Review of Agricultural Economics—Volume 30, Number 3—Pages 425–434
DOI:10.1111/j.1467-9353.2008.00416.x

*Efficient Conservation Measures in Irrigated Agriculture to Sustain Urban and Environmental Water Demands**

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The Lower Colorado River Authority (LCRA)-San Antonio Water System (SAWS) Water Project (referred to here as the LSWP) emerged from the Texas regional water supply planning process directed by the Texas Water Development Board, mandated by Senate Bill 1 during the 1997 Texas Legislature. That planning process identified water supply needs and recommended solutions for the lower Colorado River Basin and the San Antonio region. Several factors related to avoiding future water shortage motivated the need for this proposed project. Both San Antonio and the lower Colorado River Basin face long-term water shortages (LCRA/SAWS ; Institute for Science, Technology, and Public Policy ; Norvell and Kluge ; Eaton and Kabir). Cities, farmers, businesses, recreation, and the environment continue to see growing competition for water. The result of this growing competition points to three potential water shortfalls that could occur without special action.

First, agriculture in the lower Colorado River Basin could face a water supply shortfall of up to 50% by 2050. This would significantly affect the rice-growing

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*This paper was presented at the Principal Paper session, "The Economics of More Flexible Approaches to Simultaneously Meeting Competing Water Demands of Irrigated Agriculture, Cities, and the Environment," Allied Social Sciences Association annual meeting, New Orleans, LA, January 4–6, 2008.

The articles in these sessions are not subject to the journal's standard refereeing process.

communities in Colorado, Matagorda, and Wharton Counties where rice farming generates considerable economic benefits (HDR Engineering Inc.). Second, rural communities upstream of the City of Austin and the Highland Lakes, including Lake Travis and Lake Buchanan, foresee a potential shortfall of water by 2050. These rural communities need reliable adequate water supplies. Third, San Antonio faces long—term water shortages. The city's primary source of supply is currently the Edwards Aquifer. As a result of federal litigation under the Endangered Species Act (ESA) and with the support of the Texas Legislature, the Edwards Aquifer Authority (EAA) has imposed annual pumping limits for all water users in order to manage the aquifer and protect endangered species within the aquifer downstream. Beginning in 2008, SAWS' annual water allotment from the Edwards Aquifer will decrease. The SAWS has enacted extensive water conservation and reuse programs and is actively pursuing a range of options to meet its water supply needs. Still, the San Antonio metropolitan area's water needs will nearly double by 2050.

Considerable work has focused on forecasting agricultural demands for water in this region, but we are unaware of any previous work that has used rigorous economic principles guided by economic objectives and constraints facing irrigated agriculture to develop these water demand forecasts. The contribution of this work is to examine the economics of agricultural water conservation as a measure for dealing with potential costly water shortages facing irrigated agriculture interests of Colorado, Wharton, and Matagorda counties, Texas.

This article examines economically efficient measures that conserve surface water for urban and environmental uses while sustaining the economic well-being of irrigated agriculture. Reductions in irrigation demands serve the dual purposes of reducing projected future irrigation water shortages and increasing the water yield available for urban and environmental uses. A linear programming model was developed to identify factors influencing irrigated acreage, regional farm income, irrigation water demand, and potential irrigation water conservation. The model application is to rice-producer behavior guided by an economic objective. That objective is to maximize discounted net farm income, which assumes that producers make decisions that prefer a higher to a lower present value of net income. The model was used to forecast the time path of future irrigation water demands associated with several water-conserving measures with and without the proposed water-sharing agreement between the Lower Colorado River Authority and the San Antonio water system. These measures include (*a*) three levels of precision grading, (*b*) multiple inlets, (*c*) conservation tillage, (*d*) tailwater recovery, and (*e*) higher-yielding water-saving rice varieties. The model identifies the demand for water with and without the water-sharing agreement as well as the number of acres adopting each of the various conservation measures. Results are presented for both optimistic and pessimistic scenarios regarding crop prices, production costs, and water prices. This conserved water will allow the SAWS to implement its pumping restrictions on the Edwards Aquifer and protect associated endangered species, as well as secure water needs of its growing population and provide a more reliable water source for the rice farmers in the lower Colorado River Basin.

Methods

To meet this objective, a linear programming model was developed for use in quantifying factors influencing irrigated acreage, regional farm income, and irrigation water demand for the LCRA service area of Lakeside, Garwood, and Gulf Coast irrigation divisions in Texas' Lower Colorado River Basin for the period 2005–90. To support development of irrigation water demand and acreage projections, the model objective function was designed to identify rice-producer behavior that maximizes discounted net farm income. Rice is the only crop in the current model implementation. Maximum net farm income is found by examining the profitability of rice crops grown in Texas' lower Colorado River Basin using the required resources and incurring the costs required to produce these crops. Data on several measured variables are used in the model to determine irrigation water demands and acreage in production for the region. These variables include crop prices, crop yields, production costs, water costs, and three types of water conservation systems for Lakeside, Garwood, and Gulf Coast irrigation divisions.

As part of the farm revenue stream, federal rice support payments are included in the model. Crop enterprise budgets, developed by the Texas A&M Extension Service (Jensen 2003, 2004) and augmented by discussions with rice producers in early 2007, provided detailed economic information. This information includes current crop prices, variable production costs, fixed production costs, yields, farm program payments, and irrigation water applications. The model also includes assumptions on the costs of investing in three water-conserving land improvements (Kuhr), based on a detailed and comprehensive model developed by Texas A&M University (Wilson 2001–2006, 2006; Wilson and Yang; Wilson et al.; Wilson, Yang, and Stansel), known as RiceWCA (water conservation analyzer).

The Project

The LSWP, if implemented, would conserve water, develop groundwater, and capture excess and unused river flows to make available as much as 330,000 acre-feet of water a year. The project would conserve and develop water in three ways:

- Conserve irrigation water.
- Capture excess and unused river flows.
- Use groundwater for agriculture when surface water is not available.

Without project

Without-project conditions are defined as those current and future conditions from 2010 to 2090 that are expected to occur without special action taken by LSWP to promote water conservation. These conditions are defined as consisting of:

- Conventional rice varieties only, no higher-yielding rice varieties.
- No access by producers to LSWP cost share subsidies on water-conserving land improvements.

- Access by producers to federal (EQIP program) and Texas State (House Bill 1437) cost share subsidies on water-conserving land improvements. However, these cost share programs are expected to expire on or before 2010.
- Surface water availability for irrigated agriculture defined by the LSWP Surface Water Availability Team.
- LCRA surface water prices for interruptible supply and shortage allocation rules that would emerge over time without the Project implementation.

With Project

The with-project conditions are defined as conditions that will occur with the interventions by LSWP designed to promote water conservation. These are current and future conditions from 2010 to 2090 that are expected with the Project. Some of these conditions are defined by:

- New higher-yield rice varieties scheduled to be released 2010–11.
- Full access by producers to cost share subsidies on water-conserving land improvements.
- Continued access by producers to federal and Texas State cost share subsidies on water-conserving land improvements to the year 2010, but with only limited access after 2010.

On-Farm Water Conservation Measures

Baseline—No Conservation

The without-project level of water conservation is not zero conservation. Some producers have already implemented some of the conservation measures (Jensen 2006), and the Region K plan assumes a trend toward increasing water conservation without the project. Multiple inlets refers to the practice of releasing water through a series of inlets along an in-field lateral canal, rather than at one point at the top of a field and allowing the water to drain from cut to cut across the entire field. The in-field lateral is an open canal with turnouts. Intermediate checks may be required where the slope demands it. Precision grading is a term applied to the process of grading the land surface, often using laser-guided equipment, to improve water's movement across the field. It also provides more uniform depth of flood, minimizes the length of levees, and improves field drainage. Costs per acre of precision grading are included as part of the total costs of production. Conservation tillage consists of seedbed preparation in a field in the fall and letting it lie idle over the winter, then applying an herbicide treatment in the spring, followed by drill seeding. A no-till planter, which is more robust than a conventional drill seeder, is required to break through the more compacted soil resulting from conservation tillage. Tailwater recovery involves capturing tailwater in either a specially designed reservoir, or in a lower part of a bench-graded system. Water captured in the reservoir is then pumped either to the top part of the field from which the water flowed, or more often, to a field with inlets near the collection reservoir.

Water Use Requirements

For the current version of the model, costs per acre for both first and second crops are based on the Rice WCA model developed by Texas A&M University and from cost and return budgets. Second-crop-producer behavior outcomes for higher-yielding rice varieties are subject to considerably more uncertainty than for conventional varieties. Many of these uncertainties relate to the impact of rainfall, evaporation, and temperature over a growing season. Because the higher-yielding rice varieties have a longer growing season, it is assumed technically and economically infeasible to produce a second crop with the higher-yielding varieties.

Land Use Requirements

Each acre brought into production requires one acre of available land in the season when the production occurs. A single acre can be used for main crop early in the season, and second crop in the late summer and early fall. Total supplies of land for each of the three irrigation divisions are based on acreage in actual production for the year 2005.

Water Supply, Water Price, and Water Costs

Three major factors influencing the use of water in irrigated agriculture in the current version of the model are the supply of water, surface water price, rice production costs, and the annual equivalent cost of investing in the various conservation measures described above. For surface water supplies, irrigation costs to customers (measured in costs per acre-foot) were obtained from the LCRA for each of the three irrigation divisions. The cost and availability of groundwater is currently excluded from the model because of data limits.

Land Supply and Acreage Constraints

In addition to the data used from the sources described above, special resource constraints were included to reflect historical trends in acreage, cropping patterns, and water use. A constraint on irrigated land was incorporated to limit the acreage that can be currently used for irrigated rice production as well as limiting the future acreage that can be converted to more water-conserving irrigation delivery systems. Due to the differences in soil type and topography, not all areas can be converted to more water-conserving irrigation systems. This constraint prevents the model from converting all irrigated acreage to water-conserving measures that are not technically feasible, even though such conversions would be favored by an income maximization model lacking the constraint.

Production Costs

Nonwater production costs for the baseline scenario are based exclusively on the cost and returns budgets assembled from producer panels in early 2007. These budgeted costs include costs of fixed capital (buildings and machinery) and operating capital (interest). They also include costs for fertilizer, herbicides, pesticides, irrigation labor, and various postharvest operations, including rice drying, rice hauling, and rice storage. Generally, these costs are considerably lower for the second crop than for the first crop, since few additional resources are required for the second crop beyond additional water, labor, and fertilizer.

Figure 1. Acres adopting water conservation, without water-sharing project, optimistic prices and costs, Texas Gulf Coast

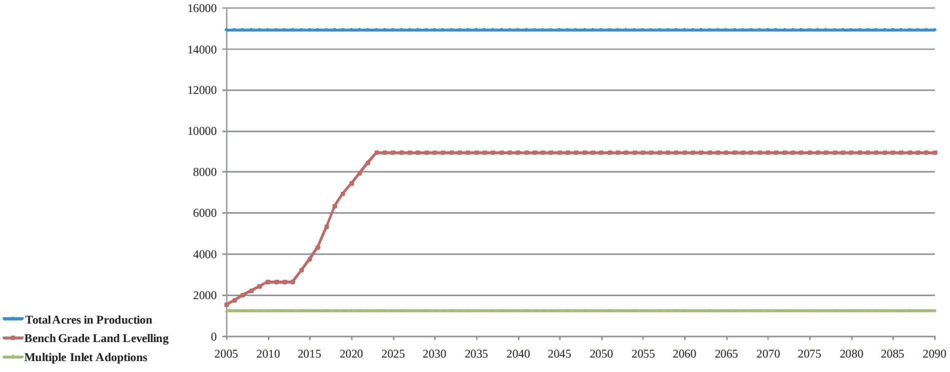
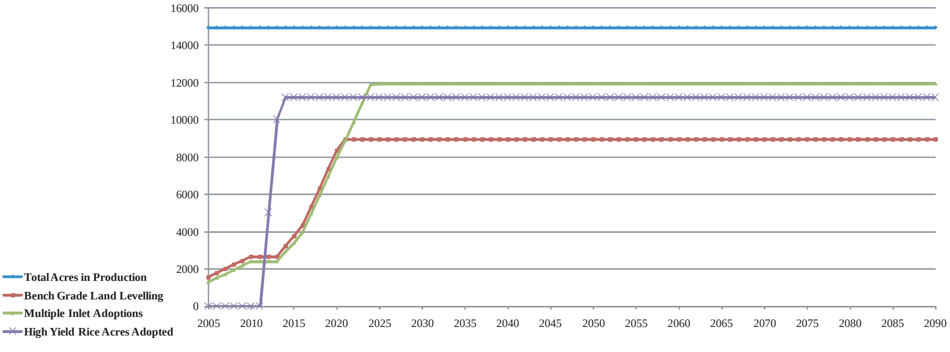


Figure 2. Acres adopting water conservation, with water-sharing project, optimistic prices and costs, Texas Gulf Coast



Results

Figures 1 through 6 show results from two scenarios that were intended to place reasonable bounds on the economic outlook for rice production in the Texas Gulf Coast region. Figures 1–3 show results for the optimistic case of rice prices, rice production costs, and irrigation water prices. Figures 4–6 present results for the pessimistic case of the same variables.

Figures 1–3 show that for the optimistic case, all acres enter production both without project and with the project, despite historical declines in the region's rice acres. Even without cost shares provided by the water-saving project or from other sources, producers still find it profitable to improve the land with precision grading (i.e., bench grading). Precision grading is the only land improvement that both increases crop yield and conserves water. The resultant positive impact on net present value from precision grading more than offsets the initial capital investment and annual operation and maintenance costs for all acres where this technology is technically feasible. However, absent the project, producers fail to invest in any other additional water-saving technology beyond what was in place by 2005. Absent the project, high-yield rice varieties are unavailable.

Figure 3. Water use with and without water-sharing project (ac-ft/year), Texas Gulf Coast: optimistic prices and costs

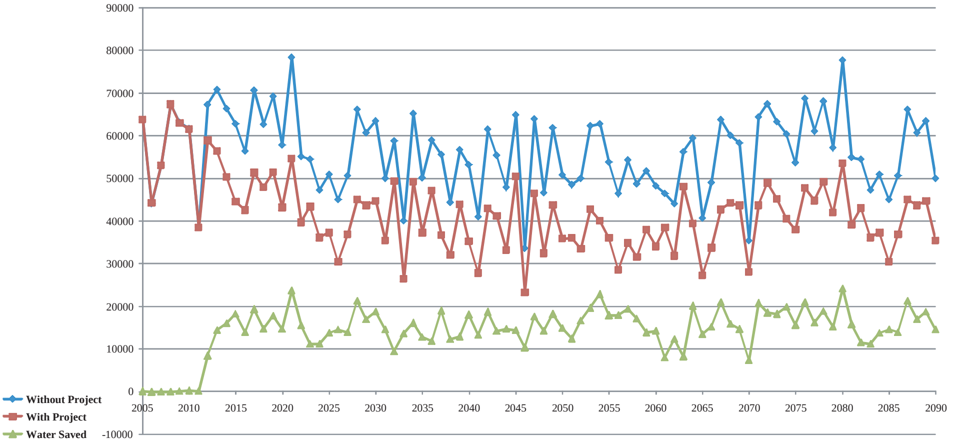


Figure 4. Acres adopting water conservation, without water-sharing project, Garwood division, Texas Gulf Coast: pessimistic costs and prices

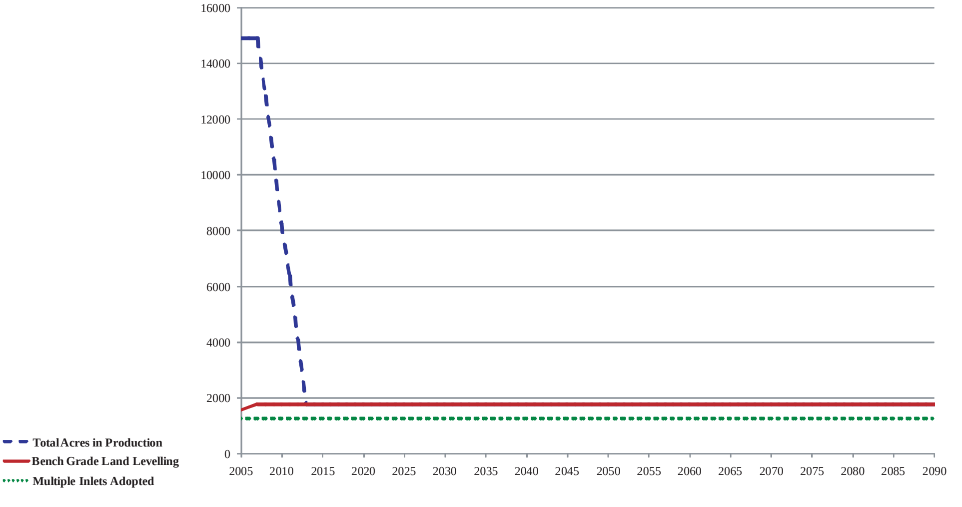


Figure 2 shows the with-project alternative for the optimistic case. When each technology is offered for zero up-front capital cost, notice that producers choose to add multiple inlets as well as precision grading, wherever technically feasible. Producers also find it profitable to adopt the high-yield rice varieties in spite of the foregone opportunity for second crop rice under this option. For all three of these technologies, the combined water savings and yield benefit are sufficient to offset the annual operation and maintenance costs. These technologies prove more beneficial to producers' net incomes than either conservation tillage or a tailwater recovery system.

Figure 5. Acres adopting water conservation, with water-sharing project, Garwood division, Texas Gulf Coast: pessimistic costs and prices

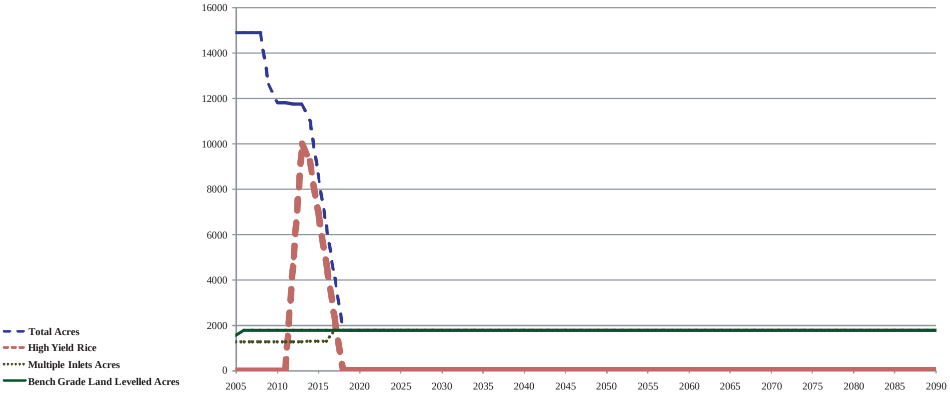


Figure 6. Water use with and without water-sharing project (ac-ft/year), Garwood division, Texas Gulf Coast: optimistic price and cost scenario

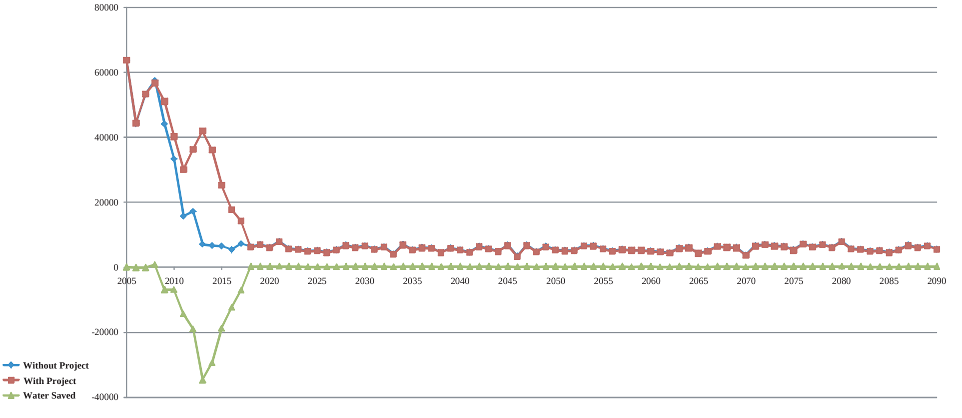


Figure 3 shows water use both with and without the water-saving project for the optimistic case. Annual variation in water use is due primarily to the variation in temperature, precipitation, and other factors related to evapotranspiration (ET). Given the unchanged total acres that producers choose to keep in production shown in figure 1, the downward trend in water use both with and without the project is due to investment in and increased use of water-saving technologies. Based on a repeat of the historical weather record, average on-farm water use is shown to fall both with time and with the project. The with-project alternative shows irrigators choosing to adopt several water conservation measures, resulting in an average net decrease in water use of about 30% or 15,000 acre feet per year relative to the without-project alternative.

In this scenario, rice production is sustained, net farm income is increased, and water is conserved and available for other uses.

Figures 4–6 show equivalent results under pessimistic future economic conditions for the region's rice production. They show that a combination of falling rice prices, rising production costs, and rising water prices drives out of production all acres save those that were so profitable they had already adopted conservation measures. Figure 4 shows that fewer than 2,000 acres stay in production for both with and without the Project, falling from the 2005 level of nearly 15,000 acres. The economic conditions in the pessimistic scenario are so unfavorable that even the promise of higher yields from precision grading and high-yield varieties coupled with a zero capital cost of investing in water conservation measures are insufficient to sustain rice agriculture in the Texas Gulf Coast region. Under this scenario, rice production falls to less than 15% of 2005 acres, and the foregone irrigation water is conserved and available for other uses.

Figure 5 shows that with the water-saving project, in an attempt to compensate for weak economic conditions, producers adopt high-yield rice for a brief time beginning in 2011, lasting until 2018. But even those investments are short lived and high-yield rice along with acreage already adopting multiple inlets before 2005 are gone by 2018. The only acreage remaining with the project are the few that had already invested in precision grading by 2005, which sustain themselves at just under 2,000 acres.

Figure 6 shows water use both with and without the water-saving project for the pessimistic case characterized by weak economics for the rice industry. The without-project alternative shows declining water use for the period 2005–13, as land in rice production falls to just under 2,000 total acres. The with-project alternative shows that adoption of high-yield rice allows up to 10,000 acres to stay in production for a short time that would not have survived without the project. However, by 2018, the delay in lost acreage induced by the project plays out, and total acreage even with the project falls to just under 2,000 acres. The savings in lost acreage induced by the project in years 2008–18 causes additional water use than would have occurred without the project. In this scenario, rice production is for the most part not sustained, net farm income is increased for a short period of time, and while considerable water is made available for other uses, none of that water is produced by the water-saving project itself, but instead is produced by very weak economic conditions facing the Texas Gulf Coast rice industry.

Conclusions

This article has presented results of a linear programming model that forecasts the demand for water with and without the water-conserving agreement as well as the number of acres adopting using each of the various conservation measures. Results are presented for both optimistic and pessimistic scenarios regarding crop prices, production costs, and water prices.

The best- and worst-case scenarios were designed to bracket the range of future economic conditions facing Texas Gulf Coast rice producers. The best-case economic scenario facing the state's rice industry keeps all acres in production in spite of historical declines. The worst-case conditions drive out all acres except those that were so profitable that they had already adopted conservation measures. The worst-case projections were so unfavorable that even high-yield varieties do not save the day.

References

Eaton, D.J., and J. Kabir. *Assessing Future Rice Irrigation Demands in the Lower Colorado River Authority Service Area*. Lyndon B. Johnson School of Public Affairs, University of Texas at Austin, 2000.
HDR Engineering Inc. *Consideration of Economic and Other Factors Related to a Change in Irrigation Water Pricing*. Consulting report, available from the Lower Colorado River Authority on request. Austin, TX, 2004.
Institute for Science Technology and Public Policy. *Ecological, Economic, and Policy Alternatives for Texas Rice Agriculture*. Texas: Texas Water Resources Institute, TR-181, 2000.
Jensen, K. *Lakeside Farmer Landowner Acreage and Tenure History*. Unpublished dataset, available from the Lower Colorado River Authority on request, 2003.
——. *Representative Cost and Return Budget for Irrigated Rice*, Lower Colorado River Basin. Texas: 2004.
——. *Monthly Irrigation Demands from LCRA 2010–2060*, Unpublished dataset, available from the Lower Colorado River Authority on request. 2006.
Kuhr, K. *Unit Prices for Agricultural Conservation*. Parsons & Martinez, Wright, and Mendez, 2006.
LCRA/SAWS. *Program Summary*, *Lower Colorado River Authority—San Antonio Water System Water Project*. Austin, TX: LCRA/SAWS, 2005.
——. *Sharing Resources to Ensure Enough Water for the Future*, Austin, TX: LCRA/SAWS, 2006.
Norvell, S., and K. Kluge. *Socioeconomic Impacts of Unmet Water Needs in the Lower Colorado Water Planning Area*. Austin, TX: Texas Water Development Board Office of Water Resource Planning, 2005.
Wilson, L.T. *Development of a Web-Based Rice Water Conservation Analysis Model (Software Documentation)*. Beaumont, TX: Texas A&M University, 2006.
——. *Texas Rice Newsletters*. Texas: A&M Research and Extension Center 2001–2006. Accessed July 2006. Available at http://beaumont.tamu.edu/eLibrary/eLibrary_default.htm.
Wilson, L.T., and Y. Yang. *Rice Water Conservation Analysis Database Schema*. Beaumont, TX: Texas A&M Research and Extension Center, 2006.
Wilson, L.T., R.E. Tabien, S.O. Samonte, and J.C. Medley. *LCRA/SAWS High Yielding*, *Water Efficient Rice Development Project 2005. Comprehensive Progress Report*. Beaumont, TX: Texas A&M Research and Extension Center, 2005.
Wilson, L.T., Y. Yang, and J. Stansel. *Development of a Web-Based Rice Water Conservation Analyzer (Model Documentation)*. Beaumont, TX: Texas A&M University, 2006.