Statistical Testing for Precision Graded Verification

Does precision leveling save water?

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1. Introduction

The agricultural Water Conservation Program (HB1437 program) is a central component of the Lower Colorado River Authority's (LCRA) water conservation programs for agricultural uses. The HB1437 program is tied to a mandate from the Texas Legislature to develop water for transfer to the Brazos River Basin, which in effect requires that the LCRA reduce the volume of water used by agricultural customers to comply with its water transfer responsibility. To account accurately for the conserved water developed through this program, the LCRA depends upon its ability to explain the difference in water use between many potential sources of water savings and the HB1437 conservation programs LCRA implements such as precision leveling of farmland. The LCRA monitors and evaluates to ensure that sufficient water savings targets are achieved so water can be transferred to the Brazos River Basin with no adverse impact on the Colorado River Basin, as required in the HB1437 legislation.

The objective of this Statistical Testing for Precision Graded Verification is to develop and implement a reliable and rigorous water conservation savings verification program for precision leveling. This study focuses on the Precision Graded Verification Pilot Study in Lakeside Irrigation Division.

2. Data Sources

This study uses three data sources: LCRA data collected for billing purposes from WAMS (Water Application Management System), information collected through a survey of farmers and weather data. These data sources are described below. A more extensive description of the data sources including the survey instrument can be found in the interim report "Statistical Testing for Precision Graded Verification" and in the "Survey Report." This study uses a sample set of approximately 195 fields each year over a five-year period (N=727). This is the second year (2009 and 2010) that the survey and "Precision Graded Verification" methodology have been implemented in Lakeside Irrigation Division.

Water Application Management System (WAMS) Database

LCRA staff collects information about field characteristics through its annual water contracting process. For example, the LCRA's water customer billing system collects the following information for first and second crop: contract name, field name, year the field was in production, whether the field was in production during the second crop, field acreage (ac), field water use (ac-ft) and number of delivery structures.

Survey data

To increase the accuracy of the conservation verification analysis during this survey effort, project staff collected new data (2010) as well as information from farmers who did not respond to the 2010 survey or who submitted an incomplete response. The data collected in the survey is farmers' self-reported information; field verification of this information was outside of the scope of the study. A high response rate was achieved as a result of the in-person surveys and the multiple follow-up phone calls. Over the following months, 64 of 73 surveys were completed. This accounted for 86 percent of the surveys mailed. Over 80 percent of both rice fields in production and planted acreage per year were represented in completed surveys. More than half (62 percent) of all completed surveys were face-to-face questionnaires; the remaining surveys were received via return mail.

Weather data

Weather data were collected from Eagle Lake 7 NE station, Colorado River at Altair and Wharton station from the Lower Colorado River Authority's (LCRA) Hydromet System.[1] Windspeed, solar radiation and humidity were collected from the Eagle Lake Research Center from the Texas A&M AgriLIFE Research Center due to the unreliability of these data collected by LCRA's Hydromet System. Daily weather data were averaged during the average growing season for each station. Growing season refers to the average time between the first and last water delivery of the set of fields within each polygon.

Farmer Management Data

This analysis separates the 'precision leveling effect' from 'management skills' related to on-farm water usage. To separate the effects of precision leveling in light of farmers' skills and practices, it is important to recognize that a single farmer manages groupings of fields. Although it is plausible that a single farmer may manage one field, information from Lakeside from 2006-10 shows that this one-to-one relationship is unlikely. Table 1 shows the presence of groupings of fields by farmer: on average one farmer managed four fields. Grouping of fields by farmers supports the idea that different fields managed by the same farmer may display some similarities in water use.

Table 1: Number of Fields per Farmer

Year	Average	Maximum
2006	4	10
2007	4	14
2008	4	14
2009	5	14
2010	4	11

Source: Survey and WAMS database 2011

3. Analytical Approach

A first step is to evaluate whether different types of fields have different patterns of water use. To tease-out precision leveling water savings, one needs to separate the effects of factors that can reasonably be expected to influence water usage of fields. Different fields managed by the same farmer may display some similarities in water use. Farmers may differ from one another on the judgments and choices they make about how, when and what amount of water to apply to their fields among other farming decisions they make. Hierarchical Linear Models (HLM) are particularly useful to deal with groupings of fields that share management style as well as when the same data points (fields in this case) do not occur at a regular interval (yearly). The expanded and validated data will be used in the Hierarchical Lineal Model (HLM) to quantify the separate effects that a range of factors that

[1] LCRA's website http://hydromet.lcra.org/

influence farmers' use of irrigation water. A more extensive description can be found in the interim report "Statistical Testing for Precision Graded Verification."

4. Analytical Results

Data from both WAMS and the Survey were used in modeling water usage and savings. When reviewing the results it is important to note that water demand is measured in acre-feet of water used per each acre farmed. An acre-foot is the amount of water required to cover an area of one acre to a depth of one foot. For this study, Table 2 shows the factors included in the HLM analysis.

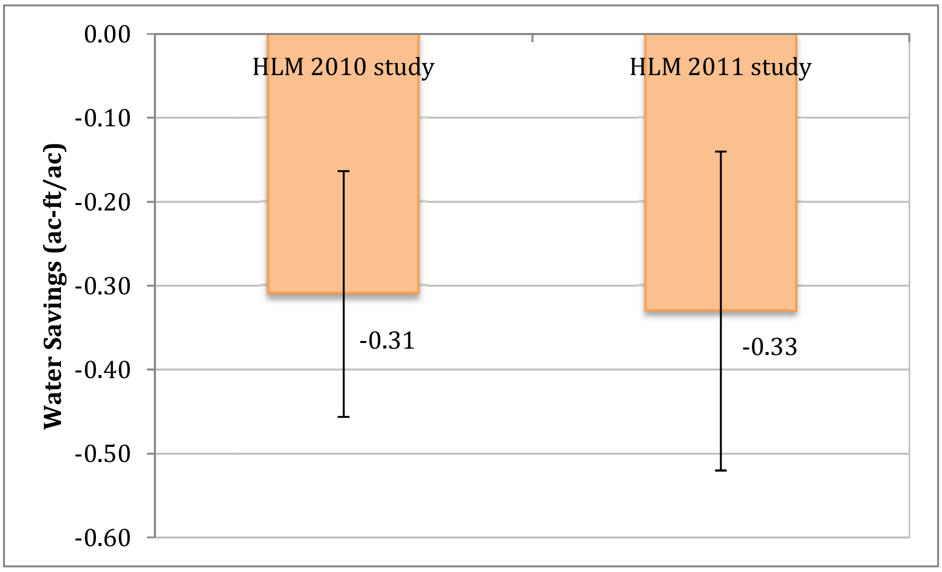
Table 2: Factors Included in the HLM Analysis

WHAT ARE THE FACTORS?	
FACTORS	**DESCRIPTION**
PRECISION LEVELING	Whether a field has been precision leveled or not
MULTIPLE INLETS	Number of unmetered water inlets in a field.
RAIN	Average daily precipitation during the average growing season.
EVAPOTRANSPIRATION	Average daily evapotranspiration during the average growing season.
CASH	When the person who farms the land pays cash to rent the field from the landowner.
HYBRID*GROWING	Number of days between the first and last water delivery to a field planted with hybrid rice.
NUMBER OF LEVEES	Number of internal levees in a field as part of the irrigation system.
STRAIGHT LEVEES	When internal levees in a field are straight or have a slight bending.

Factors that influence water use

The 2011 results suggest that farmers who precision leveled a field use on average 0.33 acre-feet per acre less irrigation water than a farmer who does not precision level a field. The 95 percent confidence interval indicates that precision leveling reduces the water usage of a field by no less than 0.14 acre-feet per acre and no more than 0.54 acre feet per acre. The 2011 result is consistent with the 2010 first crop water savings (0.31 acre feet per acre) attributable to precision leveling (see Table 3). The 2011 confidence intervals increase slightly after 116 observations were removed from 2010 to 2011 to achieve a high reliability to all data points (see Figure 1) in that data were verified in the face-to-face survey. Some levee (n=54) and multiple inlet (n=62) observations were dropped to maintain the quality of the data. The results indicate that the water savings estimate for precision leveling is robust, as the values are essentially the same even with an additional year of data and the removal of second crop.

Figure 1: Precision Leveling Water Saving Estimates



These results also suggest that if a field is precision leveled, the type of levee (straight or contour) does not affect fields' water usage (see Table 3). The correlation is high (0.70) between whether a field is precision leveled and the type of levee of levee system. A possible explanation for this result is that of the 91 precision-leveled fields with a contour levee-system in Lakeside Irrigation Division, almost half (43 percent) are managed by two farmers with superb management practices. These result contrast with 2010 data, which appeared to indicate an interaction between precision leveling and levee type. In 2010 the Interim Report on the "Statistical Testing for Precision Leveling Verification" recommended that the number and type of levees of fields be checked to improve unreliable data and ensure accurate estimates. After the levee type verification and levee count verification, (which improved greatly the accuracy of the levee data), ten percent of the fields were found to have been mis-categorized in terms of their levee type.

Multiple inlets, another conservation farm investment, reduce on-farm water use. The first survey in 2009 gathered multiple inlet data in intervals. To improve the accuracy of the results, the 2010 study collected the exact number of multiple inlets in each LCRA field. Results show that if a field that has one multiple inlet, the use of irrigation water will be reduced by 0.035 acre-feet per acre (see Table 3). Multiple inlets have a statistically significant effect on the water usage of fields. The data from the study indicates a lower rate of water saving than estimates reported by some experimental field studies. One reason is that prior studies evaluate the performance of multiple inlets using a small sample of experimental plots, as field experiments occur in controlled research environments. Researchers seek to control all other influences except for the one technology (variable) tested that could cause a reduction in farmers' water usage. This controlled research approach isolates the effect of the factor that scientists wish to examine. Field experiments are likely to provide high (upper boundary) estimates of water savings.

The factors of rainfall and evapotranspiration were included to isolate the effect of precision leveling and other conservation measures from the effect of year-to-year variation in weather. While the previous study in 2009 included temperature, the 2010 study has improved this variable by including the evapotranspiration in the place of temperature. Including evapotranspiration as a factor in the analysis provides more accurate estimates of the marginal effect of year-to-year variation on the water usage of rice fields because higher farm water consumption is not only associated high temperatures but it also influenced by other weather factors (humidity, radiation, wind).

As expected, a one-inch per month increase in rain on average decreases the irrigation water usage of a field by 0.18 acre-feet per acre (see Table 3). This result indicates that farmers reduce the use of irrigation in years with high rainfall, as it contributes to the supply of water. Results also show that in a 'hot' year, with a one-inch per month increase in evapotranspiration, water usage in a field would increase on average by 0.13 acre-feet per acre (see Table 3). Higher farm water usage is associated with high evaporation, which in turn corresponds to noticeable high temperatures and low humidity in a given year. Including evapotranspiration in the verification study accounts for changes in maximum and minimum temperature, humidity, wind speed, and sunshine hours because these factors are used to estimate evapotranspiration.

In 2011, results also show that farmers that plant hybrid rice uses 0.03 ac-ft/ac more irrigation water for each additional day water is delivered to a field (see Table 3). Hybrid rice in itself does not affect the water usage of a field, but hybrid rice in relation to the growing period does. When farmers plant hybrid rice, this cultivar's longer growing periods lead to higher levels of water usage. In comparison, the data for the 2010 study showed that rice variety was unimportant, suggesting that no direct relationship exists between the rice variety cultivated and water use of a field

The data indicates that, in each year of the study (2006-2010), farmers who cash-rent use less irrigation water per acre farmed than do farmers who share-rent or farm their own land. Results from this verification study show that farmers who cash-rent on average use 0.20 acre-feet per acre less water. When the person who farms the land cash-rents a field, the effect of costs (such as labor and water costs) and profit are tangible and immediate. A farmer who cash-rents bears all the financial risk in the rice production of any given field. Due to the increased financial risk, they are likely to pay more attention to the amount and management of the water they order. This finding is consistent with opinions that farmers who participated in The HB1437 Agricultural Fund Advisory Committee voiced in reaction to what the 2010 data indicated, which seemed contrary to their experience. The improved data (2006-2010) of the 2011 study has results that are consistent with what farmers would expect.

Table 3: Influence of Factors on the Water Usage of Fields

STATISTICALLY SIGNIFICANT VARIABLES		
FACTORS	**SIGN**	**DESCRIPTION**
PRECISION LEVELING	Negative	Precision land leveling, on average, reduces farmers' water usage by 0.33 acre-feet per acre during the 1st crop.
MULTIPLE INLETS	Negative	Having one multiple inlet reduces the water usage of a field by 0.03 acre-feet per acre during the first crop.
RAIN	Negative	A one-inch per month increases in rain, on average decreases the water usage of a field by 0.18 acre-feet per acre.
EVAPOTRANSPIRATION	Positive	A one-inch per month increase in evapotranspiration, on average increases the water usage of a field by 0.13 acre-feet per acre.
CASH	Negative	Farmers who cash-rent their land, from planting to harvest during the first crop, use 0.20 acre-feet of water less than farmers who share-rent or farm land they own.
HYBRID*DIFF_GROW2	Positive	Farmers that plant hybrid rice uses 0.03 acre-feet per acre more irrigation water for each additional day water is delivered to a field.

5. Recommendations

A more extensive description of the recommendations including a budget can be found in the "LBJ Proposal 2011."

SECOND CROP: Including 2011 data

An HLM analysis of only the second crop is an important next step to estimate precision leveling water savings only during the second crop. If the LCRA can gather water use and farm practices information for a sixth year (2011) it will be possible to compute for the first time a water savings coefficient for precision leveling for the second crop using the methodology delineated in "Statistical Testing for Precision Graded Verification." Estimating the total effects of precision leveling that include savings during the second crop, in addition to the water savings coefficient for the first crop is an important step to revise LCRA's current coefficient of 0.75 acre-feet of water saved per acre leveled for both crops.

SURVEY 2011

A new and more complete data set (2006-2011) will not only improve the quality, accuracy and reliability of precision leveling water savings, but also increase the sample size necessary to separate precision-leveling water savings during the second crop. Because the accuracy of the results of this conservation verification analysis depends on the information collected, this study involves the revision of the survey instrument and the implementation of face-to-face interviews to cross check and to expand existing information with an additional year of data (2011). The 2011 survey data is necessary to estimate the second crop water savings from precision-leveled fields.

MULTIPLE INLETS

This verification study has the added benefit of estimating water savings for other conservation such as multiple inlets. Multiple inlets are a less costly conservation measure than precision leveling and may have comparable water savings. If the LCRA were to collect data on multiple inlets and levees by physical field rather than by LCRA billing fields, it would be possible to estimate reliable water savings from multiple inlets and levees. LCRA's field boundaries sometimes aggregate a number of different "physical" fields for billing purposes. If the data were to be collected at the individual field level, instead of at the aggregated billing field level, the LCRA could develop two conservations measures (precision leveling and multiple inlets) with verified water savings to better plan and invest in conservation programs.

Multiple inlets is a conservation measure LCRA can invest on to further reduce the volume of water used by agricultural customers. Multiple inlets could eventually complement precision leveling if and when precision-leveled acreage reaches a saturation point and remains steady over time. Increasing the amount of water conserved in agriculture would allow the LCRA to better meet the objective of transferring a volume of water to the Brazos River Basin with no adverse impact to the Colorado River basin.

Water savings attributable to multiple inlets and number of levees is dependent on the quality of these data. Collecting multiple inlets and levee data at the physical field level is necessary to achieve an accurate water savings associated with multiple inlets. This is an additional benefit from this verification study which not only verifies the water savings associated with precision leveling but also from other conservation measures.

6. Conclusion

LCRA is delivering on its promise to evaluate its precision-leveling conservation program in Lakeside Irrigation Division. So far, the verification study provides a water saving estimate for precision leveling that is robust, as the values are essentially the same in the 2010 study as in the 2011 study. The sample changed between the 2010 to the 2011 study with an additional year of data (2010), the removal of second crop and an overall increase in fields surveyed each year (2006-2009).

Progress in estimating the relationship between precision leveling and the water usage of fields should be directed to estimate water savings during the second crop. With better data, LCRA will have precision leveling water savings coefficients for both the first and second crop to compare with the current 0.75 ac-ft/ac coefficient. Absence of adequate data on multiple inlets and levees by physical field also hampers LCRA's ability to capitalize on the added benefit of this verification study to estimate water savings attributable to other conservation measures besides precision leveling. With additional data on multiple inlets LCRA will be in a stronger position to evaluate the feasibility of funding additional water conservation measures through the HB1437 grant program. With verified water savings from precision leveling, LCRA can ensure that sufficient water savings targets are achieved so water can be transferred to the Brazos River Basin with no adverse impact on the Colorado River Basin, as required in the HB1437 legislation.