

A MODEL OF A LEY FARMING SYSTEM, WITH PARTICULAR REFERENCE TO A SUB-MODEL FOR ANIMAL PRODUCTION

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Summary

The structure of a model of a ley farming system in a Mediterranean environment is briefly described. A sub-model for predicting liveweight changes and wool production of Merino wethers grazing annual grass-clover pastures is described in detail. Predicted liveweights were within 5 per cent of actual liveweights for most of the year on pastures varying widely in botanical composition and grazed at either a high or low stocking rate. Predicted wool production was within 15 per cent of actual values. Problems in obtaining data for the model functions, and the value of the model are discussed briefly.

I . INTRODUCTION

Much research has been, and currently is being, carried out on many facets of the production of crops, pastures and animals in Mediterranean environments. However, when we attempted to integrate the available information into a study of the whole ley farming system, we found that there was insufficient information available to structure the processes involved. Our objective in modelling the ley farming system is to highlight strengths and weaknesses of our present knowledge of the system, and provide a basis for planning future research more effectively.

A word picture of the overall system was constructed using a similar structure and terminology to that proposed by Van Dyne (1970) for the Grassland Biome model. Crop and pasture variables include pools of seed, green vegetative mass and dead material. Animal variables include numbers in different age and sex classes and animal type, the mean weight per animal in each class, and, for sheep, the mean weight of fleece per animal. Driving forces are rainfall, temperature and radiant energy. The model also contains the physical processes such as cultivation for, and harvesting of crops, and the effects of marketing of products. A simplified visual picture is shown in Figure 1.

The overall model was then considered as a series of sub-models, each describing a different component of the system. The sub-models are crop growth, cultivation, pasture growth, animal liveweight change and wool growth and animal numbers (reproduction). These are designed to be readily interfaced within the structure of the overall model, so that different components can be developed separately, and modified versions of these component sub-models can be included, when necessary, without affecting the remaining structure of the model.

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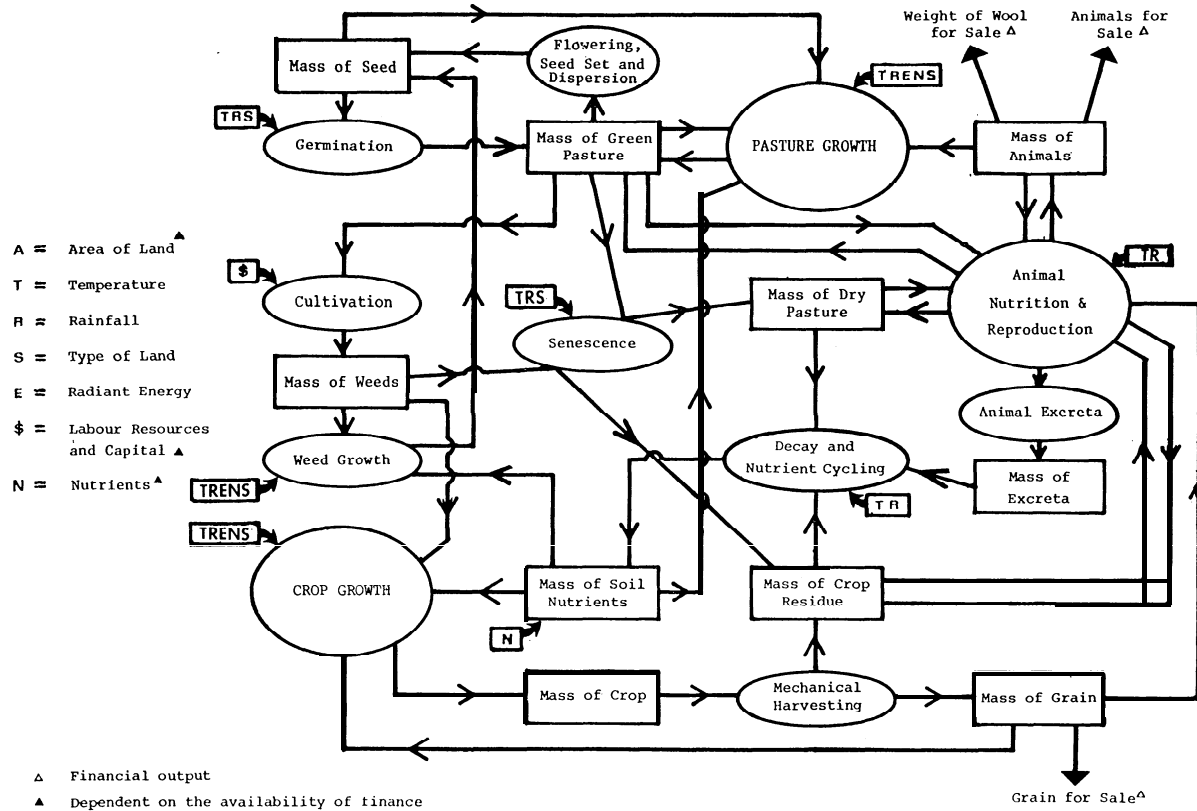


Fig. 1.—A descriptive model of the physical inputs, some of the transfer and regulatory mechanisms, the pools of materials within the system, and the outputs for a ley farm.

It was decided to develop the animal liveweight change and wool growth sub-model initially, as input-output data was available for validation of the sub-model after it was built, and the extent of knowledge of the processes involved was more detailed than for the other sub-models.

II. ANIMAL GROWTH SUB-MODEL

(a) *Liveweight change*

The model predicts the daily liveweight of medium **Peppin** Merino wethers grazing annual pasture containing any proportions of *Bromus mollis* and *Trifolium subterraneum*. The validation is on original data, from a grazing experiment, some of which have been published by Davies *et al.* (1966) and Greenwood *et al.* (1968). Sequential values for available pasture dry matter were measured at three weekly intervals, and daily figures determined by interpolation. The relationships described below were derived from the relevant literature and from data collected at the W.A. Laboratories, and converted into mathematical functions. A more detailed write up and a computer listing is available on request.

Digestible organic matter intake is assumed to be a function of liveweight, "available" pasture and the digestibility of the pasture on offer, with maintenance requirement a function of "available" pasture and liveweight. The resulting energy surplus or deficit is then converted to tissue gain or loss. This summary is expanded below, with equations of the model given in Table 1.

The diet selected by the grazing animal is a function of the quantity and quality of plant material on offer. The amount of green material relative to the total dry matter of the pasture is taken as the major determinant of diet quality, because the animal will select heavily for green material in preference to dry whenever possible.

The per cent green herbage in the diet (PGD) is a function of per cent green herbage in the pasture (PGP) and total dry matter (TDM) present — equation 1. Arnold *et al.* (1966) found that even on low pasture availability (less than 500 k/ha) the diet contained less than 4 per cent of dry herbage, although the pasture contained up to 40 per cent.

Because of this selectivity by the animals, TDM is adjusted for the amount of green material the animal selects (given by PGD) to give the "available" dry matter (ADM) which determines intake — equation 2. When the pasture is dry, ADM is taken as simply TDM. The maximum potential organic matter intake of all herbage (OMI-g/day) is initially a function of liveweight (LWT) — equation 3, based on Allden (1968) and Arnold *et al.* (1964), and is then adjusted for "available" dry matter and pasture composition. Species with erect growth habits, such as grasses, sustain higher intakes at low availabilities than species with prostrate growth habits such as clover; Greenwood and Davies (unpublished); Smith and Biddiscombe (unpublished); and Arnold and Dudzinski (1967a, b). Thus the function relating OMI and ADM is adjusted for the per cent grass in the diet, which is assumed to be the per cent grass in the green herbage (PGR) — equation 4.

Since it is assumed that the sheep eat grass and clover (both green and dry) in proportion to the amounts of each present (if digestibility is non-limiting) the

TABLE 1

Equations used in the model†*

Function	No.	Equation
Percentage green in diet	1	$\text{PGD} = 100 [1 - \exp \{C * \text{PGP}\}] \frac{1}{1 - M}$ $C = 0.005 - 0.002 * \text{TDM}$ $M = 1.40 - 0.000047 * \text{TDM}$ For TDM > 1500 kg/ha, take TDM = 1500 for these functions
Available dry matter	2	$\text{ADM} = \text{GRM} * \text{PGD} + \text{DRM} * (1 - \text{PGD}) \quad \text{DRM} \leq 1000$ $\text{ADM} = \text{TDM} = \text{GRM} + \text{DRM} \quad \text{DRM} > 1000$
Organic matter intake		
(i) Liveweight	3	$\text{OMI} = 55 * \exp \{-0.025 (\text{LWT} - 25)\}$
(ii) "Available" dry matter	4	$\text{OMI} = \text{OMI} [1 - \exp \{C * \text{ADM}\}]$ where $C = -0.0013 - 0.000011 * \text{PGR}$
(iii) Digestibility	5	$\text{OMG} = \text{OMG} [0.5 (1 + 3363 * \exp \{-0.274 * \text{DGR}\}) \frac{1}{-1.28} + 0.3]$
	6	$\text{OMC} = \text{OMC} [0.7 (1 + 240 * \exp \{-0.296 * \text{DCL}\}) \frac{1}{-0.61} + 0.3]$
Maintenance requirement	7	$\text{DME} = 10.35 \text{LWT} - 1.15 * \exp \{0.0060 * (\text{ADM} - 1050)\} \quad \text{ADM} \leq 1050$ $\text{DME} = 8.05 \text{LWT} + 1.15 * \exp \{-0.0034 * (\text{ADM} - 1050)\} \quad \text{ADM} > 1050$
Energy conversion	8	$\text{ECV} = (\text{h} - 0.225 + 0.040 * \text{LWT}) / 0.54$
Wool growth		
(i) Adjusted for DOM	9	$\text{WLG} = \text{WLG} [(1 - 1.230 * \exp \{-0.1082 * \text{DOM}\}) \frac{1}{0.81}]$
(ii) Adjusted for percentage nitrogen (PNC)	10	$\text{WLG} = \text{WLG} [0.5 + 0.25 * \text{PNC}] \quad \text{PNC} \leq 2$ $\text{WLG} = \text{WLG} \quad \text{PNC} > 2$

* The fractions in square brackets range between 0 and 1

† Key to table 1.

ADM	Available dry matter
DCL	Digestible clover
DGR	Digestible grass
DME	Animal maintenance requirement
DRM	Dry material on offer
ECV	Energy conversion
GRM	Green material on offer
LWT	Liveweight
OMC	Organic matter intake of clover
OMG	Organic matter intake of grass
OMI	Organic matter intake
PGD	Per cent green herbage in diet
PGP	Per cent green herbage in pasture
PGR	Per cent grass in the green herbage
PNC	Per cent nitrogen content
TDM	Total dry matter
WLG	Wool growth

organic matter intakes of grass (OMG) and clover (OMC) are given by:

$$\text{OMG} = \text{OMI} * \text{PGR}$$

$$\text{OMC} = \text{OMI} * (1 - \text{PGR})$$

Organic matter intake is then adjusted for the digestibility of the grass and clover, using data published by Ulyatt *et al.* (1967); Osbourn *et al.* (1966) and Conrad (1966). The slope of the curves appears to be similar for most temperate species but the position appears to change — equations 5 and 6. Digestibilities and nitrogen contents of the four fractions viz.: green (DGG) and dry (DDG) grass, and green (DGC) and dry (DDC) clover are read in. Digestible organic matter intake (DOM) is then calculated from the organic intakes and digestibilities:

$$\text{DOM} = \text{DGR} * \text{OMG} + \text{DCL} * \text{OMC}$$

where $\text{DGR} = \text{PGD} * \text{DGG} + (1 - \text{PGD}) * \text{DDG}$

$$\text{DCL} = \text{PGD} * \text{DGC} + (1 - \text{PGD}) * \text{DDC}$$

Digestible organic matter for animal maintenance requirement (DME) (equation 7) is determined as a function of pasture availability, derived from results of Graham (1966). The energy gain or loss of the animal (EGL) is simply the difference between DOM and DME. If there is a surplus of energy, this is converted to tissue, the energy value (ECV) (equation 8) of which is taken as a linear function of liveweight comparable to that of Searle and Graham (1970). If there is a deficit of energy for maintenance, the energy obtained from tissue catabolism, is given by dividing ECV by 1.8 (from Figure 5, Graham 1969). The liveweight change (LWC) is then given by:

$$\text{LWC} = \text{EGL} / \text{ECV}$$

(b) **Wool growth**

Wool growth (WLG) has a maximum potential of 20 g clean wool/sheep/day. This value is then adjusted according to energy intake (equation 9 — based on Pattie and Williams (1967)) and for nitrogen content of the diet (PNC) (equation 10 — adapted from Piper and Dolling (1969)), the latter being determined in a similar way to digestibility.

(c) **Validation**

Agreement between simulated and actual liveweights for all sets of data (two stocking rates by three nitrogen levels) is within 5 per cent for most of the year for sheep grazing pastures ranging from grass to clover dominance. Figure 2 shows the results for either grass or clover dominant pastures only. Although wool growth was simulated daily, the seasonal changes in wool growth were not measured in the experiment. Predicted weights of clean wool at shearing were from 0 to 15 per cent higher than actual weights (see Figure 2). The effect on liveweight of changing parameter values was examined for most functions. Greatest sensitivity was to changes in equations 4 to 6 and 8. The effect of putting the grass parameter values for clover in equation 6 is shown in Figure 2a, c.

The results are encouraging since the evidence on differences in intake, digestion and metabolism of clover and grass diets, and on selection by animals between them is inadequately quantified for modelling. Also, there is little information on wool growth in relation to energy intake.

To test the model more stringently, a validation experiment is in progress, in which detailed measurements of inputs and animal responses are taken fortnightly to obtain model “throughputs”. Until this information is available there seems

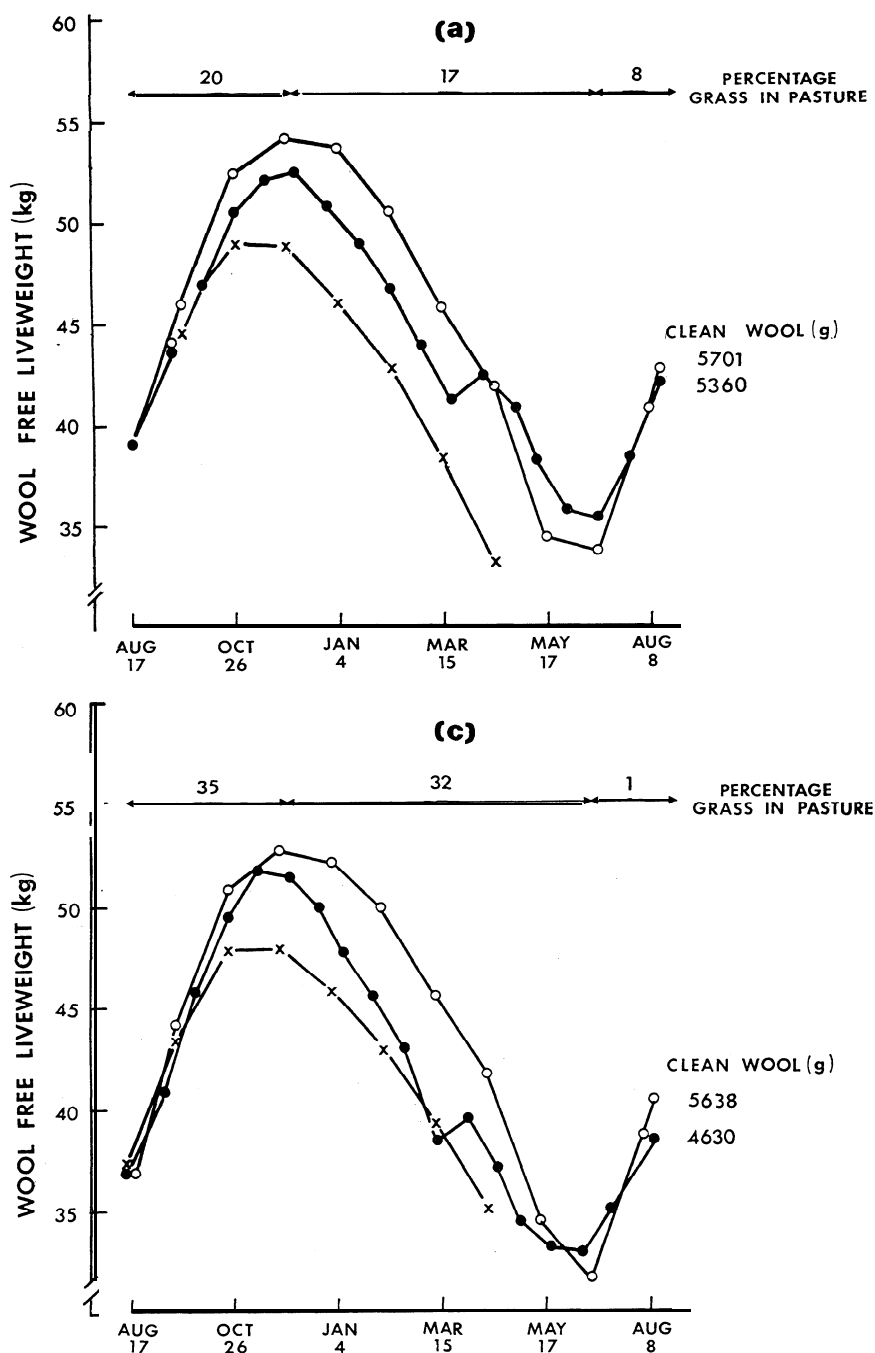
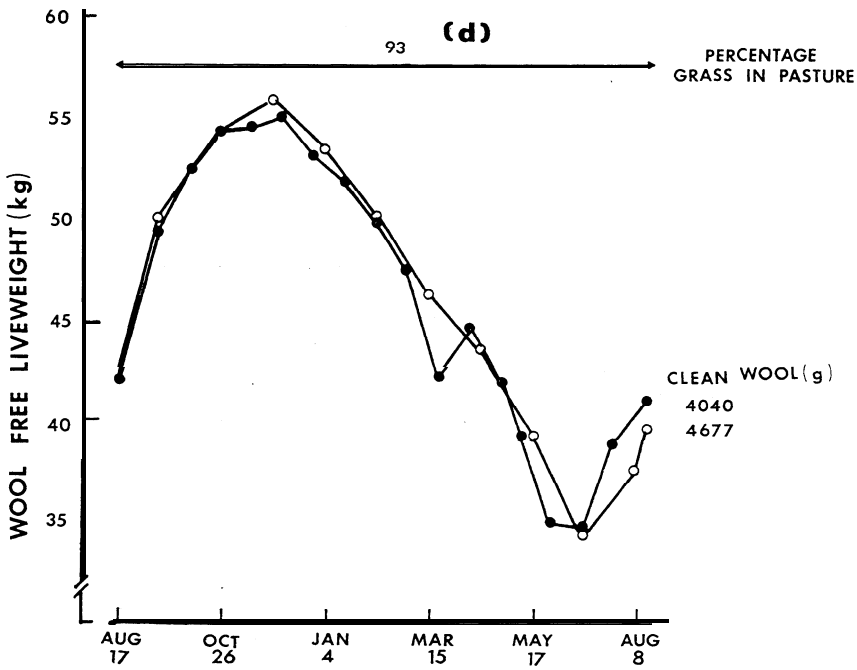
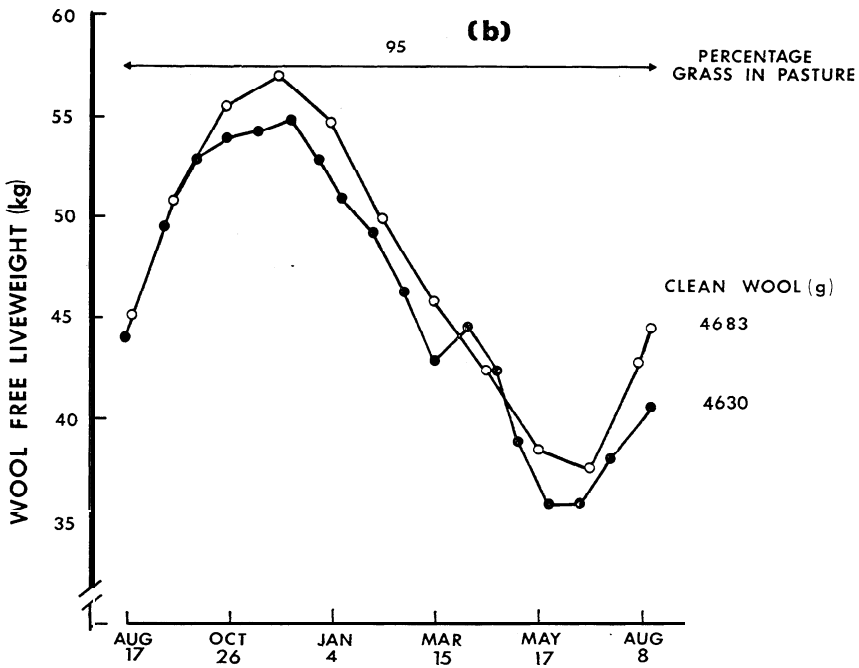


Fig. 2. (a)—Pasture grazed at 8.6 sheep/ha (no nitrogen applied)
 (b)—Pasture grazed at 8.6 sheep/ha (850 kg/ha nitrogen applied)
 (c)—Pasture grazed at 12.3 sheep/ha (no nitrogen applied)
 (d)—Pasture grazed at 12.3 sheep/ha (850 kg/ha nitrogen applied)

○—○ Predicted by model
 ●—● Actual
 ×—× Predicted by model but with equation 5 used instead of equation 6.



little value in attempting to obtain a closer agreement between the actual and predicted liveweights as we do not know in what area(s) the sub-model is deficient.

(d) *Problems and value*

Little information is available to define accurately many of the functions because most studies are limited to responses of animals for only one, two or three levels of an input, or to part of the annual cycle in "ecosystem" studies.

This sub-model was not constructed to give predictions of sheep liveweight independently. Its value for this purpose will depend on whether the parameter values of the functions differ markedly for different environments, and this cannot be tested unless there are precise input data. In the future, these inputs will be provided from the pasture growth sub-model. Once a successful model has been developed it can be used to study the effects of various management techniques on the production of ley farming systems and to predict the likely production of various aspects of the farming system in different seasons.

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