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Economic Impacts of Small-Scale Irrigation under Drought Conditions in Northwestern Saskatchewan: An Application of the Agricultural Drought Impact Evaluation Model

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ABSTRACT

The Agricultural Drought Impact Evaluation Model is used in this paper to evaluate the economic impacts of a drought mitigating strategy—development of small scale irrigation. The area selected for the study was the northwestern region of Saskatchewan. A total of 16 000 irrigated acres, distributed as 400 plots of 40 acres each, were developed as forage plots. This resulted in higher forage yields, and release of some land for other dryland crop production. Increase in net farm income was $51 per irrigated acre under no drought, and reduced slightly to $48 per irrigated acre under a one-year drought but increased to $61 per irrigated acre under a two-year drought. There was a gain of $1·7 to $2·5 million in terms of gross domestic product under no drought to a two-year drought. Thus, small scale irrigation development provides a stabilizing effect on existing livestock operations during years of drought.

INTRODUCTION

This is the last in a series of three papers on the agricultural drought impact evaluation model—ADIEM (see Kulshreshtha & Klein, 1989; Klein *et al.*

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1989). In this study, the ADIEM is used to evaluate the drought mitigating effect of small-scale irrigation development in the northwestern region of Saskatchewan, Canada.

A lack of precipitation during spring months often means that forage yields will not reach their potential and cattle feed deficiencies will occur. These deficiencies will have to be covered with grains or imported hay; if these are not available, cattle numbers will have to be reduced to balance the level of feed supplies. It is thus prudent to consider as a mitigative measure, the value of an irrigation water supply that eliminates dependence of fodder supplies on spring rains. A secondary benefit of irrigated forage land would be the reduced amount of land base required with the higher yields; thus extra land would be made available for other purposes, including dryland grain production. Alternatively, a net increase in hay production could support an increase in stock numbers, which, in turn, would boost overall regional economic activity.

The overall objective of this study is to investigate the extent to which small scale irrigation can be used as a drought mitigative strategy in northwest Saskatchewan. Specifically, the intent is to evaluate farm level consequences of small scale irrigation on beef producing farms in northwestern Saskatchewan under drought and normal conditions, and to use these estimated farm level impacts as bases for estimating regional and provincial economic impacts.

STUDY METHODOLOGY

The advantages of small scale irrigation are evaluated under normal and drought conditions. The overall procedure is shown in Fig. 1. Base results

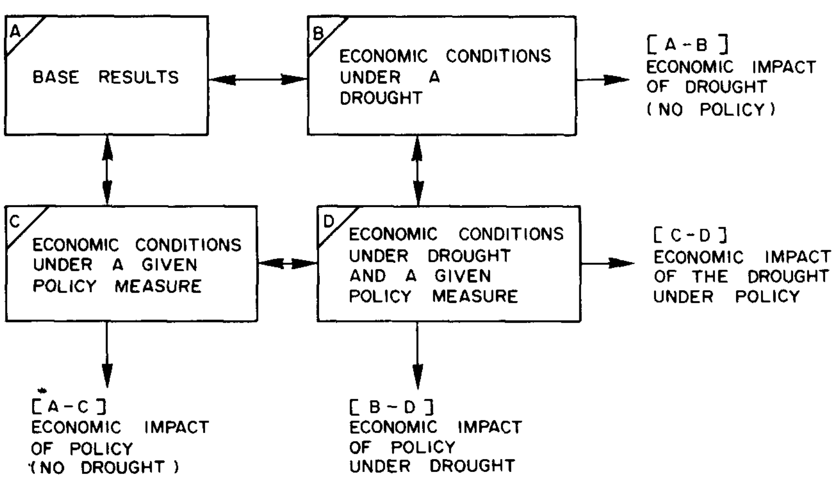

Fig. 1. Framework for drought impact analysis and drought mitigative policy analysis.

(those of a normal year with no irrigation) are compared with three other results: (i) those with a specific drought condition but no irrigation, (ii) those with no drought conditions, but where farms have undertaken small-scale irrigation development, and (iii) those with drought conditions where the farms have irrigation. Comparison of base results with those under drought conditions provides estimates of the economic impact of the drought (without irrigation). Comparison of base results with (ii) above provides estimates of the economic impacts of irrigation under a non-drought condition. Similarly, comparison of base results with (iii) above provides estimates of economic impacts of irrigation under a drought condition. Evaluation of the latter results provides the drought-mitigating effects of irrigation.

DESCRIPTION OF STUDY AREA

A major constraint to small-scale irrigation is imposed by the availability of 60 acre-feet apportionments of water: the minimum necessary for irrigation during any particular crop year, especially during back-to-back drought years. Such irrigation development can take place in the northwest region adjacent to the North Saskatchewan River, the Battle River, the west side of the South Saskatchewan River, Eagle Creek, Turtle Lake River, and large water bodies (e.g. north end of Jackfish Lake) (Fig. 2).

Irrigation water from standing water bodies, such as small sloughs and shallow lakes, is restricted due to: (1) water quality problems, (2) pre-emption by other water users including recreation and industry, (3) size restrictions, and (4) high evaporation losses caused by dry and hot weather. It is estimated that standing water bodies would provide irrigation for about fifty 40-acre plots.

The irrigation area along Eagle Creek is restricted due to an annual guaranteed flow of only 4000 dam^3 during dry years. This would limit the number of irrigated areas of 40 acre forage plots in this area to about fifty.

Water is the main restricting factor on the Battle, North and South Saskatchewan rivers. Other factors that restrict irrigation development along these rivers include: soil texture and drainage, high pumping costs encountered with large heads resulting from high river banks and topography, and resistance to cooperative endeavors for plot clustering. Apart from the above possible restrictions, an approximation of irrigation area can be estimated by river length and pumping accessibility (e.g. both or one side of the river and terrain). A total of 300 irrigated forage plots can be supported by these rivers, bringing the grand total to 400 (300 from Battle, North and South Saskatchewan Rivers, 50 from Eagle Creek, and 50 from other bodies of water), and the total irrigated area to 16 000 acres.

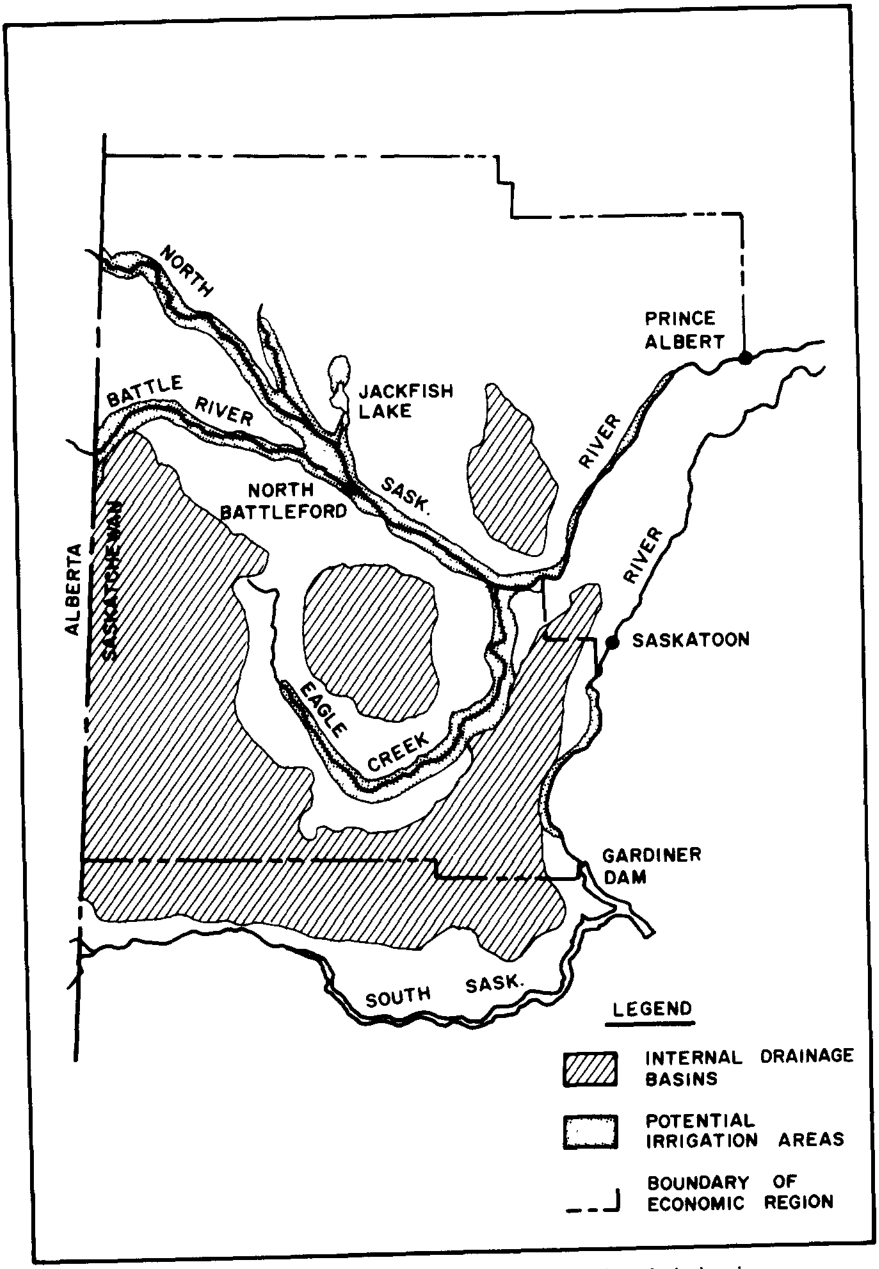

Fig. 2. Possible areas for the uptake of small scale irrigation.

METHOD OF IMPACT EVALUATION

Four representative cow–calf farms were constructed to simulate effects of small-scale irrigation in the study area (Klein *et al.*, 1989). These representative farms were developed for the region and the province on the basis of census data, as well as unpublished data from the Saskatchewan and Canadian Departments of Agriculture. Farms were allotted resources in ways that all crop areas and livestock numbers were accounted on large and small farms of various types in each of the soil zones in the province. Full details of the procedure for development of these representative farms is contained in Klein & Klein (1983). Since the soil in the study area is in a transitional zone, two of the representative farms (one small, the other large) were considered to be from the dark brown soil zone and the other two farms were considered to be from the black soil zone. Yields and certain production practices are different on farms in each soil zone. A summary of physical and financial characteristics of each of these representative farms is provided in Table 1.

TABLE 1
Characteristics of Cow–Calf Representative Farms in Northwestern Saskatchewan

	Dark brown soil		*Black soil*	
	Small	*Large*	*Small*	*Large*
Physical				
Farmland (ac.)	1 374	2 728	796	1 174
Cropland	369	732	213	315
Tame hay	36	72	21	31
Tame pasture	120	239	71	102
Other	21	41	11	18
Unimproved	828	1 644	480	708
Cows (hd)	69	137	40	59
Financial				
Assets ($)				
Land and buildings	278 145	543 360	137 760	253 995
Cattle	37 771	76 089	21 826	32 782
Machines	34 760	93 375	49 793	39 349
Other	33 629	57 120	20 413	29 031
TOTAL ($)	384 305	769 944	265 792	355 157
Debts ($)				
Long term	46 803	93 769	32 370	43 253
Intermediate term	14 116	28 281	9 763	13 045
Short term	23 504	47 090	16 256	21 722
TOTAL ($)	84 423	16 940	58 389	78 020

Community pasture was available for one third of the cow–calf units on these farms. This is consistent with availability for cattle on all types of shared pastures; Prairie Farm Rehabilitation Administration (PFRA) pastures, provincial community pastures, private leases and grazing association pastures. Improved land was valued at $300 per acre in the dark brown soil zone and $325 per acre in the black soil zone. Improveable native pasture land was valued at $265 per acre in the dark brown soil zone and $250 per acre in the black soil zone. These were typical land values in the respective areas in the early 1980s. Buildings were of minimum shelter standards and of moderate age. Other than the cows and heifers, only bulls (at the rate of one for every thirty cows) were in the beginning inventory. Machines selected for these farms were small and relatively old.

Level of indebtedness for each of the representative farms was based on survey results reported by Farm Credit Corporation. Debts for beef related farms were estimated as 22% of total assets: 65% were long term, 17% were intermediate term, and 28% were short term.

The type of beef enterprise on the cow–calf farms was raising and selling of weaned calves. Only the breeding herd and replacements were kept over the winter season. Cows were bred naturally. The winter feeding season was five months in length. Diets included as much pasture as possible. The rate of live calf births was set at 94% for mature cows and 85% for first-calf heifers.

Cropping rotations were one-third summerfallow and two-thirds crops on all farms. No oilseeds were planted. A discer was used for planting operations on all farms except the small farm in the black soil zone where a press drill was used. Both small farms had a power-take-off (PTO) swather; both large farms had a self-propelled swather. The small farm in the dark brown soil zone had a PTO combine; the large farm had a self-propelled combine. Neither farm in the black soil zone had a combine. In both cases, custom combining was used to harvest their relatively small crops. Machines were replaced at 60% of their useful life.

All prices used in this study were based on 1983 price levels. Barley prices were $2·70 per bushel at the farm level. Finished steers and heifers had prices of $74·32 and $70·39 per hundred weight, respectively. Weanling calves had prices of $85·29 and $76·69 per cwt for steer and heifer calves, respectively. Cull cows were sold at $49·01 per cwt.

To accommodate the 16 000 acres of potential irrigation, the representative farms were modified to include small irrigation plots of 20 acres (on small farms) and 40 acres (on large farms) (see Table 2). In each case the differential yields between irrigated and tame hay were calculated and the number of acres required to produce the equivalent total yield on irrigated land were transferred from forage to crop production. The net result was to have the same forage output in the region as before the irrigation (in a

TABLE 2
Distribution of Representative Cow–Calf Farms in the Study Area of Northwest Saskatchewan

Farm size	*Soil zone*	*Acres irrigated*	*Number of farms*	*Total area (acres)*
Small	Dark brown	20	96	1 920
Large	Dark brown	40	48	1 920
Small	Black	20	432	8 640
Large	Black	40	88	3 520
TOTAL			664	16 000

normal year), but higher grain production. The same forage production meant the same number of cow–calf units on farms in the region. The extra grain produced could have been used for two alternative purposes: (1) exporting extra grain from the region, or (2) exporting the same amount of grain but increasing the feedlot industry in that region of the province by producing a larger output of finished beef. The second alternative was the one chosen for this study, since it offered the potential for more value-added activities and accompanying employment in the region. Thus, the number of feedlot animals that it would take to consume the extra grain grown in the region was calculated (7100) and considered to be fed to finish on farms in the region, rather than to be exported to other regions as feeders.

A beef, forage and grain simulation model (Klein & Sonntag, 1982) was used to compare the financial performance of these representative farms in drought years as compared to 'normal' years. The normal year consisted of 1970 type weather conditions (chosen on the basis of weather patterns existing in Saskatchewan over the period 1916–1980) applied to 1980 levels of agricultural technology. The first type of drought to be compared to the normal condition was one of rather severe conditions (based on 1935 type weather patterns). Yields for this analysis were based on unpublished records of yields during average and drought years (Table 3). In the one-year drought both cereal and forage yields were considerably reduced. The second type of drought to be analyzed was a two-year drought where the first year was the same as that described in the one-year drought, but the second year affected mostly the forage enterprise. This second year would involve very dry spring and early summer seasons that would affect greatly the forage yields, but with good late summer weather conditions that would produce near normal yields of cereal crops.

Irrigated yields were assumed to stay at the same level despite the length of drought considered in this analysis.

TABLE 3
Expected Cereal and Forage Yields on Farms in Northwestern Saskatchewan, Normal and Drought Conditions

	Normal	*One year drought*	*Two year drought*	
			Year 1	*Year 2*
Barley — Smf (bu./ac.)	43·0	32·2	32·2	41·2
— St (bu./ac.)	34·2	22·0	22·0	32·7
Dark Brown Soil Zone				
Native pasture (lbs. DM/ac.)	485	323	323	161
Imp. pasture (lbs. DM/ac.)	1 040	693	693	347
Tame hay (Tons DM/ac.)	0·75	0·50	0·50	0·25
Irrigated hay (Tons DM/ac.)	1·50	1·50	1·50	1·50
Black Soil Zone				
Native pasture (lbs DM/ac.)	810	540	540	270
Imp. pasture (lbs DM/ac.)	2 600	1 733	1 733	867
Tame hay (Tons DM/ac.)	0·75	0·50	0·50	0·25
Irrigated hay (Tons DM/ac.)	1·50	1·50	1·50	1·50

The financial performance of each type of representative farm was aggregated to determine the total farm level impacts of the small scale irrigation strategy. Since only a modest number of farms were involved, aggregation bias was considered to be not a problem.

Data generated by the farm level simulation model was the starting point of determining aggregate impacts of the strategy in the region and province. Certain manipulations of data were required to make farm level data consistent with industry data in the input–output model. Net farm income (labour income) was calculated for the region by using the following relationship: Net farm income = gross receipts − expenses on non-labour items. This transformation made the farm level results comparable to data for other industries. The data are in the form of purchasers' prices and reflect total purchases irrespective of the place of purchase. Marketing margins were removed. The resulting figures are purchases by agriculture from Saskatchewan industries, valued in producers' prices. The regional input–output model and the employment model were used to estimate aggregate economic impacts.

RESULTS

Small-scale irrigation on farms in the northwest region of Saskatchewan resulted in significantly increased net farm incomes for farms under normal

TABLE 4
Farm Level Change[a] in Net Farm Income Per Year for Small-Scale Irrigation

Particulars	*Dark brown soil*		*Black soil*		*Total*
	Small	*Large*	*Small*	*Large*	
Individual Farms[b]					
Normal conditions	2 810	3 666	608	1 259	—
One-year drought	2 793	3 517	534	1 147	—
Two-year drought	2 906	4 176	810	1 748	—
Total for Region ('000$)					
Normal conditions	269	175	283	111	818
One-year drought	268	169	231	101	769
Two-year drought	279	200	350	154	893

[a] Relative to non-irrigated conditions.
[b] All values are reported in 1983 dollars.

and drought conditions (Table 4). In all cases the conversion of forage land to crop land permitted each of the representative farms to sell much higher levels of grain, resulting in increased crop receipts. In addition, the provision of irrigated forage made it possible for them to reduce the level of cattle expenses for such things as supplements. However, because of the larger cropping enterprise when irrigation development was added, cropping expenses were substantially increased (Table 5). In total net farm incomes were increased by $608–$3666 per farm by adding small plots of irrigation.

TABLE 5
Annual Increase in Farm Expenditures on Cow–Calf Farms for Small Scale Irrigation in Northwest Saskatchewan

Particulars	*Cow–calf farms*		
	Normal	*One-year drought*	*Two-year drought*
Cash expenses for livestock	0	0	0
Feed and supplements	11	−22	193
Fertilizer	232	232	232
Chemicals	105	105	105
Land taxes	266	266	266
Mach. repairs	18	18	16
Bldg. repairs	−51	−30	−30
Seed cost	596	596	596

TABLE 6
Aggregate Provincial Impacts of Small-Scale Irrigation, Saskatchewan Economy

	Increase over no irrigation ('000$)		
	No drought	*One-year drought*	*Two-year drought*
Value of good and services produced			
Agriculture	1 995	1 954	2 180
Non-agriculture	1 302	1 683	1 820
Total	3 298	3 637	4 006
Household incomes	1 553	1 608	1 825
Gross domestic product	1 709	1 775	2 470
Imports	1 014	1 054	1 253
Employment (No. of workers)	25	25	46

Surprisingly the advantages to small-scale irrigation over complete dry land operations was not much greater under drought conditions than under normal conditions. In fact, on all representative farms the increases in net farm income from the small irrigation plots were slightly lower under the one-year drought than under the normal conditions. The two-year drought showed significant drought mitigation impacts on three of the four representative farms.

Total increase in net farm income from small-scale irrigation in that region of the province was approximately $818 000 on cow–calf farms, or about $51 per irrigated acre. During drought, the gains decreased to $48 per irrigated acre for a one-year drought, and increased to $61 per irrigated acre under a two-year drought.

Results for aggregate provincial level impacts of small-scale irrigation in this region during normal and drought years are presented in Table 6. During a normal year economic impacts are similar to those realized during a one-year drought. During a drought year, increases in agricultural sector's output was about $2 million, which, through inter-relationships in the economy, added another $1·3–1·8 million worth of goods and services produced by non-agricultural industries. The net result was a gain of $1·7 million worth of gross domestic product (at market prices), of which $1·6 million were income to households. Results for the two-year drought were slightly higher than those for the one-year drought, but about the same on a per year basis.

Increased economic activity also results in a gain of 25–46 full-time equivalent employment.

CONCLUSIONS

This analysis demonstrated the use of components of the Agricultural Drought Impact Evaluation Model (ADIEM). This model has capability for a wide range of analyses of farm level and aggregate analyses of impacts of drought as well as estimation of mitigating effects of various governmental programs and farm management strategies.

The benefits accruing to small scale 40-acre irrigation plots in this analysis are small. The main reason for this result is that during the years of analysis, profitability in the beef-producing industry was very small or negative. The farms would have had higher net incomes if the cow–calf enterprise had been allowed to shrink. During the drought years, the profitability of the beef-producing enterprise was even worse. Lower input prices, lower finished quality, or higher cattle prices would have resulted in larger benefits for the small-scale irrigation. Such situations, however, are not unusual during a drought period. Small plot irrigation, therefore, should be thought of as a stabilizer for existing operations (or an insurance policy). To increase production as a result of irrigation inclusion may increase drought vulnerability in some cases.

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