Pasture yield responses to irrigation in Canterbury

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Abstract

Major findings from 13 pasture irrigation experiments conducted in Canterbury are discussed. Yields and response curves on 8 of the experimental sites were very similar to those of the long-term trial (34 years) site at the Winchmore Research Station. Irrigating when soil moisture dried to 50% asm (available soil moisture), increased annual pasture DM yields by an average of 5.2 t/ha DM (80% increase over the non-irrigated yield). Response per irrigation and yield variation between years decreased as the number of irrigations increased. During water restrictions, irrigators often choose to either keep watering their whole farm with a longer irrigation return period, or drop out paddocks and fully irrigate the remainder. The irrigation response data are used to discuss these and other possible strategies.

Keywords: irrigation, pasture yields, response curves, water restrictions

Introduction

Canterbury irrigation schemes were originally designed to supply sufficient water to irrigate 66% of the land within the scheme. Many of the farmers considered irrigation as an insurance. In recent years, however, there has been a growing realisation of the true value of irrigation water. This has led to many farms being fully developed for irrigation (e.g. on the Ashburton/ Lyndhurst scheme in the period 1980 to 1990, a further 7000 ha or 27% of the total scheme was developed for irrigation). Response to irrigation and irrigation efficiency are now key issues.

The irrigation season is nominally from September to April. Most border strip irrigation schemes in Canterbury draw water from rivers that are under minimum flow regulations. When these minimum flows are reached, draw off for irrigation is restricted or in extreme cases stopped. Irrigation organisations usually manage water restrictions by allocating the same flow of water to the irrigator, but for less time per week or month. During this time the irrigator must decide how best to use the water.

Pasture production response to irrigation in Canterbury has been reported at Winchmore Research Station for 25 years (Rickard & McBride 1986), and other sites; Mid-Canterbury (8 sites), Rakaia (2 sites), Waiau (2 sites) for shorter periods (Hayman & McBride 1984; Hayman 1984). The Winchmore trial continues and data from the next nine years to date, is included.

This paper outlines the major findings of those studies and discusses possible management strategies in times of water restrictions.

Approach

The Winchmore trial site was originally established in 1949 and has been operating with the present treatments since 1960. These included plots irrigated when the top 100 mm soil profile dried to 50% asm (available soil moisture), 25% asm, or 0% asm (wilting point), plus one irrigation every 21 days.

The mid-Canterbury sites were established in 1975 to study the effect of soil type and rainfall on the response of pasture to irrigation. Stony, medium and deep soil sites were selected in each of three rainfall zones; coastal (600 mm annual rainfall), mid plains (750 mm), and upper plains (900 mm). Irrigation was applied when the top 100 mm soil profile dried to 50%, 25%, 0%, and -10% asm.

The Rakaia and Waiau sites were established in 1979 on 2 soil types (stony and medium) in each area. Irrigation was applied every 2, 3, 4, 5, or 6 weeks, with the qualifier that the soil moisture was below 60% asm when the irrigation was due.

On all sites the soil was free draining, suitable for border-strip irrigation. A non-irrigated treatment was included on all sites.

Irrigation was applied by border-strip irrigation at Winchmore and by flooding-small basins (8 m x 4 m, a basin for each treatment) at all other sites. Approximately 100 mm of water was applied at each irrigation.

Production was measured by mowing approximately monthly during the growing season September to May. The Winchmore site was under sheep grazing and used the moving frame technique (Lynch 1966) while all the other sites were ungrazed and used the clipping returned method.

Other methods and measurements were similar over all sites and are described in Hayman & McBride 1984 and Rickard & McBride 1986.

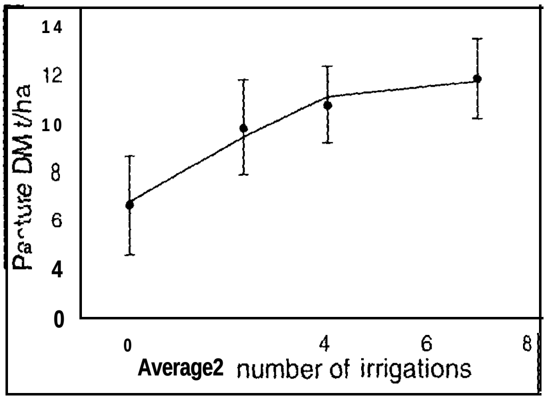
Results and discussion

Average seasonal production data from the Winchmore trial is presented in Table 1 and annual totals are graphed against the average number of irrigations for each treatment in Figure 1.

Table 1 Pasture production (DM kg/ha) from Winchmore Research Station trial-average of 34 years.

Irrigation treatment	Winter	Spring	Summer	Autumn	Total
N/I	725	3650	1295	t 040	6710
0% asm	715	4010	3515	1615	9955
25% asm	705	4330	3970	1765	10790
50% asm	725	4460	4645	2065	11915
21-day	715	4540	4205	1955	11415

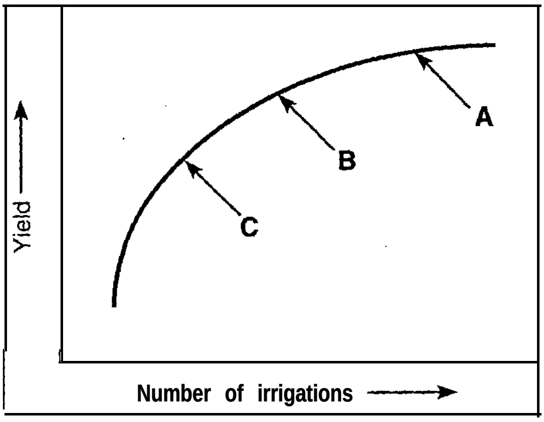
Figure 1 Pasture response to irrigation. Winchmore Research Station average of 34 years (vertical bars show 95% confidence limits for individual yearly values).



Pasture yields were lifted from 6.7 t/ha DM to 11.9 t/ha DM when irrigation was applied when the soil dried to 50% asm. This required a mean of 7 irrigations per season ranging from 2 to 11. On average 65% of the total response to irrigation was in the summer months December to February. Spring and autumn responses averaged 15% and 20% respectively.

Care must be taken in interpreting the averaged data shown in Figure 1. The 34-year mean yield for the 50% asm treatment is 11.9 t/ha DM, but the number of irrigations required (determined by the treatment protocol) is very rainfall dependent and has ranged from 2 to 11. For example in 1988189, 3 irrigations were applied for an annual yield of 11.3 t/ha DM, while in 1992/93, 9 irrigations were required for a yield of 11.2 t/ha DM. However, in any one year, the range of treatments on this trial normally produces a typical diminishing response curve (Figure 2) with dry matter response decreasing with increasing number of irrigations (Rickard & McBride 1986). The slope of the response curve (Figure 1) suggests that further gains are possible with more frequent irrigation. However, Rickard (1972) reported that weekly irrigation did not increase production over fortnightly or 50% asm treatments.

Figure 2 Normal irrigation response curve.



The number of irrigations required on the 50% asm treatment has decreased with time (Rickard & McBride 1986), and the trend reported there has continued. Two factors seem to be influencing this. Firstly, the post-winter soil moisture on the irrigated plots has increased with time and therefore it takes longer to dry to the required soil moisture. Over the past 10 years, the first irrigation on average was 29 days later than at the beginning of the trial; this relates to approximately one irrigation.

Secondly the average interval between irrigations on the 50% asm treatment has increased from 22 days (first 10 years) to 27 days. Over 181 days (October to March) this relates to a decrease from 8.2 irrigations to 6.7 irrigations required. Rainfall over the two periods was comparable.

Analysis to date has failed to explain this, but it appears to be due to changes in soil physical properties of the irrigated plots.

Production on the non-irrigated treatment was closely related to days of agricultural drought (Rickard & McBride 1986), and varied ± 66% from the mean. Variation around the mean declined when irrigation was applied: ±35%, ± 28%, and ±28% for the 0% asm, 25% asm and 50% asm treatments respectively. This is higher variation than previously reported (Rickard 1972), but includes years of exceptionally low yields (Rickard & McBride 1986).

Twelve other sites in Canterbury were established to measure pasture response to irrigation under different soil types and rainfall zones. Yields on the non-irrigated plots increased with soil depth (water-holding capacity) and rainfall. Increased soil depth and rainfall also decreased the number of irrigations applied on the soil moisture based treatments.

On 8 of the sites, where the soil ranged from stones to the surface to no stones to 600 mm, the response curves to irrigation and maximum yields were very much the same as the Winchmore site in comparable years (Hayman & McBride 1984; Hayman 1984). They concluded that while other sites ran only 5 or 6 years, the Winchmore site gives an accurate guide to irrigation response of pasture for much of the irrigatable land in Canterbury.

Two important conclusions can be drawn from the Winchmore data:

1. As irrigation frequency increases the response per irrigation tends to decrease, but importantly the yield percentage variation between years also decreases.
2. After 34 years of irrigation, yields on the 50% asm treatment are now higher than they were at the beginning, but the number of irrigations applied as required by the protocol of that treatment has decreased. Over the past 10 years the 50% asm treatment has required an average of 6.2 irrigations. This is somewhat less than the number applied by local farmers.

Water restrictions

The impact of water restrictions on individual farmers is now greater than in the past for several reasons:

1. Farmers are now irrigating on the steeper portion of the irrigation response curve (see Figure 2). In the past with only 66% of their farm developed for irrigation, with their allocation farmers were able to irrigate at point ‘A’. When restrictions were imposed this would move them to point ‘B’ on the curve, causing only a small reduction in pasture production. As they have developed more of their farm for irrigation this has meant irrigating more towards point ‘B’. When restrictions are imposed a greater yield reduction occurs as they move to point ‘C’.
2. Irrigation farmers are now utilising more of the extra production achieved from irrigation. As they moved away from the ‘insurance’ type mentality, they have set their stock carrying capacity to utilise the extra production and when water restrictions are imposed there is now much less spare production to counteract this.
3. Neighbouring farms are using more of their water. In times past, for various reasons some farmers chose not to take their full allocation of water, creating some ‘slack’ in the scheme that was utilised by others. This is now not the case.

During times of water restrictions the farmer must decide on how best to use the water. Two scenarios are common: some farmers keep watering the whole farm rotationally but with a longer irrigation return period, while others drop paddocks out and irrigate the remainder at the normal return period. Attempts have been made to measure (Hayman & McBride unpublished data), derive (Hayman 1984) (see Table 2), or model (Rickard et al. 1986) the effects of these two options. These studies have shown that the best option will depend on the severity and duration of water restrictions, soil type (Table 2) and rainfall.

Table 2 Total pasture production (t DM) over summer on a 100 ha irrigated farm with system capacities of 4.3 or 2.4 ha/day. (After Hayman 1984.)

System Capacity (ha/day)	Irrigation Interval (days)	Area Irrig. (ha)	Area Dry (ha)	Total tonnes DM Deep soil	Total tonnes DM Shallow soil
4.3	23	100	0	370	305
	17	74	26	310	280
2.4	42	100	0	280	140
	34	82	18	270	180
	28	67	33	250	190
	23	55	45	225	190
	17	40	80	190	175

However the derived and modelled data studies were somewhat flawed in that ‘dryland’ pasture production data were used to determine ‘dry’ pasture production during restriction periods. Yields during periods of no irrigation will be different from pastures previously irrigated, than from pastures that have been continuously not irrigated. The long-term consequences (e.g. effect of grass grub attack on pasture survival) of not irrigating portions of the farm were also not considered.

Table 2 presents pasture yield data on two soil types irrigated by systems of different capacity. This table can also be used to demonstrate the effect of irrigation restrictions. When water flow is sufficient to irrigate 4.3 ha/day, the best option on both soils is to irrigate the whole farm with an irrigation return period of 23 days. If a 45% restriction is imposed and the system can irrigate only 2.4 ha/day, the best option depends on soil type. On the deeper soil the irrigator is best to continue irrigating the whole farm but on a 42-

day irrigation return period, whilst on the shallower soil, the best option is to irrigate only 67% of the farm with a 28-day irrigation return period.

If only moderate irrigation restrictions are in place, irrigating the whole farm may still be the best option on all soil types. This allows pasture plants to respond more quickly to rain or irrigation than if they had been allowed to become dormant with no irrigation (Hayman 1984).

Four alternative strategies are suggested:

1. Establish a portion of the farm in pasture species mixes that cope with reduced or non-irrigated conditions better. Good selection of species should ensure that production is not reduced during times of normal irrigation .
2. Block off and don't irrigate a proportion of individual borders at each irrigation (R. Stoker pers. comm.). This will increase the water flow to the remaining borders in the group, increasing the efficiency by reducing the set time and the irrigation return period, thus minimising the effect of the restriction. If the blocked-off borders are rotated among each group, then only when restrictions are on for a long time will individual borders miss more than one irrigation in the season.
3. Short water a proportion of borders in each irrigation rotation. This will improve irrigation efficiency over the area irrigated. Again, alternating the short watered borders between irrigations will reduce the long-term effect of dry conditions.
4. During times of redevelopment, especially on older schemes, shorter borders or decreasing the number of borders per group will improve irrigation application efficiency. The resulting shorter return periods will reduce the effect of water restrictions.

Conclusions and practical implications

1. Irrigating pasture in Canterbury will increase average yields by up to 5.2t/ha DM (80%). Most of this response to irrigation is in the summer.
2. As the frequency of irrigation increases the response per irrigation decreases, but importantly, the variation in yield between years decreases. Thus, permanent irrigated pastures allow pastoral farmers to plan stocking rates and feed allowances with confidence.
3. Under irrigation and good management, high pasture yields can be maintained without pasture renewal. The amount of irrigation required to sustain these yields does not increase with time.
4. Irrigation restrictions will reduce pasture production but good strategies will minimise the impact.

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