Measuring the Stochastic Monetary Benefits of Multiple Inlet Irrigation in Arkansas Rice Production

K. Bradley Watkins, Tatjana Hristovska, and Merle M. Anders*

Contact Author:
Bradley Watkins
University of Arkansas Rice Research & Extension Center
2900 Hwy 130 E
Stuttgart, AR 72160
(870) 673-2661
kbwatki@uark.edu

*The authors are, respectively, Associate Professor and Agricultural Economist, Program Associate, and Assistant Professor and Systems Agronomist, University of Arkansas Rice Research & Extension Center, Stuttgart, Arkansas.

Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Birmingham, AL, February 4-7, 2012

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Abstract

Irrigation fuel costs represent a significant portion of rice production expenses. Multiple inlet (MI) irrigation represents a water saving alternative to conventional flood irrigation. This study uses simulation to calculate the range of monetary benefits to MI in rice production. Water savings from MI relative to conventional flood irrigation along with rice yields, rice prices, and prices for key production inputs (diesel and fertilizer) are simulated, and stochastic rice net returns above variable and fixed expenses are calculated for different pump lifts with and without MI. Monetary benefits to MI are measured as the difference in net returns with and without MI. The results indicate MI monetary benefits depend greatly on pump lift and the presence or absence of a yield increase. Monetary benefits to MI increase as pump lifts become larger, and relatively small increases in yield resulting from MI irrigation can greatly enhance its payoff.

Introduction

Rice in Arkansas is a very water intensive crop. Scott et al. (1998) reported rice irrigation amounts in Arkansas ranging from 18 to 36 ac in per year depending on cultivar type and averaging 30 ac in per year. More recently, Vories et al. (2006) reported rice irrigation amounts in Arkansas ranging from 18 to 56 ac in, and an average application amount of 31 ac in per year. Because of the large water requirement for rice production, irrigation fuel costs represent a significant portion of rice production expenses. Irrigation fuel costs account for 16 to 18% of total variable production expenses for the crop depending on seed type (Flanders et al. 2010). Most irrigation water is delivered to the crop using wells. Approximately 83% of rice acres received irrigation water from groundwater sources (wells), while 17% of rice acres received irrigation water from surface water sources (streams and on-farm reservoirs) in 2009 (Wilson et al. 2010). Because rice is very water intensive, extensive pumping has caused a steady depletion of the alluvial aquifer in many rice producing areas of eastern Arkansas (Czarnecki 2010; Gillip and Czarnecki 2009; Schrader 2010), and several counties in eastern Arkansas have either partially or totally been designated as critical ground water areas because of significant groundwater declines resulting from intensive irrigation (Czarnecki 2010; Gillip and Czarnecki 2009).

Most rice acres in Arkansas are irrigated using conventional levee and gate systems (Wilson et al. 2010). Flooded rice production under these systems uses a well or riser in the highest-elevation portion of the field. Contour levees are constructed at approximately every 60 mm elevation drop, and adjustable spills are placed in the levees. Water released from the well or riser fills the first paddy and then flows over the spills into lower paddies (Vories et al. 2005).

Conventional levee and gate systems accounted for over 56% of rice acres in 2009 (Wilson et al. 2010).

Multiple inlet (MI) irrigation represents a water saving alternative to conventional flood irrigation. Rather than discharging water directly from the well or riser into the first paddy, the riser is connected to a pipe, and gates or holes are placed in the pipe for each paddy. Multiple inlet irrigation allows each paddy to be watered concurrently instead of receiving overflow from a higher paddy. By adjusting the gates, the operator can fill all paddies simultaneously (Vories et al. 2005). Multiple inlet irrigation accounted for over 42% of rice acres in 2009 (Wilson et al. 2010).

Water savings may be achieved using MI irrigation over conventional irrigation because the field is flooded quicker and irrigation efficiency is increased through reduced pumping time during the season. Reported water savings for MI based on Arkansas rice field demonstration data from 2000 through 2007 ranged from 5 to 44% and averaged 21% across field demonstrations and years (Table 1). Other benefits of MI include reduced irrigation labor and possible higher grain yields. Vories et al. (2005) reported a positive though non-significant numeric rice yield difference of 3.4% for field demonstrations in Arkansas using MI versus conventional irrigation. The authors speculated the numeric yield difference may be due to shallower depth of water on MI fields relative to conventional fields, a reduction in the "cold water" effect of groundwater observed in areas around the well or riser that are typically later maturing and lower yielding than the rest of the field, and improved nitrogen efficiency.

The objective of this study is to measure the monetary benefits possible for MI given the range in water savings possible using this irrigation method as reported in field demonstration studies throughout Arkansas. Simulation is used to calculate the range of monetary benefits to

MI in rice production for three different pump lift scenarios (stationary relift, standard well, deep well). The stationary relift scenario represents water pumping from surface water sources (20 ft maximum vertical pipe), while the standard and deep well scenarios represent pumping from wells 120 ft or less and between 120 and 240 ft, respectively, as reported in Hogan et al. (2007).

Rice yields, rice prices, and prices for key production inputs (diesel and fertilizer) are simulated using SIMETAR (SIMulation and Econometrics To Analyze Risk), and stochastic rice net returns above variable and fixed expenses are calculated for each pump lift scenario with and without MI and with and without a 3.4% rice yield increase in simulated yields for MI irrigation. Stochastic per acre monetary benefits to MI are calculated as the difference between net returns to rice under MI and net returns to rice under conventional flood irrigation. Cumulative distribution functions of stochastic monetary benefits to MI are evaluated by water resource scenario with and without the 3.4% yield increase.

Materials and Methods

Five hundred iterations of rice yields, rice prices, fuel and fertilizer prices, and water savings from MI relative to conventional flood irrigation were simulated using the Excel Add-In, SIMETAR (Richardson et al. 2008). Empirical distributions were used to simulate rice yields and water savings from MI. The empirical distribution assumes a continuous distribution and interpolates between the specified points on the distribution (including the minimum and maximum) using the cumulative distribution probabilities (Richardson et al. 2008). Water savings to MI were simulated based on field demonstration data for the period 2000 through 2007 (Table 1). Water savings to MI represent the percent reduction in applied water from MI relative to conventional flood irrigation on each field demonstration. The rice yield empirical distribution was simulated using eleven years of historical yield data from a long-term rice-based cropping systems study at Stuttgart, AR for the period 2000-2010 (Anders and Hignight 2010). The historical rice yield data used in the analysis are presented in Table 2. Summary statistics for simulated yields and MI water savings over conventional flood irrigation are presented in Table 3.

Multivariate empirical distributions (MVEs) were used to simulate rice prices and prices for key production inputs (diesel, urea, phosphate, and potash). A MVE distribution simulates random values from a frequency distribution made up of actual historical data and has been shown to appropriately correlate random variables based on their historical correlation (Richardson et al. 2000). Parameters for the MVE include the means, deviations from the mean or trend expressed as a fraction of each variable, and the correlation among variables. All price simulations were based on historical prices obtained from the USDA, National Agricultural Statistics Service (2002, 2006, 2009, 2010, 2011) for the 2000-2010 period, adjusted to 2010 dollars using the Producer Price Index (PPI). The nominal series for each rice and input price and the PPI are reported by year in Table 2.

Deviations from the trend and their associated correlations were used to simulate the MVE price distributions for each price series, but mean prices for the period 2005-2010 were used rather than 11-yr means to represent expected prices for the MVE price distributions. Prices for the latter five years of the 11-yr period better represent current farmer price expectations. The MVE approach has been shown to reproduce the historical correlation matrix and maintain the historical coefficient of variation from the original historical data series even when using means different from the historical mean (Ribera et al. 2004). Summary statistics for simulated prices are presented in Table 3.

Direct and fixed expenses for the analysis were based on cost data used in the 2010 Arkansas Rice Research Verification Program (Runsick et al. 2010) and irrigation cost data from Hogan et al. (2007). Direct expenses included expenses associated with fertilizer, pesticides, seed, operator labor, machinery and irrigation fuel, machinery and irrigation repairs and maintenance, and interest on operating capital. Fixed expenses for machinery are composed of both machinery depreciation and interest. Irrigation variable expenses vary primarily by diesel fuel consumption and assume 0.5, 1.0, and 1.5 gal of diesel fuel are required to deliver 1 ac in of water to the field for a stationary relift, (20 ft maximum vertical pipe), a standard well (120 ft or less), and a deep well (between 120 and 240 ft), respectively (Hogan et al. 2007). Fixed expenses associated with irrigation items (well, pump, gearhead, and power unit) were adjusted to 2010 dollars using the PPI, and represent expenses associated with depreciation, interest, property taxes, and insurance. Average budgeted expenses are presented for conventional flood and multiple inlet rice by pump lift in Table 4. Average budgeted expenses increase as pump lift increases for both irrigation methods due to increases in energy costs associated with pumping water from greater pumping depths. Average expenses are approximately equal for both irrigation methods under the stationary relift scenario but are smaller for multiple inlet irrigation under both the standard and deep well scenarios. These numbers indicate that on average, the monetary value of water savings from multiple inlet irrigation is approximately equal to the cost of poly pipe installation and removal for the stationary relift scenario but exceeds the cost of poly pipe installation and removal under both the standard and deep well scenarios.

A total of 30 ac in of water was assumed for rice under conventional flood irrigation. Applied water under MI was stochastic and calculated as follows:

$$MII_k = CFI * (1 - MISAV_k) \qquad (1)$$

where:

k = 1 to 500 simulated iterations;

MII_k = total applied water under MI for iteration k (ac in);

CFI = total applied water under conventional flood irrigation (30 ac in); and

$MISAV_k$ = simulated MI water savings compared with conventional flood irrigation for iteration k (decimal).

The non-diesel installation and removal cost of irrigation tubing was \$9.52 ac^{-1} based on costs reported by Hogan et al. 2007 updated to 2010 dollars. Total diesel and labor used to install and remove irrigation tubing was set to 0.291 gal ac^{-1} and 0.289 hr ac^{-1}, respectively, based on estimates derived from Hogan et al. (2007).

Using the above mentioned data, stochastic net returns per acre were estimated for conventional flood rice and multiple inlet rice by pump lift using the following formula:

$$NR_{ijk} = Y_{ik} * P_k - SVC_{ijk} - SHC_{ik} - NSVC_{ij} - F_{ij} \quad (2)$$

where:

i = 1 to 2 irrigation methods (conventional flood = 1, multiple inlet = 2);

j = 1 to 3 pump lift scenarios (stationary relift = 1, standard well = 2, deep well = 3);

k = 1 to 500 simulated iterations;

NR_{ijk} = the net return per acre for irrigation method i, pump lift j, and iteration k;

Y_{ik} = the stochastic rice yield for irrigation method i and iteration k;

P_k = the stochastic rice price for iteration k;

SVC_{ijk} = the total stochastic variable costs of fuel and fertilizer for irrigation method i, pump lift j, and iteration k;

SHC_{ik} = the total stochastic harvest cost per acre of drying, check off and hauling for irrigation method i and iteration k;

$NSVC_{ij}$ = the total non-stochastic variable cost per acre for irrigation method i; and pump lift j; and

F_{ij} = the fixed cost per acre for irrigation method i and pump lift j.

Net returns above direct and fixed expenses for MI rice production were estimated both with and without a 3.4% yield increase in simulated rice yields to determine the impact of a modest increase in rice yields on the monetary benefits of MI irrigation. Monetary benefits to MI irrigation in this study are defined as follows:

$$MBMI_{jk} = NR_{2jk} - NR_{1jk} \tag{3}$$

Where:

$MBMI_{jk}$ = the monetary benefits per acre to MI for pump lift j and iteration k;

NR_{2jk} = the net return per acre for MI rice for pump lift j, and iteration k; and

NR_{1jk} = the net return per acre for conventional flood rice for pump lift j, and iteration k;

Results and Discussion

Summary statistics of stochastic net returns to rice under MI and conventional flood irrigation (CF) are presented with and without a 3.4% MI yield increase in Table 5. Net returns to MI without the 3.4% yield increase reflect the monetary impact of MI water savings net of MI installation and removal costs on rice net returns. Net returns to MI with the 3.4% yield increase reflect both the monetary impact of water savings net of MI installation and removal costs and the positive monetary benefit of greater yields resulting from use of MI over conventional flood irrigation. Average net returns decline for both CF and MI as pump lifts become deeper and regardless of whether or not MI results in a yield increase, reflecting the increase in costs associated with pumping water from greater depths.

Assuming no yield increase, average net returns for the two irrigation methods are approximately equal for the stationary relift scenario but larger under MI for the standard and deep well scenarios. Similarly, minimum returns to MI and CF are equal for the stationary relift scenario but larger under MI for the standard and deep well scenarios. Maximum returns are larger for MI than for CF for every pump lift scenario, but the difference in maximum returns between MI and CF increases in magnitude when going in order from stationary relift to standard well to deep well. Relative net return variability as measured by the coefficient of variation (CV) is nearly equal between MI and CF for each pump lift scenario but becomes slightly larger for both irrigation methods as pump lifts become progressively deeper. These results collectively indicate that MI reduces the downward impact of increasing pump lifts on rice net returns. A 3.4% increase in simulated yields under MI results in an upward shift in MI net returns. The upward shift averages approximately \$30 ac^{-1} across pump lifts and ranges from a minimum of approximately \$20 ac^{-1} to a maximum of approximately \$43 ac^{-1} across pump lifts. These upward shifts are found by subtracting the average, minimum, and maximum net returns to MI without the yield increase from the average, minimum and maximum net return to MI with the 3.4% yield increase in Table 5.

Summary statistics of stochastic MI monetary benefits over CF in Arkansas rice production are presented with and without a MI yield increase in Table 6. Without a yield increase, the average monetary benefit to MI ranges from negligible for the stationary relift scenario to \$16 ac^{-1} for the deep well scenario. Thus monetary benefits to MI increase as pump lifts increase. The negligible average monetary benefit to MI for the stationary relift scenario implies the average value of MI water savings is offset by nearly equal MI installation and removal costs. Thus, MI tends to pay for itself on average for the stationary relift scenario under the more conservative assumption of no MI yield increase. Minimum MI monetary benefits for all three pump lift scenarios are negative assuming no MI yield increase, indicating all three scenarios exhibit some likelihood that MI installation and removal costs exceed the value of MI water savings. Alternatively, maximum monetary benefits to MI are positive for all pump lift scenarios and grow in magnitude as pump lifts become progressively deeper.

Monetary benefits are much greater when yields are increased as a result of MI irrigation. Average monetary benefits to MI range from \$30 ac^{-1} for the stationary relift scenario to \$46 ac^{-1} for the deep well scenario when simulated MI yields are increased by 3.4% (Table 6). Minimum monetary benefits to MI are positive across all pump lift scenarios under the most optimistic assumption of increased yields, and maximum monetary benefits are much larger across pump lifts than those under the more pessimistic assumption of no yield increase.

Cumulative distribution functions (CDFs) of stochastic MI monetary benefits assuming no MI yield increase are presented by pump lift scenario in Figure 1. The cumulative probability of receiving a zero or negative MI monetary benefit is found where each CDF crosses the vertical axis and varies by pump lift. The probability of receiving a zero or negative MI monetary benefit is greatest for the stationary relift scenario (61%), and is relatively much smaller for both the standard well scenario (14%) and the deep well scenario (7%). Alternatively, CDFs that lie farthest to the right reflect greater likelihoods of receiving large MI monetary benefits. The deep well scenario exhibits the largest likelihoods of receiving large positive monetary benefits from MI because its CDF lies farthest to the right of the other two CDFs mapped in Figure 1. Conversely, the stationary relift scenario exhibits the smallest likelihood of receiving large monetary benefits to MI because its CDF lies everywhere to the left of the other CDFs mapped in Figure 1.

Cumulative distribution functions of stochastic MI monetary benefits assuming a 3.4% MI yield increase are presented by pump lift scenario in Figure 2. Increasing rice yields by 3.4% under MI irrigation has the effect of moving the CDFs of all three pump lift scenarios farther to the right, thus improving the odds of receiving large MI monetary benefits and removing the possibility of receiving zero to negative MI monetary benefits. Again, monetary benefits to MI are everywhere greatest for the deep well scenario (deep well CDF farthest to the right) and everywhere smallest for the stationary relift scenario (stationary relift CDF farthest to the left).

Summary and Conclusions

Multiple inlet (MI) irrigation represents a water saving alternative to conventional flood irrigation in rice production. This study uses simulation to calculate the range of monetary benefits to MI in rice production for three different pump lift scenarios. Rice yields, rice prices, and prices for key production inputs (diesel and fertilizer) are simulated using SIMETAR, and stochastic rice net returns above variable and fixed expenses are calculated for each pump lift scenario with and without MI and with and without a 3.4% rice yield increase in simulated yields for MI irrigation. Stochastic per acre monetary benefits to MI are calculated as the difference between net returns to rice under MI and net returns to rice under conventional flood irrigation.

The results of this study indicate monetary benefits to MI irrigation depend greatly on pump lift and the presence or absence of a yield increase. Without a yield increase, monetary benefits are smallest for stationary relift fields, but MI tends to pay for itself on average in this circumstance. Monetary benefits to MI increase with deeper pump lifts, primarily because of savings in irrigation energy costs resulting from less applied water. The presence of a small numeric yield increase for fields under MI irrigation (3.4% in this study) significantly increases the magnitude of MI monetary benefits in rice production. Thus potential yield increases resulting from MI irrigation do not have to be significantly large to increase the monetary payoff of MI in rice production. It is hoped that findings from this study will help promote more efficient water usage in eastern Arkansas rice production.

Acknowledgements

This research was funded by the Arkansas Rice Research and Promotion Board.

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Table 1**.** Rice field demonstration water savings data for multiple inlet irrigation compared with conventional flood irrigation by county, soil type, and year, 2000 – 2007.

Year	County	Soil Type	MI Water Savings (decimal) [a]
2000	Poinsett	Clay	0.1750
2000	Ashley	Clay	0.1800
2001	Arkansas	Silt Loam	0.2100
2001	Crittenden	Clay	0.2900
2001	Crittenden	Silt loam	0.1700
2001	Cross	Silt Loam	0.1600
2002	Crittenden	Sandy Loam	0.0900
2002	Desha	Silt Loam	0.2600
2002	Poinsett	Clay	0.4400
2002	Poinsett	Clay	0.4200
2002	Poinsett	Silt Loam	0.1700
2003	Drew	Silt Loam	0.1300
2003	Lonoke	Silt Loam	0.2500
2004	Crittenden	Clay	0.2300
2004	Poinsett	Silt Loam	0.2200
2004	Poinsett	Silt Loam	0.2800
2005	Craighead	Clay	0.1800
2005	Cross	Silt Loam	0.2900
2005	St. Francis	Silt Loam	0.1900
2005	White	Silt Loam	0.2700
2006	Poinsett	na[a]	0.1300
2006	Poinsett	na	0.0800
2006	Cross	na	0.1900
2006	Cross	na	0.2200
2007	Arkansas	na	0.1800
2007	St. Francis	na	0.2300
2007	White	na	0.0500
Mean			0.2106

[a] MI water savings represent the percent reduction in applied water from multiple inlet relative to conventional flood irrigation on each field demonstration

[b]na = not available.

Source: Tacker P. and Tacker et al. (2000–2008). Rice irrigation-water management for water, labor, and cost savings. *In:* BR Wells Rice Research Studies, University of Arkansas Agricultural Experiment Station, Research Series 485, 495, 504, 517, 529, 540, 550, and 560.

Table 2. Rice yields, nominal prices for rice, diesel, urea, phosphate, and potash, and the Producer Price Index by year, 2000 – 2010.

Year	Rice Yield (bu ac^{-1}) [a]	Rice Price ($ bu^{-1}) [b]	Diesel ($ gal^{-1}) [b]	Urea ($ lb^{-1}) [b]	Superphosphate ($ lb^{-1}) [b]	Potash ($ lb^{-1}) [b]	PPI [c]
2000	195	3.51	1.43	0.1378	0.1503	0.1141	132.7
2001	160	2.43	1.39	0.1803	0.1459	0.1156	134.2
2002	181	2.64	1.24	0.1240	0.1409	0.1310	131.1
2003	186	4.63	1.47	0.1658	0.1411	0.1204	138.1
2004	197	4.04	1.51	0.1593	0.1542	0.1272	146.7
2005	181	3.84	2.25	0.1866	0.1567	0.1584	157.4
2006	168	4.76	2.48	0.1834	0.1587	0.1649	164.7
2007	199	5.83	2.42	0.2370	0.2113	0.1653	172.6
2008	170	6.58	3.45	0.2499	0.4320	0.2552	189.6
2009	195	6.44	1.71	0.2249	0.2355	0.4492	172.9
2010	193	5.18	2.48	0.2125	0.2215	0.2675	184.7

[a] Rice yields were collected from a long-term rice based cropping systems study at Stuttgart, Arkansas, and represent rice yields from a two-year rice-soybean rotation.
[b] USDA, National Agricultural Statistics Service. Rice prices represent season average harvest prices; diesel prices are bulk delivery prices for the Delta region of the US; urea, phosphate, and potash prices represent prices for the South Central region of the US.

[c] PPI = Producer Price Index (US Department of Labor, Bureau of Labor Statistics).

Table 3. Summary statistics of simulated rice yields, water savings of multiple inlet relative to conventional flood irrigation, rice prices, and key production input prices.

Stochastic Variable	Mean [a]	SD	CV [b]	Minimum	Maximum
Rice Yield (bu ac^{-1})	184	12	7	160	199
MI Savings (decimal)	0.2106	0.0861	41	0.0499	0.4401
Rice Price (\$ bu^{-1})	5.42	0.93	17	4.14	6.94
Diesel (\$ gal^{-1})	2.46	0.48	20	1.64	3.51
Urea (\$ lb^{-1})	0.2155	0.0251	12	0.1698	0.2636
Superphosphate (\$ lb^{-1})	0.2362	0.0650	28	0.1774	0.4203
Potash (\$ lb^{-1})	0.2505	0.0735	29	0.1710	0.3979

[a] Summary statistics calculated from 500 simulated iterations.

[b] Coefficient of Variation (CV) is a unitless measure of relative risk and is equal to 100 multiplied by the quotient of the standard deviation (SD) divided by the mean.

Table 4. Direct and fixed expenses for conventional flood rice and multiple inlet rice by pump lift, 2010 dollars.

	Stationary Relift [a]		Standard Well		Deep Well	
Cost Item	CF ($\$ ac^{-1}$) [b]	MI ($\$ ac^{-1}$)	CF ($\$ ac^{-1}$)	MI ($\$ ac^{-1}$)	CF ($\$ ac^{-1}$)	MI ($\$ ac^{-1}$)
Direct Expenses						
Seed	59.48	59.48	59.48	59.48	59.48	59.48
Fertilizers [c]	123.68	123.68	123.68	123.68	123.68	123.68
Herbicide	78.10	78.10	78.10	78.10	78.10	78.10
Insecticide	0.41	0.41	0.41	0.41	0.41	0.41
Custom Application	44.48	44.48	44.48	44.48	44.48	44.48
Irrigation Supplies	7.45	12.95	7.45	12.95	7.45	12.95
Labor						
Machinery	9.75	9.75	9.75	9.75	9.75	9.75
Irrigation [d]	4.60	6.59	4.60	6.59	4.60	6.59
Diesel						
Machinery [c]	21.64	21.64	21.64	21.64	21.64	21.64
Irrigation [c]	36.90	29.90	73.81	59.08	110.71	88.25
Repairs and Maintenance						
Machinery	16.82	16.82	16.82	16.82	16.82	16.82
Irrigation [d]	4.56	3.70	5.35	4.33	8.23	6.60
Post-Harvest Expenses [c]	107.21	107.21	107.21	107.21	107.21	107.21
Interest on Operating Capital	11.22	11.21	12.25	12.03	13.35	12.89
Total Direct Expenses	526.29	525.90	565.03	556.53	605.90	588.84
Fixed Expenses:						
Machinery	50.34	50.34	50.34	50.34	50.34	50.34
Irrigation	28.66	29.62	25.92	26.88	39.55	40.51
Total Fixed Expenses	79.00	79.96	76.26	77.22	89.89	90.85
Total Expenses	605.29	605.86	641.29	633.75	695.79	679.69

[a] Stationary Relift = 20 ft maximum vertical pipe; Standard Well = well 120 ft or less deep; Deep Well = well between 120 and 240 ft deep.
[b] CF = conventional flood irrigation; MI = multiple inlet irrigation.
[c] Expense item is stochastic (average calculated from 500 simulated iterations).
[d] Irrigation labor and repairs and maintenance for multiple inlet irrigation are stochastic (averages calculated from 500 simulated iterations).

Table 5. Summary statistics of simulated rice net returns for conventional flood and multiple inlet irrigation by pump lift.

Pump Lift [a]	Irrigation Method [b]	Mean ($ ac^{-1}) [c]	SD ($ ac^{-1})	CV [d]	Minimum ($ ac^{-1})	Maximum ($ ac^{-1})
		Without a Multiple Inlet Yield Increase				
Stationary Relift	CF	382	151	39	110	687
Stationary Relift	MI	382	152	40	110	693
Standard Well	CF	347	145	42	82	637
Standard Well	MI	355	147	41	88	656
Deep Well	CF	294	138	47	37	567
Deep Well	MI	309	142	46	49	601
		With 3.4% Multiple Inlet Yield Increase				
Stationary Relift	CF	382	151	39	110	687
Stationary Relift	MI	412	158	38	130	736
Standard Well	CF	347	145	42	82	637
Standard Well	MI	385	153	40	108	699
Deep Well	CF	294	138	47	37	567
Deep Well	MI	340	148	44	69	644

[a] Stationary Relift = 20 ft maximum vertical pipe; Standard Well = well 120 ft or less deep; Deep Well = well between 120 and 240 ft deep.

[b] CF = conventional flood irrigation; MI = multiple inlet irrigation.

[c] Summary statistics calculated from 500 simulated iterations.

[d] Coefficient of Variation (CV) is a unitless measure of relative risk and is equal to 100 multiplied by the quotient of the standard deviation (SD) divided by the mean.

Table 6. Summary statistics of multiple inlet monetary benefits over conventional flood irrigation in Arkansas rice production by pump lift.

Pump Lift [a]	Mean ($ ac^{-1}) [b]	SD ($ ac^{-1})	CV [c]	Minimum ($ ac^{-1})	Maximum ($ ac^{-1})
			Without a Multiple Inlet Yield Increase		
Stationary Relift	-1	4	-703	-8	16
Standard Well	7	8	104	-7	38
Deep Well	16	11	72	-5	62
			With 3.4% Multiple Inlet Yield Increase		
Stationary Relift	30	8	27	13	54
Standard Well	38	11	29	15	77
Deep Well	46	14	31	18	100

[a] Stationary Relift = 20 ft maximum vertical pipe; Standard Well = well 120 ft or less deep; Deep Well = well between 120 and 240 ft deep.

[b] Summary statistics calculated from 500 simulated iterations.

[c] Coefficient of Variation (CV) is a unitless measure of relative risk and is equal to 100 multiplied by the quotient of the standard deviation (SD) divided by the mean.

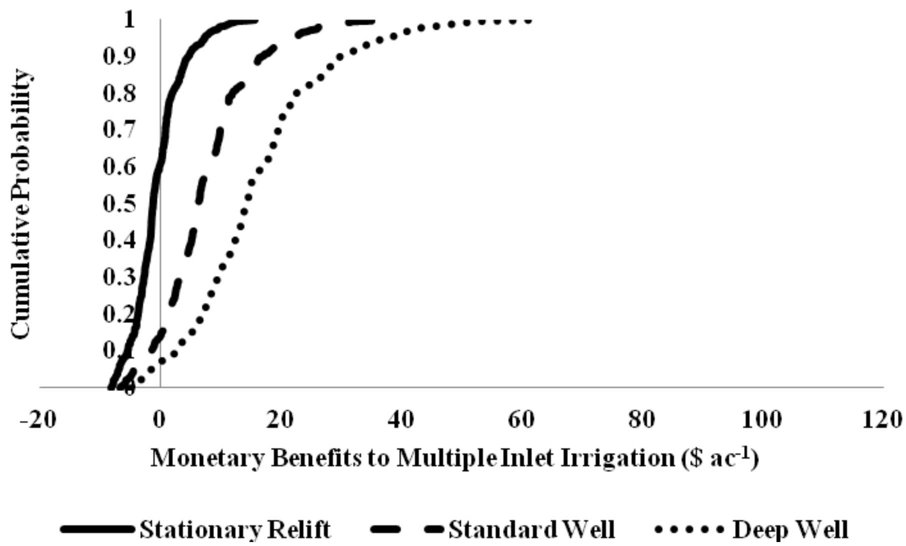

Figure 1. Cumulative distributrion functions of multiple inlet monetary benefits over conventional flood irrigation in Arkansas rice production by pump lift without a multiple inlet yield increase.

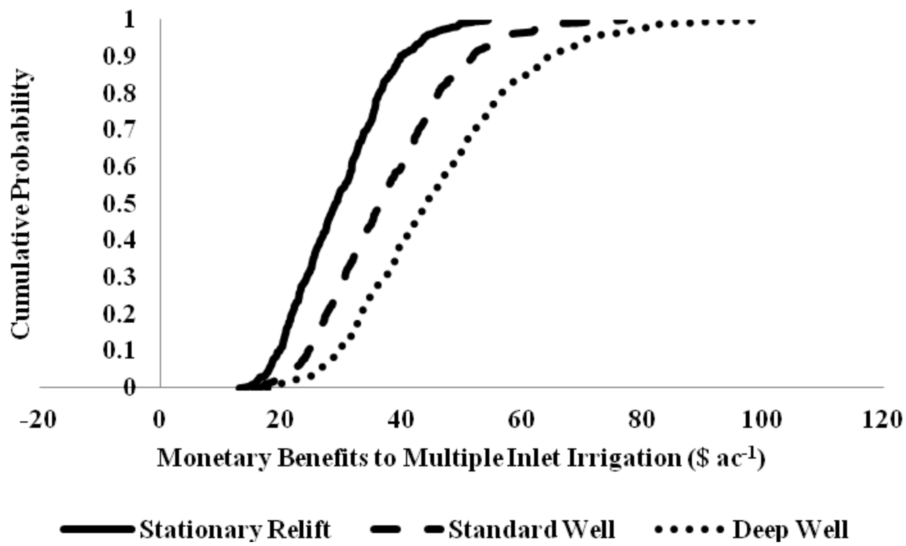

Figure 2. Cumulative distributrion functions of multiple inlet monetary benefits over conventional flood irrigation in Arkansas rice production by pump lift with a 3.4% multiple inlet yield increase.