CAPITAL BUDGETING ANALYSIS OF UNCERTAINTY IN IRRIGATION INVESTMENTS

by

Wesley N. Musser

Irrigation as a risk response has received considerable attention under S-180. Part of this research, such as Boggess and Bosch and Eidman, concerns the application of standard risk efficiency criteria to production and income risk associated with use of irrigation. At the same time, such standard research has been recognized as having limited relevance for the current issues associated with financial stress which has emerged as an important component of the activities of S-180. Young raised this limitation in reference to Boggess' work in noting its abstraction from financial and institutional risk. Subsequent reviews of literature on irrigation (Bosch, Eidman, and Oosthuizen; Tew and Boggess) have also considered these broader dimensions of risk associated with irrigation. A general bias towards short term issues in empirical risk research can be related to limitations of empirical irrigation research. McCarl and Musser noted that focus on short term issues in risk research arises from the ease of specification of probability distributions required for risk efficiency models for such issues. Further, they also note that analysis of issues of longer term risk or uncertainty, such as those identified for irrigation, require more eclectic empirical models than has been common in research on standard production and marketing risk analysis. The current ongoing research under S-180 on financial stress is an example of this proposition.

The purpose of this paper is to evaluate the potential of capital budgeting methods to evaluate some of the uncertainty issues associated with irrigation. This paper rose out of informal discussions at the 1985 S-180 meeting concerning irrigation as an example of investments during the past decade that may have contributed to current financial stress. The next section of the paper presents data on irrigation for the states cooperating in S-180 to explore national trends in irrigation uses as background on the relevance of this issue. The subsequent section considers a capital budgeting model of irrigation investments, with particular attention to risk. The selection of a capital budgeting model is partially based on its consistency with the issues

---

*Wesley N. Musser is a visiting associate professor in the Department of Agricultural and Resource Economics, Oregon State University.

A. Gene Nelson made helpful comments on a draft of this paper and John Hewlett developed the data in Table 1.

of long term risk (McCarl and Musser). In addition, such an approach would allow a broad national analysis of investments in irrigation, under S-180. The final section of the paper therefore discusses a regional approach to research in this topic. Even if such a coordinated research effort does not emerge, this conceptual review will provide more evaluation of the basic capital budgeting model in analysis of uncertainty.

Trends in Irrigated Crop Production

Historically, irrigation was considered a production practice that allowed agricultural production on arid lands. For example, classic textbooks in land economics such as Ely and Wehrwein and Barlowe only discuss irrigation in the context of areas with very limited rainfall. In the modern era, several trends in agricultural production systems make this concept seem quite quaint. First, the biological revolution in varieties, fertilization, and pest control increased the marginal product of water in agricultural production so that supplemental irrigation to accommodate stochastic rainfall in subhumid areas became an economically viable practice (Burt and Stauber). The development of the concept of irrigation schedules related to stochastic rainfall (Mapp and Eidman) was an important concept to accommodate such an irrigation practice. Even before the mid-1970s, irrigation was being used in many areas that could not be considered arid, especially for higher-valued crops.

In the 1970s, two developments accelerated this process. First, the development of modern automated irrigation systems had several important impacts. This new technology probably reduced the relative cost of irrigation compared to other inputs. Perhaps more importantly, it raised the marginal product of irrigation on soils with low water retention capacity in which timing is important. Secondly, the price increases for many commodities in the mid-1970s raised the value of the marginal product of irrigation. The resulting increases in irrigation after 1974 are documented in Table 1. Between 1974 and 1982, harvested irrigated cropland increased in all regions except New England and the Mid-Atlantic. The largest acreage increases were in the West North Central region with over 3.6 million acres, the Mountain region with over 1.4 million acres and the Pacific region with over 1.3 million acres. However, both the South Atlantic and East South Central regions had increases of over 500,000 acres. On a percentage basis, the East North Central and the East South Central regions, increased over 100 percent, and the West North Central and the South Atlantic regions increased over 50 percent.

Most states in S-180 shared in these increases. Only New York, Texas, Oklahoma, and Arizona had decreases. Nebraska with over 2 million acres had the largest increase with Arkansas second with over 1 million acres, and California third with increases of over 800 thousand acres. Illinois, Michigan, Minnesota, Kansas, Missouri, Georgia, Florida, Mississippi, Montana, Colorado, Washington, and Oregon were

Table 1. Trends in Harvested Cropland in the United States by Regions and Selected States, 1974-82

States / Regions	Irrigated Harvested Cropland Year 1974	Year 1978	Year 1982	Changes Absolute 1974-1982	Changes Percentage 1974-1982
	------ acres ------				
NEW ENGLAND:	34775	36284	33833	-942	-2.71
Maine	5701	6563	5825	124	2.18
MID ATLANTIC:	156186	145137	150205	-5981	-3.83
New York	52650	55005	50673	-1977	-3.75
EAST NORTH CENTRAL:	319785	680211	863455	543670	170.01
Ohio	20537	24747	27338	6801	33.12
Indiana	31972	74008	131251	99279	310.52
Illinois	49951	128394	163112	113161	226.54
Michigan	93702	222946	284047	190345	203.14
WEST NORTH CENTRAL:	6288398	9216101	9917891	3629493	57.72
Minnesota	74769	268599	312667	237898	318.18
Missouri	146015	339892	400668	254653	174.40
North Dakota	66341	136219	160726	94385	142.27
Nebraska	3871105	5506573	5948974	2077869	53.68
Kansas	1948650	2546895	2639024	690374	35.43
SOUTH ATLANTIC:	1298125	2019811	2156542	858417	66.13
Maryland	22230	28281	38219	15989	71.93
Virgina	26850	42213	42400	15550	57.91
North Carolina	47841	90941	79607	31766	66.40
South Carolina	9043	31048	80738	71695	792.82
Georgia	107479	452469	567378	459899	427.90
Florida	1063972	1340389	1303315	239343	22.50
EAST SOUTH CENTRAL:	187218	386720	530780	343562	183.51
Kentucky	9426	13112	21503	12077	128.12
Alabama	12890	55303	63448	50558	392.23
Mississippi	156933	306306	429447	272514	173.65

WEST SOUTH CENTRAL:	8204480	9261419	8493654	289174	3.52
Arkansas	928855	1676577	2019406	1090551	117.41
Oklahoma	473165	512964	468043	-5122	-1.08
Texas	6117521	6402619	5319716	-797805	-13.04
MOUNTAIN:	10147357	11681636	11549482	1402125	13.82
Montana	1367432	1513656	1537067	169635	12.41
Wyoming	1059496	1146284	1146996	87500	8.26
Colorado	2357978	2748776	2656328	298350	12.65
New Mexico	693570	743256	702040	8470	1.22
Arizona	1048819	1109761	1042527	-6292	-0.60
PACIFIC:	9303069	10599471	10663464	1360395	14.62
Washington	1150329	1467074	1499888	349559	30.39
Oregon	1167291	1345385	1376498	209207	17.92
California	6917486	7708753	7787078	869592	12.57

Source: U.S. Department of Commerce, Bureau of Census, 1981 and 1984.

with Georgia second at over 425 percent. Other states above 300 percent include Indiana, Minnesota, and Alabama.

Without dwelling on more details, several conclusions are readily apparent. Except for the Northeast and the Southwest, increases in irrigation were a component in recent production increases throughout the nation. Although irrigation is still centered in the West, large increases have been occurring in many states east of the Rocky Mountains and even the Mississippi River. Thus, irrigation investments are a national issue and the uncertainty associated with these investments are worthy of national attention. Issues associated with irrigation are much broader than risk management; for example, the water availability issues which undoubtedly influenced the trends in the Southwest impact on risk management but are outside the analytical focus of S-180. Furthermore, the local or regional aspects of the problems are not necessarily ameanable to national research in S-180. However, the market forces which create price uncertainty have national origins; furthermore, production uncertainty processes are similar enough that a national approach may be feasible. Presentation of a simple analytical framework to incorporate these management issues is the concern of the next section.

A Capital Budgeting Model for Farm Investments in Irrigation

The past 20 years have seen a revolution in the incorporation of models of capital budgeting from corporate finance into farm management. Such a discussion is now a standard component in agricultural finance, farm management, and production economics texts. Nevertheless, a fairly elementary review may be helpful to some participants and will serve as a basis to discuss empirical issues. A standard corporate finance capital budgeting model is based on net present value (NPV) of an investment:

$$(1)\quad NPV = \sum_{t=1}^{n} \frac{R_t(1-m)}{(1+k)^t} + \sum_{t=1}^{n_1} \frac{mD_t}{(1+k)^t} + \frac{S_n - ST}{(1+k)^n} - C_o + ITC$$

where R_t = net cash flows before interest and taxes in period t, m = marginal income tax rates of the firm, n = length of planning horizon, k = after tax weighted-average cost of capital, D_t = depreciation allowance for taxes in t, n_1 = length of depreciation period $\leq$ n, S_n = market salvage value in period n, ST = income taxes on salvage value, C_o = current installed cost of the investment, and ITC = investment tax credit. This model discounts cash flows to all sources of financing with a weighted average cost of capital, k which is specified as:

$$(2)\quad k = k_e(1-m)(1-L) + k_d(1-m)L$$

where: k_e = before tax cost of equity capital, k_d = effective interest rate on debt, and L = ratio of market value of debt to market value of assets. Both k_e and k_d reflect rates on incremental capital rather than existing capital.

Some agricultural economists, including the author in some applications, still use the alternative concept of explicitly including after-tax value of debt cash flows and discounting all cash flows by $k_e(1-m)$. Such a procedure can yield the same NPV as (1) if applied correctly (Brigham; Levy and Sarnat). However, correct application precludes the major advantage of realism in explicitly treating debt financing for the investment. The correct treatment of explicit debt is to set cash flows from debt so that the ratio of debt to the value of the asset is consistent with the overall leverage position of the firm throughout the planning horizon. Initial debt = LC_o and terminal debt = $L(S_n - ST)$ with principal payments included for other periods to maintain debt equal to L times the salvage value of the asset after taxes. This principle reflects the concept of separation of financing and investment which has risen from the Modigliani and Miller propositions. Quite simply, inclusion of cash flows from actual debt associated with an investment does not account for all the financing aspects of the investment on the firm unless the investment is financed at the same proportions as the overall leverage of the firm. For example, using all equity financing augments the credit reserve of the firm while complete debt financing depletes the credit reserve. Usually, (1) is much simpler than accommodating these debt cash flows and will be used in this paper. However, income taxes for farm firms, treatment of risk, and estimates of k_e for (1) and (2) all require some adaptation for use in farm finance and are further discussed in this section.

Income Taxes

Many farm firms have business organizations that subject them to individual income taxes rather than corporate taxes. Under individual taxes for farmers several modifications in (1) and (2) are necessary. Annual rather than quarterly tax payments results in an assumption that ITC is received in period (1) rather than immediately. A less standard modification concerns the assumption of a constant value of m in (1). Under the corporate tax structure, the highest marginal rate is achieved at taxable income levels quite small for most corporate enterprises so that constant m is reasonable. However, individual tax rate structures have much more variation both in size of bracket and number of brackets. Most evidence seems to point to values of m less than the maximum amount for most farm firms, and investments the size of an irrigation system would likely vary m over several brackets. Musser, Tew and White demonstrate that relaxing the assumption of a constant m can affect chance of depreciation method, and Mackey and Musser demonstrate that it can alter the lease vs. purchase decision. Such results are consistent with the detailed modeling of income tax law in whole firm programming and simulation models.

Relaxing constant m in capital budgeting requires a few more parameters than in (1) in order to determine charges in income taxes arising from the investment (ΔT_t):

(3) $\Delta T_t = T_t' - T_t = f(TI_t') - f(TI_t)$

where: T_t' = income tax liability in t with the investment, T_t = income tax liability in t without the investment, TI_t' = taxable income in t with the investment, TI_t = taxable income without the investment, and $f(TI_t)$ = the income tax rate structure. TI_t' is specified as follows:

$$(4) \quad TI_t' = TI_t + R_t - D_t \qquad \text{for } t = 1,\ldots n-1$$

$$= TI_t + R_t - D_t + S_n' \qquad \text{for } t = n$$

where S_n' = taxable income for salvage value of the investment. In empirical analysis only the tax rate structure $f(TI_t)$, and TI_t must be specified. A whole firm model could be used to specify TI_t but it could also be a parameter on which sensitivity analysis is conducted (Mackey and Musser). Note that (3) does not include interest from the investment in the definition of TI_t, which is consistent with the general concepts in (1). Tax effects of additional debt can be modeled with specifying m_t in the definition of k consistent with TI_t', which accommodates all after tax effects of financing the investment (Musser, Tew and White). If interest payments could cause the marginal tax rate to vary over several brackets, the average of the rate associated with TI_t and the next lower or lower rates could be used. When m_t varies among periods then k is not constant over the planning horizon. The discount rate for period t($PVIF_t$) is then (Musser, Tew and White):

$$(5) \quad PVIF_t = \prod_{t=1}^{t} [\, 1 + [k_e(1-m_t)(1-L) + k_d(1-m_t)L] \,]$$

Variations in k_e and k_d among periods could also be accommodated in (5).

Capital Budgeting and Risk

Several methods have been used to accommodate risk in the capital budgeting framework. Several methods involve adaption of single period risk efficiency criteria to the investment content. For such methods, R_t in (1) is considered a random variable. Moments of NPV can then be derived for E-V analysis. Alternatively, a probability distribution of NPV can be evaluated with stochastic dominance - Boggess and Amerling is a recent application of this procedure to irrigation investments. Risk-free discount rates should then be used with these methods (Levy and Sarnat; McCarl and Musser). The problem with these methods under uncertainty is the difficulty in specifying long-run probability distributions (McCarl and Musser). Generalization of the methods in Boggess and Amerling may allow simulation of "long-run distributions." Such a procedure for coordinated regional research appears difficult if not impossible since crop simulators would have to be available for all cooperating production regions.

Another method involves assuming R_t and the other cash flows in (1) are certainty equivalents and using a risk-free rate for k. As an empirical method this approach is even more limiting than risk efficiency criteria because stable utility functions are required along with probability distributions. However, such a theoretical interpretation can be used to rationalize k as a risk adjusted discount rate. Following Robichek and Myers, assume R_t is the expected value of incremental returns in t, r = risk-free interest rate, and α is the ratio of the certainty equivalent of returns to R_t. For a single period investment, NPV of the certainty equivalent (NPV') is:

$$(6) \qquad NPV' = \frac{\alpha R_1}{(1+r)} = \frac{R_1}{(1+r)/\alpha} = \frac{R_1}{(1+k)}$$

where $k = [(1+r)/\alpha] - 1$. Alternatively α could be calculated as:

$$(7) \qquad \alpha = \frac{(1+r)}{(1+k)} .$$

Such an approach does have limitations if k and r are assumed constant throughout the planning horizon. Generalizing the concept of α to single period values α_t, the relationship in (7) becomes:

$$(8) \qquad \alpha_t = \frac{(1+r)^t}{(1+k)^t} = \frac{(1+r)}{(1+k)} \alpha_{t-1} < \alpha_{t-1} .$$

A declining value of α_t over time implies that the certainty equivalent of returns with a constant mean is declining over time. Assuming constant risk aversion, the risk of returns is implicitly increasing over time if k and r are constant among periods. Of course the value of k_t could be allowed to be a declining function of t in order to maintain a constant α_t. However, increasing risk over time does seem to be the essence of long-term uncertainty (McCarl and Musser). Thus, the implicit risk assumptions in the risk adjusted discount rate model appears to be consistent with the problem of concern in this paper. Since k subsumes risk aversion in this model, this variable must be considered as one moves toward application.

Cost of Equity Capital for Farm Firm

If the definition of k in (2) is examined, most of the variables are commonly calculated in farm management applications. One exception is k_e. While it is not a traditional farm management variable, it is related to opportunity cost of equity capital. Given that risk in investments is incorporated in this variable, an understanding of k_e and its differences with traditional farm management concepts is crucial for use of the risk-adjusted discount model.

In corporate finance theory, k_e is the long-term capitalization rate in market valuation of common equity. If P_o is the current price of a share of common equity and D_t is the expected dividend in period t, k_e can be determined for the following equation:

$$(9) \qquad P_o = \sum_{t=1}^{\infty} \frac{D_t}{(1+k_e)^t} = \frac{D_1}{k_e - g}$$

where g = constant growth rate in dividends. Relaxing the assumptions associated with g, leads to more complex formulations of (9). In the agricultural economics literature, Melichar used (9) to explain land values, where D_1 is interpreted as current returns to finance capital. Obviously, k_e is a before tax discount rate for equity capital. Traditionally, this rate has been called an opportunity cost of equity capital and in practice has been approximated with the borrowing rate, k_d. Finance theory and extensive empirical information would suggest $k_e > k_d$ to reflect a risk premium arising from equity being a residual claimant on income. For positive analysis of investments by representative farm firms, implementation of the cost of equity concept has the merit of representing rates of return agricultural investors are willing to accept. The methodological problem of course is that market data on D_t and P_t do not exist. Similar to Melichar, market values of assets and income flows can be used to estimate k_e at least for overall investments in aggregate agriculture — White, Musser and Oosthuizen earlier made such an attempt. However, this methodology probably requires refinement. An additional problem is that the appropriate value of k_e for an irrigation investment may differ from the overall rate if risk on irrigation investments differ from that of the overall investment portfolio. Further, examination of the influence of risk on k_e is helpful in clarifying this issue. The standard concepts of business and financial risk (Gabriel and Baker) can be used to disaggregate k_e as follows (Levy and Sarnat):

$$(10) \qquad k_e = r + BRP + FRP$$

where r = risk-free interest rate, BRP = premium for business risk, and FRP = premium for financial risk. In this model, r + BRP is the required rate of return on investments with zero leverage. This sum is required rate of return on investments with zero leverage. This sum is the overall market capitalization rate of Modigliani and Miller. In addition, FRP is an increasing function of leverage (L).

The consensus of research reviewed earlier in this paper is that irrigation reduces business risk. If L and therefore FRP are constant, k_e for irrigation should therefore be lowered from dryland investments. However, the irrigation literature suggests that these investments increase financial risk and therefore FRP. Corporate finance theory and data relate lower BRP and higher FRP as L and FRP increases as BRP decreases. For example, public utilities have a higher value of L because of lower business risk than other industries. Current levels of L among agricultural firms with different production enterprises in Table 2 also seem consistent with this logic. While these data partially reflect the differential effect of current financial stress among agricultural enterprises, they also correspond with intuitive views of level of business risk. Sonka and Patrick reported coefficients of variation for real labor income for 1965-79 for several Midwestern states. While these data varied considerably across states, a generalization is that the coefficients are lowest for dairy and highest for hogs and beef with grain farms having an intermediate position (p. 101). Current values of L are 29 percent for dairy farms, 26 percent for cash grains and 17 to 18 percent for general livestock and other livestock in Table 2. In addition, the high value for poultry and eggs of 35 percent is consistent with reduction in business risk due to vertical integration in the industry. Other enterprise situations, largely for horticulture, are difficult to interpret because of aggregation and lack of comparable data.

Table 2. Average Debt-Asset Ratios for U.S. Agricultural Firms by Enterprise Types, 1984.

Enterprise Type	Debt-Asset Ratio
	(Percent)
Cash grain	26
Field crops	18
Vegetable and melon	25
Fruit and nut	22
Nursery and greenhouse	17
General crop	20
General livestock	17
Dairy	29
Poultry and egg	35
Other livestock	18

Source: U.S. Department of Agriculture, Appendix Table 6.

These cross sectional data are also consistent with similar findings of Gabriel and Baker using time series and aggregate U.S. data. In the irrigation situation, anecdotal evidence also suggests that agricultural lenders are willing to lend more on irrigation than other investments. Thus, the overall value of L probably increases with investment in irrigation which dampens the decreasing influence of irrigation on k_e. Probably, k_e is somewhat lower than the overall rate but not as much as the reduction in business risk would suggest.

Under the above hypothesized effects of irrigation, the benefits to the firm of the increased overall leverage must also be included in the analysis. Levy and Sarnat argue that the benefits allocated to an investment from such increased leverage is the tax shelter of the additional interest on the increased debt. Separation of investment and financing precludes evaluation of the cash flows from the equity capital which the increased debt releases for other investments. Assuming L' is the new leverage rate and A = assets before the investment, the interest tax shield is $k_d(L'-L)A$, which needs to be subtracted from TI' in (4) above.

The Adapted Model

Summarizing the above reasoning, it may be helpful to rewrite earlier equations to present the model appropriate for irrigation investments. The basic model is:

$$(1') \quad NPV = \sum_{t=1}^{n} (R_t - \Delta T_t) PVIF_t + S_n PVIF_n + ITC\ PVIF_1 - C_o$$

where $PVIF_t$ is defined in (5) using k_e appropriate to irrigation in the discussion of (10) above and L' the new leverage level. (1') has tax effects, other than ITC, external to the above equation. ΔT_t is defined in (3) based on a value of TI' as follows:

$$(4') \quad TI'_t = TI_t + R_t - D_t - k_d(L'-L)A \qquad \text{for } t = 1, \ldots n-1$$

$$= TI_t + R_t - D_t - k_d(L'-L)A \qquad \text{for } t = n .$$

In (1') and (4'), all stochastic values are expressed by their expected value with k_e and k_d including risk premiums over r.

Towards Application

The NPV model has become a standard analytical method in agricultural economics. Part of its usefulness arises from the minimal number of parameters to be estimated and/or subjected to sensitivity analysis. Sensitivity analysis appears to be a feasible approach in analysis of uncertainty so this model is of particular interest on long-term risk issues. Furthermore, uncertainty arising from investments and their financing is the essence of the current financial crisis so that more rigorous single period risk models have limited value for such management issues. As with all economic models, this model has two complementary or alternative uses in research on uncertainty in irrigation; (1) source of hypotheses on sources of uncertainty, and (2) a model for empirical evaluation of the uncertainty for a particular investment. Hypotheses concerning irrigation will be discussed below; then some comments about empirical analysis in a regional research framework will be discussed.

Trends in irrigation in Table 1 suggest that irrigation was a desirable investment in the mid-1970s so that NPV > 0, based on expectations on expected returns and discount rates at that time. It is also plausible that the actual realized returns on such investments were lower than expected, similar to many other investments made in the 1970s. Thus, a general working hypothesis is that ex post NPV was less ex ante NPV. Hypothesized ex post revision of key variables in the NPV model are presented in Table 3. All of these hypothesized effects, which seem consistent with my image of the agricultural economy,

Table 3. Hypothesized Effect of Parameters on NPV Model of Historical Irrigation Investments

Variable	Hypothesis
R_t	Lower than expected because of output price levels
TI_t	Lower than expected because of price levels
T_t	Lower than expected because of TI_t and tax rate cuts
S_n	Lower than expected because of NPV decline
r	Higher than expected because of fiscal policy
FRP	Higher than expected because of variable interest rates
BRP	Higher than expected because of price variability (?)

support the working hypothesis. Obviously, R_t has been lower for many crops. The lower prices also result in lower TI_t and tax rates; the tax cuts in this decade further reinforce this tendency. Lower tax rates reduce the benefits of the fixed value of depreciation but increase the cash flows from production. Although the effects of tax changes are mixed, the joint effects of R_t and taxes surely cause reduction in cash flows. The value of S_n probably also decline if irrigation is no longer a profitable alternative. The variables affecting discount rates suggest higher discount rates. Most definitely, r which affects both k_e and k_d increased in the 1980s. The emergence of variable rate loans in the 1970s also increased FRP and k_e. BRP and therefore k_e may have also increased if expectation on price risk had not fully adjusted to the new levels. Finally, lower tax rates would also increase k. Thus k would definitely have increased which would lower $PVIF_t$. Lower cash flows combined with higher discount rates definitely support the general working hypothesis.

Empirical analysis of the general working hypothesis could take several approaches which can be summarized on a continuum. At the one end would be ex ante and ex post calculation of NPV. At the other extreme, only the hypotheses in Table 2 would be tested to arrive at qualitative effects on NPV. Intermediate positions would be to estimate some components but not all of NPV — for example after tax expected cash flows. The ambiguity in my recommendations reflects concern about data and methods to estimate such components as BRP and (L -L) of the basic model. Some of these components may be indirectly tested even though they are not directly estimable.

The case for a regional approach to such a research effort arises from both problem orientation and methodological development. The technological change and price levels which made irrigation a desirable investment in the 1970s were national economic forces. Although cash flows from irrigation and risk premiums vary locally, as much qualitative similarities are present as any firm research. In addition, coordinated research would be useful to resolve methodological issues and allow comparability of results, nationally, similar to the current financial crisis analysis under S-180.

REFERENCES

Barlowe, R. Land Resource Economics. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1958.

Bosch, D. and V. Eidman. "The Value of Soil Water and Weather Information in Increasing Irrigation Efficiency." Risk Analysis for Agricultural Production Firms: Concepts, Information Requirements and Policy Issues. Dept. of Ag. Econ., Michigan State University, Staff Paper 85-85, Nov. 1985, 207-218.

Bosch, D., V. Eidman and L.K. Oosthuizen. "A Literature Survey Dealing with Economic Efficiency of Water Use for Irrigation." Unpublished manuscript, Dept. of Ag. Econ., Virginia Polytechnic Institute and State University, 1985.

Boggess, W.G. "Risk Aspects of Irrigation Decisions." Risk Analysis for Agricultural Production Firms: Concepts, Information Requirements and Policy Issues. Dept. of Ag. Econ., University of Illinois, AE-4574, July 1984, 176-188.

Boggess, W.G. and C.B. Amerling. "A Bioeconomic Simulation Analysis of Irrigation Investments." S. J. Ag. Econ. 15(1983): 85-92.

Brigham, E.F. Financial Management-Theory and Practice. 2nd ed. Hinsdale, IL: The Dryden Press, 1979.

Burt, O.R. and M.S. Stauber. "Economic Analysis of Irrigation in a Subhumid Climate." Amer. J. Ag. Econ. 53(1971): 33-46.

Ely, R.T. and G.S. Wehrwein. Land Economics. New York: The Macmillan Company, 1940.

Gabriel, S.C. and C.B. Baker. "Concepts of Business and Financial Risk." Amer. J. Ag. Econ. 62(1980): 560-64.

Levy, H. and M. Sarnat. Capital Investment and Financial Decisions, 3rd ed. Englewood Cliffs, NJ: Prentice-Hall, 1986.

Mackey, R.B. and W. N. Musser. "Income Taxes in the Lease Versus Purchase Decision for Farm Firms." Unpublished manuscript, Dept. of Ag. and Res. Econ., Oregon State University, 1985.

Mapp, H.P., Jr. and V.R. Eidman. "A Bioeconomic Simulation Analysis of Regulatory Groundwater Irrigation." Amer. J. of Ag. Econ. 57(1975): 47-53.

McCarl, B.A. and W.N. Musser. "Modeling Long Run Risk in Production and Investment Decisions." Risk Analysis for Agricultural Production Firms: Concepts, Information Requirements and Policy Issues. Dept. of Ag. Econ., Michigan State University, Staff Paper 85-85, Nov. 1985, 129-148.

Melichar, E.O. "Capital Gains Versus Current Income in the Farming Sector." Amer. J. Ag. Econ. 61(1979): 1085-92.

Modigliani, F. and M.H. Miller. "The Cost of Capital, Corporation Finance and the Theory of Investment." Amer. Econ. Rev. 48(1958): 261-297.

Musser, W.N., B.V. Tew and F.C. White. "Choice of Depreciation Methods for Farm Firms." Amer. J. Ag. Econ. forthcoming.

Robichek, A.A. and S.C. Myers. "Conceptual Problems in the Use of Risk-Adjusted Discount Rates." J. of Finance. 21(1966): 727-30.

Sonka, S.T. and G.F. Patrick. "Risk Management and Decision Making in Agricultural Firms." Risk Management in Agriculture, P.J. Barry, editor, Ames: Iowa State University Press, 1984, 95-115.

Tew, B.V. and W.G. Boggess. "The Risk Aspects of Irrigation Scheduling: A Firm Perspective." Paper presented at the 1985 Annual Meeting of the WAEA, Saskatoon, Saskatchewan, July 7-9, 1985.

U.S. Department of Agriculture, Economics Research Service. Financial Characteristics of U.S. Farms, January 1985. Agric. Inf. Bul. 495, Washington, D.C., U.S. Government Printing Office, July 1985.

U.S. Department of Commerce, Bureau of the Census. 1978 Census of Agriculture. Vol. I, Part 51, Washington, DC, U.S. Government Printing Office, July 1981.

U.S. Department of Commerce, Bureau of Census, 1982 Census of Agriculture. Vol. I, Part 51, Washington DC, U.S. Government Printing Office, Oct. 1984.

White, F.C., W.N. Musser and J. Oosthuisen. "Cost of Capital for American Agriculture: Its Use in Agricultural Policy Formulation." Ag. Fin. Rev. 38(1978): 21-8.

Young, D.L. "Discussion: Irrigation and Pest Control on Risk Reducing Inputs." Risk Analysis for Agricultural Production Firms: Concepts, Information Requirements and Policy Issues. Dept. of Ag. Econ., University of Illinois, AE-4574, July 1984, 176-188.