The Effects of Agricultural Expansion on Regional Hydrology in Southeastern Turkey
NAG5-11338

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Progress Report
Year 1 (9/1/01 – 8/31/02)

May 16, 2002

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 and river discharge 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 impact on water balance partitioning, each of these tasks will be integrated into a framework based on the complementary hypothesis for evaporation estimation first put forth by Bouchet (1963). Together, the research has the objective of answering the following three important 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? and 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 water budget estimates, a keystone for sustainability of water resources, and could quantify whether economies of scale of water resource exist due to scale dependencies of physical water balance mechanisms.

Main accomplishments during the first year are:

1. Development of baseline and irrigated lands maps with categories representing the extent and distribution of irrigated area on a two-year basis between 1990-2001. This map forms the basis of change analysis involving expansion of irrigation.
2. Building of a 26-year climate dataset with critical meteorological parameters with data purchased from Turkey. This dataset, coupled with areal estimates of irrigated area, allows us to test our hypothesis of changing water-partitioning patterns between the surface and the atmosphere as a result of LCLUC.
3. Preliminary analysis of climate dataset to find trends in moisture status in the region.

Work during the second year will include:

- Converting of irrigated area estimates into water usage with the help of our Turkish collaborators
- Implementing the Bouchet – Morton Hypothesis on areal evapotranspiration using climate dataset from Turkey and irrigated area estimates from remote sensing to understand the LCLUC impacts on water balance partitioning, specifically the impacts on evapotranspiration.

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 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 **(current period of performance).**
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 (second year).
iii) To identify the long-term impacts of changes in irrigated area on regional hydrology and climate using a meso-scale climate model (Third year).

The first goal (current year of performance) is largely complete. Various components of this objective can be further detailed as follows:

- This research applies remote sensing change detection techniques to map changes in irrigated area in the study site in SE Turkey between 1992 – 2002. In order to provide a quantitative basis for exploring the impacts of this change, the research objective is to provide an accurate account of the amount and patterns of changes in irrigated area. To this end, related research questions are: i) Which change detection methods produce most accurate results? ii) How many images at which time periods are needed to account for the so-called “agriculture problem?” (difficulty in correctly classifying agricultural LC with single date imagery) iii) Which image normalization/correction method leads to most accurate results? iv) What is the best method to operationalize irrigated area change detection algorithms?
- One critical factor influencing the regional water balance will be the areal estimates of land under irrigation. In order to provide a quantitative estimate of this input, the research objective is to convert irrigated area estimates to water usage. Related research questions are: i) Is there an “effective” water usage value that could be used for the entire study area? ii) How does remote sensing estimates compare to official estimates of irrigated water volume in the region?

First year progress

To date, we have acquired the image data as well as long-term climate data for the project. We have geometrically corrected all images and tested different image normalization methods for best results. We have also examined the impact of number of input images on the ability to discriminate agricultural lands from natural vegetation. The performance of different image classification (unsupervised clustering, decision trees, neural networks) and change detection algorithms (multi-date classification, image arithmetic, etc.) were also evaluated to discern agriculture / natural vegetation as well as irrigated / non-irrigated classes.

Two main types of changes are identified as a result of irrigation in the study area: **a)** *rain-fed to irrigated:* conversion of initially rain-fed agricultural lands into irrigated agricultural fields and **b)** *grasslands to irrigated*: conversion of natural grasslands into irrigated agricultural lands. In both cases, the key to identifying changes with remote sensing will be in spectral separation of spring and summer vegetation. Using pre-irrigation dataset (ca. 1987) that consists of 4 Landsat images spanning the growing cycle (April – August), a baseline agriculture map was developed. This map is used to distinguish changes within croplands (rain-fed to irrigated) from changes in natural grasslands (grasslands to irrigated) when used as a binary mask. The best results were achieved using decision tree supervised classifier with at least two images, one in early and another in late growing season. Overall accuracy of this map is high (> 87 %), based on preliminary image-based evaluation. Inclusion of multispectral band transformations into classification process did not contribute to improved results. Furthermore, simple radiometric correction using bright and dark targets was found to improve results by only ~ 10 %. The final accuracy evaluation of this map will be performed following up-coming summer field-work in the region. Based on this preliminary map, the area under agricultural production is estimated at 900,000 hectares (ca. 1987).

Irrigated lands and their changes through time were mapped also using a supervised decision tree algorithm. NDVI calculated from four post-irrigation Landsat images, all acquired during intense irrigation period (July-September), were used as inputs to this process. This map displays the extent and distribution of irrigated lands at each biennial period, between 1992 and 2002. In doing so, it also captures the expansion of irrigated lands, either on existing rain-fed agriculture or on grasslands. The preliminary evaluation of this map indicates high map accuracy for all classes (>80%). Comparison of other change detection/classification indicates that supervised decision tree procedure outperforms all other methods. Again, simple radiometric correction using bright and dark targets improves the results only slightly with this procedure. Due to stark differences between irrigated (vegetated) and non-irrigated (therefore non-vegetated) lands in summer in this semi-arid region, NDVI alone was found to be sufficient in identifying irrigated fields. The final evaluation of this map will be performed following planned field visits in June – August 2002. Preliminary estimates of irrigated area is approximately 232,000 hectares as of 2001. Of this, 20% was brought under irrigation between 1999 – 2001. This dataset will be used as inputs to the complementary hypothesis as well within meso-scale climate model.

Finally, preliminary evaluation of the climate dataset suggests that there is strong positive trend in summer time vapor status over irrigated lands when compared to control (non-irrigated) regions (Figure 2). This finding helps us to get one step closer to validating the Complementary hypothesis on changes in feedback mechanisms with changing surface moisture status.

New findings: Two types of changes are occurring in the region. Over 230,000 ha land has been brought under irrigation since 1992. Consecutively, there is significant positive change in summertime vapor status and humidity over irrigated areas when compared to the control group

New potential: "-"

New Products: Map of baseline agriculture (pre-irrigation – ca. 1987).
Map of irrigated lands showing distribution as well as changes in irrigated area (1992 – 2002).

Conclusions

Work during year one resulted in two important map products, the baseline agriculture map and irrigated lands map, in accordance with our goals of this period of performance outlined in Table I. These maps are at the heart of our research regarding LCLUC impacts on regional water resources in this semi-arid region. Preliminary analysis of limited number of climate parameters reveal a strong positive trend in vapor status over irrigated lands. At present, we are preparing for our field visit to the study site (June-August). Information gathered during this field visit will allow final evaluation of the two maps produced as well as

Publications

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

Table I. Schedule of tasks and milestones

RESEARCH TASKS	Project Year I – 2001/2002				Project Year I – 2001/2002				Project Year I – 2001/2002			
	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				*	*		**	**		*	**	**

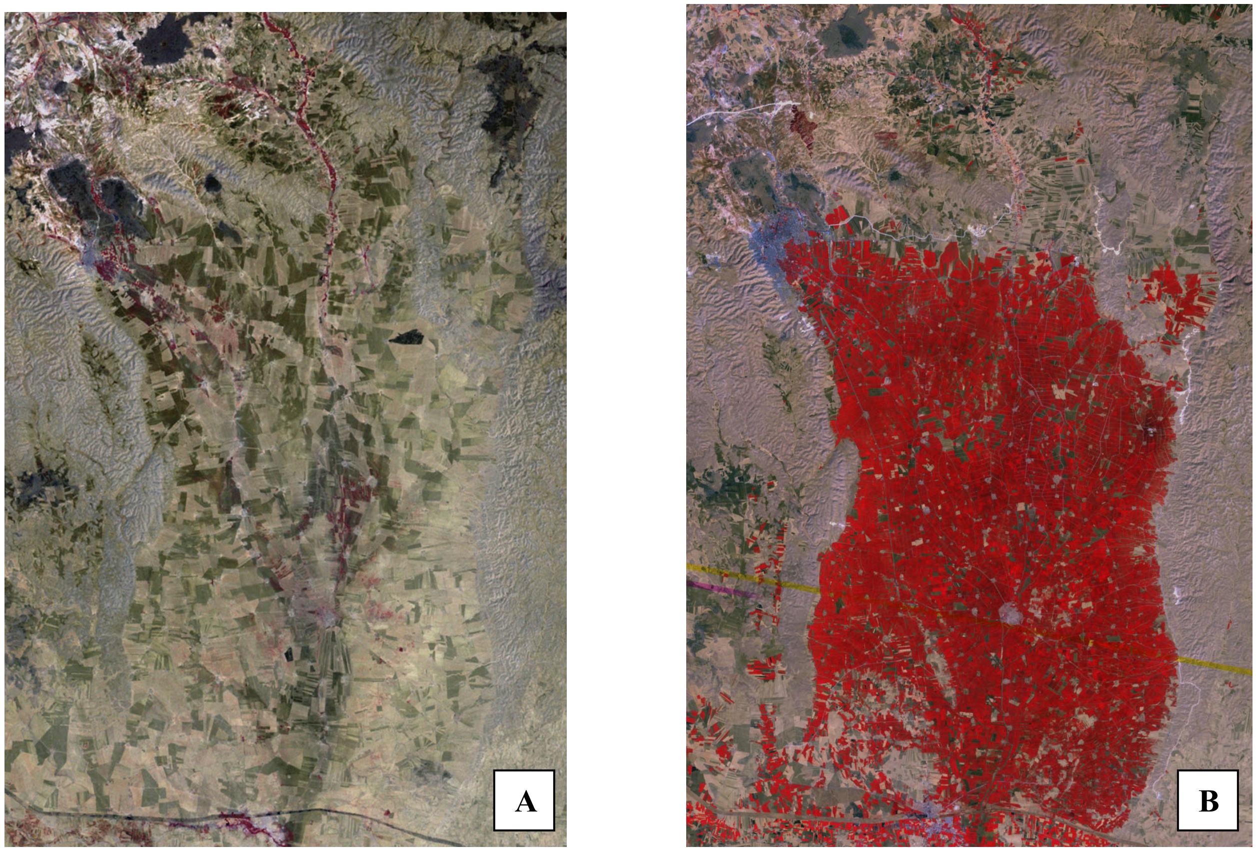

Figure 1. Changes in summer irrigated area in the Harran Plain between 1975 (A) and 1999 (B) as revealed by Landsat.

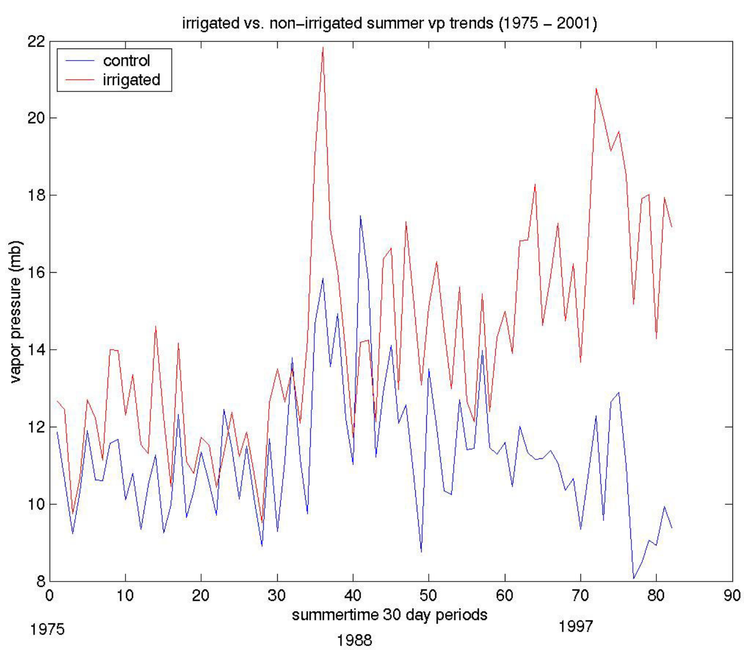

Figure 2. Changes in summertime vapor pressure trends (1975 – 2001) for irrigated and control stations.