GARWOOD IRRIGATION DIVISION, TEXAS: EXPLORATION OF WATER USE AND CONSERVATION: 2012-2016

By

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A directed research submitted to the Geography Department of

Texas State University in partial fulfillment

of the requirements for the degree of

Master of Applied Geography

with a specialization in Resource and Environmental Studies

May 2018

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Acknowledgements

I would like to thank my Advisor, Dr. Tim Loftus for providing me the opportunity to be a graduate student worker for the LCRA study. Also, thank you, Dr. Loftus, for the guidance you provided as I organized the data, carried out my analysis, and wrote this directed research report. I would also like to thank Dr. Rusty Weaver for always being willing to meet with me to discuss statistics and for your recommendations and edits while I drafted this report. Also, I'd like to thank the faculty, staff and my fellow students in the Geography Department. Each one of you has been a piece of the puzzle that is my grad school career. I came here not knowing anyone in the department and I'm leaving with dear friends, mentors, and so many great memories. Thank you.

Dedication

To Dad,

I would like to thank you for all your support and encouragement as I made my journey through graduate school. Thank you for always being a voice of reason and encouragement and a sounding board for my many questions. Most of all, thank you for simply being there for me. Without your unconditional love and giving nature, I would not have been able to do this. “The bonds we have are everlasting.”

Contents

Introduction

This directed research report covers my analysis following the work I did in collaboration with Dr. Loftus and Dr. Weaver for a project funded by the Lower Colorado River Authority (LCRA). Using the dataset that was constructed for the LCRA project (Loftus, Weaver, and Barnard 2017), I use statistical testing to investigate the possibility that precision leveled fields had a lower water demand than non-precision leveled fields during the 2012-2016 growing seasons. Secondly, I investigate how much more likely it is that a farmer will precision level their field if the LCRA provides some amount of cost share to the farmer for the cost of precision leveling.

As population in Texas has continued to grow, water resources statewide have become more strained. Greater municipal demand for water in cities competes with water for agricultural use. Farmers who grow water intensive crops like rice are constantly experimenting with alternative ways to conserve water during their growing processes. One water conservation method of interest to rice farmers is known as precision leveling. The purpose of precision leveling is to remove the valleys and hills from a field to have a more uniform surface and thereby a more uniform coverage over the crop growing acreage. Since rice is a flood irrigated crop, having a perfectly flat surface should allow for a lower amount of water to be used to uniformly flood the crop.

Precision leveling, like all on-farm water conservation practices, is costly to farm owners. Depending on what conservation practice is being implemented, the cost to the farm owner can vary significantly. Cost share programs help farmers by reducing their financial burden to implement water conservation practices. Previous studies have investigated if these cost share programs can encourage more farmers to adopt water conservation practices in their agricultural operations.

Delivering water from the Colorado River Basin to the Brazos River Basin is important to the residents of Round Rock and Williamson County, where population has grown rapidly in recent years. The Austin-Round Rock Metropolitan Statistical Area (MSA) is comprised for five counties: Travis, Williamson, Bastrop, Caldwell, and Hays. Per the Austin Chamber of Commerce, the Austin-Round Rock MSA had a population of 1,249,673 in the year 2000 and a population of 2,000,860 in the year 2015 (Austin Chamber of Commerce 2015). From 2000-2010 population change was a 37.3% increase, and between 2010-2015, the change was a 16.6% increase. The Austin metropolitan area is continuing to experience rapid growth due to a healthy and diversified economy (Austin Chamber of Commerce 2015). This population growth, especially regarding Williamson County, places heavier stress on water resources.

Background

Garwood Irrigation Division (GID) is an area of south Texas where rice farming, and other forms of agriculture have been practiced since the late 1800s (Pandey 2012). The three irrigation divisions owned, operated, and maintained by the LCRA are: GID, Lakeside, and Gulf Coast. Pierce Ranch Irrigation company is not operated by the LCRA, but the LCRA owns the water rights (LCRA 2009). In 1900, farmers in Garwood obtained water rights to the Colorado River (Pandey 2012). Water rights of GID predate the rights held by the city of Austin. Rice farming is accomplished with flood irrigation. This means that water is taken from the Colorado river and pumped into irrigation canals that line the rice fields. From these canals, the water is pumped onto the rice fields and allowed to flow until a uniform layer of water completely covers the field.

The LCRA oversees water allocations within the Colorado River Basin in Central Texas. In 1999, the 76th Texas State Legislature passed House Bill 1437 (HB1437) which allows the LCRA to make an interbasin transfer from the Colorado River Basin to the Brazos River Basin, for the City of Round Rock, if there is "no net loss" of water in the Colorado River Basin (Gerlach 2016). No net loss means that if a certain amount of water is conserved by downstream users, then that amount water can be transferred upstream between the two river basins. There are also two other stipulations placed on this interbasin transfer: 1) payment for water by the recipient entity of an amount sufficient to pay both LCRA's applicable water rate and the costs of mitigating any adverse effects from the transfer and 2) a 25,000 acre-feet maximum annual volume of transferable water (Gerlach 2016). HB 1437 also created the Agricultural Water Conservation Fund. This fund was created to cover mitigation costs and can only be used for water resources development and implementing conservation best management practices that make water available for the interbasin transfer and meet the stipulation of no net loss of water to the basin.

In 2012, volumetric measurement and pricing was implemented by the LCRA in the GID to further water conservation incentives (Gerlach 2016). This is a change from the previous way farmers were billed for irrigation water. Previously, farmers were allotted a set amount (acre-feet) of irrigation water per growing season based on how many acres they were irrigating (Pandey 2012). The farmers were charged a lump sum for water that was allocated to them. Usually this amount exceeded what was needed for an average growing season and any leftover water would be converted to runoff or evaporate. Using the new volumetric measurement and pricing system, the farmer's irrigation water is measured at the field inlet and they are charged by volume delivered. This practice is meant to encourage farmers to use less water by charging them for every acre-foot that is delivered to their fields. Using excess water on a field will mean that the farmer will pay more during that growing season. An additional conservation practice, precision leveling, was made possible by the HB1437 Precision Leveling Fund. Through this fund, farmers voluntarily agreed to precision level their fields with cost-share incentives being provided by the LCRA (Ramirez and Eaton 2012). The LCRA's cost share program ran from 2006-2013. In 2013, the amount of funding that the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) precision leveling program was providing to Gulf Coast rice farmers was high enough that the LCRA decided to end its cost share program for precision leveling (LCRA 2016). Table 1 shows the acres leveled and HB1437 cost share grant amounts awarded to farmers.

Division	Fields Leveled	Acres Leveled	Total Project Cost	HB 1437 Grant Amount
Lakeside	189	16,177*	$5,645,770	$996,763
Garwood	162	13,023	$3,730,554	$689,938
Gulf Coast	14	1088	$305,932	$61,818
Total	**365**	**30,288**	**$9,682,255**	**$1,748,518**

* Excludes 682 acres leveled with HB 1437 grant funds but refunded to the Ag Conservation Fund in 2010 and 2011 due to contractual issues.

Table 1. 2006-2013 precision leveling costs share results (LCRA 2017a).

In the years since the passage of HB1437, there have been some tensions between upstream water users and the rice farmers in the GID. In 2013, during the historic drought in Texas, the Burnett County Commissioners office sent a letter to the LCRA to ask them not to release any water to Garwood rice farmers for a second crop (Walker 2013). Citizens of the Highland Lakes area just northwest of Austin depend on the lakes for drinking water and much of the home values in that area are related to them being lake front property. In 2013 the Central Texas Water Coalition (CTWC) recommended that the LCRA buy rice fields as a water conservation practice to make more water available for upstream water users. The Colorado Water Issues Committee (CWIC) responded to the CTWC's claims that land should not be bought from farmers (Gertson 2012). Due to the low levels of the Highland Lakes in 2013, the LCRA Board Members voted to pass a resolution that allowed the LCRA to raise lake level thresholds for Lake Buchanan and Lake Travis to 1.1 million acre-feet, an increase from the previous level of 850,000 acre-feet. If by March 1, 2014, the lake levels had not reached 1.1 million acre-feet, the LCRA would greatly reduce the volume of irrigation water released from the Highland Lakes. The TCEQ approved the resolution in January of 2014 (Price 2014). Lake levels did not surpass the 1.1 million acre-ft threshold and the LCRA only released 15,952 acre-feet of irrigation water to Garwood including an estimation of 1,675 acre-feet being lost due to evaporation, bank seepage, or conditions changing that eliminated the need for irrigation water. Lakeside, Gulf Coast, and Pierce Ranch received no irrigation water from the Highland Lakes in 2014 and 2015 with GID also not receiving Highland Lake water in 2015 (LCRA 2014). Table 2 below shows the source and amount of water that was delivered to the different irrigation operations from 2012 to 2016. Water contracts held by LCRA irrigation operators are termed "interruptible water contracts". During times of drought, stored water (reservoir water) availability to these contract holders is subject to cutbacks to have enough stored water for "firm water contract holders" such as municipal and industrial (LCRA 2015). Water supplied to irrigation operations from downstream water rights are termed "run-of-river" water rights

(LCRA 2015). Water availability for these rights is determined by the natural flow in the river that is available under law at a given point on the river and at a given instant in time to honor a right with a given priority date (LCRA 2015).

Water supplied from the Highland Lakes	2012	2013	2014	2015	2016
Garwood Irrigation Division	8,896	19,321	14,277	0	0
Lakeside Irrigation Division	0	0	0	0	6,581
Gulf Coast Irrigation Division	0	0	0	0	91
Pierce Ranch Irrigation Company	0	0	0	0	983
Subtotal from Highland Lakes	8,896	19,321	14,277	0	7,655
Water Supplied from Downstream Water Rights	**2012**	**2013**	**2014**	**2015**	**2016**
Garwood Irrigation Division	76,582	71,153	67,836	66,548	68,325
Lakeside Irrigation Division	649	0	0	0	81,560
Gulf Coast Irrigation Division	11,812	10,696	0	1,667	84,409
Pierce Ranch Irrigation Company	4,729	4,101	4,613	6,508	12,134
Subtotal from Downstream Water Rights	93,772	85,950	72,449	74,723	246,428
Total from both sources	102,668	105,271	86,726	74,723	254,083

Table 2. Total Water Pumped for LCRA's Agricultural Water Customers (acre-feet) (adapted from LCRA 2017b).

Many of the farming operations, families, and communities have been established in the irrigation districts since before many of the highland lake communities existed and as such have some of the most senior water rights in the Lower Colorado River Basin. There are many stakeholders in the Colorado River Basin with many competing uses of that water. There likely will be conflict again between them when another drought like the one during 2011-2015 occurs again.

Literature Review

This study draws on and contributes to four bodies of literature: (1) water conservation and efficiency in irrigated agriculture; (2) precision leveling as a conservation practice; (3) the relationship between funding support and conservation practice implementation; and (4) the economic impact of the Texas rice crop to the state's overall agricultural economy as well as the Texas rice crop contribution to the total US Rice crop economy.

Water conservation and efficiency in irrigated agriculture

There are potentially large water savings available through conservation practice implementation in irrigated agriculture. For instance, in the Colorado River Watershed, in the western United States, water conservation in agriculture is one of the most cost effective at 0.12-0.61 $/cubic meter and greatest potential for volumetric savings totaling 1,233 million cubic meters/year (Richter 2014). Finding new and creative ways to conserve water in agriculture is at the forefront of water resource planning worldwide (Richter 2014). Something to consider is what is the most cost-effective way to help solve these water shortages? Finding new sources of water such as: a pipeline delivery of a distant water source, brackish groundwater desalination, etc., can be very expensive propositions. Options other than building a reservoir are discussed below.

As water resources have become more stressed, farmers have sought ways to grow the same number of crops but with less water. In the Texas Panhandle, many farmers have moved to center pivot irrigation with full drop line, and low-pressure sprayers. This method has an irrigation efficiency close to 95 percent. Another very efficient irrigation practice is drip irrigation. This technique uses either hard or flexible tubes to route irrigation water directly to the root zone of a crop and disperse only drips of water. Currently this practice is primarily used in the fruit and vegetable industry as there is a higher economic return on those crops as opposed to corn or wheat (Cech 2003).

Another method to encourage farmers to conserve water is through water pricing. The theory behind this technique is that if farmers are required to pay more for the water they use, then they will likely try to conserve water (Richter 2014). Another way to conserve agricultural water is through improving the irrigation infrastructure. In areas like the Lower Rio Grande Valley in Texas, irrigation water is channeled through unlined and uncovered ditches and canals which can allow water to leech into soils or evaporate. Losses can be as high as 30% (Sansom, Armitano, and Wassenich 2008). Another item that could be updated is all the fittings and pipes that convey water in the irrigation system. This will eliminate water waste do to leaking pipes and fittings. An example of such improvements is the city of Roma, TX in the Lower Rio Grande Valley. Here, much of the irrigation water is delivered by canals. The city of Roma paid $2.8 million to update irrigation canals and used the agricultural water saved from these improvements as new municipal water (Sansom, Armitano, and Wassenich 2008).

Another irrigation water conservation technique is an irrigation suspension program. This is where a municipality will pay farmers not to irrigate their crops and arrive at some agreed upon price for water so that the water not used for agriculture can be used for drinking water in that municipality (Sansom, Armitano, and Wassenich 2008). Irrigation suspension programs can help avoid the need to build a new reservoir to store water.

Precision leveling as a conservation practice

Rice grown in the Gulf Coast region of Texas is watered using a practice known as flood irrigation. The practice of flood irrigation involves delivering water to a rice field through either a single inlet, or multiple inlets, until a relatively uniform layer of water covers the entire growing area of the field. Fields usually have slight elevation variations over the crop growing area. The greater the difference in elevation between the highest and lowest point of the field, the greater the amount of water that will be needed to flood the field to a uniform level. Precision leveling is used to create a more uniform and level field. Using a laser mounted on a tripod and a tractor pulling a field grader with a laser receiving unit attached to it, a farmer drives around the field and the planer is adjusted as the laser and receiver identify the higher and lower spots on the field. Once laser leveling is completed the field is almost perfectly level. The less elevation difference between the low and high end of a field, the less water that is needed to flood the field to a uniform depth (Wilson et al. 2012). Also, precision leveling can allow for a reduction in the maximum depth of water that must be maintained on the field to cover the entire field during the growing season (Salassi 2001). This can greatly reduce the amount of water needed to grow a rice crop. A previous study reported direct savings of water on precision leveled fields of 0.3 acre-feet per acre during the first crop in the nearby Lakeside Irrigation District (Ramirez and Eaton 2012). Precision leveling also leads to the additional benefits of greater crop vigor, uniformity of growth, and greater yield (Laughlin and Mehrle 1996). Precision leveling can reduce the levee area within a field by reducing the number of levees. This increases the rice growing acreage which in turn uses more water than the levees do. Thus, the potential water savings of a historically heavily leveed field may be slightly offset by increased irrigation demand of the increased growing acreage (Wilson et al. 2012).

Relationship between funding support and conservation practice implementation

When farmers are looking for ways to conserve water there are several things they must consider. Some of these include: learning new skills to implement new conservation practices, the complexity of the new technologies, compatibility of the new technologies with current practices and existing equipment, and the financial investment (Adrian, Norwood, and Mask 2005).

A factor that influences a farmer's decision to invest in long term conservation improvements is overall cost. If the benefits outweigh the costs, then an investment will be made (Featherstone and Goodwin 1993). Initial costs to implement precision leveling, according to the Texas Water Development Board, can range anywhere from $150/acre-$500/acre (TWDB 2016). Cost share programs have been instituted in agriculture across many areas of the country through agencies such as the United States Department of Agriculture - Natural Resources Conservation Service (USDA NRCS 2017). These cost-share programs cover a percentage of the overall cost to implement conservation practices, like precision leveling, and alleviates some of the farmer's financial burden. Results from a 2004 study, using a revealed preference approach, suggest that cost sharing should have substantial effects on the adoption of several conservation practices (Lichtenberg 2004). Another research study of 541 individual Kansas farms throughout the 1980's statistically showed that farms which received direct government payments were more likely to invest in conservation programs (Featherstone and Goodwin 1993).

In addition to the cost of implementing conservation programs, farmers also consider how long it will take to recoup those initial costs in water savings. Precision leveling for instance is a long-term investment in the land and will require several years of production to recover the costs invested (Salassi 2001).

Economic impact of Texas' rice crop to the state's overall agricultural revenue as well as the Texas rice crop contribution to the total US Rice crop economy

Rice is grown in four regions of the United States: the Arkansas Grand Prairie, Mississippi Delta, the Gulf Coast (Texas and Southwest Louisiana), and the Sacramento Valley in California. Approximately half of U.S. produced rice is sold on the domestic market. The other 50% is exported to markets predominantly in Mexico, Central America, Northeast Asia, the Caribbean, and the Middle East. Smaller volumes are exported to Canada, the European Union, and Sub Saharan Africa (USDA 2017).

The chart below (Figure 1) shows what the Texas rice industry contributes, economically, to the overall U.S. rice industry. Data compiled from the U.S. Department of Agriculture National Agricultural Statistics Service (USDA NASS 2017), shows that between 1990 and 2016, the Texas contribution to the annual US rice crop was on average 7.73%. From 1990 to 2016 the maximum value of the Texas rice crop was $199,422,000 and the minimum value was $60,803,000. There are three instances where overall U.S. Rice Production shows a downward trend. This could possibly be from drought that may impact the U.S. rice growing regions with some regularity.

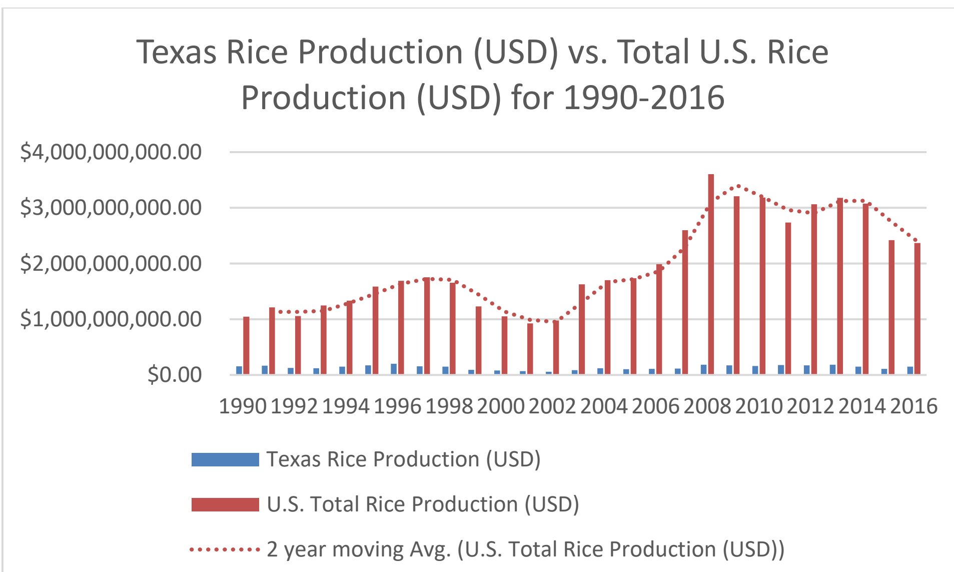

Figure 1. Comparison of Texas and U.S. total rice production value.

In 2012, the total value of agricultural goods produced and sold in Texas was $25,375,581,000. Texas ranked 3rd in the United States for overall agricultural commodity value. The Texas rice crop had a production value of $148,673,000 in 2012 (USDA 2018). This accounts for approximately 0.59 percent of the overall value of Texas agriculture 2012.

The Texas Rice industry also contributes to the state's economy by promoting outdoor activities such as hunting and bird watching. The rice production area of Texas is along the Central Flyway which migratory birds use during their migration south and for winter feeding grounds. Rice paddies also attract ducks which has led to the area becoming a popular destination for duck hunters (Texas A&M 2018).

Texas State Study for the LCRA

In the Summer of 2016, Texas State University was approached by the LCRA to conduct an analysis of water savings that may be attributed to volumetric measurement and pricing, which had been implemented as a conservation strategy in the GID in 2012. Five years of data were expected to become available at the end of 2016 and plans were made to obtain the necessary data to develop a statistical model using an approach that had been used in a previous study in the nearby Lakeside Irrigation Division. I was approached by Dr. Timothy Loftus in the Fall of 2016 about a research opportunity he had available that concerned water resources. I officially started working on the project in February 2017.

Data were collected from several different sources. Both Dr. Loftus and myself collected survey questionnaire data from farmers, in person, in Garwood, Texas. Water use billing data and GIS-based shapefiles of GID fields were provided by the LCRA. Also, climate data were sourced from LCRA's Hydromet system of weather gages (temperature and rainfall) and Texas A&M University's Eagle Lake Research Station (evapotranspiration). Pre-2012 (i.e., prior to implementation of volumetric measurement and pricing) data at the farmer/field level were not available, as was initially expected. Due to lack of historical data, estimating the independent effects of volumetric measurement and pricing on water use was not possible. However, analyses of the dataset created by the project team did yield considerable insight into the relationship between annual water use by rice farmers and a variety of explanatory factors (Loftus, Weaver, and Barnard 2017).

A three-level longitudinal model that groups observations by time (level 1), field (level 2), and farmers (level 3) was constructed by the project team. Each of these levels was hypothesized to have some influence on water usage. Finally, a log-level model of 15 major explanatory variables was developed (Loftus, Weaver, Barnard 2017).

List of variables evaluated by model	*Is the variable retained by model?*
Time (relative to 2012)	Yes
Cost per unit ($, mean-centered)	Yes
Field size (acres, mean-centered)	Yes
Growing season (days, mean-centered)	Yes
Temperature (average annual, mean-centered)	Yes
Levee density	Yes
Hybrid rice (all other rice types considered "nonhybrid")	Yes
Interaction: hybrid rice * growing season	No
Farmed by owner (all other relationships considered "not farmed by owner")	Yes
Precipitation (total for growing season)	No
Evapotranspiration (total for growing season)	No
Precision level (Yes, No)	No
Interaction: precision level * levee density	No
Permanent perimeter levee (Yes, No)	No
Conservation Tillage	No
Number of inlets	No
Levee type	No

Table 3. Explanatory variable evaluated by the log-level model (adapted from Loftus, Weaver, and Barnard 2017).

Interestingly, the multilevel models did not reveal a statistically significant relationship between water use and precision leveling. In other words, the expected inverse association between water use and the presence of leveled fields (see above) was not observed after the

Texas State research team controlled for other relevant variables (Loftus, Weaver, and Barnard 2017). One possibility for this null finding is that the multilevel model examined water use over the full 2012-2016 time period. If, for example, leveled fields were linked to substantially less water use than non-leveled fields in just one or a few years, then this difference might be difficult to detect by a multivariate regression model. For that reason, in this study I follow up the multivariate analysis by comparing water demand—where water demand is defined as water use (in acre feet) per acre of field—between leveled and non-leveled fields on a year-by-year basis. In addition, working under the assumption that precision leveling does help with water conservation in rice farming in general—notwithstanding the specific null finding by the Texas State team—I explore the connection between LCRA funding mechanisms and the adoption of precision leveling in GID. More precisely, I investigate the possibility that LCRA-provided matching funds for leveling technology affects the odds of a field being leveled in GID. Together, the results from these two exercises represent important extensions to the research by Loftus, Weaver, and Barnard (2017).

Research Methods

Study Area

The GID is a rice growing region in south Texas. The rice fields are located in Colorado and Wharton counties and are south of Interstate 10 (Figure 2). The nearest large town is Columbus, Texas. The rice fields are irrigated by water pumped from the nearby Colorado River through a network of canals, ditches, and flood gates. From the data gathered during the survey of rice farmers, it was found out that many of the farmers live in the cities of Garwood and El

Campo. The LCRA has a district office located in Garwood, where contracts for LCRA water are drafted and signed by the farmers each growing season.

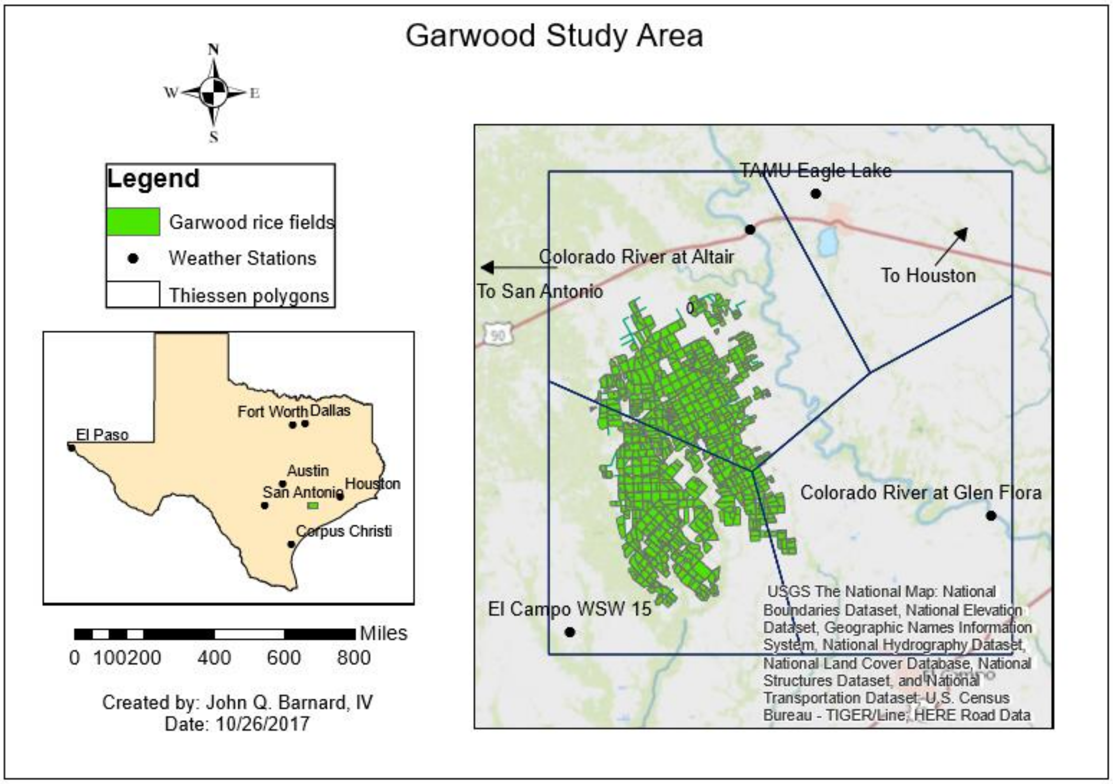

Figure 2. Map of GID Study Area.

Data Collection

Upon starting the project with Dr. Loftus, the LCRA sent me contact information for farmers in the GID the last week of February 2017. I made attempts to contact all the GID farmers on the list. If a farmer answered, I told them I was a graduate student worker at Texas State University and a part of a project analyzing water usage in the GID, on behalf of the LCRA. Finally, I asked if the farmer would be willing to participate in a short survey, the first week in March, at the LCRA District office in Garwood? Farmers that agreed to participate were told of available time slots and dates to come to the GID office to participate in the survey.

I used a spreadsheet in Microsoft Excel to keep track of which farmer and what date and time they would be coming in for the survey.

The first week in March 2017, Dr. Loftus and I made three trips from San Marcos to Garwood to administer the survey questionnaire (see Appendix A). Dr. Loftus and I both surveyed farmers individually. The LCRA provided both of us with laptops that allowed us to access an internal LCRA web application called UMap. This web application showed an aerial view of the rice fields in Garwood that were irrigated with LCRA water. Clicking on an individual field brought up a list of attributes about that field such as: years farmed, ownership/contract for that field, LCRA name for the field, and the acreage.

The LCRA also provided the project team with farmer and field data the previous month. From this data I constructed a list of fields farmed by which farmer, the years farmed, and the acreage of the field. I used this data when surveying farmers about their fields for the 2012-2016 growing seasons. During the survey, both Dr. Loftus and myself sat with the farmers, located the field in question using the UMap web application for reference, and proceeded to ask the questions on the survey.

In July, the LCRA provided the project team with billing files for all Garwood fields that were farmed during the 2012-2016 growing seasons. This data would be used to determine how many acre-ft. of water was used on an individual field during a growing season and how much money a farmer was charged for that amount of water. The billing data only listed the name of the billing contract (farm of farmer name), what acreage a field was, and how much water and total price charged. I cross referenced the farmer and field data the LCRA had sent me earlier in the project with the billing data by verifying field acreages agreed between the two. This allowed me to put a volume of water and price charged with a named field from the project dataset.

Monthly precipitation totals, and average monthly temperature values were obtained from the LCRA's Hydromet database which consists of a network of weather stations that are owned and operated by the LCRA (LCRA Hydromet 2017). Average monthly evapotranspiration values were obtained from the Texas A&M University Beaumont Research Institute near Eagle Lake, TX. These monthly values were tabulated in Microsoft Excel. Since the water usage and billing files are at the annual scale rather than monthly, I summed the climate parameters for the growing season (April - October) to produce an annual total for rainfall and evapotranspiration and summed monthly temperature values to produce and annual average.

The LCRA provided me with GIS shapefiles to use in ESRI's ArcMap software. The GIS data allowed me to determine which fields were tracts of separate lands being billed together as one contiguous field. In these cases, a decision was made to combine dataset entries to match the billing files. An outcome of this process was a dataset with a reduced number of entries.

Survey data was organized into an MS-Excel spreadsheet. I used the GIS shapefiles to create Thiessen Polygons to assign nearest climate station values to each of the fields. Next, I added the billing data into the dataset. As previously mentioned there were instances where the project dataset and billing files did not agree with one another. A decision was made to combine dataset records to reflect what was in the billing files. However, this presented a challenge. Some of the dataset values were additive in nature, such as field acreage and number of levees. Others, like slope percentage and levee type were not additive and resulted in data being dropped when the entry values that needed to be combined were in conflict with one another. In the case of two entries with different levee types, a new levee category was created and called "combination".

Some farmers revealed during the survey interview that they had supplemented LCRA surface water with groundwater from privately owned wells. Dataset entries that reflected supplemental groundwater usage were dropped from the dataset as there was no way to quantify the total amount of groundwater used.

Approximately 45 entries were dropped from the original survey dataset after combining their variable values with the corresponding record from the billing data. After a thorough dataset review for consistency between the survey dataset and the billing file, the project team was left with 275 records or unique combinations of year/farmer/field name, 246 records without null values in final model variables, 153 unique field names, 14 farmers interviewed, and 5 years of data (Loftus, Weaver, and Barnard 2017).

Data Analysis

Of interest to the LCRA is whether precision leveled fields in the GID used less water per growing season than non-precision leveled fields. I extracted water demand (total growing season water use/field acreage) for all precision and non-precision leveled fields, from the dataset, using an MS-Excel pivot table. Also, I extracted the average, standard deviation, and field count, as shown in Table 3 below.

Year	Non-leveled fields			Leveled fields		
	Average Water Demand (acre-feet/acre)	Std Dev of Water Demand	Field count	Average Water Demand (acre-feet/acre)	Std Dev of Water Demand	Field count
2012	4.45	0.83	15	4.34	1.06	33
2013	4.04	0.87	17	3.86	1.00	32
2014	2.57	0.81	23	2.95	0.79	37
2015	2.53	1.35	14	2.75	0.99	30
2016	3.38	0.98	22	2.62	0.70	33

Table 3. Average water demand and field count for precision leveled and non-leveled fields.

Using the open source statistical software Gretl (Gretl 2018), I performed an independent-samples t-test by comparing the demand means for leveled and non-leveled fields on a year-by-year basis. The t-test is a common means for identifying differences in a continuous variable (e.g., water demand) across two independent groups (Rogerson 2015). Prior to performing the t-test, I first performed F-test to compare variances—ultimately, this test revealed the variances to be unequal in the two groups (Rogerson 2015). That being said, the null hypotheses of the ensuing t-tests were all that the difference in average water demand between leveled and non-leveled fields is equal to zero. The alternative hypotheses were therefore that mean water demand is different between the two groups. Using a significance level of $\alpha = 0.05$, Table 4 shows the results from these tests.

Year	Difference between Non-leveled and leveled fields avg. water demand	p-value (two tailed)	Null Hypothesis
2012	0.11	0.7248	Fail to reject
2013	0.18	0.5312	Fail to reject
2014	0.38	0.0797	Fail to reject
2015	0.22	0.5359	Fail to reject
2016	0.76	0.0014	Reject null hypothesis

Table 4. Results of T-test comparing two means.

Next, I performed a chi-squared test of independence, and computing associated odds ratios, between the categorical variables precision leveling (=1 if yes) and whether farmers had received funding from the LCRA (=1 if yes) to level their fields (Table 5).

	Funding received	No funding received
Precision leveled	133	29
Non-precision leveled	4	86

Table 5. Contingency table: Number of leveled and non-leveled fields with funding and without funding ($\chi^2[1] = 140.63; p \ll 0.0001$).

The odds ratio associated with Table 5 is found by dividing the ratio of funded/precision leveled fields to funded/non-precision leveled fields (i.e., the odds of leveling for funded fields) by the ratio of non-funded/precision leveled fields to non-funded/non-leveled fields (i.e., the odds of leveling for unfunded fields). The resulting odds ratio (OR) is equal to 98.6.

$$OR = \frac{133/4}{29/86} = 98.6 \qquad (1)$$

In practical terms, the odds of precision leveling a field are nearly 100 times higher if a farmer receives partial funding to do so relative to cases in which the farmer bears the full cost of leveling. The chi-square test of independence (with Yate's Correction) between these two variables is a test of the null hypothesis that funding provision and leveling are statistically independent—that is, farmers will level their fields at the same rate regardless of whether partial funding is provided (Rogerson 2015). As expected from the high OR shown in Equation 1, this null hypothesis is easily rejected, with a p-value of less than 0.0001. Thus, I can conclude that precision leveling and funding are dependent: the odds that a farmer will precision level their field are statistically significantly higher if cost share funding is provided.

Results/Discussion

Precision leveling and water demand

In all years except 2016, precision leveling did not have a statistically significant effect on average water demand. This helps to explain the output of the log level model in that, precision leveling was not retained as a significant explanatory variable (Loftus, Weaver, and Barnard 2017). Graphing average water demand for both leveled and non-leveled fields (Figure 3) shows a consistent negative trend over the study period in water demand among precision leveled fields and a negative trend among non-leveled fields during the first four years of the study period followed by an increase in water demand for the 2016 growing season.

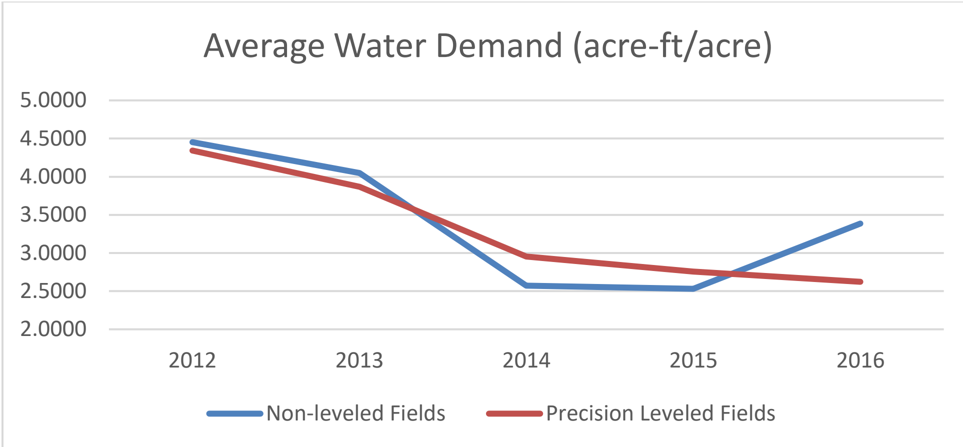

Figure 3. Average Water Demand of Precision Leveled and Non-leveled fields.

The precision leveled fields trend may be due to farmers having to adjust their watering scheme after a field is leveled. Given enough time, perhaps a farmer could reduce water usage on a precision leveled field to the absolute minimum required to grow their rice crop. Although, now that farmers are charged volumetrically for the water delivered to their fields, one could assume all farmers would strive to reduce their water usage to a minimum value.

Another thing that I think should be considered when reviewing water demand is that the data from my study period was from a time when Texas was experiencing exceptional drought conditions except for 2016. The years 2012-2015 were not what would be considered "average" growing seasons regarding water availability for irrigation (Table 2). Water diversions from the Highland Lakes and downstream water rights from the Colorado River, however, increased from 74,723 acre-feet in 2015 to 254,085 acre-feet in 2016. This is likely attributable to the greater availability of water for the 2016 growing season after the drought ended in 2015. In 2016, non-leveled fields show an increase in water demand whereas leveled fields do not (Figure 3). This could be attributable to farmers of leveled fields having adjusted the amount of water used to grow their crop, while farmers of non-leveled fields having to apply more water to sustain their crop. This agrees with my finding that in 2016, precision leveled fields had a statistically significant lower water demand that non-leveled fields. Even though more water was available in 2016, precision leveled fields did not need as much water as non-leveled fields did to produce the same crop.

Odds ratio: Precision leveling fund influence

The odds ratio revealed that a farmer is 98.6 times more likely to precision level their field if the cost is supplemented by the LCRA. The Chi-squares test produced a p-value of less than 0.0001. This is much less than the significance coefficient of $\alpha=0.05$. From this, I can assume that the association between cost share funding and precision leveling is statistically significant. This has policy relevance to the LCRA if further research shows that GID precision leveled fields use less water after learning the new leveled fields minimum water requirements. If the LCRA wishes to reduce water usage in the GID then providing more cost share opportunities to farmers to precision level their fields could be a way to do that. Another policy relevant item is the need for enforcement of precision leveling when funding is administered for that purpose. The dataset shows four fields were given precision level funding but were listed as not being precision leveled.

My literature review revealed that there are many different factors that ultimately influence a farmer's decision to implement water conservation practices and/or equipment. Cost is one of them, but also time needed to learn how to use the new equipment, the compatibility of current equipment and infrastructure with new water conserving equipment and infrastructure are a few other things that are considered. As previous research suggests, land ownership plays a role in implementing conservation practices. Land that is not farmed by the land owner (rented for cash) is likely not to benefit from the same conservation ethic that is applied to a field that is both owned and operated by the same farmer (Loftus, 1999; Esseks and Kraft, 1989).

Recommendations and Future Research

Recommendations

During the dataset construction process for the LCRA project, connecting a billing file to a field from the surveys proved to be a time-consuming task. This is because currently, billing data only lists the farm name and/or farmer and fields acreage as identifying attributes. The Umap data that I obtained from the LCRA lists a field name, which the LCRA chooses, and the acreage. When I attempted to match a dataset entry from the Umap data to the billing data, I had to use acreage as the identifying variable rather than field name which could have been more easily searched for.

I recommend that the LCRA use a standard field name like the USDA Farm Service Agency number, for mapping in GIS, billing system files, and the contracts farmers sign. There would be no confusion as to the location and attributes of a field in question. Also, this would mean a field could be tracked across growing seasons. This would aid in tracking a fields water usage from one growing season to the next. The LCRA often assigns a new field name to an individual field each growing season. This means that a parcel of land could have different names over the course of several years.

While administering the surveys to farmers in the GID, I asked them to recall field characteristics from the past five years. While most farmers seemed to remember their field levee numbers, number of inlets, and other attributes well, other seemed to have to offer their best recollection. A solution would be to administer the survey when the farmers come in to the district office each year to fill out a contract for the upcoming growing season. This would mean the farmer only has to recall back as far as the previous growing seasons field characteristics.

Future Research

Further research is needed to determine if water demand of precision leveled fields approaches some minimum value. Factors such as rainfall and temperature could also affect water demand. More research over a longer period is needed. As shown in (Figure 3), the precision leveled fields average water demand slowly trended down and started to level out near the end of the study period. Also, the 2016 growing season was the first to show a statistically significant lower average water demand amongst precision leveled fields versus non-leveled fields. Verifying if subsequent growing seasons show that precision leveled fields have lower average water demand would add strength to the argument that additional rounds of precision level funding from the LCRA could help to further reduce water usage in GID.

Conclusion

The project team started out with the research goal of verifying if the LCRA's new practice of volumetric measurement and volumetric pricing resulted in water savings in the GID. Although, this was not possible due to the lack of historical data at the field level, our research created a comprehensive dataset of field attributes and water usage for 153 individual fields (Loftus, Weaver, and Barnard 2017). Also, my additional analysis of the dataset showed that precision leveled fields showed a downward trend in water demand over the 2012-2016 growing seasons, eventually resulting in a statistically significant lower average water demand in 2016 than non-leveled fields in that year. Also, my analysis has shown that farmers are 98.6 times as likely to level their fields if the LCRA shares some of the cost to do so. Furthermore, my analysis has shown the association between cost share funding and a farmer's decision to precision level a field to be statistically significant.

It is my hope that this research report can be used by a future researcher into quantifying the effectiveness of the LCRA's water conservation and efficiency strategies in the GID.

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Appendix A

VOLUMETRIC MEASUREMENT AND PRICING AS A CONSERVATION PRACTICE

RICE PRODUCTION FARM PRACTICES SURVEY
2012-2016

INTRODUCTION: The purpose of this survey is to investigate how volumetric measurement and pricing of water, and other water conservation practices, as currently applied by farmers in LCRA's Garwood Irrigation Division influence on-farm water use. A research team from Texas State University will analyze data collected by this survey.

Your voluntary response to the survey is important to understanding the effects of certain conservation practices on water use. The information you share will be compiled into a report that has aggregated data for the entire division, and LCRA will not release your individual information unless required to do so by law.

If you do not wish to answer a question, you are not required to do so. The survey consists of three parts: general information, farming practices and field characteristics. We greatly appreciate your time and effort.

PART 1: GENERAL INFORMATION - In the general information section you will be asked to provide information about yourself to help LCRA and the research team better understand the factors most related to conservation and water use.

PART 2: FARMING PRACTICES - These questions refer to water conservation measures and management practices.

PART 3: FIELD CHARACTERISTICS - These questions are central to verifying the benefits of the program to pay for farm land improvements. You will be asked about ALL fields planted from 2012 to 2016 (one row per field per year). Please bring farm records you consider necessary to ensure the information is as accurate as possible. If you do not have records for some fields or years, please let us know. If you have questions about the terminology in the survey, refer to the glossary attached to this survey.

The project team will use LCRA's uMap tool to verify your fields. If there are fields incorrectly marked, not part of your farming operation or missing, please let us know. If you have questions about completing this survey, contact Stacy Pandey at 800-776-5272, ext. 7471 or by email at stacy.pandey@lcra.org. We look forward to completing the survey with you.

Survey respondent name: ____
LCRA contract holder name: ____
Date: ____________________

Part 1 – General Information

Name: _________________________

Role in farm operation: __________________________

Gender: _____ Male _____ Female

Total area of your farm operation: _____ acres

Years you actively have farmed: _____

Please circle your age (optional).

- Less than 30
- 31-40
- 41-50
- 51-60
- More than 60

Please circle your level of formal education (optional):

a. Completed grade school
b. Completed high school
c. Attended a four-year or junior college
d. Graduated from a four-year college
e. Attended graduate or professional school
f. Completed graduate or professional degree

Part 2 – Farming Practice

1. What percentage of your total working time (i.e., time spent generating income) do you spend working on:
   a. Farms you own _____
   b. Farms rented for cash_____
   c. Farms share rented _____
   d. Off-farm activities _____

   Total 100 percent
2. In your farming practice, please circle who makes the management decisions for crop variety, pesticide use, labor and water orders when land is:

<u>Farmed by owner</u>	<u>Rented for cash</u>	<u>Share rented</u>
Landowner	Landowner	Landowner
Tenant	Tenant	Tenant
Manager	Manager	Manager
Field hand	Field hand	Field hand
Ag/crop consultant	Ag/crop consultant	Ag/crop consultant
Other_________________	Other_________________	Other_________________

3. Which of the following conservation practices do you practice to reduce water use? Circle all that apply.
    a. Precision land leveling
    b. Multiple inlets
    c. Permanent levees
    d. Other: ___________________

4. Please rank the reasons below for adopting conservation practices such as precision land leveling, multiple inlets or permanent perimeter levees (1 being most important, 5 being least important).
    a. Increase yield. _____
    b. Land topography _____
    c. Reduce labor costs _____
    d. Water savings _____
    e. Financial support _____
    f. Other, please specify: ______________________

5. Please estimate the percentage of your farmland that has been precision leveled (i.e., land graded to a slope of less than 2 percent).
    _____ percent
6. How often do you perform land-grading maintenance on your precision-leveled fields?
    a. Each year they are in production.
    b. Every other year they are in production.
    c. Every _____ years.
    d. As needed based on visual inspection.
    e. Other:___________________________
7. What circumstances lead you to perform land-grading maintenance on your precision-leveled fields?
    a. Weather
    b. Fallow-field flooding
    c. Livestock damage
    d. Other: ____________________________

8. Please rank the following sources of farming knowledge (1 being most important, 5 being least important).
    a. My own practice and experience _____
    b. Parents/relatives _____
    c. Other farmers _____
    d. University Extension/USDA _____
    e. School/professional training _____
    f. Ag/crop consultant _____
    g. Other, please specify: _______________________________

9. How has volumetric measurement and pricing of water affected your water usage (choose one answer)?

    a. I use about the same amount of water as I always have.
    b. I use less water than I did prior to implementation of this pricing mechanism.
    c. I use more water than I did prior to implementation of this pricing mechanism.

10. Since volumetric measurement and pricing were introduced, are you managing water in your fields differently with greater investment in labor or some other management technique?
    a. Investing in more labor to increase efficiency of water use.
    b. Other technique (please describe): ____________________________________

11. Do you manage/maintain your private lateral canals on a regular basis and if so, what is the primary reason(s) for doing so?
    - No
    - Yes, because____

12. On your farm fields, do you collect rainfall or other weather data?
    - Yes
    - No

13. Do you flush your field(s) as a standard practice before holding a permanent flood?
    - Yes
    - No

14. Do you flush to start a herbicide?
    - Yes
    - No

Are there any other things that you can tell us about your farming practice that influence your water use? ____

PART 2: FIELD CHARACTERISTICS *Please list the fields you farmed in 2012 and place a check in the appropriate box to describe each field*

Survey ID:

2012	2nd crop	Management		Conservation Measures								
Field name	**Abandoned harvest of 2nd crop**	**Rice Variety**	**Ownership stake**	**Conservation Measures**	**In-field lateral**	**Multiple Inlets**	**Levees**		**Slope**	**Multiple Inlets Funding**	**Precision Leveling Funding**	**Water by wells**
LCRA: **Owner:** FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ____	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ______	Precision Leveled ____yr % of field leveled ____ Multiple Inlets ____yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ______	Yes No	Number of water inlets controlled by farmer ____	Permanent Straight Contour None Other (specify) ____	Number of Levees ____	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ______	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other______	Yes if Yes, %water ____ No
LCRA: **Owner:** FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ____	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ______	Precision Leveled ____yr % of field leveled ____ Multiple Inlets ____yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ______	Yes No	Number of water inlets controlled by farmer ____	Permanent Straight Contour None Other (specify) ____	Number of Levees ____	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ______	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other______	Yes if Yes, %water ____ No
LCRA: **Owner:** FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ____	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ______	Precision Leveled ____yr % of field leveled ____ Multiple Inlets ____yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ______	Yes No	Number of water inlets controlled by farmer ____	Permanent Straight Contour None Other (specify) ____	Number of Levees ____	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ______	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other______	Yes if Yes, %water ____ No
LCRA: **Owner:** FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ____	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ______	Precision Leveled ____yr % of field leveled ____ Multiple Inlets ____yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ______	Yes No	Number of water inlets controlled by farmer ____	Permanent Straight Contour None Other (specify) ____	Number of Levees ____	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ______	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other______	Yes if Yes, %water ____ No
LCRA: **Owner:** FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ____	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ______	Precision Leveled ____yr % of field leveled ____ Multiple Inlets ____yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ______	Yes No	Number of water inlets controlled by farmer ____	Permanent Straight Contour None Other (specify) ____	Number of Levees ____	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ______	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other______	Yes if Yes, %water ____ No

PART 2: FIELD CHARACTERISTICS *Please list the fields you farmed in 2013 and place a check in the appropriate box to describe each field* Survey ID:

2013 Field name	2nd crop	Management		Conservation Measures								Water by wells
	Abandoned harvest of 2nd crop	Rice Variety	Ownership stake	Conservation Measures	In-field lateral	Multiple Inlets	Levees		Slope	Multiple Inlets Funding	Precision Leveling Funding	
LCRA: Owner: FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ____	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ____	Precision Leveled ____yr % of field leveled ____ Multiple Inlets ____yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ____	Yes No	Number of water inlets controlled by farmer ____	Permanent Straight Contour None Other (specify) ____	Number of Levees ____	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ____	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other____	Yes if Yes, %water ____ No
LCRA: Owner: FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ____	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ____	Precision Leveled ____yr % of field leveled ____ Multiple Inlets ____yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ____	Yes No	Number of water inlets controlled by farmer ____	Permanent Straight Contour None Other (specify) ____	Number of Levees ____	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ____	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other____	Yes if Yes, %water ____ No
LCRA: Owner: FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ____	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ____	Precision Leveled ____yr % of field leveled ____ Multiple Inlets ____yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ____	Yes No	Number of water inlets controlled by farmer ____	Permanent Straight Contour None Other (specify) ____	Number of Levees ____	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ____	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other____	Yes if Yes, %water ____ No
LCRA: Owner: FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ____	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ____	Precision Leveled ____yr % of field leveled ____ Multiple Inlets ____yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ____	Yes No	Number of water inlets controlled by farmer ____	Permanent Straight Contour None Other (specify) ____	Number of Levees ____	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ____	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other____	Yes if Yes, %water ____ No
LCRA: Owner: FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ____	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ____	Precision Leveled ____yr % of field leveled ____ Multiple Inlets ____yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ____	Yes No	Number of water inlets controlled by farmer ____	Permanent Straight Contour None Other (specify) ____	Number of Levees ____	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ____	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other____	Yes if Yes, %water ____ No

PART 2: FIELD CHARACTERISTICS *Please list the fields you farmed in 2014 and place a check in the appropriate box to describe each field* Survey ID:

	2nd crop	Management		Conservation Measures								
2014 **Field name**	**Abandoned harvest of 2nd**	**Rice Variety**	**Ownership stake**	**Conservation Measures**	**In-field lateral**	**Multiple Inlets**	**Levees**		**Slope**	**Multiple Inlets Funding**	**Precision Leveling Funding**	**Water by wells**
LCRA: Owner: FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ____	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ____	Precision Leveled ____yr % of field leveled ____ Multiple Inlets ____yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ____	Yes No	Number of water inlets controlled by farmer ____	Permanent Straight Contour None Other (specify) ____	Number of Levees ____	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ____	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other____	Yes if Yes, %water ____ No
LCRA: Owner: FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ____	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ____	Precision Leveled ____yr % of field leveled ____ Multiple Inlets ____yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ____	Yes No	Number of water inlets controlled by farmer ____	Permanent Straight Contour None Other (specify) ____	Number of Levees ____	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ____	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other____	Yes if Yes, %water ____ No
LCRA: Owner: FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ____	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ____	Precision Leveled ____yr % of field leveled ____ Multiple Inlets ____yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ____	Yes No	Number of water inlets controlled by farmer ____	Permanent Straight Contour None Other (specify) ____	Number of Levees ____	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ____	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other____	Yes if Yes, %water ____ No
LCRA: Owner: FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ____	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ____	Precision Leveled ____yr % of field leveled ____ Multiple Inlets ____yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ____	Yes No	Number of water inlets controlled by farmer ____	Permanent Straight Contour None Other (specify) ____	Number of Levees ____	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ____	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other____	Yes if Yes, %water ____ No
LCRA: Owner: FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ____	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ____	Precision Leveled ____yr % of field leveled ____ Multiple Inlets ____yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ____	Yes No	Number of water inlets controlled by farmer ____	Permanent Straight Contour None Other (specify) ____	Number of Levees ____	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ____	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other____	Yes if Yes, %water ____ No

PART 2: FIELD CHARACTERISTICS *Please list the fields you farmed in 2015 and place a check in the appropriate box to describe each field* Survey ID:

2015 Field name	2nd crop: Abandoned harvest of 2nd crop	Management: Rice Variety	Management: Ownership stake	Conservation Measures: Conservation Measures	In-field lateral	Multiple Inlets	Levees		Slope	Multiple Inlets Funding	Precision Leveling Funding	Water by wells
LCRA: Owner: FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ______	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ______	Precision Leveled ______yr % of field leveled ______ Multiple Inlets ______yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ______	Yes No	Number of water inlets controlled by farmer ______	Permanent Straight Contour None Other (specify) ______	Number of Levees ______	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ______	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other______	Yes if Yes, %water ____ No
LCRA: Owner: FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ______	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ______	Precision Leveled ______yr % of field leveled ______ Multiple Inlets ______yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ______	Yes No	Number of water inlets controlled by farmer ______	Permanent Straight Contour None Other (specify) ______	Number of Levees ______	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ______	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other______	Yes if Yes, %water ____ No
LCRA: Owner: FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ______	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ______	Precision Leveled ______yr % of field leveled ______ Multiple Inlets ______yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ______	Yes No	Number of water inlets controlled by farmer ______	Permanent Straight Contour None Other (specify) ______	Number of Levees ______	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ______	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other______	Yes if Yes, %water ____ No
LCRA: Owner: FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ______	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ______	Precision Leveled ______yr % of field leveled ______ Multiple Inlets ______yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ______	Yes No	Number of water inlets controlled by farmer ______	Permanent Straight Contour None Other (specify) ______	Number of Levees ______	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ______	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other______	Yes if Yes, %water ____ No
LCRA: Owner: FSA number Description: Acres:	Yes No	Traditional Seed Hybrid Other ______	Farmed by owner Rented for cash Share rented 50/50 Other (specify) ______	Precision Leveled ______yr % of field leveled ______ Multiple Inlets ______yr Permanent Perimeter Levees Conservation Tillage Other (please specify) ______	Yes No	Number of water inlets controlled by farmer ______	Permanent Straight Contour None Other (specify) ______	Number of Levees ______	Slope = 0.2% 0.2% > Slope > 0.1% Slope = 0.1% Slope = 0.05% Zero grade Other (specify) ______	NRCS funding Yes No	Cost-share with NRCS Yes No All Private funding Yes No Other______	Yes if Yes, %water ____ No

PART 2: FIELD CHARACTERISTICS *Please list the fields you farmed in 2016 and place a check in the appropriate box to describe each field* Survey ID:

2016	2nd crop	Management		Conservation Measures								Water by wells
Field name	Abandoned harvest of 2nd crop	Rice Variety	Ownership stake	Conservation Measures	In-field lateral	Multiple Inlets	Levees		Slope	Multiple Inlets Funding	Precision Leveling Funding	
LCRA: Owner: FSA number Description: Acres:	□Yes □ No	□Traditional □ Seed □ Hybrid □ Other ____	□Farmed by owner □ Rented for cash □ Share rented 50/50 □ Other (specify) ____	□Precision Leveled ____yr % of field leveled ____ □ Multiple Inlets ____yr □ Permanent Perimeter Levees □ Conservation Tillage □ Other (please specify) ____	□ Yes □ No	Number of water inlets controlled by farmer ____	□Permanent □ Straight □ Contour □ None □ Other (specify) ____	Number of Levees ____	□Slope = 0.2% □ 0.2% > Slope > 0.1% □ Slope = 0.1% □ Slope = 0.05% □ Zero grade □ Other (specify) ____	NRCS funding □ Yes □ No	Cost-share with NRCS □ Yes □ No All Private funding □ Yes □ No □ Other____	□Yes if Yes, %water ____ □ No
LCRA: Owner: FSA number Description: Acres:	□Yes □ No	□Traditional □ Seed □ Hybrid □ Other ____	□Farmed by owner □ Rented for cash □ Share rented 50/50 □ Other (specify) ____	□Precision Leveled ____yr % of field leveled ____ □ Multiple Inlets ____yr □ Permanent Perimeter Levees □ Conservation Tillage □ Other (please specify) ____	□ Yes □ No	Number of water inlets controlled by farmer ____	□Permanent □ Straight □ Contour □ None □ Other (specify) ____	Number of Levees ____	□Slope = 0.2% □ 0.2% > Slope > 0.1% □ Slope = 0.1% □ Slope = 0.05% □ Zero grade □ Other (specify) ____	NRCS funding □ Yes □ No	Cost-share with NRCS □ Yes □ No All Private funding □ Yes □ No □ Other____	□Yes if Yes, %water ____ □ No
LCRA: Owner: FSA number Description: Acres:	□Yes □ No	□Traditional □ Seed □ Hybrid □ Other ____	□Farmed by owner □ Rented for cash □ Share rented 50/50 □ Other (specify) ____	□Precision Leveled ____yr % of field leveled ____ □ Multiple Inlets ____yr □ Permanent Perimeter Levees □ Conservation Tillage □ Other (please specify) ____	□ Yes □ No	Number of water inlets controlled by farmer ____	□Permanent □ Straight □ Contour □ None □ Other (specify) ____	Number of Levees ____	□Slope = 0.2% □ 0.2% > Slope > 0.1% □ Slope = 0.1% □ Slope = 0.05% □ Zero grade □ Other (specify) ____	NRCS funding □ Yes □ No	Cost-share with NRCS □ Yes □ No All Private funding □ Yes □ No □ Other____	□Yes if Yes, %water ____ □ No
LCRA: Owner: FSA number Description: Acres:	□Yes □ No	□Traditional □ Seed □ Hybrid □ Other ____	□Farmed by owner □ Rented for cash □ Share rented 50/50 □ Other (specify) ____	□Precision Leveled ____yr % of field leveled ____ □ Multiple Inlets ____yr □ Permanent Perimeter Levees □ Conservation Tillage □ Other (please specify) ____	□ Yes □ No	Number of water inlets controlled by farmer ____	□Permanent □ Straight □ Contour □ None □ Other (specify) ____	Number of Levees ____	□Slope = 0.2% □ 0.2% > Slope > 0.1% □ Slope = 0.1% □ Slope = 0.05% □ Zero grade □ Other (specify) ____	NRCS funding □ Yes □ No	Cost-share with NRCS □ Yes □ No All Private funding □ Yes □ No □ Other____	□Yes if Yes, %water ____ □ No
LCRA: Owner: FSA number Description: Acres:	□Yes □ No	□Traditional □ Seed □ Hybrid □ Other ____	□Farmed by owner □ Rented for cash □ Share rented 50/50 □ Other (specify) ____	□Precision Leveled ____yr % of field leveled ____ □ Multiple Inlets ____yr □ Permanent Perimeter Levees □ Conservation Tillage □ Other (please specify) ____	□ Yes □ No	Number of water inlets controlled by farmer ____	□Permanent □ Straight □ Contour □ None □ Other (specify) ____	Number of Levees ____	□Slope = 0.2% □ 0.2% > Slope > 0.1% □ Slope = 0.1% □ Slope = 0.05% □ Zero grade □ Other (specify) ____	NRCS funding □ Yes □ No	Cost-share with NRCS □ Yes □ No All Private funding □ Yes □ No □ Other____	□Yes if Yes, %water ____ □ No

Name	Description
CONSERVATION TILLAGE	Any practice where a field is not tilled in the spring before planting (including minimum tillage, stale seedbed planting, and limited tillage)
CONTOUR LEVEE	Unmodified slopes; levees are usually serpentine and irregularly spaced
CROP CONSULTANT	Whether or not management decisions (such as amount of water applied to a field, application of herbicides, pest control, rice variety etc) about rice production are influenced by an independent crop consultant
CONVENTIONAL RICE VARIETY	A rice variety such as Cocodrie or Cypress or Presidio
EXTENSION AGENT	Government sponsored agent who disseminate agricultural technical information by talking to farmers, sponsoring demonstrations, field days and meetings
FAILED 2ND CROP	Whether harvest of the rice field was completed or the rice field was abandoned
FARM GAUGE	Sensors installed on fields to transmit rainfall or other weather data to the farmer
FARMED BY OWNER	When the person who farms the land is the landowner
FIELD HAND	Paid labor used on the field to produce the rice crop
FLUSH	Number times irrigation water is applied to the field prior to holding a permanent flood
FUNDING	Whether or not a farmer received cost-sharing or incentive payments for installing/using conservation practices on this field
HYBRID RICE VARIETY	A hybrid rice variety such as rice tech varieties
IN-FIELD LATERAL	Presence of an open canal with a series on inlets controlled by the farmer to release water at multiple points on a field
LEVEE DENSITY	Number of levees used in the field as part of the irrigation system to cascade water from one level to the next; number of levees divided by the size of the field
MANAGEMENT DECISIONS	Decisions on farming practices such as crop variety, pesticides, water use, labor and infrastructure investments
MANAGER	Also called operator; paid worker who makes management decisions regarding rice production
MULTIPLE INLETS	Presence of unmetered multiple inlets on a field; multiple-inlet distribution is the practice of releasing water at multiple points along the side of a field utilizing a field lateral and multiple control structures instead of feeding all water through the highest cut of a rice field and cascading it down through each lower cut.
OWNERSHIP	Ownership stake: does the farmer own, rent, or only work the field
PERIMETER PERMANENT LEVEE	A field that contains permanent levees surrounding the field that are not plowed between growing seasons
PERMANENT FLOOD DATE	When floodwaters are maintained over the entire rice field throughout much of the growing season
PERMANENT LEVEE	Type of system used to apply water to a field; where the field contains permanent levees (e.g. in bench grading) that are not plowed between growing seasons
PLANTING DATE	Date the field was planted

PRECISION LEVEL	Whether or not a field was graded using laser-guided excavation equipment to a uniform slope equal to or less than 2 percent (conforming to minimum NRCS standards)
RENTED FOR CASH	When the person who farms the land is not the landowner and he/she pays cash to rent the field
SEED RICE VARIETY	Rice that is grown for the purpose of seed production
SHARE RENTED	When the person who farms the land is the not the landowner, but shares crop production from this field with the landowner
STRAIGHT LEVEE	Fields with 0.1 percent grade, where levees are usually straight or have a slight bending
VOLUMETRIC MEASUREMENT AND PRICING	The practice of measuring water use once a day at each farm turnout, equipped with a standardized aluminum slide gate, by determining flow rate with a portable velocity probe flow meter.
WELL	Whether or not wells were used to supplement water to irrigate a field
YEAR	Year when a field was in production (i.e., crop year)
ZERO GRADE	All slopes are removed; the fields are devoid of internal levees