

# **The Effects of Agricultural Expansion on Regional Hydrology in Southeastern Turkey**

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**Year 2 Progress Report  
(9/1/02 – 8/31/03)  
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## **Project Summary**

The goal of this research is to determine the water resource impacts of land use and land cover change (LCLUC) that are occurring as part of the large-scale water development and irrigation projects in semi-arid Southeastern Turkey. Our approach is a multidisciplinary research program involving change detection analysis using Landsat imagery, statistical analyses of long-term meteorological observations, application of models of evaporation specifically suited to changing soil moisture supply, and simulation analyses with a meso-scale climate model. To address the issue of LCLUC impacts on water balance partitioning, each of these tasks are integrated into a framework based on the complementary hypothesis for evaporation estimation. Together, the research has the objective of answering the following three questions: i) How has the irrigated area changed over the course of the last 10 years? ii) What is the impact of this irrigation on the regional hydrology? iii) What is the long-term impact of this irrigation both on hydrology and regional climate as simulated by a regional climate model? The proposed research has important implications for the sustainability of regional water resources through quantifying the changes in the components (especially evaporation) of the regional water budget.

*Main accomplishments during the first year (completed) were:* [1] Development of MODIS-based temporal information database of irrigation dynamics to help guide Landsat acquisitions; [2] Development of a baseline (ca. 1987) and irrigated (1993-2002) agricultural lands maps. These maps form the basis for analysis of impacts of irrigated land area expansion on regional water resources and climate; [3] Building of a 26-year climate dataset containing critical meteorological parameters to be used in hydroclimatological impact study of second year.

*Second year accomplishments (current year of reporting):* [1] Development of a method to effectively convert irrigated acreage (from remote sensing) to irrigation water use. This was accomplished using combined information from plant water requirements and irrigation transport efficiencies based on our collaborator's work in the field. Comparison of remote sensing based estimates and government reported estimates irrigation water use yield high degree of correlation; [2] Development and application of an empirical evaporation model suited to environmental conditions of our study area. Results of this work indicate that the original hypothesis of complementarity between potential and actual evaporation holds, providing a simple tool to determine actual evapotranspiration from routine meteorological measurements; [3] Initialization of a meso-scale climate model, which involved domain characterization, debugging, and forcing data acquisition;

*Work during the third year will include:* [1] Implementation of a meso-scale climate model to test/evaluate the complementary relationship as well as to determine the effects of future irrigated acreage changes on water resources. This work will also include a study to determine the fate of increasingly available moisture in the region; [3] Evaluation of the results of simulation studies using a 23-station network;

## **Key Words**

Research Fields: Irrigation, Change detection, Evapotranspiration.

Geographic Area/Biome: Mediterranean, Semi-arid.

Remote Sensing: Landsat, MODIS, AVHRR.

Methods/Scales: GIS, Regional Scale, Local Scale.

## Research Questions

*The project addresses the following NASA ESE scientific questions:*

1. What are the changes in land cover and/or land use?
2. What are the consequences of LCLUC?

## Project Themes and proportions

1. LCLUC impacts on water resources: 75 %
2. LCLUC impacts on water climate: 25 %

\* The proportion of Social Science used in the study is 0 %.

## Research goals

The schedule of tasks and milestones for this project is given in Table I. Current period of performance (year 2) is highlighted. Overall, the project has three principal goals, roughly corresponding to three research years. In broad terms, these goals are:

- i) To identify the changes in irrigated area in the region with remote sensing (completed).
- ii) To identify the impacts of changes in irrigated area on water resources of the region using climate data and remote sensing estimates of irrigated area and long-term climate data (**current period of performance**).
- iii) To identify the long-term impacts of changes in irrigated area on regional hydrology and climate using a meso-scale climate model.

The first goal is complete and the resulting map products can be found in the project web page (<http://www.bu.edu/remotesensing/Research/Turkey/index.html>). The second goal (current year of performance) is largely complete. Various components of this objective can be further detailed as follows:

- One critical factor influencing the regional water balance is the land under irrigation. In order to quantitatively determine the impact of irrigation on the components of the regional water budget, a meaningful method to convert irrigated acreage to seasonal water use must be found. Our approach to this issue was to combine crop consumptive requirements (mainly for cotton) and irrigation efficiency for the type of irrigation. Our results agree well with state reported amounts of irrigation water use.
- the second half of current performance year was devoted to analysis of long-term climate data (1979-2002) with goal of testing the hypothesis of complementary relationship between actual and potential evaporation. Using an combined energy balance-diffusion approach for estimating potential evaporation, our results indicate that the complementary relationship holds, at least for the summer (main irrigation period).

## Second year progress

As described above, we began our second year of study with one major goal to achieve: What is the impact of large scale irrigation on regional hydroclimatology? To answer this question, we first developed a database containing information on changes in irrigation water use. This database is not only used for determining the water input into the system in the form irrigation, but also to verify evaporation model results.

The annual irrigation water use database was developed with the help of combining crop consumptive requirements and irrigation efficiency. Our field work in the region indicates that cotton accounts for over 95% of the summer irrigated crops. Thus using consumptive irrigation requirements for cotton (approximately 1200mm/season for an average precipitation year) and irrigated acreage from remote sensing, we developed a basic “water requirements” database. However, in order to determine the amount of actual water applied, irrigation efficiency must be taken into account. While the method of irrigation has not changed during our study period, irrigation efficiency has improved, primarily due to rising water table and increased use of irrigation return flow. Using a time-varying irrigation efficiency, we developed a final database of annual water use between 1993-2002 (Figure 1) which can be found in project’s web site listed above. To summarize, irrigation water use have increased by almost 300 percent from about 300,000 m<sup>3</sup> in 1993 to over 1 billion m<sup>3</sup> in 2003.

The main part of our hydroclimatological impact study involved the testing and application of the Bouchet-Morton complementary evaporation hypothesis (Bouchet, 1963) between actual and potential evaporation. In our application we found that the extreme conditions of our study area required that the soil surface temperature be estimated directly from the surface energy balance, instead of using the air temperature linearization implicit in the Penman equation. We analyzed 26-year (daily) observations of routine meteorological variables such as temperature, humidity, wind speed and radiation within this model to determine the impact of irrigation on the components of the surface energy balance. Results indicate that over each summer (main irrigation) period between 1993 and 2002, mean humidity level in the region has increased, while mean wind speed has decreased.. The combined effect of increase humidity and decreased wind speed is overall reduction in potential evaporation in the region, and is directly attributable to positive changes in irrigated area. The complementarity theory states that under such changing moisture conditions in positive direction (such as a marked increase in irrigated area), there exists a complementary relationship between actual and potential evaporation. As available energy is preferentially used to evaporate water (increase in actual evaporation), there is similar but opposite change in potential evaporation (Figure 2a). Application of complementary relationship to observational data from the study site reveals that the theory holds, at least in the summer period, as a response to irrigation (Figure 2b).

The support for the complementary theory on changes in feedback mechanisms between the land surface and the atmosphere as a result of our analysis is very exciting. The relevant advantage of the hypothesis is that actual evaporation can be easily calculated with routinely measured meteorological variables. Our actual evaporation calculations show a good agreement with those calculated with a simple water balance approach (Figure3). Using these simple yet relatively accurate calculations, we begin to understand the magnitude of the problem of sustainability of

water resources in the region. For example, in our study area, the current year agricultural water use exceeded 1 billion cubic meters. While this represents mere three percent of annual Euphrates flow, currently developed irrigation schemes only represents eight percent of the total area to be irrigated (by 2015). When all irrigation projects are realized, the agricultural water withdrawals will be quite significant.

**New findings:** Irrigated area and thus irrigation water use has changed ~300% between 1993-2002. As result, the partitioning of available energy between latent and sensible heat fluxes has also changed, leading to strict complementarity between actual and potential evaporation. The support for complementary hypothesis exists and allowed calculation of actual evaporation which increased from about 2 mm/year to 6 mm/year within same time period.

**New potential:** “-“

**New Products:** [1] Irrigation water use database (1993-2002); [2] evaporation database (1993-2002)

## **Conclusions**

Work during year two resulted in a major accomplishment. We found strong support for complementary theory within observational climate data. This result is at the heart of our research regarding LCLUC impacts on regional water resources in our study area. The next step is to look for a similar support within a meso-scale climate model. If verified, we will apply the simulation model to determine future hydroclimatological effects of irrigation as more and more areas are planned to be irrigated. At present, we are preparing the model itself and relevant inputs.

## **Publications**

### Articles in review

Ozdogan, M., Woodcock, C.E., and Salvucci, G.D., 2003. The value of MODIS data in support of local mapping of irrigated lands with Landsat, *International Journal of Remote Sensing (in review)*.

Ozdogan, M., Woodcock, C.E., Salvucci, G.D., and Demir, H., 2003. Monitoring changes in summer irrigated crop area in Southeastern Turkey using remote sensing: Implications for agricultural water use and local climate, *Agricultural Water Management (in review)*.

### Articles in preparation

Ozdogan, M., Woodcock, C.E., and Salvucci, G.D., 2003. A comparison of inputs and methods for mapping agricultural land cover in Southeastern Turkey, *Photogrammetric Engineering and Remote Sensing (in prep.)*

## **Presentations**

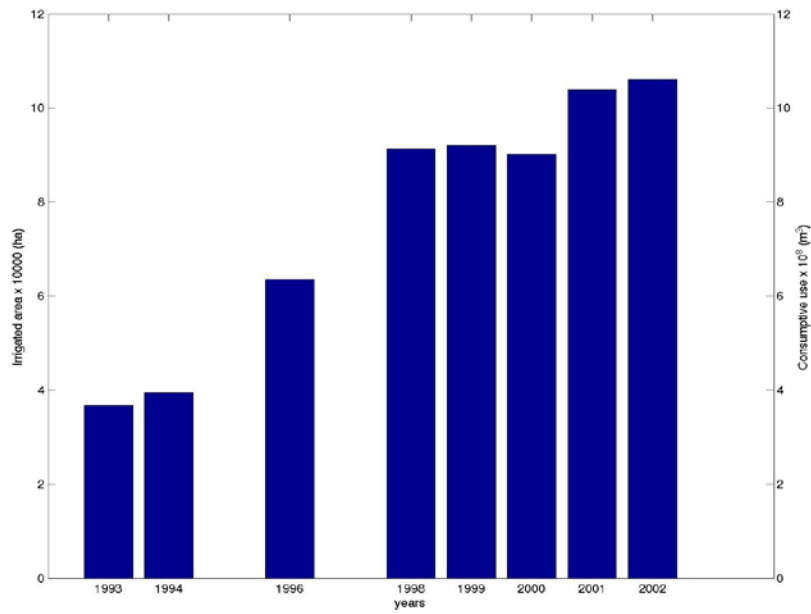
Ozdogan, M., Woodcock, C.E., and Salvucci, G.D., 2002, Monitoring changes in irrigated agriculture in SE Turkey, *Proceedings of AGRO ENVIRON 2002* Cairo, Egypt 26-29 October.

Ozdogan, M., Woodcock, C.E., and Salvucci, G.D., 2003, Monitoring irrigation dynamics and its effects on regional hydrology and climate in SE Turkey, *AGU Chapman Conference*, June 13-18, Santa Fe, New Mexico, USA.

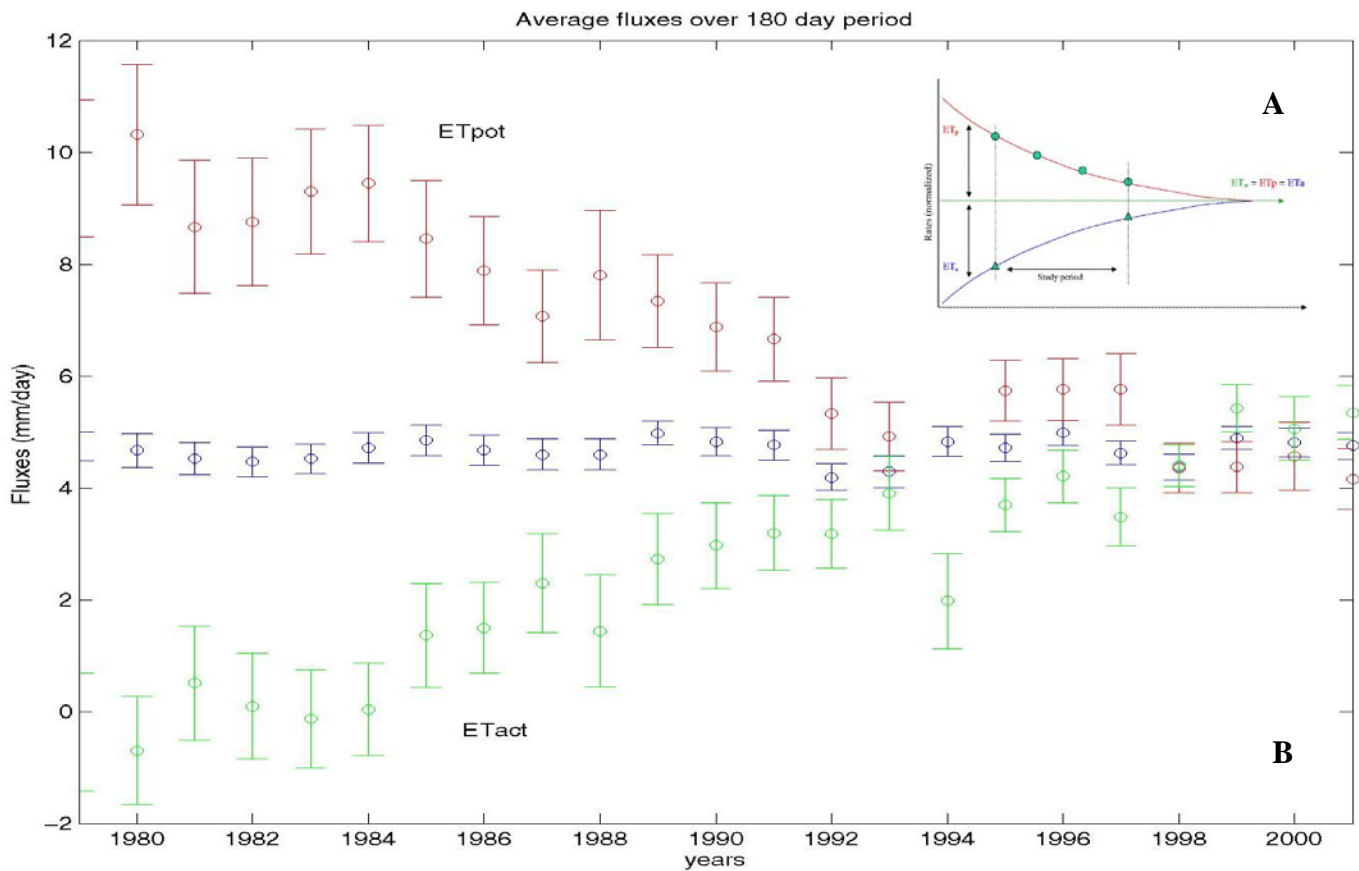
Ozdogan, M., Woodcock, C.E., and Salvucci, G.D., 2003, Monitoring changes in irrigated lands in SE Turkey: A Comparison of methods, *Proceedings of IGARSS'03*, Toulouse, France, July 21-25, 2003.

**Table I.** Schedule of tasks and milestones

RESEARCH TASKS	Project Year I – 2001/2002				Project Year II – 2002/2003				Project Year III– 2003/2004			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. Image data acquisition	***	*							*			
2. Climate data acquisition		**	**		*							
3. Image preprocessing	**	**	*									
4. Baseline agriculture classification		**	**									
5. Irrigated area identification		*	**	*								
6. Field data collection				**	**		**	**	**			
7. Evaluation of Irrigated area estimates				**	**							
8. Conversion of estimates to water usage					*	**	*					
9. Application of B-M hypothesis w/ climate data						**	*	*				
10. Implementation of meso-scale model								*	**	*		
11. Evaluation of results				**	*		**	**	*			**
12. NASA Team meeting / Reporting		**				**				**		
13. Data product release / outreach				**	**		**	**			**	**
14. Conference presentations / publications				*	*		**	**	*	*	**	**

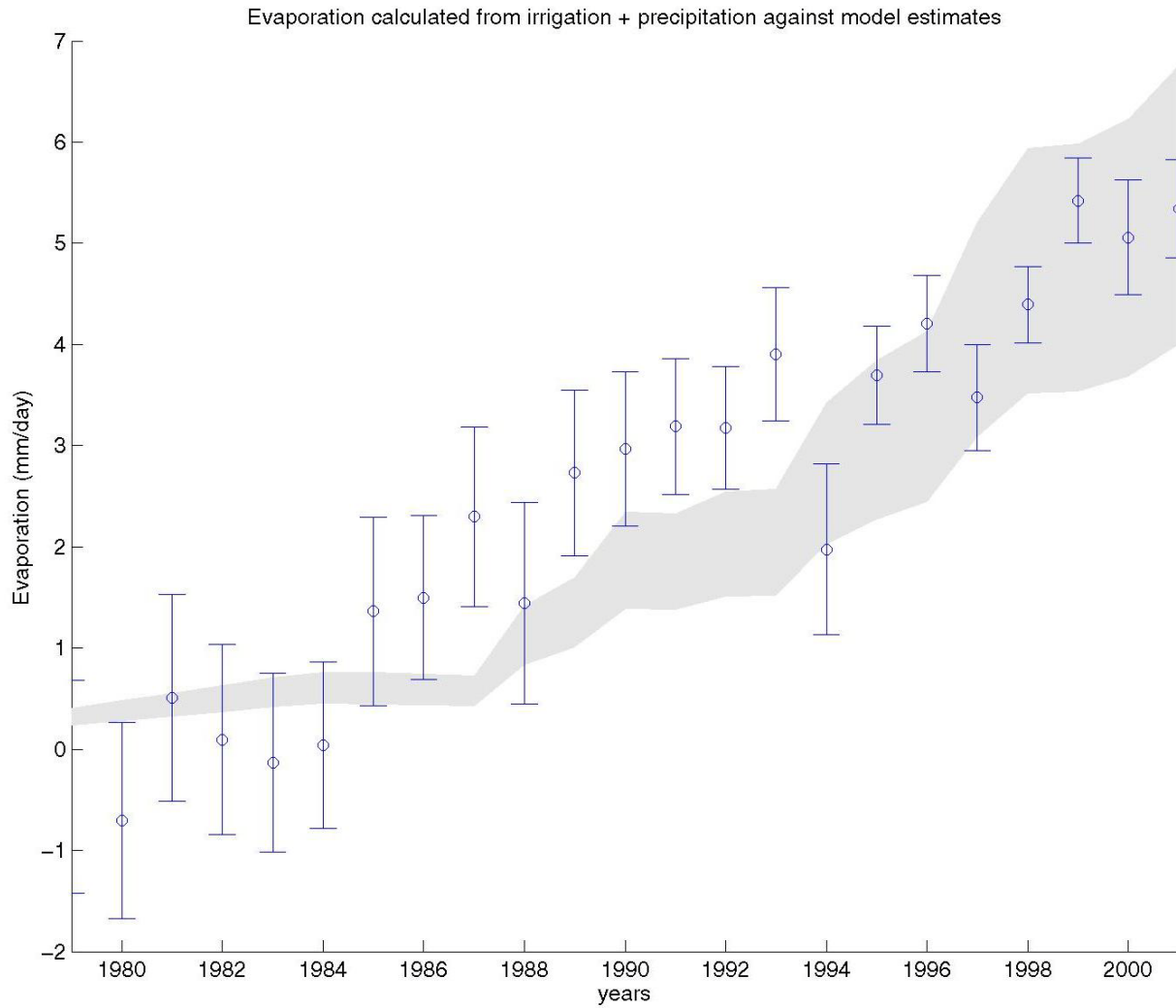


**Figure 1.** Changes in summer irrigated area and related water use in the Harran Plain between 1993 and 2002.



**Figure 2.** Complementary hypothesis; a) hypothetical situation, b) results obtained with observational data.





**Figure 3.** Actual evaporation calculated with the complementary method. The gray envelope represents evaporation calculated with a simple water budget approach (i.e. effective precipitation plus irrigation).