Deer in Queensland

A Decision Support System

A report for the Rural Industries Research and Development Corporation

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FOREWORD

A clear priority of our Deer Research and Development sub-program in recent years has been 'to increase the size and production capacity of the national herd'. Attainment of this objective has been considered an integral step to providing continuity and reliability of supply of deer products (venison and velvet) to specific targeted markets, in conjunction with cost-effective processing and marketing through economies of scale.

The quantitative assessment of management scenarios for agricultural property management has been enhanced in recent years by the adoption of computer based Decision Support Systems (DSS). While numerous DSS have been compiled to assist in information transfer, farm scenario evaluation and supportive decision making on a whole property level for a range of rural industries in Australia, there is a noticeable absence of comparable DSS for emergent animal industries such as the deer industry. The authors of this report detail a novel approach to address static deer herd numbers in Queensland through provision of a pioneer industry specific DSS.

The report provides information on the model development, compilation, evaluation and commercialisation of a deer management DSS package, based on the template of an existing beef cattle DSS modified for inclusion of deer modules. Discussion of results and resultant recommendations detail the suitability of a deer industry DSS as a tool to enhance information transfer and contribute to both deer herd expansion and increased productivity on existing and proposed deer farm enterprises in Queensland. The relevance with regard to the national deer industry is also discussed.

This report, a new addition to RIRDC's diverse range of over 400 publications, forms part of our Deer R&D program which aims to foster an Australian deer industry as a profitable and efficient mainstream agricultural enterprise.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- Downloads at www.rirdc.gov.au/reports/Index.html
- Purchases at www.rirdc.gov.au/pub/cat/contents.html

Peter Core
Managing Director
Rural Industries Research and Development Corporation

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We also acknowledge, with thanks, the contributions of both Dr. Keith Woodford, Reader in Rural Management and Agribusiness and Dr. Gordon Dryden, Senior Lecturer in Animal Production; The University of Queensland – Gatton College, in the provision of unpublished research data and deer management advice in general. This information was important in both the derivation of deer production equations and the bio-economic interpretation of deer management systems.

Finally, we wish to acknowledge the foresight of the Rural Industries Research and Development Corporation in providing funding for this project which, while directly applicable to the proportionally small Queensland deer industry, provides important precursor information of a national focus pertaining to the provision of computer software based Decision Support Systems designed for the Australian deer industry.

Contents

Executive Summary

The farmed deer industry in Queensland is currently considered an emergent animal industry within a consolidation/commercialisation phase. The industry is based on two major species, namely temperate adapted red deer (*Cervus elaphus*) and tropically adapted rusa deer (*C. timorensis*). Recent survey data elucidates some 20,000 head in total from approximately 100 farmers, however only 20% of farms account for more than 75% of the total deer, with 77% of farms having deer fence areas < 40 ha and deer numbers < 200 head. The inability of the industry to attract commercial operations with economies of scale for management, product processing and marketing has been a recognised major impediment to industry growth and development. This then poses the question of how new participants can be encouraged into the industry and existing larger farmers encouraged to expand activities.

We hold the view that in spite of the uniqueness and infancy of deer farming in Queensland, diversification by say existing commercial beef producers into deer production would be encouraged by an interactive computer-based decision support systems (DSS). A decision support system can be defined as any computer-based system used as a tool in decision making, normally as an integrated decision model with a strong decision-oriented approach. It would aid in information transfer, farm scenario evaluation and decision making. In recent years in Queensland there has been a progression of usage and refinement of computer models applicable to pastoral activities from that of primarily research tools to adaptable user-friendly computer programs designed for integrated decision modelling at the whole property level. However while DSS packages are readily available to, and to an extent used by, the beef industry in Queensland, there is a noticeable absence of equivalent user-friendly software decision support available for the deer industry.

In view of limited resources available to the deer industry for research and development it seemed appropriate to adapt an existing beef cattle management DSS to encompass deer management scenarios. FEEDMAN Version 2 is a computer based DSS for pastoral-based beef cattle production in south east Queensland. It is user-friendly software that compares feeding management scenarios for growing cattle in terms of forage utilisation (including supplementation), animal performance, market options and economics. In view of the similarities of soil types, vegetative zones and pasture species specified for FEEDMAN with those evident for both intensive and semi-extensive deer production systems in southern Queensland, it was a logical step to adapt FEEDMAN to simulate deer production from pastures in south eastern Queensland.

With regard to model development; while the basic structure, and in particular data input and forage production/utilisation rules and calculation remained the same, the animal production module and some aspects of mob management and economics had to be modified for deer. While the original FEEDMAN calculated animal production based on a user-specified potential monthly liveweight gain (Plwg) for a standard 200 kg crossbred steer for a given forage, insufficient field and research observations on animal growth precluded this approach for deer. Rather, the Plwg specified for steers on each forage type was regarded as a ‘steer bio-assay’ that reflected local expert knowledge on pasture quality and was regressed to estimate potential metabolisable energy (ME) of a selected forage each month. On this basis, and using the principles of growth prediction from ME intake as determined in accepted ruminant feeding standards, ME intake and ultimately animal production (growth) was calculated using algorithms derived from both published and non-published datasets

regarding information pertaining to red and rusa deer in Queensland. Further modifications to both potential dry matter intake and growth prediction were also required, to account for the complex interactions of breed, genotype, seasonality and breeding (rut) effects evident in deer biology and production. Velvet production for stags can be derived from default values or by calculation based on liveweight. Deer production algorithms and assumptions were incorporated into the existing DSS template based on Microsoft® Access 97 (© 1996 Microsoft Corp.) using Access Basic™ program code. All algorithms were first developed and tested using a spreadsheet. The compiled new version of FEEDMAN, encompassing both deer and beef cattle production systems, is formatted as IBM-compatible CD-ROM software to be marketed by the Queensland Department of Primary Industries as FEEDMAN v 3.0, a pioneer deer management DSS for Queensland.

Users of the software are required to input information on the farm, its forage types, monthly rainfall, mob management, market specifications and variable costs. Default values are also available. The deer module requires further specification of the deer farm area and the option of harvesting velvet from entire mature males (ie. stags) is available. Only growing deer can be specified (ie. stags, castrates and non-pregnant, non-lactating hinds) and with regards to mob management, deer and cattle can not graze together in the same paddock. The program interface has been designed to allow ease of data entry and selection of farm management options. All key parameters have default values, which can be changed to reflect local conditions. Input data is compiled and calculated to generate results provided in the form of reports, detailing forage supply and utilisation, mob management, animal production (liveweight change), performance summaries, and economic outputs with market options. The reports are supplemented by summary graphics regarding performance and mob value, costs and profit. The program also generates, where appropriate, velvet production and velvet value reports. Sustainable stocking rates are assessed from estimates of forage growth and safe levels of forage utilization.

The FEEDMAN package has been satisfactorily validated and evaluated for both forage production and animal production by comparison of experimental and field observations against the models predictions. Deer production was validated against a very limited dataset of research observations, due to the scarcity of data on performance for farmed deer in Queensland, especially across a range of forage types. Nevertheless deer performance predicted by FEEDMAN was similar to observed data from a research farm, and is in reasonable agreement with deer farmer observations correlated to deer turnoff age and weight. On this basis, and in view of the confidence in the biological parameters and results generated, commercialisation of the package was initiated. On-farm evaluation for FEEDMAN is anticipated as an on-going process, however a combination of current low confidence in the deer industry, deer farm rationalisation in the state and minor delays in program compilation have negated ‘real time’ field data validation and evaluation to date.

FEEDMAN is a technically complex package in that a range of soil, rainfall, vegetation and forage, animal, market and economic variables must be integrated, assessed and reported. Nevertheless the package is presented in a user-friendly format and application that allows beef cattle producers and deer farmers to evaluate numerous feeding and mob management scenarios, particularly cost-effective feeding management to meet specific market requirements. Estimates of farm forage and animal production are complemented by market options and economics as an important aid to both tactical and strategic decision making. While FEEDMAN is designed to be interactive and user-friendly, the degree of technical inputs and interpretation required for effective use of this package suggests a target user group of competent farmers, agricultural professionals and farming systems proponents.

Whilst the software package is used to evaluate alternative management scenarios it is the end-user who is responsible for decision making, and the program should not be perceived as a ‘black box’ for generating unchallenged output data. Information provided by FEEDMAN is not precise or necessarily complete, and users should analyse outputs in conjunction with appraisal of other information sources, their own physical and financial resource constraints and individual social preferences.

The importance of a computer DSS to aid in effective transfer of new information and technology to pastoral animal industries is widely recognised and the FEEDMAN package is no exception. FEEDMAN has the facility to provide technical and economic input into deer production systems in Queensland that will aid in the encouragement of industry expansion and productivity gains within the state. On a national level, such productivity gains can also be measured in the ability to contribute to year round venison supply and hence compliment seasonal venison production in the southern states.

Modification of an existing beef cattle DSS has provided a cost-effective means of introducing computer-based DSS into the Australian deer industry. While FEEDMAN is clearly a suitable tool to use in decision making aimed at encouraging new industry participants and herd expansion, the attractiveness of deer farming as a viable livestock enterprise will rely on other industry initiatives to improve confidence and provide viable financial incentives. Computer-based decision support systems can provide technology the deer industry can exploit, but they are not designed to instigate industry change or direction *per se*. Successful integration of pastoral deer and cattle farming systems exists in New Zealand and should be a valid management option for southern Queensland which can be evaluated as ‘what if’ scenarios by FEEDMAN. However, the eventual impact of the FEEDMAN DSS on industry will depend, ultimately, on how well it is accepted.

1. Introduction

1.1 Overview of the Queensland deer industry

Commercial deer farming was initiated in Queensland through the late 1970s and early 1980s, with aspects of early farming development and species establishment having been adequately discussed and documented previously by Woodford (1997). Recent industry statistics and information obtained from farm survey data (Sinclair 1997) in association with industry stakeholder consultation has revealed that:-

- there are around 21000 head on approximately 110 farms sourced from four main species, namely red (*Cervus elaphus*), rusa (*Cervus timorensis*), fallow (*Dama dama*) and chital (*Axis axis*) deer,
- the major commercial species farmed in Queensland are rusa and red deer comprising in excess of 85% of the total herd,
- Queensland is estimated to have between 9 to 12% of the national farmed deer herd, account for 10% of national slaughter numbers, 14% of national venison production (as Hot Carcass Weight (HCW)) and 10 to 14% of national velvet production,
- The majority of deer (greater than 75%) are farmed on a minority (20%) of farms, with greater than 80% of farmed deer and deer farm areas currently located in the south-east of the state, although some commercial rusa herds are evident in northern central Queensland,
- The majority of deer farmers have small properties (less than 40 ha) and only derive a small part-time income from deer. Most deer are farmed on a minority of commercial size enterprises (greater than 100 ha), although again deer provide secondary sources of primary production income for all but 3% of farmers with deer in the state.
- Venison is the major farm product for income, with the majority of venison processed at export abattoirs for destinations in Europe and, to a lesser degree Asia. The venison is essentially sourced from forage-based pastoral systems.

It is apparent that the Queensland deer industry is comparatively small in size and would be classified as an emergent animal industry, with inherent problems and constraints (Woodford 1997). A couple of constraints, recognised by the Australian deer industry and recently documented in a five year deer research and development program (RIRDC 1996), are the scarcity of quantitative nutrient requirements for venison and velvet production necessary for the formulation of strategic feed management (constraining production efficiency, product quality and information transfer), and low overall herd numbers (constraining market product volume and cost-effective processing). Knowledge of the seasonal feed requirements for farmed deer is considered paramount in contributing to commercially efficient and ecologically sound modern deer farm management (Pearse and Drew 1998). In addition, relatively small herd size is recognised as a major constraint in further development of the deer industry, both within Queensland and nationally (Woodford 1997; Tuckwell 1999).

Red and rusa deer are the major commercial deer species in Queensland, and are the species on which future stability and expansion of the industry will be based. Rusa deer appear well adapted to a range of Queensland environments and pasture quality, are gregarious in nature and suited to larger herd farming, appear to have low parasite burdens or risk, and exhibit natural resistance and tolerance to cattle tick (*Boophilus microplus*) exposure. However farming environments are constrained by areas likely to cause severe hypothermia and where exposure to sheep results in losses due to acquiring Malignant Catarrhal Fever (MCF). The areas of potential MCF risk and cool/wet winters correspond to the southern and western zones of the state. Red deer are considered a very tractable species for farming and appear to tolerate a wide range of farming environments, however their temperate origins and adaptability greatly constrains their performance in tropical and sub-tropical zones where climatic stress and cattle tick infestation risk (due to low tolerance and high susceptibility), combined with wider ranges in seasonal pasture quality result in unsuitable farming environments. Currently red deer are farmed in southern and south-east Queensland within the area bounded by latitude 25^{o}S and longitude 149^{o}E. This area appears to be the current practical limit of their commercial range and offers a seemingly tolerable climatic zone coupled with land types suitable for semi-intensive to intensive production systems offering suitable feed quality year round. Obviously environment and breed interactions exist in matching appropriate deer species to appropriate Queensland bio-physical environments (Woodford 1997).

It is to be appreciated that the Queensland environment encompasses a wide range of soil types, climatic zones and topography (Weston 1988). Although deer farming extends along the coastal inland in spasmodic area concentrations from approximately 17^o to 29^{o}S, survey data collated by Sinclair (1997) reveals that virtually all red deer and around 75% of rusa deer are currently farmed within the south/south-east corner of the state bounded by latitude 24^{o}S and longitude 148^{o}E. While environmentally there is no constraint to rusa deer farming in the central and northern coastal inland areas, numbers are generally few and farms spasmodic, due largely to abattoir and logistical constraints. Average annual rainfall ranges from around 700 mm in the western margin to 1400 mm near the coast, but is highly variable. The climatic zone would be broadly classified as subtropical and humid, although inland areas experience cooler winter seasons with possibly higher winter rainfall probability; nevertheless rainfall is summer dominant. Soils are also variable in fertility, with intensive deer farming on the relatively fertile cracking clays and loams associated with Brigalow (*Acacia harpophylla*) and Queensland bluegrass (*Dichanthium sericeum*) communities suitable for sown pastures and crops, contrasting with more semi-extensive deer farming on poorer quality duplex soils within native pasture (predominantly black speargrass, *Heteropogon contortus*) communities and supporting limited sown pasture or forage crop options. Temperate pastures may be an option in cooler southern areas and summer and winter forage cropping is viable. Thus a wide range of forage options are available for the particular zone and soil type, amount and variability of rainfall, temperature and grazing management, and all need to be considered when selecting suitable forages for a farm.

Deer farming in Queensland is characterised by self-replacing breeding and finishing units producing venison and velvet using pasture-based production systems. The assumptions used to derive the system nomenclatures of intensive and semi-extensive are based, in part, on similar observations of world deer farming systems by Pearse and Drew (1998) although the Queensland industry has not yet acquired suitable economies of size nor market stability to utilise finishing-only units. General management knowledge and qualitative summation of feed requirements have been derived in Queensland based on several years research and observation (Dryden 1997; Woodford 1997; Puttoo *et al*. 1998), and compiled with other relevant nutritional information in a recent literature review by Sinclair (1999). Nutrient supplementation and interventions evident are similar to feed management strategies outlined by Cheffins (1996) in optimising beef cattle production in the subtropics using pasture-based finishing systems, ie. strategic nutrient intervention using mainly energy (grain and molasses) and protein (protein meals, legumes) supplements and forage cropping/selected sown forages. Deer are a ruminant species and deer farming, or more specifically pastoral venison production, is already integrated with existing beef cattle production systems in NZ (Cowie 1991).

It is important that the deer industry has a stable herd size to equate to economies of size allowing cost-effective production, processing and marketing concomitant with production systems providing a quality product, be it venison or velvet antler. Appraisal of current industry statistics suggests that any major expansion of the deer industry in Queensland will be reliant on a minority of current commercial size deer operations concomitant with entry of new commercial size participants into the industry. In view of the preceding discussion elucidating a probable synergy between beef cattle and deer production using forage-based nutritional management systems, a likely bio-economic resource for new deer industry participants are existing beef cattle producers in central and southern/south-east Queensland. The challenge for the deer industry in Queensland (and indeed nationally) is to provide a ‘tool’ to encourage both existing deer farmers, and potential new entrants from the beef industry (in the guise of a viable livestock enterprise alternative) in adopting cost-effective, productive and sustainable deer production systems in association with herd expansion. It is the premise of this report that an industry specific decision support system provides such a ‘tool’.

1.2 Decision support systems (DSS) for livestock industries

Encouragement for primary producers to undertake a livestock production diversification to include (or expand) deer enterprises requires information on deer production, economics, market specifications and management so as to provide a framework for informed decision making. The quantitative assessment of management scenarios for agricultural property management has been enhanced in recent years by the adoption of computer decision support system software.

A decision support system (DSS) can be defined as any computer-based system used as a tool in decision making, normally as an integrated decision model with a strong decision-oriented approach (Bennet 1992). Issues of productivity, sustainability, stability and equitability (profit distribution) are normally addressed as evaluation criteria within the bio-economic framework. Major characteristics of a DSS, bearing in mind a large range in definitions and applications exist, appear to be: complex problem or scenario assessment allowing decision maker input and influence, utilisation of databases and mathematical models incorporating decision logic/decision rules in their make-up, incorporation of economic elements for profitability and/or financial risk assessment, and selective incorporation of those elements deemed only essential in addressing the decision process (Bennet 1992). It is important to note that while DSS involve computer models that quantitatively assess management scenarios, there is the implicit assumption that they act only as a tool to be used in final management decisions. Hence a decision *support* system used to quantify problems and possible solutions to thereby ‘assist’ a farm manager in decision making and resource allocation. Other technical/resource factors will impinge on the decision to incorporate a particular farm enterprise (such as deer farming). In addition, the goals, attitudes and social factors affecting the farmer are variable for individuals.

In recent years in Queensland there has been a progression of usage and refinement of computer models applicable to pastoral activities from that of primarily research tools (eg. GRASP, McKeon *et al.* 1990) to adaptable user-friendly computer programs designed for integrated decision modelling at the whole property level (eg. FEEDMAN Beef management package, version 2.0 © The University of Queensland; Rickert *et. al*. 1996). In addition DSS offer powerful tools for the comparison of management and development scenarios in beef cattle production systems within Northern Australia, as exemplified by the use of RANGEPACK Herd Econ computer software package in comparison of management technologies for 'typical' Northern Australian beef cattle properties (Foran *et al*. 1990), or evaluation of drought and stocking rate policies (Gillard and Monypenny 1990). However while DSS packages are readily available to, and to an extent used by, the beef industry in Queensland (eg. Holmes 1988), there is a noticeable absence of equivalent user-friendly software decision support available for the deer industry. The use of computer models in farm management have been adopted to a varying degree in the NZ deer farm industry where a range of software products provide essentially three functions (integrated or individually), namely data capture, record analysis and strategy analysis (Fennessy and McCall 1990). It is the aspect of farm production strategies and 'what if' scenario testing that is of relevance in this report.

2. Objectives

In the context of the preceding discussion, the research problem confronting deer herd expansion in Queensland is "How can new participants be encouraged into the deer industry and existing participants encouraged to expand activities?" Such activities to be sustainable from a production, economic and environmental perspective.

The research problem defined above then raises *research questions* of;

- Do we have sufficient technical/nutritional knowledge for deer production systems to predict animal performance?
- Can existing beef cattle decision support models be modified to accommodate deer management systems?

As a progression to our research questions, we can specifically state *research objectives* as;

1. Derivation of animal production functions for red and rusa deer under Queensland pastoral (nutritional) conditions and constraints.
2. Modification of an existing beef software management package (FEEDMAN v 2.0) to incorporate deer.
3. Project information dissemination and the commercialisation of a beef and deer management DSS.

These are then the project objectives to which this report addresses. Within this context the overall aim of the project has been the:-

- development and commercialisation of existing knowledge into a computer Decision Support System (DSS) management package which will evaluate both nutritional and economic 'whole farm' management scenarios for red (*Cervus elaphus*) and rusa (*Cervus timorensis*) deer in Queensland, and
- to provide existing deer farmers a tool to improve information and management skills on a 'whole property' basis, in addition to acting as a precursor for further industry expansion.

3. Methodology

3.1 Selection of existing beef cattle DSS for deer model development

There are several key design criteria necessary for the development of a DSS package for deer in Queensland if project objectives and aims are to be fulfilled. These criteria must also be compatible within the context of a currently small and emergent animal industry where human, physical and financial resources are limited. The key criteria are stated below in Table 1 and include supportive notes on the compatibility of the FEEDMAN beef management package as the selected template for deer DSS model development. The notes on FEEDMAN are based on more comprehensive analysis and description of the program as previously described by Gaffney (1997) and Rickert (1998).

Table 1 Compatibility of FEEDMAN beef cattle management package to key criteria for attaining project goals

Key model criteria	FEEDMAN DSS package specifications
User-friendly input data interface and software compatibility	Based on MS Access™ database management framework with compatibility to allow information transfer to other Microsoft software applications.
A 'whole property' perspective for animal and forage management	User can input farm area, layout, paddock number, land units and soil type, rainfall, animal class and mob specifications to generate outputs in forage production/utilisation and animal production.
Encompass the range of forage types and land/soil classes evident in central/south-eastern Queensland	FEEDMAN encompasses 27 land unit/soil classes (eg. Brigalow and belah (unit) with red-brown medium clay, cracking and self-mulching (soil)) with 42 pasture or forage types (tropical, temperate, legume and forage crop). In addition 9 supplementation options (eg. grain, cottonseed meal, hay) are also available.
Allow for manipulation of rainfall given major impact on forage growth	FEEDMAN contains datasets for variable rainfall (very dry year, dry year, median year, wet year, very wet year) over 3 SOI# scenarios for 41 recording stations across central and southern Queensland, in addition to user ability to enter own local data.
Allow assessment of common management options and output of information	Mobs of cattle (animals) can be moved between paddocks, fed variable forage combinations on variable land types, and supplementary fed. A comprehensive range of reports and graphs are generated for interpretation of information, with default values and customised input data available for individual farm scenarios.
Encompass market specifications and farm economics	User can customise market specifications and prices for sale animals. Variable forage and animal costs, combined with sale revenue are used to generate partial budget analysis and farm cash surplus/deficit.
Environmental sustainability	FEEDMAN calculates sustainable stocking rates for a farm based on set forage utilisation values, concomitant with stocking rate calculation for individual farm scenarios. User can manipulate stocking rate accordingly to conserve the pastoral resource on the farm.
Ability to incorporate deer modules with minimal modification	Program coding is in Visual Basic™ and enables deer production algorithms to be incorporated for weight change and velvet growth. Deer mob management, market specifications and economics can be added to the existing management package framework.

Southern Oscillation Index

Furthermore, the generalised agricultural/pastoral zone for which the FEEDMAN package is designed and/or compatible in Queensland is illustrated in Figure 1. This zone contains notable areas of 'endowed' status for beef cattle production (*as per* Meat and Livestock Australia northern Australia beef cattle enterprise zoning regarding productivity potential, McLennan 1997) and also encompasses greater than 90% of the current deer farms and deer numbers in Queensland (Sinclair 1997).

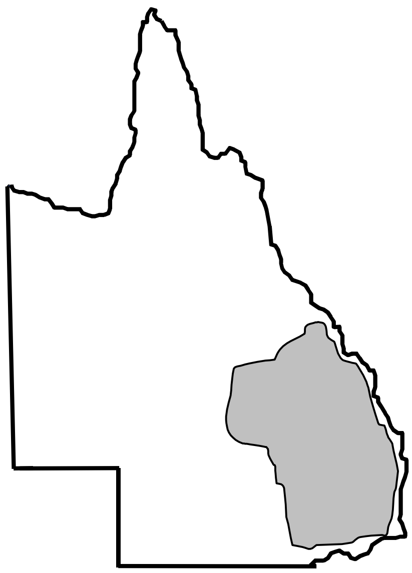

Figure 1 Map showing the general area of Queensland for which the FEEDMAN DSS is compatible (including FEEDMAN v 3.0).

The FEEDMAN package is then a useful template for a deer DSS model to be developed upon, and enables farm management scenarios to be evaluated and compared. It is a repository for results from over 45 years of past research on feed management strategies for beef cattle in central and south-east Queensland (Rickert 1998) and provides a useful precursor for compiling existing deer farming bio-economic knowledge into the FEEDMAN DSS package for information transfer to industry.

The relative merits of FEEDMAN viz a viz GrazFeed™

During the initiation of this project, the Deer Industry Research Advisory Committee were interested in the merits of using existing DSS for the deer industry and in particular an appraisal of the merits of FEEDMAN, given initiatives directed in southern Australia toward modification of the GrazFeed™ computer model for nutritional management of grazing ruminants (GrazFeed v 4.0.2 © CSIRO 1989-1998; Freer *et al*. 1997). It is opportune to now further the arguments for selecting FEEDMAN as the DSS template for a Queensland based deer model. It is worth noting that the proceeding discussion seeks to acknowledge that both FEEDMAN and GrazFeed are worthy DSS templates and in no way infers faults in either approach, merely justification for matching the appropriate model to the identified research objectives.

Uncertainty does exist regarding the appropriateness of the GrazFeed model to tropical/subtropical grazing systems given some apparent bias in the SCA (1990) feeding standards toward temperate pastoral systems combined with equivocal data results in comparative analysis with beef and sheep production measured in Queensland (Hall 1996; McLennan 1997). Essentially GrazFeed estimates animal production based on estimation of an animals potential intake, the quantity and quality of herbage on offer and supplementation offered, and subsequent calculation of metabolisable energy (ME) and protein intake converted to animal production (eg. weight change, milk yield, wool growth for sheep). The approach is based on previously published feeding standards for ruminant livestock in Australia (SCA 1990) with a design preference for temperate southern Australia grasslands and sown pastures, with some modification as described more fully in Freer *et al*. (1997). The latest GrazFeed version (4.0.2) does include a tropical pasture option however. The approach to calculation of beef cattle and deer production in the modified FEEDMAN model is also based broadly on SCA (1990) principles with similar methodology for derivation of potential intake, supplementation and conversion of energy intake (but not protein) to growth and production (Section 3.2).

However notable exceptions in derivation of herbage (forage) quality and presentation/interpretation of information generated are evident between FEEDMAN and GrazFeed. The alphabetical points below elucidate the exceptions.

a) GrazFeed relies heavily on the accuracy of user inputs regarding correct estimation of herbage composition (dead and green components), presentation and quality (digestibility parameters) to derive pasture M/D (energy, MJ ME/kg DM). This has been a stated major limitation, necessitating technical training of users and further imposing the main user profile as being a professional agricultural advisor (Freer *et al*. 1997). Conversely FEEDMAN derives herbage M/D via a ‘steer bio-assay’ (Section 3.2.3.1) necessitating merely inputs of potential steer growth for selected herbage types based on local knowledge and not specifically requiring technical input or professional ability. The complexity and variability of both pasture components and quality in tropical/subtropical grazing environments has, to date, negated practical user inputs for pasture composition *as per* GrazFeed.
b) GrazFeed has beneficial daily production outputs in tabular form regarding specific nutritional parameters to animal production and supplement cost. FEEDMAN has a broader perspective to incorporate whole property analysis of several mobs/paddocks with a comprehensive output of information in both tabular report and graphics incorporating animal production, forage utilisation and growth across the farm, and farm economics. While GrazFeed offers more comprehensive animal production estimates for a particular forage and supplement, FEEDMAN provides the ability to test whole farm scenarios across numerous mobs and paddocks combined with economic analysis and marketing options.

3.2 Model development

The FEEDMAN beef management package was selected as the template for the development of the deer DSS model. Aspects of product development with regard to the FEEDMAN package have been described previously by Rickert (1998) and involved progression from development of spreadsheet versions, to software prototype, model validation and evaluation prior to subsequent commercialisation. Essentially the basic structure (refer also to Section 4.1) with respect to farm description (soil land class types, pasture/forage types and rainfall), forage production/utilisation calculation (incorporating forage growth and yield), cattle mob management and farm economic analysis remain as described in the commercial version by Rickert *et al*. (1996). However the introduction of deer farming options necessitated major modification to animal production models, with minor alterations to mob management and farm economics.

The spreadsheet model for deer production (to be inclusive of liveweight change and velvet antler production) was developed using Microsoft Excel 97 software (©1985-1997: Microsoft Corporation), and based on the same logical progression of formulae and algorithm development, parameter insertion, data simulation, model verification and sensitivity analysis as described by Suntariporn Duan-yai (1994). This approach was chosen for simplicity and transparency, where data required for developing model functions could be adequately detailed and knowledge based without being necessarily comprehensive. However a comprehensive review of literature with regard to the nutritional management of red and rusa deer in Queensland was undertaken to compile existing knowledge regarding venison and velvet production systems, and enable the development of algorithms and compilation of production parameters for insertion into the deer model (Sinclair 1999). Algorithms are defined as systematic mathematical procedures that enable problems to be solved in a finite number of steps using defined processes and rules for calculation. The spreadsheet model was on a single paddock basis modelling deer production over 12 months (Jan. to Dec.), and using forage parameter inputs from the existing commercial FEEDMAN package.

The approach chosen to model deer production in Queensland was then based on definitive sectors (or modules) of a known deer farming bio-economic system (Woodford 1997) utilising accepted model methodology and mathematical formulae construction. Basal input data from the literature review was complemented by existing feeding standards for ruminants in Australia (SCA 1990) based on metabolisable energy (ME), and combined with sound physiological premise (Hall 1996). Notably a similar approach has been adopted in New Zealand for red deer feeding standards, with extrapolated ME recommendations used for red deer in southern Queensland; rusa deer feeding standards were also initiated in Queensland based on ME (refer Sinclair 1999).

Spreadsheet model verification and sensitivity

Outputs generated by the spreadsheet model (deer LW change and velvet production) have been compared to historical data in literature (Sinclair 1999) and been shown to be in agreement quantitatively in both magnitude and trend. However, there were some unique problems with model verification for deer production systems in Queensland, namely;

- Scarcity of historical data, particularly on-farm, for both red and rusa deer farming systems over the range of forage and supplement types used in the model,
- Limitation of the quantitative majority of historical datasets to intensive, irrigated pasture studies with supplementation,
- The desire to 'preserve' essential datasets for model validation (Section 4.4) so as not to compromise integrity of model construction.

An important data verification point observed has shown the model to be able to interpret trends in red deer genotype LWG consistent with literature observations whereby greater advantage is observed on high M/D (MJ ME/kg DM) pasture for European or hybrid animals, but this diminishes on lower quality pasture concomitant with higher energy requirements. This suggests a 'robustness' in the current model formulas and arguments to accommodate both forage intake influences and animal energy requirements across seasons, genotypes and age. Nevertheless, constraints in available field data for model verification are limits imposed by an emergent, small animal industry with minimal R&D base and limited stakeholder participation. Field data collection has also been compromised historically by the scarcity of larger scale commercial deer enterprises in the state (Sinclair 1997).

The object of model sensitivity within model construction is to observe the response in generated output parameters to changing input data, and gauge the significance of such responses with a view to 'fine-tune' model parameters and functions. Changes in forage yield and utilisation will be sensitive to stocking rate, rainfall, land unit and forage type (Rickert *et al*. 1996) thereby influencing forage production and yield inputs from the existing commercial beef cattle model (FEEDMAN) into the spreadsheet model. In wetter or drier years, forage utilisation by mobs of deer is decreased or increased accordingly corresponding to forage growth and monthly yield. Some trends observed with the model are;

- LWG performance of deer is significantly influenced by forage type and seasonal quality as it impacts directly on dry matter intake (DMI) and hence ME intake.
- The performance of castrates verses entire males is variable, but understandable in view of the negation of seasonal "rut' DMI and corresponding LWG performance with castration. However supplementation during the 'rut' of stags is responsive.
- Supplement quality and basal forage quality are interactive, nevertheless feeding higher quality supplements on a specified basal forage improves LWG performance.
- European genotype red deer have higher dry matter intake (DMI) than Australian genotypes, with stags greater than hinds.
- The model clearly illustrates effects of the mating season or 'rut' on red deer intake from yearling age, with winter feed depression more pronounced for red stags than red hinds.
- Rusa stags, while having annually higher feed intakes than hinds or castrates, also show more marked seasonal variation in feed intake with 'rut' influence.
- The proportion of DMI as a factor of bodyweight declines with age for all deer species, sex and genotype.
- DMI as a proportion of bodyweight shows seasonal variations reflective of both feed quality and sex, species.
- Deer production on a specified forage (other inputs constant) appears particularly sensitive to pasture quality (M/D), consistent with use of ME intake to generate production outputs.
- Noticeable differences in LWG between males (entire and castrate) and females
- Stags have more pronounced seasonal LWG patterns than either castrates or hinds once sexual maturity is reached.
- European genotype influence for red deer shows greater capacity for LWG on quality pasture (high M/D), however advantage diminished on lower quality pastures. A function of changing pasture M/D inputs concomitant with higher energy requirements.

Examples of sensitivity analysis is provided in Table 2 where basal input values have been modified by single parameter changes. Note that mean yearly LWG for entire male deer is influenced by age and maturity via the observed 'rut' effect on feed intake depression. This is clearly illustrated in Figure 2 which provides a graphic example of model sensitivity to genotype and supplementation.

Table 2 Sensitivity of spreadsheet model parameters.

Input	Input variance	Output	
		LWG (12 mth mean)	Velvet weight

		g/d	kg/hd
Base value #		12	2.15
Higher quality forage	Pasture quality M/D 8.5 - 11	26	2.30
Genotype	European (incl. hybrid)	20	2.53
Yearling stags	Start age 14 mths; start LW 90 kg	75	1.55
3 year old stags	Start age 38 mths; start LW 165 kg	-26	2.42
Supplementation	Fed May-Aug, good quality		
Grain	0.25 kg/hd/d	20	2.23
	0.50 kg/hd/d	29	2.30
	0.75 kg/hd/d	37	2.38

Basal input values consisted of fixed parameters:
2 year old red deer stag, Australian genotype, start age 26 months, start LW 140 kg, grazing period Jan. to Dec., Average condition tropical grass pasture (no legume), median rainfall year (Gatton, S.E. Qld), no supplementation, stocking rate 0.42 head/ha.

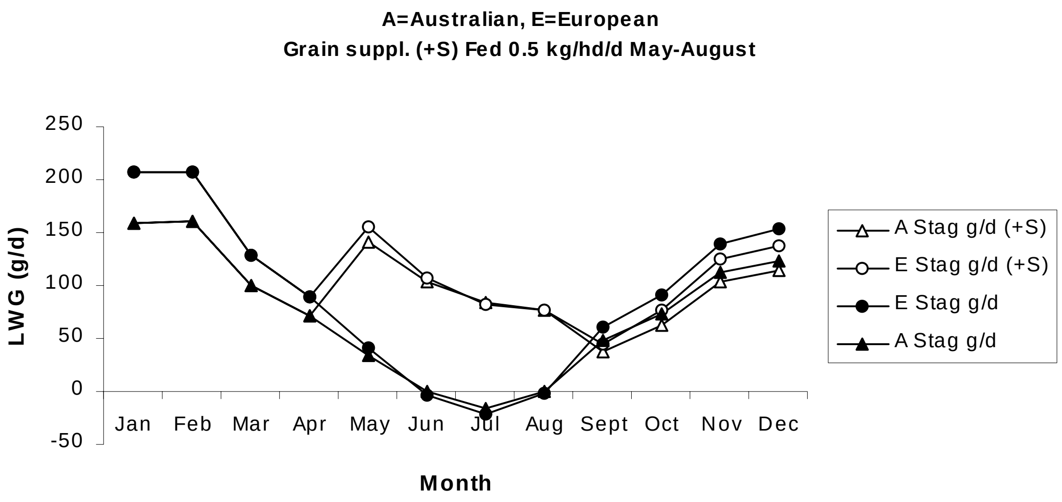

Figure 2 Liveweight changes for yearling red deer stags on tropical grass pastures (no legume) using the spreadsheet model.

Using the allometric LW and velvet growth prediction equation of van den Berg and Garrick (1997), estimates for both Queensland red deer genotypes, based on stag velvet weight and corresponding LW at given age (from data in Woodford 1997), were calculated and plotted against measured values (Figure 3). The plotted data suggests that allometric equations have merit in predicting velvet weights in Queensland and provide a guide to interpretation of velvet production from LW inputs.

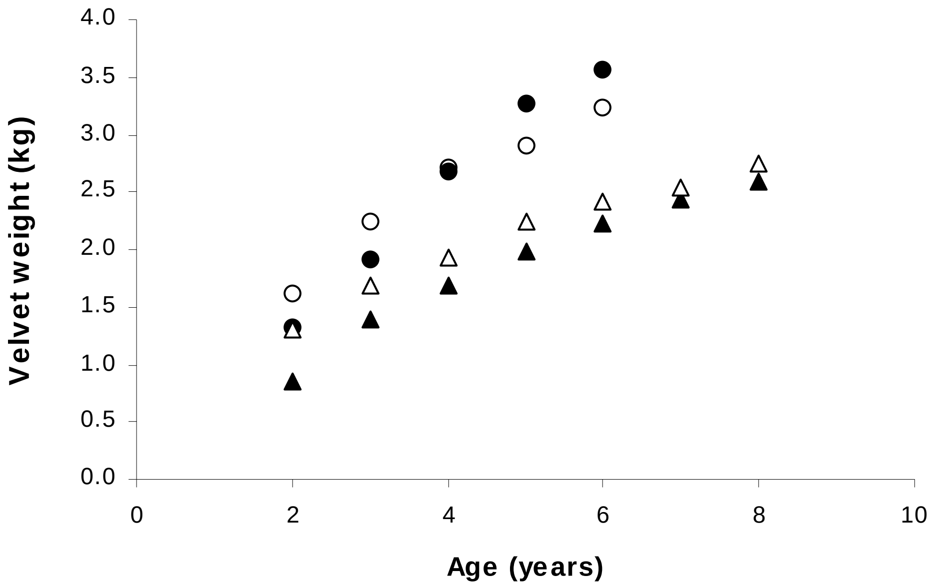

Figure 3 Measured velvet weights for Australian genotype (σ) and European genotype (●) red deer stags comparative to estimates for the same genotypes, Australian (△) and European (O), using the equation of van den Berg and Garrick (1997) with stag data derived from Woodford (1997).

Given confidence in the spreadsheet model, combined with the suitability of the existing FEEDMAN DSS package for modification and incorporation of deer production modules (Section 3.1), the proceeding technical parameters were developed. Deer production algorithms and assumptions were incorporated into the existing DSS template based on Microsoft® Access 97 (© 1996 Microsoft Corp.) using Visual Basic™ programming.

3.2.1 Herd descriptions - Deer

Mobs of deer on the farm are allocated to paddocks and are described in terms of name, animal class (eg. ARS equals Australian Red deer Stag), initial liveweight, number, and age. Only growing animals (stags, castrates and non-pregnant, non-lactating hinds) are classified. Breeding hinds are not currently accommodated in the program. The red deer genotypes in Queensland have been described for comparative purposes as both Australian genotypes (derived from *Cervus elaphus scoticus*) and the larger European genotypes (*Cervus elaphus hippelaphus*, incl. hybrids) as indicated by Woodford (1997). For the purposes of this software program both Javan rusa (*Cervus timorensis russa*) and Moluccan (*Cervus timorensis moluccensis*) x Javan hybrids are classified as 'Rusa' only with no genotype distinctions in production calculation. Liveweight of each deer mob each month is then estimated. Where indicated, velvet production is also allocated to a mob of stags.

Since a paddock may contain more than one deer mob and more than one forage, this complexity is accommodated by:-

(i) expressing the number and class of deer in each mob

(ii) calculating liveweight gain for mobs on each forage in the paddock, and when a paddock contains more than one forage, the liveweight gain for the highest performing forage is used.

Appropriate deer mob names are tabulated below.

Red deer mob names	Rusa deer mob names
Weaner stags or hinds	Weaner stags or hinds
Yearling stags, hinds or castrates	Rising 1 year (R 1 yr) stags, hinds or castrates
2 year old stags, hinds or castrates	Rising 2 year (R 2 yr) stags, hinds or castrates
3 year old stags, hinds or castrates	Rising 3 year (R 3 yr) stags, hinds or castrates
Mature stags	Rising 4 year (R 4 yr) stags or castrates
	Mature stags

It is likely that for red deer, mature stags (> 2 year old) may be kept for velvet production and farmed as a separate mob. However regarding venison production, stags, hinds or castrates would ideally be sent to market by 3 year old. Note that velvet stags may be culled for venison production at any age. Rusa deer, due to predominantly mid-year calving patterns, are termed as 'rising age' animals as at January of each year, or weaners in their year of birth. In view of the lower priority for velvet production from rusa deer, it is likely no production class of entire male rusa deer will be retained past 4 years of age. Again, with regard to venison production, stags, castrates and hinds would ideally be sent to market by 3 year old.
Male deer are normally castrated at 8 to 10 months of age, hence castrate mobs are only available initially as yearling or R 1 yr respectively for red and rusa species. Deer age categories assume red deer calves are born October to December and weaned in March, while rusa deer calves are predominantly born in March to May and weaned in August/September.

3.2.2 Standard animal - Cattle

The standard animal is a crossbred weaner steer of 200 kg (Brahman X British). Potential liveweight gain, PLWG, is the liveweight (kg/head/d) gain by a standard animal at low stocking rate in a good season on a defined forage type. The PLWG is an integral component of the new software package (Section 3.2.3) with values derived from a default table or manually entered by the user (Rickert *et al.* 1996). It is the upper limit of liveweight gain obtained when monthly forage growth is near to a maximum. Usually, predicted liveweight change, LWC, is less than PLWG in response to the proportion of forage growth previously consumed, ie forage utilisation. However, PLWG needs to be adjusted to account for two special situations.

(i) A month of low rainfall impacts on PLWG irrespective of forage utilisation because forage quality declines. Under these conditions PLWG is reduced.

(ii) A very wet month impacts on PLWG because of a dilution of forage protein or by changing the grazing behaviour of cattle. Under these conditions, PLWG is reduced.

Sustainable stocking rate (Ssr_f) demonstrates the strong linkage between monthly forage growth, a safe level of forage utilisation and stocking rate. Utilisation (%) is the proportion of forage growth consumed by cattle or deer; it increases directly with stocking rate. If utilisation exceeds a critical value then pasture degradation is likely to occur. Thus, if the critical or safe level of utilisation for a forage is known, the stocking rate that gives that level of utilisation is called a sustainable (safe) stocking rate.

$$Ssr_{farm} = \sum Ssr_f$$

where Ssr_{farm} is the monthly sustainable stocking rate for the farm.

Ssr_f demonstrates seasonal fluctuations in monthly forage production and likely feed shortages. In practice, feed surpluses in the wet season tend to offset feed shortages in the dry season and Ssr_{farm}, averaged over a year, is a good indicator of a safe stocking rate in relation to overall feed supply.

3.2.3 Calculation of liveweight change for Deer[1]

The procedure in the new software program (Section 4.1) for calculating animal liveweight change is illustrated in Figure 4. Notice that 3 production model sectors have been identified, namely;

(i) a Steer bio-assay,

(ii) Supplementary feeding and

(iii) Derivation of feed intake (defined as dry matter intake (DMI)) and subsequent calculation of liveweight change from associated ME intake data.

[1] Note that procedures for estimating beef cattle production (liveweight gain) were modified from the existing FEEDMAN package (version 2.0) and are now based on the use of both Metabolisable Energy (ME) and Net Energy (NE) systems as described in the Feeding standards for Australian livestock – Ruminants (SCA 1990), including recent modifications introduced by Hall (1996) and Freer *et al*. (1997).

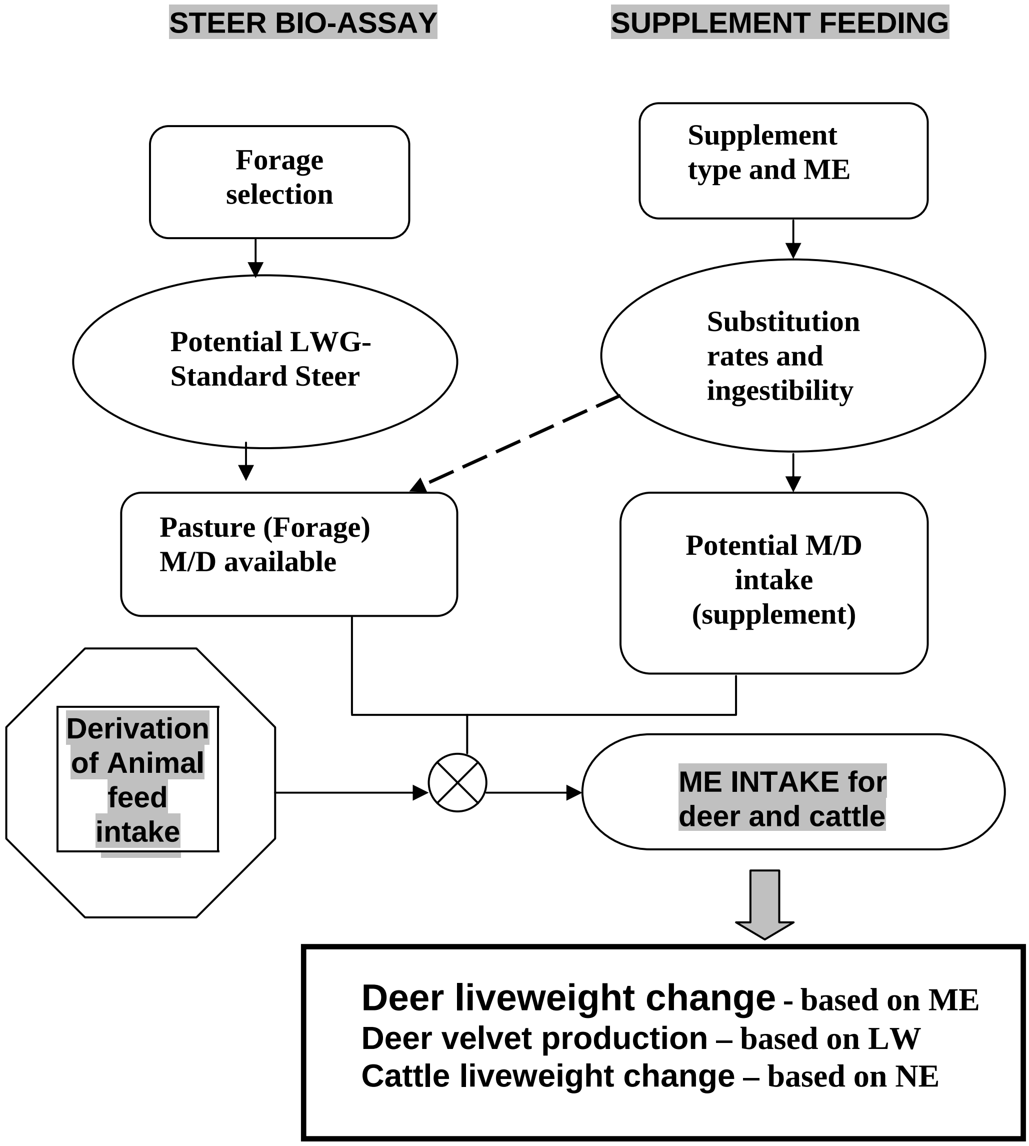

Figure 4 Animal production model sectors (modules)

3.2.3.1 Steer bio-assay

Estimated energy values or M/D (MJ ME/kg DM) of a specified forage is derived from the regression equation (below) of liveweight change and ME diet calculated for a standard animal using prediction equations for animal production based on Australian ruminant feeding standards (SCA 1990). This is referred to as the 'steer bio-assay'.

ME of forage (MEf) = $2.7664 * Plwg_{f,m} + 7.9176$ ($R^2 = 0.983$)

where potential monthly liveweight gain for a forage ($Plwg_{f,m}$) by a standard animal is subject to adjustments.

3.2.4 Supplementary feeding – Deer

Supplementary feeding can be specified for each paddock in terms of type, amount, and duration of feeding. One of nine (9) supplements can be selected and can be defined as either 'Good' or 'Average' which will then provide key M/D values and supplement relative ingestability values (Rel_IngS) as illustrated in Table 3. The Rel_IngS factor is calculated from supplement M/D values (SCA 1990) and a ingestability function for supplements specified by Hall (1996). Relative ingestability is a function of digestability and expressed as a decimal. Note that the rationale in this section is also applicable to beef cattle in the new software model.

Table 3 Supplement types and associated energy and ingestability values

Supplement Type #	Rating 'Good'		Rating 'Average' ##	
	M/D	Rel_Ing	M/D	Rel_Ing
Cottonseed meal (CSM)	10.5	0.89	9.5	0.79
Other Protein meal	11.5	0.99	10.5	0.89
Fortified Molasses	10.0	0.84	no value	no value
Pellets	12.0	1.04	no value	no value
Grain	12.0	1.04	11.0	0.94
Maize grain (Corn)	12.2	1.06	11.5	0.99
Lucerne hay	9.5	0.79	8.0	0.64
Pasture hay	7.5	0.59	no value	no value
Silage	10.0	0.84	8.5	0.69

\# Other protein meals include soybean, sunflower, whole cottonseed etc. Fortified molasses is based on a general industry formulation of 84% molasses, 3% urea, 3% minerals and 10% protein meal. Pellets refer to industry stockfeed company formulations providing generally 'complete' energy and protein supplements in pelletised form.
\#\# Assumes pellets and molasses of uniform 'Good' quality, Average values default to Good values. Note that with regard to pasture hay supplement type, only 'Good' quality is an option for deer (see information below).

Relative availability of a supplement (Hall 1996), Rel_AvailS, is defined as:-

Rel_AvailS = MIN(1.0, 10.0/ME_{supp}, amt. of supplement/PI/Rel_IngS) decimal

Where ME_{supp} is the M/D value for a supplement, PI the potential intake of DM by the animal, and Rel_IngS the relative ingestibility factor.

The relative intake of a supplement (Hall 1996) is then derived as,

Rel_IntS = Rel_AvailS * Rel_IngS decimal

The DMI of a supplement is then a function of PI and relative intake of the supplement 'Rel_IntS' such that;

DMI_{supp} = PI * Rel_IntS kg DM/hd.d^{-1}

The amount of supplement offered to animals can not exceed 2.5% of bodyweight for Lucerne Hay; 2.0% of bodyweight for Grain, Corn, Silage and Pasture Hay; 1.5% of bodyweight for CottonSM, Pellets, OtherProtMeal; and in the case of FortifiedMolasses 0.5% bodyweight. These restrictions are designed to ensure that this FEEDMAN program is centred on forage-based production systems. The software model is not suitable for animals removed from a forage base (pasture/crop) for situations of say drought feeding in yards or 'sacrifice' paddocks nor lot-feeding situations.

Supplements fall into two categories according to whether they increase or have no effect on the intake of pasture (associative effects), or depress the intake of pasture (substitution effects). It is desirable that supplements have ME values exceeding forage quality M/D on offer, and assume that animals select supplement before selection of similar or inferior quality forage (Hall 1996). Experience with supplementation of deer suggests that only good quality feedstuffs should be offered in view of diet selectivity and feed intake modifications. In this respect good quality pasture hay is applicable, however crop stubble hay and poorer quality roughages are generally not suitable for deer production systems.

Substitution rates (Sub_Rate; reduction in pasture intake per unit intake of supplement) are influenced by both pasture quality, supplement quality and forage yield, $Yieldf_{f,m}$ (herbage mass), with lower substitution rates as forage yield declines (SCA 1990). Pasture or forage quality is defined as high or low if M/D value derived from steer bio-assay ≥ 9.5 or < 9.5 respectively. Four substitution rate scenarios exist, based on linear regression extrapolation of substitution rate response curves for variable supplement quality and forage quality and yield as defined in SCA (1990), namely:

(i) Good supplement and High quality forage or pasture

$Sub\_Rate = MIN(0.0896X, 0.064X + 0.811, 1.0)$ decimal

Where $X = Yieldf_{f,m} / 1000$

(ii) Good supplement and Low quality forage or pasture

$Sub\_Rate = MIN(0.5617X, 0.046X + 0.418, 1.0)$ decimal

(iii) Average supplement and High quality forage or pasture

$Sub\_Rate = MIN(0.376X, 1.0)$ decimal

Where $100 < X <= 1000$ kg DM/ha

(iv) Average supplement and Low quality forage or pasture

$Sub\_Rate = MIN(0.9071X, 0.09X + 0.654, 1.0)$ decimal

Change in forage intake with supplement fed is then,

Change DMIf = Sub_Rate * DMIs kg DM/hd,

where DMIf is intake of forage.

Recalculation of forage intake DMIf = actual DMI of forage adjusted for any supplement use and substitution, eg. a supplement fed with DMIs of 0.5 kg/hd and Sub_rate of 0.5 means that DMIf is reduced by 0.25 kg/hd.

Feeding pasture hay (good quality only) to deer as a supplement should be confined to limited feeding on lower quality or low yield forage, and to rusa deer production systems rather than red deer production systems. Feeding poorer quality supplements on higher quality pasture suggests that at a higher forage yield on offer, progressive refusal of the supplement will occur (SCA 1990). Consequently in situations of high quality pasture, supplement feeding is constrained to conditions where forage yield ($Yieldf_{f,m}$) is > 100 and < 1000 kg DM/ha. A supplement M/D test is calculated such that supplement M/D must be ≥ forage M/D (i.e. $ME_{supp} \geq MEf * Rif_{f,m}$) otherwise a warning is evident to change forage type; and where $Rif_{f,m}$ represents a restriction index factor describing the reduction in intake that occurs as stocking rate increases or duration of grazing increases (Rickert *et al.* 1996).

In order to accommodate the production responses to protein meals such as cottonseed meal in an energy-based system, the M/D value has been modified to reflect observed growth responses associated with protein intake (Cheffins 1996). Response to protein meal supplementation declines with intake level and is also influenced by forage quality (M/D) and intake factors;
Thus, where CottonSM is the selected supplement,
MEIsupp = DMIsupp * MEsupp * MEsuppPmodifier

3.2.5 Derivation of dry matter intake (DMI) - Deer

Relative intake (Rel_Int) is derived from the regression equation of liveweight change (LWG) and RI calculated for a standard animal using prediction equations derived for animal production based on Australian ruminant feeding standards (SCA 1990).

$Rel\_Int = 0.1774 * Plwg_{f,m} + 0.7639$ ($R^2 = 0.983$)

Potential intake (PI) = 0.024*LW*(1.7-ELW/SRW) as defined in SCA (1990),
where SRW is standard reference weight and ELW = start_LW (“Jan”), then subsequent monthly LW.

SRW refers conceptually to the weight an animal (eg. a beef steer) reaches when it attains its mature skeletal size with median condition score (SCA 1990; as interpreted by Hall 1996). It is influenced by breed and sex, and while no data is available for defined SRW values for deer, estimated SRW values based broadly on mature weights assumed from literature (Sinclair 1999) and modified by sex and breed (genotype) have been used. With regard to hinds, further numerical adjustments for genotype and age have been made. Animal classifications and associated SRW values used in FEEDMAN v 3.0 for deer are provided in Table 4.

Table 4 Standard reference weights (SRW) for particular deer breed and sex

Animal Class code	Class/breed	SRW (kg)
ARS	Australian Red deer Stag: Australian genotype	190
ARC	Australian Red deer Castrate: Australian genotype	190
ARH	Australian Red deer Hind: Australian genotype < 16 months	130 #
	Australian Red deer Hind: Australian genotype ≥ 16 months	155 #
ERS	European Red deer Stag: European genotype (incl. hybrids)	210
ERC	European Red deer Castrate: European genotype (incl. hybrids)	210
ERH	European Red deer Hind: European genotype (incl. hybrids) < 16 months	150 #
	European Red deer Hind: European genotype (incl. hybrids) ≥ 16 months	180 #
RUS	Rusa deer Stag: Javan and J x Moluccan hybrids	130
RUC	Rusa deer Castrate: Javan and J x Moluccan hybrids	130
RUH	Rusa deer Hind: Javan and J x Moluccan hybrids	95 #

Estimated mature weight with additional numerical adjustment upward for potential intake calculation.

The estimated actual dry matter intake of a forage by deer (DMIf) is a function of the potential intake of the animal, an intake modifier or restriction index based on forage utilisation ($Rif_{f,m}$), and class indices (CI). Class indices refer to sex x season interactions evident in deer > 12 months of age with regard to feed intake potential. For red deer only, genotype is also a feed intake modifier. Both CI and genotype intake modifiers are expressed as numerical factors and range from 0.85 to 1.10. The minimum feed intake restriction indice is applied.

Deer species have identified cyclical feed intake patterns influenced by environmental and hormonal factors, and are more pronounced in stags than hinds or castrates. Temperate zone adapted red deer have greater CI magnitude than tropically adapted rusa deer. Such cyclical feed intake patterns generally only become evident in animals > 12 months of age.

Determination of actual DMI for forage (DMIf) is calculated thus:-

Red deer

$DMIf = PI * MIN(Rel\_Int, Rif_{f,m}, CI) * \text{Genotype factor}$ kg DM/hd.d^{-1}

and

Rusa deer

$DMIf = PI * MIN(Rel\_Int, Rif_{f,m}) * CI$ kg DM/hd.d^{-1}

The actual intake of a forage is also adjusted for any supplement use and substitution.

3.2.6 Derivation of liveweight gain (LWG) - Deer

The Metabolisable Energy Intake for an animal (MEI) is the summation of ME intake from forage and supplement (if fed), such that:-

$MEI = DMIf * MEf + DMI_{supp} * ME_{supp}$ MJ/d

Coefficients for maintenance energy requirements (coeff.MEm) for deer are derived from Basedata tabulations using values compiled from literature (Woodford 1997; Sinclair 1999). MEm coefficients are expressed in MJ/kg $^{0.75}$ /d and are influenced by sex and age. Genotype is also an implicating factor for red deer with adjustments for 'Australian' or 'European' genotypes reflective of the higher proportional ME requirements for larger 'European' red deer implied from literature (+ 14% for weaners and + 6% for yearlings and older; refer Sinclair 1999).

Determination of MEm values for animals = ELW $^{0.75}$ * coeff.MEm MJ/d

where ELW = start_LW ("Jan"), then subsequent months, cumulative monthly LW, ie. $\sum$LW (mth(n1)..mth(n12)

ME available to the animal for production (MEp; ie. growth and LWG) is the arithmetical difference between ME intake and MEm, whereby

MEp = MEI – MEm MJ/d

Coefficients for animal production energy requirements (coeff.MEp) for deer are derived from Basedata tabulations using values compiled from literature (Woodford 1997; Sinclair 1999). MEp coefficients are expressed in MJ / kg LWG and are influenced by sex and age. Genotype is also an implicating factor for red deer. Determination of deer LWG for each forage in a paddock (Deer $LWG_{f,m}$) is determined by:-

Deer $LWG_{f,m}$ = (MEp / coeff.MEp) * 1000 g/d

With the maximum $LWG_{f,m}$ across forages selected as Deer LWG_m.

Liveweight for the *m* th month for each mob is given by:-

Deer $LW_m = LW_{m-1} + (LWG_m * 30.4 * 1000)$ kg/head

Forage yield is updated in response to intake, trampling and senescence as described in Ricker *et al*. (1996).

3.2.7 Calculation of velvet production for Deer

The procedure for estimating velvet production from entire male deer (ie. stags) is based on several factors depending on species and age;

Red deer stags

- yearling (spiker) velvet harvested at age > 10 months and ≤ 16 months is estimated by using either a default value or manually entering local default data.

- Mature stag velvet production (generally > 22 months of age) is derived by default from;
  (a) the allometric equation of van den Berg and Garrick (1997), such that:-

  $Y = 0.21 * X^{1.4}$

where Y is the velvet weight (10^{-2} kg) and X is the arithmetic mean of stag liveweight in the velvet mob from September to December, ie. $X = (\sum_{m=9}^{12} LW_m) / 4$, or

(b) Default values from database for deer covering two age groups, namely > 16 and ≤ 48 months, and > 48 months of age.

Default values for mature velvet production may be replaced by manually entering own default data if available for animal classes.

Rusa deer stags

- Yearling (spiker) velvet harvested at age > 10 months and ≤ 16 months is estimated by using either a default value or manually entering own data if available.
- Default values are provided for mature rusa stag velvet production covering two age groups, namely > 16 and ≤ 48 months, and > 48 months of age. Alternatively local data may be entered if known for particular animal class.

Generally only stags greater than 12 months of age are able to provide velvet production parameters. The decision to have a 'velvet mob' and harvest velvet is entirely optional, and likely to be commercially more applicable to red deer rather than rusa deer production systems. Note also that for a mob overall, total velvet production is velvet yield (ie. velvet production per animal; kg/hd) multiplied by the number in the mob (based on the animals on hand at the start of December for convenience).

Liveweight output

Firstly FEEDMAN estimates and stores monthly liveweight of mobs on a paddock-by-paddock basis. Secondly, because mobs might graze more than one paddock, the stored data is collated for mobs across paddocks. Together these two processes provide inputs to the various reports on cattle and deer performance and to the Economic analysis.

3.2.8 Economics

Market options are based on age, sex, and liveweight. With respect to deer farming systems, if velvet production is also selected, market options are based on species and velvet weight. FEEDMAN scans a table of market options for each mob of cattle and deer each month, and selects the option with the highest prevailing price. Thus, if market prices are regularly updated by the user, the prevailing value of animals for a particular mob is calculated as the product of liveweight (and/or velvet weight for deer) and highest prevailing price.

Calculation of variable costs for forages, supplements and animals are determined as described in Ricket *et al*. (1996) using specified input parameter cost lists, market outlets and prices as determined by the user or default values (refer also Table 5; Section 3.3). Mob and farm economics to derive basic operating cash surplus and simplified profit parameters for a farm are modified for a deer velvet mob to include variable costs and derived profit from velvet harvesting.

NetVelvetValue = VelvetPrice * VelvetYield - VelvetVetCost

whereby
ProfitAnimal = Animal value (+ NetVelvetValue)- TcsystAn $/head

Where NetVelvetValue is the net value of velvet production for the designated velvet mob and is calculated for December only (for convenience). Note that Animal value for deer does not include value for velvet antler, which is categorised as a separate item and included in farm profit ($ProfitFarm_m$). Note that all cattle classes, and deer classes excluding stags will not include 'Velvet Value' in economic analysis.

If sales have occurred then system profits (SystProfits) for the n th mob and m th month are given by:-

$$SystProfits = Saleno * [Animal\ Value\ (+\ NetVelvetValue_{n,r}) - Total\ system\ costs - Variable\ sale\ costs]\ \$$$

Finally, profit of a farm with mobs of cattle or deer ($ProfitFarm_m$) is given by:

$$ProfitFarm_m = \sum_{n=1}^{n=tm} SystProfits_{n,m}\ (+ \sum_{n=1}^{n=tm} NetVelvetValue_{n,m})$$

Designated stag velvet mobs can include a market option of culling for venison production at any age. Mature stags during the mating season (rut) have undesirable meat quality characteristics and behaviour problems, negating marketing during the period of late February/March to July for red deer stags and generally from May to September for rusa deer stags. Castrates, and non-lactating, non-pregnant hinds (ie. females for meat production) can be marketed all year.

3.3 Input data

The existing FEEDMAN DSS is characterised by the detail employed in analysis with respect to input data and outputs produced (Gaffney 1997). In order to model feed supply and quality on a property (and hence enable animal intake and resultant animal production outputs) the user identifies type of country (land units), fertility and water holding characteristics of the soil, type of pasture and forage and its condition, and an indication of tree density if applicable. Rainfall data for the region can either be accessed from a comprehensive default list or entered manually. The user is then able to identify animal types and classes for inclusion as 'mobs' on the paddocks, and provide additional information on supplementation in the paddock if so desired. Animal production outputs are complimented by economic analysis derived from data input on forage and animal variable costs and specified market prices. The range of inputs required for FEEDMAN are listed in Table 5.

Table 5 List of input items and actions within the FEEDMAN DSS

Input Item	Default Values	Action for Change
Farm description		
Total farm area, area designated for deer	none	enter new
Paddock areas and names	none	enter new
Land Units or soil type/vegetation associations		
Name and land units	select	add to list
Total soil nitrogen for the land unit	given	enter new
Plant available water content for soil type	given	enter new
Forages		
List of forage types	select	no changes #
Tree density in forage	0	enter new
Condition of forage	good	select new
Nitrogen fertiliser applied	0	enter new
Lifespan	given	enter new
Cost of machinery, seed, fertiliser and chemicals	given	enter new
Rainfall		
Historical records for different stations	select	no changes #
Local monthly rainfall	0	enter new
Animals		
Breed and class of cattle	select	no changes #
Species, genotype and class of deer	select	no changes #
Type of supplement	select	no changes #
Cost of supplement	given	enter new
Cost of cartage, commission, yard dues	given	enter new
Veterinary charges	given	enter new
Cost of velvet antler removal (velvet costs)	given	enter new
Interest on buying price	given	enter new
Base data		
Market Name and specification	select	add to list
Monthly market prices	given	enter new
Monthly rainfall use efficiencies for forages	given	enter new
Monthly potential liveweight gain for forages – Standard animal (x-bred weaner steer) ONLY	given	enter new

no changes are possible because the given lists are coupled to specific parameters or computer code.

4. Results

A quantification of the results of the new FEEDMAN DSS (v 3.0), as detailed in this Section, is based on a 'tutorial exercise' described within the user manual accompanying the CD-ROM package. A description of the tutorial exercise is provided in the appendices (Appendix I).

4.1 Components and structure of FEEDMAN v 3.0

Since FEEDMAN predicts animal performance and economics in a wide range of scenarios; farm forages, rainfall, management options and economic conditions need to be described. This is a complicated task that occupies a large part of the package and is represented in Figure 5 by the boxes on the left-hand side. Scenario descriptions are then processed in 3 steps: forage production (growth and quality), animal production and economics, as represented by the central boxes in Figure 5. After data processing, the results appear as reports or graphs for the various components, as shown by the right hand boxes in Figure 5.

In practice, FEEDMAN consists of 3 linked databases. One for data input, processing and reporting, one for base data that can be copied and customised for different regions, and one for storage (and retrieval) of each farm description. The compiled new version of FEEDMAN encompasses both deer and beef cattle production systems, existing as IBM-compatible CD-ROM software to be distributed by Queensland Department of Primary Industries as 'FEEDMAN v 3.0'.

Requirements for FEEDMAN v 3.0
FEEDMAN will run on any IBM-compatible PC with the following minimum requirements:

- 486 CPU processor but a higher processor is recommended;
- Microsoft Windows 95™ or later;
- CD ROM drive
- Microsoft Mouse® or other compatible pointing device;
- VGA or sVGA colour monitor;
- 32 Megabytes (MB) of random-access memory (RAM);
- a hard disk with at least 10 MB of free space;
- although strongly recommended but not essential, an 80 column printer with graphics capability will allow the reports and datasets from FEEDMAN to be printed; and
- although optional and not essential, if Microsoft Word™ and Microsoft Excel™ are also installed, data can be transferred from FEEDMAN into these packages.

FEEDMAN was compiled in Microsoft Access 97 and has many of the regular features of other products operating in Windows™.

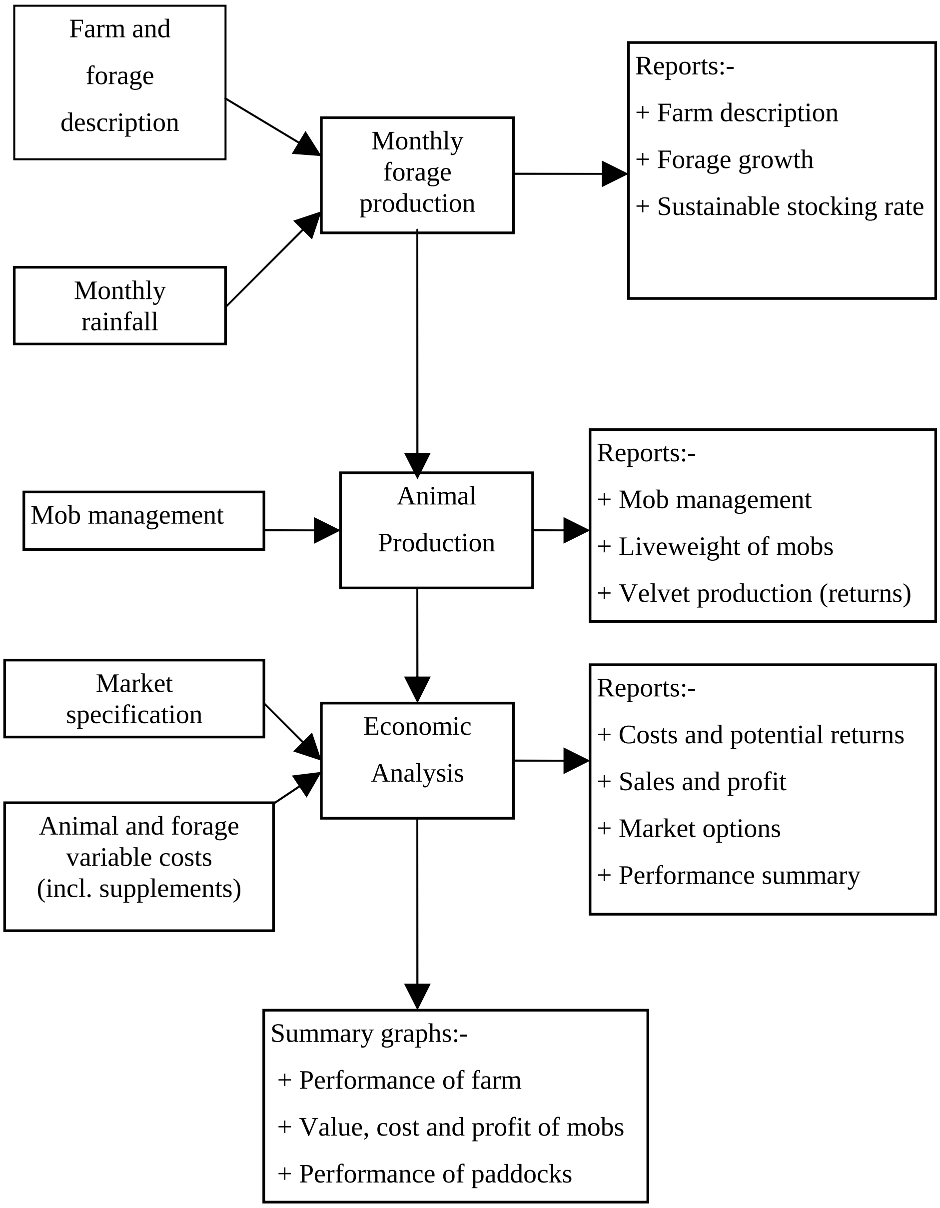

Figure 5 Components and structure of FEEDMAN and their interaction (modified from Rickert *et al.* 1996)

4.2 User interface

The FEEDMAN v 3.0 program interface is based on a Microsoft® Access 97 form design incorporating user-friendly dialogue boxes, option and data entry buttons, and help notes (Figure 6).

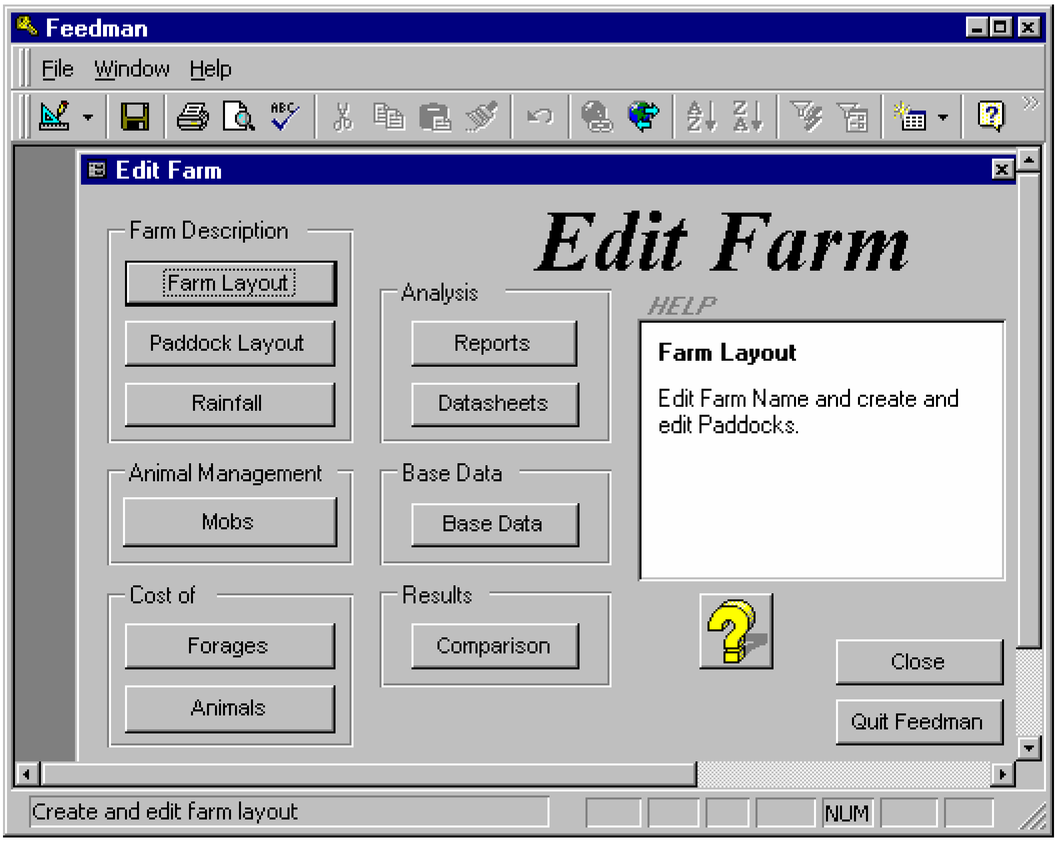

Figure 6 Example of a screen interface for FEEDMAN v 3.0 DSS.

The interface has been designed to allow ease of data entry and management/farm input option selection. An extensive range of help notes in FEEDMAN are available for explanations on the operation of the package. Three types of help notes exist:

1) A help box on the right side of each data entry window displays a brief explanation of the button or field under the cursor.
2) On-line help, activated by the F1 key or ? button, displays explanations of components of FEEDMAN, topic by topic, in a manner that is typical of Microsoft products.
3) Advice and warnings in message boxes point to the possibility of errors in data entry or processing.

In addition, the following colour codes are used for windows in FEEDMAN to assist data entry and function.

- white fields are available for data entry;
- green fields contain totals that cannot be changed directly;
- yellow fields contain supporting data that cannot be changed directly;
- buttons with black text carry out a routine function;
- buttons with red text modify, process or delete data.

Outputs of the program are provided for both in report form and graphically, and may be either printed directly or saved as data files and transferred to other Microsoft packages (refer Section 4.1).

4.3 Program features

FEEDMAN is designed for individual farms that are described by a set routine that is versatile, user friendly and suitable for testing a wide range of management options. A relational database is useful in this situation because components of a farm description can be stored in separate but linked tables.

To assist a user in describing a farm, information is supplied in a series of windows designed for data entry. Where possible, input information is selected from a list supplied by the system. Six steps need to be completed:

(i) enter the name and area of a farm and the name and area of its paddocks;
(ii) select the type and area of land units in each paddock, and type and area of forage in each land unit from lists provided;
(iii) select or enter monthly rainfall for a chosen location;
(iv) allocate mobs of cattle or deer to the various paddocks, their sequence of grazing and supplementation;
(v) specify variable costs for the forages and animals; and
(vi) calculate results and inspect results as reports, datasheet tables and graphics.

Steps can be repeated to change the farm description to test different management options. An example of the above process is provided by the tutorial exercise described in Appendix I. Basedata is used to inspect or modify default values for costs, markets (specifications and prices), forage growth and animal production.

A paddock is a fenced area of forages (pasture or crop) that can be grazed by cattle or deer. It may contain any number of land units and any number of forages. Each paddock is described by a unique name and area, the type and area of land units it contains, and the type and area of forage within each land unit. Cattle and deer can be grazed on the same property, however the user must specify a defined deer farm area within the overall farm description by nominating specific deer paddocks. Consider the grazing for each mob separately, commencing with January and moving in sequence to December. Mobs may move between paddocks and sales are indicated by a reduction in mob number across months. However, to split a large mob across paddocks will create animal transfers misinterpreted as sales. Rather, it is desired to create individual mob records for each small mob planned to eventually split from a large mob. Any number of mobs may graze a paddock concurrently, with the exception that cattle and deer can not graze concurrently. Cattle can graze in paddocks nominated as deer paddocks, but deer can not graze in paddocks that exist outside nominated deer paddock areas. Deer farming requires specialised fencing; so logically, while cattle can graze behind a deer fence, deer will not be adequately restrained behind a standard cattle fence. Consequently deer mobs must graze the specified deer paddocks.

When selecting for velvet antler (velvet) production with deer, it was seen to be advisable to differentiate deer mobs within paddocks into velvet and non-velvet mobs in order to separate market strategies and mob management for liveweight performance and velvet growth.

A land unit, or soil-vegetation unit, is described by the original vegetation type and the associated soil type, which is further characterised by total soil nitrogen (%, 0-10 cm) and plant available water capacity (mm in root zone). The original vegetation type usually has distinguishing features (e.g. dominant species) that are reflected in its name. Total soil nitrogen, a reflection of inherent fertility, influences forage growth. Default values in land unit descriptions can be replaced by local values and new landunits can be added to the list.

Forages are listed as groups or types that have similar characteristics. For example, sown grass pastures, based on green panic, buffel grass or rhodes grass are grouped as TropGnolegume (i.e. tropical grass without a legume) because, under similar conditions they give similar animal performance. Furthermore, some groups share the same default rainfall use efficiency (RUE; e.g. native pasture and tropical grass without a legume) because they cannot be separated by experimental evidence.

Input data is compiled and calculated to generate results provided in the form of reports, detailing forage supply/utilisation, mob management and animal production, performance summaries, economics and market options. These reports are supplemented by summary graphics regarding performance and mob value, costs and profit *as per* original FEEDMAN (Rickert *et al*. 1996). The additional deer module also generates, where appropriate, velvet production and value reports. Sustainable stocking rates can also be assessed from input data regarding animal class stocking rate values (default or user modified). The results of a farm scenario 'run' are detailed within a comprehensive range of reports and graphs, which are numerically listed below for convenience:

- **Report (1)** Farm Description. Type and area of land units, soil types and forages in each paddock, listed in alphabetical order.
- **Report (2)** Forage Growth. Monthly growth of forages in each paddock, along with total forage growth on the farm.
- **Report (3)** Stocking Rates. Monthly sustainable stocking rates, expressed as adult equivalents, or weaner equivalents, for each forage. Sustainable stocking rates consume 30% of forage growth.
- **Report (4)** Management. Description of each animal mob in a paddock, its period of grazing and supplementation, plus total number of animals on the farm.
- **Report (5)** Monthly Liveweight. Liveweight of each animal mob, together with type and amount of supplementation.
- **Report (6)** Market Options. Highest priced market for each mob of cattle or deer on a month-by-month basis.
- **Report (7)** Per Animal. Animal value, and components of variable costs ($/head) for each animal mob, accumulated across months.
- **Report (8)** Mob Sales Outcomes. Number, value and profit from sales for each animal mob on a month-by-month basis.
- **Report (9)** Performance. Monthly animal liveweight, and average forage yield and utilisation, for each mob/paddock combination.
- **Report (10)** Velvet Production and Returns. Yield, net value and market option for select deer (stag) mobs where velvet antler is harvested (removed).
- **Graph (1)** Farm Graphs. Monthly sales, profit, variable costs, and average forage yield and utilisation, for the whole farm.
- **Graph (2)** Mob Graphs. Variable costs, value, and potential profits for a selected mob.

- **Graph (3)** Paddock Graphs. Monthly yield and utilisation of each forage in a selected paddock.
- **Graph (4)** Farm Comparison. Sustainable stocking rates and annual cash flow for a selection of different farms or scenarios.

An example of an overall system performance report is provided in Table 6. This type of report illustrates the plethora of information that FEEDMAN generates, and has been considered by Gaffney (1997) as the most valuable of reports. Specifically, the performance summary in Table 6 illustrates, for specified monthly rainfall, paddock ID (denoting area and soil type, fertility) and forage type (including supplementation), results in calculation of forage yield, utilisation and animal performance are generated. Note that both cattle and deer can be accommodated on the same property. Monthly liveweight performance is recorded for both species, with stags in this example also selected for velvet production, which has been duly calculated and recorded. Monthly liveweight gain is provided as a graphic option for individual mobs within the 'mob list', and is illustrated for the red deer stag mob in Figure 7.

Table 6 Example of a performance summary report from a hypothetical beef and deer property in southern Queensland as described in Appendix I

Performance: Average performance of mobs and forages in each paddock *09-Oct-99*
Farm Name:- **TUTE1** Rainfall Description:- **SOI Ignored ; Median Year** Rainfall Station:- **MILES**

Item of Performance	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Rainfall mm/month	102	62	54	30	33	37	40	27	29	61	71	89

Mob:- 110 Weaner steers; XBS class **ID2**:- 16 **Paddock**:- NP/Back **Forage**: 2 forages in pdk
Supplementation:-Grain at 2 kg/hd/d from May to Aug **LW(kg/head), start**:- 180 **max**:282 **Velvet kg** 0

AvLiveWeight kg/head	0	0	0	189	203	215	225	236	243	252	266	282
AvForageYield kg/ha	1747	2056	2224	2048	1790	1530	1289	1180	1153	1611	2269	3143
AvForageUtilisation %	27	26	26	31	34	36	37	38	39	36	32	27

Mob:- 90 2 yr-old stags; ARS class **ID2**:- 19 **Paddock**:- SP/Deer **Forage**:TropGnolegumeNew
Supplementation:-none **LW(kg/head), start**:- 140 **max**:151 **Velvet kg** 2.27

AvLiveWeight kg/head	144	147	148	148	147	146	144	142	144	146	148	151
AvForageYield kg/ha	1532	1806	1968	1889	1724	1438	1179	1048	1011	1389	1944	2649
AvForageUtilisation %	26	25	26	28	30	32	35	37	38	35	32	28

XBS X-bred steer ARS Australian Red Stag

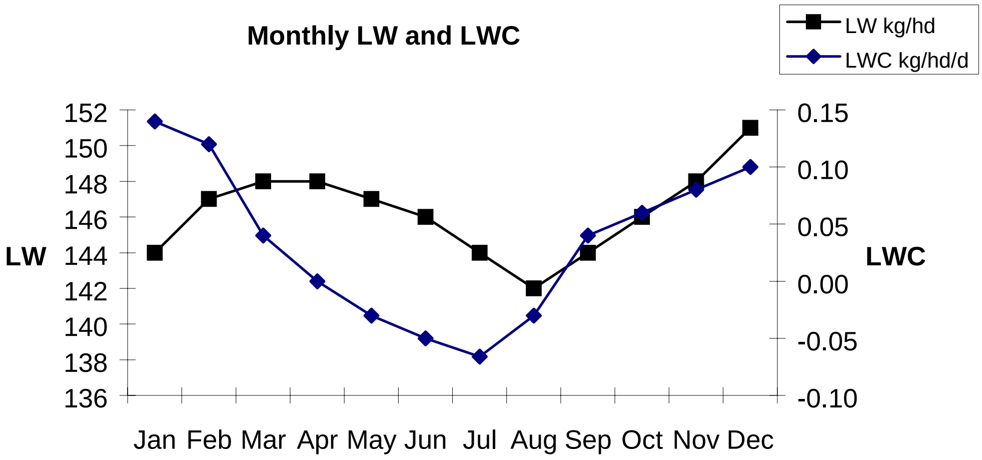

Figure 7 Example of 'Performance Summary of Mob' graph taken from 'Mob List' for Mob description: **ARS**; Name: **2 yr-old stags**; Number in mob **90** *as per* farm tutorial exercise (Appendix I). LW = liveweight and LWC = liveweight change

Reports and graphs in FEEDMAN also generate a range of economic information, specifically farm and mob variable cost and profit data. An example of sales and profit report is shown in Table 7. Note that mob sales are tracked on a monthly basis, and where a deer mob is identified, velvet harvesting is indicated if applicable. It is important that velvet harvesting is recognised (where applicable) in that, for the case of the 2 year old stags in Table 7, animal sale value and profit for mob in December is inclusive of both live animal sale value and velvet value.

Table 7 Example of a mob sales outcome report from a hypothetical beef and deer property in southern Queensland as described in Appendix I

Mob Sales Outcome *09-Oct-99*

Farm Name:- **TUTE1** Rainfall Description:- **SOI Ignored ; Median Year** Rainfall Station:- **MILES**

Cash Flow Effect	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mob:- 80, 2 yr-old steers; XBS class **ID:-** 18 **Paddocks:-** SP/Road; Crp/House **Velvet:-** No												
Supplementation:- None **Initial Cost/hd** $558.00												
i Number of Sales	0	25	0	20	0	0	20	0	60	0	0	0
ii Value of Animal $		16185		12975			13104		46413			0
iii Profit from Sales $		592		212			-288		3873			0
Mob:- 90, 2 yr-old stags; ARS class **ID:-** 19 **Paddocks:-** SP/Deer **Velvet:-** Yes												
Supplementation:- None **Initial Cost/hd** $168.00												
i Number of Sales	0	0	0	0	0	0	0	0	0	0	0	25
ii Value of Animal $												23949
iii Profit from Sales $												17155
Farm Cash Surplus/Deficit												
$'000/mth	0.0	0.6	0.0	0.2	0.0	0.0	-0.3	0.0	3.9	2.5	1.2	17.2
$'000/year	25.3											

4.4 Validation and evaluation

The outputs of FEEDMAN were validated and evaluated both 'qualitatively' to see if they agreed with the experience of researchers and extension staff as well as 'quantitatively' by comparison with unpublished field datasets derived from the University of Queensland (UQ)-Gatton College deer unit.

Validation is an essential component of the testing of a model, and evaluation of outputs appropriate for its intended purpose (Harrison 1991). Validation studies of observed versus predicted forage yield using the existing FEEDMAN beef cattle management package have already been completed by Rickert (1998) over a range of forages and soil types. The line of best fit had an R^2 value of 0.79; considering the complexity of modelling a 'whole property' and interpreting forage production outputs, the relationship of the predicted to observed values appears reasonable. The forage calculation and utilisation functions were unaltered in modification of the package. Aspects of computational efficiency, user friendliness and input data logistics have also been evaluated favourably in previous assessments (Gaffney 1997; Rickert 1998).

Subjective evaluation of the modified FEEDMAN package using deer module outputs has been completed against known, but limited, management and production data for Queensland sourced from a recent literature review (Sinclair 1999) concomitant with initial appraisal by workers experienced in deer production systems. The results were favourable, and also appear to be in agreement with deer farmer observations when correlated to deer turnoff age and weight. While face validity provides a useful initial screening, comparison of performance against field observation datasets is important, with 'live testing' using farm trials in an operational environment with the DSS and expert particularly beneficial (Harrison 1991). Unfortunately proposed live field testing (evaluation) of red and rusa deer production systems has to date been negated by two major factors beyond the researchers control:

1. Recent low returns to farmers and a lack of confidence in the industry (Tuckwell 1999) have resulted in significant herd downsizing and/or management changes on several suitable (from herd number and pasture resource perspective) south-eastern Queensland deer farm test sites, effectively negating any field testing attempts.
2. Rationalisation of resources, in addition to deer industry stagnation, have been largely responsible for the current downsizing of the UQ-Gatton deer unit to a point where field testing at this facility was also not viable.

As a consequence, validation has concentrated on use of unpublished field data derived from observations at the UQ-Gatton deer unit from 1995 to 1997 (K.B. Woodford, *personal communication*). This 'preserved' dataset is essentially the only reliable deer production data from on-farm in Queensland (refer also to earlier discussion regarding spreadsheet model verification, Section 3.2).

Recorded animal production on-farm for both red and rusa deer were evaluated against model generated outputs using a tested prototype of FEEDMAN v 3.0. In addition to input data of birth cohorts, mob management and animal production (liveweight change), details of land units and associated soil types, fertiliser regimes, forage types, irrigation management and supplementary feeding were as detailed for the research farm using information from Elliott (1992) and Woodford (1997) in addition to data provided. As a background to the validation test, the UQ-Gatton deer unit is situated on predominantly yellow podzolic duplex soils and black earths, within open eucalypt woodland communities supporting predominant grass species of couch (*Cynodum dactylon*), rhodes grass *(Chloris gayana*), green panic (*Panicum maximum* var. *trichoglume*) and kikuyu (*Pennisetum clandestinum*). There is a minimal legume component. Comparisons of predicted (FEEDMAN) versus observed (UQ-Gatton) datasets for red deer are shown in Figure 8. The deer were fed supplementary grain (sorghum or barley) in addition to irrigation regimes. A strong similarity in monthly LW trend was noted for red hinds from weaner to yearling growth stages (Figure 8) where measured overall LWG over the 20 month period for observed and predicted data was 95 and 84 g/d respectively. Red deer stags also showed similarity in LW trend, particularly in the first 'rut' as rising 2 year olds, however variability in magnitude of LW response from October to February was noted.

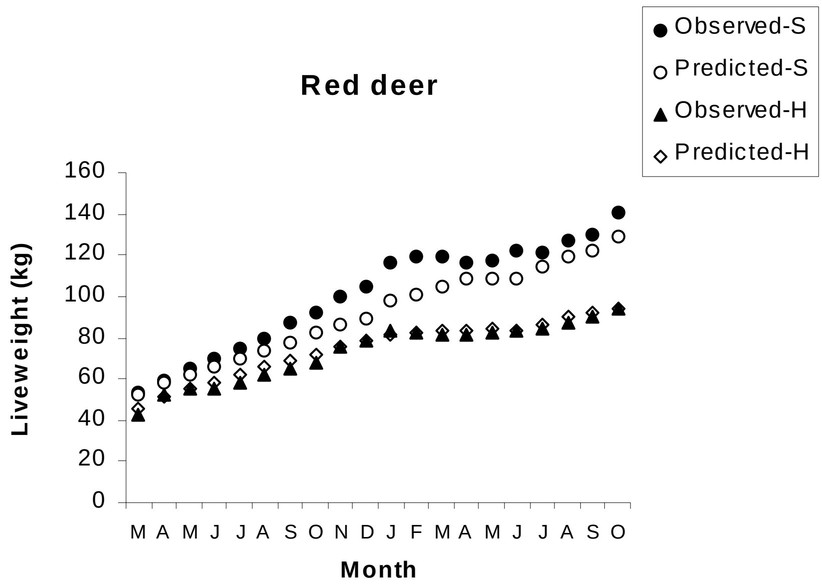

Figure 8 Predicted versus Observed monthly LW for Australian Red deer stags (S) and hinds (H)

Several factors are compounding these observations, namely errors in accurately extrapolating on-farm environment to the program coupled with some problems in interpreting the on-farm irrigation and supplementary feeding regimes in particular. It is also likely that possible compensatory growth on-farm was not interpreted in the model. Observed versus predicted overall LWG for stags over the period were 153 and 127 g/d respectively.

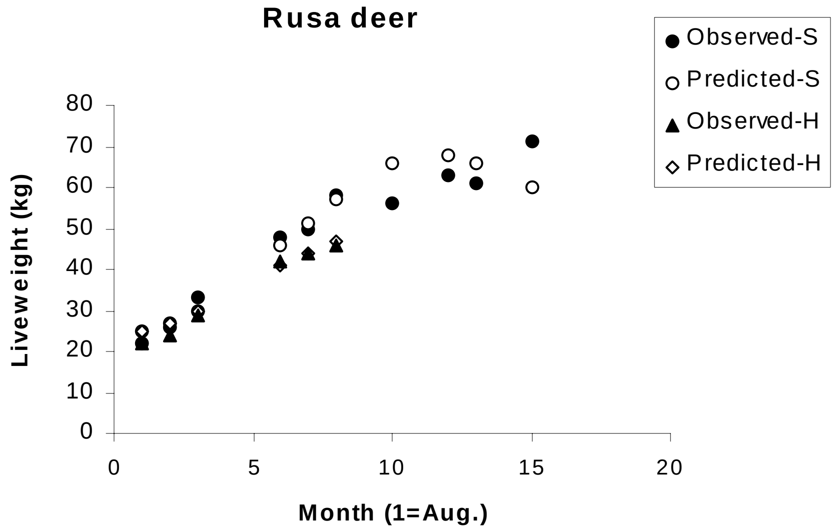

Figure 9 Predicted versus Observed monthly LW for Rusa deer stags (S) and hinds (H)

A similarity in monthly LW trend was noted for rusa hinds from weaner to yearling growth stages (Figure 9) where measured overall LWG over the 8 month period for observed and predicted data was 134 and 103 g/d respectively. Rusa deer stags also showed a resemblance in LW trend, however variability in magnitude of LW response from May to August was noted. Again errors in farming environment extrapolation to program and problems in interpretation of supplementary feeding data and irrigation regime over this period would have been compounding factors. Observed versus predicted overall LWG for stags over a recorded 12 month period was 124 and 104 g/d respectively.

5. Discussion of results

Overview of structure and performance capability

FEEDMAN is an easy-to-use IBM-compatible computer program to help both beef cattle and deer producers compare feeding options for growing animals in terms of forage utilisation, animal performance, market options (specifications and price) and economics. Some key points are the ability of the program to:

- assist in determining sustainable stocking rates and animal production, combined with
- basic economic assessment for differing seasons and management decisions.

It has been designed for the "endowed" zone of northern Australia, notably the region in central and south-east Queensland with relatively fertile soils and effective rainfall. A novel incorporation has been deer farming management strategies with growing animal classes to allow deer farming options to be assessed solely, or in conjunction with beef cattle enterprises. Note that currently only classes of growing deer are accommodated. There is no breeding hind classification in this package.

FEEDMAN is a technically complex package in that a range of soil, rainfall, vegetation and forage, animal, market and economic variables must be addressed and interpreted for results compilation and analysis. Nevertheless the package is presented in a user-friendly format and application acknowledged by peer review (Gaffney 1997). The program is compiled such that the software is easy to use (Windows™ based application), has good computational parameters, and results (outputs) are readily transferable to other applications providing basedata suitable for further biological or economic assessment by the user if so desired. Such features are considered necessary for a DSS to be effective both in purpose and suitability to end users (Cox 1996). Note that the choice of using a computer-based DSS for the deer industry is an acknowledgment of the increasing importance of computer technology use in agriculture, and particularly the uptake of computer programs for farm decision making and as a tool used in technical/production advice (O’Sullivan and Hamid 1999).

FEEDMAN is also in a sense an ‘expert system’ that allows beef cattle producers and deer farmers to evaluate numerous feeding and mob management scenarios in order to validate or assess on-farm strategies, particularly cost-effective feeding management to meet specific market requirements (Rickert 1998). Inherent in this DSS approach is the acknowledgment that the software package is used to evaluate alternative management scenarios however it is the end-user who is responsible for decision making (Gillard and Monypenny 1990). Animal production and farm forage information is complemented by market options and economics to enhance the information value to the user as an important aid to both tactical and strategic decision making. While FEEDMAN is designed to be interactive and user-friendly, the degree of technical inputs and interpretation required for effective use of this package suggests a target user group of competent farmers, agricultural professionals and farming systems proponents (Gaffney 1997).

Essentially the design of the new FEEDMAN software consists of interrelationships between inherent biological models (both deer and cattle) and the overall DSS framework, as exemplified in recent DSS packages for the temperate Australian cattle and sheep grazing industries (Foran *et al.* 1990; Donnelly *et al*. 1997). The importance of a computer DSS to aid in effective transfer of new information and technology to pastoral animal industries is widely recognised (Donnelly *et al*. 1997; Gaffney 1997) and the FEEDMAN package is no exception (Rickert 1998). Indeed, the addition of a deer module has effectively provided a conduit for existing deer farming technical and management knowledge (both research and field data) to be passed on to both existing and potential deer farmers in southern Queensland. In view of the limited knowledge of farming both sub-tropical (rusa) and temperate (red) deer species in the sub-tropical environment of southern Queensland, such information transfer can be seen as critical in aiding industry development (Woodford 1997).

To further expand on the industry development theme, emergent animal industries such as deer farming require successful adoption by commercial size enterprises in order to reach economies of size essential for industry viability (Woodford, 1997). Hence the development of FEEDMAN v 3.0 was specifically targeted to assist existing commercial size beef producers evaluate (and hopefully adopt) deer farming systems on their properties as part of an enterprise diversification. Successful integration of pastoral deer and cattle farming systems exists in New Zealand (Cowie, 1991) and is a valid management option for southern Queensland. The addition of deer management systems to the package may also provide a stimulus for wider adoption of the FEEDMAN series (Rickert, 1998). Finally, the FEEDMAN package provides for evaluation of ‘what if’ scenarios perceived by both researchers, professional agricultural advisors and farmers alike as greatly enhancing the appeal of DSS (Donnelly *et al*. 1997; Rickert 1998).

Validation of the program

Considering the complexity of modelling a ‘whole property’ combined with the intricacies of deer LW patterns with sex x season, the relationship of the predicted to observed values for both red and rusa deer in south-east Queensland, when using FEEDMAN to predict performance of deer at the UQ-Gatton research farm, did appear reasonable. In observations between predicted and measured beef cattle production in Queensland using DSS growth models, McLennan (1997) noted that (generally) predicted growth rate was appreciably lower than that measured, and considered this the result of ME intake being under-predicted resulting in poor growth rate predictions. This may well be a factor with our deer DSS model, however measured deer growth is further complicated by sex and season influences, particularly mature stags. It is also to be appreciated that the UQ-Gatton dataset is derived from an intensive farming operation where high stocking rates (approx. 20 animals per ha) combined with frequent rotational grazing and involved supplementation/irrigation regimes added to the difficulty of extrapolation of inputs to the program. This dataset is currently the only suitably accurate on-farm deer production data available to the authors for comparative testing.

Decision support system models are said to be only evaluated in relative terms, their primary role being heuristic (Cox 1996). This argument is suggested by Cox (1996) to imply that models must be accepted to contain degrees of resolution (suitably validated) within a context of substantial background noise. This is certainly the case in attempts to model complex ‘whole property’ management scenarios. Furthermore, validation and evaluation are not static processes but rather should be viewed as dynamic, as new information and model roles materialize (Harrison 1991; Cox 1996). In the case of FEEDMAN v 3.0, current validation studies and evaluation have relied on very limited production data based on a minority of forage types, land classes and feeding management regimes. The range of validation and evaluation studies will need to be expanded to include other forage combinations (tropical/temperate with crop and legume), supplementation options and differing types of country as information becomes available (Rickert 1998).

Commercialisation and marketing
The logical progression from model development and evaluation involves the commercialisation process whereby the package is appropriately compiled and distributed, to the satisfaction of contributing funding bodies and organisations, and appropriate to target client base (Rickert 1998). Aspects of the commercialisation process, namely intellectual property and communications strategy, are detailed in Sections 7 and 8 respectively. It should be noted that a comprehensive legal disclaimer is included with the product, as is standard practice with regard risk minimisation of litigation arising from poor or ill-informed decisions based on predictions from the model.

The product (FEEDMAN v 3.0) is to be published and marketed by DPI Publishing in accordance to DPI corporate standards and professionalism. Minor delays in completion of the project have been attributable to conversion of existing software template to a later version, and the underestimation of the time frame required to test model code and general evaluation. In addition, some required program ‘debugging’ has added to the frustration in meeting original time frame goals.

6. Implications and recommendations

6.1 Implications

FEEDMAN v 3.0 DSS is a pioneer computer-based management package for the deer industry in Queensland and consists of a multi-dimensional matrix of paddocks, soil types, forages, cattle and deer mob options, market options, climatic (rainfall) variation, time scales (12 month; Jan. to Dec.) and management inputs. This level of complexity is necessary if whole farm feed management and market/economic options are to be adequately represented by the program. Nevertheless the program is presented in user-friendly format and interface for ease of input data entry and interpretation of results. The computer software is based on a commonly used spreadsheet/database format designed for Windows applications, and operates within IBM-compatible hardware specifications. Thus the management package is applicable for use by a wide range of clients using readily available computer software and hardware. In addition, future additions/modifications to the existing program derived either from new technical knowledge or end-use objectives can continue to be accommodated, as was the case in the development of the current version of FEEDMAN.

Whole property management options can be evaluated, and outputs generated by the program avail themselves to generation of 'what if' scenarios, comparing feed planning options and evaluation of both tactical (short term) and strategic (long term) decisions. FEEDMAN enables users to combine biological science with economic inputs and market options in order to test different management strategies for beef and deer properties in southern and central Queensland. Some examples of a range of possible management scenarios are provided below.

Tactical questions (short term, months to a couple of years)

- What effect will a given rainfall pattern for the next 2 to 12 months have on farm carrying capacity, cattle and deer performance, forage availability and farm profit?
- How will supplementary feeding with grain or cottonseed meal affect production and profitability?
- What is the influence of various forage options on costs, performance and profitability?
- What profit will result from buying a specific mob of cattle or deer and feeding under specified forage systems within a set of climatic (rainfall) and market price conditions?
- When should you cull velvet stags?
- Which deer mob should be set aside for priority feeding to meet spring schedules?

Strategic questions (longer term, say 2 to 5 years)

- What is the productivity (forage production, animal production) of a property (farm) relative to other farms?
- What is the relative profitability of different beef cattle or deer farm enterprises?
- What is the estimated sustainable carrying capacity of the property?
- What are suitable market specifications to target, and when?
- For a specified market or production goal, what forage system could optimise profit for given classes of cattle or deer?
- Should the deer farm target velvet production in addition to venison production, and to what degree?

Note that modification of FEEDMAN has allowed for the comparison of beef cattle and deer production systems within the same property, thereby providing current beef producers with a decision support tool with which to evaluate deer systems on their specific properties and model output scenarios.

The relevance of the FEEDMAN DSS beef and deer management package, both in Queensland and nationally.

Decision support systems provide a conduit for transfer of information to users which is derived from extensive collation of existing knowledge packaged into a user-friendly format. In the case of current deer farmers in Queensland, the FEEDMAN program provides a tool for feed management planning and selection of market options using forage

–based systems and paddock supplementation. The deer model is of sufficient biological reliability to enable animal production estimates for various management scenarios, and further provide for sustainable forage use, so that given animal production plans are both economic and environmentally sound. The software program is compatible to the current need of the deer industry to provide quality slaughter animals from a sustainable resource base, and provides the necessary farm management information to assist in decision making, particularly attainment of adequate slaughter weights to market specification, and within a specific time frame. Thus FEEDMAN has the facility to provide technical and economic input into deer production systems in Queensland that will aid in the encouragement of industry expansion and productivity gains within the state. On a national level, such productivity gains can also be measured in the ability to contribute to year round venison supply and hence compliment seasonal venison production in the southern states.

The problems of low supply volumes of deer products (particularly venison) in increasing costs of processing and frustrating efficient marketing objectives have been well documented in the deer industry to date. Increasing deer numbers appears to be only attainable from encouraging existing commercial size operators to expand their operations, or more importantly, encourage new participants into the industry. Beef producers in central and southern Queensland offer enormous potential for the deer industry to achieve larger state herd size, and FEEDMAN provides the tool with which to evaluate deer farming as a viable livestock enterprise alternative for beef producers, on a whole property basis.

While design parameters in FEEDMAN are specific to central and southern Queensland environments, nutritional management and economic analysis principles are applicable on a national level, and the results of this project should compliment activities in southern states to develop DSS software for temperate pastoral/grazing zones, probably based on GrazFeed. In particular, existing management and nutritional knowledge has been sufficient to enable development of deer production algorithms, and ultimately incorporation of deer modules into a DSS framework. Modification of an existing beef cattle DSS has provided a cost-effective means of introducing computer-based DSS into the Australian deer industry.

While FEEDMAN is clearly a suitable tool to use in decision making aimed at encouraging new industry participants and herd expansion, the attractiveness of deer farming as a viable livestock enterprise will rely on other industry initiatives to improve confidence and provide viable financial incentives. Computer-based decision support systems can provide technology the deer industry can exploit, but they are not designed to instigate industry change or direction *per se*.

6.2 Recommendations

FEEDMAN is a fairly complex and integrated management DSS package, and while user interface and input protocols are simplified and user-friendly, a degree of technical and management knowledge would be beneficial to fully utilise the programs features. The target client base is stated as farm managers, rural advisors, agribusiness professionals and government agricultural department extension personnel. However, depending on the desired use of the software by the user, a client profile can be recommended:

1. For provision of deer farm management scenarios to aid in information transfer to the industry and encouragement of allocating feed resources for desired animal production and target markets; target client base should be technically competent deer farmers, or farmers assisted by rural advisors/government extension officers.
2. For encouragement of existing commercial beef producers to evaluate deer farming options on their properties; target client base should be technically competent beef producers, assisted by rural advisors/government extension officers and agribusiness professionals.

Essentially FEEDMAN provides decision support either for extension agents or professionals which decide on advice and assistance to clients, or for farmers themselves to decide what actions to take. FEEDMAN can also provide researchers with an aid for the assessment of research proposals and scenario planning. Note that while currently the software program is only applicable to growing red and rusa deer animal classes (ie. stags, castrates, non-pregnant, non-lactating hinds), future provision for breeding hinds and calves (fawns) should be considered when appropriate technical production knowledge is available.

Decision support systems are designed to assist users in their decision policies (tactical and strategic) including risk management, and act as a supportive tool only. The FEEDMAN package in particular should not be perceived as a 'black box' for generating unchallenged output data. Information provided by the software is not precise or necessarily complete, and users should analyse outputs in conjunction with appraisal of other information sources, their own physical and financial resource constraints and individual social preferences. FEDMAN is a generic model with default values and basic underlying mathematical calculations based on experience and technical information available. Users of the package, with sufficient technical expertise or assistance, can re-calibrate and customise the model to better accommodate their own particular farming system. Again, the role of the model as an additional information source and aid to decision making must be kept in context.

In conclusion, while management strategies are now in the process of being refined for efficient venison (and velvet) red and rusa deer production systems in Queensland, attempts at verification and validation of such strategies on-farm are yet to be realised. The development of FEEDMAN v 3.0 DSS offers scenario evaluation and strategy simulations within an integrated approach to problem solving, from an holistic perspective using biological and economic parameters. An ultimate goal may well be continuation of this holistic approach, that is to incorporate multi-variate analysis of on-farm evaluations of deer herd productivity, management practices, and establishment of baseline data as initiated in the NZ deer industry by Audige′ *et al*. (1993).

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8. Appendices

Appendix I Tutorial exercise[2]

Early experience is gained in FEEDMAN by entering data for a simple farm consisting of 4 paddocks, with 3 mobs of cattle and 1 mob of deer. By following the steps below, the user is able to familiarise themselves with the package and its outputs.

- Click the **New Farm** button, enter the farm name (e.g. Tute1) and description (e.g. Tute from manual). Then select the base data file to be attached to the farm; only BASEDATA will be available immediately after installation. Click OK.
- After automatically going to the *Edit Farm* window click the **Farm Layout** button and enter the total area of the farm (700 ha); of which 100 ha is to be selected as available for deer farming area, the area thus remaining (ie. 600 ha) for cattle production only, then click the **New** button.
- Enter the name and area of a paddock and click the **OK**. Repeat until the following paddocks are entered: Crp/House (purpose as 'cattle'), 50ha; NP/Back (purpose as 'cattle'), 300ha; SP/Deer (purpose as 'deer'), 100 ha; SP/Road (purpose as 'cattle'), 250ha. Note the total area displayed in the green fields. Inspect your entries by clicking the list or pie-chart button, then close the *Farm Layout* window.
- Open the *Paddock Layout* window. Note the default Land Unit and Forage for each paddock. Enter the data on land units and forages below (eg. TropGnolegumeNew represents sown tropical grass, no legume and recently established). Display your entries by the **All Paddocks** button. Close the window.

Subform	**Land Unit (LU)**		**Forage**			
Paddock	LU no	Area	Type	Area	Tree Density	Condition
Crp/House	6	50	Oats	50	0	good
NP/Back	12	300	Native-Pasture	200	0	good
			NP-trees	100	4	good
SP/Deer	14	100	TropGnolegumeNew	100	0	good
SP/Road	1	250	TropGnolegumeOld	250	0	good

- Click the **Rainfall** button and note the default record for Gayndah. Click the **Historical** button to select a new location and record: Miles (note the deer farming species suggestion); SOI Ignored; median year. Click **OK** to examine the record and **Select** to use the record on display. Rainfall will be revisited. Close the *Select Rainfall* window.
- Click the **Mobs** button to open the *Mob List* window, then click the **New Mob** button to enter the following details on four mobs:-

Mob details	**Mob 1**	**Mob 2**	**Mob 3**	**Mob 4**
Class/breed	XBS	XBS	XBS	ARS
Name	Weaner steers	Yearling steers	2-yr old steers	2-yr old stags
Number	110	140	125	90
LW kg	180	250	465	140
Age (mths)	6	14	26	26
Start paddock	NP/Back	NP/Back	SP/Road	SP/Deer
Starting month	April	Jan	Jan	Jan
Velvet	N/A	N/A	N/A	Yes (√ click box)

XBS = crossbred steer ARS = Australian red deer stag

- Select the weaner steers and click the **Feed Year Plan**. Either double click May to November (enters 110 for each month) or enter manually 110 for each month. Sell 50 head in November by reducing the

[2] Based on the exercise outlined in Rickert *et al*. 1996 and modified for deer management options.

number to 60 in Dec. This is the method for incorporating animal sales in the program. The end of year (EOY) figure should equate to the Dec. figure (double click for default or manually entered). Note that if no EOY value exists, or a lower value than Dec. is entered, then December animal sales will be implied. Close the window.

- Select the yearling steers and click the **Feed Year Plan** button. Double click Jan to July, then the **Change Paddock** button to transfer the mob to the SP/Road paddock from Aug to Dec. Sell 25 in October by entering 115 for Nov. Use the **Performance Table** button to examine performance of this mob and forage. Note the high forage utilisation (for native pasture) and low LWC (liveweight change) from May for the NP/Back paddock then close. Click the **Supp** button (for NP/Back paddock) and feed grain (good quality) at 2 kg/hd/d from May to July to improve the liveweight change. Remember the weaner steers are also in this paddock and they will also receive the supplement. Re-inspect the performance table, then close the window.
- Select the 2 yr-old steers and click the **Feed Year Plan** button. Double click Jan to Jun, and adjust for sales of 25 in February (enter 100 Mar.) and 20 in Apr (ie. enter 80 for May). Then use the **Change Paddock** button to transfer the mob to the Crp/House paddock from Jul to Sep with sales of 20 in July (60 Aug) and 60 in September (zero or blank Oct). Close the window.
- Select the 2 yr-old stags and click the **Feed Year Plan** button followed by the **All Year Grazing** button. Sell 25 head in December by entering 65 for EOY value. Close the window.
- Inspect results by using the **List, History, Graphs** and **Markets** buttons on the *Mob List* window, then close the window. Note that new market specifications and prices can be added to the list of options for both cattle and deer using the Base Data window.
- Click the **Forages** button to inspect the default values for forage variable costs. Close the window.
- Click the **Animals** button to inspect the default values for variable costs of animals. Close the window.
- Click the **Reports** button, then the **Calculate All** button to calculate all results.
- To compare a total estimated stocking rate, with the sustainable stocking rate from FEEDMAN, click the **Stocking Rate** button, followed by the **Adult Equiv**. Button. Then enter the following data in the table in the *Adult Equivalents* window, new lines appear automatically. Although the mean sustainable stocking rate from FEEDMAN is lower than the total estimated stocking rate, the conservative difference would be partly offset by the grain supplement reducing forage utilisation.

Class	Adult Equivalent	Number*
Weaners steers	0.6	106
Yearling steers	0.8	136
2 yr-old steers	1.0	68
2 yr old stags	0.4	89

* average number per month over a 12 month period

- Examine each report and graph. Observe that velvet sales and profit are defaulted to appear for Dec. only.
- Return to the *Select Rainfall* window and form a new record - a very wet year for Miles. Return to the *Reports* window and click the **Calculate All** button. Examine the impact this has on animal production (liveweight gain and velvet yield) and forage utilisation.
- Click the **Compare** button on the *Edit Farm* window, and select two farms (e.g. Tute1 and Tfcopy1 if available). The **Open** button leads to a graph comparing the sustainable stocking rates and cash flow for each farm.