THE EFFECT OF SOIL AND RAINFALL ON THE RESPONSE OF PASTURE TO IRRIGATION

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ABSTRACT

Pasture responses to irrigation were measured over 3 years at 8 sites on the mid Canterbury plains. There were 3 rainfall zones and within each zone trial sites were selected with soils of varying depth and water holding capacity. There were 5 treatments at each site: no irrigation and irrigation when the available soil moisture (asm) in the 0-100 mm layer fell to the following levels:

Coast and mid plains – 50%, 25%; 0 and -10%
Upper plain – 50%, 30%; 15% and 0

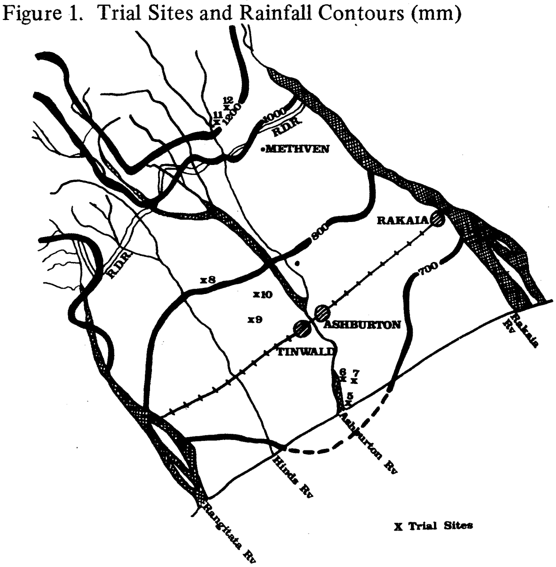
When irrigated at the same asm, 5 of the 8 soils yielded similarly. One deep soil produced at a higher level and 2 very stony soils at a much lower level. The pasture DM increase per irrigation was greatest when irrigating at low asm and it declined with more frequent irrigations. Production varied between soils but was not related to soil water holding capacity or soil depth.

Variation in rainfall between seasons had a large effect on the number of irrigations required, and the pasture DM response per irrigation.

INTRODUCTION

The Canterbury plains enjoy a sub humid climate with the mean annual rainfall varying from 600mm near the coast to approximately 1000mm near the Western foothills (Fig. 1). Though the long term monthly average shows this rainfall to be evenly distributed throughout the year, there are large seasonal variations. Thus periods of low rainfall in summer and autumn can combine with high temperatures and dry winds to produce droughts of varying length and intensity. (Rickard and Fitzgerald 1969).

Figure 1. Trial Sites and Rainfall Contours (mm)



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Flood irrigation has been developed in Canterbury over the past 40 years to water 45,000 ha. and there are plans (in varying stages) to irrigate a further 300,000 ha.

The most common soils of the plains are shallow free draining loams of moderate water holding capacity overlying deep gravels. However there is a significant area of deeper soils with higher water holding capacity.

To date the majority of irrigation research in Canterbury has been carried out at Winchmore Irrigation Research Station situated on a Lismore stony silt loam in a 'medium' rainfall zone (750mm). Little is known about yield responses to irrigation on other soils under different rainfalls.

It was to gather such data that a series of trials was established in mid-Canterbury in the spring of 1975. Interim results from the first three years of the pasture section of these trials are presented below.

MATERIALS AND METHODS

Eight trial sites were selected in mid-Canterbury to provide soils with a range of water holding capacities (WHC) in each of 3 rainfall zones (Table 1). There were 5 treatments at each site with irrigation being applied when the 0-100 mm soil layer dried to the following levels of available soil moisture (asm).

Coastal and mid-plains - 50%, 25%, 0%, -10% and no irrigation.

Upper plains - 50%, 30%, 15%, 0%, and no irrigation.

Individual plots were formed into level basins 8 m x 4 m and sown in September, 1975 with ryegrass (20 kg/ha), white clover (3 kg/ha) and subterranean clover (3 kg/ha). Superphosphate (375 kg/ha) was drilled with the seed and an equal amount top-dressed each winter. Potassium chloride (100 kg/ha) and

TABLE 1: Soil type and water holding capacity* (mm water/600 mm soil)

Rainfall Zone	Soils: Stony (stones to surface)	Medium (stones below 450mm)	Deep (no stones to 900 mm)
Coastal	Eyre stony silt loam: 100*	Wakanui clay loam: 199	Wakanui clay loam: 184
Mid Plains	Lismore very stony silt loam: 81	Eyre silt loam: 147	Wakanui clay loam: 185
Upper plains	Ruapuna very stony silt loam: 60	Mayfield silt loam: 227	–

* Water holding capacity = mm of soil water held between Field Capacity and oven dryness.

lindane (for grass grub control) were also topdressed in winter 1978.

Pasture yields were measured monthly from September - May by cutting with a reel mower set at 25 mm. Clippings were returned and there was no grazing.

Irrigation was applied to individual plots by a portable pump and hoses. Each plot was flooded with approximately 100 mm of water at irrigation to ensure that the whole soil profile was returned to field capacity. Irrigation timing was determined by gravimetric soil moisture sampling. Soil physical properties were determined as described by Rickard and Cossens 1966.

RESULTS AND DISCUSSION

(a) Soil effects

Without irrigation, and within rainfall zones, pasture production increased with soil depth to stones (Table 2). With irrigation, the effect of soil on pasture production was compared in 2 ways:

(i) Pasture DM at similar available soil moisture.

The pasture DM yield is plotted against available soil moisture (0 - 100mm) at irrigation in fig. 2.

At each irrigation level (i.e. common asm) pasture DM yields on 5 of the 8 soils were within 1250 kg DM/ha of each other. On a sixth soil (Deep Coastal) the pasture showed a similar pattern of response but actual yields were 1100 to 1760 kg DM/ha higher than the next highest yielding pasture. On the mid-plains and upper plains stony soils pasture yields were more than 2500 kg DM/ha less than any others. These 2 soils contained 48% and 54% stones in the top 300 mm, which compares with 19% in the coastal stony soil and less than 3% stones in all other trial soils.

In all zones the stony soils required more irrigations to maintain any given asm level (Table 2)

(ii) Pasture DM per irrigation.

The 3 year mean increase in pasture DM per irrigation was calculated thus:

$$\frac{\text{(irrigated DM - non irrigated DM)}}{\text{number of irrigations}}$$

It is plotted against number of irrigations applied in Fig. 3. On all but the two very stony soils, which supported low pasture production, the 3 year mean pasture DM response per irrigation was related to the mean number of irrigations applied. It was greatest with few irrigations and declined as the number of

TABLE 2: Pasture DM production number of irrigations and pasture DM response per irrigation. (mean of 3 years)

Treatment	Stony: Yield kg DM/ha	No of irrig	Response/ irrig. kg DM/ha	Medium: Yield kg DM/ha	No. of irrig.	Response/ irrig. kg DM/ha	Deep: Yield kg DM/ha	No. of irrig.	Response/ irrig. kg DM/ha
Coastal Zone									
Not irrigated	4900	0	–	6290	0	–	7540	0	–
irrig. at -10% asm	9090	5	840	8870	2.3	1120	10730	2	1600
irrig. at 0 asm	9800	5	980	10020	3	1240	11550	2.7	1490
irrig at 25% asm	10210	7.3	730	11070	5	960	12840	5	1060
irrig. at 50% asm	11350	10.7	600	11430	8	640	12980	9	600
Mid plains zone	Stony			Medium			Deep		
Not irrigated	3090	0		5570	0	–	7090	0	–
irrig. at -10% asm	4810	4	430	7840	2	1140	8820	1.7	1020
irrig at 0% asm	4870	4.7	380	10430	3	1620	9280	2.3	950
irrig. at 25% asm	6040	7	420	10570	5.7	880	11080	4.7	850
irrig. at 50% asm	6290	9	360	11560	8.3	720	10580	7	500
Upper plains zone	Stony			Medium					
Not irrigated	5480	0	–	9880	0	–			
irrig. at 0 asm	6710	2.3	530	10240	0.7	510			
irrig. at 15% asm	8570	3.7	840	10520	1.3	490			
irrig at 30% asm	6700	5	240	10930	2.7	390			
irrig. at 50% asm	7710	7	320	11070	5.3	220			

Figure 2 Pasture response to irrigation (3 year mean)

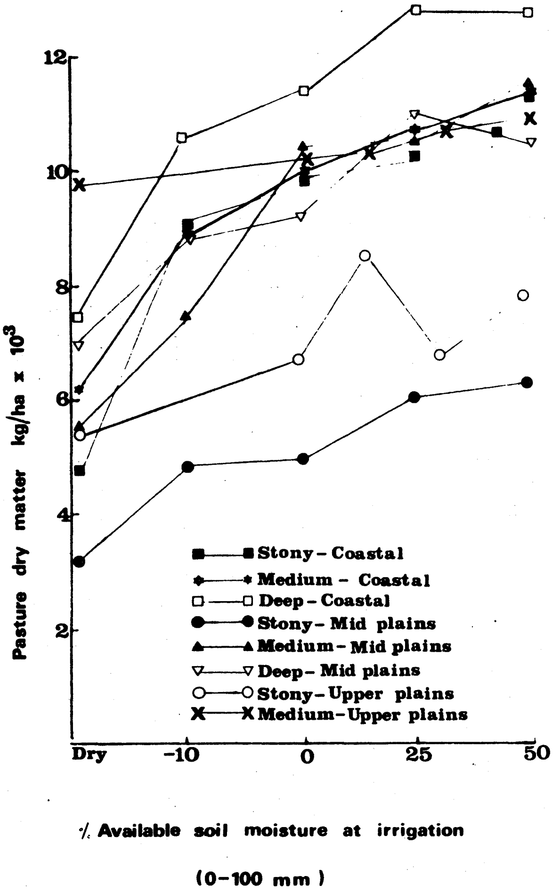
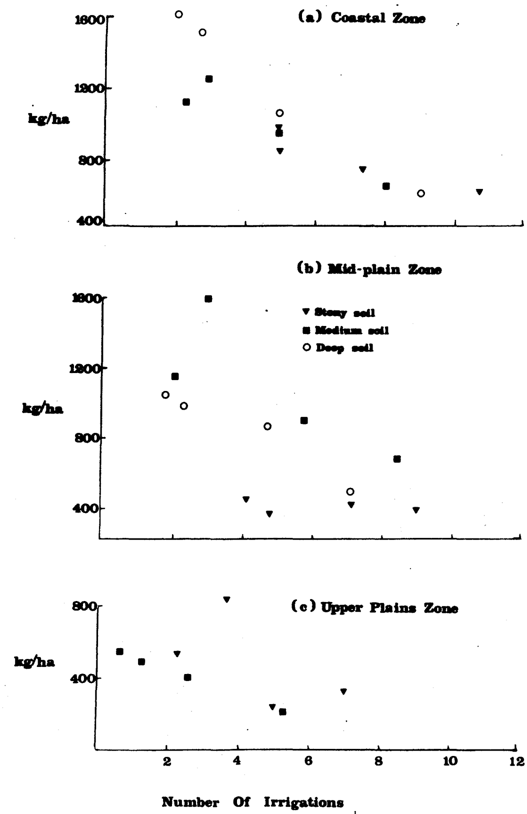


Figure 3 Effect of number of irrigations on pasture D M increase per irrigation (Kg DM/ha/irrig.).



irrigations increased. It was of a similar magnitude in the coastal and mid-plains zones, (ranging from 1600 kg DM/irrigation to 500-600 kg DM/irrigation), but much less in the higher rainfall upper plains zone. (Table 2 & Fig. 3).

There were important differences in the responses of the three stony soils. On the Eyre stony silt loam near the coast, the response per irrigation was similar to that on the higher water holding capacity soils.

On the Lismore very stony silt loam (mid-plains) the response per irrigation was almost constant from 4 to 9 irrigations, and very much lower than on the other soils in the zone. The response per irrigation on the Ruapuna very stony silt loam in the upper plains zone was comparable to the other soil in the zone, but showed no consistent relationship with the number of irrigations applied.

In all cases, the minimum number of irrigations required on the stony soils was at least twice the minimum required on the other soils in the zone.

(a) **Rainfall effects:**

Rainfall varied between seasons, both in total amount and distribution (Table 3). The effect of these variations on the 'dryness' of the season is portrayed to some extent in the figures for 'days of agricultural drought' (D.D.) recorded at Winchmore Irrigation Research Station in the mid plains zone. D.D. is defined as the number of days in which the 0-100 mm layer of soil under non irrigated pasture is at or below wilting point (i.e. 0 asm). The long term average D.D. at Winchmore is 42 (Rickard pers. comm.). From this perspective 1977/78 was classed as a very dry year while the other two were wetter than average.

The effect of these rainfall differences on irrigation response was measured in two ways:

(i) as the difference between similar soils in different zones, and

(ii) as the difference between seasons on the same soil.

Neither method was completely satisfactory. In the former the comparison between zones was confounded with differences between soils, while in the latter the effects of irrigation could not be completely separated from other seasonal effects such as temperature, age of pasture etc. To minimise these limitations, only the 3 medium soils, which produced similar mean annual pasture yields when irrigated at 50% asm (Table 2), have been compared in Table 4.

The effect of rainfall changes from the coast to the mid plains was small and could not be separated from soil variation. However, the much higher rainfall in the upper plains zone greatly reduced the response to irrigation in that area.

The difference in the irrigation response between years was also large but it did not correspond as closely with the D.D. as might be expected. In particular, the response in 1976/77 was unexpectedly

TABLE 3: Rainfall (mm) October - March.

Year	Coastal	Mid Plains	Upper Plains	Seasonal mean	Days of Agri* Drought
1976/77	380	450	680	530	24
1977/78	220	280	350	290	68
1978/79	470	530	850	620	28
mean for zone	360	420	630		

* Days in which 0-100 mm soil layer was below wilting point under non- irrigated pasture at Winchmore Irrigation Research Station.

TABLE 4: Pasture response to irrigation at 50% asm on medium soils (Kg DM/ha).

Year	Coastal	Rainfall zone Mid plains	Upper plains	Seasonal mean
1976/77	2110	1610	100	1270
1977/78	7760	10380	2150	6760
1978/79	5560	4760	1330	3880
Mean	5140	5580	1390	

low. There are 2 possible reasons for this. Most of the 24 D.D. in that year occurred in March when pasture growth rate was well below its maximum. Secondly the pasture was in its second year and still not in full production. In 1978/79 the 28 D.D. occurred in mid summer on a four year old pasture when response to irrigation could be expected to be at a maximum.

The figures illustrate the fact that irrigation in Canterbury is supplementary to a variable rainfall and consequently responses vary greatly from year to year.

Implications for irrigation practice.

A large proportion of the irrigated and potentially irrigable soils of the Canterbury plains are shallow and stony. Consequently the irrigation responses of the three stony soils in this series of trials have particular relevance for irrigation planning and practice in this area.

Firstly the irrigation responses of the three soils were very different.

When irrigated, the coastal stony soil was comparable to the deeper soils. It produced a similar amount of pasture DM, and when similar numbers of irrigations were applied, the production increase per irrigation was similar. In contrast the other two stony soils produced less pasture DM and on the mid-plains stony soil the response per irrigation was less than on the deeper soils.

The reasons for these differences are not clear, but it does seem that the proportion of stones in the topsoil may be a factor.

Thus, in irrigation planning it is important to know the potential of the soils to produce under irrigation, before deciding on the allocation of water.

Secondly, the stony soils required more irrigations to maintain any given level of soil moisture. In the three years of these trials, the stony soils in the low and medium rainfall zones required an average of 4 or 5 irrigations to maintain the soil moisture at or above wilting point, while the deeper soils required 2 or 3. In effect this means that the average interval between irrigations was less on the stony soils.

The importance of these factors in irrigation practice depends on the actual situation encountered. In the trial, the decision to irrigate was made on the basis of soil moisture measurements, while on farms it is most often made on a time basis, with some allowance for soil moisture. Most farm paddocks would receive a mixture of the trial irrigation regimes during the course of a season. They would probably be irrigated at about 50% asm early in the season and after rain, while druing droughts the soil moisture may fall to wilting point or lower before irrigation. The longer this interval between irrigations, the greater would be the disadvantage of the low WHC soils relative to high WHC soils.

On the other hand, the low WHC soils require less water at each irrigation to restore the profile to field capacity. Therefore, where it is possible to apply only enough water to correct the deficit, as with a centre pivot irrigator, it would be advantageous to apply smaller amounts more frequently on a low WHC soil.

CONCLUSIONS

Pastures growing on a wide range of soils in Mid-Canterbury were found to be capable of producing in excess of 10,000 kg DM per annum if they were irrigated to maintain soil moisture (0 - 100 mm) at 25% asm or above. However, some very stony soils were not capable of reaching this level of production with the technology used.

Soils with low WHC required more frequent irrigations to maintain a given level of soil moisture.

The increase in pasture DM per irrigation declined with increasing frequency of irrigation on most soils. It was small in areas of high rainfall. It varied between soils but was not related to soil water holding capacity or soil depth.

Variation in rainfall between seasons had a large effect on the number of irrigations required, the irrigation interval, and the pasture DM response per irrigation.

These data have been collected from treatments irrigated at a fixed soil moisture level. They do not necessarily apply to time-based irrigation practices common on farms.

Finally, they are interim data collected over only 3 years on 8 soils in one county. It is not yet known if they have long term validity or apply in other areas.

ACKNOWLEDGEMENTS

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