



Farming, Food and Health. **First**

*Te Ahuwhenua, Te Kai me te Whai Ora. Tuatahi*

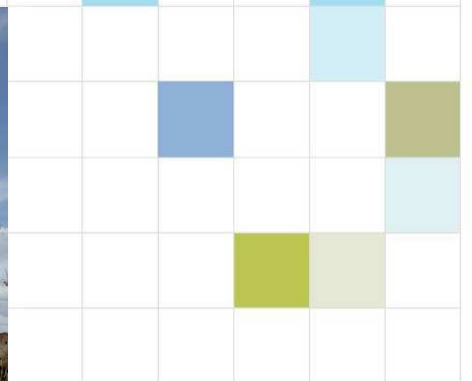
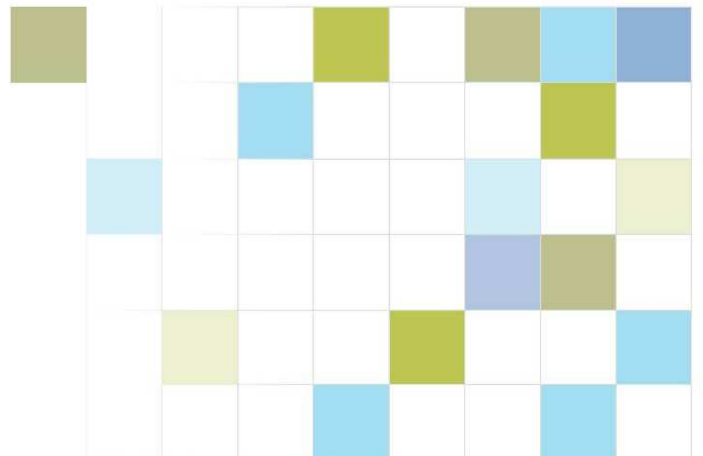
# Upper Waitaki Farm Systems and Nutrient Assessment

## Stage 2: Pasture growth literature review

May 2008



*New Zealand's science. New Zealand's future.*



# **Upper Waitaki Farm Systems and Nutrient Assessment**

## **Stage 2: Pasture growth literature review**

**Report prepared for GHD**

**May 2008**

Warren King

**DISCLAIMER:** While all reasonable endeavour has been made to ensure the accuracy of the investigations and the information contained in this report, AgResearch expressly disclaims any and all liabilities contingent or otherwise that may arise from the use of the information.

**COPYRIGHT:** All rights are reserved worldwide. No part of this publication may be copied, photocopied, reproduced, translated, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of AgResearch Ltd.

## Table of Contents

1.	Executive Summary.....	2
2.	Introduction .....	3
3.	Review of the available literature.....	3
3.1	General commentary .....	3
3.2	Dryland and irrigated pasture production .....	3
3.2.1	Dryland .....	3
3.2.2	Irrigated.....	4
3.3	Fertiliser trials.....	4
3.4	Influence of soil and climate .....	5
3.5	Influence of grazing management .....	6
3.6	References.....	6

## 1. Executive Summary

- Despite a considerable body of published material based on field experiments in the Mackenzie Basin (and nearby), few data exist that show pasture production in sufficient detail. However, key papers by Scott (at Haldon) and Radcliffe (at Poolburn) provide some indication of the pasture production potential for the Mackenzie Basin and of the relative importance of irrigation and fertilisation.
- The effect of low temperatures on limiting pasture production was noted. Potential pasture production in the Mackenzie Basin is highly variable spatially and temporally. From 10 years' data, Radcliffe recorded a maximum total annual pasture yield of 12 t DM/ha/yr, with a mean of 9. Assuming the same variability in Scott's data gives a maximum value perhaps approaching 15 t DM/ha/yr and some legumes likely to achieve 18.
- Maximum daily pasture growth rates of greater than 100 kg DM/ha/yr have been recorded but this can only be sustained for periods longer than a month or so in late spring with fertilisation and irrigation.
- It is anticipated that simulation modelling would show patterns of relative yield (with respect to the effects of irrigation and fertilisation) that are similar to that shown in these trials. Total annual yields may be somewhat higher in the simulations given the lack of minor nutrient limitations and lack of consideration of local soil textural complexities, for instance.

## **2. Introduction**

The purpose of this review was to provide context for the simulation modelling of pasture production in the Mackenzie country (see separate report). Published data that provided detail on pasture production was sought, especially where there was separate consideration of the effects of irrigation and fertilisation. The most useful data to provide a 'benchmark' for the simulation modelling would be: total annual pasture production, the pattern of production through the year and daily pasture growth rates – all on a specific year-by-year basis.

## **3. Review of the available literature**

### **3.1 General commentary**

Given the relatively low total animal production from the Mackenzie country as a proportion of New Zealand's total animal production, there is a surprisingly large body of pasture production literature from this region. Besides a history of pasture trials in the Mackenzie country itself, there is also data from MAF's (now-defunct) Tara Hills Research Station near Omarama - though little of this is formally published - and some data from Central Otago that is also germane. Many of these trials use similar pasture species and varieties and standardised cutting protocols so the results are broadly comparable. Much of this data is derived from experiments that were completed in the 1970s and 1980s but there are few more recent data available. The recent series of papers by Scott (e.g. Scott 1999) is based on work in the Mackenzie Basin but is mostly focused on hill country pastures is not directly relevant here.

Nearly all of the available data is reported only as annual yields or, if intra-annual production is described, only as averages from multiple years. This means that, while inter-annual variability in pasture production is described, the determination of intra-annual variability is more difficult. Only one published paper shows intra-annual variation, for three years (Scott & Maunsell 1981). Nevertheless, it is clear that pasture production in the Mackenzie Country is highly variable, both from one year to the next and within-year. The only feature that every study has in common is the almost complete lack of pasture production for three months over winter – it is simply too cold for plant growth.

### **3.2 Dryland and irrigated pasture production**

#### **3.2.1 Dryland**

Pasture production on dryland soils in the Mackenzie Country is strongly limited by the water that is available for plant growth. This means that the production potential at any given site is determined both by rainfall and by the soil moisture-holding capacity in the root zone of the soil. Soils in this region vary widely in their moisture-holding capacity, from perhaps less than 50mm to more than 100mm. Most of the published data on pasture production has come from better soils that are likely to have higher moisture-holding capacities, although this has never been quantified.

The best data on pasture production comes from a series of trials done between 1972 and 1974 (Scott & Maunsell 1981). A range of more than 20 pasture species, varieties and combinations were grown at Haldon Station, where the rainfall was quite low (c.450mm) with moderate soil quality (25-50 cm loess over gravel). The experimental treatments included irrigation and various rates and types of fertilisation. The data from the perennial ryegrass/white clover mixture (cv Ruanui/Huia) are the most relevant to this review given that the simulation modelling also uses these (nominal) species. With no fertiliser or irrigation, this mixture yielded 3.0 t DM/ha/yr, on average, with virtually all of that herbage produced in October, November and December. No data were published to show variation in annual production between years for this combination.

A nation-wide series of pastures trials undertaken in the 1960s and 1970s (Radcliffe 1974) did not include a Mackenzie Country site but there were three in Central Otago, including one at Poolburn that is broadly similar (Radcliffe & Cossens 1974), with an average annual rainfall of about 400mm and a brown-grey soil type of only moderate moisture-holding capacity (Rickard & Cossens 1966). Over ten years (1961-1971), the average pasture yield was 2.8 t DM/ha/yr but annual yields ranged from less than 0.8 to 4.6 t DM/ha/yr. Some other unpublished data is contained in internal reports from Tara Hills (see Greenwood, unpublished) that showed annual pasture yields that were consistent with the above data.

### **3.2.2 Irrigated**

Both the Scott and Radcliffe trials included irrigation treatments, though the methods of irrigation differ. Scott used a combination of trickle and spray irrigation whereas Radcliffe's plots were part of a border-dyke system. In fact, Scott and Maunsell (1981) is part of a series of papers on pasture irrigation in the Mackenzie Basin. However, the later papers are less relevant to this review since they focus on different aspects, for example, the effect of timing of fertiliser application on production or species mixtures for hay (Scott et al. 1982; Scott & Maunsell 1986). Without fertilisation, the irrigated plots at Haldon (Scott & Maunsell 1981) yielded double the amount that the dryland plots did: 6.0 t DM/ha/yr. The seasonal pattern of growth was changed too: the spring peak was not so pronounced and growth continued throughout the summer and autumn. Later work by Scott at Tekapo suggested that livestock carrying capacity (as a measure of productivity) could be increased by 3.3 times with irrigation of those pastures (Scott 2002). Radcliffe's data (Radcliffe & Cossens 1974) showed a three-fold yield increase with irrigation, to 8.7 t DM/ha/yr. There was also a significant reduction in the year-to-year variability: production ranged from 4.3-11.7 t DM/ha/yr. This is rather higher than Scott's 1981 data but it should be remembered that some superphosphate had also been applied.

### **3.3 Fertiliser trials**

Only the data of Scott (Scott & Maunsell 1981) allows for separate consideration of the effects of fertiliser and irrigation since they used a full factorial treatment combination. As outlined above, pasture yields in unfertilised dryland conditions were doubled by irrigation, from 3.0 to 6.0 t DM/ha/yr. Scott used P and N fertilisers, as well as some K and micronutrients, at various rates.

The highest rates were 72 kg P/ha (as superphosphate, applied in spring), 345 kg N/ha (as nitrolime, in three split applications) as well as 88 kg K/ha, 18 kg elemental S/ha and 0.21 kg Mo/ha. Pasture yields in the fertilised plots were approximately double the yield in the unfertilised plots for both irrigated and unirrigated treatments. In effect, the fertiliser and irrigation water acted additively so that the irrigated, fertilised plots yielded nearly four times the dryland, unfertilised plots: 11.7 vs. 3.0 t DM/ha/yr. These values are averages over the three years of the experiment and figures for specific years will be greater (and lesser) than the mean. The assumption that the variation about the mean in Scott's data would be about the same as Radcliffe's data (mean 8.7, maximum 11.7 t DM/ha/yr) suggests that a possible maximum yield for the pastures of Scott in a given year might approach 15 t DM/ha/yr, with lucerne and red clover achieving 18 t DM/ha/yr.

Later work by Scott at Tekapo suggested that livestock carrying capacity (as a measure of productivity) could be increased by nearly 5 times with fertilisation of those pastures (Scott 2002). Scott has also shown that the longer-term pasture production response to both fertilisation and irrigation may be compromised by rapid leaching of sulphur, especially in low-rainfall areas where soils are poorly weathered and have low buffering capacity (Scott et al. 1982; Scott 2000)

### **3.4 Influence of soil and climate**

The primary drivers of pasture production in the Mackenzie Basin are temperature and moisture. Virtually no growth is possible during winter no matter what pasture species are sown. The growth potential in spring and autumn can be affected by local-scale variation in topography (slope, aspect) but this is beyond the scope of this review. It is also affected by the locality with the Mackenzie Basin itself as there is some variation in altitude and rainfall distribution that results in sub-region scale zonation. In general, warmer areas have a higher growth potential. However, these areas also tend to be drier, with less weathered (and therefore less productive) soils. Even in the most favourable location with good soils, pasture growth can be limited by cold temperatures at almost any time of the year. Even in irrigated and fertilised conditions, this results in considerable variability both in total annual production and in the distribution of production within a year.

Daily pasture growth rates have been published for each of three years for one variety of white clover (Huia) under irrigated, fertilised conditions (Scott & Maunsell 1981). This data shows nearly 10-fold differences in daily pasture growth rates at some times of the year despite only an approximately two-fold difference in total annual yields. For example, daily growth rates in mid-December ranged from more than 100 kg DM/ha/day in 1973, to less than 10 kg DM/ha/day in 1974. Some exceptional daily growth rates were recorded in this study – up to 115 kg DM/ha/day. Some recent (2008) data has shown growth rates of up to 130 kg DM/ha/day (D. Smeaton, pers. comm.) – these can only be achieved for sustained periods with irrigation and fertilisation. Maximum growth rates from dryland, unfertilised pasture are typically less than 100 kg DM/ha/day and last only for a month or so in late spring.

Under dryland conditions, the effect of temperature is overlaid on the variation in growth potential derived from the water that is available for plant growth. This includes the relative difference between rainfall and evapotranspiration as well as the water-holding capacity of the soil. These

factors will co-vary over quite small distances, with changes in soil type and local-scale soil development, for instance.

The effect of soil fertility on growth is marked with fertiliser application typically doubling pasture production (or better). Each of these factors - temperature, water, fertility - interact multiplicatively in a non-linear way to determine pasture production potential at a sub-paddock scale. Other factors such as pasture composition have an influence too, and the result is a complex set of environmental controls on pasture production. With the exception of temperature, most of these factors can be controlled in the field.

### 3.5 Influence of grazing management

There is very little relevant data available to describe the effect of grazing management on pasture production. Scott (Scott 2002) suggested livestock carrying capacity (as a measure of productivity) would be decreased by nearly 40% with set-stocking compared with mob-stocking of pastures at Tekapo (Scott 2002).

### 3.6 References

- Greenwood P.B. (Unpublished) Irrigation Research at Tara Hills High Country Research Station 1948-1982. Compiled by P.B. Greenwood, Invermay Agricultural Research Centre. 166pp (+ figures).
- Radcliffe JE 1974. Seasonal distribution of pasture production in New Zealand. 1. Methods of measurement: *New Zealand Journal of Experimental Agriculture* 2: 337-340.
- Radcliffe JE, Cossens GG 1974. Seasonal distribution of pasture production in New Zealand. 3. Central Otago: *New Zealand Journal of Experimental Agriculture* 2: 349-358.
- Rickard DS, Cossens GG 1966. Irrigation investigations in Otago, New Zealand. 1. Description and physical properties of irrigated soils of the Ida valley: *New Zealand Journal of Agricultural Research* 9: 197-217.
- Scott D 1999. Sustainability of New Zealand high-country pastures under contrasting development inputs. 1. Site, and shoot nutrients: *New Zealand Journal of Agricultural Research* 42: 365-383.
- Scott D 2000. Sustainability of New Zealand high-country pastures under contrasting development inputs. 6. Fertiliser efficiency: *New Zealand Journal of Agricultural Research* 43: 525-532.
- Scott D 2002. Sustainability of New Zealand high-country pastures under contrasting development inputs. 8. Modelling sheep carrying capacity: *New Zealand Journal of Agricultural Research* 45: 151-163.
- Scott D, Clifford PT, Archie WJ 1982. Pasture irrigation in the Mackenzie Basin. 2. Yields on a shallow outwash soil: *New Zealand Journal of Experimental Agriculture* 10: 129-132.
- Scott D, Maunsell LA 1981. Pasture Irrigation in the Mackenzie Basin New-Zealand 1. Species Comparison: *New Zealand Journal of Experimental Agriculture* 9: 279-290.
- Scott D, Maunsell LA 1986. Pasture Irrigation in the Mackenzie Basin New-Zealand 3. Hay Mixtures: *New Zealand Journal of Experimental Agriculture* 14: 25-30.