Integrating Spatial Data with a Grazing System Model: Assessing Variability of Pasture and Animal Production at a Regional Scale

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ABSTRACT: Spatial data representing pasture type, fertility and climate were coupled with a simulation model to assess the effect of spatio-temporal variability on pasture production and weaned weight of lambs in a temperate high rainfall environment. Both climate and pasture type had significant effects on the spatial pattern of pasture and animal production. Pasture type was the most important major determinant of long-term averages, but climate was more important in defining the pattern of variability between years. Spatio-temporal interactions in agricultural systems may be more readily understood using simulation models utilising spatial data.

Key Words: Spatial Data, Grazing Model, Pasture Production, Animal Production

INTRODUCTION

Pasture growth and animal production depend on many factors which vary in space and time at different scales and intervals. Grazing system process models such as the GrassGro DSS (Moore et al., 1996) combine feed intake and ruminant nutrition with daily simulation of pasture growth and dynamics. Such models enable simulation of process outcomes for many different input scenarios, but only for one location in space at a time. At paddock, farm, region and continental scale, there is widespread interest in the integration of spatial data with process modelling in order to capture the interaction between temporal process and spatial variation.

We recently described the loose coupling of satellite and other spatial data with the GrassGro DSS to describe spatial variation of pasture production for a CSIRO research station on the Northern Tablelands of NSW (Hill et al., 1999). Loose coupling refers to the situation where the model and the spatial data are not directly linked, but where the spatial information provides the data values for use in simulation, and a spatial template for reclassification in order to display model output.

At the regional scale, information on productivity of animal production systems is difficult to obtain except through census statistics. In this paper, we describe the use of the above processing system to map the pasture and animal production at a regional scale using part of the Northern Tablelands and Slopes of NSW as an example.

MATERIALS AND METHODS

Study Area

The simulations were carried out for an area of 78.3 x 91.0 kilometers located in the Northern Tablelands (Figure 1). The landscape is a mosaic of native perennial grass pastures, semi-improved pastures with additions of clover and fertiliser, and highly improved pastures based on introduced perennial grasses.

Figure 1. Map of the study area showing the five climate zones which correspond closely with the pattern of elevation; historical zone means are shown in Table 1.

Climate

Elevation and its influence on climate provides the major environmental variation influencing pasture production. Elevation was characterised by a 100m resolution digital elevation model supplied by AUSLIG covering the four 1:100,000 map sheets surrounding Armidale. Mean monthly climate surfaces were constructed from the digital elevation model and the Australian Climate Surfaces (Hutchinson 1989) using elevation, latitude, longitude and distance from the coast as independent variables. Monthly surfaces for maximum and minimum temperature, rainfall and evaporation were subjected to a clustering procedure and aggregated to provide five climate zones (Figure 1).

In order to run simulations for these climate zones using the GrassGro DSS, it was necessary to create daily weather data sets for each zone.
Table 1. Northern NSW climate data for 1959-1994. (Annual mean radiation 19.23 MJ/m² for all zones)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Maximum Temperature (°C)</th>
<th>Minimum Temperature (°C)</th>
<th>Rainfall (mm)</th>
<th>Evaporation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.7</td>
<td>7.4</td>
<td>737</td>
<td>1667</td>
</tr>
<tr>
<td>2</td>
<td>20.7</td>
<td>6.3</td>
<td>785</td>
<td>1587</td>
</tr>
<tr>
<td>3</td>
<td>19.6</td>
<td>6.1</td>
<td>823</td>
<td>1498</td>
</tr>
<tr>
<td>4</td>
<td>18.7</td>
<td>6.5</td>
<td>811</td>
<td>1387</td>
</tr>
<tr>
<td>5</td>
<td>17.5</td>
<td>5.9</td>
<td>886</td>
<td>1282</td>
</tr>
</tbody>
</table>

Table 2. Values assigned to fertility scalar corresponding to three fertility levels on three pasture types

<table>
<thead>
<tr>
<th>Pasture</th>
<th>Fertility scalar</th>
<th>Stocking Rate s/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>high</td>
<td>medium</td>
</tr>
<tr>
<td>Native pasture</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Summer and improved grasses</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Improved pasture</td>
<td>1.0</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Mean monthly averages for each zone were extracted from the climate surfaces (Figure 1) and a table of differences between these values and the mean monthly averages for the CSIRO Pastoral Research Laboratory at “Chiswick” was established. The table of differences was then used to adjust the daily climate data for “Chiswick” to create the daily climate data sets for each zone.

Pasture

Pasture was described by two spatial data layers based on a Landsat TM image for November 1993.

The image was processed to produce a three class pasture growth status map (Vickery and Hedges, 1987). The three class map was used to provide values for the fertility index used to adjust soil fertility responses in GrassGro (Table 2; Hill et al., 1999).

Using the association between field botanical composition data from sites across the Northern Tablelands and pasture growth status classes, the image was processed to create a three class map depicting most probable pasture type: highly improved, semi improved or degraded, and native pastures.

Values of the fertility scalar were assigned to pasture type and fertility level according to Table 2.

For the purposes of simulation, the species composition of the three pasture classes was assigned as follows:

highly improved = phalaris with clover;
semi-improved or degraded = some phalaris with volunteers; and
native = Themeda/Bothriochloa dominant.

Figure 2. Three class pasture growth status map of the study area.

SIMULATIONS

Simulations were conducted with the GrassGro DSS (Version 2.2) for each combination of climatic zone, pasture type and fertility index. Model outputs were written to a lookup table. This lookup table was used to reclassify a spatial template based on a combination of climate zone, pasture growth status and most probably pasture type using a set of rules which linked the data for each zone.

RESULTS AND DISCUSSION

The relative influence of the climate zones, fertility scalar and assumptions about pasture type and corresponding parameter inputs is illustrated for average annual weaned weight of lambs in Figures 3 and 4. There was a gradual increase in total weaned weight of lambs per hectare from climate zone 1 to 5, although there was little difference between zones 3 and 4 (Figure 3).

However, as a result of assumptions built into the allocation of values for the fertility index between pasture species, the difference between improved and the other pasture types provided the greatest difference in weaned weight of lambs (Figure 4). As a result, the spatial pattern exhibited by the pasture growth status map might be expected to provide the primary influence on the spatial pattern of aggregated model outputs.

Indeed, the spatial pattern of average annual pasture production (Figure 5a) and total weaned weight of lambs...
Figure 3. Total weaning weight (kg/ha) for each climatic zone.

Figure 4. Total weaning weight for the range of fertility indices for pasture types (Figure 5b) primarily reflect the influence of the pasture growth status map (Figure 2) on the fertility scalar (Table 2). Both annual pasture production and total weaned weight of lambs were highest along the central spine of the Tablelands between Guyra and Walcha.

The influence of climate zones was more evident in the temporal standard deviation in annual pasture production (Figure 5c) and weaned weight of lambs (Figure 5d). Variability in pasture production generally increased from west to east (Figure 5c) reflecting the natural rainfall gradient and the greater potential for summer growth with increasing proximity to the coast. However, temporal variation in annual total weight of weaned lambs was lowest in the middle section of the study area (Figure 5d). This area is predominantly in climate zone 4, and contains most of the fast pasture growth status class (Figure 2). This behaviour is probably due to the better nutritional characteristics of the improved pasture buffering the impact of climate variability on lamb growth in the model. The higher temporal variability in weaned weight of lambs to the east and west of the central spine, probably reflects the interaction between the predominantly degraded or native pasture and the seasonal variability in climate.

In this simulation, lambs were born on the first of October and weaned at the end of January. Hence lamb growth was dependent on pasture conditions from mid-spring until late summer. Using the same climate zones, we found that spring and summer seasonal pasture production was primarily explained by rainfall in that season and the preceding 3 months, but the percentage of variation explained declined from 80% in zone 1 to 55% in zone 5 (Hill et al., 1997). As altitude increased less variation could be explained by climate variables. On the western side of our study area, conditions are most favourable for lamb growth in early spring, but finishing the lambs is dependent on the maintenance of pasture quality into late summer. Growth is sometimes supported by summer rainfall, but at other times conditions may be very harsh. By contrast, on the eastern side, spring is often very dry, and the pasture quality is dependent on the onset of easterly wind patterns and coastal rain. If lambing date had been adjusted in simulations to match these geographical differences in pasture production, lamb growth and variability may have been different.

This study provides an example of the ability of a combination of spatial data and a simulation model to summarise the effects on pasture and animal production of complex interactions between climate, pasture type and fertility. The results are highly dependent on the validity of the model, and the assumptions used to convert spatial data layers into model parameters and parameter sets. However, understanding of spatio-temporal processes is crucial to improved management of agriculture in the landscape into the next century.

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REFERENCES


Figure 5. Spatial distribution of a) mean net pasture production kg/ha, b) mean net weaning weight kg/ha, c) temporal standard deviation of net pasture production kg/ha and d) temporal standard deviation of net weaning weight of lambs.