CONTACT REVIEW

RESEARCH, DEVELOPMENT AND VALIDATION OF NEW SUSTAINABLE FARMING SYSTEMS - THE PHILOSOPHY AND AN EXAMPLE

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SUMMARY

This contract explores the philosophical and physical requirements of research aimed at developing new sustainable farming systems all the way from discovery of new key elements to their incorporation and validation on a 'whole-farm' scale. In doing so it uses the Martindale Research Project's experience with the leguminous fodder shrub tagasaste as an example.

In the first paper Jim Fortune discusses what we believe to be the critical and often overlooked elements of farming systems. It is pointed out that 'whole-farm' computer models such as MIDAS are useful tools for scientists but that they lack many of the subtleties and flexibility that may make or break a real farm. The new farm systems being measured at the 'Dunmar Research Station' use innovative approaches to fencing and stock water supply as well as rotations, ration feeding and opportunistic grazing of tagasaste to meet particular demands of animal groups.

In the second paper Chris Oldham presents a summary of the research results with respect to establishment, feed production, feed utilisation and animal production from tagasaste that suggested that it had the potential to be the key element in new sustainable systems for farming sandplain in south western Australia.

The third paper, by Bruce Mattinson, briefly describes the MIDAS type 'whole-farm' computer model used to help evaluate individual research results with respect to the current farming system. It also presents examples of the computer output used to justify the design of the 3 alternative 'farm-scale' prototypes using tagasaste that have been established. These prototype farms are being measured to gather information to be used to modify and validate the MIDAS modeling.

Finally, Ted Lefroy describes the theoretical and practical considerations involved in setting up and measuring 'whole-farm' prototypes. Keeping control over the flow of information and its potential to influence management decisions in a biased way, if not given sufficient consideration, has proved very challenging.

It is concluded that the overall approach taken by the Martindale Research Project has been very successful in discovering a new fodder source for farms in south western Australia. The final stage of operational research, to integrate the new development into the established system, is an ongoing project whose success or failure will take more time to assess.

INTRODUCTION

Scientists are continually accused of myopic vision because they do not carry highly focused basic research results through to their incorporation into new management strategies. To our knowledge there are no published examples to follow and few people with the vision and resources to fund such a program of research and development. An exception is Martindale Pty Ltd, who, through the University of Western Australia and the Martindale Research Project, have sponsored a program of Research and Development (R&D) ranging from basic studies to farm-scale prototypes used to validate computer predictions and to explore the practical management needs for incorporating particular research findings.

In 1986, Martindale Pty Ltd contracted to invest a minimum of $250000 per year for 4 years in a program of 'on-farm research'. Hence, the Martindale Research Project (MRP) was initiated with the broad objective to increase the profitability of farming in the 400–500 mm rainfall zone in south-western Australia by concentrating on the animal component of the farming system.

Byerlee *et al.* (1991) describe 'on-farm research or farming systems research' as having 2 major stages. A diagnostic stage to describe and understand the farming system and identify production constraints followed by an experimental stage in which promising technological solutions are tested under farmers' conditions. Thus, in framing its research policy the Research Committee of the MRP sought to develop a program of R&D that successfully integrated the research process from the basic question to the applied demonstration. The program of R&D was planned to be conducted at 3 levels:

(i) *Basic Research,* to generate new ideas and facts with which to manipulate the biological and physical resources,

(ii) *Developmental Research,* to develop these ideas and facts into industrial facts and

(iii) *Operational Research,* to integrate new developments into practice — either established practice or into entirely new practice (R. J. Moir pers comm.).

The adaptation of the 'whole-farm' model, MIDAS (Kingwell and Pannell 1987), to the commercial farms being utilised in the R&D program was a core element of this approach. Basic research in the areas of predictive modeling, animal production, feed production and feed utilisation were commenced in parallel.

As basic information was confirmed, developmental research was introduced with the help of the MIDAS model. Runs of the computer model were used to evaluate individual projects and set priorities on new information. By the end of 1987, the research program had focused on the leguminous fodder shrub tagasaste *(Chamaecytisus palmensis)* grown on deep sand, a previously uneconomic land management unit. It was concluded that tagasaste was a robustly economic source of feed, when directly grazed by sheep or cattle, to replace grain fed in autumn (Mattinson and Oldham 1989; Oldham and Mattinson 1990). Approximately 10% of the arable area of the farm established to tagasaste replaced hand feeding. Later, it was found that sheep grazing tagasaste over summer grew 30% more wool than flockmates grazing dry pasture. Given this result analysis of runs of the model suggested an optimum solution with tagasaste at 30% of the arable area.

The policy adopted by the Research Committee recognised that scientists are continually criticised for the errors in extrapolating trial plot results to the larger areas managed by farmers as a part of their farming system (Davidson and Martin 1966). Thus, it stated that the final stage of operational research, with respect to new strategies, must validate the predictions of the MIDAS model within 'farm-scale' prototypes, as functional parts of a complete production system. Fully replicated 'farm-scale' experiments would be prohibitively expensive. Therefore, in March 1988 a series of 'farm-scale' prototypes were established. These were to be used to measure the relative performance of land management and animal units within them in order to validate the MIDAS model of sandplain farms. Each prototype had the same mix of soils but increasing proportions of their deep sands established to tagasaste.

CRITICAL ELEMENTS OF FARMING SYSTEMS

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The farming system we are dealing with in southern Australia is a mixture of cropping and livestock (ley farming) with the ratios being determined by rainfall and economics. The evolution and selection of such farming systems has been strongly driven by profit maximization while still attempting to maintain the productivity of the land. Fine-tuning is through recognition of variation in the physical environment, availability of resources, current market conditions and by the inclination and capacity of individual primary producers (Stem 1979).

The focus is often on the positive aspects of a given farming system, but it is important to recognise factors contributing to total failure. The poor sandy soils of the 2 main experimental sites for tagasaste represent about 3 million hectares of land in south Western Australia alone. On these soils, rapid degradation has occurred since clearing due to their inability to support a self-regenerating pasture, stable population of grazing animals, or economic crops. This usually results in a rapid downward economic spiral as cost recovery is attempted by further cropping and opportunistic cash gathering from agistment, both of which exacerbate the problem.

The problem or reality of variation

Any area of land will vary topographically, vegetatively and in its soils. Land subdivisions that were geometric complicated management by providing paddock resources that had a simple common denominator of distance to the house rather than any inherent production characteristic.

McKinney *et al.* (1978) in a sheep grazing trial showed that the optimum stocking rate varied from 8.5–30 weaners/ha and 8–20 ewes/ha. The area used was a subset of 15 paddocks out of 45 in a total farm area of 160 ha. The components of this variation were not effectively partitioned but may have included soil depth, aspect and slope, soil moisture characteristics, and nutritional interactions with soil and moisture. Most attempts to model such dynamic systems will invariably result in compromise between generality and accuracy. Models such as MIDAS (Kingwell and Pannell 1987) have partially addressed site variation by allowing for some soil class and crop rotational history when computing an optimal solution. However, for an individual property the mosaic of areas may be highly complex and real gains may necessitate, and flow from, more finely tuned management of resources such as fencing to soil type, use of plant species adapted to particular niches, and utilisation based on a history of paddock performance.

Arguments about grazing management

'Any management scheme for animals other than continuous set-stocking at conservative levels involves additional and often heavy expense, and can only be justified by substantial increases in production'. With those words it might reasonably be argued that Christian (1987) ignored ley-farming as a system that has variable and interacting management of plant and animal components as the core of its success. By contrast, Brougham (1970) seems more constructive in highlighting our common failure to recognise interactions between season, management system, animal behaviour and intake patterns, and plant performance when arguing for some perceived universal grazing management system. If these messages are adopted it is possible to see how strategies to cope with the seasonality of plant growth from annuals and perennials can be linked with an animal production enterprise that will incorporate the feed demand of groups such as growing and reproducing animals. A set of feeding priorities and feed resources will rarely be optimised by simple set-stocking. The tagasaste work discussed in this contract is an example of where combinations of rotational use of shrub areas, rationed feeding and opportunistic usage have all been successfully used to meet demands of particular animal groups.

Basic resources to contain and manage livestock

Table 1 summarises some of the improvements that have become readily available over about the past 30 years which individually and collectively alter the cost-structure and labour usage for managing grazing livestock. Many of the arguments concerning grazing management fail to take account of the impact of these developments on current attitudes and the flexibility that is achieved in the whole-farm operation.

Table 1. Changes and innovations in the past 30 years that effect costs and inputs into livestock management

Innovation	Gain
Prefabricated troughs	Rapid installation & low cost
Mains electricity	
pumps	Water reticulation & reliability
fencing	Low cost subdivision
Plastic pipe	Water reticulation
New pasture species & cultivars	Production & niche performance
Bulk grain and fodder handling	Low labour supplementary feeds
Livestock handling equipment	More animals/labour unit
Grain legumes	Effective crop-animal integration
Soil testing	Optimising fertilizer inputs

In this overall project, elements of all the changes (Table 1) in resources have contributed to a system that is endeavouring to alter livestock carrying capacity from about 1.5–2 sheep/ha to about 6 sheep/ha. As well as the production gains from this, land degradation of the unstable sands is being minimised.

DATA IN SUPPORT OF FODDER SHRUBS AS THE BASIS FOR A NEW APPROACH TO FARMING SANDPLAIN

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Tagasaste *(Chamaecytisus palmensis),* commonly called 'tree luceme', is a hardy evergreen leguminous shrub or tree, native to Palma island in the Canary Islands. It was introduced into Australia from the Royal Botanical Gardens, Kew in 1879. It will grow vigorously from seed on the most infertile deep sands, reaching 3 to 5 m in height and all parts of the stem and branches are enveloped in leaves. Its potential as a fodder tree has been promoted by a series of scientists since 1863 (Oldham *et al.* 1989). However, there have never been any field scale data to support their claims and their dream of an agricultural revolution based around tagasaste has remained unfulfilled.

There are around 3 million hectares of poorly productive deep sands in the south of Western Australia and a further 2 million hectares in South Australia on which plantations of tagasaste could be grown. Merino sheep provide the major source of income in these areas and their annual production of wool and surplus sale stock is largely constrained by the Mediterranean-type climate. The summer drought typically lasts 3 to 7 months, during which the dry annual pastures are of low quality and associated with a low rate of wool growth and poor reproductive performance. Optimum stocking rates dictate that farmers must budget to hand feed grain to their sheep in autumn.

Six years of research, by the MRP, has shown the large comparative advantage on deep sands of the deep rooted perennial shrub tagasaste in production of edible dry matter compared with conventional annual pastures (Southern 1988; Oldham and Mattinson 1990). However, the value of edible dry matter also depends on its cost of establishment, annual cost of maintenance, season of consumption, spatial distribution and nutritive value.

Basic information on tagasaste introduced into the MIDAS model

General. At 'Newdale', New Norcia, tagasaste was established as single rows of trees 5 m apart, giving about 2 km of tagasaste hedge or between 1000 and 2000 trees per hectare. The original stand of tagasaste was sown into an area of white to yellow sand greater than 15 m deep in May 1983.

Sheep are grazed directly on the shrubs and not conditioned to grazing tagasaste in any way. The stocking rate is estimated visually from the estimated yield of edible leaf and stem per metre of hedge converted into sheep grazing days (sgd=1 kg edible dry matter per day) divided by the required number of days of grazing. Once grazing has commenced the defoliation of the trees is observed regularly. When a clear grazing line has been established at about 1.2 m above ground the hedges are cut at about 0.5 m. In experimental plots, barkstripping has only been a minor problem and only when cutting has been delayed too long. Sheep are removed as soon as the cut material has been eaten.

Establishment. It was clear from the outset that tagasaste could be established from seed on deep infertile sand and would persist over summer without rain. There were over 60000 trees 2 to 3 m high on 50 ha of deep sand at 'Newdale' when the the project started in July 1985. However, a series of experiments established the importance of fertiliser placement, press wheel weight, weed control and insect control (Oldham and Mattinson 1990).

Feedproduction. Initial cutting and grazing studies conducted in 1985/87 showed;

(i) yields of 3000 kg of edible dry matter (Southern 1988) or 3000 sgd per hectare per year (Oldham and Mattinson 1990) from 400–450 mm of rain in winter and spring. These yields were 4 times higher than the 700 sgd per hectare per year (2 dse) obtained before tagasaste,

(ii) that it was not economic to apply extra phosphorus or potassium (Southern 1988),

(iii) that grazing tagasaste in November and again in May produced 40% less sheep grazing days than grazing in May alone (C. M. Oldham, B. C. Mattinson, unpublished data) and

(iv) that, over a number of experiments and a number of years, 3000 sgd/ha.year from 10 months regrowth harvested by direct grazing and cutting during a 30-40 day grazing period in autumn, was a robust estimate of annual productivity.

Feed utilisation. In summer and autumn the edible fraction of tagasaste contains 15% crude protein and is 70% digestible in nylon bag studies. However, animals failed to grow appropriately. Initially, it was thought that spatial distribution may restrict intake but estimates of intake from young grazing sheep were commonly in excess of 1 kg per day. At this level digestibility must be 5–10 units less than indicated in *in vitro* and nylon bag studies (J. A. Fortune unpublished data). There are significant amounts of phenolic compounds in tagasaste that are hypothesised to control nutritive value and palatability (J. A. Fortune and A. Bailey unpublished data).

Animal production. Tagasaste, cut and carried to sheep grazing dry subterranean clover–ryegrass pastures in autumn, was readily eaten as fresh or chopped branches, but had a nutritive value less than lupin grain. However, intakes as low as 200 g per day of leaf dry matter was sufficient to maintain ewe weaners (1986/87; J. Hemsley, CSIRO, unpublished data).

Merino ewe weaners, grazed on tagasaste in surnrner cut 30% more clean wool than flockmates grazing dry pasture with a lupin supplement in autumn, with half the accepted increase in micron (Oldham and Moore 1989). The amount of extra wool produced by sheep grazing tagasaste over summer was similar in ewes, wethers and weaners but the extra wool from the weaners was more valuable (Oldham *et al.* 1991).

Merino ewes joined on tagasaste in November had 20 extra ovulations per 100 ewes ovulating compared to pasture fed controls and weaned 10 extra lambs per 100 ewes joined (Oldham *et al.* 1989; C. M. Oldham unpublished data).

Weaners with restricted access to tagasaste in autumn, i.e. ration grazed on tagasaste 1 day/week or 3 days/week, at stocking rates of ≥100 weaners/ha, maintained liveweight and the tensile strength of their fleece (Oldham *et al.* 1991). This effectively increased the yield of tagasaste to at least 6000 sgd/ha.year (see Mattinson; Fig. 1).

Cattle maintained liveweight grazing tagasaste in autumn but their rate of gain of liveweight if grazed on tagasaste throughout summer has been poor and variable (Oldham *et al.* 1991). More recently, heifers, set stocked on tagasaste from September 1991, have maintained growth rates of around 500 g/heifer.day until the time of writing in March 1992. The trees have been maintained with a residual of around 600 g of green leaf and edible stem per tree and may not need annual cutting.

Grazing management. It is general practice to graze or mechanically trim new stands of tagasaste to force a multi-stemmed form that is thought to be more resilient to direct grazing. Experiments showed that young trees were safe to be grazed by sheep and cattle when 11 months old or 25 cm high, which ever came first.

Tagasaste grazed once per year must be cut back to around 0.5 m to ensure maximum regrowth within the grazing reach of sheep and cattle the following year. Tree mortality increased linearly if grazing by sheep continued for longer than 10 days after all the initial edible leaf and stem had been removed by grazing and pruning. It was not possible to use cattle to control height and also maintain an economic rate of gain of liveweight when tagasaste was used only in summer/autumn.

EVALUATION OF FODDER SHRUBS IN A WHOLE -FARM SYSTEM

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Increased profitability normally encourages farmers to change their farming systems. However when major changes are proposed to the farming system, assessment of their profitability is difficult using traditional budgeting techniques. To evaluate the role of tagasaste in a farming system, a mathematical programming model of a whole farm was adapted to include tagasaste. This paper describes the model, its data and analysis of runs of the model. Sensitivity to a range of wool prices and cropping returns are reported and discussed with reference to the district practice.

The Model

A whole-farm model was adapted for 'Newdale', the 4500 ha commercial farm and centre of the early research program, at New Norcia in south-Western Australia (the original model is described in detail in Kingwell and Pannell 1987). The model is a mathematical programming model with about 1500 activities and 400 constraints. The objective function is to maximize farm profit. The model is of an whole farm and has a number of components:

(i) It has five classes of soil on which a range of cropping and pasture activities are possible.
(ii) Merino sheep are an activity that can be chosen and sheep draw feed from a number of possible sources. The feed requirement is calculated from the metabolic body size of sheep in each month and the feed supply is in monthly periods.

(iii) Pasture activities, both as part of a rotation with crops and as long term stands are included. Pasture production and decay is modeled in monthly increments.
(iv) A range of cropping activities, including wheat, barley, oats, lupins and triticale are included. Fertiliser response curves and response to legume nitrogen are included.
(v) A financial section includes constraints on overdraft and borrowings and a progressive tax scale.

Data

Data for the model were drawn from trials conducted by the Western Australian Department of Agriculture and published biological relationships. The model output is frequently verified by comparing it with actual production from the farms it was designed to mimic. Initial information on output from tagasaste production was drawn from a trial in which it was shown that a hectare of tagasaste provided sufficient feed to maintain 50 kg wethers for a total of 3400 grazing days. This information was established on deep sands and observations suggested that production would be no greater on heavier soil classes. Hence, the same production of tagasaste was assumed on all soil types. It was also assumed that the time the tagasaste is grazed does not affect the tagasaste production, hence, production equivalent to 3400 grazing days per hectare was available for any month.

The benefit calculated in the model includes the opportunity cost of foregone production for an adult tagasaste plantation and the timing of the benefit to a farm. The cost of establishment, including seeding, seed, planning, insect control, fencing and water was $225 per hectare. The annual cost (years 2 to 15) of fertiliser and cutting is $38 per hectare (Oldham and Mattinson 1990). The return on investment is calculated from the results on benefits, costs and foregone income. These data are expressed on a monthly basis over a 15 year period.

Results

Tagasaste was the most profitable activity on deep sands. This soil class forms just under 10% of the arable area on ‘Newdale’ but 65% of the arable area on the ‘Dunmar Research Station’. The production from tagasaste would need to be at least 150% higher than 3400 sheep grazing days before tagasaste would be chosen as the most profitable activity on heavier soil types. The gross return was $136.80 per hectare (1988 prices) of deep sands planted to tagasaste. Tagasaste was used as a feed source to replace grain feeding in late summer and autumn. Tagasaste in the farming system reduced the stock number slightly due to the reduction in winter and spring pasture on the deep sands. Without the need to grain feed sheep in late summer and early autumn, the quantity of grain sold increased. If the area of deep sand was larger, sufficient tagasaste to supply feed to ewes and weaners over summer and autumn was chosen. However, even if the farm were all deep sand, tagasaste would not have been chosen as a winter or spring feed source. When tagasaste was evaluated in 1988, as an investment over a 15 year period, the real return on investment was 23%. This compared favourably with the real interest rate of about 10% in 1988 (Table 2).

Table 2. The sensitivity of return on investment from tagasaste grown on deep sand and grazed 7 days per week to replace grain feeding in autumn (adapted from Mattinson and Oldham 1990)

	Return on investment	Sheep grazing days	Change in sheep grazing days
‘Newdale’	23%	3400	0
	Target		
	20%	3060	340
	15%	2550	890
	10%	2170	1230

Discussion

Planting tagasaste on deep sands in south-western Australia is a profitable investment. The fact that tagasaste appears to produce no more than pasture on the better classes of soils and the low opportunity cost on the deep sands explains the choice of tagasaste on the deep sands.

Grain feeding is the most expensive sheep feeding activity on a farm in south-western Australia, hence tagasaste was chosen to replace this expense before being used at other times of the year. Summer is the next most critical time for feed, hence if there is sufficient tagasaste to replace grain feeding, extra tagasaste was used as a feed over summer (Oldham and Moore 1989; Oldham *et al.* 1990). Tagasaste was not chosen as a winter or spring feed due to the high cost of tagasaste feed relative to the low cost of traditional annual pastures of a similar quality at these times of the year. Tagasaste plays a unique role as a supplier of quality feed at a time of the year when pasture quality is low.

Model update

The model was updated in February 199 1, based on our improved understanding of many aspects of the feeding value and management of tagasaste.

(i) The nutritive value of tagasaste was reduced by about 10%.
(ii) A requirement for some dry pasture to complement the tagasaste in autumn was introduced into the model.
(iii) The extra wool produced per sheep from grazing tagasaste was reduced in the model.
(iv) Minor changes were made to the cost of cutting and establishment.
(v) Pasture responses resulting from deferment of grazing until late winter were introduced.
(vi) Changes in pasture growth based on measured productivity of the various land management units on the 'Dunmar Research Station' were introduced.

The new model based on the above changes and the wool and grain prices existing in 1989 strongly favoured an increase in the area of tagasaste on deep sands (compare model runs in 1989 versus 199 1 at 935 cents per clean kg of wool; Fig. 1). With the potential to ration graze tagasaste to fill the autumn feed gap more tagasaste is available to increase overall sheep numbers and hence wool returns per hectare. The benefits of restricted grazing and pasture deferment, more than offset the fall in the price of wool and nutritive value of tagasaste.

Wool price sensitivity

The upgrade of the model was overshadowed by the major fall in the price of wool (see Fig. 1.) but the farm plan for each farm was not sensitive to changes in the price of wool. The major changes involved less hand feeding and the proportion of ewes mated was reduced to the minimum for a self-replacing flock. The gross margins of the farms fell to negative values. It was only when overheads were cut back that a break-even budget was achieved.

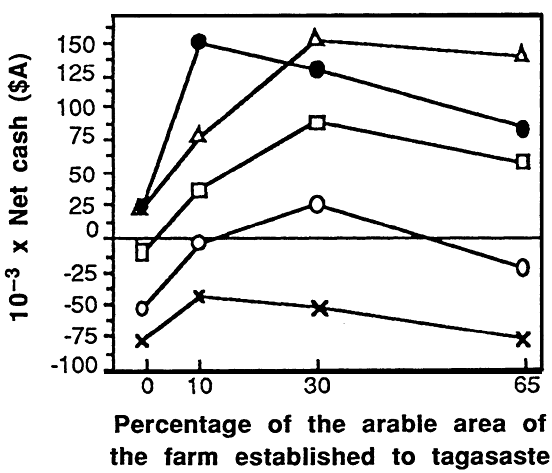

Fig. 1. A comparison of the analysis of the MIDAS model output comparing the net cash returns from farms with zero, 10%, 30% or 65% of their arable area as tagasaste in 1989 (●) and 1991 (△) at a wool price of 935 cents per clean kg. The analysis in 1991 also included the influence of a range in the price of wool, 406 cents (x), 582 cents (0), 759 cents (□) and 935 cents (△) per clean kg. The major assumptions in the 1991 analysis were, tagasaste ration grazed = 6000 sgd/ha in autumn, tagasaste grazed 7 days per week in all other situations = 3000 sgd/ha, no cropping and net cash ($A) does not include interest on the investment in tagasaste.

Cropping sensitivity

During the wool price sensitivity testing the model consistently suggested that it was economic to include some cropping of the better sands when the price of wool fell below 935 cents per clean kg. This was despite the current low value of wheat and high costs of cropping. The stubble from crops are modeled as important sheep feed, particularly if restricted grazing was practised in autumn. Although the model consistently selected cropping activities, the district practice does not include a large portion of crop.

ON FARM RESEARCH OR FARMING SYSTEMS RESEARCH; VALIDATION OF MODEL PREDICTIONS WITH RESPECT TO TAGASASTE

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The most difficult part of developing new systems in agriculture is their on-farm validation. For the valid comparison of alternative prototype systems they must be similar in all but 1 basic characteristic and they must have all of the essential elements of the current full scale production system that they seek to represent. At the same time, sufficient technical data must be collected about each, so that relative performances can be analysed to improve further on one or all prototypes. These data must also be adequate to explain the source or sources of differences between prototypes. This information should then allow a modified 'whole-farm' model to predict the role of the new strategy for any farm in the medium to high rainfall zone of the south of Western Australia.

A major experiment was initiated on the Dunmar Research Station, a farm on which 65% of the arable area is deep sand, to compare and contrast the productivity of the various land management and animal units combined in 3 farming systems based on the use of tagasaste (Table 4). In mm these will be compared and contrasted with those of a control unit run according to the conventional strategy used by farmers in the area.

The control farm runs a self replacing flock of Merino sheep (35% mated ewes) stocked at 3.3 dse/ha. This stocking rate includes hand feeding of young sheep and mated ewes in March, April and May. The land management units are detailed in Table 3 and a brief summary of the rules or assumptions about the best way to manage them is given in Table 4. However, whereas most established farms are fenced roughly on the square, independent of soil type, the 'Dunmar Research Station' was surveyed and fenced rigidly to soil-type closely following the recommendations of McHarg (1971) for optimal whole-farm planning. Paddocks were kept to a maximum 25 hectares for 4 of the 5 prototypes to create a minimum number of 12 paddocks on each prototype.

In the first experimental system, 10% of the farm, or 25% of the least productive sand, was established to tagasaste and used to replace grain feeding in autumn.

In the second, 30% of the farm or 80% of the sand was established to tagasaste. Initially, the extra tagasaste was to be used to grow more wool per sheep over summer, but, as the experiment evolved it became apparent that substantially more sheep also could be carried.

In the third system it is assumed that sand established to tagasaste is more productive than sand growing annual pasture alone. Therefore, 65% of the farm or 100% of the sand was established to tagasaste. The 65% tagasaste option has two versions, the first, the small 65% farm is about 240 ha and similar in size to the zero, 10% and 30% farms while the large 65% farm is 800 ha. The *large 65%* farm was included in the comparison to further explore problems associated with scale (paddock and flock size).

General management

The farms are stocked and managed according to a set of rules formulated for the various land management units (see Table 4) and scrutinized by a panel of local farmers and consultants. An expert panel of advisors was assembled as a Management Committee and they have met every month since the project commenced in February 1988. As the aim of the operational research is to continue to develop all the systems based on objective measurement, the general and specific rules can not always be adhered to and are dynamic.

Initially each paddock within land management unit was stocked similarly but they were graded after the first year (see Table 4) and reassessed each year, on the basis of realised sheep grazing days for the equivalent of 50 kg wethers, prior to setting the next annual grazing plan in May. Monthly measurements have also been made of the edible dry matter on offer and its composition in 3 examples

Table 3. The area, distribution of land management units (fodder and soil type) and distribution of livestock, on the 5 prototype farms comprising the 'Dunmar Research Station', at shearing in October 1991

Resource	Experimental farm (proportion of arable area as tagasaste)				
	Zero	10%	30%	Small 65%	Large 65%
Land management units					
Pasture on sand (– fertiliser)	42	42	42		
Pasture on sand (+ fertiliser)	82	64	44	0	0
Blue lupin on sand	37	38	0	0	0
Crop on sand	0	0	0	0	0
Tagasaste on sand	0	26	81	162	521
Pasture on gravel	79	75	80	77	279
Total area	240	245	247	239	800
Layout					
Maximum paddock area (ha)	25	25	25	25	45
Number of paddocks	12	16	16	14	29
Stock (dse)					
Sheep	800	920	1195	1553	1971
Cattle	0	0	0	0	2556
Total (dse/ha)	3.3	3.8	4.8	6.5	5.7

Table 4. Summary of rules or assumption about general management and specific management of land management units within and between the various prototype farms (October 1991)

General rules or assumptions about optimum management

1. No more than 1000 sheep per water trough
2. No tagasaste to be grazed for more than 30 days per year
3. Paddocks with tagasaste in them can be grazed for short periods in winter and spring with little penalty to the regrowth of tagasaste
4. Wool production is maximum if sheep transfer from green spring pasture to tagasasaste for summer
5. Young sheep can not be run with older sheep because they fail to thrive
6. Trace minerals to be fed to all weaners over summer and to adult sheep grazing tagasaste
7. The separation of the paddocks within experimental farms will not be used as an excuse for not carrying out a grazing strategy, e.g. short term rotation such as tagasaste 3 days per week

Land management units	Grade	When to graze	No. of dse/ha	Special
Pasture on sand	(good)	195 days – break of season to December	6.6	
	(medium)		3.7	
	(bad)		1.9	
Blue lupin on sand	(good)	150 – 1st November to 1st April	9.7	Lupinosis
	(medium)		7.3	
	(bad)		4.9	
Crop on sand		210 days – summer and autumn	4.3	
Tagasaste on sand	10% of farm	90 days – autumn feed gap	48	Ration
	30% of farm	210 days – summer	15	weaners
	65% of farm	when necessary to maximise overall stock numbers	Variable	all classes
Pasture on gravel	(good)	capable of being set stocked	8	
	(medium)	(365 days) or able to be grazed at	5	
	(bad)	any time of the year	3	

of each land management unit. Animals in the 3-year-old group in each sheep class are weighed a minimum of 5 times through the year and wool production is measured by sheep class and farm.

Problems in running farm-scale prototypes

Continual assessment and reconciliation of realised paddock yields versus budgeted yields is a major part of every farmer's day. Similarly, if farmers are to maximise their incomes, their budgets must be sensitive to market shifts within any budgeting period. On the 'Dunmar Research Station' these functions are served by the monthly management meetings. Hence, the original strategies for maximizing returns from the farms with varying areas of tagasaste have evolved and will continue to do so. For example, in response to market forces 3 major policy decisions were made by the Management Committee in May 199 1.

1. To manage all the flocks to maximize the return from wool production by grazing all classes of sheep to maintain condition score 2 and hence minimize the mean fibre diameter of the wool they produce.
2. To maximize the proportion of dry sheep run by all farms. In the case of the large 65% tagasaste farm no ewes were purposely joined with rams.
3. In addition, the large 65% farm has adopted cattle up to 55% of total dse's. The strategy here is to use the extra carrying capacity to turn off young store cattle. Experimental data for cattle have so far ruled out using paddocks of tagasaste to finish cattle. However, recent data from cows set-stocked on tagasaste for 7 months (September to March 1992) give cause for optimism and may cause the Management Committee to change its attitude and grazing rules with respect to tagasaste and cattle.

The range of results (approximately 200%) within examples of the same land management unit across all prototypes is a major problem for those attempting to model 'whole-farms' (McKinney *et al.* 1978). We require more basic studies to better understand this variation within land management units as well as measured performance of the same paddocks over a range of seasons before we can be confident about using the MIDAS modeling to predict the long term level of productivity, stability and sustainability of farming systems on sandplain.

CONCLUSION

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This contract is not about establishing a definitive recommendation with respect to the success or failure of tagasaste as a new source of fodder but rather about the philosophy and physical requirements for research aimed at developing new sustainable farming systems all the way from discovery of new key elements to their incorporation and validation on a 'whole-farm' scale. It is concluded that the overall approach taken by the Martindale Research Project has been very successful in discovering a new fodder source for farms in south western Australia. It has established sufficient basic facts with respect to tagasaste grown on deep sands to give farmers confidence to grow enough tagasaste to replace their budgeted requirements for hand feeding in autumn. The final stage of operational research, to integrate the new development into the established system, is an ongoing project whose success or failure will take more time to assess. However, it has already shown that more basic research into the factors controlling the nutritive value and palatability of tagasaste is a priority area.

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