Impacts of Energy Cost Increases on Irrigated Land Values

Norman K. Whittlesey and Jon P. Herrell

Irrigation development in the Pacific Northwest expanded rapidly during the 1960s and 1970s when economic conditions, including very cheap electricity for pumping water, were favorable for this activity. Thousands of acres of land were irrigated that required lifting water 400 feet or more. The cost of energy for irrigation pumping has risen as much as 400% in recent years, and many of these high pump lift farms are in serious economic difficulty. This study shows that farms with pump lifts exceeding 400 feet will not be able to replace capital irrigation equipment to remain in production in the long run. Land values on these farms will be determined by dryland production alternatives leaving no rents to sustain the incentive for irrigation.

Key words: energy cost, irrigation, pump lift.

The 1960s and 1970s were favorable years for irrigation development in the Pacific Northwest (PNW). Farm commodity prices were relatively high, real interest rates were near zero, and electrical energy costs for pumping water were low. During this period, most farmers utilizing irrigation in the PNW were paying less than 10 mills per kilowatt hour for pumping energy, and there was little expectation that energy costs or other general economic conditions for farming were soon to change. In fact, there was considerable encouragement through public policies and the electric utilities to increase irrigation development and the resulting demand for energy. There was no perceived limit to the cheap energy for pumping irrigation water or the public and private benefits of additional irrigated acreage. Of course, these general economic conditions favorable to agriculture and its development were prevalent throughout the nation.

This economic environment resulted in an increase of more than 800,000 irrigated acres in the PNW during this era (Whittlesey). Most of this new development was funded with private capital, though some U.S. Bureau of Reclamation (USBR) development was ongoing at the time. Virtually all new development during the 1960s and 1970s was irrigated by sprinklers (Harrer). Much of the new irrigation development occurred in areas requiring high pump lifts. Both ground and surface water sources were used to irrigate new lands with pump lifts ranging from 200 feet to more than 800 feet. Because of this new development and a steady shift from gravity flow to sprinkler irrigation systems on previously irrigated lands, electrical power sales for irrigation in the PNW increased from 2.3 million megawatt hours in 1970 to 5.2 million megawatt hours in 1980 (Bonneville Power Administration).

Beginning in about 1980 it was recognized that hydropower sources of electricity could no longer be expanded indefinitely. New additions to the power supply would have to come from relatively expensive thermal production or be obtained through conservation by present users. The costs of additional power supply would be about the same in either case. Some misadventures with nuclear power plant construction in the PNW compounded the problem by adding significantly to power user costs. These phenomena dramatically increased electricity costs during the last five years. Power costs for irrigation pumping have risen from the level of 6–10 mills per kilowatt hour in the mid-1970s to nearly 40 mills per kilowatt hour in 1985 (Bonneville Power Administration, Whittlesey). Additional power cost increases

Norman K. Whittlesey is a professor and Jon P. Herrell was a research assistant, Department of Agricultural Economics, Washington State University.

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during the next decade are expected to continue upward at a nominal rate of about 8% per year.

Farmers have recently encountered other financial problems caused by low commodity prices, high real interest rates, and rising production costs (Melichar). When compounded by these problems, irrigated farms with high pump lifts have been particularly devastated by the rising costs of energy. The purpose of this article is to assess the farm income and land value impacts of rising energy costs for high pump lift irrigation. Further, we address some of the long-term implications of high pump lifts and continued increases in energy costs for these farms. These study results will provide information about irrigated land that may be returned to dryland uses, the asset losses due to depressed land values, and how these farms may compete with others having little or no irrigation pumping requirements.

The setting for this analysis is the Columbia Basin region of eastern Washington and eastern Oregon, though the results will apply to other areas where high pump lift irrigation prevails. In this area there are farms utilizing both ground and surface water sources with pump lifts ranging from zero to 800 feet. Those with no required pump lift for irrigation water are largely using water delivered through USBR projects.

Procedure

For this analysis, a representative farm was developed consisting of 1,560 irrigated acres using twelve 130-acre center pivot systems. It was assumed that six wells were being used to supply water for this farm. Water supply was assumed not to be limiting except as the cost of water is affected by energy prices. The zero pump lift farm receives water from a canal typical of a USBR project. The cost of water to this farm was estimated to be $22 per acre per year for purposes of comparison with the deep-well farms. Crop alternatives consisted of wheat, alfalfa, dry beans, field corn, and potatoes under full irrigation (Whittlesey et al., 1981, 1982). While some fruit and vegetable crops are grown in the region, this model farm did not consider such alternatives.

Limited irrigation of wheat was allowed as an alternative to broaden the range of water uses when pumping costs were increased. This alternative was used in some cases when water costs became high. Finally, land use could return to a dryland wheat-fallow rotation when irrigation became prohibitively expensive.

A maximum profit linear programming model representing this irrigated farm was used to assess farm income and land use effects of changing pump lifts and energy costs. The model represented a single growing season producing the above described crops. Upper bound acreage constraints limited beans and potatoes to 25% of total land, alfalfa and field corn to 33% of total land, and wheat to 50% of total land. Dryland wheat was produced in a summer fallow rotation and one acre of potatoes required a rotation of at least three acres of other crops. A long-run version of the model considered well investment costs as being variable and maximized the returns to land and management. Other features of the model allowed the use of different levels of irrigation efficiency, energy costs, and pump lifts.

Crop production costs represented 1984 levels, while yields and prices received were based on the most recent three-year average for the region. Water-related costs, including ownership and operating costs of irrigation equipment, were adjusted to reflect pump lifts from 200 to 1,000 feet. Center pivot irrigation equipment was used for all situations.

The linear programming model was used to develop cropping patterns and estimate net farm income for all combinations of pump lifts from zero to 1,000 feet and power costs ranging from 10 to 60 mills per kilowatt hour. The zero lift situation was assumed to require no wells, using pumping energy only to pressurize center pivot sprinkler systems. The net farm income estimates from the linear programming model were then used in a land valuation model to assess the impact of energy cost changes on land values.

The baseline farm represented a typical farming situation having a low pressure center pivot irrigation system (100 feet of operating head or 43 psi), a 65% efficient pumping plant, an 80% irrigation efficiency, and field slopes of 3% or less. A fifteen-year planning horizon required depreciating all pumps, surface irrigation equipment, and wells, leaving net income as a return to land and management. This procedure carries an implicit assumption that returns to both land and management will be capitalized into land values.

Farmland value was estimated through the

Table 1. Baseline Parameter Values for Land Valuation

Parameter/Unit	Value
Net revenue ($/acre)	[a]
Net revenue growth rate (%)	4.5
Marginal tax rate (%)	28.0
Comparative land value ($/acre)	1,500.00
Land value growth rate (%)	4.5
Capital gains tax rate (%)	11.2
Required rate of return (%)	5.0
Inflation rate (%)	4.0
Down payment on land (%)	30.0
Nominal interest rate (%)	9.0
Mortgage period (years)	30.0
Planning horizon (years)	15.0

[a] Net revenue is estimated in the farm model.

present value of a discounted income stream derived from farm net revenue and the capital appreciation of farmland. These income streams are adjusted for tax benefits derived from interest payments on mortgaged farmland and the relative values of the nominal discount rate and the mortgage interest rate. The model used here was originally developed by Lee and later modified by Dunford and Gillis (Whittlesey et al. 1981).

The valuation model is

$$P_v = \left\{ \sum_{j=1}^{n} \frac{NR_O(1+r)^j(1-t)}{(1+y)^j} + \frac{P_O(1+s)^n(1-g)}{(1+y)^n} \right\}$$
$$\div \left\{ c + (1-c)\left[\frac{(1+y)^x - 1}{(y)(1-y)^x} \cdot \frac{i(1+i)^x}{(1+i)^x - 1}\right] - (1-c)(t)(i)\left[\frac{i(1+i)^x}{(1+i)^x - 1}\right] \cdot \left[\sum_{j=1}^{x} \frac{1}{(1+y)^j} \cdot \frac{(1+i)^{x-j+1} - 1}{i(1+i)^{x-j+1}}\right] - \frac{g}{(1+y)^n} \right\}$$

where P_v is present value of farmland ($/acre); n, planning horizon (years); NR_O, net revenue per acre ($/acre); r, farm net revenue growth rate (%/year); y, after-tax nominal discount rate

$$y = (d + f + df)(1 - t),$$

where d is before-tax opportunity cost of capital in real terms, f is general price inflation, and t is ordinary income marginal tax rate (%); P_O is observed comparative land price; s, nominal rate of land value growth (%); g, capital gains tax rate (%); c, down payment (decimal portion); x, term of mortgage (years); and i, mortgage interest rate (%).

The baseline parameter values listed in table 1 describe the conditions of the average farmland buyer used in this study. The value of $1,500 per acre was used as a comparable market price for irrigated land in the region as a required assumption to drive the valuation model. This value is typical of existing irrigated land with a low pump lift requirement.

Results

Low Pressure Irrigation System

The baseline farm consists of 1,560 irrigated acres with characteristics as described above. The estimated net farm income, representing returns to land and operator management is shown in table 2 for alternative pump lift and energy cost combinations.

The zero pump lift situation reflects a farm receiving surface water at an annual cost of $22 per acre. At low energy costs (10 mills/kilowatt hour) the zero pump lift farm has a small net income advantage over the 200-foot pump lift farm, but this advantage rapidly increases as energy costs rise.

Going from 20 to 30 mills per kilowatt hour at zero pump lift decreased net farm income by $8,213. The comparable net income loss is $24,082 and $39,315 for the 200- and 400-foot pump lift situations, respectively. All situations showing a net farm income of $6,013 reflect the dryland wheat-fallow land use pattern. The effects of changing pump lifts are not linear because of the additional costs of pumping facilities associated with the deeper wells. A 1,000 foot pump lift situation was shown to be infeasible at all energy cost levels in the long run.

The data in table 2 reflect a long-run situation in which well depreciation charges are deducted from net farm income. It is implied that farms with more than 400 foot lifts will be unable to replace capital investments in wells if real energy costs remain above 30 mills per kilowatt hour. However, such farms are covering variable production costs and the fixed costs of all irrigation equipment except wells up to a cost of about 50 mills per kilowatt hour. If present economic conditions prevail, most

Table 2. Annual Returns to Land and Operator Management for the Baseline Farm

Pump Lift in Feet	Power Rate in Mills per Kilowatt Hour					
	10	20	30	40	50	60
	($)					
0	165,334	157,121	148,908	140,695	132,483	124,269
200	147,437	123,355	99,273	75,818	52,780	29,741
400	107,803	66,722	27,407	6,013	6,013	6,013
600	71,014	6,013	6,013	6,013	6,013	6,013
800	33,046	6,013	6,013	6,013	6,013	6,013

of these farms should remain in irrigated production for many more years even though it would not be economically feasible to develop additional wells for irrigation with such high pump lifts.

A comparison across energy cost levels shows the relative impacts of pump lift on net farm income. At 20 mills per kilowatt hour there is a net income difference between the 200- and 400-foot pump lift situations of $56,633, while at 30 mills per kilowatt hour this difference expands to $71,869. At 40 mills per kilowatt hour, all but the 200-foot pump lift farm have returned to agriculture in the long run.

The energy costs per acre inch of applied water shown in table 3 illustrate the effects of both pump lifts and energy prices. At zero pump lift, the energy cost of pressurizing the sprinkler system is rather low for all energy price situations. However, as pump lifts increase, the energy requirements rise in a linear fashion. At the higher prices of energy, the costs of pumping water become very large. At 40 mills per kilowatt hour the energy cost per acre inch of applied water for an 800 foot well reaches $4.72.

It will be noted in table 3 that the energy cost per acre inch at which the farmer turns to dryland wheat production is lowest for the high pump lift situations. This occurs because the fixed costs of wells and irrigation equipment rise with increasing pump lifts. It is the combination of depreciable facility cost plus the cost of energy that determine the total cost of irrigating.

The land values shown in table 4 were generated using the land valuation model and net revenue estimates from the linear programming model. These land values are based upon the underlying assumptions contained in table 1. These land values represent the maximum that a prospective buyer would be willing to pay for land under these circumstances. The estimated value of nonirrigated cropland was calculated as $579 per acre where income is based on dryland wheat production.

The estimated land values shown in table 4 illustrate the estimated impacts on farmland value as they have been affected by rising energy costs during the past few years. The first column of land values reflects those that existed in 1979 or 1980 prior to the rapid increase in energy costs. At 10 mills per kilowatt hour, irrigated farms having pump lifts up to 600 feet are estimated still to have land values of about $1,200 per acre. The difference between land values for the zero and 600-foot pump lifts is nearly $900 per acre. Even the

Table 3. Energy Cost of Applied Water

Pump Lift in Feet	Power Rate in Mills per Kilowatt Hour					
	10	20	30	40	50	60
	($/acre inch)					
0	.13	.26	.39	.52	.66	.79
200	.39	.79	1.18	1.57	1.97	2.36
400	.66	1.31	1.97	2.62*	3.28*	3.94*
600	.92	1.84*[a]	2.76*	3.67*	4.59*	5.51*
800	1.18	2.36*	3.54*	4.72*	5.91*	7.09*

[a] Asterisks indicate situations that no longer irrigate and rely on dryland wheat production.

Table 4. Baseline Farmland Value Estimates

Pump Lift in Feet	Power Rate in Mills per Kilowatt Hour 10	20	30	40	50	60
	($/acre)					
0	2,074	2,001	1,914	1,840	1,767	1,694
200	1,906	1,681	1,454	1,234	1,017	802
400	1,534	1,149	780	579	579	579
600	1,188	579	579	579	579	579
800	833	579	579	579	579	579

800-foot pump lift farm would be able to pay for all irrigation costs and still increase land values above dryland levels.

The zero pump lift farm decreases in land value $160 (8%) per acre when energy costs rise from 10 mills per kilowatt hour to 30 mills per kilowatt hour. The 200-foot pump lift farm loses about $452 (24%) per acre, while the 400- and 600-foot pump lift farms lose $754 (49%) and $609 (51%), respectively, in land values. Actually, the 600-foot lift farm returns to dryland production and is saved from greater losses only because of the land value provided by nonirrigated wheat production. Many parts of the region with these high pump lifts have only a rangeland grazing alternative with much lower expected land values and would experience greater losses than shown here when irrigation is abandoned.

It is shown that energy costs rising from 10 mills per kilowatt hour into the range of 30 to 40 mills per kilowatt hour have dealt a devastating blow to many of these high pump lift farms. They may have been hurt even more than shown here because the market for farmland tends to reflect future expectations for land values which would exaggerate the effects of short-run changes in farm income.

Sensitivity Analysis

The sensitivity of the land value model to parameter value assumptions is illustrated in table 5. Each of the parameters are implicitly based upon the expectations of a land buyer or seller and will vary according to individual financial status and perception of the future. The 200-foot-pump-lift-40-mill-per-kilowatt hour situation producing a $1,234 per acre land value was used for the sensitivity analysis. However, similar sensitivity to parameter value changes would be shown for other power cost and pump lift situations. Each parameter was varied by itself with all other values held to the levels in table 1. The sensitivity analysis was not designed to consider the response of land values to alternative economic conditions where several of these parameters would be simultaneously changed. Instead, the purpose was to elicit the importance of each individual parameter assumption. Each parameter was increased 10% from its base value to allow an easy comparison of the response to each parameter as shown in the last column of the table. Those standing out as having the largest impacts are net farm revenue, land value growth rate, and the nominal interest rate. At the other extreme are the capital gains tax rate, the percent down payment, and the mortgage period, each having a relatively small impact on land values.

Table 5. Land Value Sensitivity to 10% Model Parameter Changes

Parameter/Unit	Base Value	Percent Land Value Change
Net revenue ($/acre)	48.6	3.9
Net revenue growth rate (%)	4.5	1.3
Marginal tax rate (%)	28.0	1.6
Land growth rate (%)	4.5	4.1
Capital gains tax rate (%)	11.2	−.3
Required rate of return (%)	5.0	−1.5
Inflation rate (%)	4.0	−1.2
Down payment (%)	30.0	0
Nominal interest rate (%)	9.0	−4.9
Mortgage period (years)	30.0	.1
Planning horizon (years)	15.0	2.1

Note: Based on the situation of a 200-foot pump lift and 40-mill-per-kilowatt-hour power cost where land value was $1,234 per acre.

A 10% increase in the expected growth rate of land values or net farm income would increase land values by 4.1% and 3.9%, respectively. Increasing the nominal interest rate from 9.0% to 9.9% represents an increase in the real rate of interest from .5% to .9% since inflation is being held constant at 4%. This increase in interest rates would decrease the land value by 4.9%. Other parameters of some importance are the required rate of return on capital and the rate of inflation, both having a depressing effect on land values.

An increase in the planning horizon allows a longer compounding period. In computing the present value of capital gains in the land value model, an increase in the time horizon increases (decreases) that value when the growth rate of capital gains is larger (smaller) than the computed discount rate. For this reason, at low net return levels it is possible for a longer time horizon to lower the present value of land.

Another factor that can affect potential land values is the choice of high pressure or low pressure irrigation systems. Some farms, because of steep slopes and soils with lower water infiltration rates, are unable to adopt low pressure sprinkler systems and, hence, incur higher per acre energy costs. Net returns for the high pressure system are lower because of the additional 100 feet of head (43 psi) required to operate the center pivot application systems.

A difference in land value of $284 ($1,840 vs. $1,556) per acre was calculated for the zero lift-40 mill per kilowatt hour case between the two irrigation systems to suggest the level of potential benefits to such farms if low pressure conversion is possible. Also, at the electricity cost of 40 mills per kilowatt hour, a $300 ($1,234 vs. $934) per acre advantage in land value was found for the low pressure system at the 200-foot lift situation. The relative advantage of low pressure irrigation systems becomes greater as energy costs rise. The net income effect of adopting the low pressure system will be affected by the level of water use and the cost of energy. For a more thorough economic comparison of high pressure and low pressure irrigation systems see Taylor (1985, 1986).

Conclusions

This article focuses on one segment of agriculture that is experiencing rapid changes in economic conditions and likely will face drastic adjustments in the near future. The profit squeeze on high pump lift irrigated farms caused by increasing pumping energy costs is clearly illustrated. Farms with pump lifts of 400 to 600 feet already face possible conversion to dryland farming under current electrical power rates. Electricity costs above 40 mills per kilowatt hour may cause farms with pump lifts of less than 400 feet to abandon irrigation. Even farms with pump lifts of 200 feet will experience extreme land value losses as electricity costs rise above this level. Of course, a change in the general economic conditions for farming, either better or worse, could alter these assessments. In any case, the differences in land values among irrigated lands with differing pump lifts have been widened by recent energy cost increases and will continue to persist. The changes in land values imposed on irrigated farms by increased energy costs are compounded by those affecting agriculture in general. Such farms are in the process of incurring drastic reductions in asset values with all of the associated problems that persistently follow.

This analysis of the land value impacts from rising energy costs is probably more accurately revealing of long-run conditions than a reflection of actual recent land market data. The rapid rise in pumping energy costs coupled with major changes in other economic conditions have been relatively recent and, hence, have not been thoroughly felt in the imperfect system of land markets. Moreover, this is an analysis of long-run impacts which fully reflect the requirement of replacing all investments in wells and irrigation equipment. Many farmers with pump lifts exceeding 400 feet are continuing to irrigate by covering only variable operating costs. Indeed, a good well may have an expected life of more than thirty years if the water resource is not depleted. The result is that many farmers operating near the margin of dryland farming as shown in this analysis could continue to irrigate for many more years. Farms still repaying the investment costs of irrigation development may go bankrupt or be forced to liquidate, but with the result that someone else will continue to irrigate the farm as long as existing wells and irrigation equipment are operable.

There are other implications of this research. A public concerned about keeping the high pump lift farms in operation in the long term should consider energy cost subsidies or other means to reduce irrigation operating costs in order to raise farm net revenues. Where the demise of irrigated farms is relatively certain, there may be a requirement for financial or managerial assistance to ease the adjustment out of agriculture or to a different type of agriculture. Where property taxes have been slow in adjusting to lower land values for these farms, this research could be used to argue for a lower tax rate. The implications of this research are applicable to all areas where high pump lifts prevail or where declining water tables are increasing required pump lifts.

Finally, the relatively higher costs of energy for deep well pumping will have the effect of conserving water. The expected life of groundwater supplies will be extended as farmers are required to use less water. To this extent, a long-term social benefit may result from the higher costs of energy. In any case, the relatively higher energy costs for irrigation pumping will curb the expansion of high pump lift irrigation and will eventually eliminate some portions of this form of agriculture. The contraction phase will seem much more painful and troubling than was the expansion phase.

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