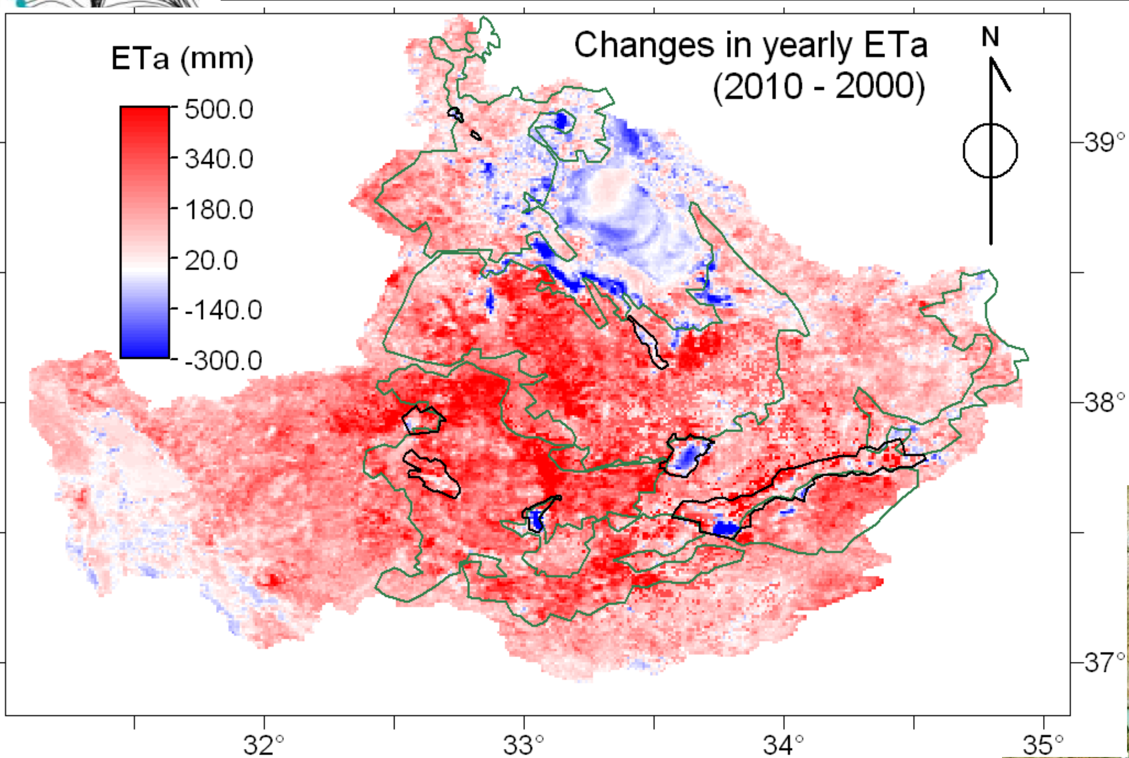


Fig. Long-term (1965-2007) trend in average air temperature. **Source:** Sen & Basaran (2008). (>1.96 indicates significant increase. The study concludes, it's uncertain how much of this rise is caused by urbanization or global climate change.

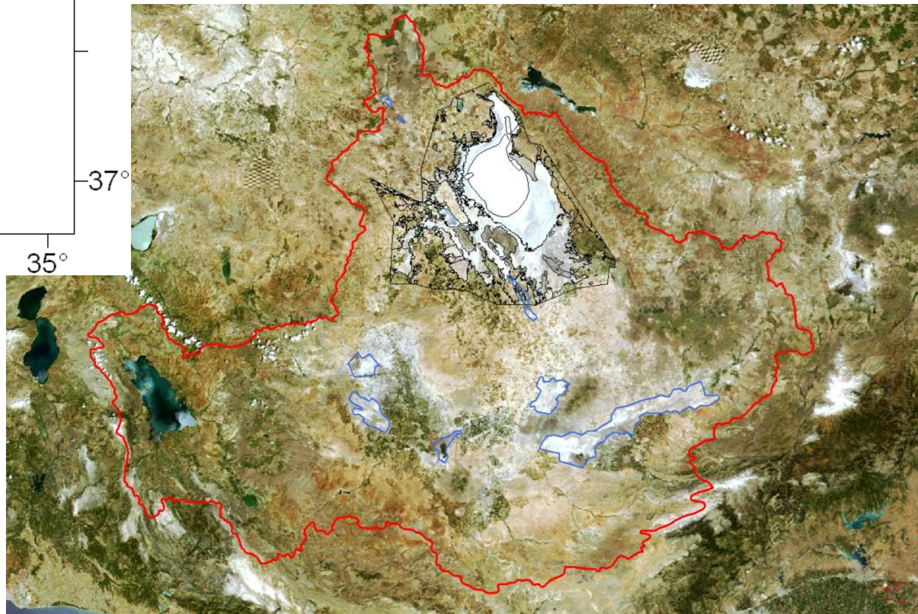


3.3. Difference in yearly ET from 2000 to 2010



	Total Volume of ET (MCM)		Change (MCM)
	2000	2010	
Agriculture	10,150	13,750	3,600
Small lakes	76	48	-28

* Regional Water Authority figures indicate a potential safe GW yield of ~1700 MCM per year.



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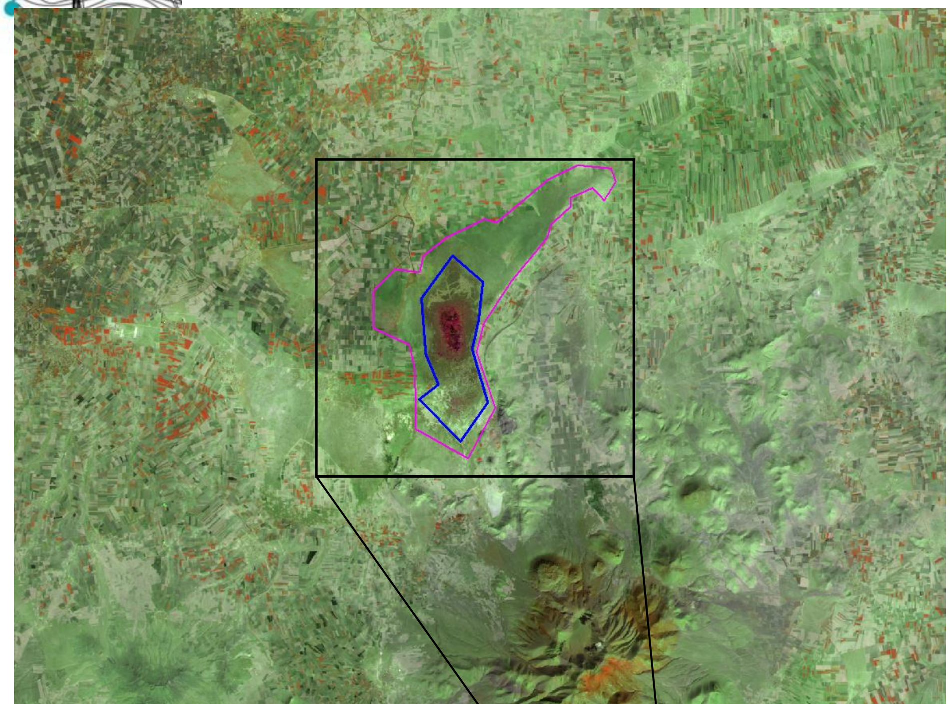
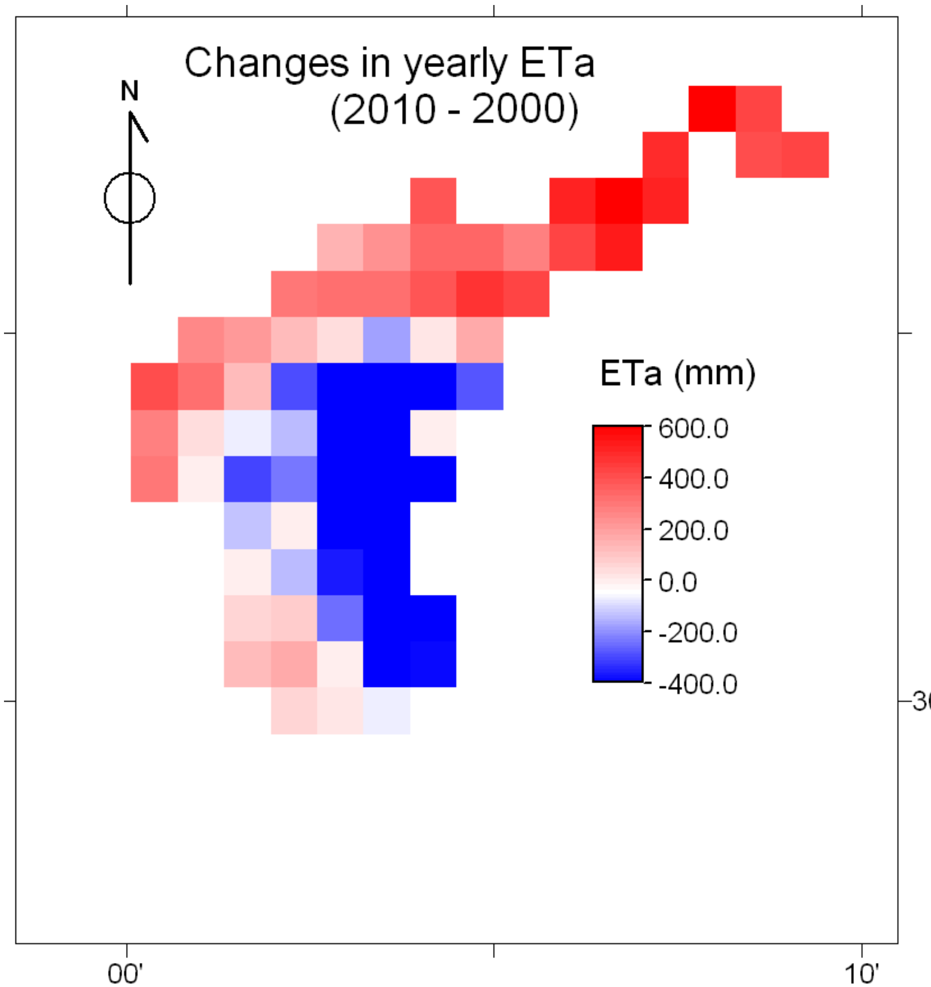
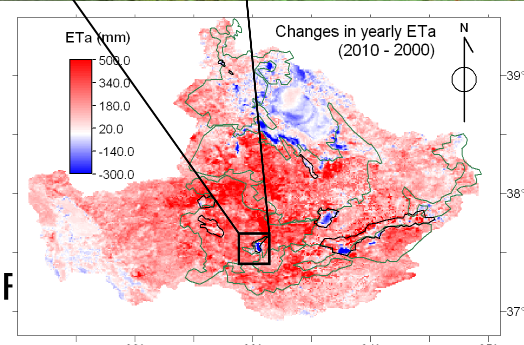
3.3. A closer look to Hotamis wetland







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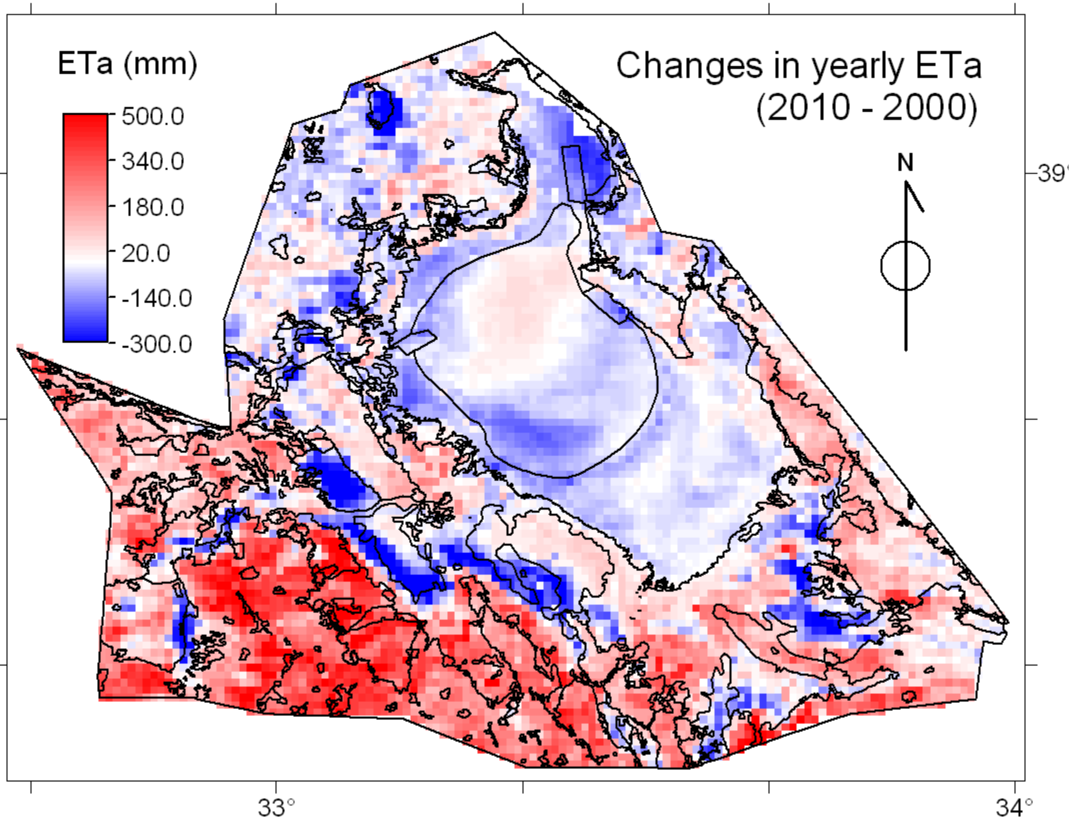
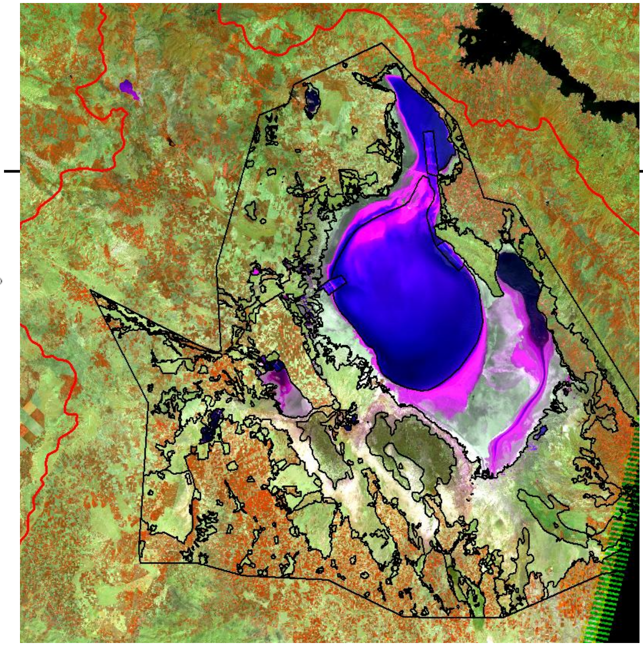
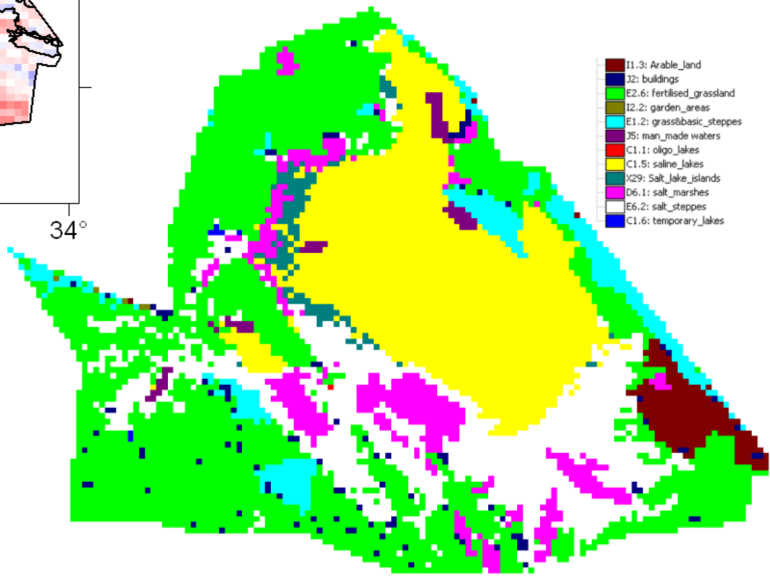
3.3. Downstream Tuz Lake and the wetlands (Nature protection site)

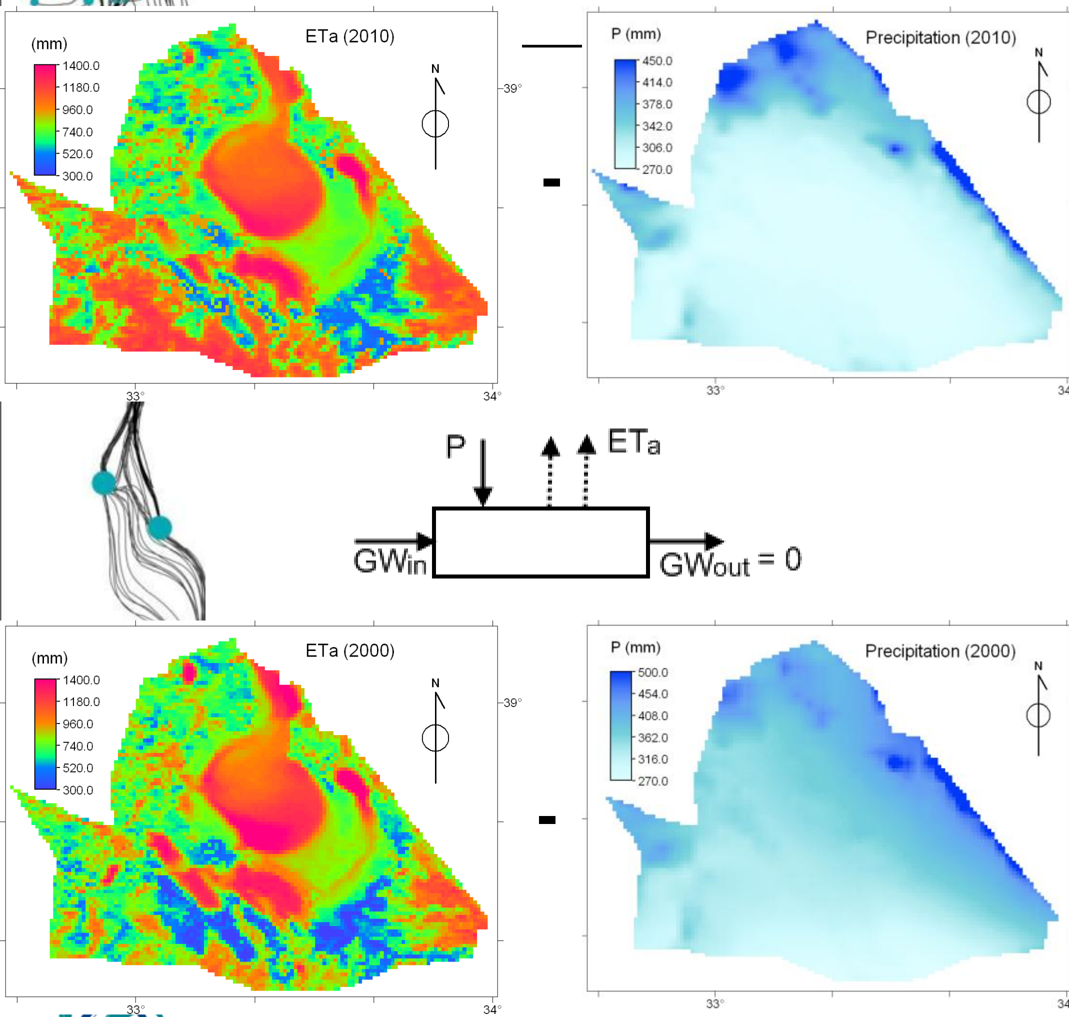


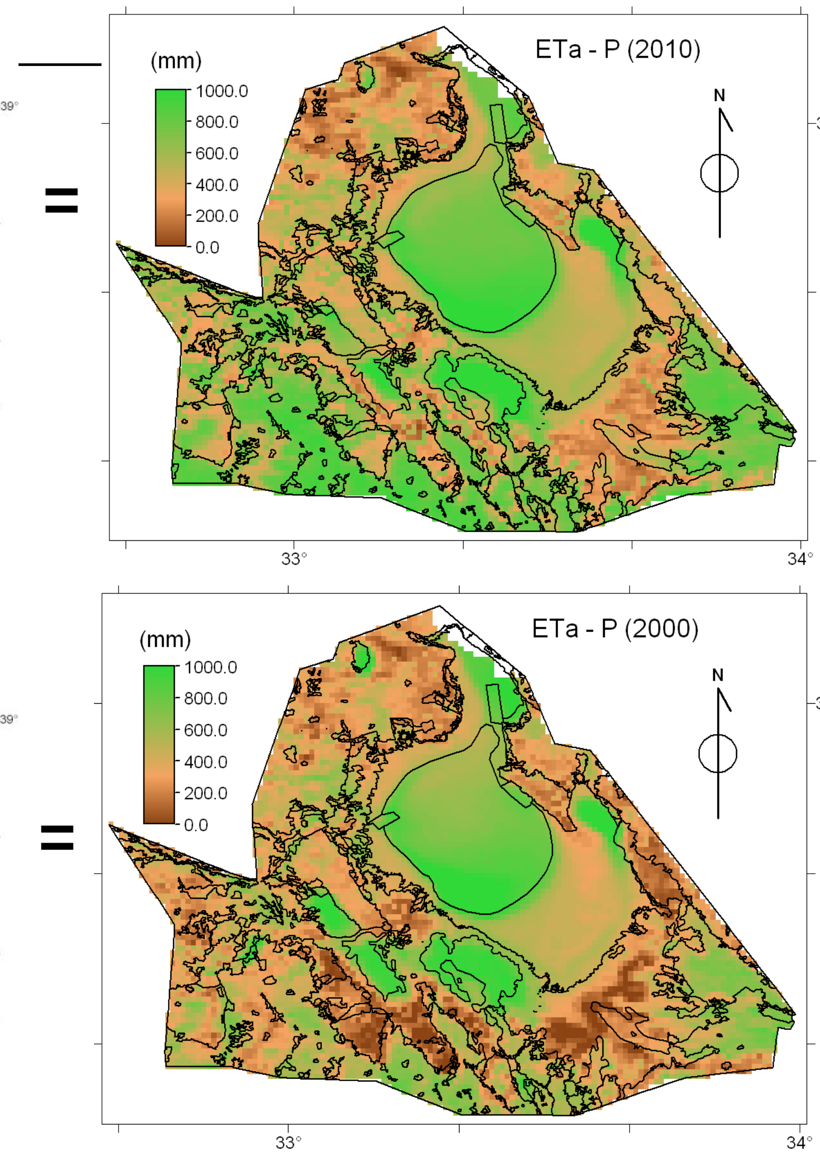




	Total Volume of ET (MCM)		Change (MCM)
	2000	2010	
Tuz Lake	1,750	1,650	-100
Salt marshes	450	430	-20
Salt steppe	930	985	55

3.4. Ecological GW demand (Groundwater influx, or GW discharge for the lake and wetlands), and GW abstraction for agricultural lands.



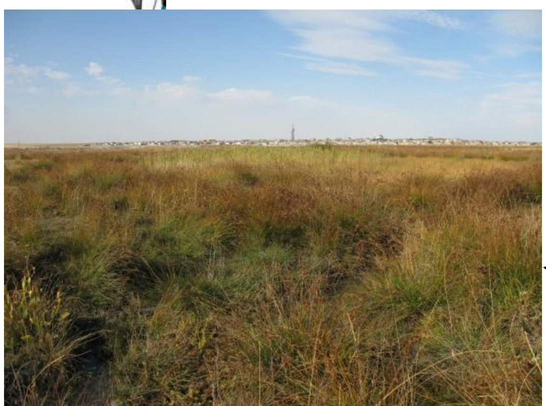


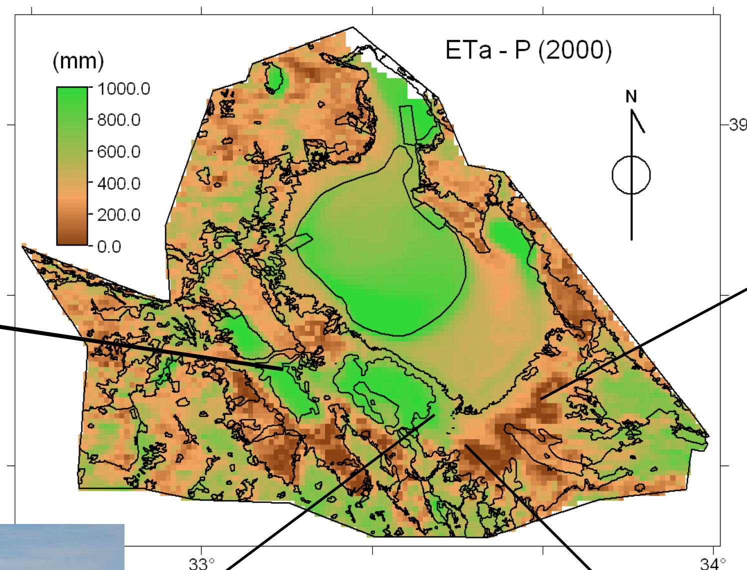
3.5. Adaptation of natural vegetation to water stress

(large variability of transpiration and water use efficiency)

1) Salt marshes (high GW dependence)
ETa - P ≈ 700-1000 mm/year

2) Salt steppe
(less / no significant GW dependence)
ETa - P ≈ 0-300 mm/year





CONCLUDING REMARKS

- **RS based SEB Models** are the only tool to quantify spatial and temporal ET Flux, and provide great opportunity ecohydrological monitoring.
- Comparison of **yearly ET maps reveal** that, there has been significant environmental changes in the water limited KCB by increasing human pressure, besides the uncertainties by changing climate.
- Nature protection sites in the downstream can not be considered independent from the whole basin, as the **GW is connected at basin scale**.
- **Good agricultural practices & planning** should be an integral part of sustainable water resources management & nature protection.
- "***ET – P***" is a good indicator for calculating **ecological GW demand**. However, "**Sustainable yield**" concept by GW resource managers needs to be reconsidered. How to share the GW resources b/w agricultural and ecological demands?

THANK YOU.