IRRIGATION AND FARM LEVEL RISKS:

AN HISTORICAL ANALYSIS OF THE SOUTH SASKATCHEWAN RIVER IRRIGATION DISTRICT

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1. INTRODUCTION

1.1 Background

Summerfallowing is a major cause of soil degradation in Saskatchewan through increased soil erosion, soil salinity and loss of organic matter (SASCC, 1987). Irrigation offers a potential remedy for the problem of soil degradation through summerfallowing, and potentially provides relief from the risks of drought by supplying adequate moisture to grow crops. Irrigation may however, increase the vulnerability of the farm to financial and management risks. Returns from irrigation would, therefore, have to be higher in order to allow a trade-off between income and stability. The increased fixed costs may also create an additional disadvantage of requiring most farmers to borrow capital to develop irrigation, thereby increasing the financial risk associated with their farming operations. Many farmers not wishing to increase the financial risks of their farms will not adopt irrigation. The on-farm adoption of irrigation also requires increased management ability, and if this is not forthcoming on the part of the farm manager the overall risks associated with the operation may increase even further.

1.2 Objectives of the Study

The primary objective of this study is to provide information on the on-farm economics and risks associated with irrigation in Saskatchewan. In particular, the study attempts to show the benefits and costs of irrigation both in terms of the level of net returns, as well as in terms of variability in yields and net returns. No attempt is made here to assess the risks in irrigation farming associated with managerial ability.

II. CONCEPTUAL FRAMEWORK

2.1 Types of Risk

Two major types of risk face farm business managers. These major risk types have been labelled business and financial risk (Barry,

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1984). Business risk is commonly defined as the inherent risk in the type of business, independent of the way it is financed. Financial risk can be defined as the added variability of net returns to owner equity that results from the financial obligations associated with debt financing.

The major sources of business risk in agriculture have been categorized as follows: production or technical risk, market or price risk, technological risk, legal and social risk, and human sources of risk (Barry, 1984). Production or technical risk refers to the inherent variability in the farm's output resulting from weather, diseases and pest infestations. Market or price risk refers to the variability of prices for both farm commodities and farm inputs. Technological risk is the variability in net returns resulting from technological change in production processes that may render some buildings, machinery and equipment obsolete and cost ineffective. Legal and social risk refers to the variability of net returns resulting from the farm business entering into more business contracting with regards to marketing of commodities, securing supplies of inputs, rental and leasing arrangements, etc. Changes in government programs are also a form of legal and social risk. Human sources of risk refers to the variability of net returns resulting from changing health and the goals and objective of key management and labour personnel.

The level of financial risk a farm business has to deal with depends on the nature and extent to which the business uses borrowed capital. Financial leverage, defined here as the amount of debt capital divided by the amount of equity capital, allows the farm business manager to use debt capital to multiply the potential gain or loss realized on equity capital. The potential gain or loss is higher the more financial leverage is used. There are also other financial risks inherent in using credit. Interest rates can fluctuate widely, the availability and terms of credit can change over time, and credit can become unavailable to certain farm businesses. These financial risks, combined with business risks, influence the farm manager's total return.

2.2 Measurement of Risk

The risk associated with various production technologies can be analyzed by a number of methods. One of the more common methods is to calculate the mean and standard deviation. Plotting the mean and standard deviation of various variables generated by production technologies in an X-Y graph, that is with means on the vertical axis and standard deviations on the horizontal axis, can also demonstrate their relative risk. Those production technologies exhibiting the lowest standard deviation for a given mean level of the variable in question or conversely the highest mean for given levels of standard deviation of the variable in question are said to be on the risk efficiency frontier of risk-neutral and risk-averse decision makers.

Therefore, those alternatives with higher standard deviations for given levels of the mean or lower means for given levels of standard deviations are below the risk efficiency frontier and are thereby eliminated from the decisions of risk-neutral and risk-adverse decision makers.

The data plotted in this mean-standard deviation space provides information as to the type and amount of risk associated with various production technologies. Yields associated with various production technologies and plotted in mean-standard deviation space represent their respective production risks. Net returns plotted in the same manner will reflect the overall business risk associated with various production technologies.

The relative financial risk associated with various production technologies is best measured by leverage ratios. The debt-to-asset ratio will define the level of financial leverage and thereby financial risk. Current studies indicated that farm businesses with debt-equity ratios exceeding 0.6 to 1 will experience some problems with servicing debt and those with a 1.5 to 1 debt-equity ratios will most likely experience an inability to service debt (Kohl and Warman, 1987). Comparison of debt-equity ratios between farms using different types of production technologies will demonstrate their relative levels of financial risk.

3. METHODOLOGY

3.1 Calculation of Crop Costs and Returns

The cost and returns per acre from 1968 to 1986 for a number of crops grown under dryland and irrigated conditions were calculated for the South Saskatchewan Irrigation District #1 (SSRID#1) (Brown and Schoney, 1988). The crops grown under dryland conditions used in this study include: hard spring wheat on fallow and stubble, flax on fallow and stubble and lentils on stubble. The crops grown under irrigated conditions used in this study include: hard spring wheat, soft spring wheat, flax, alfalfa, fababeans, and potatoes. The calculation of the costs and returns is as follows; price times yield equals gross returns; minus variable cash costs equals gross margin; minus opportunity costs for interest on variable cash costs and operator labor equals return above variable costs; minus fixed costs equals returns above total costs.

The prices used are from Statistics Canada and or Saskatchewan Department of Agriculture (SDA) reports. The hard spring wheat price in any one year was the initial and final payment received from the CWB for #1, 2, 3, and feed grades minus transportation to the terminal point, country elevation, and removal of dockage charges. The calculated price was then weighted by the amount of #1, 2, 3, and feed wheat marketed in crop district #6 (the SSRID#1 area) that year (Ulrich and Furtan). The soft wheat price in any one year was calculated the same as the hard wheat price except that the grade distribution is one grade lower, because very little #1 soft wheat is grown. For the years 1968 to 1973 the soft wheat price was unavailable and was estimated by the relationship exhibited between the calculated hard and soft wheat prices for 1974 to 1986. The prices for flax, lentils, and fababeans were the "farm price" taken from various years of the annual Saskatchewan Agriculture publications. The price for potatoes was taken from Statistics Canada publication #21-516 for 1968-1974 and #22-003 for 1975-1986. The alfalfa prices used were provided by staff of the Irrigation Services Division of the Saskatchewan Water Corporation (SWC) from sources in their library.

Dryland hard wheat and flax yields on both fallow and stubble were from the Saskatchewan Crop Insurance Corporation (SCIC) and were the average yields for risk area 12 (the SSRID#1 area). The stubble yield data for 1968 to 1972 was not available, so the average crop yield was adjusted by the relationship between fallow and stubble yields established through 1973 to 1986. The yield for lentil on stubble was obtained from the SCIC for risk area 12 for 1979 to 1986 and an average Saskatchewan yield for all other years were obtained from the annual Saskatchewan Agriculture publications. These dryland yields have been reduced by 8% due to the poor soils in the SSRID #1 (Bohrson, 1988).

Crop yields under irrigation were very difficult to substantiate. The SCIC factor up their dryland coverage for irrigated crops and therefore do not have a set of irrigation yields. The yield data used in this study was either from the Saskatchewan Agriculture publication or SWC Irrigation Services Division staff records. Yields for all crops other than potatoes were supplied by SWC staff records. The yield for potatoes was taken from Statistics Canada publication #21-516 for 1968-1973 and from Saskatchewan Agriculture for 1974-1986. The low end of the range from the Saskatchewan Agriculture data was used to come more in line with Statistics Canada publication #22-003. An additional 20% of yield was removed to compensate for storage losses and unmarketable crop.

The categories of variable cash costs included: seed (recommended seeding rate times last year's price plus 20% for cleaning), fertilizer (recommended nitrogen and phosphorus rates times their price), pesticides (herbicides and insecticide), irrigation machinery operating (the operating costs directly associated with the irrigation system itself), other machinery and buildings operating costs (operating costs associated with the power and field machinery), and other variable cash costs (twine for hay and water tax for irrigated crops). Variable noncash costs included an interest charge on the variable cash costs (for 1/2 year at prime plus 2%) and a charge for operator labor.

The categories of fixed costs included cash for property taxes and overhead items including utilities, telephone, accounting fees, subscriptions, etc. (assumed at 5% of variable costs and property tax) and the noncash capital recovery charge for the irrigation and other machinery and building investment.

The variable and fixed costs except for seed, water tax, property tax, and overhead costs have been calculated in a similar manner. Various studies as outlined in Brown and Schoney (1988), were perused and pertinent data noted for the year in question. Those years without a data reference were indexed by the appropriated Statistics Canada index. In addition, the 1968 reference was indexed forward to 1986 by the appropriate index. Next, the 1986 reference was indexed back to 1968 by the appropriate index. Finally, all three -- (1)the actual referenced data with missing data indexed, (2)the 1968 referenced data indexed forward, and (3) the 1986 referenced data indexed backward -- were added together into an overall average.

The major costs not estimated in the tables include an allowance for the operator's management and a return to the land investment. These particular categories of costs are very difficult to estimate with any degree of accuracy. Therefore, the net return levels in the tables represent a return to land, and management for each crop in each year.

3.2 Hypothetical Fixed Crop Rotations

Given the above costs and returns, a number of hypothetical fixed crop rotations for the period 1968 to 1986 were calculated. The rotations selected for both dryland and irrigated conditions are shown in Table 1. Two points should be noted in the calculation of rotation gross margins, returns above variable costs, and returns above total costs. First, the weightings of the crops in each rotation have been kept constant over time because the objective was to compare the distributions of net returns from fixed rotations. One or several other rotations in which individual crop weightings change from year to year may well be more risk efficient than the rotations outlined in Table 1. Second, the yields of other crops in rotations which include lentils, fababeans, and alfalfa have not been adjusted to compensate for the nitrogen fixing ability of these crops.

3.2.1 Saskatchewan Crop Insurance Corporation (SCIC), Western Grain Stabilization Program (WGSP), and Special Canadian Grains Program (SCGP)

The monetary effect on a per acre basis of participation in the SCIC, WGSP, and SCGP have been calculated into the net returns of each rotation. Average annual SCIC payments to farmers less premiums for risk area 12 have been calculated on a per acre basis for 1971 to 1987. These calculated annual acreage benefits or costs have been added to or subtracted from the rotation returns for the year in question. The method of calculation used is not rotation specific but

Table 1: Fourteen Hypothetical Crop Rotations Showing Percentage of Each Crop In Each Rotation, 1968-86

Dryland Rotations	Fallow	Wheat/f	Wheat/st	Flax/f	Flax/st	Lentils/st
1	50	50				
2	30	30	40			
3			100			
4	50	25		25		
5	60	25				25
6	30	15	20	15	20	
7	30	30	20			20

Irrigated Rotations	Hard Wheat	Soft Wheat	Flax	Potatoes	Alfalfa	Fababeans
8	100					
9		100				
10	20				80	
11	60		20	20		
12	60		20			20
13	40		20	20		20
14	20		20	20	20	20

f = fallow   st = stubble

does reflect the monetary effect of crop insurance on a per acre basis for the SSRID#1.

WGSP payments to Saskatchewan farmers less producer levies paid were divided by the total marketings of the seven crops included in the program each year to derive an annual per tonne impact of the program (Saskatchewan Agriculture). The per tonne impact was then added to the price of wheat and flax in appropriate year and calculated into the returns of each rotation. No WGSP impact was calculated for the other crops as they are not included in the program.

The SCGP payments on a per tonne basis were added to the price of wheat and flax in 1986. No SCGP adjustment was calculated for the other crops as they were not included in the program.

3.2.2 Canadian Wheat Board (CWB) Quotas

The effect of CWB quotas on the rotation net returns were calculated. The CWB quotas for wheat and flax were gathered from CWB annual reports for the 1968-1986 period. Quotas were adjusted to account for the level of delivery allowed for all grades of wheat and flax. That is, if one grade of wheat had an open quota and another only 10 bushels per quota acre, the wheat quota that crop year was calculated as 10 bushels per quota acre. A quota acre was considered to be the same as a rotation acre. that is, it included that portion of the rotation acre either seeded to the crops considered or fallowed. The CWB 'Bonus Acres' program was included in the calculation from 1982 to 1986.

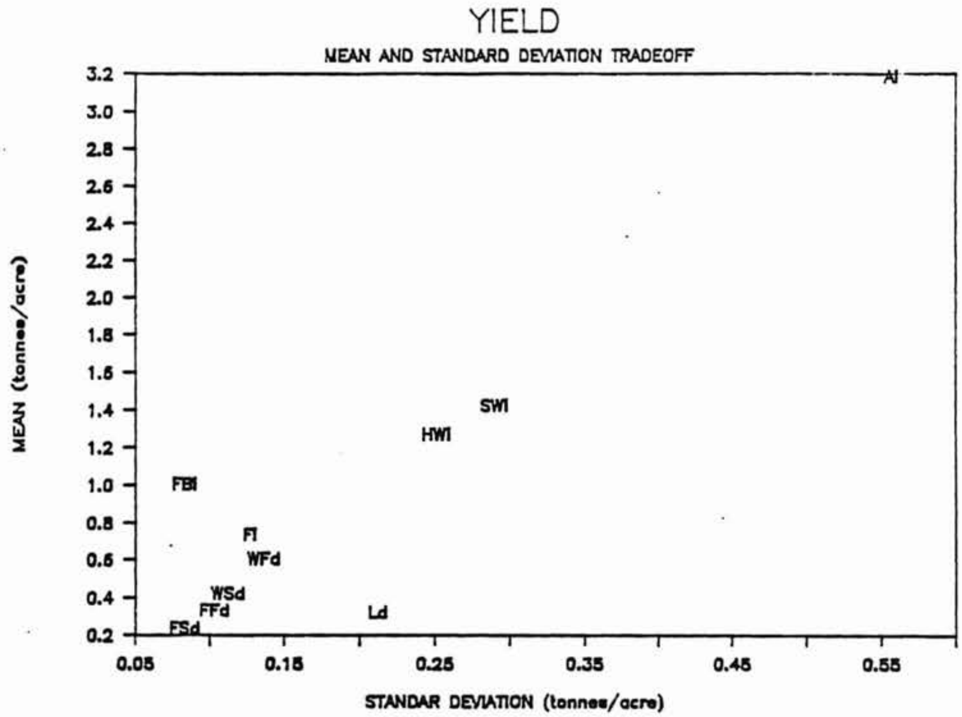
For years when the production of one crop from a particular rotation was above its quota level and the production of another crop in the same rotation was less than its quota level; quota allocations were adjusted accordingly to allow for the maximum delivery of all crops. Production above the quota level was stored at no cash cost and sold when the quota level permitted. This adversely affected rotation gross margins in low quota years and greatly increased them in subsequent years when quotas eventually increased or became open. This method of calculation is a valid measure of the variability of cash flows resulting from following the fixed rotations during the time period.

4. RESULTS

4.1 Irrigation Versus Drlyand - Individual Crops

4.1.1 Yields

The means and standard deviations of the various crops under dryland and irrigated conditions are plotted in Figure 1. Figure 1 can be interpreted as a measure of the production risk associated with various crops. Note that for plotting purposes the data for alfalfa and potatoes under irrigation are not included because they have means and standard deviations of 3 and 0.6, and 6.3 and 1.75 tonnes per acre, respectively. This level of mean and standard deviation demonstrates high production potential but also high production risk. It can be seen that irrigated hard and soft wheat yields (HWi and SWi) are substantially larger than the dryland yields (WFd and WSd). However, the standard deviations of the irrigated wheat yields has also increased substantially, thereby increasing production risk. Finally, Figure 1 demonstrates that the most risk efficient crops from a production point of view are fababeans, hard wheat and soft wheat on irrigation. The yield data for fababeans did not vary much from year to year, thereby resulting in a lower standard deviation than may truly be the case.



Legend: FBi-Irrigated Fababeans, FFd-Flax on Fallow, WFd-Hard Wheat on Fallow, Ld-Lentils on Stubble, SWi-Irrigated Soft Wheat, FSd-Flax on Stubble, WSd-Hard Wheat on Stubble, Fi-Irrigated Flax, HWi-Irrigated Hard, Ai-Irrigated Alfalfa

Figure 1: Mean and Standard Deviation of Yields Per Acre, Dryland and Irrigated Crops

4.1.2 Gross Returns

The gross returns were significantly higher under irrigation than under dryland conditions mainly because the yields increased significantly. Potatoes and alfalfa generally had the highest gross returns under irrigated conditions. Lentils on stubble had the highest, but also highly variable, gross returns under dryland conditions.

4.1.3 Variable Cash Costs

The variable cash costs are significantly higher under irrigation than under dryland conditions. The major contributors to this increase are: fertilizer - due to increased recommended rates, irrigation system operating costs - due to the fact there are none on dryland, other machinery operating costs -- due to increased yields and investment requirements under irrigation, and water tax. Seed costs did not increase under irrigated conditions because recommended seeding rates generally did not change. Pesticide costs were very similar for hard wheat under irrigated and dryland conditions. These costs increased by about 40% for flax under irrigation as compared to dryland conditions. The variable cash costs associated with growing potatoes under irrigation were significantly higher than the other crops.

4.1.4 Gross Margin

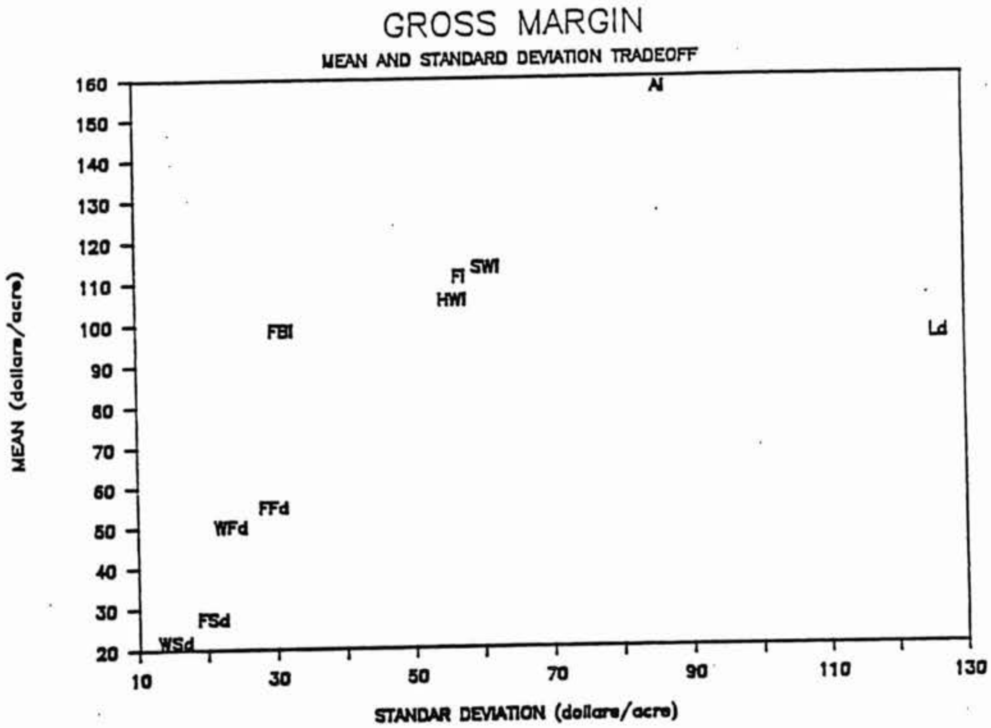
The mean and standard deviation gross margins per acre are higher under irrigation than under dryland conditions (Figure 2). However, all crops other than lentils on stubble are relatively risk efficient. Those farm managers preferring low risk, and thereby low gross margins, will stay with the dryland crops, except for lentils. Lentils on stubble increases the mean gross margin but also greatly increases risk. Those farm managers wishing to take on more risk will prefer the irrigated crops. The potato mean gross margin of $700 per acre and standard deviation of $561 per acre was too large for plotting purposes.

4.1.5 Total Variable Costs

Total variable costs include the variable cash costs plus an interest charge on these cash costs and a charge for the operator's labor. Both the interest and the operator labor charge are opportunity cost calculations that may or may not be cash. The interest figure is directly related to the level of variable cash costs and is significantly higher for irrigated conditions. The operator labor charge is significantly higher under irrigation than under dryland conditions. The main reason for this has to do with the increased yields under irrigation thereby resulting in more crop material to be handled. Tillage operations are also increased under irrigation.

4.1.6 Returns Above Variable Costs

The means and standard deviations of returns above variable costs are similar to the gross margins in that they are generally higher under irrigation than under dryland conditions because the increase in variable cash costs, interest and labor charges do not overcome the advantage of increased yields (Figure 3). The mean and standard deviation of return above variable costs per acre for potatoes at $594 and $507, respectively, is still too large for plotting purposes.



Legend: See Figure 1

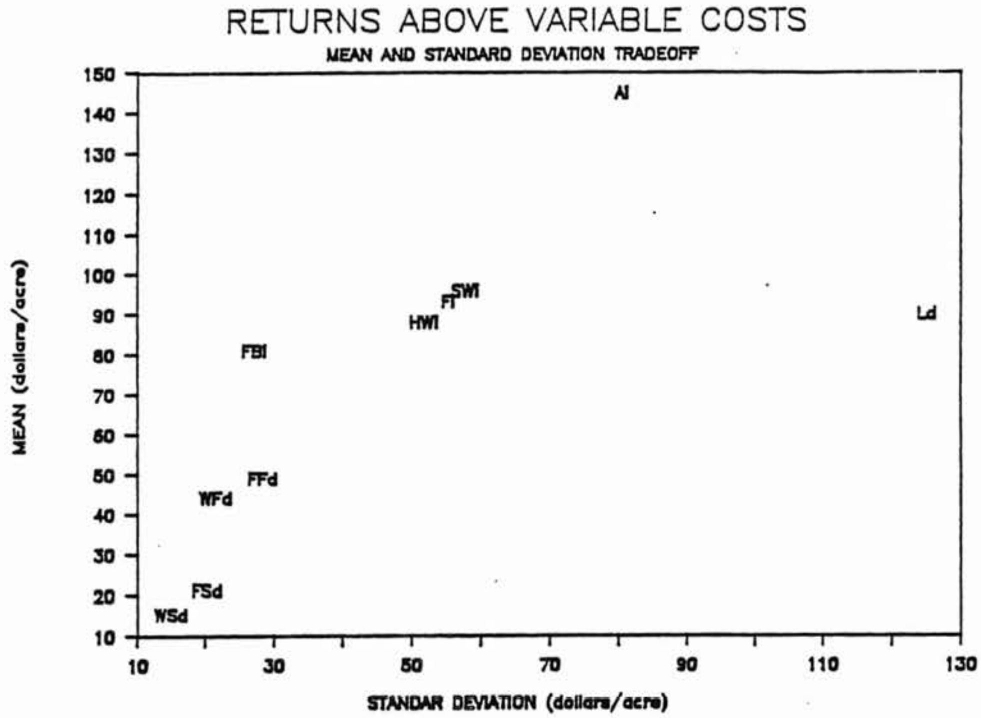
Figure 2: Mean and Standard Deviation of Gross Margins Per Acre, Dryland and Irrigated Crops.

4.1.7 Total Fixed Costs

Fixed costs include property tax, overhead charges, and a capital recovery charge for both irrigation and other machinery investment. The property tax is very similar whether the land is irrigated or not. The overhead charge is 5% of variable costs plus property tax and is significantly higher for irrigated conditions. The capital recovery charge for machinery is significantly higher for the irrigated conditions than the dryland because of the higher investment requirements.

4.1.8 Returns Above Total Costs

The means and standard deviations of returns above total costs shift dramatically from those of the gross margins and returns above variable costs. For the most part the irrigated crops have low or negative mean returns above total costs and higher standard deviations



Legend: See Figure 1.

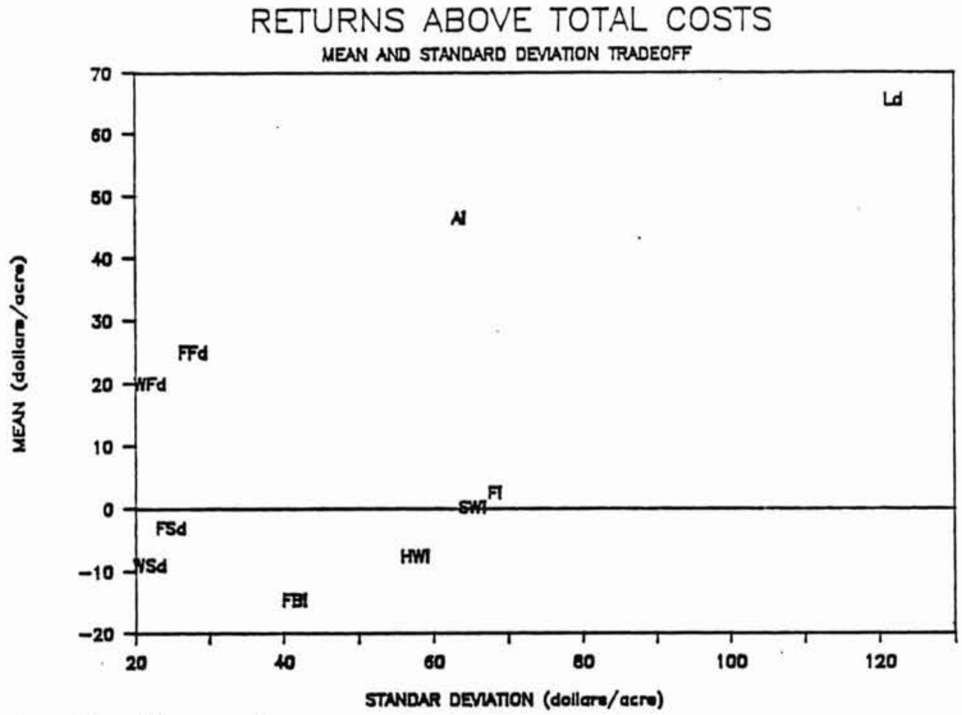
Figure 3: Mean and Standard Deviation of Returns Above Variable Costs Per Acre, Dryland and Irrigated Crops

of returns above total costs than to the dryland crops (Figure 4). One can also see that stubble cropping on dryland is neither risk efficient nor profitable. The most risk efficient crops are wheat and flax on fallow, irrigated alfalfa, lentils on stubble, and irrigated potatoes. The mean and standard deviation of return above total costs per acre for potatoes at $335 and $407, respectively, is still too large for plotting purposes.

4.2 Irrigation Versus Dryland - Hypothetical Fixed Crop Rotations

4.2.1 Gross Margins, Returns Above Variable Costs and Returns Above Total Costs

The means and standard deviations for the gross margins, returns above variable costs, and returns above total costs resulting from following the 14 hypothetical fixed rotations listed in Table 1 are presented in Figure 5, 6, and 7 respectively. There is no shifting of the relative risk efficiency of the various rotations between Figures 5, 6, and 7. The means and standard deviations of the dryland

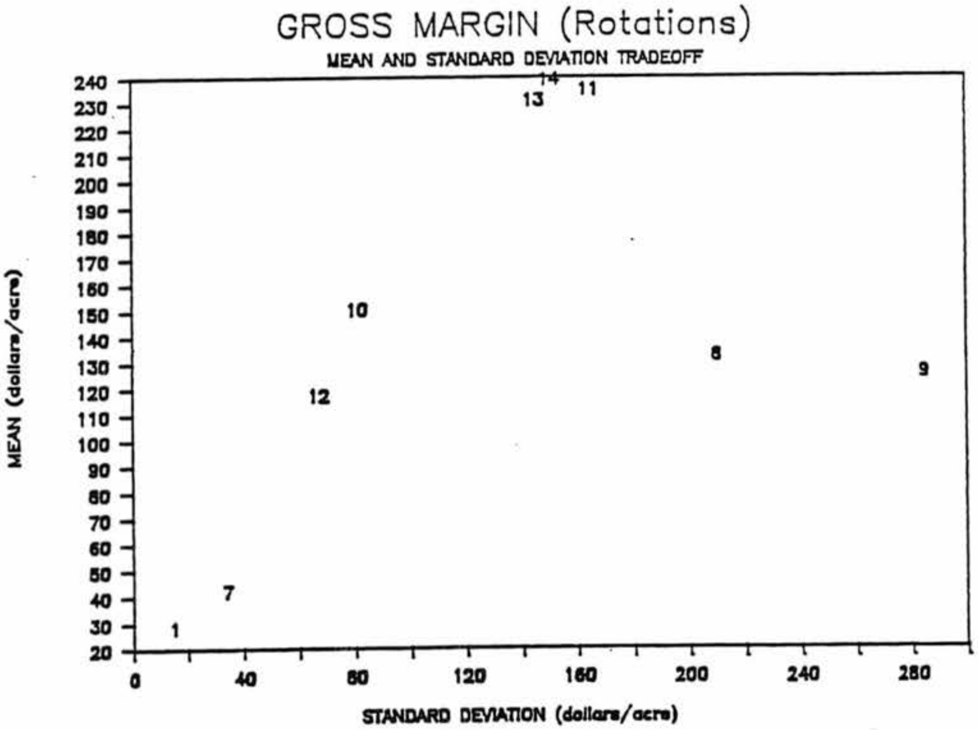


Legend: See Figure 1.

Figure 4: Mean and Standard Deviation of Returns Above Total Costs Per Acre, Dryland and Irrigated Crops.

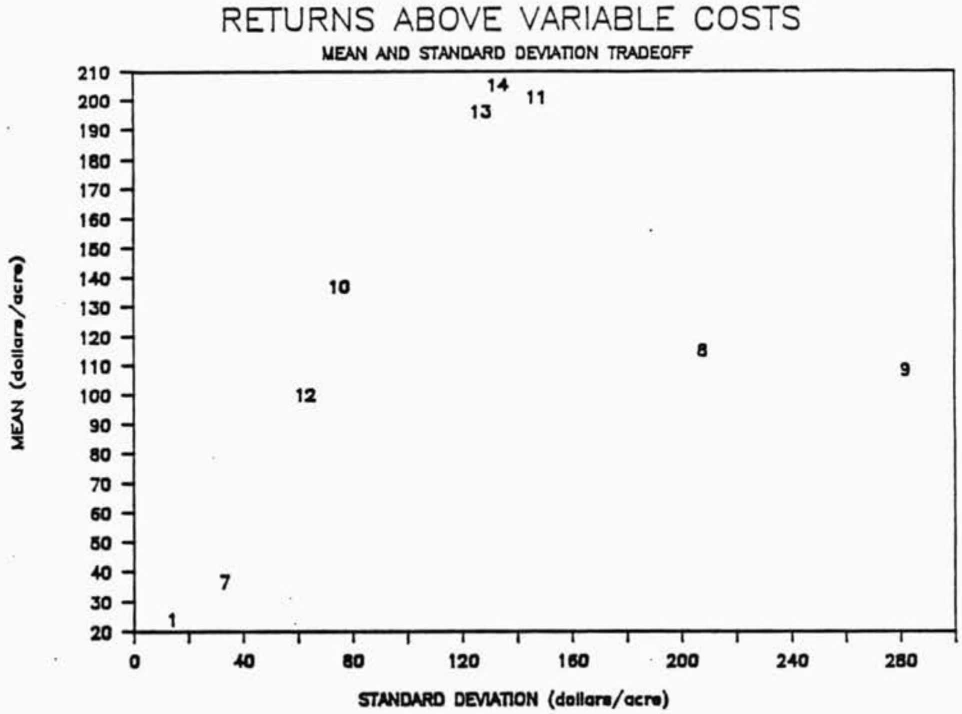
rotations were so similar compared to the irrigation rotations that for readability purposes only rotations 1 and 7 are plotted.

Most of the rotations both dryland and irrigated are risk efficient. The irrigated rotations exhibit higher mean net returns but also higher risk. The only rotations that are not risk efficient are the continuous irrigated hard wheat, (8) continuous irrigated soft wheat and (9) a rotation consisting of 60% irrigated hard wheat, 20% irrigated flax, and 20% irrigated fababeans (12). A main cause for the relative risk inefficiency is the CWB delivery quotas. Low quota years result in a build-up of inventories that are then disposed of in open quota years, thereby adding to the variation in net returns. In reality, most irrigation farmers do not irrigate all their land, and can therefore, use land that is summerfallowed to dispose off CWB crops, that are grown under irrigation. Another reason why rotation 12 is relatively inefficient is that there is a difference between the fixed and variable cost structure of potato and other crops. Rotations 11, 13 and 14 include potatoes and although they exhibit high variation in net returns, they also have high mean net return. Rotation 12 does not contain either potatoes or alfalfa on results in low mean net returns and relatively high variation.



Legend: 1-50% Fallow, 50% Wheat on Fallow;
7-30% Fallow, 30% Wheat on Fallow, 20% Wheat on Stubble, 20% Lentils on Stubble;
8-100% Irrigated Hard Wheat;
9-100% Irrigated Soft Wheat;
10-20% Irrigated Hard Wheat, 80% Irrigated Alfalfa;
11-60% Irrigated Hard Wheat, 20% Irrigated Flax and 20% Irrigated Potatoes;
12-60% Irrigated Hard Wheat, 20% Irrigated Flax, 20% Irrigated Fababeans;
13-40% Irrigated Hard Wheat, 20% Irrigated Flax, 20% Irrigated Potatoes, 20% Irrigated Alfalfa and 20% Irrigated Fababean
14-20% Irrigated Hard Wheat, 20% Irrigated Flax, 20% Irrigated Potatoes, 20% Irrigated Alfalfa and 20% Irrigated Fababean

Figure 5: Mean and Standard Deviation of Dryland and Irrigated Crop Rotations Gross Margins



Legend: Same as Figure 5

Figure 6: Mean and Standard Deviation of Dryland and Irrigated Crop Rotation Returns Above Variable Costs.

4.3 Distribution of Debt-Equity Ratio for Dryland and Irrigation Farms

A survey of farmers was conducted to determine level of financial risks, and the role played by them in the adoption of irrigation. Average debt-equity ratio and its distribution is shown in Table 2. Average debt-equity ratio for dryland farmers was 0.413, about half as much that of irrigated farmers which was estimated at 0.889. A statistical test for equality of leverage ratio indicates that irrigation farmers do have a higher ratio[1] and thus, more susceptible

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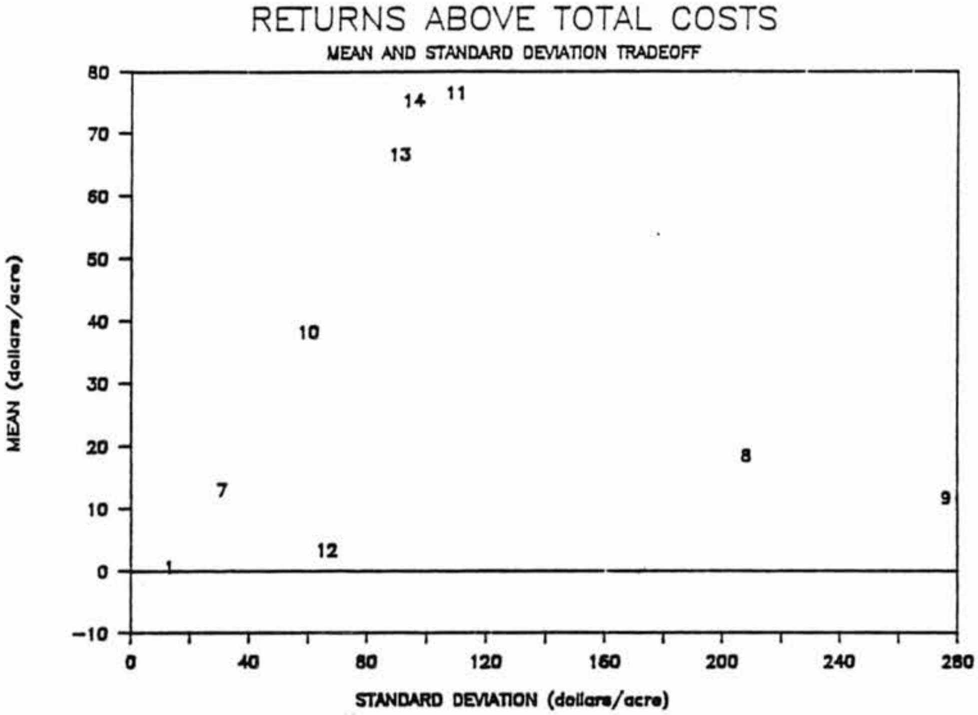
[1] A one-tail t-test is used to show that irrigated farmers have a higher leverage ratio

$$t = \frac{0.889 - 0.413}{0.346} = 1.374$$

$$P(t) = 0.085$$

Thus, the hypothesis that irrigated farmers have a higher leverage ratio is supported at 10 percent level of significance.



Legend: Same as Figure 5

Figure 7: Mean and Standard Deviation of Dryland and Irrigated Crop Rotations Returns Above Total Costs

to financial risks.

5. CONCLUSIONS

The results of this paper indicate differences in the risks associated with dryland and irrigation production. Production risks decrease with irrigation as demonstrated by plotting mean crop yields and standard deviations of crop yields for dryland and irrigated conditions. Overall business risks increase with irrigation as demonstrated by plotting the mean and standard deviations of returns above variable costs for dryland and irrigated conditions. Financial risks also may increase with irrigation because of the higher than average leverage ratios exhibited by the farmers surveyed. Higher financial risks, as exhibited by higher debt-equity ratio, makes the irrigation farmers more vulnerable to market fluctuations, both in product markets as well as capital markets. Unfavorable interest rates may deter irrigation expansion as well as do low product prices.

Table 2: Distribution of Debt-Equity Ratio for Dryland and Irrigated Farms

Category	Dryland Farm	Irrigated Farm
	--------Percent of Total-------------	
< 0.10	65.7	22.1
0.11 - 0.20	4.1	3.7
0.21 - 0.30	1.4	9.3
0.31 - 0.40	8.2	5.6
0.41 - 0.50	2.8	5.6
0.51 - 1.00	6.8	20.4
1.01 - 1.50	0	9.3
1.51 - 2.00	2.8	1.9
2.01 - 2.50	0	9.3
> 2.50	8.2	12.7
Average $\left(\frac{D}{E}\right)$	**0.413**	**0.889**
S.D.	**1.131**	**1.504**

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