IDENTIFYING OPPORTUNITIES FOR DISTRICT-WIDE WATER SAVINGS USING REMOTE SENSING TECHNOLOGY

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ABSTRACT

Irrigated agriculture is the largest water user in New Mexico; in southern New Mexico's Lower Rio Grande region, agriculture uses about one million acre-feet of water each year. Previous research has estimated that the average irrigation efficiency in the area is 44%. This relatively low aggregate efficiency indicates a large potential for water savings from agriculture. In order to determine the potential water savings, the amount of water depleted by crop evapotranspiration (ET) in the Mesilla Valley section of the EBID was estimated using satellite information and ground-level measurements to calculate plant consumptive water use on scales ranging from individual farms to the larger watershed.

Two areas of potential water savings were evaluated using the satellite-generated consumptive use information: 1) potential water saving at the farm level and 2) potential water saving at the district level.

This study found that the majority of farms in the study region were growing crops under deficit irrigation conditions. Therefore, irrigation improvements at the farm-level are likely to increase both yields and water depletion.

Potential water savings at the district level were evaluated by comparing the total volume of water diverted for irrigation versus aggregate ET. From the satellite-generated ET data, district-level efficiency was determined to be 55% in 2002 (a full allocation year). Thus, there appears to be a potential for improving district-level efficiency. This can be accomplished by using regional ET depletion values to plan water releases from the reservoir and improve the diversion and distribution within the canal networks.

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INTRODUCTION

Irrigated agriculture is the largest water user in New Mexico and is responsible for 90% of depletion. In southern New Mexico’s Lower Rio Grande region, about one million acre-feet of water are used for agriculture each year. Previous research has estimated the average district-wide irrigation efficiency in the Elephant Butte Irrigation District to be 44% (Magallanez and Samani 2001). This relatively low district-wide efficiency appears to indicate a large potential for water savings from agriculture. The conventional wisdom in the study region and in many other irrigated areas is that reduced consumptive use by agriculture through investments in on-farm technology and changes in on-farm water management practices will increase system-wide efficiencies and result in large quantities of water available to other users (e.g., municipal, industrial, environmental, etc). In order to determine the amount of potential water savings by agricultural water users, the amount of water depleted by crop evapotranspiration (ET) must first be estimated. ET is the true depletion from the hydrologic system which cannot be reused (other than a small amount which is returned in the form of precipitation). Any water applied to crops but not depleted has the potential to be recycled, reused, or transferred to other users (although quality factors, timing issues, and spatial limitations may reduce the potential).

Various methods have been developed for estimating ET, including the popular use of crop coefficients and climatic parameters. One commonly used method of assessing ET is the eddy covariance technique, which estimates real time ET in the field. Estimates of ET also can be made through soil moisture monitoring or lysimeters. While these methods can provide point measurements of ET, they cannot cost-effectively account for broad-scale, field-level spatial variability of ET under real-world growing conditions. However, due to recent advances in remote sensing technology, basin-wide, field-level ET accounting is now both technically and financially feasible. Remote sensing has made it possible to combine ground measurement of ET with remotely-sensed satellite data and ground level climatological data to arrive at regional ET values. This combination of ground-level and remotely-sensed data provides the most advanced and cost-effective approach to estimating ET over large areas with non-uniform, field-level crop production conditions. As a result of remote sensing, it is now possible to comprehensively assess basin-wide depletion as a result of crop production. Remotely-sensed information on crop coefficients and crop consumptive use can be used to increase water management efficiency, enhance water conservation, and increase water use accountability.

METHODOLOGY

A remote sensing technology, the Regional Evapotranspiration Estimation Model or REEM, developed at New Mexico State University (Samani et al. 2005, 2006, 2007) was used in combination with ground measurements to determine daily ET depletion by agriculture in the Mesilla Valley section of southern New Mexico’s Elephant Butte Irrigation District. LandSat images for 2002 (12 images) and 2003 (10 images) were processed to develop ET and crop coefficient (Kc) maps for the Mesilla Valley. The years 2002 and 2003 were selected because 2002 was a typical full allotment year where the farmers received three acre-ft per acre per year of water and 2003 was a dry year where the farmers received only nine inches of surface water. REEM results led to the development of daily ET maps for agricultural crops and estimation of potential water savings at both the farm and district levels.

The REEM model was validated on a daily basis using actual measurements of ET from data collected by eddy covariance flux towers located in a pecan field in the Mesilla Valley (latitude 32.18 N and longitude 106.74 W; elevation above sea level 1,144 m). Using satellite images from clear days, maps of ET and Kc were generated. The 2002 and 2003 comparisons of measured and REEM-predicted ET for a mature pecan orchard are shown in figure 1 and figure 2. REEM was also used to predict daily ET by alfalfa, cotton, and other minor crops. Pecans, alfalfa, and cotton account for approximately 75-80% of the irrigated acreage in the study region.

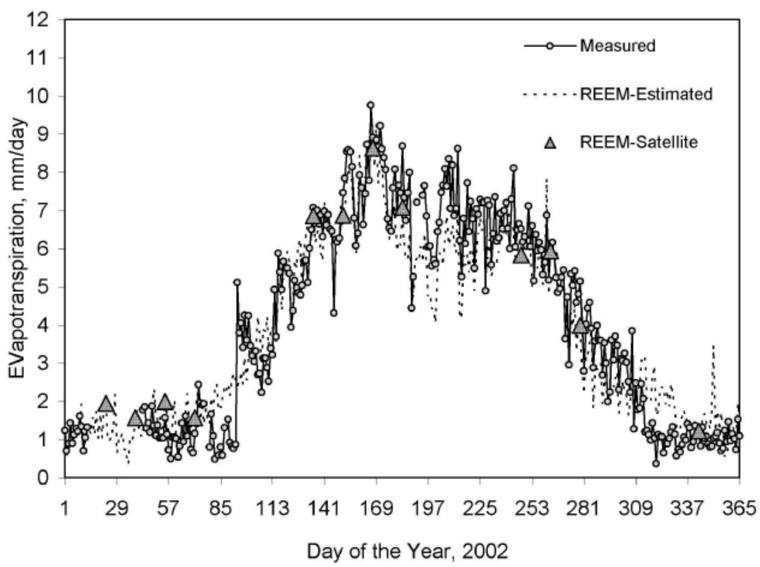

Figure 1. Comparison of daily measured and predicted pecan ET for 2002.

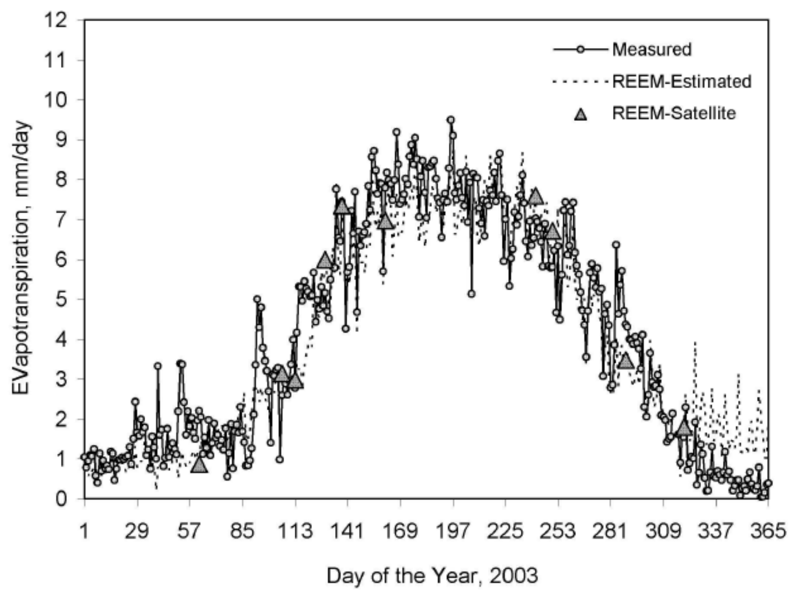

Figure 2. Comparison of daily measured and predicted pecan ET for 2003.

Daily maps of ET were then integrated to develop monthly and yearly values of ET for each field in the study region. Figure 3 and figure 4 show annual ET maps for 2002 and 2003. The ET values were calculated for each pixel 30 m by 30 m (98 x 98 ft) pixel. Individual fields were delineated using the 2005 DOQQ (Digital Orthophoto Quarter Quadrangle) maps and superimposed on the ET maps. Average ET for each delineated field was calculated by summing up the individual volumetric water use for each pixel and dividing it by the area of each field. The final satellite-generated consumptive use results were used to evaluate two areas of potential water savings: 1) potential water saving at the farm level and 2) potential water saving on the district level.

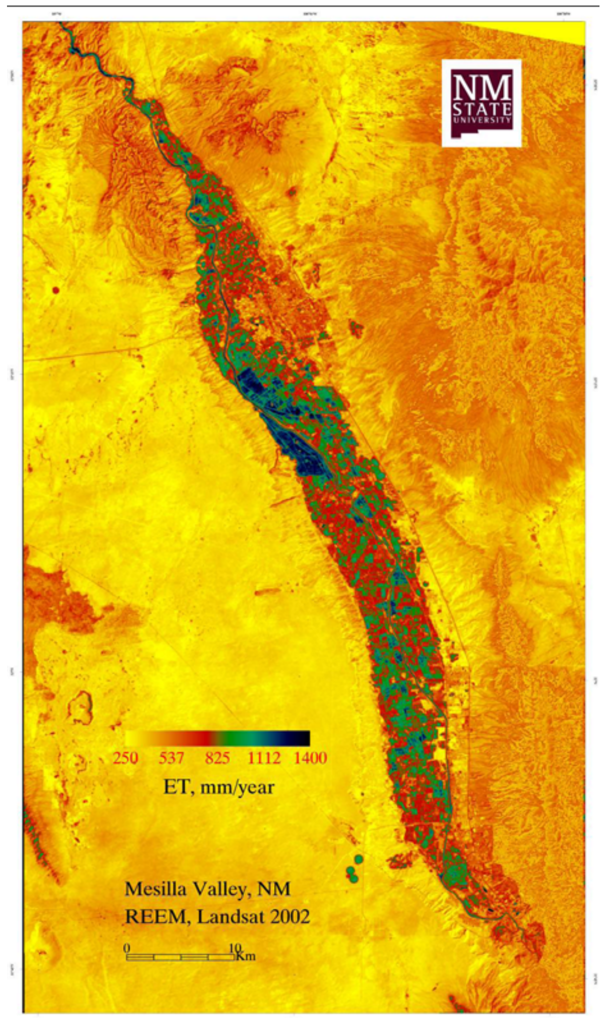

Figure 3. Annual ET for 2002, Mesilla Valley, NM.

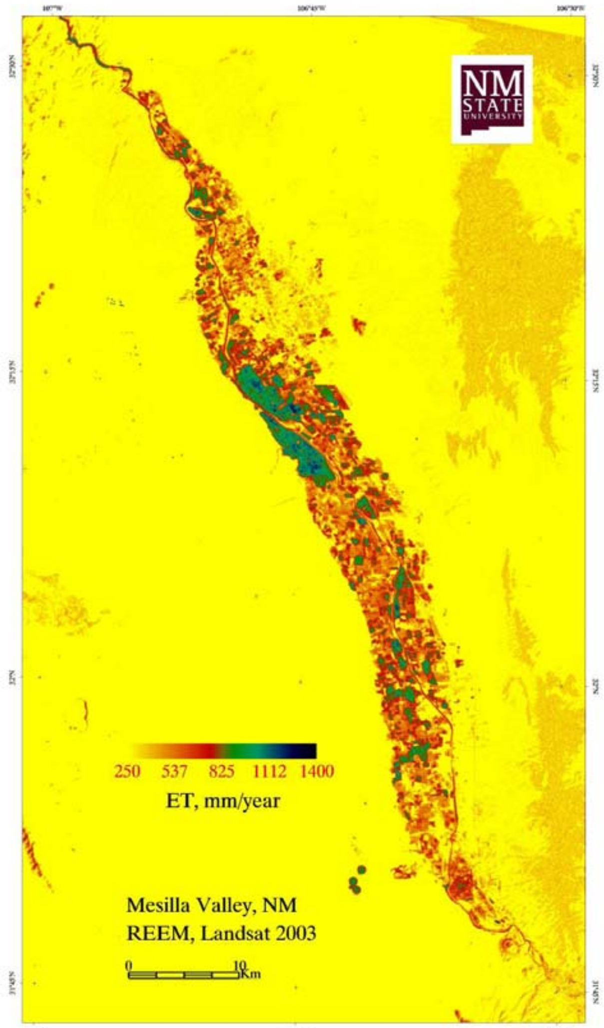

Figure 4. Annual ET for 2003, Mesilla Valley, NM.

POTENTIAL WATER SAVINGS AT THE FARM LEVEL

It is conventionally believed that changes in on-farm water management have the potential to result in water savings and reduce the amount of water "wasted" by agriculture, thus releasing water to other users (both in time and space). However, scatter plots for pecan and alfalfa fields in the study region show that the majority of the fields are under-irrigated and are being managed under deficit irrigation conditions relative to potential ET and potential yields. For both pecans and alfalfa, reduced ET is strongly correlated with reduced yields.

Deficit irrigation on Mesilla Valley farms is the result of several factors, including:

- Lack of sufficient ground water to supplement surface water supplies on individual farms;
- Limited or no access to ground water of adequate quality on many farms;

- Lack of knowledge of crop water consumptive use and associated benefits of irrigating to meet that demand;
- Inability of existing canal system to deliver surface water in a timely manner;
- Poor irrigation practices (e.g., non-uniformity of water application) and soil variability;
- Low volume of inflow and poor on-farm water distribution systems;
- Issues related to agronomic practices (e.g., alfalfa flood irrigation and harvest operations, etc.).

Given the high incidence of deficit irrigation in the study region, improvements in irrigation system design, modernized technology, or finely-tuned on-farm scheduling are likely to increase both yields and depletion of water. These results are strongly at odds with many of the prevailing assumptions regarding agricultural irrigation in the Mesilla Valley. It is often assumed that agricultural irrigators regularly overwater, and are thus creating opportunities for water savings with improved irrigation technology and practices. However, given the current prevalence of deficit irrigation, improvements in irrigation scheduling or modernization of on-farm irrigation technology are likely to compromise the release of water from agriculture for other uses. Thus, the real potential savings of water within this region appear to be at the district level.

POTENTIAL WATER SAVINGS AT THE DISTRICT LEVEL

Potential water savings at the district level were evaluated by comparing the total volume of water diverted for irrigation versus aggregate REEM-estimated ET in the study region. The REEM-predicted ET in the Mesilla Valley for the years 2002 and 2003 were 265,554 and 205,207 acre-feet, respectively. Efficiency was calculated based on the net diversion and rainfall (which was 7.4 inches during 2002 and 4.7 inches in 2003). Total net diversion was calculated by subtracting inflow at the Leasburg Dam (beginning of the Mesilla Valley) from the outflow at Courchesne Bridge (at the end of the Mesilla Valley).

The total EBID Rio Grande diversion for 2002 and 2003 in the Mesilla Valley was about 421,000 and 163,000 acre-feet, respectively. Accounting for the rainfall, the total diversions for 2002 and 2003 were about 482,000 and 202,000 acre-feet (diversion + rainfall). Figure 5 and figure 6 compare annual ET versus diversion in the Mesilla Valley section of the EBID for 2002 and 2003. An efficiency of 55% ((district ET / (rainfall + diversion)) was estimated for 2002, and 101% was estimated for 2003. The 2003 high efficiency is due to drought-induced ground water pumping which increased the depletion relative to diversion. Depletion from ground water was estimated to be 30,600 acre-feet in 2002 (a full allocation year) and 74,000 acre-feet in 2003 (a partial allocation year). Ground water depletion was estimated by subtracting net surface water inflow into the Mesilla Valley (rainfall included) from REEM-estimated depletion in the region. There are no actual measured data available regarding ground water depletion in this region against which to compare this estimate.

The results presented in figures 5 and 6 illustrate that, on the district level, there is a potential for improving basin-wide irrigation efficiency, particularly in full allocation years. The disparity between REEM-estimated ET and actual diversion shows that for a full allocation year there was a potential savings of approximately 150,000 acre-feet. Examination of the water budget and downstream delivery obligations shows that the district spilled approximately 140,000 acre-feet of water. The disparity between diversion and depletion illustrated throughout 2002 and in several months of 2003 could be reduced by using regional ET depletion values to forecast and plan water releases from the reservoir and improve surface water distribution within the canal networks.

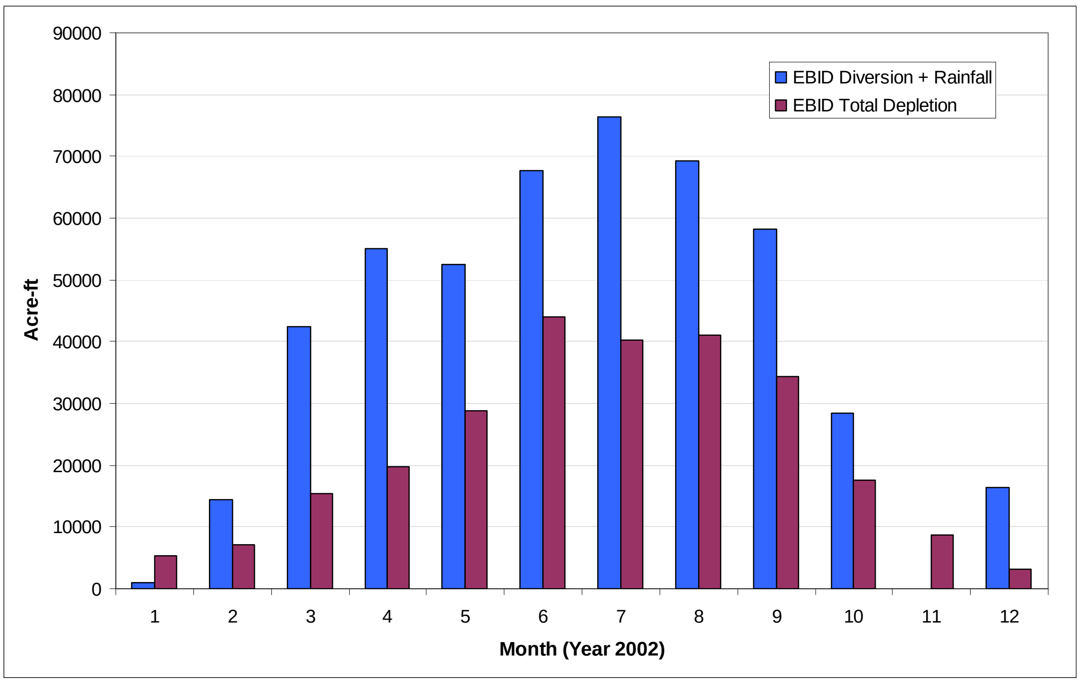

Figure 5. Comparison of total depletion and EBID surface water diversion + rainfall, 2002.

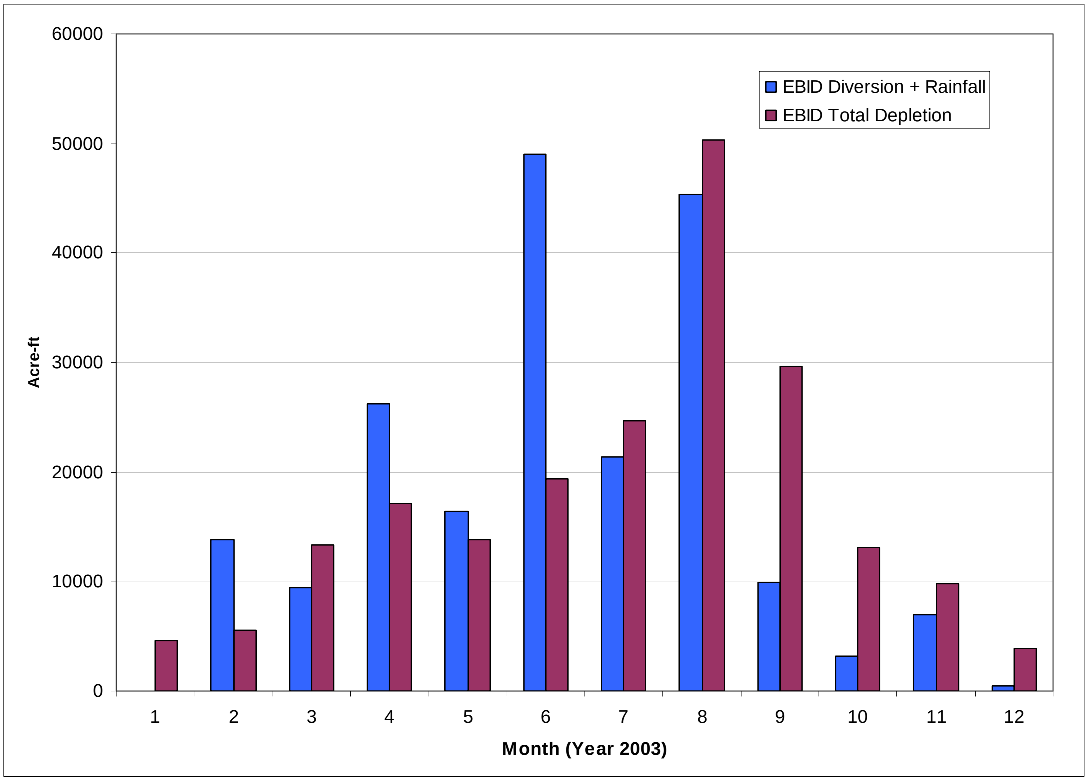

Figure 6. Comparison of total depletion and EBID surface water diversion + rainfall, 2003.

CONCLUSIONS AND RECOMMENDATIONS

The results of this research indicated that farms in the Mesilla Valley are generally under-irrigated, and thus under-achieving with respect to yields and gross financial returns. There is a potential to improve farm-level water management, increase productivity, and enhance water use efficiency in the study region through measures such as accurate irrigation scheduling and improved irrigation technology. However, these changes would likely improve economic returns to agriculture in the Mesilla Valley at the expense of increased consumptive use by agriculture – rather than create opportunities to release water from agriculture to other users. This research also found that the potential for water savings more likely exists at the district-level, if the district develops the ability to manage diversions in accordance with real-time crop consumptive use needs. However, if current levels of upstream district-wide efficiency have created and guarantee downstream water users' supplies, then changes in district-level management could have serious consequences for the downstream users.

The results presented here illustrate the potential for field-level remotely-sensed ET estimates to be extended to district-wide management. The model and methodology presented here can be used by water resource planners, managers, engineers, farmers, and others to estimate water use by crops as well as by urban or natural landscapes. The ultimate objectives of the model and methodology are more efficient water management, water conservation, and increased water use accountability – objectives which satellite data can help achieve both comprehensively and cost-effectively.

ACKNOWLEDGEMENTS

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