Monitoring Changes in irrigated area in SE Turkey and its impacts on regional hydrology

Guido Salvucci, Curtis Woodcock, Mark Friedl, Bruce Anderson, and Mutlu Ozdogan
Department of Geography and Center for Remote Sensing, Boston University, 725 Commonwealth Avenue, Boston, MA, USA

1. Background

- Large-scale water resources development project in SE Turkey known as GAP
- 22 dams within the Euphrates – Tigris Basin to irrigate 1.7 million Ha land
- Currently ~300,000 irrigated

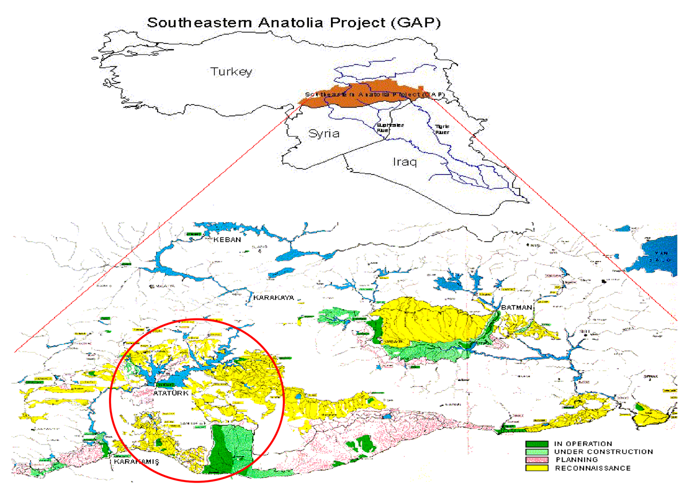


Figure 1. General setting of the study area

2. Questions addressed

- How has the irrigated area changed in last 10 years (1993 – 2002)
- What is the hydrologic impact of this change
- What is the long term impact of continuing change on water resources and carbon

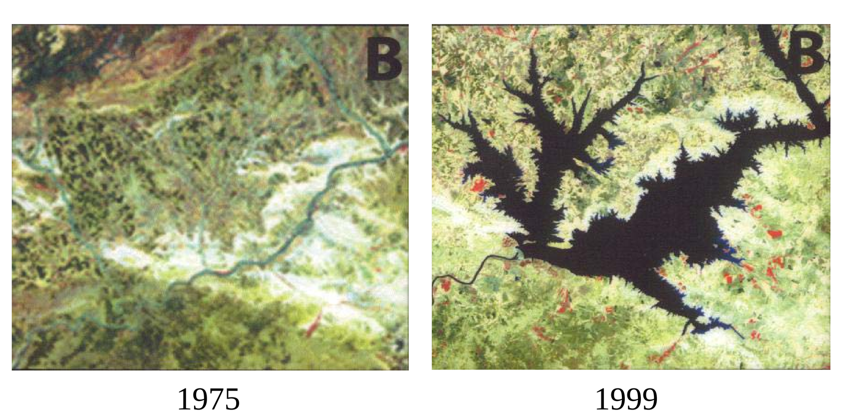


Figure 2. 1975 -2001 Landsat image showing the Ataturk reservoir, which is the main source of irrigation

3. Main Inputs

- Satellite data (NDVI)
  - High temporal-resolution (AVHRR-MODIS) time series
  - Landsat time-series
- Estimate of water use for irrigated fields (collaborators)
- Meteorological data from 24 stations
- Re-analysis data for meso-scale climate modeling

Figure 3. Main transport structures and field canals illustrating the method of irrigation

4. Monitoring changes in irrigated area

- We used a 2 source approach

A. Use of high temporal-resolution data (AVHRR – MODIS) to understand

i) vegetation dynamics

ii) changes in cropping pattern

iii) Timing of high resolution data

Results of this analysis indicate that peak greenness in the region occurs in mid- to late-April. With the onset of irrigation, there is a change in cropping pattern: While In April 1992, Harran Plain is fully vegetated (rain-fed agriculture), during same period in 2001, Harran Plain is fallow, getting ready for summer irrigation. Additionally, main irrigation period in July-August, at which time spectral contrast between irrigated and fallow is greatest. Therefore, timing of Landsat is chosen to be July-August-September.

B. Use Landsat data to map irrigated lands

i) decision tree approach

ii) final map showing location and changes in irrigated area

Summer season time series Landsat data (1993 – 2002) is used in an iterative decision-tree type setting to map distribution and changes in irrigated area. The input is NDVI, found to be sufficient to distinguish irrigated lands. Intermediate map with 48 classes, number of unique combinations for each field being irrigated or not over 10 years. The final maps have two classes, showing irrigated vs. non-irrigated per year. Results for the Harran Plain indicate rapid increase in irrigated are between 1996-1998 followed by gradual increase in area of irrigated lands.

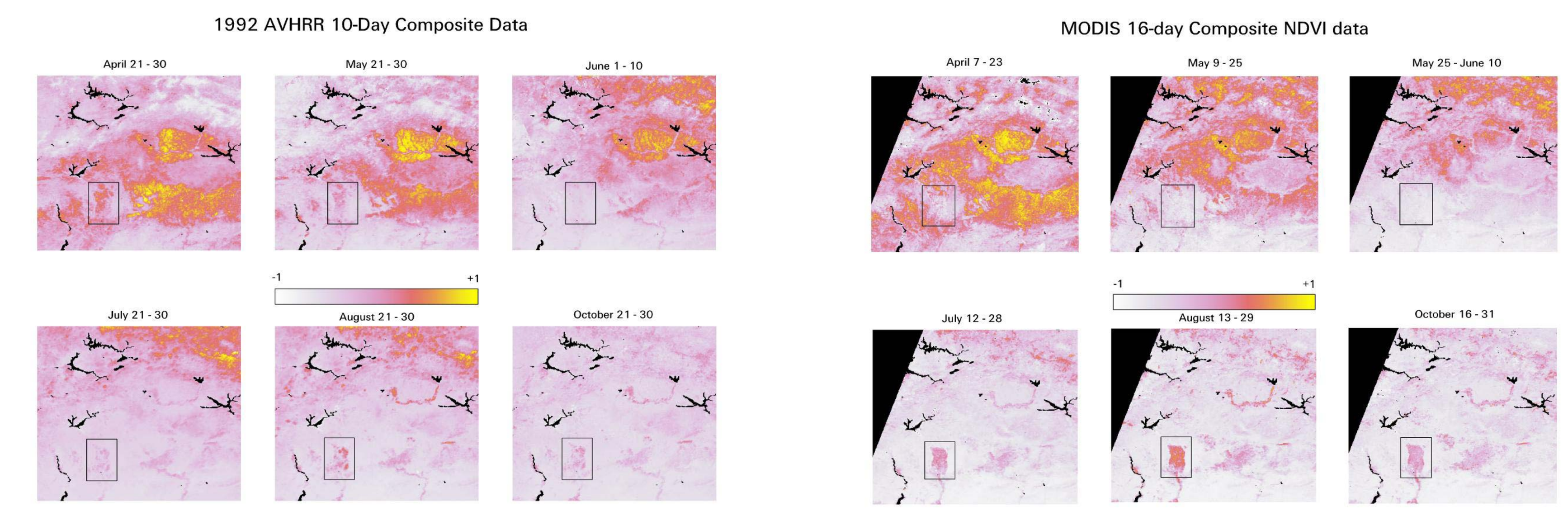
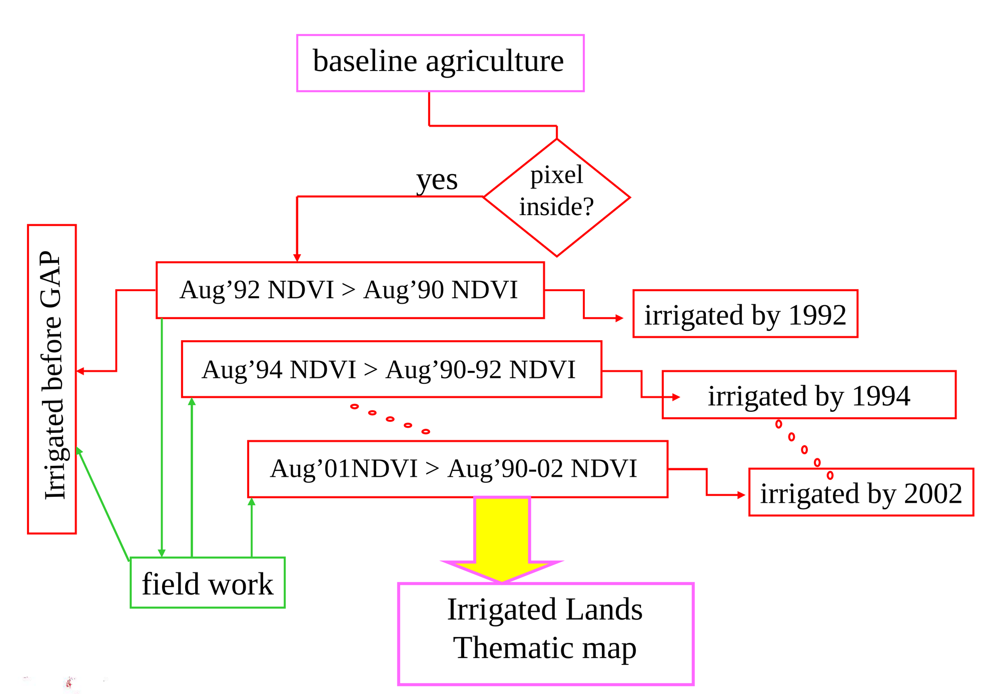


Figure 4. Analysis of AVHRR-MODIS data (1992 vs. 2001), illustrating changes in cropping pattern as well as timing of irrigation.

Process – Mapping Irrigated Lands



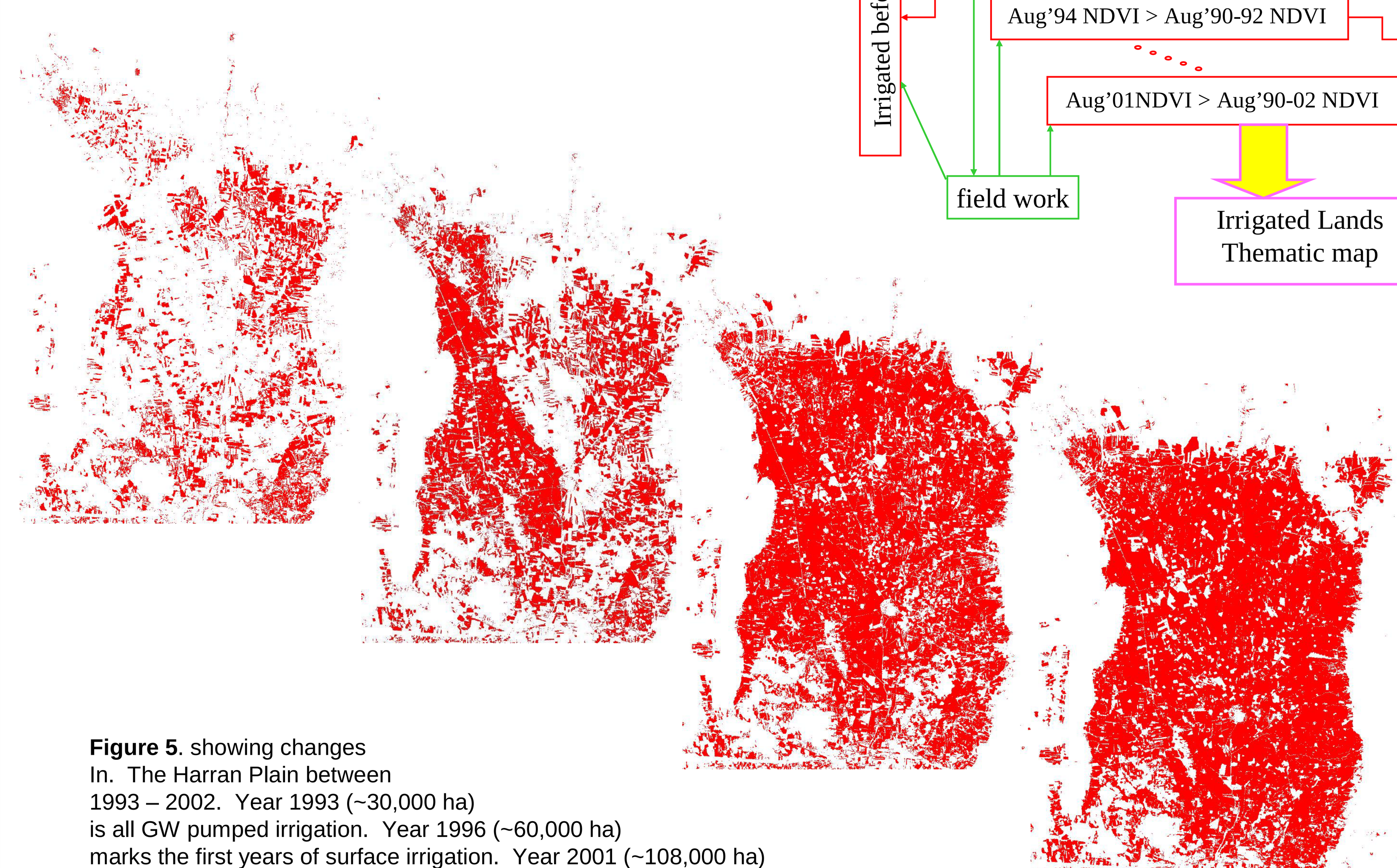


Figure 5. showing changes In. The Harran Plain between 1993 – 2002. Year 1993 (~30,000 ha) is all GW pumped irrigation. Year 1996 (~60,000 ha) marks the first years of surface irrigation. Year 2001 (~108,000 ha) is the largest single irrigated Plain in the region. 90 % of irrigated f fields are cotton with rest either soy-bean or second crop (Maize, alfalfa)

5. Water usage

We compared remote sensing estimates to those provided by the State. Results indicate that, although conservative, remote sensing estimates are Constantly larger than State estimates. One explanation is that state estimates are based on wholesale water distribution with given carrying capacity. On the other hand, RS estimates are synoptic view of irrigated vs. non-irrigated.

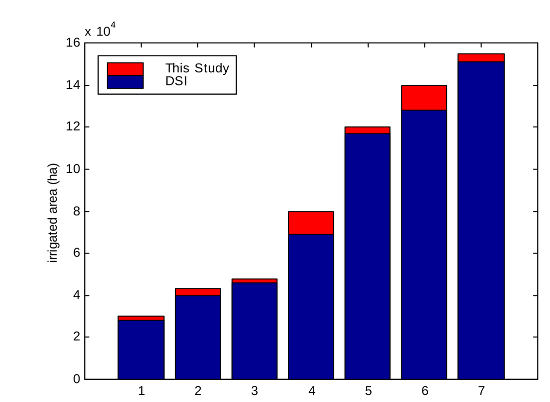


Figure 6. Remote sensing vs. State estimates of irrigated area in the Harran Plain

Previous studies in the area suggested several irrigation modules based on the climate, soil texture and crop type. Based on these indicators, we adapted irrigation module of :

1 liter / ha/ second

This leads to a total of ~1,200 mm per year of water input into the system and its monthly distribution is given in Figure 7.

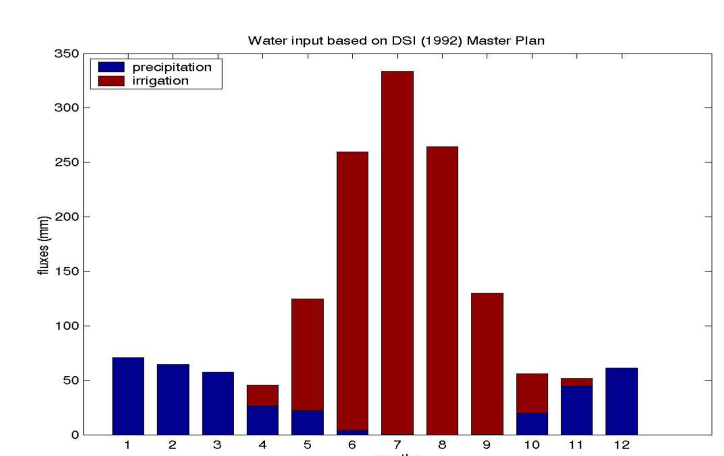


Figure 7. Monthly irrigation in the Harran Plain

5. Testing and application of the Complementary hypothesis (Early Results)

In 1963 Bouchet hypothesized that over areas of regional size and away from sharp discontinuities there exists a complementary relationship between the actual (ETa) and potential (ETp) evapotranspiration. The general form of the complementary hypothesis can be expressed as:

$$ETp + ETa = 2ETw$$

where ETw represents wet environment evapotranspiration and where ETa equals ETp. In this representation, the potential ET is not an independent casual factor, or climatologically constant forcing function, but instead is predicted upon the prevailing conditions of moisture availability. Capitalizing on this characteristic, estimation of potential ET leads to a direct estimation of actual ET, an important part of the water budget in the region.

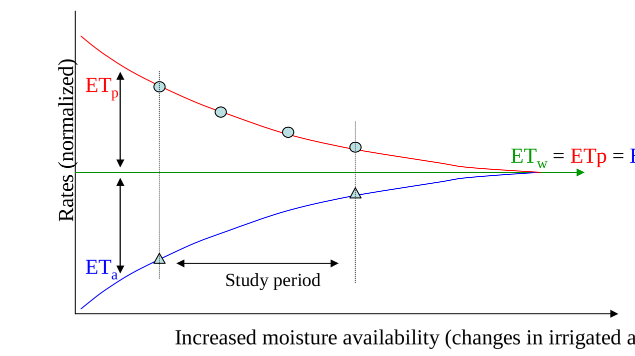


Figure 8. Conseptual model of the Complementary hypothesis

At the heart of application of the BM hypothesis to the study area lies the method to estimate actual and potential ET. In this work we use both Advection aridity (AA) (Brutseart and Strickter, 1972) and Morton's CRAE (Complementary Relationship of Aerial Evaporation) both of which use routine meteorological observations of air temperature, humidity, radiation, wind speed and additional parameters to estimate both ETp and ETw. Using these inputs and the complementary hypothesis, we have determined the actual ET with few routine meteorological variables.

Our early results are promising. We are able to see the general shape of the complementary hypothesis with limited data (Figure 9). This is due to increased evaporating surface and consequent reduction in atmospheric vapor demand which together lead to decrease in potential ET while actual ET is increasing due to water availability.

These early results lend credibility to the hypothesis itself and to our approach. Our goal now id to test this hypothesis in other part of our study area, and once validated, we will make estimates of regional ET surface as an important component of the regional hydrology.

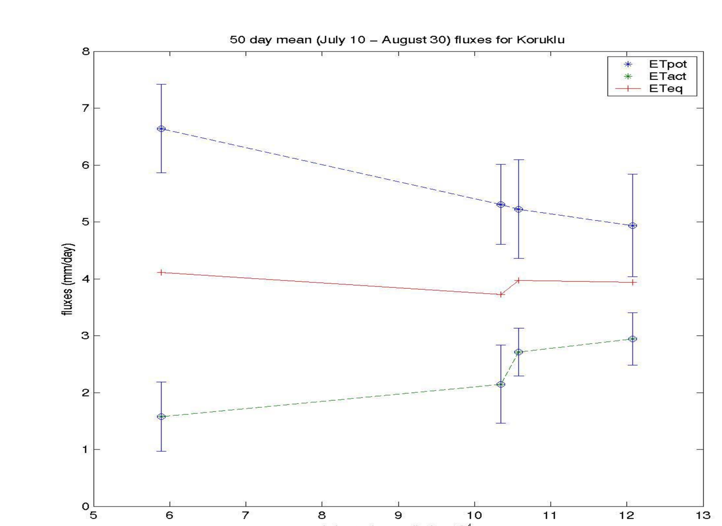


Figure 9. Actual and potential ET as calculated with the AA method. Note the complementary relation between ETact and ETpot.