Biological Control of Giant Reed (*Arundo donax*): Economic Aspects

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Abstract: *Arundo donax* is a large, invasive weed consuming large quantities of water in the riparian area of the Texas Rio Grande Basin. With water availability a concern to the area, the USDA-ARS is investigating biological control agents to increase available water, creating a benefit to both the region's economy and society in general.

Introduction

Water is a vital resource needed for life. As populations continue to grow, the availability of fresh water is of concern, especially for regions such as the Texas Lower Rio Grande Valley. This region is one of the fastest-growing metropolitan areas in the United States (U.S. Census Bureau 2000). As such, growing demands for water have placed pressure on city leaders to find alternative ways to conserve existing water supplies. One such method currently under examination is through the control of an invasive species, *Arundo donax*.

Arundo donax (a.k.a. giant reed) is a large, bamboo-like plant that grows 20-30 feet tall and consumes large quantities of water, as much as 528 gallons per square meter (Bell 1997). Giant reed thrives in the Mediterranean climate of the Rio Grande, and without any native control, the plant has invaded several thousand acres of the Rio Grande riparian area. This invasion is not only consuming large amounts of water, but since the plant has grown to such a high density, the Border Patrol has experienced safety and security problems, as infrared sensors cannot detect any heat beneath the plant canopy (Goolsby 2007).

In an effort to control giant reed and alleviate Border Patrol and water-demand concerns, the United States Department of Agriculture-Agricultural Research Service (USDA-ARS) is investigating four insects for biological control of *Arundo donax* (Goolsby 2008). This paper examines the economic implications for the Texas Lower Rio Grande Valley of using these biological control agents, including (a) a base analysis of the water saved being applied to agriculture irrigation due to the reduction of *Arundo donax*, (b) a benefit-cost analysis, and (c) an economic impact analysis for the region.

Summary of Methodology

This project encompasses many different disciplines, including teams from entomology, genetics, rangeland ecology, and resource economics. Due to the multi-disciplinary nature and early stages of this project, a form of the Delphi technique was employed to estimate the impacts of biological control, whereby several experts were repeatedly interviewed until a consensus was reached among the experts. The USDA-ARS provided data of the acreage infested with giant reed. The study and release of the biological-control agents are still under investigation as primary data continue to be collected. Thus, the results presented are preliminary.

This research involves several steps to estimate the impacts of the biological controls. The temporal biology of the plant must be approximated, along with water use to establish a base for estimating savings and effectiveness. The estimated level of control of *Arundo* is then used to determine the associated water savings. Recognizing water savings over future years, the value of this water is estimated assuming it is used to irrigate crops. Lastly, a benefit-cost analysis and the economic and employment impacts of the water savings are estimated.

Plant Growth

To model the amount of water saved from the control of the plant, an unmitigated base situation is estimated with continued *Arundo donax* plant growth and acreage expansion. This benchmark is established by estimating the number of acres present, and then using an expansion rate of the plant to project the number of acres in future years. From this base situation, the expected water savings and associated potential value of saved water (due to the control of *Arundo* from the release of the biological-control agents) are estimated. Although the mathematical results in this analysis identify water saved from the reduction of acres infested with *Arundo donax*, actual reduction of *Arundo* from the insect release will not likely strictly occur in the form of fewer acres, but rather in the form of a reduction in the density and height of the plant, as well as possibly some modest acreage reduction. This study used reduced acres, however, as a proxy for reduction in *Arundo* biomass. This is an assumption of convenience for the analysis, assuming the analytical results are comparable to realty.

USDA scientists provided data of estimated infested acres for 2002 and 2008, with a total growth rate of 15% over the time period (Yang 2008). Distributing the growth equally among the years suggests an annual growth rate of 2.36%. This yearly rate is used to forecast expected growth 50 years into the future, which is the base used to estimate impacts of *Arundo* control scenarios.

In 2007, a natural occurrence of a wasp (one of the four insects selected for biological control) was discovered near Laredo (Goolsby 2008). A study of the impact of the natural occurrence of the wasp indicates its impact is minimal. Although the impact is minimal, the effect of the natural spread of the wasp is included in establishing the base from which impacts of the introduced biological agents are estimated.

Potential Water Saved

The *Arundo* water consumption rate found in the literature is applied to the reduced acreage of giant reed to assist in the projection of the amount of potential water saved. However, water use by native replacement vegetation is considered to realize an estimate of net water savings. The resulting net water saved is allocated to an irrigated composite acre based on specific crop usage levels specified in the Texas AgriLife Extension Service crop enterprise budgets for the region (Texas AgriLife Extension Service 2007). The resulting calculations represent the direct impacts of the biological control of giant reed. Environmental and recreational values are not included, nor are benefits accruing to the Department of Homeland Security and the Border Patrol.

Value to the Rio Grande Valley

Associated with the control of *Arundo* is an expected increase in irrigated acres that are converted from dryland production in the defined study area. Such acreage conversion suggests increased yields and higher values of production. The initial estimate of the value of *Arundo* control is based on the increase in returns to water (based on crop prices received and costs paid by farmers). This net value is estimated annually 2009-2058, as control becomes more effective and extensive through time. Using capital budgeting techniques, the present value of annual returns, as well as the present value of total water saved, is calculated for the 50-year (2009-2058) planning horizon.

Water Valuation

Since municipalities have a legal priority for water and receive sufficient water to meet their needs, any increase in water is logically used for irrigation (Griffin 2006); i.e., agriculture is the residual beneficiary of any increases in real water supplies.[1] To determine the direct impact of the saved water from the control of *Arundo donax*, the value of irrigated water is used as the appropriate measure of benefits. This is accomplished by developing a composite acre for dryland crops, and also for irrigated crops. A composite acre is a representative acre consisting

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[1] The valuation of water for use on irrigated crops is based on the criteria that municipalities in the area have a priority for water supply and are already receiving the amount they need, i.e., they receive first priority and there are sufficient supplies to handle their needs. As a result, all additional water realized through the mitigation of *Arundo donax* is assumed used in agriculture and adds value to crops. Some acreage of some crops currently being farmed as dryland acres are converted to irrigated acres. Irrigation crops typically leads to higher yields, resulting in positive returns to water (Lacewell 2008).

of the respective proportionate number of acres of the different crops in a region (Lacewell et al. 1995). Further, to facilitate estimating a range of potential benefits, two irrigated crop composite acre budgets are established, one consisting of all irrigated crops, including those with high-marginal returns such as citrus and vegetables, and another for only irrigated crops with relatively low-marginal returns, such as cotton, corn, and sorghum.

The difference in net returns between the two scenarios of composite irrigated acres and the composite dryland acre represents returns to water. Consideration of the amount (i.e., acre-feet) of water used per respective composite irrigated acre facilitates determining a range of per unit values of the water.

Composite Acre Development

The most current available data of planted acres from National Agricultural Statistical Service and Texas AgriLife Extension Service crop enterprise budgets are used to develop a composite acre for each of the three categories listed above; i.e., dryland, irrigated high-value crops, and irrigated low-value crops. Data for planted acres are taken from National Agriculture Statistics Service (USDA-NASS) and averaged for 2000-2007 for each crop. Exceptions occur for vegetables and citrus, where only the 2002 census data are available, and sugarcane, where only 2001-2007 harvested acres are available.

When determining the value of the saved water, two sets of crop prices are used: (a) current expected prices received by farmers, and (b) normalized prices developed to account for significant price fluctuations in the short term (Roberts 2007), as well as removing the effect of government farm programs. Market prices are used for estimating direct benefits or impacts to the region, while normalized prices provide the basis for estimating benefits to society. Impact analysis is based on the change in gross returns and the current prices received by farmers (Lacewell 2008).

Benefit-Cost Analysis

The irrigated composite acre (including higher-value crops and alternatively only with the lower-value crops) is applied to the projected net quantity of water saved as a result of the deployment of the beneficial insects. The result is an estimate of the market value of the net water saved to the Rio Grande Valley due to the effectiveness of the biological controls. The normalized prices applied to the crops of the composite acres are also multiplied by the number of acre-feet of water saved from the use of the biological control agents. The annual costs of the beneficial-insect control program and annual benefits are inflated at 2.043% and then discounted at 6.125% discount rate to calculate present value of benefits and costs (Rister et al. 2008). These values are used in developing the benefit-cost analysis of the project for the Rio Grande River Basin. For social benefits in a benefit-cost analysis, the normalized prices for crops are applied (Lacewell 2008).

Economic Impact Analysis

Economic impacts to the Texas Lower Rio Grande Valley in terms of economic activity and employment due to the projected saved water are determined using the IMPLAN model, an input/output model developed by Minnesota ImPLAN Group, Inc. (2004). This model generates multipliers to estimate increased economic activity and employment resulting from an increase in gross revenue by sector (crops in this case). The multipliers can be developed for a region such as the Lower Rio Grande Valley, a state, or the entire United States. The ImPLAN approach to estimating economic impact is widely used by economists in measuring the consequences of existing and potential activities (Lacewell 1995).

To estimate the employment and economic impact to the region of control, market prices for crops are used (Lacewell 2008). The added irrigated composite acres generate a total revenue value (gross sales) associated with the biological control program. Similarly, a composite dryland (non-irrigated) acre for agriculture represents reduced total revenue as it shifts to irrigated production. The change (increase) in gross revenue associated with the additional irrigated acreage above the replaced dryland acres provides an estimate of the direct economic effect and a basis for further analysis. The change in gross revenue is estimated for each year of the 50-year projection period, where there are greater *Arundo* control and greater annual benefits to be realized over time.

Results

Results were generated based on data provided by the USDA-ARS, USDA-NASS, and the literature for water use, compound rate (i.e., inflation), and discount rate. To date, the results indicate positive returns and a positive impact to the economy from controlling giant reed.

Plant Growth

The results reveal *Arundo donax* reaches a maximum of approximately 58,000 acres by the year 2058, growing at a rate of 2.36% per year with no control from natural insect infestation. Projecting the effect of natural occurrence of the wasp (natural insect infestation) over the 170 miles prevalent area of infestation results in an estimated effective 1,000 acres of reduced *Arundo*, and suggests a minimal impact of the natural wasp without the use of additional (i.e., introduced) biological control. Although mathematically an estimated 1,000 acres of *Arundo* are controlled by the natural insect infestation, the area of reduction occurs throughout the 58,000 acres and does not represent a separate and independent 1,000 acres of *Arundo*.

Water Use and Valuation

To decipher the total value that controlling giant reed has in association with the amount of water saved, the percent control from the release of the insects is applied to the total acres infested with *Arundo donax*. The number of acres controlled are then multiplied by the *Arundo* water use per acre to obtain total potential reduction in water consumption by *Arundo* for the region. After accounting for water uptake from natural vegetation regrowth and Mexico's allotment of the water, the amount of U.S. water saved in year one totals 912 acre-feet and amounts to more than 57,000 acre-feet in year 2058.[2] The net water savings amount to approximately one acre foot per acre of expected infestation.

Composite Acre

The composite acre approach was developed to calculate the value of the water to the region and is assumed to reflect a representative acre of the crops in the Lower Rio Grande Valley. The composite acre with low-marginal crop values, including corn, cotton, and sorghum, has an estimated return to water of $190 per acre-foot using market prices, and $139 per acre-foot using normalized prices (Table 1). The high-marginal value crops composite acre include corn, cotton, sorghum, citrus, vegetables, and sugarcane, and has an estimated composite acre

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[2] The study area is also located in a gaining reach of the River, where several "no name" tributaries add water to the main stream. Any measured gains from these tributaries in this reach of the River can be considered as split 50/50 between the United States and Mexico (Rubinstein 2008).

return to water of $273 per acre foot using market prices, and $259 per acre-foot using normalized prices (Table 1).

Table 1. Per Acre Irrigated Crop Water Use Estimates and Returns per acre-foot: High-Value and Low-Value Composite Acre, Lower Rio Grande Valley, 2008.

Irrigated Crops	Water Use (acre-feet per acre)	Value of Water Returns to Water ($/acre-foot)	
		Market Prices	Normalized Prices
High-Marginal Value	1.40	$ 272.97	$ 258.98
Low-Marginal Value	0.54	$ 190.39	$ 139.22

As illustrated in Table 1, the high-marginal value irrigated crops use approximately 1.40 acre-feet of water per composite acre, while the low-marginal value irrigated crops use approximately 0.54 acre-feet of water per composite acre. The water use per acre for high- versus low-value crops ultimately impacts the number of acres converted from dryland crops to irrigated crops, with the addition of the water saved from the control of giant reed upstream.

Total Value of Water Saved

Based on 2009 dollars, the total value to the Rio Grande Valley of the water saved in 2009 using the low marginal-value irrigated crop composite acre is more than $173 thousand, compared to $4.5 million for 2024 and $10.0 million in 2058, using market prices. Inflated at 2.043% and discounted at a rate of 6.125%, the net present value for 50 years (2009-2058) is $100.4 million for the low-marginal value crops. Results for the high marginal-value crops were similarly obtained, producing a total value of $249.1 thousand for 2009, $6.4 million for 2024, and $15.7 million for 2058. When the sum total for 50 years (2009-2058) is inflated at 2.043% and discounted at 6.125%, a net present value of $144.0 million is obtained. These results are presented in Table 2.

Table 2. Real Returns to Saved Water Using Market and Normalized Prices, *Arundo donax* Control, Lower Rio Grande Valley, 2009-2058.

	Returns to Water in Million $	
Composite Acre Value Classification of Irrigated Crops	Market Prices	Normalized Prices
Low-Marginal Value	$100.40	$73.40
High-Marginal Value	$144.00	$136.60

Benefit-Cost Analysis

For the benefit-cost analysis, normalized prices are used to reflect the social benefits of the saved water. Similar to the market-price analysis, the totals are summed, inflated at 2.043%, and discounted by 6.125% to obtain the net present value. The low-value crop mix has a net present value (normalized) of $73.4 million, and the high-value crop mix has a normalized net present value of $137.0 million, as shown in Table 2. The costs of the program were provided by Goolsby (2008) and are $1,000,000 for each year from 2007 to 2010, $2,000,000 in year 2011, $3,000,000 in year 2012, $4,000,000 in year 2013, $5,000,000 in year 2014, $1,500,000 in year 2015, and $500,000 in year 2016. The present value of the program costs was estimated at approximately $16,850,000. The present value of benefits is divided by the net present value of the project costs to calculate the benefit-cost ratio, as shown in Table 3. The low-marginal returns crop mix has a benefit-cost ratio of 4.36, and the high-marginal returns crop mix has a benefit-cost ratio of 8.11.[3]

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[3] Benefit-cost ratios equaling 1.0 are considered "breakeven." These ratios exceeding 1.0 are considered favorable.

Table 3. Benefit-Cost Analysis Results, *Arundo donax* Control, Lower Rio Grande Valley, 2009.

	Social Benefits (Using Normalized Prices)		
	Low Value of Water	High Value of Water	Costs
NPV ($)	$73,430,163	$136,591,524	$16,849,799
Value per Year	$4,740,027	$8,817,187	---
Benefit-Cost Ratio	4.36	8.11	---

Since the present value of the benefits is greater than the present value of the costs, in both cases, these results suggest that the biological control project is economically viable. The benefit-cost ratio is an indication of the returns to society per dollar of government cost.

Economic Impact

Multipliers for economic activity, value-added, and employment are applied to assess the economic impact of controlling *Arundo*. The impacts are estimated based on increases in gross returns to crops for the Lower Rio Grande Valley (the Southernmost region of Texas – the four counties of Cameron, Hidalgo, Starr, and Willacy) and for the state of Texas. The IMPLAN program (Minnesota ImPLAN Group, Inc. 2004) is the source for the economic multipliers. Additionally, the gross revenues for each crop have been obtained from the Texas AgriLife Extension Service crop budgets. Results for this phase of the project are currently in the process of verification.

Discussion

The water saved as a result of the biological control of *Arundo donax* along the Rio Grande occurs between San Ignacio and Del Rio on the Mexico-Texas, U.S. border. Water flow for this reach of the Rio Grande is controlled by the operation of Falcon and Amistad dams. The reduction in *Arundo* suggests increased flow into the reservoirs. Since Falcon has more water losses than Amistad, any water saved between the dams will allow more water to be held at Amistad, thus improving the efficiency of the system (Rubinstein 2008).

The early involvement of economists in this project has provided opportunities for participation during the total research project. This has been helpful in ensuring the appropriate (e.g., type and required accuracy) data are collected to conduct the economic analyses.

The use of the biological control agents is anticipated to result in added water for use in the Texas Lower Rio Grande Valley. With rapid population growth and shortfalls of water, this will be beneficial to the region and help to maintain irrigated agriculture. A key piece of the study relates to whether the benefits justify the expenditures of federal (social) resources. The amount of water saved, and the value thereof, from the control of giant reed is still an estimate at this date (i.e., February 2009).

The USDA-ARS is in the process of obtaining a permit for the release of one beneficial insect and is in the process of receiving permission for the release of a second insect. Once *Arundo donax* is controlled, more water will be available for South Texas. Given agriculture is expected to be the beneficiary of the saved water, there will be added acres irrigated, which means more production of commodities and hence, increased returns and increased gross revenue. The overall conclusion of this report is a favorable benefit-cost ratio, the creation of jobs, and added economic activity.

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