Value of Water Conservation Improvements on Arkansas Rice Farms

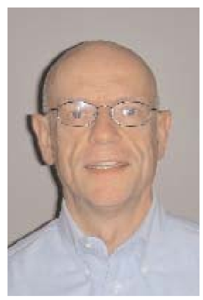
By Kenneth B. Young, Eric J. Wailes, Jennie H. Popp, and James Smartt

Abstract

The net present value (NPV) of net returns to rice and soybean land in eastern Arkansas is estimated to range from $283 to $3,300 per acre in alternative resource situations. Investment in water conservation improvements to increase irrigation efficiency and to conserve rainfall runoff greatly enhances land values in the face of a declining ground water supply. The MARORA model is used to estimate the NPV of net returns to land under alternative ground water supply conditions with and without on-farm water conservation improvements including reservoirs/tail-water recovery systems, underground pipe conveyance systems, and land leveling.

Introduction

Ground water from the Alluvial Aquifer in eastern Arkansas is used to irrigate about four million acres of crops (Scott et al., 1998). With increased aquifer exploitation, the water table has declined, forcing owners to lower their pumps and/or drill additional wells to maintain the irrigation level. Increased attention has been given in recent years to better utilize both the remaining ground water and rainfall with greater use of on-farm reservoirs, tail-water recovery, and the adoption of water-conserving cultural practices.

Kenneth B. Young is a senior research associate in agricultural economics at the Univeristy of Arkansas in Fayetteville. He received his B.S. and M.S. degrees from the University of Manitoba and Ph.D from Montana State University. His current interests include rice irrigation economics and the transport and marketing of poultry litter.

Eric Wailes is the L.C. Carter Professor with the department of agricultural economics and agribusiness, University of Arkansas, Fayetteville. He earned his B.S. degree at Cornell University and Ph.D. degree at Michigan State University. He teaches courses in agricultural policy, marketing and development economics. His research focuses on the economics of rice production, marketing and trade.

Jennie Popp is an Associate Professor in the Department of Agricultural Economics and Agribusiness. Her current areas of research include risk management and the identification of agricultural best management proctices to sustain water and soil resources. She received her B.S. degree from University of Scranton and her M.S. and Ph.D. degrees from Colorado State University.

James Smartt is a Research Associate in the Department of Agricultural Economics and Agribusiness at the University of Arkansas. He received his B.A. degree from the University of Texas at El Paso, and his M.S. in computer science from New Mexico State University. Current projects include agricultural water usage modeling and an interactive grain merchandising instructional game.

Less than 45 feet of saturated thickness remain in the Alluvial Aquifer in the older, more developed irrigated areas of eastern Arkansas such as the Grand Prairie (Scott et al., 1998)[1]. Remedies to supply additional water are limited. Artificial recharge is not economically feasible (Smith and Griffis, 1972, Fitzpatrick, 1990, White et al., 2000). Average annual natural recharge in the region is less than 1.5 inches because of the relatively impermeable clay cap overlaying the aquifer (Scott et al., 1998). Proposals to supply new external surface water sources for irrigation in the region including diversions from major rivers such as the White River have been strongly contested to date because of economic and environmental concerns (U.S. Army Corps of Engineers, 1998). Authority to regulate new well drilling has been established for critical aquifer areas but no restrictions have been imposed yet (Scott et al., 1998).

Eastern Arkansas is an important agricultural region, producing nearly half of all rice in the U.S. The climate is humid sub-tropical, with about 50 inches annual rainfall. Irrigation is essential for the rice crop, which is valued at nearly one billion dollars per year. Irrigation is also needed to assure good cotton and soybean yields due to frequent drought periods during the summer months.

Due to the importance of irrigation for agricultural production, the available ground water supply, access to on-farm surface water sources, investments in on-farm improvements to conserve rainfall and tail-water runoff, and increases in irrigation application efficiency all determine the value of irrigated farmland in eastern Arkansas. To evaluate the impact of water conservation improvements on land value, a farm level irrigation system analysis model identified as Modified Arkansas Offstream Reservoir Analysis (MARORA) was developed at the University of Arkansas (Young et al., 1998, Wailes et al., 2000, 2002). The value of the local ground water supply situation and water conservation improvements on a farm are assessed with this model by evaluating the NPV of projected annual net farm income with and without the water conservation improvements. Major water conservation improvements that increase irrigation application efficiency in eastern Arkansas include precision land leveling, underground pipe, and on-farm water collection reservoirs and tail-water recovery systems (Wailes et al., 2002, Popp et al., 2003).

The major objective of this study is to estimate the NPV of net returns to land and the water use per acre with and without the use of on-farm water conservation improvements. The model evaluates the economics of water conservation improvements on eastern Arkansas irrigated cropland. This objective is achieved by estimating the benefits and costs of on-farm reservoirs and tail-water recovery systems, underground pipe, and land leveling under two alternative ground water supply situations. This study demonstrates the use of MARORA to estimate the impact on NPV of the net returns to the land, the benefit/cost ratios of different water conservation improvements, plus the water use and irrigation costs for rice and soybeans with alternative water conservation improvements. The water conservation improvements that are evaluated include a reservoir/tailwater recovery system, underground pipe, land leveling, and combinations of two or more of these improvements.

Competition Between Ground and Surface Water Use

Past economic analyses of water conservation improvements by agencies such as the Natural Resource Conservation Service (NRCS) have typically been based on general guidelines developed from farm case studies. Few studies have used simulation modeling to estimate the value of these improvements (Hill, 2003). Assessment of the economic value of a rainfall storage reservoir to a farm operation for irrigation is relatively complex in Arkansas. Ground water is generally a much cheaper water source than surface water collection with on-farm reservoirs in Arkansas as the ground water pumping level averages less than 150 feet in the Arkansas alluvial aquifer (Scott et al., 1998). As shown in previous analyses (Young et al., 1998, Wailes et al., 2000), most producers will drill more wells rather than invest in on-farm reservoirs and idle valuable cultivated land because the NPV of net income to land is generally higher with wells compared with reservoirs. Thus, it is difficult to stop the continued depletion of ground water reserves in eastern Arkansas.

Use of an on-farm rainfall collection reservoir is essential to sustain irrigation without adequate ground water or other reliable surface water access. Other water conservation improvements to increase irrigation application efficiency such as underground pipe have little value without some source of irrigation water. On-farm rainfall collection reservoirs are currently the only water conservation improvements that an eastern Arkansas individual farmer can adopt to sustain irrigation when ground water irrigation is no longer feasible.

Description of MARORA

The MARORA model is a simulation model that is designed to estimate the optimal reservoir investment that will maximize the NPV of net returns to land. Major components of the model are: 1) soil water balance, 2) ground water hydraulics, 3) crop yield estimation, 4) reservoir water balance, and 5) an incremental search optimization to identify the optimal reservoir capacity that will maximize the NPV of the net annual farm income discounted over a long term time period. Water conservation improvements including precision land leveling and underground pipe are accounted for in the model in terms of the effect of such improvements on irrigation efficiency (Smartt et. al., 2002). Effects of improvements in irrigation efficiency are assumed to be additive when a combination of underground pipe and land leveling is used.

The MARORA model incorporates equations to calculate the daily soil water balance equation for rice and soybeans, the daily reservoir balance if a reservoir is used, and the daily surface and ground water use for irrigation. Crop yield and crop water use are estimated as a function of the crop transpiration over the growing season. The ground water table decline rate is specified exogenously based on reported average annual decline rates in the region of study (ASWCC, 2003). However, the daily well draw down for each well is calculated by the model, and pumping is terminated when the point of maximum draw down is reached.

Other equations incorporated in the MARORA model calculate: 1) the amount of dirt removal and loss of cropland to construct on-farm reservoirs, 2) the impact of a declining water table level on well yield, and 3) the amortization of investment costs for on-farm reservoirs and other water conservation improvements.

A weather generator sub-model based on historic Arkansas rainfall data estimates daily rainfall, evapotranspiration, and other weather data during the growing season. The only ground water supply parameters that change from year to year are the water table level and annual rate of decline which determine well yield over the period of projection. New wells may be added over the projection period to maintain the water supply as a program option where the remaining saturated thickness is adequate to make new well drilling economically feasible.

The model permits rice to shift out of the rotation to soybeans with less water requirements when water is restricted. The rotation evaluated in this study is one year of rice followed by one year of soybean unless a water constraint on rice is reached. A rice-soybean rotation is commonly used in Arkansas to prevent disease or weed build up problems such as red rice. Dryland soybeans are produced when irrigation is terminated. Water use is optimized on an annual basis to maximize the NPV of annual net income from land.[2]

Description of Water Conservation Improvements

An on-farm reservoir/tail-water recovery system has a storage reservoir constructed with levees, a collection ditch or pit to recover the runoff, and lift plus discharge pumps. The MARORA model estimates the cropland area allocated to reservoir construction and the system cost.

An underground pipe system includes buried pipe and risers to connect the water source to all irrigated fields. Precision land leveling reduces the number of field levees and the field slope to about 0.1 percent. Conventional non parallel contour levies are replaced with parallel straight levies after leveling. Assumptions regarding the cost and effect on irrigation efficiency of alternative improvements are shown in Table 1.

Methodology

For this study, MARORA evaluates water conservation improvements for two ground water situations: (1) relatively adequate and (2) relatively inadequate (Table 1). Situation (1) has 50 feet of initial saturated thickness and 0.5 feet annual decline. Situation (2) has 30 feet of initial saturated thickness and 1.0 feet annual decline. Water conservation improvements that are evaluated include: (1) underground pipe to increase irrigation efficiency by 10 percent, (2) moderate-efficiency land leveling to increase irrigation efficiency by 10 percent and crop

Table 1. List of assumptions for estimating NPV of net returns to land

Item	Assumptions[1]
Baseline Model	irrigation efficiency of 45% for soybeans and 50% for rice
Reservoir/T-W System	captures 80% of tail-water and rainfall run-off with a 30-year projected life; cost varies with reservoir size
Wells	cost $14,500 with 1200 GPM capacity and 30-year life unless water is depleted; three wells are used on 320 acres
Well pumps	complete pumps cost $14,000 with a 15-year life unless water is
NPV of income	discounted annual net farm income at 8% for 30 years (8% is 10-year average private rate for land loans)
Relatively adequate ground water	50 feet saturated thickness and 0.5 feet annual decline
Relatively inadequate ground water	30 feet saturated thickness and 1.0 feet annual decline
Underground pipe	buried pipe costs $94/acre; increases irrigation efficiency 10% above the baseline
Land leveling	leveling cost $300/acre; increases irrigation efficiency by 10 to 20% plus crop yield by 10%
Crop prices	rice $4.75/bu, soybean $5.80/bu; prices are based on loan rate plus direct payments and counter cyclical payments
Crop yields	rice 160 bu/acre, soybean 50 bu./acre; yields increased 10% with land leveling
Crop rotation	1:1 rice-soybean rotation as continuous rice can cause a red rice problem
Crop production cost	basis 2003 Arkansas CES estimate
Rainfall data	historic weather for Stuttgart, Arkansas
Reservoir cost	$1.00/cubic yard dirt excavation plus $700/acre levee seeding cost
Land area	360 acre cultivated tract, less land allocated to reservoir/tail-water system construction

[1] The assumptions listed are representative of conditions on rice-soybean farms in eastern Arkansas. Other assumptions and data sources are reported by Smartt et al., 2002. The 2002 report is available on request by contacting Jim Smartt at 479-575-2378 or jsmartt@uark.edu

yield by 10 percent, (3) high-efficiency land leveling to increase irrigation efficiency by 20 percent and crop yield by 10 percent and (4) an on-farm reservoir and tail-water recovery system to recapture 80 percent of the rainfall runoff and tail-water loss as a source of irrigation water. The analysis includes assessment of the reservoir/tail-water system, underground pipe and land leveling as individual conservation improvements and combinations of these improvements.

The NPV of net returns to land is estimated for two alternative ground water situations with and without water conservation improvements. The three water conservation improvements and combinations of these three improvements including a reservoir/tail-water system, underground pipe, and land leveling are evaluated with respect to their estimated investment cost and their effect on NPV of net returns to land to compute a benefit/cost ratio. Assessments of the economic feasibility of water conservation improvements are based on the respective benefit/cost ratios.

Source of Data and Assumptions

All key assumptions including production cost, yields, etc., used in this study are reported in Table 1. Data inputs include 2003 crop production cost estimates from the Arkansas Cooperative Extension Service (CES); historic daily weather data for Stuttgart, Arkansas; reservoir, well, and irrigation cost data from the NRCS and local contractors; hydrologic data on water table decline; and other factors from the U.S. Geological Survey (See Table 1). Production costs include all variable and fixed costs to calculate the net return to land over a 30-year projection period. The model accounts for land lost to reservoir construction as a loss of net income. A 320-acre land tract is assessed.

The baseline irrigation application efficiency from water source to crop root zone without any water conservation improvements is assumed to be 50 percent for rice and 45 percent for soybeans. Application efficiency may be increased by 10 percent above the baseline level for both crops with the use of underground pipe, and from 20 to 30 percent above the baseline level with both precision land leveling and underground pipe

(Tacker, 2000). Land leveling also provides a potential 10 to 15 percent increase in crop yield (Scardaci, 1994, Salassi, 2001). The analysis reported here assumes a 10 percent yield increase with land leveling.

Results of Study

Application of the MARORA model provided estimates of the NPV of net returns from the 320-acre tract with alternative ground water situations and with alternative on-farm water conservation improvements including a reservoir/tail-water recovery system, an underground pipe system and land leveling. The NPV estimates were used to calculate benefit/cost ratios of the alternative improvements.

Impact on NPV of Net Returns to Land

Results in Table 2 show a higher NPV of net returns to land for the relativity adequate ground water situation compared with the relatively inadequate ground water situation. A reservoir/tail-water recovery system is not economical in the relatively adequate ground water situation as it provides less NPV of net returns to land than no reservoir/tail-water system. MARORA did not estimate the NPV of net returns to land with a reservoir in a valuation of the relatively adequate ground water situation as a reservoir is not in the optimal solution. However, underground pipe and land leveling increase the NPV of net returns to land in the relatively adequate ground water situation. Estimated NPV of net returns to land per acre ranges from $2,516 with no improvements to as high as $3,300 with both underground pipe and land leveling. The $3,300 estimate per acre assumes a 20 percent efficiency increase with land leveling in the relatively adequate ground water situation. Increased irrigation efficiency increases the NPV of net returns to land by reducing the ground water pumping cost. However, increased irrigation efficiency on one farm does not prolong the life of groundwater irrigation as water table decline is a regional problem.

Irrigation cannot be sustained without a reservoir/tail-water recovery system in the relatively inadequate ground water

Table 2. Estimated NPV of net returns to land with water conservation improvements

Ground Water Situation/Conservation Improvement	Irrigation Efficiency (%)		Optimal Reservoir Size in Acre Feet[3]	Cultivated Acres		Water Use		NPV Per Acre
	Soybean	Rice		Rice	Soybean	Rice	Soybean	
Relatively Adequate GW[1]:								
Baseline (no reservoir)	45	50	0	160	160	40	26.2	$2,516
Baseline (optimal reservoir)	45	50	0	160	160	40	26.2	$2,516
u. pipe (no reservoir)	55	60	0	160	160	33.5	21.6	$2,619
u. pipe + moderate efficiency leveling (no reservoir)	65	70	0	160	160	28.8	18.4	$3,227
u. pipe + high efficiency leveling (no reservoir)	75	80	0	160	160	25.2	16.1	$3,300
Relatively Inadequate GW[2]:								
Baseline (no reservoir)	45	50	0	0	320	0	0	$283
Baseline (optimal reservoir)	45	50	620	127	127	39.7	26.7	$2,312
u. pipe (optimal reservoir)	55	60	520	132	132	33.1	22	$2,456
u. pipe + moderate efficiency leveling (optimal reservoir)	65	70	440	136	136	28.4	18.5	$2,625
u. pipe + high efficiency leveling (optimal reservoir)	75	80	400	138	138	24.8	24.8	$3,130

[1] Situation with 50 feet initial saturated thickness and 0.5 feet annual decline.
[2] Situation with 30 feet initial saturated thickness and 1.0 feet annual decline.
[3] A rainfall collection reservoir and tailwater recovery system is not profitable for the relatively adequate ground water situation.

Table 3. Estimated cost and increased NPV of net returns to land with water conservation improvements

Ground Water Situation/Conservation Improvement	Irrigation Efficiency		Opt. Res. Size Acre Feet[3]	Invest. Cost/Acre	NPV/Acre	Change in NPV/Acres from Baseline	Improvement Increases in NPV	Benefit/Cost Ratio for Improvements [4]
	Soybean %	Rice %						
Relatively Adequate GW[1]:								
baseline (no reservoir)	45	50	0	$0	$2,516	$0		0
u. pipe (no reservoir)	55	60	0	$94	$2,619	$103	$103	1.1
u. pipe + moderate efficiency leveling (no reservoir)	65	70	0	$394	$3,227	$711	$608	1.8
u. pipe + high efficiency leveling (no reservoir)	75	80	0	$394	$3,300	$784	$681	2
Relatively Inadequate GW[2]:								
Baseline (no reservoir)	45	50	0	$0	$283	$0		0
Baseline (optimal reservoir)	45	50	620	$496	$2,312	$2,029	$2,029	4.1
u. pipe (optimal reservoir)	55	60	520	$556	$2,456	$2,173	$144	3.9
u. pipe + moderate efficiency leveling (optimal reservoir)	65	70	440	$781	$2,991	$2,708	$535	3.5
u. pipe + high efficiency leveling (optimal reservoir)	75	80	400	$769	$3,130	$2,847	$674	3.7

[1] 1Situation with 50 feet initial saturated thickness and 0.5 feet annual decline.
[2] Situation with 30 feet initial saturated thickness and 1.0 feet annual decline.
[3] A rainfall collection reservoir and tailwater recovery system is not profitable for the relatively adequate ground water situation.
[4] Ratio of change in NPV of net returns to land per acre from baseline NPV and investment cost per acre for improvements.

situation. Without any irrigation, the estimated NPV is extremely low at only $283 per acre with production limited to dryland soybeans (Table 2). Estimated NPV of net returns per acre increases from $283 to $2,312 with use of an on-farm reservoir/tail-water recovery system to sustain irrigation in the relatively inadequate ground water situation. The further addition of underground pipe plus land leveling increases NPV per acre to as high as $3,130 (Table 2). NPV of net returns to land is reduced with the use of reservoirs to sustain irrigation compared with ground water use. The NPV of net returns to land is reduced due to both the relatively high investment costs in a reservoir/tail-water recovery system and the loss of returns from crops that were produced on land displaced by the reservoir construction. With the relatively inadequate ground water situation, increased irrigation efficiency reduces the reservoir size required which, in turn, reduces the amount of cropland lost to reservoir construction (Table 2).

All 320 acres of land can be in crop production without a reservoir (Table 2). With a reservoir, rice and soybean production are each limited to 127 to 138 acres depending on the size of the reservoir.

Results of Benefit/Cost Analysis

Increases in NPV per acre from the baseline irrigation efficiency level are calculated to show the benefits of adding improvements for the relatively adequate ground water and relatively inadequate ground water situations (Table 3). Starting with the relatively adequate ground water situation, NPV per acre increases by $103 with the addition of underground pipe to as high as $784 with the combination of both underground pipe and land leveling. The estimated benefit/cost ratio is 1.1 for underground pipe, increasing to 1.8 for both underground pipe and leveling with a 20 percent efficiency increase above the baseline, to a high of 2.0 for both conservation improvements if efficiency is increased by 30 percent above the baseline. Investment cost per acre for improvements is $94 for underground pipe and $300 for land leveling.

In the relatively inadequate ground water situation, NPV of net returns to land per acre increases by $2,029 with the use of a reservoir/tail-water recovery system to sustain irrigation and replace dryland production (Table 3). The further addition of underground pipe increases NPV by $2,173 per acre above the baseline, and the addition of both underground pipe and land leveling increases NPV by up to $2,847 per acre. Cost of a reservoir/tail-water recovery system ranges from $375 to $496 per acre excluding the cost of land used for reservoir construction. The estimated benefit/cost ratios are 4.1 for the reservoir/tail-water system alone, 3.9 for the reservoir plus underground pipe, 3.5 for the reservoir plus both the pipe and land leveling with 20 percent increase in efficiency, and 3.7 for the same with 30 percent increase in efficiency (Table 3).

Other Results of Study

Although the estimated NPV per acre is only about $200 less with the reservoir and other water conservation improvements in the relatively inadequate ground water situation compared with the relatively adequate ground water situation, there are increased risks in depending only on rainfall runoff. Long term average annual runoff is about 18 inches in eastern Arkansas including about seven inches during the growing season (SCS, 1987). A reservoir capacity of about 440 acre feet is the maximum that can be filled from available on-farm average annual rainfall runoff on a 320-acre tract. Runoff from other adjacent land would be needed to fill reservoirs larger than 440 acre feet. Rainfall also fluctuates from year to year, which in turn, causes runoff to fluctuate. Thus, the irrigation supply from rainfall runoff will likely be more variable than with ground water use if the farm is solely dependent on its own runoff. The availability of adjacent additional land to collect runoff would help to assure an adequate water supply in low rainfall years.

The MARORA model is a user friendly tool currently available to Arkansas rice and soybean producers. Application of this model to other areas of the country would require the development of a weather generator sub-model based on local historic rainfall data as was done in Arkansas. For further application throughout the nation, MARORA would have to be modified to evaluate crops other than rice and soybeans.

The estimated NPV of net returns to land with MARORA will differ from actual land prices because of other factors that affect land value besides the rice and soybean income. MARORA may include a lease value per acre for duck hunting in eastern Arkansas but the revenue can vary from farm to farm depending on the popularity of the location for hunting. Typical rice-soybean irrigated land values around Stuttgart, Arkansas are $2,000 to $2,500 per acre compared with $1,000 per acre for dryland farms (Jacobs Realty, personal communication, January 2004). Sales data are not currently available to evaluate the contribution of underground pipes, land leveling and reservoirs to the selling price of land as there has been little turnover of land with recent major conservation improvements in eastern Arkansas.

Summary

The value of on-farm improvements to conserve irrigation water on Arkansas rice farms depends on the ground water supply situation, and the impact of these improvements on irrigation application efficiency. Alternative improvements evaluated in this paper included an assumed baseline irrigation efficiency of 45 percent for soybeans and 50 percent for rice with no improvements, 10 percent above the baseline with underground pipe, and 20 to 30 percent above the baseline with both underground pipe and precision land leveling. The MARORA model is used to estimate the value of on-farm reservoirs and other water conservation improvements on Arkansas rice-soybean farms with two diverse ground water situations.

With the relatively adequate ground water situation, the model estimated that an on-farm reservoir is not in the optimal solution as it is not necessary to sustain irrigation and it would occupy valuable cropland within the projection period. With the relatively adequate ground water situation, the estimated impact on NPV of improvements per acre is $103 for underground pipe, and an additional $608 to $681 for land leveling depending on the increase in irrigation efficiency achieved. The benefit/cost analysis shows that both underground pipe and land leveling are profitable investments in the relatively adequate ground water situation.

With the relatively inadequate ground water situation, the ground water supply is quickly depleted. An on-farm reservoir of 620 acre feet optimal size, with the 45/50 percent baseline efficiency level, is required to sustain irrigation on the 320-acre farm parcel. Estimated NPV of net returns per acre is $2,312 with the reservoir compared with only $283 without the reservoir. Other improvements may be combined with the reservoir to increase the NPV of net returns to land, including underground pipe (+$144 per acre) and leveling (+$535 to $674 per acre), provided that irrigation is sustained. Benefit/cost analysis shows that underground pipe, land leveling and on-farm reservoirs are all profitable investments in the relatively inadequate ground water situation.

In conclusion, it is estimated that irrigated farmland in eastern Arkansas can be worth from $283 to $3,300 per acre based on the NPV of current estimated annual net income. The most important factor is the ground water situation. With relatively adequate ground water and no water conservation improvements, the NPV per acre is $2,516 compared with a potential NPV of up to $3,300 with both underground pipe and land leveling. Land with a non-sustainable, relatively inadequate ground water situation has more variable NPV, ranging from $283 per acre with dryland soybean production to a possible $3,130 per acre with underground pipe and land leveling if there is adequate surface water runoff to maintain irrigation with an on-farm reservoir. With average rainfall, the 320-acre tract would have only enough annual rainfall runoff to fill a 440-acre foot reservoir. The reservoir supply could be deficient in below average rainfall years unless there was access to other surface water.

The calculated benefit-cost ratio to invest in underground pipe and land leveling is greater that 1.0, for relatively adequate ground water situations. Irrigation reservoirs are not economical in relatively adequate ground water situations.

Endnotes

[1] Saturated thickness is the thickness of the water bearing formation in the Alluvial Aquifer.

[2] MARORA is designed to compute the NPV of projected annual net farm income and to estimate the optimal reservoir size to maximize the NPV. A computer compact disk and instructions to use MARORA are available from the department of Agricultural Economics and Agribusiness at the University of Arkansas (Smartt et al., 2002). Jim Smartt may be contacted at 479-575-2378 or jsmartt@uark.edu.

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