IRRIGATION PRODUCTION AND DESIGN TECHNIQUES

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Abstract

Production with irrigation is high and some of the economic advantages of irrigation farming are given. To achieve this high and steady rate of production, engineering and hydraulic principles must be followed in the design and construction of the border strips. If pasture is irrigated more than five times an economic advantage exists for a border strip length of 220 m as compared with 110 m or 440 m. As lengths of border strips are shortened, watering rates are increased and a grcater area can be covered with the same amount of water or the area may be watered more frequently.

INTRODUCTION

IRRIGATION in Canterbury and North Otago increases production and will give an economic gain to those who use it to the best advantage.

Many people have said that water can dóuble production. Rickard and Fitzgerald (1971) have established a general relationship between soil moisture and pasture production. Mean annual production from a non-irrigated pasture at Winchmore Irrigation Research Station has been 6040 kg/ha with a range of approximately ± 49%. Production from a well-irrigated pasture had a mean of 11 870 kg/ha with a range of approximately ± 12%. The average increase is 97% and there is a response to irrigation in all seasons. During the wet 1952-3 season with 968.3 mm of rain (63% above the mean) in the growing season (September-May) there was a 41% increase over the non-irrigated treatment. This involved two irrigations only. In. the dry 1954-5 season with only 458.4 mm of rain (September-May) there was a 289% increase involving thirteen irrigations. This pasture production must be put to use.

The sheep-carrying capacity unit of almost 11 ha at Winchmore Irrigation Research Station was bordered, sown down and fenced in 1949. During the first season it carried 7.4 ewes/ha and by the early 1950s it had risen to 17.3 ewes/ha and, except for a little flutter in the late 1950s at 18.5 ewes/ha, it stayed at 17.3 ewes/ha until the late 1960s. During this period it had an average lambing of 113.9% and produced 278 kg/ha meat and 80 kg/ha of wool. Stocking was maintained at this level because it was believed that this was the maximum, but it is the writer's opinion that a managerial limit had been reached. In 1967-8 stocking was increased by 1.24 ewes/ha and with very little managerial trouble. Three more increases have taken place and now the unit is carrying 22.2 ewes/ha and in the 1972-3 season produced 289 kg/ha of meat and 98.4 kg/ha of wool. Topdressing has been basically superphosphate at a rate of 375 kg/ha and approximately 800 mm of water has been applied annually. From these average production figures and low inputs one can deduce the economic returns that could be obtained.

IRRIGATED FARMS

Many people consider that farm production does not match the production of a research station. Morrow (1972) stated that he obtained an annual net gain from irrigation of $6785, or a reward to investment and management of $35.51 per effective irrigable hectare, with no account of the monetary gain from autumn irrigation. He operates an intensive cropping farm system on a Temuka silt loam peaty phase soil in the Lowcliffe coastal district of Mid-Canterbury. No stock is carried from late October until after harvest and he can irrigate his total area with a sprinkler plant.

Wright (1972) on a sheep plus 10% cropping property on a Lismore stony silt loam just above Hinds, stated that he would expect a $25 to $30/ha net additional profit for irrigation. He had 47% of his farm bordered with the possibility of wild flooding another 39%. He would have bordered a greater area but felt that he might over-commit his water supply. He had a spring grazing capacity of 11.6 stock units/ha in 1965 when he began planned development and progressed to 19.3 and 21.3 stock units/ha in 1970 and 1971.

Barwell (1974), on the south bank of the Selwyn, has $20 000 invested in his irrigation plant. The soils of his farm are of the Templeton series which is a medium cropping soil with some light stony strips. He is proud of his stock performance on his irrigated farm and last season drafted just under 100% of his lambs before weaning at the end of October. This allowed him to shut up the maximum area for white clover. He has shown an average owner's surplus of $190/ha for the four years since he sunk his first well, compared with $64/ha for the previous three years, He stated that his figures suggest that the annual extra income from irrigation is sufficient to pay off the capital cost in about a year or two.

In each of these cases water has been used to generate increased and steady production which in turn has meant better returns for the farmer.

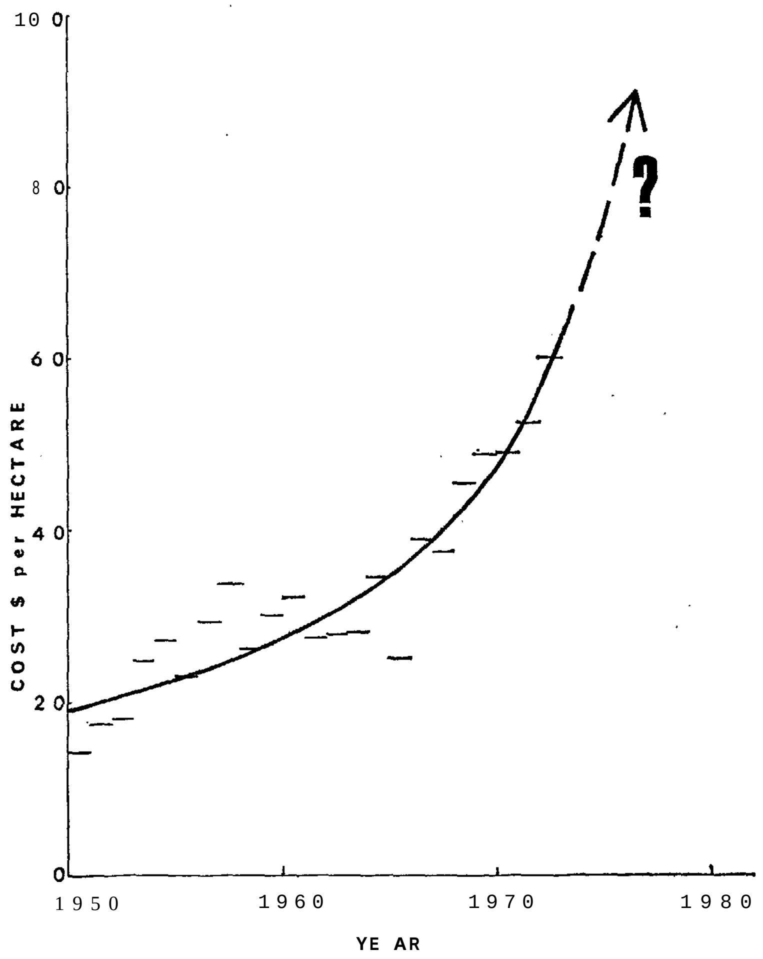

FIG. 1: *Earthwork costs, Ministry of Works and Development. (From Annual Report of the Canterbury Irrigation Schemes, MWD.)*

For a long time labour was a restraint to the development of farm irrigation systems, but a system has been developed for 'surface irrigation, controlling the shifting of water by clocks and other devices. Originally one man-hour per hectare was required for irrigating but now a man can set up enough equipment in one hour to irrigate up to 100 ha. With this low labour input into irrigation, more attention must be focused on the engineering and hydraulic aspects of the construction and operation.

LAND PREPARATION

The following discussion relates to the costs involved in preparing an area for surface irrigation coupled with the rate of watering and water costs. The cost of preparation of an area of land for border strip irrigation will vary from area to area because of the slope, microrelief, soil type, machinery used for construction, and the farmer. Ministry of Works and Development contracted to carry out earth works for the farmer in the five schemes where they supply water. Figure 1 shows how the costs have varied. (Annual report of the Canterbury Irrigation Schemes MWD.)

The increase over the years is a reflection of inflation as well as the fact that in earlier years the easier areas were developed first. The more difficult areas are now being developed incorporating automatic headraces.

Table 1 shows how the length of the border strip will alter the cost per hectare. Included in this table are the additional costs which must be added to the two major costs of levelling and headrace construction. Annual cost is calculated to return 8% on the capital invested and 1% for repairs and maintainance. It can be seen that, as the borders increase in length, the cost per hectare decreases.

SURFACE IRRIGATION HYDRAULICS

The border strip can be considered as a wide, shallow channel in which the water flows from the headrace to the end of the strip in an elongating thin sheet moistening the soil as it goes. The inflow of water to the border strip must exceed the infiltration rate to allow the water to flow on down the strip. The hydraulics of surface irrigation depends on the size of the irrigation stream, the rate of advance, the length of the strip, the depth of flow, the infiltration rate, the slope of the strip, surface roughness, shape of border strip, and the depth of water to be applied.

TABLE 1: COSTS OF BORDER STRIP PREPARATION

	Length of Border Strip (front Headrace Centre-line to Head-race Centre-line) Metres 110	220	440
Cost of levelling ($/m of width) ..	0.55	1.10	2.20
Headrace ($/m)	0.50	0.50	0.50
Structure and sills ($/m)	0.84	0.84	0.84
Control mechanisms ($/m)	0.11	0.05	0.02
Total per metre ($)	2.00	2.49	3.56
Construction cost ($/ha) ...	181.82	113.18	80.91
Surveying ($/ha)	12.00	12.00	12.00
Construction supervision ($/ha)	10.00	8.80	8.80
Total ($/ha)	203.82	133.98	100.91
Annual cost ($/ha)	18.34	12.06	9.08

Basic Data

1. Flow design 240 l/s
2. Border construction and strip-levelling—$50/ha
3. Headrace construction-$0.50/m
4. Structures, $20 installed-$0.42/m average
5. Sills, $5 installed-$0.42/m average
6. Control mechanisms, $20 per unit.

These factors are all dynamic. This is one reason why the solution to obtaining a relationship between the rate of advance of the water down the strip and the infiltration rate is so complex. Over the last three seasons data on the factors outlined above have been collected at Winchmore Irrigation Research Station and two farms in the Ashburton County.

A relationship developed by Dr Graham A. Jobling (pers. comm.) and data from field work have been used to calculate the time when the water should be cut off for different lengths of border strips and different streams of water. Data were collected at Winchmore Irrigation Research Station on border strips 220 m long and for a number of pasture heights, soil moistures and flow rates. These data supported the Jobling relationship which was used to calculate the 110 m and 440 m length border strip cut-off times shown in Table 2. From this the quantity of water required per hectare can be calculated and this is shown in Fig. 2. For each length there is very little difference between the three larger flows but the 30 l/s flow uses considerably more water and so would be less efficient.

TABLE 2: CUT OFF TIME FOR DIFFERENT WATER FLOWS AND DIFFERENT BORDER LENGTHS

	Cut-off Time (min)		
	Border Length (m)		
Flow (l/s)	110	220	440
30	82	183	633
60	31	72	215
90	20	47	139
120	15	34	101

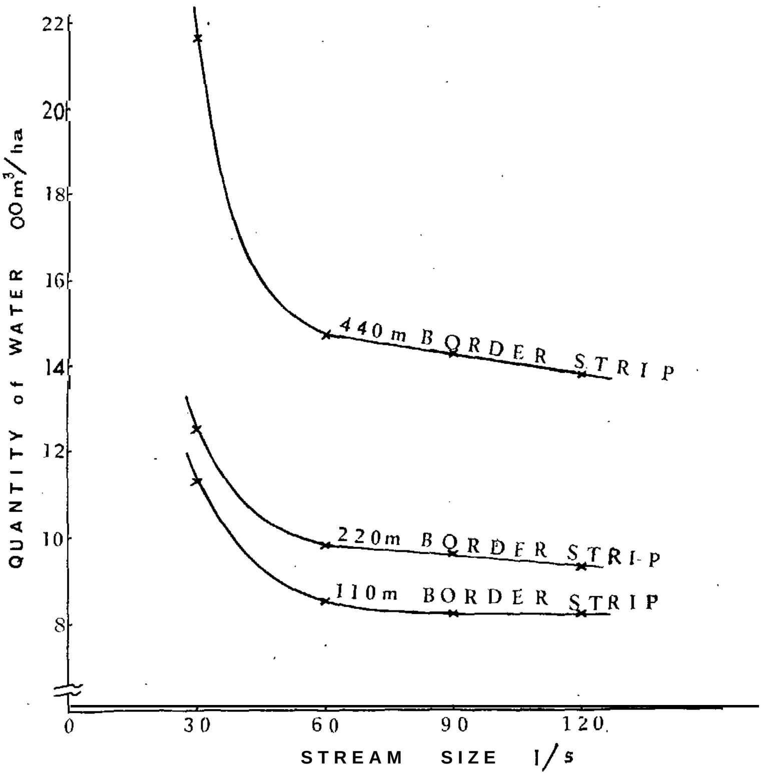

FIG. 2: *Water required.*

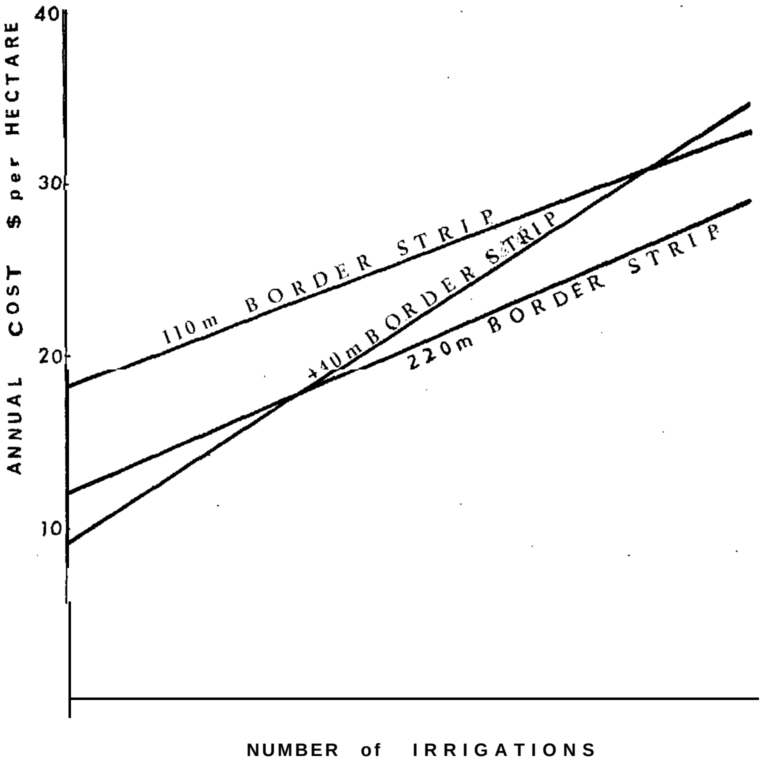

FIG. 3: *Annual cost of irrigafion (flow of 60 lifres per second).*

COST AND AVAILABILITY OF WATER

Water in the new Morven-Glenavy Irrigation scheme will cost $1.44/1000 m^3 for the first 300 mm on the contract area and $0.72/1000 m^3 for any extra water supplied. In this paper a flat rate of $1.08/1000 m^3 is used for the cost of water.

Figure 3 shows how the cost varies with each irrigation using a flow rate .of 60 l/s. A border length for pasture of 440 m would cost the least for under five waterings while for more than five waterings the 220 m border strip would cost the least. The very short 110 m border strip would cost the least after only 45. waterings.

So far it has been assumed that availability of water is unlimited and, as this is not usual, the rate of irrigation must be considered. With a scheme designed to supply water at 0.7 l/s/ha con-

TARLE 3: IRRIGATION RETURN PERIOD

Flow (l/s)	Return Period (days) Border Length (rn) 110	220	440
30	18.5	20.7	35.7
60	14.1	16.2	24.3
90	13.6	15.9	23.5
120	13.6	15.4	22.8

tinuously, the times shown in Table 3 would be required to elapse before it would be possible to irrigate one area again if the total farm was watered.

It is apparent from the figures above that for pasture irrigation not only the annual cost of the land preparation and the water charge must be taken into account but also the time it takes to water the farm. If a farmer wants to irrigate approximately every two weeks during a dry spell, the length of the 'border strip will have to be 220 m or less, otherwise he must obtain more water. Usually at a time like this extra water is not available and the farmer is left in the unfortunate position of not being able to obtain the production that he planned for.

OTHER FACTORS

Other factors that should be given consideration are the effect of slope, a possible change to a cropping system and a larger or smaller distribution flow of water. Irrigating on slopes with less gradient than those at Winchmore Irrigation Research Station has the same effect as increasing the length of the border strip— that is, more water will be used and more time will be required per irrigation.

Where cultivated soil is irrigated by the border strip method, up to twice as much water may be required per irrigation for an area. Although the crop will not have to be watered as often, the requirement for water often comes at a peak time and with a limited supply available this could cause some managerial problems in deciding where the water can be used to the optimum advantage. A larger flow supplied to the farmer may alter construction costs but not to any great extent. They may allow greater areas to be irrigated but would use the same amount of water. With flows of less than 100 l/s, cost of construction and operation will increase and this may mean that some other method of irrigation may be more economical.

The engineering and hydraulic aspects of border strip design must be considered if the farmer is going to achieve optimum production from his system at a high and steady rate.

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