DROUGHT MANAGEMENT STRATEGIES
FOR IRRIGATED AGRICULTURE

by

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Introduction

Interest in drought impacts and strategies to minimize these impacts follow a cycle that matches the occurrence of drought. The more severe and widespread the drought, the greater the interest. During 1977, interest in Idaho and most of the west was high. Idaho's 1976-1977 snowpack, the best predictor of water availability for the following summer, ranged from 14 to 55 percent of normal, resulting in the worst drought in the state's recent history. Unfortunately, as precipitation levels returned to normal in the fall of 1977 interest again waned. While the urgency of developing coordinated local, state, and regional drought policies has declined, the need remains.

A study of farmer's strategies during 1977 was proposed where farmers would have been interviewed during the growing season, to determine their tentative plans, and again at the end of the season, to evaluate the effectiveness of these plans. Because of a delay in funding, the focus of the study shifted to an ex-post study of strategies and impacts at the farm and water manager level.

Three areas in southern Idaho were chosen for the study (Figure 1), to include differing degrees of drought impact severity. Severity of impact was based on information obtained from the Agricultural Stabilization and Conservation Service, the Soil Conservation Service, and the Idaho Department of Water Resources. Areas selected included Bingham-Bannock counties on the upper Snake River as a slight impact area, Ada-Canyon counties on the Boise River as a moderate impact area, and Blaine-Lincoln counties on the Big Wood and Little Wood Rivers, and Fish Creek and Silver Creek as a severe impact area. From a total of 158 personal interviews conducted with farm operators in June of 1979, 151 were complete enough to use. These included farms in three primary crop categories: 1) hay-grain-forage, 2) annual row crops, and 3) perennial cash crops; and two types of water application: 1) gravity, and 2) sprinkler. All farmers included in the survey obtained most of their water from surface sources, flow or storage, rather than groundwater. The study areas also represented three distinct cropping areas based on physical and climatological characteristics. Bingham-Bannock counties produce mostly alfalfa, grain, and potatoes; Blaine-Lincoln counties primarily produce hay and grain; while Ada-Canyon counties produce not only the crops found in the other two areas, but many high value seed and specialty crops as well as perennial crops such as mint, hops, and various tree fruits. Water organizations (canal companies and irrigation districts) serving farmers in the three study areas were also surveyed. Their response to the drought had important implications not only to the farmers they serve, but to other water users in the area as well.

Early irrigation projects in southern Idaho relied only on direct diversions from stream flows where nature controlled the level and timing of water availability. Storage reservoirs, developed with later irrigation projects, provided additional water and improved the distribution of water over the growing season. Even with this improved security, total water availability still ultimately depends on fluctuating levels of precipitation.

This does not mean, however, that water users and water managers are without management options. For example, farmers allocate water between crops, and also specify the crops grown which can modify total water needs. They can also adjust other input use, affecting their crops' ability to withstand water stress. Water organizations can also make changes in their normal operating procedures to better manage the water resource during a drought. Both farmers and water organizations, however, face restrictions and limitations on their adjustments to drought. Four questions relating to water management and input adjustments as possible drought strategies will be examined in the remainder of the paper, using the study of southern Idaho farmers and water managers for illustration.

How Should Water Be Allocated During A Drought?

The allocation of water is an important issue in non-drought situations, but takes an even greater importance during drought. Two alternative allocation plans will be examined; pro rata sharing and hierarchical allocation. Idaho's water law follows the hierarchical system under the doctrine of prior appropriation, where priority in right follows priority in time. The priority date established when the appropriator first put the water to beneficial use, provides the hierarchy used in allocating water when stream flows are insufficient to fill all rights. The hierarchical system applies to direct divertors, but the bylaws of a delivery organization usually specify pro rata sharing for distributing water to users in the service area. An example follows that will illustrate the effect of these two allocation schemes.

Assume 100 farmers each with 200 acres and with a water right for one miner's inch (M.I.) per acre. Each farmer has a right to 200 M.I. of water for a total of 20,000 M.I. Also assume that the crop response function exhibits decreasing marginal returns to water with a discontinuous segment (Figure 2). If the stream flow drops to 19,800 M.I. the farmer with the most recent water right would be cut off completely under the doctrine of prior appropriation, bearing the full brunt and suffering a total crop loss. If one M.I. per acre puts the yield response on the nearly flat portion of the production function as shown in Figure 2, than the same water cut could have been spread over all the users with little or no loss. One farmer is better off without making anyone appreciably worse off. Switching from a hierarchical to an equal share basis improves efficiency in this situation.

Assume now that there are only two water users with the same acreage and water rights as above, a total stream flow of 400 M.I., and the flow drops to 200 M.I. In this situation, sharing the remaining water equally would result in both farmers losing their entire crop rather than just one if the hierarchical approach were used. Equal sharing in this situation has the opposite effect from the first example and results in lower efficiency.

A strict interpretation of the appropriation doctrine will result in hierarchical allocation, regardless of whether a more efficient result could be obtained. An equally inefficient situation can result if water organizations follow a strict policy of pro rata sharing. When the water reduction is less than that necessary to reach the discontinuity point on the production function, then equal sharing is preferable. Beyond this point it would be better to cut some users completely so that all users would not suffer a total loss. However, this may not be possible if the organization bylaws dictate equal sharing of water.

In addition to the institutional constraints imposed by water law and water organization bylaws, physical barriers exist that prevent water organizations from making necessary adjustments. The physical design of canals and turnouts to laterals may make the entire system non-functional below a certain water level, even when water remains. This helps to further illustrate the need for a broad multi-disciplinary approach to drought and drought policy, and should be kept in mind throughout the remainder of the paper; especially since time constraints allow only a cursory treatment of each question.

How Should a Farmer Adjust His Normal Cropping Pattern In View of a Projected Water Shortage?

Adjustments to a farmer's "normal" cropping pattern constitute early-season strategies, requiring decisions before full information about water availability for the season is known. These options are mutually exclusive, and for the most part irrevocable for that irrigation season. Basic early season cropping options include: 1) no change, 2) change to early maturing or dryland crop variety, 3) change to lower water consumptive crop, and 4) idle cropland. The choice between these changes would depend on the farmer's perception of the overall seriousness of the drought and how his water availability would be affected. If the farmer chooses no adjustment or a mild adjustment, such as changing crop varieties, anticipating little or no drought impact and there is none, his decision will be the right one and preferable to a more severe adjustment, changing crops or idling land. However, the outcome will be reversed if the water shortage is severe. Unfortunately for the farmers in southern Idaho, in 1977, accurate predictions of drought severity were unavailable.

The economic impact of cropping adjustments involves lost income from reduced yields, lower value crops, and idled cropland; as well as changes in production costs when crops or crop varieties are changed. The best method to accurately determine these impacts involves a with/without drought comparison of net income. The drought impact would be:

$$\text{Change in Net Revenue} = \text{Acres} \times \left[\left(\text{Yield with Drought} \times \text{Price with Drought} \right) - \left(\text{Yield without Drought} \times \text{Price without Drought} \right) \right]$$

$$+ \left[\text{Crop Production Cost per Acre Without Drought} - \text{Crop Production Cost per Acre With Drought} \right]$$

Since history cannot be repeated, the yield and price without drought can only be approximated. For the study of farmers in southern Idaho, questions on crop yield for 1977, normal crop yield, and non-drought factors that affected yields were asked. The drought impact was calculated as the difference between the normal yield and the 1977 yield after adjusting for the non-drought factors. Price levels could be affected by drought and should also be adjusted. Determining the magnitude or even the direction of change, however, could be very difficult. With over 60 different crop prices each requiring individual adjustments, no attempt was made to adjust them and prices prevailing in 1977 were used.

Table 1 shows cropping changes made by farmers in the three study areas. The number of acres and the percent this represents of the total cropland is given for each change. The unharvested acres would indicate whether sufficient adjustments were made to insure the survival of the remaining crops. Looking across the table for each change shows that a greater percentage of cropland was involved in each type of change as the droughts severity increased, the exception being crop changes in Blaine-Lincoln counties. These counties grow few higher value, higher water consuming row crops, preempting this option. Table 2 shows the economic loss associated with the three cropping changes, the unharvested acreage, and the loss from reduced crop yields. While farmers did make use of the various cropping adjustments, by far the most prevalent strategy was to proceed with normal cropping practices. The high proportion of the loss associated with reduced yields and the relatively small fraction of land involved with acreage changes are indicative of the prevelance of this strategy. Table 2 also gives the loss per acre by spreading the total loss for each strategy over all the cropland. The loss per acre for only the affected acreage is shown in Table 3 and illustrates in absolute terms the increasing severity of those adjustments when going from variety changes to unharvested acreage. The values followed the expected trend except in Bingham-Bannock counties where the small acreage involved in adjustments made these per acre loss estimates unreliable.

What Other Adjustments Can Farmers Make to Drought?

With the exception of changing crop varieties, cropping changes represent rather severe adjustments to drought. Other less drastic options are also available in the form of input adjustments. These are changes that either increase crop tolerance to drought, or decrease the farmer's potential dollar loss if a complete crop failure occurred. Drought may require farmers to find new optimal levels of input use. Determining the optimal level using production economic theory is simple if the level of all input use can be specified, but is more complicated if interaction occurs between inputs. The problem that drought interjects is the uncertainty of the level of the water supply, an interactive input. While decision theory under risk and uncertainty can show how to determine an optimal solution, the problem becomes more complex and requires the development of risk preference and utility functions. While farmers don't explicitly derive all the information needed even under the most simple case, they must still in their own way resolve these problems. Another example of interaction between inputs that complicates the decision process involves the detrimental effect that fertilizers can have on a crop if sufficient moisture is unavailable for the level of fertilizer used.

Farmers in the three study areas made adjustments in input use. This involved both a re-allocation of existing resources, as well as the acquisition of additional inputs. One third of the farmers surveyed reported reduced use of fertilizers and other chemicals totaling nearly $138,000. The majority of this, 98%, was for fertilizers. Labor and water adjustments also figured prominently in the input adjustments.

Table 4 shows the reported impact of the drought on irrigation labor requirements. Because the questionnaire covered only additional labor, this may not fully represent the drought induced labor changes. Table 4 does illustrate how varying degrees of drought severity effects labor requirements. Farmers in severely impacted Blaine-Lincoln counties made less use of additional labor than farmers in the other areas which appears contradictory. However, this is to be expected in a severely impacted area if water supplies are depleted; which did in fact happen in Blaine-

Lincoln counties. The largest irrigation project was out of water by mid-July. These labor figures would be even lower if the labor saved on idled and unharvested cropland was included and applies to the other areas as well. Farmers in Ada-Canyon counties, the moderate impact area, made the greatest use of additional labor. Unlike Bingham-Bannock counties where the droughts impact required few adjustments, the water shortage was serious enough to encourage these adjustments, but not so severe as to preclude them as in Blaine-Lincoln counties.

Table 5 shows the adjustments made in water allocation beyond those associated with acreage changes. Total water applied was reduced by irrigating less frequently or by applying less water per irrigation with the same frequency. Irrigating less frequently was sometimes imposed on farmers as the result of a formal rotation adopted by the water delivery organization. More labor was often expended to make more frequent sets or to monitor the water more closely. Applying less water per irrigation was a common response where irrigators received a reduced proportion of their normal water, a common situation where water organizations delivered water on a continuous basis. Farmers used various manual cutback systems to reduce the flow of water after initially wetting the furrow, or just simply reduced the number of hours per set and kept the flow the same.

Were Responses to the Drought in Southern Idaho Efficient?

The efficiency of any particular response to drought in southern Idaho is difficult if not impossible to determine. From an overall point of view the responses helped to minimize a potentially disastrous situation, although some examples of conflicting or detrimental strategies can be found. Differences in physical or institutional characteristics between areas can result in opposite results using the same strategy. An adjustment at the water organization level designed to help users improve water use efficiency can hurt other water users who relied on a high level of return flows for their water source.

The major farmer responses to drought (cropping and input adjustments) show that their actions did follow economic rationality. Lower value crops (hay, grain and forage) were sacrificed for the higher value row crops and perennials, or as in Blaine-Lincoln counties the hay crop necessary to maintain a viable livestock operation was favored over the more valuable grain crops. Farmers also substituted the normally more expensive input labor for the normally inexpensive water. With the relative value of the water increasing compared to labor, because of its scarcity, this type of substitution is expected.

Evaluating the actions of water organizations is not quite so easy. Their options are few and center mostly around methods of water delivery. Even with these options they are constrained by Idaho Water Law, organizations bylaws, and physical limitations of their system.

The interaction between strategies at different levels makes it impossible to determine the impact of a strategy without first accounting for changes introduced by strategies at other levels. This was beyond the scope of the study and would not always have been possible to separate. While no explicit evaluation of the relative merits of different levels of water management strategies is possible, a few examples of how they interact will help illustrate the problem of water management during a drought.

The first example involves changes in the normal water delivery pattern. Several water organizations reported changing water delivery from continuous or demand to a rotation basis, if not for the entire season, at least for part of it. Farmers in some of these same areas responded to the threatened water shortage by switching from gravity to sprinkler application. While sprinklers normally function more efficiently than a gravity system, they do require a continuous source of water. From the point of view of the water organization a rotation could provide a farmer a larger head of water, allowing him to complete his irrigation sooner. If each farmer has equal water rights, then they share equally the benefit of having a larger stream of water as well as sharing the "cost" imposed by a rigorous rotation schedule. In the case of an individual farmer making an adjustment to sprinklers, the farmer incurs the entire cost (assuming no aid program) and may or may not derive the benefit from "saving water." If the farmer was under the Boise River Board of Control he would benefit because individual water accounts are kept for each user. If on the Blackfoot Irrigation District, he would have benefitted only until they went on a rotation. If the change to sprinklers was temporary through buying or renting a portable system, as was common, the farmer could possibly switch back to a gravity application system.

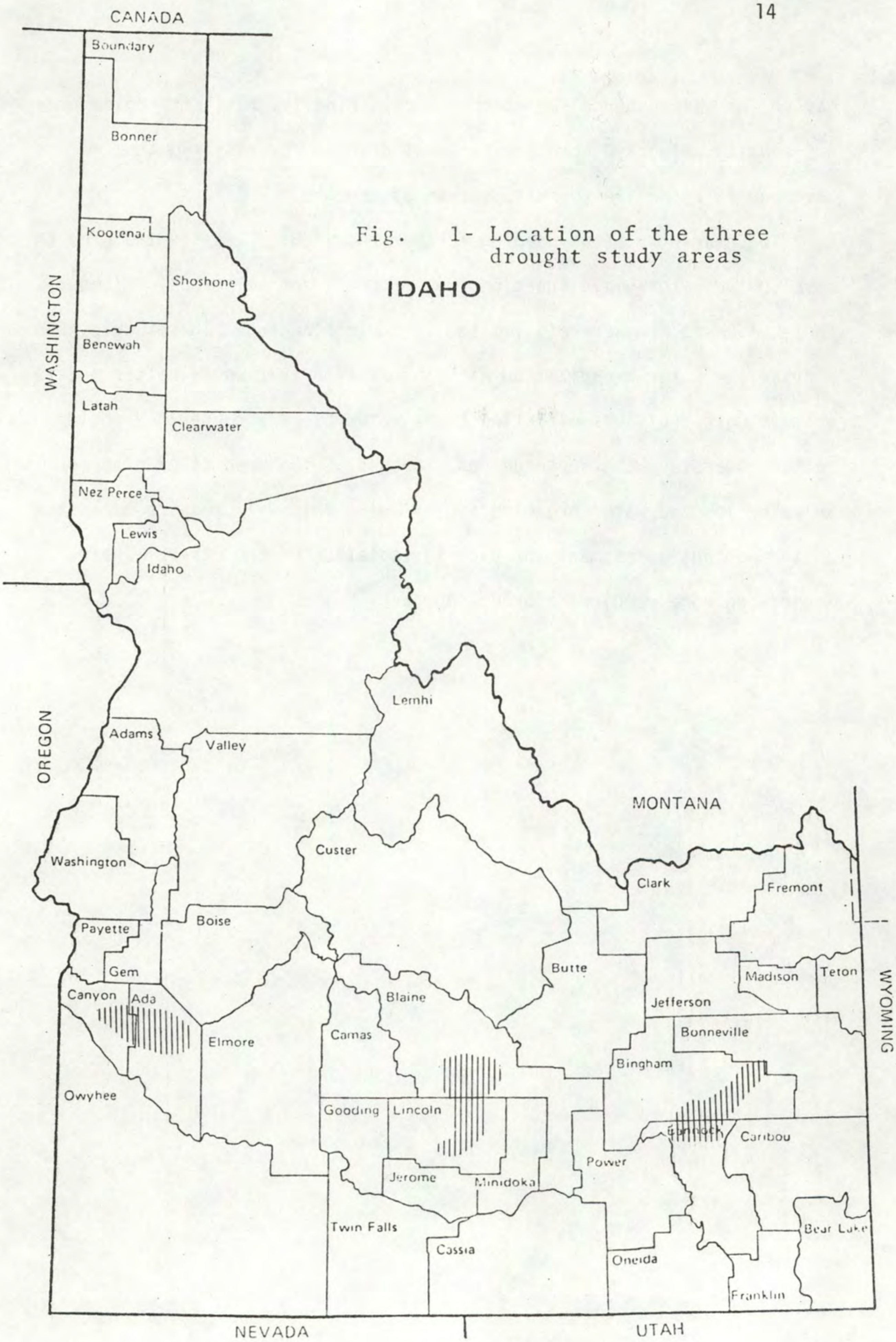
The second example also concerns water delivery to the farmer. How water is delivered over the growing season can interact with a farmer's cropping strategy both positively and negatively. If water is normally delivered on a continuous basis and this is continued during a water shortage, but on a reduced basis, the farmer would have to reduce the acreage planted to crops that have high water consumption. Unless he did so, continuous flow at a reduced rate would be insufficient during peak periods of water needs. In such a situation the farmer would be better prepared by switching to grain crops and away from crops such as potatoes and sugar beets. If the water organization went to a scheduled rotation where a farmer could get a larger amount of water, but for a shorter period of time, the important points of consideration would be how well the crop could withstand stress and the needed frequency of irrigation during periods of peak use. A shallow rooted crop like beans requires irrigation more frequently than sugar beets with its higher total water consumption. Depending on the length of the rotation (the period between irrigations), the farmer could be better off with sugar beets compared to beans if water is available for the entire season.

Summary and Recommendations

A number of different drought management strategies exist at each level of water distribution. How to choose between these is complicated by a lack of information about the length and severity of a predicted drought, by restrictive and occassionally conflicting institutional regulations, and by interaction between water management decisions between users on the same level, as well as with decisions of different levels. In Idaho, as most certainly with other western states, the diversity in crops, water availability, irrigation systems, and the area hydrology make it impossible to develop strategies that would apply equally well to all areas. Even within an area, conflicts occur because of the interdependent nature of water rights. Return flows from one farm or project may be the water source for another user. Finally, most strategies are not equally effective across a range of drought severity, so that no one strategy is effective for all degrees of drought.

There are two areas needing further research. First is the need to develop the water-yield function from Figure 2 for all crops. Without these, farmers are severely limited in their planning. These would also provide the water organization with information that would better enable them to make decisions effecting their water users because they would better understand the consequences. Second is the need to examine conflicts in water law and water organization bylaws. This will require more than an independent assessment for each in isolation of the other. Their interdependence requires a broad approach.

Fig. 1- Location of the three drought study areas



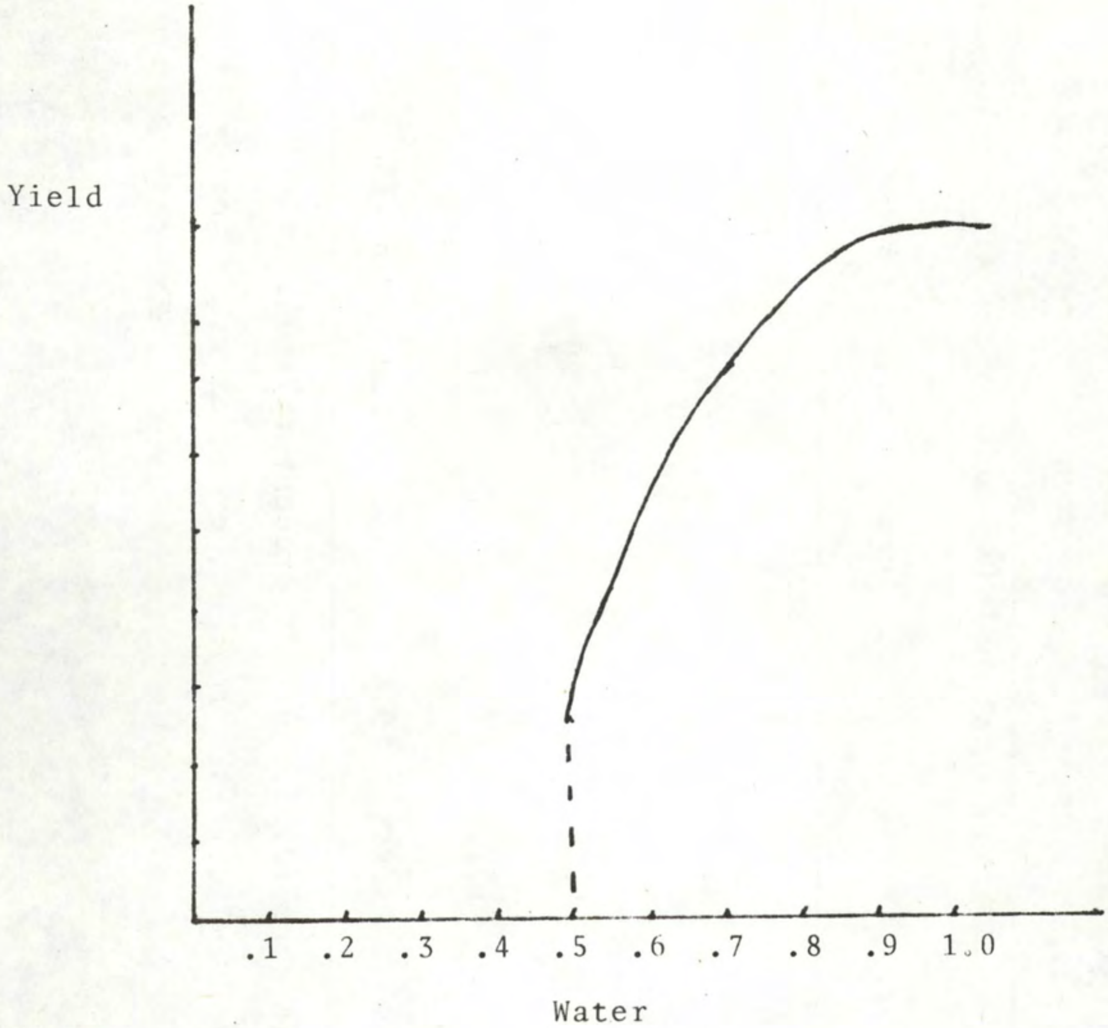


Fig. 2
Water/Yield Response Function

Table 1 Drought-related acreage changes in 1977, by area

	Ada-Canyon		Blaine-Lincoln		Bingham-Bannock		All three areas	
	Acres	% of total acres[2/]	Acres	% of total acres[2/]	Acres	% of total acres[2/]	Acres	% of total acres[2/]
Variety change	652	2.6	890	4.6	0	0	1,542	2.5
Crop change	1,111	4.5	465	2.4	287	1.7	1,863	3.1
Idled acreage	390[1/]	1.6	1,109	5.7	10	.06	1,509	2.5
Unharvested acreage	50	0.2	1,392	7.2	133	.8	1,575	2.6
Total	2,203	8.9	3,856	19.9	430	2.6	6,489	10.7

[1/] Excludes 35 acres that were idled, but not drought related.

[2/] Percentage of irrigated and dryland cropland, excludes waste and dryland pasture.

Table 2 Summary of crop income loss in 1977

Factor	Ada-Canyon counties			Blaine-Lincoln counties			Bingham-Bannock counties			All three areas		
	Loss	% of total loss	Loss per irrigated acre[1/]	Loss	% of total loss	Loss per irrigated acre[1/]	Loss	% of total loss	Loss per irrigated acre[1/]	Loss	% of total loss	Loss per irrigated acre[1/]
Reduced crop yields	$1,201,792	75.6	48.72	$860,922	68.4	44.03	$479,215	88.6	28.14	$2,541,929	75.0	42.77
Variety changes	33,200	2.1	1.35	22,280	1.8	1.19	0	0	0	55,480	1.6	0.92
Crop changes	235,507	14.8	9.55	51,043	4.1	2.73	50,085	9.3	2.95	336,635	10.0	5.58
Idled cropland	105,175	6.6	4.26	91,789	7.3	4.90	754	0.1	0.04	197,718	5.8	3.17
Unharvested cropland	14,897	0.9	0.60	232,344	18.4	12.41	10,679	2.0	0.63	257,920	7.6	4.18
Total	$1,590,571	100.0	64.48	$1,258,378	100.0	64.80	$540,733	100.0	31.57	$3,389,682	100.0	55.33

[1/] Includes the total irrigated acreage for each area, not just the affected acreage.

Table 3. Average Loss per Affected Acre by Cropping Change.

Area	Variety Change	Crop Change	Idled	Unharvested
Ada-Canyon	$50.90	$212.00	$269.70	$297.90
Blaine-Lincoln	$25.00	$109.75	$ 82.80	$166.90
Bingham-Bannock	--	$174.50	$ 75.40	$ 80.30

Table 4 Impact of drought on labor requirements

Impact	Ada-Canyon counties		Blaine-Lincoln counties		Bingham-Bannock counties		All three areas	
	#[1]	Amount[2]	#	Amount	#	Amount	#	Amount
Percentage using more irrigation labor	49	70.0%	17	39.5%	19	50.0%	85	56.3%
Percentage hiring extra irrigation labor	12	17.1%	6	14.0%	6	15.8%	24	15.9%
Average extra hours hired labor	10	1235 hr	6	686 hr	4	340 hr	20	891 hr
Average cost of extra hired labor	11	$3983	6	$1847	5	$1440	22	$2823
Percentage using more family irrigation labor	40	57.1%	9	20.9%	12	31.6%	61	40.4%
Average extra hours family labor	28	483 hr	3	533 hr	7	373 hr	38	467 hr
Percentage using greater part of family labor for irrigation	36	51.4%	14	32.6%	14	36.8%	64	42.4%
Average hours family labor switched to irrigation	24	342 hr	10	413 hr	8	406 hr	42	371 hr

1/ Number reporting this item.

2/ Percent/amount/value reported.

Table 5. Methods Used to Reduce Water Use

	Ada-Canyon Counties		Blaine-Lincoln Counties		Bingham-Bannock Counties		All Three Areas	
	#1/	%2/	#1/	%2/	#1/	%2/	#1/	%2/
Irrigate Less Frequently	9	12.9	12	27.9	9	23.7	30	19.9
Less Water per Irrigation	21	30.0	10	23.2	5	13.2	36	23.8
Both	25	35.7	15	34.9	12	31.6	52	34.4
Number Reporting Less Use	55	78.6	37	86.0	26	68.4	118	78.1
Total Respondents	70	100.0	43	100.0	38	100.0	151	100.0

1/ Number reporting this item.

2/ Percent of questionnaires.