

*Reprinted from Watershed Planning and Analysis in Action
Symposium Proceedings of IR Conference
Watershed Mgt/IR Div/ASCE
Durango, CO/July 9-11, 1990*

**Supplemental Irrigation by Runoff Farming:
An Economic Assessment**

Gary W. Frasier and Frank G. Scrimgeour¹

Abstract

A simulation model was used to evaluate the economic potential for using runoff farming techniques for growing grain sorghum at two locations in Texas. The results show that the yearly precipitation fluctuations are magnified into large fluctuations of yearly benefits (profit/loss) and that a management decision based on mean values may be misleading. At both sites a conventional dryland farming operation would provide a greater economic benefit than the runoff farming system requiring water storage and irrigation application equipment. The principal limitations of the assumed runoff farming system is that it does not take advantage of the wet years or respond sufficiently in the dry years. Other options such as direct application of the water to the growing area from the catchment area, higher value crops, increased yield varieties, or other locations with different climatic conditions need to be evaluated on their own conditions and merit.

Introduction

In many arid and semiarid regions of the world, precipitation timing is inappropriate or rainfall quantities are insufficient for many agronomic crops and practices. Runoff farming is a cropping technique potentially suitable for growing plants in areas where

¹Research Hydraulic Engineer, United States Department of Agriculture, Agricultural Research Service, Aridland Rangeland Management Research Unit, 2000 East Allen Road, Tucson, AZ. 85719 and Lecturer, Department of Economics, University of Waikato, Hamilton, New Zealand.

conventional farming techniques and water supplies are marginal for sustainable or economic crop production.

Runoff farming involves the collection of runoff water from a portion of the land during precipitation events for use on the remaining crop growing area. In its simplest form, runoff water is diverted from uplying areas onto lower lying fields where it infiltrates into the soil profile. This technique was used over 4000 years ago in the Negev Desert of Israel (Evenari, et al., 1961). Recent runoff farming techniques consist of collecting runoff water from areas (catchments) that have been treated or modified to increase the amount of precipitation runoff. The collected water may be applied directly to the crop growing area or stored in a pond or reservoir for later application by an irrigation system. There are many types of runoff farming systems but most of them would be classified as some variation of the two described techniques.

The ultimate performance of any runoff farming system is highly dependent upon the timing and quantity of the precipitation events. Arid and semiarid regions are characterized by large variations in precipitation quantities. Over a long period of time, runoff farming might be of an economic benefit, but in the short term, many farmers may not have sufficient capital to withstand economic losses of a few years. This paper presents an approach that can be used to evaluate the potential for an annual profit from a farming operation and specifically a runoff farming system. The example is based on a runoff farming system using water impoundment and supplemental irrigation for growing grain sorghum at two locations in Texas.

Methods

A simulation model developed by Scrimgeour, 1989, was used to evaluate the economic potential of a water harvesting (runoff farming) system for growing grain sorghum. The model incorporates hydrologic, biologic, and economic information into a conceptual framework to estimate the costs and benefits of the farming system for making risk assessments for different environmental (ie., precipitation) and economic (ie., price) conditions. This approach accounts for the stochastic dependence resulting from the joint dependence of the variables.

The model consisted of five modules: catchment (runoff), impoundment (water storage), soil, crop, and economic. Input data includes daily rainfall, monthly pan evaporation, production costs, and grain prices.

The model simulates production, providing a range of outcomes (maximums, minimums, averages, and standard deviations) and shows how yields, costs and profits vary by years (seasons) for a given cropping system design and decision criteria.

We investigated the effect of one parameter, yearly growing season precipitation, on the economic benefits of growing grain sorghum using runoff farming. Two sites, Temple and Bushland, Texas, were selected as test locations. Both locations are USDA-ARS research laboratories with detailed soil, climate and crop production data. The simulated farm layout consisted of an 80 hectare area. During the growing season, runoff was collected from the entire 80 ha and stored in an impoundment reservoir for later application in two supplemental irrigations to a 53 ha crop area within the farm. The remaining 27 ha was primarily used as a water contributing area planted to a dryland grain sorghum which would provide some grain production in the wetter years.

The growing season was assumed to be March to June in Temple and from June to September in Bushland. Based on studies by Frasier, 1975, it was estimated that the total annual water yield from the area could be approximated by assuming that runoff would be 40% of any daily rainfall in excess of a threshold of 6.4 mm. Seepage losses from the water storage were assumed to be 6 mm per day of wetted perimeter and total evaporation losses, assuming a partial measure of evaporation control, were 40 percent of open pan evaporation. These values are based on various research studies and are believed realistic of what might occur in a field situation.

The storage reservoir could hold, at any single time, a volume of water equivalent to 58 mm per irrigated acre. The collected water, up to a total of 116 mm, (two full storages), was applied to the irrigated area in two applications at a total cost of \$9.30 per hectare. Any collected water in excess of the 116 mm but less than the 174 mm (three storages) was applied in a third irrigation at a cost of \$4 per hectare. The soil profile was assumed to be saturated when a total of 254 mm was accumulated via irrigation and/or precipitation. Excess infiltrated water was lost through deep percolation. The water necessary to establish a crop was assumed to be 152 mm. Each additional 25 mm increment of available soil water was assumed to increase crop yield by 350 kg per hectare. Once the total available plant water exceeded 635 mm, each additional 25 mm of water produced only 100 kg per hectare.

Variable costs (cultivation, seed, fertilizer, labor, weed and pest management, and harvesting) were assumed to be \$29 per hectare for the 27 hectares of dryland sorghum and \$32 per hectare for the 80 hectare supplementally irrigated area. The water harvesting system was assumed to cost \$26,000 for the water storage and \$20,000 for the irrigation equipment. This is equivalent to an annual cost of \$15 per irrigated hectare using 9 percent interest, a 20 year life of the irrigation system and an indefinite life of the water storage facility with annual maintenance costs of \$520. Sorghum prices were assumed to be \$0.11 per kilogram.

Results and Discussion

Scrimgeour (1989) showed that the simulation model approach was a realistic tool for assessing the economic impact of both fixed parameters and stochastic variables. The yearly profit/loss values over a 44 year period are shown in Figures 1a and 1b for Bushland and Temple, respectively. At Bushland there was an average loss equivalent to \$7.30 per hectare per year while at Temple, the average profit was \$34 per hectare per year. There were extreme fluctuations in yearly returns, even at Temple where the average profits are positive. The yearly growing season precipitation values at each location (Figure 1c and 1d) show similar fluctuations around the long term precipitation mean indicating the dependency of the yield to the precipitation. These results illustrate the potential hazard of using mean growing season precipitation as opposed to the changing yearly precipitation values.

At Temple there was a profit with growing season precipitation quantities of 150-200 mm per year which are less than the average growing season precipitation (Figure 2a). At Bushland a profit was not realized until the growing season precipitation was 230-250 mm per year, above the long term mean of 200 mm (Figure 2b).

As would be expected, at both locations there is a correlation between the growing season precipitation and the yearly profit/loss, Figures 2a and 2b. This correlation is not linear. It is recognized that the quantity of water stored in the soil profile prior to the growing season and the water evaporation from storage during the growing season influence profits but the dominant determinant in the yearly variations in profit (loss) appear to follow the variations in the annual amount of growing season precipitation. The significance of the rainfall variation and the variation in profit is shown by the coefficients of variation ($CV = \text{standard deviation/mean}$).

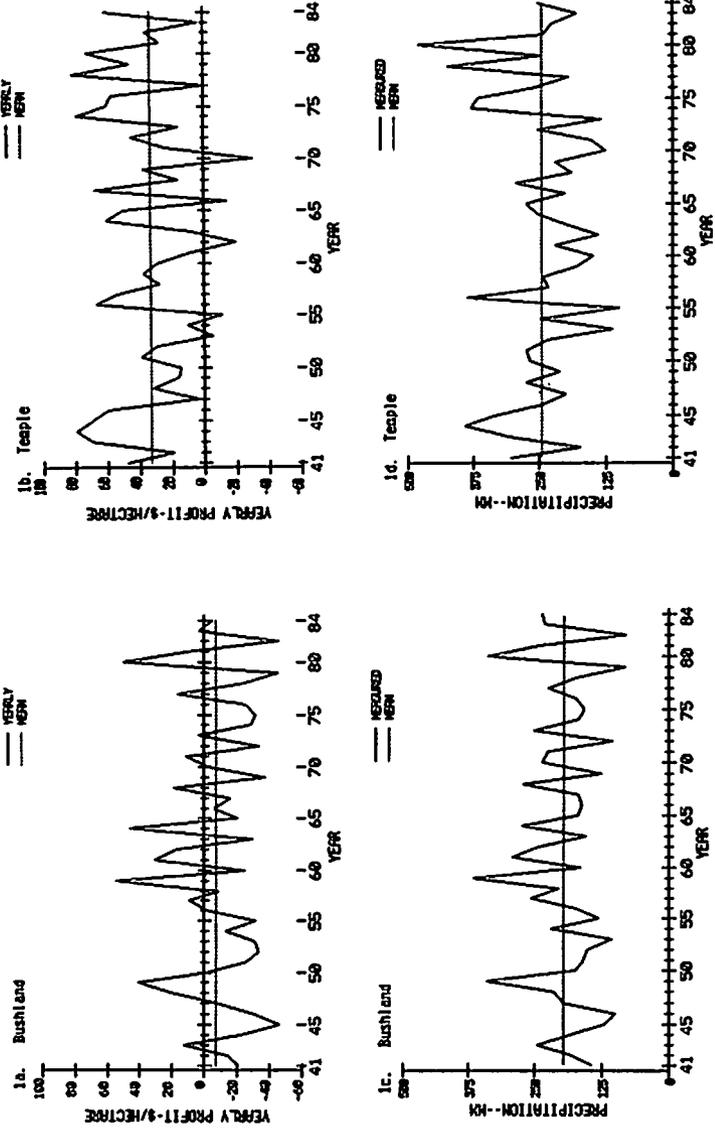


Figure 1. Yearly simulated profit or loss (1a and 1b) for growing grain sorghum with runoff farming techniques and growing season precipitation (1c and 1d) at Bushland and Temple, Texas respectively.

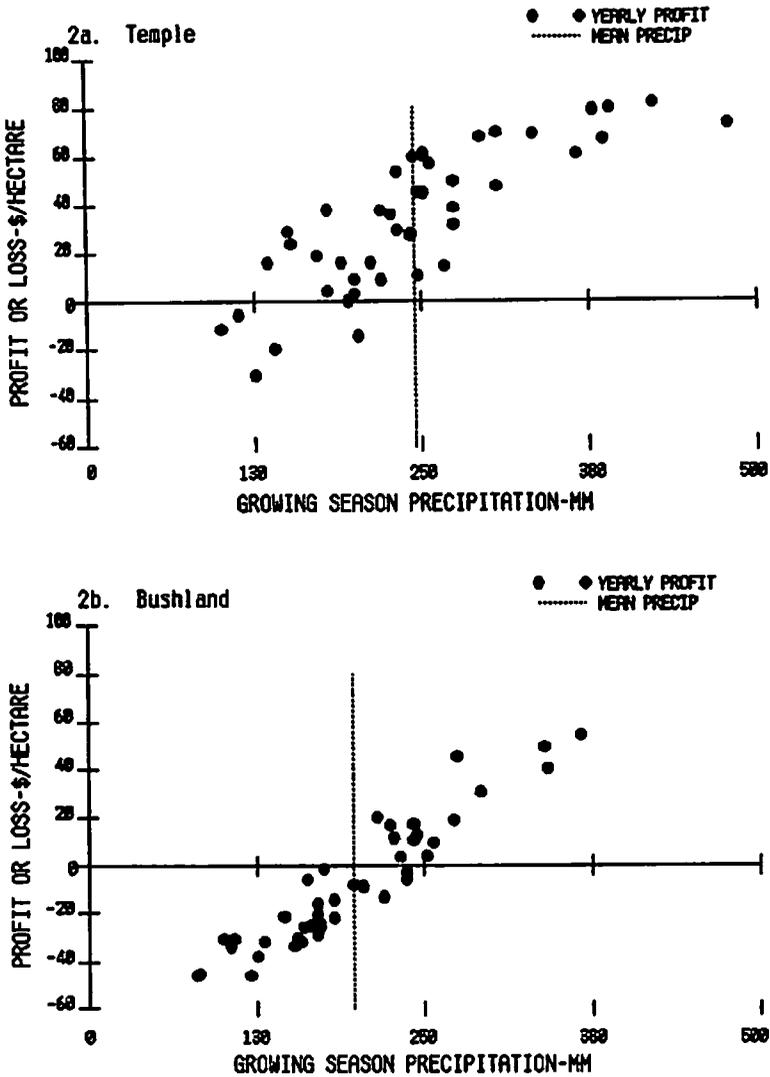


Figure 2. Yearly simulated profit or loss as a function of growing season precipitation at Temple and Bushland, Texas, 2a and 2b respectively.

Coefficients of Variation

	Bushland	Temple
Growing season precipitation	0.34	0.34
Profits per acre	0.86	3.60

These coefficients show a larger variation in profit than there is in the growing season precipitation, implying that changes in precipitation quantities are magnified in the resulting profit/loss values. This is explained by the fact that in wet years water overflows and is lost from the storage and because, as more irrigation water is applied, there is a point where the relative increase in grain yield begins to decline. In the dry years there is insufficient water harvested to increase the yield. Also, this analysis does not include the effect of any residual soil moisture that might be remaining in the soil profile from the previous year.

While there is a profit associated with runoff farming at Temple, both on an average and among most years, it may not be as economically favorable practice as a "conventional dryland farming" operation. A considerable amount of capital may be required for constructing the system and the farmer may be required to change "normal" farming practices. Without an economic benefit, "new" farming practices will not be adopted. The yearly net benefit (profit or loss) compared to dryland farming of grain sorghum is shown for both sites in Figures 3a and 3b. The majority of the 44 years shows a net loss from the assumed runoff farming system compared to a conventional dryland farming operation. Apart from the variability caused by precipitation, price variation also adds to the risks a farmer must take and so adds to a greater variability than shown.

Conclusions

These results showed that, for the conditions specified in the model, yearly fluctuations in benefits are significant factors. The analysis showed that any fluctuations in the growing season precipitation are magnified in fluctuations in yearly net benefits. The water harvesting system showed a profit at the Temple, Texas site for more years than were found at the Bushland, Texas site. This is attributed to the higher growing season precipitation amounts at Temple.

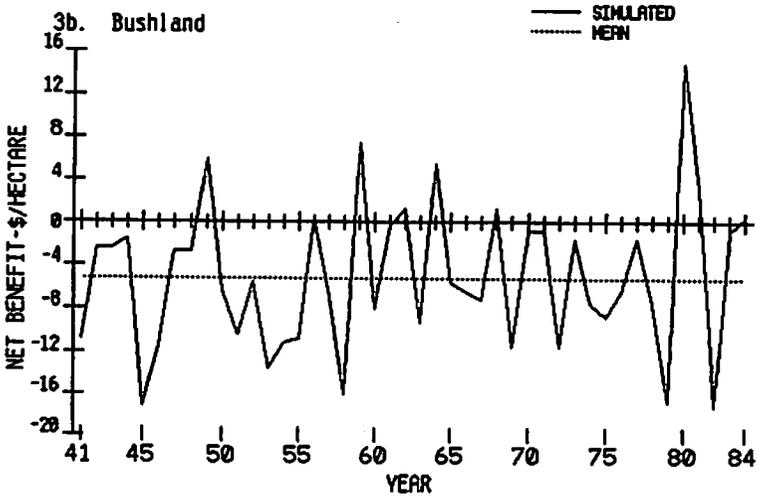
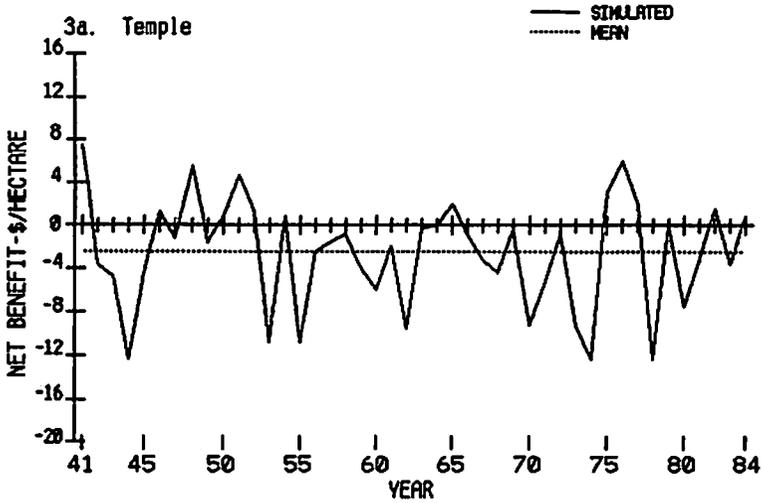


Figure 3. Comparison of the net benefit (profit or loss) of water harvesting vs conventional dryland farming of grain sorghum at Temple and Bushland, Texas, 3a and 3b respectively.

For the conditions specified in the analysis, it is concluded that water harvesting for the growing of grain sorghum at these two sites in Texas would not be a viable economic alternative compared to a conventional farming practice. The principal limitation of the assumed runoff farming system is that it does not take advantage of the wet years or respond sufficiently in the dry years. The analysis also showed that it can be very misleading to base the management decision on mean values.

At both sites a conventional dryland farming operation would be of greater economic benefit than the utilization of a runoff farming system requiring water storage and irrigation application equipment. Other options such as direct application of the water to the growing area from the catchment area, higher value crops, or increased yield varieties were not investigated. This does not mean that there are not situations or conditions where runoff farming would be of economic benefit. Each situation needs to be evaluated on its own conditions and merit.

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