Native pasture is the major feed source for beef cattle grazing in south-east Queensland (Scattini 1981a). The dominant grasses in these pastures are black spear-grass (Heteropogon contortus), forest blue grass (Bothriochloa bladhii) and Queensland blue grass (Dichanthium sericeum) (Scattini 1973). Rainfall has a 70% summer incidence with high variability and this is reflected in animal production. Animals gain weight when pastures grow in summer and lose weight in winter when pastures are almost dormant (Addison 1970). If summer rains fail, the resulting drought causes poor animal production and mortalities increase. However, the impact of variation in amount and distribution of rainfall on animal production varies with pasture management.

Commercial management of native pasture in relation to removal of trees, season of grazing, stocking rate and timing and frequency of fires has largely evolved from producer experience. Research has emphasised the evaluation of exotic species to replace or modify native pasture rather than management and utilization of native pastures (Woolcock 1972; Scattini 1981a).

This study examines the interaction between rainfall, stocking rate and frequency of fire in spring on herbage and animal production from native pasture. The analysis uses computer models since it is almost impossible and certainly impractical to reveal these interactions with traditional experiments. Models of soil water balance, herbage production and animal production are described and used to simulate production from climatic records collected at "Brian Pastures" Pasture Research Station at Gayndah since 1958. The models are based on data from several field experiments at "Brian Pastures", however, only one field experiment (with only one year's data) has been conducted to compare burning with no burning (Ash 1982). As a result there are few data for model validation. However, the development of a model at this stage of research provides an opportunity to guide future data collection, to generate hypotheses and to provide a framework for interpreting and extrapolating past experimental data. The model is also being applied to other forage options such as sown grass pastures and forage crops, so that efficient integration of forage resources can be examined for variable climates.

The two management options investigated in this report, fire and stocking rate, are easy to manipulate and are controversial topics among pastoralists in south-east Queensland. Native pastures are usually continuously grazed although the stocking rate of a paddock may vary during the year with herd movements. The long-term stocking rate of a property is based on stock performance in relation to market requirements and availability of feed in droughts. Burning native pastures after rain in spring is widely practised to make new growth more accessible to animals and for other reasons (Tothill 1971). However feed becomes scarce after a spring fire if summer rains fail, particularly at high stocking rates. In this study we attempt to evaluate the likely beneficial effect of fire on diet selection against the likely increased risk of feed shortages. The possible influence of fire on botanical composition, timber regrowth, and soil erosion are not yet considered.

* Department of Primary Industries, Toowoomba, Qld 4350.
** Department of Primary Industries, Dalby, Qld 4405.
Pasture growth is affected by wide variations in amount and distribution of rainfall. At Gayndah, south-east Queensland, annual rainfall since 1880 has ranged from 1686 to 251 mm with a mean of 779 mm (C-V: 28%). A soil water balance model accounts for the effects of this variation in water supply on plant growth by frequently estimating soil water storage and utilization.

**STRUCTURE AND OPERATION**

WATSUP is designed for crop, pasture or bare fallow, and functions either alone or as a sub-routine in a larger model of plant growth. It simulates soil moisture in three user-defined layers. Thereby it fills a gap between one-layer models (e.g. Fitzpatrick and Nix 1969) that often provide insufficient information for research, and complex multi-layer moisture models (e.g. Carbon and Galbraith 1975) that require input information that is often unavailable.

Inputs for WATSUP include: (i) climate: daily rainfall (RD) and pan evaporation (EO) or its estimate; (ii) soil: wilting point (WP), field capacity (FC), initial soil moisture (SM), and depth for each of the three soil layers; wet and dry infiltration rate for layer 2; and moisture content at saturation and air dried state in layer 1 (SW, AD); (iii) plant: depth of rooting, green surface cover (GCOV) and dead cover factor (DCF).

Outputs include: daily runoff, through-drainage, soil evaporation (ES), transpiration (ET), available water, a water supply index for plant growth (SWIX), and water content of each layer (SW). Subscript i, 1 to 3, refers to soil layers.

Potential evapotranspiration (EP) equals EO and is partitioned into potential soil evaporation (EFS) and potential transpiration (EPT) through GCOV and DCF: 

$$EP = EO \times GCOV$$ and $$EFS = EO \times (1.0 - GCOV) \times DCF$$

with the restriction of $$EFS + EPT < EO$$. Measurements in green panic pasture and native pasture gave Gcov as a function of green herbage yield (GP) (Fig. 1a):

$$GCOV = 1.0 - \exp(-0.00125 GP)$$

with an upper limit being $$GCOV = 1.0$$. The factor DCF reduces soil drying rate as the amount of total dead herbage (TD = litter + standing dead) increases. Analysis of data from Rickert (1974) where soil drying was measured under three rates of surface litter gave (Fig. 1a):

$$DCF = 1.0 - 0.0001 TD$$

Soil evaporation (ES) from layer 1 or layer 1+2 combined, depends on the relative ability of either layer to meet the evaporative demand. The ability of either layer to supply EPS is indicated by a supply index (SI) given by

$$SI_l = A_l \times AWRI/(A_l \times AWRI + 1.0 - AWRI)$$

where AWRI is the available water ratio calculated with air dry values ($$AWRI = (SW - AD)/(FC - AD)$$) and the coefficient $$A_l$$ depends on depth of the soil layer. Data on soil drying from Rickert (1974) enabled $$A$$ values to be calculated for a self mulching clay loam (Fig. 1b). Using the appropriate $$A$$ values from Fig. 1b, the changes in SI with AWRI for layers 0-100 and 0-500 mm are shown in Fig. 1c.

Then ES equals $$EPS \times SI_l$$ or $$EPS \times S112$$ whichever is the greater, with a restriction of $$ES < EPLIM$$ (a maximum limit to daily soil evaporation, e.g. 4.0 mm/day).
Next ES is removed from $SW_1$ and $SW_2$ in proportion to the supply indices.

Transpiration (ET) is given by $ET = EPT \times SWIX$ where SWIX is a water supply index for the profile to which each layer contributes through a separate supply index ($Si$) so that $0 < Si < 1.0$. The empirical equations used to calculate $Si$ mimic a theoretical analysis of water absorption by roots. In this case AWR is based on WP and not AD as in soil evaporation; hence $AWR = (SW - WP)/(FC - WP)$. Then for layers 1 or 2 (Fig. 1d)

$$S_i = (1.0 + \sin((AWR_i - 0.5)\pi))/2.0$$

and for layer 3

$$S_3 = (1 - \cos(AWR_3\pi/2))/2.0$$

The sum of the supply index for each layer is calculated (TS) and SWIX is given by the minimum of TS and 1.0. Then, water is removed from each layer in response to ET according to the relative size of $Si$, i.e. $SW_i - ET \times Si/TS$.

Rainfall (RD) is entered and redistributed from layer 1 ($SW_1 = SW_1 + RD$) after ET and ES are estimated because most rainfall events occur late afternoon or night. Runoff is only calculated when $SW_i > FC_i$ using the model by Boughton (1968). Whenever $SW_i > FC_i$, water drains from a soil layer into the layer below until $SW_i = FC_i$. If excess water remains after filling layer 3, it becomes through-drainage.

RESULTS AND DISCUSSION

Predictions of soil water from the model have agreed with field observations for fallow, wheat and pasture. Taking native pasture as an example, soil water was measured every 6 weeks for two years in spear grass pasture on clay loam soil at "Brian Pastures" Research Station, Gayndah. Linear correlations of observed against predicted available soil moisture (mm) indicate the 'goodness of fit':

<table>
<thead>
<tr>
<th>Layer</th>
<th>Predicted</th>
<th>Mean observed</th>
<th>slope</th>
<th>intercept</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1000</td>
<td>38.3</td>
<td>0.84</td>
<td>1.03</td>
</tr>
<tr>
<td>2</td>
<td>100 - 500</td>
<td>6.1</td>
<td>0.79</td>
<td>-1.4</td>
</tr>
<tr>
<td>3</td>
<td>500 - 1000</td>
<td>18.9</td>
<td>0.05</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13.2</td>
<td>0.62</td>
<td>5.3</td>
</tr>
</tbody>
</table>

Layer 3 had the greatest discrepancy between observed and predicted values (Table 1). Estimates for layer 3 would probably improve by considering the influence of soil cracking and root growth on water entry and removal.

The runoff component of this model has limitations as rainfall is entered daily and the influence of short duration high-intensity rainfall on runoff is ignored. Records of rainfall intensity are limited but analysis of the available data might define the likely intensity of a rainfall event and permit improved estimations of runoff. Despite these limitations the predicted and observed values of soil water agree overall, and there is no consistent bias. in the estimates (Fig. 1e). The predictions of ET and SWIX for native pasture are inputs for herbage growth models based either on transpiration efficiency or potential growth.

WATSUP has other applications. The term SWIX is a component of a growth index for pasture which has been used to estimate animal growth on different pastures (McKeon et al. 1980), the long term repeatability of animal production for a fine stem stylo pasture (Rickert et al. 1981) and infestations of cattle tick (Elder 1980). The simple structure of the model is suited to micro-computers.
Fig. 1a. Relationships between green surface cover (●) or dead cover factor (○) and green or dead herbage yield (Equations 1 and 2).

Fig. 1b. Changes in "A" values (Equation 3) with depth of surface layer for a clay loam soil.

Fig. 1c. Variation in supply index for soil evaporation with available water ratio for layer 0-10 cm, ---, and layer 30-50 cm, (Equation 3).

Fig. 1d. Variation in supply index for transpiration with available water ratio for layers 1 and 2, ---, and layer 3, (Equations 4 and 5).

Fig. 1e. Observed, ●, and predicted, ---, soil water in native pasture.
MODEL STRUCTURE

The aim of the pasture production model is to predict native pasture yields accounting for variation in seasonal conditions and the effect of management options such as burning and grazing pressure. Three herbage pools are modelled: yield of green, standing dead and litter. In our case, "green" is that material capable of transpiring and growing and is used in the water balance model for the calculation of transpiration. It includes both green leaf and green stem. "Litter" is dead material which has fallen onto the soil surface. The pools are linked by the rate processes of growth which is accumulated in the green pool, death which transfers green to standing dead, detachment (standing dead to litter) and litter breakdown. Animal intake occurs only from the green and standing dead pools. The approach adopted here was to develop an accurate plant growth model and then the other process rates were calculated from pasture yield measurements.

DATA BASE

The model was developed from five experiments conducted at "Brian Pastures" Pasture Research Station, Gayndah.

(i) Experiment 1  Native pasture production was measured from 1963 to 1970 in a cutting experiment (Scattini 1981b). Plots were mown to 5 cm at either 3 weekly or 6 weekly intervals during the growing season. Yields after mowing were also measured and used to reset the model.

(ii) Experiment 2  Pasture yields were measured at the commencement and end of the summer/autumn grazing period for 3 stocking rates, 0.74, 1.24, 2.47 b/ha (Scattini 1973). From 1962 to 1970 pastures were burnt annually in spring if there was sufficient herbage.

(iii) Experiment 3  After 1970, pastures were not burnt and the experiment was split with either winter/spring or summer/autumn grazing treatments. Total standing dry matter and litter yields were measured in May and November from 1975 to 1981 (Cooksey unpublished data).

(iv) Experiment 4  Native pasture was burnt in November 1977 and lightly grazed (0.42 b/ha) subsequently. Yields were measured monthly on 15 occasions and separated into green, standing dead and litter (Rickert and Hendricksen unpublished data). Soil moisture was measured monthly (Figure 1e).

(v) Experiment 5  Half of the above pasture was burnt in October 1980 and both burnt and unburnt pastures were grazed separately at 0.8 b/ha for the following year. Both burnt and unburnt pastures were sampled at monthly intervals and separated as in Experiment 4 (Ash 1982).
Animal Production in Australia

MIX (1970). Solar radiation index (RIX) was calculated from daily solar radiation for the five years of measurement. There was little year to year variation and monthly means were used for the 23 year experiment period (1958-1981). Temperature index (TIX) was developed from seedling growth data for Mitchell grass as no temperature response data were available for the species being modelled (McKeon et al. 1980). Soil water index (SWIX) was taken as the ratio of calculated transpiration to potential transpiration from the model WATSUP. The growth index (GIX) was calculated as the product of the three components. Data from experiment 4 showed that monthly regrowth (DRG) from metre square quadrats cut to ground level was directly related to the generated growth index (McKeon et al. 1980).

\[ DRG = GIX \times \text{potential regrowth}. \]  

where potential regrowth = 46 kg/ha/day

Where yield of green material was approximately 500 kg/ha, Rickert (unpublished data) has shown that pasture growth rate exceeds measured regrowth. Under these conditions:

\[ \text{growth} = \min (\text{SWIX}, \text{TIX}) \times \text{potential transpiration} \times \text{TE} \]  

where TE is transpiration efficiency and was calculated from yields measured in experiment 1 and predicted transpiration from WATSUP (TE = 10 kg/ha/mm). If SWIX \( \leq \) TIX, equation (7) reduces to: calculated transpiration \( \times \) transpiration efficiency (i.e. same as Van Keulen). Potential transpiration changes as green yield changes thus giving the model the dynamic capability of exponential growth or reduced growth with defoliation. Pasture growth is calculated as the maximum of either equation (6) or equation (7), and hence predicts growth over the range of green yields likely to occur in a pasture. The growth model was developed from six weekly cutting trial data (Fig. 2a) and validated (Fig. 2b) using three data sets; three weekly cutting interval (8 years, experiment 1), December green yields before grazing (6 years, experiment 2), and monthly yields in the year following burning (experiment 5). No data were available to check predictions in high rainfall summers when nitrogen availability might limit production.

Comparison of model predictions with production in grazed pastures in experiment 2 (calculated from change in total standing dry matter and correcting for estimated consumption) showed that the model overestimated growth in dry summers (< 250 mm rainfall) following wet springs. Field observations (Scattini) indicated that early flowering occurred in these years. The model correctly predicted growth in experiment 1 during the same years where seed heads were removed regularly by mowing. Hence for summer/autumn growth a reduction factor as a function of spring soil moisture and summer growing conditions was developed for grazed pasture where seed heads were not removed. Thus, this analysis suggests that there is an effect of phenological development on above-ground growth.

(ii) Death, detachment and litter breakdown Death rate expressed as a proportion of the green pool was calculated from measured changes in green yield and predicted growth rates in experiment 4 and 5. Death rate was related to soil water index (SWIX).

\[ \text{death} \ (\text{day}^{-1}) = 0.002 + 0.013 \ (1 - \text{SWIX}) \]  

Experiments 4 and 5 showed that very little detachment occurs in the first two years following burning in spring (Fig. 2c). This was indicated by little change in standing dry matter and litter pools. Pasture yields from 1975 to 1980 in experiment 3 (unburnt since 1970) had low year to year variation (22% C.V.) suggesting that steady state relationships could be derived based on predicted growth rates and average measured pasture yields.

\[ \text{detachment} \ (\text{day}^{-1}) = \frac{\text{growth} - \text{consumption}}{\text{observed standing dead yield}} \]  

202
Fig. 2a. Observed and predicted yields for model development
Fig. 2b. Observed and predicted yields for model validation; 3 weekly mown DM yields (▲); green yields at commencement of summer grazing (●); monthly DM yields following burning (●)
Fig. 2c. Observed (symbols) and predicted (–) yields in a grazed pasture; green (●); total standing dry matter (●); total DM + litter (▲)
Fig. 2d. Predicted (–) and observed green (●) and total standing dry matter (●) yields in a native pasture 4 years after burning
Fig. 2e. Relationship between measured nitrogen content (burnt (●) and unburnt (▲)) and predicted green age
Annual detachment rates calculated from equation 9 increased with stocking rate (SR, b/ha) and the effect of stocking rate was higher in summer than in winter.

\[
\text{detachment (day)} = 0.00154 + \text{Kd} \times \text{SR} \tag{10}
\]

where Kd is 0.00058 in winter/spring and 0.00126 in summer/autumn.

Equation (10) under-estimated detachment rates in 1980/81 summer in the unburnt pastures of experiments 3 and 5. It is probable that the combination of days with high wind (> 400 km/day) and high rainfall caused these higher rates. However, more experimental data are required to predict detachment under these apparently infrequent conditions. For simulation studies in this contract we have used the steady state detachment rates (equation 10) two years after burning.

Litter breakdown rates have been calculated in similar fashion to detachment using the steady state approach.

\[
\text{breakdown (day)} = 0.00142 + \text{Kb} \times \text{SR} \tag{11}
\]

where Kb is 0.0010 in winter/spring and 0.00244 in summer/autumn.

Figure 2c shows observed and predicted yields of the 3 pools for experiment 4 and Fig. 2d shows the errors likely to occur in predicting standing dead yields under conditions experienced in 1980/81.

(iii) Herbage quality. The herbage flow model allows prediction of the age of green and standing dead pools. The green pool is divided into 15 age classes (GPRi, 25 days each) and this allows the preference of animals for youngest material to be modelled (equation 18). The measured nitrogen content of green material (GRN) for both burnt and unburnt pasture was related to the average generated green age (GRAGE, Fig. 2e);

\[
\text{GRN} = 0.696 + 2.39 \times \exp(-0.457 \times \text{GRAGE}) R^2 = 68\% \tag{12}
\]

or more accurately (R² = 78%) by the integration of a predicted nitrogen content of each age class. Although equation (12) predicts the higher nitrogen contents observed after burning (Ash 1982) in terms of a younger age this may be fortuitous since the effect may be a result of higher nitrogen mineralisation rates and/or lower growth rates after burning.

The model has been successfully applied to other species such as green panic and wheat. It suggests that forage option at a particular site can be simply characterised by the measurement of: (1) potential regrowth (a function of nutrition, density of growing points, grazing history); (2) transpiration efficiency (a function of nutrition, humidity); (3) a relationship between green yield and green cover; (4) separation of yields into green, standing dead and litter; (5) phenological development; (6) plant growth response to temperature.

BEEF PRODUCTION MODEL


*Brian Pastures Pasture Research Station, Gayndah, QLD 4625.
**Department of Primary Industries, GPO Box 46, Brisbane, QLD 4001.
Fig. 3a. Relationship between dietary nitrogen and liveweight change (DLWC)
Fig. 3b. Relationship between dietary nitrogen and DOMI
Fig. 3c. Relationship between green in pasture and green in diet
Fig. 3d. Comparison of observed and predicted dietary nitrogen
Fig. 3e. Observed and simulated liveweight change in native pasture; unburnt 1977-78 observed (●), predicted (— —); unburnt 1978-79 observed (■), predicted (—); burnt 1980-81 observed (▲), predicted (— —)
Fig. 3f. Observed and simulated liveweight change in individual summers at three stocking rates (beast ha⁻¹): 0.74 (●), 1.24 (■), 2.47 (▲)
STRUCTURE AND OPERATION OF BEEF PRODUCTION MODEL

Inputs include (i) animal: initial values of age, liveweight, stocking rate (SR), and breed; and (ii) pasture: yields of green and dead herbage from the herbage production model. Outputs include diet nutrition and components (green and dead), daily liveweight change (DLWG) and animal live weight (LW) for crossbred steers (3/8 Sahiwal, 5/8 Hereford). Conversion to equivalent production in Bos taurus cattle has been done using the relationship of Robbins and Esdale (1982).

Liveweight change is predicted from two equations:

\[
\text{DLWG} = 0.738 \times \text{DOMI} - 27.1 \ \text{g/kg}^{-0.75}/\text{day} \quad (13)
\]

and

\[
\text{DOMI} = \text{RESTR} \times (30.755 \times \text{DIETN} + 12.0) \ \text{g/kg}^{-0.75}/\text{day} \quad (14)
\]

where DOMI is digestible organic matter intake, DIETN is nitrogen content of diet and RESTR is a dimensionless coefficient that restricts intake when herbage yields are low. It was shown from experiments 4 and 5 that the linear regressions

\[
\text{DLWG} = 22.7 \times \text{DIETN} - 18.3, \quad (r^2 = 0.93) \quad (\text{Fig. 3a})
\]

and

\[
\text{DOMI} = 30.755 \times \text{DIETN} + 12.0, \quad (r^2 = 0.95) \quad (\text{Fig. 3b})
\]

could be combined as equation 13.

The restriction term \(0 \leq \text{RESTR} < 1.0\) in equation 14 was established from burnt or heavily grazed pastures in experiments 2 and 5. Soon after a burn, DLWG increased directly with yield of standing dry matter (SDM) up to 230 kg/ha. However with continued heavy grazing the sward structure became prostrate and herbage availability and DOMI declined as a result. Processing the results from experiment 2 with an optimisation fitting program, showed that the DOMI needed for the observed DLWG using equation 13 was curvilinearly related to the proportion of accumulated pasture growth from start of growing season consumed by animals (i.e. \(\text{PCON} = \Sigma \text{EATENxC GROWTH}\)). Combining these two conditions gives a function that restricts DOMI when herbage is removed by fire, declines in drought or has reduced availability in a prostrate sward.

\[
\text{RESTR} = \text{minimum} (\text{SDM}/230; 1.29 - 0.966 \times \text{PCON}; 1.0) \quad (15)
\]

Diet selection operates by estimating the proportion of green herbage in the diet, the contribution from different ages of green herbage, and DIETN for use in equation 14. The following equations on diet selection and quality were established on the age classes from the herbage production model that coincide with 35 field measurements of DIETN and pasture quality in experiments 4 and 5. Coefficients to equations 17 and 18 were derived by processing this data with an optimisation program.

Measurements of pasture and diet composition enabled the proportion of green in the diet to be expressed as

\[
\text{GRDIET} = 19.0 \times (19.0 \times x + 1 - x) \quad (16)
\]

where \(x\) is the proportion of green in pasture (PGR) on a transformed scale (i.e. \(x = (\text{PGR} - 0.1)/0.9\), Fig. 3c). The increased green material selected at the break of the season in spring is modelled by switching to an untransformed scale when \(GIX > 0.5\).

There are 15 age classes of green herbage (GRAGEi) generated by the herbage balance model. Animals select between age classes according to the calculated product of the age class yield (GPri) and a preference index:

\[
\text{PREFi} = \text{GPri} \times (0.0211 + (1.0 - 0.0211) \times \exp(-0.0286 \times \text{GRAGEi})) \quad (17)
\]

The total preference is \(\text{SPEFi} = \Sigma \text{PREFi}\).

The nitrogen content of green material selected from each class (GRNi, %) is given by:

\[
\text{GRNi} = 0.462 + 3.47 \times \exp(-0.1024 \times \text{GRAGEi}) \quad (18)
\]
Animal Production in Australia

It follows that the nitrogen content of the green material eaten (GRNEAT) is given by \( \sum (G_{\text{GRNI}} \times \text{PREFI} / \text{SPREF}) \). Dead herbage also contributes to the diet with a nitrogen content calculated:

\[
\text{DEADN} = 0.487 + 1.908 \exp (-0.059 \text{GRAGE}) \tag{19}
\]

where \( \text{GRAGE} \) is the average age of green material. Dietary nitrogen is then calculated as:

\[
\text{DIETN} = \text{GRODIET} \times \text{GRNEAT} + (1.0 - \text{GRODIET}) \times \text{DEADN} \tag{20}
\]

Comparisons of observed and predicted values of DIETN for burnt and unburnt native pasture showed that the model provided an accurate prediction of diet quality in both the burnt and unburnt pastures of experiments 4 and 5 (Fig. 3d).

Patch or non uniform grazing is likely to result in selection of higher quality diets and usually develops two years after a burn in native pastures grazed at low stocking rates. This causes DIETN to exceed the average for the pasture. As patch grazing developed in the unburnt experiment 3 the yield of dead herbage (litter + standing dead = DP) increased and the following modifier was derived for DIETN from equation (20) from a comparison of predicted and observed liveweight gains.

\[
\text{DIETN} = \text{DIETN} (1.0 + 0.000049 \text{DP}) \tag{21}
\]

Herbage eaten by animals is removed from the herbage classes in the pasture. Since dry matter intake increased linearly with DIETN in experiment 4 the daily herbage intake (kg/ha) for a pasture is given by:

\[
\text{TINT} = \text{RESTR} \times (43.8 \text{DIETN} + 42.9) \times \text{LW}^{-0.75} \times \text{SR}/1000 \tag{22}
\]

This is portioned into a green and dead component using GRODIET from equation 16. The dead component is removed from standing dead and the green class in proportion to the preference for a class (i.e. PREFI/SPREF). When a green class contains too little herbage for this proportional removal the deficiency carries over to the next class until all green intake is removed.

RESULTS AND DISCUSSION

The model predicted 74% of the variation in DLWG from burnt and unburnt pastures of experiment 4 and 5 with little bias (Fig. 3e). However it failed to predict large liveweight changes soon after rain ended a dry spring and low gains during wet weather. These discrepancies could be associated with compensatory weight gains, changes in gut fill and animal behaviour in wet weather.

The major area of uncertainty in the animal production model is the prediction of diet nitrogen when patch grazing occurs. The measurements of DIETN in experiments 4 and 5 were taken in a situation where patch grazing had not yet developed. When the diet preference relationships were applied to experiments 2 and 3 where patch grazing occurred even in the years following burning, the model underestimated animal production. While other factors such as animal breed and age differences between experiments cloud the issue, the most likely cause is an underestimate of DIETN and hence the development of equation 21 above.

| TABLE 2 | The effect of delayed patch grazing on the prediction of summer/autumn liveweight gains (experiment 2 and 3, mean of 17 years) |
|---|---|---|---|
| Summer SR (beast/ha) | 0.74 | 1.24 | 2.47 |
| Observed gain (kg/head) | 60 (19)* | 57 (21) | 22 (20) |
| Predicted gain (kg/head) with delayed patch grazing | 55 (26) | 50 (28) | 21 (29) |
| Predicted gain with patch grazing after burning | 58 (21) | 54 (24) | 23 (33) |

* ( ) standard deviation

207
The effect of delaying the start of patch grazing on summer/autumn gains for the combined 17 years of experiments 2 and 3 is shown in Table 2 and Fig. 3f. The effect of stocking rate on DLWG was well predicted and the best agreement between predicted and observed mean gains and standard deviations was given by the no delay patch grazing model. Nevertheless, the two year delay model (Fig. 3f) represents the best compromise over all experimental data i.e. experiments 4 and 5.

SIMULATION STUDIES

G.M. McKeon*, K.G. Rickert** and A.J. Ash**

In this contract we investigated the use of computer modelling in the management of native pastures for two main reasons: (1) models provide a framework for incorporating available plant and animal production research and for identifying gaps in knowledge; (2) models allow different management strategies to be evaluated against the historical variation in rainfall and prices. However, the conclusions resulting from such a modelling analysis are governed by a computing law, GIGO, i.e. garbage in, garbage out. So we should first consider the deficiencies in our models (our first objective above).

The main deficiency of the water balance model is that it does not predict run-off. The accurate prediction of run-off requires more detailed meteorological inputs than daily rainfall. As a result the model will, at times, over predict soil moisture available for plant growth (1 mm of run-off being equivalent to 5-10 kg/ha of growth). The situations when run-off is most likely to occur are summer storms on bare ground after burning or heavy grazing. The main deficiency of the herbage production model is the prediction of detachment as related to weather. Figure 2d shows that standing dead will be overestimated under some situations with consequent effects on green in diet (equation 16) and patch grazing effect on diet nitrogen (equation 21). Phenological development may also affect diet quality (Ash 1982) but as yet few data are available. The main area of uncertainty of the beef cattle production model, patch grazing effect on diet quality, has already been described. Its implication for the evaluation of management strategies is best considered jointly with the simulation studies on the model.

The following range of management options were considered:
(1) not burning at all; (2) 50% burnt every year (yields reset by half); (3) annual complete burning when possible after 1st August; (4) annual complete burning when possible after 1st October. The criteria used for determining if burning was possible were (1) daily rainfall > 20 mm; (2) total standing dry matter yield > 2 500 kg/ha. If these criteria were not met by 31st December no burning occurred in that year. Simulations of annual liveweight gain were conducted at two year-round stocking rates covering two practical options (0.35 b/ha, 0.70 b/ha) for crossbred steers weighing 300 kg on 1st June. The period simulated was 1958 to 1981 using daily meteorological data collected at "Brian Pastures" near Gayndah. This period included low rainfall (early 1960's), a

* Department of Primary Industries, Brisbane, Qld 4001
** Brian Pastures Pasture Research Station, Gayndah, Qld 4625

208
major drought (1968/69) and a series of above average rainfall years (early 1970's). Unfortunately, as indicated previously, there are no validation data available at Gayndah comparing burning and no burning except for the one year of experiment 5 (Ash 1982).

The simulations were run with or without patch grazing (equation 21) operating from immediately after burning. Non-uniform grazing and burning would be more correctly modelled by simulating more than one point in a pasture. The present model only simulates an "average" pasture. However, consideration of spatial variability requires data on animal preference between areas which are not yet available.

Table 3 shows that the predictions of mean annual gain were greatly affected by the patch grazing equation. The conclusion as to whether or not burning has a beneficial effect on animal production through diet quality depends on the degree to which patch grazing occurs in unburnt pastures. Other issues such as whether or not patch grazing and burning have deleterious or beneficial effects on botanical composition are just as likely to be of practical importance as the implications for animal production considered here.

**TABLE 3 Simulation studies (1959-1981)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Annual liveweight change (kg/head)</th>
<th>Pasture yield (kg/ha 31st May)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Means (s.d.)*</td>
<td>Means (s.d.)*</td>
</tr>
<tr>
<td></td>
<td>Patch grazing</td>
<td>No patch grazing</td>
</tr>
</tbody>
</table>

| Stocking rate 0.35 b/ha       |                                   |                                |
|-------------------------------|                                   |                                |
| No burning                    | 138 (50)                          | 20 (36)                        |
| 50% burnt annually           | 130 (48)                          | 62 (46)                        |
| Annual burn if possible       |                                   |                                |
| after 1st August              | 117 (54)                          | 78 (48)                        |
| Annual burn if possible       |                                   |                                |
| after 1st October             | 130 (48)                          | 90 (44)                        |

| Stocking rate 0.70 b/ha       |                                   |                                |
|-------------------------------|                                   |                                |
| No burning                    | 90 (62)                           | 29 (43)                        |
| 50% burnt annually           | 82 (68)                           | 40 (51)                        |
| Annual burn if possible       |                                   |                                |
| after 1st August              | 70 (67)                           | 43 (57)                        |
| Annual burn if possible       |                                   |                                |
| after 1st October             | 82 (63)                           | 54 (63)                        |

**TABLE 4 Predicted liveweight gain and pasture yield in drought year (1968/69)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Annual liveweight change (kg/head)</th>
<th>Pasture yield 31/5/1969</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stocking rate 0.35 b/ha</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No burning</td>
<td>2</td>
<td>6240</td>
</tr>
<tr>
<td>50% burnt</td>
<td>-11</td>
<td>2355</td>
</tr>
<tr>
<td>Annual burn</td>
<td>-71</td>
<td>1010</td>
</tr>
</tbody>
</table>

| Stocking rate 0.70 b/ha       |                                   |                         |
| No burning                    | -56                               | 3875                    |
| 50% burnt                     | -84                               | 1840                    |
| Annual burn                   | -90                               | 720                     |

*s.d. = standard deviation
Animal Production in Australia

Year-to-year variation was large even at the low stocking rate, unburnt treatment indicating that variation in amount and distribution of rainfall have a greater impact on animal production than on available dry matter and explains to some degree why researchers have had difficulty in relating pasture yield measurements to liveweight gain. The mean values suggest that the difference between treatments is not increased at higher stocking rates. However, this is not true when the simulated results for the drought year 1968/69 are considered (Table 4). The increased risk of liveweight loss and of possible animal death, associated with burning and higher stocking rates is clearly shown.

CONCLUSION

The models developed in this contract represent the first attempt to integrate past research results to predict pasture and animal production for native pasture in south-east Queensland. The results show that accurate models of soil water, plant growth and beef cattle production can be developed and can be used to extrapolate research results over time. However, in evaluating the interaction of burning and stocking rate the area of greatest uncertainty in the model has such important implications that definitive conclusions are unlikely to be made without further experimental work. Nevertheless, the native pasture model developed here provides a powerful tool in the examination of forage short-fall and hence provides a basis for the development of feed year plans with the integration of other options. The herbage and beef production models were developed at one site and need to be tried at other locations. Extrapolation to other locations will be partly achieved by adjustments to the soil parameters in the water balance model. In addition adjustments to parameters in the diet selection component of the beef production model will probably be necessary.

ACKNOWLEDGEMENTS

We are grateful to our colleague, Mr. G.B. Robbins for his helpful advice and to the Australian Meat Research Committee for provision of funds.

REFERENCES