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Climatic change effects on seasonal patterns of pasture production in New Zealand

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ABSTRACT The performance of livestock industries in New Zealand is affected by a large spatial and seasonal variability in patterns of pasture production. A software package of a database and a predictive pasture production model has been used to make an initial evaluation of the impact of climate change expected around 2030, on the average seasonal pattern of pasture growth at four sites in New Zealand. Mean annual temperature is expected to be 1.2-1.8" C warmer and annual rainfall 510% less. On two cooler/ wetter sites in Southland and Canterbury (irrigated) the predicted pasture production, compared with present, was substantially better in winter (+80%, +50% respectively), better in spring and autumn (+20 to 40%), and unchanged in summer. On two warmer/ drier sites in East Coast (North Island) and Waikato, similar analyses showed improved autumn and winter growth (20-40%) with production unchanged in spring and slightly depressed in summer. Annual production was increased by 20% at South Island sites and about 5% at North Island sites. The onset of spring growth was 2-4 weeks earlier at all sites. Present technology would be expected to be able to formulate management strategies to cope with pasture changes of this magnitude. More reliable predictions of pasture growth will depend on improved climate models which can predict seasonal change in regional climate throughout New Zealand, especially rainfall variability.

Keywords climate change, pasture production, mathematical modelling, regional climate

INTRODUCTION

The projected increases in carbon dioxide and other gases are accepted as, causes of a warming of the atmosphere and thus of changes in climate (Salinger 1987). Farming systems are affected by the amount and seasonal pattern of pasture growth (e.g. Rattray 1978).

The pattern of lowland pasture production has been measured in a series of standardised experiments throughout New Zealand based on perennial ryegrass and white clover (Radcliffe 1974a). These experiments provide basic information on annual and seasonal patterns of pasture production at various sites. Qualitative generalisations on the effect of climate changes can be made, but quantitative assessment is facilitated by a mathematical model. Pasture production models can be used to assess the effect of climatic change on pasture production for any site.

To quantify effects of climate change on pasture growth is crucial as a first step to assess the impact of climate change on agricultural production systems.

This paper will use such an approach to examine the possible effect of climatic changes expected with global warming. Predictions of regional climate within New Zealand are necessarily speculative given the present state of climatic modelling (Salinger pers. comm.), and predictions of seasonal variability have not been published yet. Nevertheless, we have attempted to predict how the average pattern of pasture growth will be affected by climatic change in four typical regional climates of New Zealand. The likely effect of pasture changes on farming systems in these areas is discussed.

METHOD FOR EVALUATION THE IMPACT OF CLIMATIC CHANGE

Climatic scenarios used were based on a 1.2-1.8" rise in air temperature and a 5-10% decrease in rainfall, depending on region.

Pasture growth and associated climatic data have recently been collated in a national MAFTech computer database for 120 sites throughout New Zealand. This database contains average pasture growth rates over fortnightly periods and average monthly climatic data for each site.

The spatial and temporal variability of the standardised growth measurements has provided a range of data to calculate the relationship between temperature and rate of pasture growth. Empirically derived relationships between soil temperature and pasture growth for local sites are used. We have found close relationships between 10 cm soil temperature and rates of growth in spring and autumn (Radcliffe 1979; Radcliffe & Baars 1987). These relationships have been incorporated on a monthly basis to describe the change in growth rate per degree change in soil or air temperature over the year for each individual site. These changes include negative effects of summer temperatures on ryegrass growth (Baars & Waller 1979).

A daily model was used. Average growth rates were adjusted by calculating the deviations resulting from the rise in air temperature from average interpolated daily temperatures. Air and soil temperature are strongly related, but there are regional differences. Soil temperatures were calculated from regional regressions between air and soil temperature. As climate change scenarios are given as changes in air temperature, these regressions were necessary. Growth rates were further adjusted by calculating a daily water balance which takes account of available water content for the soil type, number of rain days and the monthly rainfall totals (France & Thomley 1984). Predicted daily rainfall is based on reductions in total rainfall per month of 5-10% and 2 raindays less per month. In this initial study, monthly evaporation was equally distributed over the days of each month.

The likely change in derived climatic elements such as pan evaporation are partly accounted for by the use of the Priestley-Taylor equation for each site. Calculations suggested small changes in evaporation. The expected decrease in westerly winds over New Zealand also implies small changes in evaporation. No account is taken of the increase in CO_2 concentration on pasture production.

The model was applied to average patterns of pasture production for four regions: Waikato (Hamilton, Baars 1976), East Coast (Manutuke, Radcliffe & Sinclair 1975), Canterbury (Winchmore irrigated site, Rickard & Radcliffe 1976) and Southland (Mona Bush, Radcliffe 1974b). Although Canterbury is a summerdry region, we chose the irrigated site to study latitudinal effects in cooler wetter areas.

Scenarios for climatic change assumed a 5% decrease in annual rainfall for Canterbury and a 10% decrease in other areas. Increases in mean annual daily air temperature were 1.8” for Southland and Canterbury, 1.5” for East Coast and 1.2” for the Waikato (Salinger pers. comm. 1989). A decrease of 2 raindays per month for each site was assumed.

RESULTS

Effects of climate change on seasonal and annual yields are presented in Table 1 with seasonal patterns of pasture growth illustrated in Figure 1.

Southland

Winter growth will more than double while spring growth will increase by 20%. A 10% decrease in rainfall will have minimal effect on summer production, while autumn growth will increase greatly. Annual production will increase by 20%.

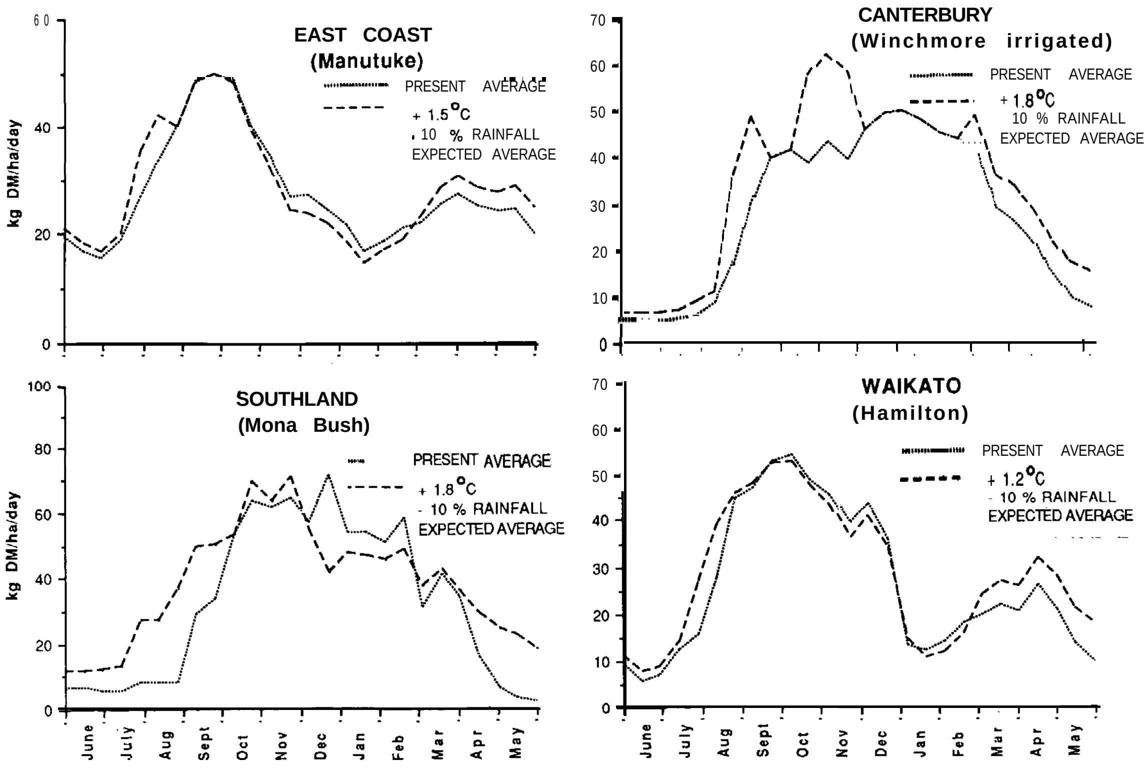

Figure 1 Average seasonal distribution of pasture growth at four sites with and without climate change.

Canterbury irrigated

The pattern of changes under full irrigation will be rather similar to that in Southland. However, a 5% decrease in rainfall will increase irrigation requirements by at least 60 mm.

East Coast (North Island)

Annual yields will be similar. Spring yield will change little but late-spring/summer yields will be slightly depressed. This decrease is compensated for by slightly higher winter and autumn yields.

Table 1 Present seasonal **and annual** yields (kg DM/ha) and changes expected with higher annual air temperature and decreased rainfall.

	Southland		Canterbury	
	Present	Predicted	Present	Predicted
Winter	944	1748 (+85%)	644	980 (+52%)
Spring	4267	5232 (+22%)	3364	4529 (+34%)
Summer	4235	4135 (-2%)	4110	4139
Autumn	2030	2707 (+33%)	1847	2518 (+36%)
Annual	11476	13822 (+20%)	9965	12166 (+22%)
	East Coast		**Waikato**	
	Present	Predicted	Present	Predicted
Winter	2151	2469 (+14%)	1452	1881 (+29%)
Spring	3708	3627 (-2%)	4321	4224 (-2%)
Summer	1899	1705 (-10%)	2031	1878 (-7%)
Autumn	2220	2533 (+14%)	1710	2298 (+34%)
Annual	9979	10334 (+3%)	9514	10281 (+8%)

Waikato

Annual yields will increase by 8%. Again yield will be redistributed with larger proportions in winter and autumn.

Spring peak

The onset of spring growth will be 2-4 weeks earlier, depending on the region.

DISCUSSION

Effects on pasture growth

The assumed scenarios have implications for pastures based on perennial ryegrass and white clover. The predicted levels of pasture growth suggest that present cooler/wetter areas in the South Island will have the biggest increases of, on average, 20% in annual yield. For all stock enterprises, improved winter/spring growth will increase higher quality feed throughout New Zealand.

Higher winter growth rates may increase nitrogen deficiencies in spring. The use of N in winter and early spring and annual ryegrasses may become attractive and profitable in many areas in the North Island. Cool-season legumes may become more important.

These analyses suggest that the peak of spring growth will be earlier. Generally there will be a latitudinal displacement of spring growth with spring growth starting 2-4 weeks earlier. However, the peak of spring growth will not be very different, possibly because of greater N deficiency. Warmer winters lead to much less build-up in microbial N in the soil and possibly a less rapid onset of spring growth. These factors are accounted for in the model by evidence from the regression analyses that there is no relationship between temperature and growth rate above 10-11° C soil temperature (Radcliffe & Baars 1987).

Effects on animal production systems

As annual productivity largely determines stock carrying capacity, South Island regions will have the greatest opportunities to increase stock numbers. Contributing to enhanced annual yields are higher spring/autumn growth rates, which will allow new management options in such areas. For example, in sheep areas like Southland, lambing can be brought forward to better coincide with the time of peak demand in the Northern Hemisphere. There will be greater opportunities to exploit the greater winter and autumn production by developing earlier winter/spring and autumn lambing systems.

In the East Coast (North Island) and the Waikato the reduction in summer pasture growth will be most marked on soils with reduced water-holding capacity, compensated for by improved autumn/winter growth. For deer enterprises in the Waikato there will be opportunities and financial benefits to finish young stags at an earlier date with a heavier carcass weight. However, hinds may suffer because of reduced summer growth of lesser quality and supplementary feeds will need to be used more.

Bull beef production systems on soils with higher available-water content in the North Island are presently geared to use pasture growth patterns to meet optimal carcass weights. Climatic change will increase opportunities to maximise meat production per unit area by higher dry matter production over winter/autumn.

Limitations of the approach

Physically based models (GRASS, Baars et *al*. 1987; Baars & Rollo 1987) may be more transferable among sites and climates than regression models. However, recent experiences with the pasture component of farm systems models shows that extensive tuning may be required: hence the choice of this initial method 'based on actual rate-of-growth data. The model has deficiencies in that it does not handle different pasture managements, pasture species with different growth patterns for the sites, different levels of soil fertility, and the effect of increased CO_2 levels on pasture growth. The latter effect may be large (Lemon

1983). Also these results apply only to a single static climatic average for the site. In an overview of pasture production from 20 New Zealand sites measured by the methods outlined by Radcliffe (1974), the variation in annual yield from year to year was greater than the differences between sites (Baars 1982; Radcliffe & Baars 1987). This highlights the importance of seasonal and annual variability in growth which should be considered in relation to the presented average and predicted average conditions in subsequent work. Notwithstanding these limitations, these preliminary analyses indicate the magnitude of annual and seasonal changes in pasture production which can be expected.

CONCLUSIONS

Increases of 1.5" to 1.8" in mean annual air temperature and a 10% decrease in rainfall will have major effects on the pastoral industries, especially in the South Island. Both positive and negative effects have been identified from these initial analyses.

Technology and management strategies are already available to enable primary producers to cope with and take advantage of increased production and/or changes in seasonal patterns of production.

This study has highlighted the need for further work on computer simulation of pasture growth to assess quantitatively the effect of climatic change on farming systems in New Zealand.

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