MIDAS: an economic modelling approach to determining research directions for wholefarm systems

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Introduction

Funds available from government and industry for agricultural research are limited. It is important that they be allocated in such a way that they provide the best return to farmers and the community.

These funds have been allocated on the basis of many judgements: researchers judge which projects to propose; farmers make judgements about their research needs and communicate these to those allocating research funds; management staff in research organisations make judgements when they budget expenditure; and committees judge the allocation of industry funds. Traditionally, there has been very little quantitative analysis to support those judgements. Researchers have sometimes been expert in only part of the farming system and have usually conducted little or no economic analysis. Funding bodies have been guided by subjectively determined priorities and the previous performance of researchers.

The MIDAS model (Model of an Integrated Dryland Agricultural System) was developed in part to provide researchers and others with a more quantitative and better economic understanding of Western Australia's wheat-sheep farming system. It was intended to calculate the effect on whole-farm profit that different research directions and projects could have, and to compute the most profitable way of incorporating new practices resulting from research. MIDAS was not built to replace fallible human judgement, nor as a substitute for subjective understanding, but to provide information to enhance judgement.

This paper discusses the influence that MIDAS has had and is having on research in the Western Australian wheat-sheep area and illustrates how it has been and is being used to exert this influence.

MIDAS

MIDAS has been described in detail elsewhere (Morrison et al. (1); Kingwell (2)); only its main features will be briefly mentioned here.

MIDAS is a mathematical programming (MP) model; this has implications for the way the farm system is represented and its usefulness for economic analysis. Because it is an MP model, it can be used to find the use of farm resources which maximises the objective of wholefarm profit, subject to limited resources and limitations imposed by the biology of the system. Results from MIDAS show not only the optimum use of farm resources but (as with all MP models) information on how far behind alternatives are and the extent to which resource and other limitations are holding back the objective.

About 400 activities represent alternative practices. These include sheep and cropping enterprises and the many different rotations in which crop and pasture can be grown. They also include some alternative ways of managing cropping and sheep enterprises (e.g. fertiliser application, sheep feeding and crop sowing). Cropping and pasture activities are specified separately for each soil type to represent different biological relationships and costs on each soil type.

About 200 constraints describe the limited resources of land, cropping and sheep plant, finance and labour and also limit the productivity of enterprises to achievable levels by considering technical and biological constraints. Variation in the quality of land is accounted for in up to seven soil types per farm.

MIDAS is different from other economic models of the cropping sheep system in the degree to which it represents biological and technical relationships, particularly interdependencies between enterprises. Interdependencies include the benefits of nitrogen fixation, other yield boost effects through rotation (e.g. disease break effect), availability of crop stubble to sheep, the effects of cropping on subsequent pasture growth and the effect of pasture on subsequent weed control costs in crops. Other biological relationships represented include diminishing returns to crop yield as a function of nitrogen, yield reduction with later sowing of crop and monthly time-steps of sheep nutrient demand, sheep intake capacity and feed availability. Constraints limit the amount of pasture and stubble which can be consumed to levels which keep erosion risks very low.

Considerable effort has been put into obtaining the best possible data for each of the regional versions of MIDAS. As far as possible trial and farm data are used, although expert estimates are at times the only data available. A process of model review has meant that the model is evolving as better data become available and more detail is represented. Spreadsheet software describe data inputs used in a form that those who are not expert in MP can understand and challenge.

While MIDAS represents the biology in great detail for an economic model, the biology involves a higher level of approximation of biological processes than the enterprise level simulation models of biologists. This is justified in terms of the costs of increasing model size and complexity and the judgement that these costs out-weigh the benefits of increased biological detail.

Since MIDAS' priority is to address issues with implications at the wholefarm level, it was considered to be of insufficient benefit to duplicate the detail of enterprise simulation models. The main criterion for inclusion of detail is whether more biological detail will make a significant difference to the results from the issues examined by MIDAS. Another relevant factor is that the MP technique, while better suited to economic analysis, is unable to represent biological processes as well as simulation does.

There are some limitations of MIDAS which should be be mentioned. These are that standard MIDAS deals only with a single "expected" season type rather than fully representing season variability, that it is single year equilibrium model and that the treatment of sheep-pasture interaction is simplistic.

Failure to represent seasonal variability may make a difference to answers from MIDAS. Evidence to date (Morrison et al. (3)) is that it tends to favour slightly riskier strategies and a Discrete Stochastic Programming version of MIDAS is being developed to test this.

To limit its size, MIDAS was constructed as a single year equilibrium model, meaning that it compares the profitability of equilibrium positions rather than the profitability of getting from one position to another. (This assumption has been avoided in analysis of long-term land degradation issues,

e.g. Salerian (4)). The treatment of time implicit in this approach makes MIDAS solutions more relevant to medium-term or strategic decisions rather than the short term or tactical decisions.

In MIDAS, sheep liveweights are determined exogenously (as a function of liveweight, liveweight change, pregnancy or laction status and the level of activity of the sheep) and the effect of sheep on pasture is based on a simple linear feedback. Methods allowing liveweight to be determined endogenously and pasture growth to be represented as function of biomass transferred from the previous period have been devised and are being introduced. It is not expected that they will greatly affect the optimum solution when they are introduced.

MIDAS use

MIDAS has been used in a number of ways to influence researchers and the research they conduct. It has been used to affect their understanding of the system, to help in the identification of high return areas of research, to set broad directions for research and to estimate benefits which could arise from specific research projects. In the process of its development and use it has helped in the identification of information gaps.

It is difficult to estimate how much effect MIDAS has had to date on research because it is difficult to estimate what would have happened in its absence. MIDAS seldom tells the researcher something totally new about the system, but it does help to put aspects of the system in perspective. This can be important. It can show, for example, that of two problems which could lead to research projects, solving one could significantly increase whole-farm profit, but solving the other would have little effect on profit. Often MIDAS answers are in accord with the preconceptions of researchers but at times they are not. The following are illustrations of its use and usefulness, rather than a comprehensive review of its applications.

Improving researchers' understanding of the system

The first benefit, providing information that adds to researchers' understanding of the system and the way they think about it, sounds vague, but it has had an effect on the adoption of an economic and farming systems way of thinking. For example, Tables 1 and 2 are small excerpts of output from MIDAS, each showing the profit maximising rotations for a soil type and showing how many dollars per hectare alternative rotations are behind the profit maximising rotation. The number of dollars behind is referred to as the shadow cost. Implications of this are that the soil types should be managed differently; while on one soil type represented in Table 1 it would be very unprofitable to grow anything but wheat/lupins, on the other soil type (Table 2) continuous wheat and continuous pasture are both part of the profit maximising solution and various wheat/pasture combinations are not very far behind.

Exposure of researchers to this kind of information means that they absorb economic concepts of an optimum and of shadow prices, and background information on the most profitable use of land of different types which is relevant to selection of research projects. While MIDAS certainly could not be attributed with discovery of farming by soil type, these results have led to increased emphasis on extension of this practice.

Table 1: Sample MIDAS output: optimum rotation and shadow costs for deep sandplain soil (S2) in the eastern wheatbelt (excerpt only)

Optimum rotation	Area(ha)
S2WLONB	460

Other rotations	Shadow costs ($/ha)
S2PPPP	-19.26
S2PPW	-26.24
S2PWPW	-25.25
S2PPWW	-26.44
S2PWW	-24.65
S2WWWW	-11.85
S2WLBEB	- 0.66
S2WWLONB	- 0.10
S2WWLBEB	- 8.89

Where:
W = Wheat
L = Lupins
P = Pasture
F = Field peas
BEB = Lupins sown before break
ONB = Lupins sown on break

Table 2: Sample MIDAS output: optimum rotation and shadow costs for red sandy clay-loam soil (S6) in the eastern wheatbelt (excerpt only)

Optimum rotations	Area (ha)
S6PPPP	547
S6WWWW	28

Other rotations	Shadow costs ($/ha)
S6PPPW	-6.91
S6PPW	-7.94
S6PWPW	-6.80
S6PPWW	-4.03
S6PWW	-3.33
S6PWWW	-6.36

Where:
W = Wheat
P = Pasture

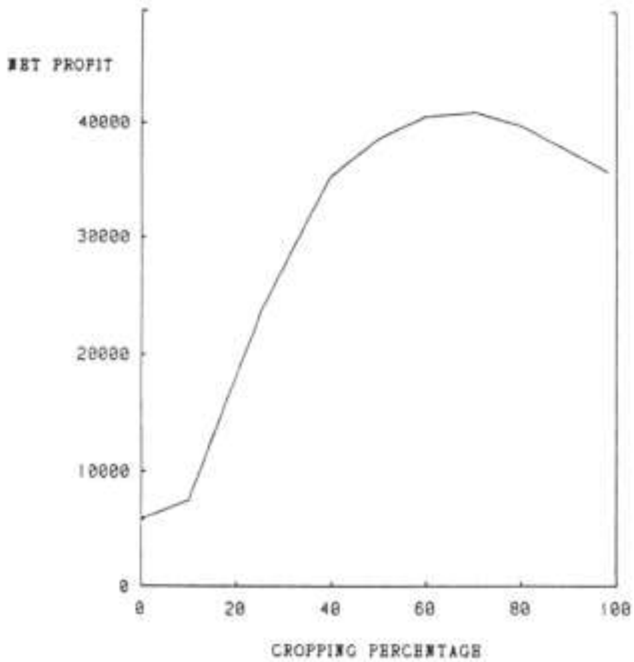

Figure 1: Farm profit as a function of cropping level

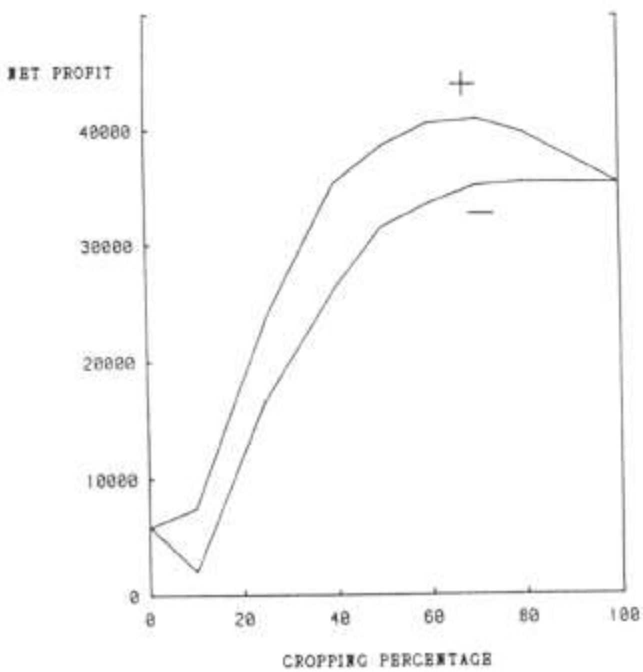

Figure 2: Farm profit as a function of cropping level with (+) and without (-) interdependencies

Figure 1 also shows MIDAS results which have affected researchers' understanding of the system. There are diminishing returns to increasing cropping levels - in fact profit is almost always found to be a quadratic function of per cent of the farm in crop, peaking in this case at around 60 per cent.

MIDAS has also been used to investigate the reason for this functional form by experimentation with different assumptions. Figure 2 (from Pannell (5)) shows that when several major interdependencies between enterprises are deleted (stubble utilisation by sheep, nitrogen fixation and yield boost effects) the curve is no longer quadratic and profit is no longer clearly maximised by a mix of crop and sheep. Further MIDAS work (Pannell and Falconer (6)) produced the estimate that nitrogen fixation and other yield boost effects of legumes on each soil type contribute more than $18,000 to whole-farm profit for an average eastern wheatbelt farmer. Results of this kind have provided quantitative support for the view of agronomists that they should be seeking an appropriate pasture or crop legume as part of the rotation on each soil type and that a mix of cropping and sheep enterprises maximises profit for most farms.

Other factors found to explain the diminishing returns to increased cropping levels are the allocation of more marginal land to cropping as cropped area increases, machinery size and sheep feed becoming limiting in winter.

Directly affecting research directions

One example of this has been the effect of MIDAS results on pasture research. In assessing on which soil type to concentrate further pasture research, Ewing and Pannell (7) showed that even though highest pasture yield increases could be expected on the loamy sandplain soils, further pasture research on this soil type is likely to be a poor prospect because of the profitability of alternative land uses. The break-even yield increase of pasture would have to be an unachievable 60 per cent above present production to displace the highly profitable wheat/lupin rotation. Pasture research was found to be a better prospect even on the acid sands, where the yield increase that could be expected to be achieved, is least.

It would be misleading to say that prior to MIDAS work no pasture researchers took any account of the profitability of alternative land uses when deciding where to concentrate their research - some did. Some researchers (but not all) did see that since there was already a cereal crop/legume rotation suitable for a soil type, it was not so important to conduct pasture research there. However, it was not recognised just how important the opportunity cost of alternatives is, leading to the counter-intuitive conclusion that research on soils where potential for increased pasture growth is low could be of more value to industry than soils with the highest potential for increased pasture production.

Another important contribution of MIDAS to pasture research has been quantification of the enormous seasonal difference in the marginal value of pasture, varying from more than 15c/kg in early winter to less than 1 c/kg in spring. While pasture researchers have, of course, always known that there is a late autumn/early winter feed-gap, they did not fully understand its economic significance and how important the seasonal distribution of pasture production is in relation to other pasture characteristics they might select for. Following the MIDAS work, there has been greater emphasis on selection

for higher seed set because increased early production is related to seed set. A trial looking at increasing early feed production by growing a fodder crop has also commenced as a result of this work.

MIDAS has also played an important role in establishing the place for a crop legume in the farming system. Lupins are difficult to evaluate without a MIDAS type of model because in addition to production of a marketable grain, lupins are of value through:

- nitrogen fixation and other yield-boost effects on subsequent crops;
- production of a relatively nutritious stubble;
- benefits that seeding time flexibility provides in utilisation of scarce seeding plant; and
- the value of lupins as a feed grain.

MIDAS accounts for all these effects. Ewing et al. (8) used MIDAS to show that even if yields or prices were only 80 per cent of that expected, lupins were still selected as profitable in rotation with wheat on some sandy soils. Recent analysis has shown that unless yields are below 60 per cent of expected levels, lupins are still profitable on the loamy sand plain soils. While agronomists have long been enthusiastic about lupins, the robustness of lupin selection by MIDAS added to the confidence of researchers about the crop and helped clarify the soil type on which further research should be concentrated.

Recently MIDAS runs with the current level of lupins grown by farmers and runs without lupins, have been used to estimate the net value that lupin research and extension is realising. This could be viewed as a public relations benefit of MIDAS, showing lupins to have a net on-farm benefit of $45m per year, well over half the Western Australian Department of Agriculture's budget. An assumption of this analysis is that without the Department, there would not be a lupin industry.

Not all analyses conducted using MIDAS have shown the Department's research to be in areas of enormous value to industry. One example is analysis of the value of increasing lambing percentage. MIDAS was used to calculate the increase in whole-farm profit that would result from higher lambing percentages. Since it is an optimisation model, the value attributed to increased lambing percentage was that corresponding to a farmer making the profit maximising use of the additional lambs. Although farm profits were found to be higher with increased lambing percentage, benefits were only of the order of $2 per ewe for a lambing increase from 70 to 80 per cent. Part of this $2 would be absorbed in costs of increasing fertility or reducing lamb death rates. Gains from higher selection pressure through increased lambing were not included in the analysis.

Although anticipated by some, these results were queried by others. For this reason, further examination of MIDAS results was undertaken to find out why the value of increasing lambing percentages is not particularly high. The reason is that the additional lambs have to be retained for some time before any benefits can be realised, and this involves the costs of running fewer adult sheep and/or feeding more grain and/or having more pasture (which is largely the opportunity cost of cropping a smaller area than it would otherwise be profitable to crop).

The standard MIDAS model has also been adapted to conduct an analysis of the effect of different strategies to ameliorate salinity. Results showed that growing saltbush could convert saltland into a profitable feed supply for sheep (Salerian et al. (9)).

Salerian (4) also modified MIDAS to incorporate the dynamics of land use and salinisation. He showed that changing land-use over the saltland recharge areas (the areas in which land use was causing the salinity problem) increased long-term profits if farmers changed from pasture to deeper rooting wheat and lupin crops. The reason for this is that cropping on recharge soils adds more to farm profits in the short term than does pasture and also adds more to long-term profits because salinisation would proceed more slowly. There is thus a fortunate coincidence between higher short-term profits and reduced rates of degradation.

However, this may not be the case for strategies required to reduce the area of salinity rather than simply arrest its rate of growth. If these strategies require reafforestation of recharge areas, they could be extremely expensive. Recharge areas are a large proportion of farmland (the majority of some farms) and it seems that in most cases a high proportion of recharge area would have to be reafforested, at a high cost of production foregone. Unless the trees used in reafforestation are almost as profitable as cropping in the short term, Salerian (pers. comm.) has found they yield much lower long-term profits than cropping. This is in spite of the fact that they reduce the area of salinity. With significantly lower profits it is likely that many farms would become unviable.

The implication of MIDAS work is not that that research into reafforestation of recharge areas is misplaced; however, it does show that with saltbush, even though it is direct treatment of the symptom rather than the cause, it can add significantly to long-term profits. On the other hand, while reafforestation does treat the cause of the problem, it is important to be aware that large-scale reafforestation could be incompatible with profitable agriculture. The challenge is to see to what extent small, strategically placed areas of reafforestation can have on the area of salinity and also to search for deep rooted, high water using species which are also profitable.

Formalised project planning

MIDAS has also been used in a more formal way to conduct ex ante analysis to plan research at the individual project level. Very recently its use has been integrated with REVS (Campbell and Morrison

(10)), a cost-benefit analysis program for research project analysis. For example, MIDAS has been used in conjunction with REVS to assess the value of allocating resources to a project to research and extend serradella pasture on acid sands. MIDAS was used to calculate the effect on whole-farm profit that the serradella would have. Because of uncertainty, a series plausible yields of serradella was included in the analysis. REVS accounted for estimated project costs, regional estimates of benefits aggregated up from per farm estimates of MIDAS, subjectively estimated probabilities for each of the estimates of serradella yield and estimated rates of adoption. From this procedure REVS generated an expected net present value, an internal rate of return for the project and a simple measure of the riskiness of the project. The analysis showed the project to have a high expected level of return (expected net present value of millions of dollars) but to be risky with a 70 per cent probability of failure.

Where the effect of a project is so significant that it will reduce the price received for the final product, this has been accounted by using MIDAS to generate a synthetic supply function, which incorporates the effect of a price fall.

Identifying information gaps

Finally, building and using MIDAS has highlighted some important information gaps. Prior to MIDAS pasture growth measurement concentrated on spring levels of production. Since MIDAS results have shown the high value of early pasture, there has been a greater emphasis on measuring early growth.

The economics of phosphate fertiliser application have been assessed on the basis of a constant value of pasture throughout the year, even though there is evidence (Bowden pers comm.) that phosphate may cause a disproportionate increase in production during the autumn-winter feed gap. Consideration is now being given to inclusion of seasonal variation of pasture value in calculating the most profitable level of phosphate to apply.

The informational requirements of MIDAS have imposed additional demands on biologists in the data they collect or generate. MIDAS results are very sensitive to the relative yields of crops and pastures on each soil type. Because of this it was considered that there was insufficient data on this and a trial comparing crop yields on each soil type has been running now for several years. A simulation model is being developed to generate pasture production for MIDAS for combinations of rotation, soil type and season.

Conclusion

The contribution of MIDAS to research effort cannot be measured accurately because we have no knowledge of how differently it would have been conducted without MIDAS. MIDAS work has meant that researchers are more aware of and understand better the economic and farming systems context of their work. It has meant that they have been exposed to information on the profit-maximising use of land, the closeness (shadow price) of alternatives, the opportunity cost of pursuing sub-optimal practices, the marginal value of scarce resources and the economic value of biological interdependencies of the farming system. In some cases further analyses are conducted to provide information on why MIDAS produced particular results.

Frequently MIDAS results have provided clear directions for future research by identifying how research could best be directed to increase whole-farm profit and where there are important information gaps. Often these results have simply supported current wisdom on directions of research but at times they have not. Seldom have MIDAS results led to the discovery of something totally new about the farming system, but they have put problems in a different perspective and contributed to different conclusions being drawn.

MIDAS' limitations mean that it is not a panacea for research planning and evaluation but an aid to the judgement of scientists and administrators in the allocation of resources to research in the cropping-sheep areas of Western Australia. While it is a misuse of tools such as MIDAS to accept uncritically research directions derived from them, it is no longer good enough to plan applied research without reference to such quantitative decision aids.

References

1. Morrison, D.A., Kingwell, R.S., Pannell, D.J. and Ewing, M.A. 1986. Agricultural Systems 20 No. 4 pp 243-268.

2. Kingwell, R.S. 1987. In: Kingwell and Pannell (Eds). MIDAS, A Bioeconomic Model of a Dryland Farm System, Pudoc, Wageningen, 15-54.

3. Morrison, D.A., Pannell, D.J. and Kingwell, R.S. 1985. Division of Agricultural Economics and Marketing, Western Australian Department of Agriculture.

4. Salerian, J.S. 1988. Paper presented to the International Economics Post-Graduate Research Conference, University of Western Australia.

5. Pannell, D.J. 1987. In: Kingwell and Pannell (Eds). MIDAS, A Bioeconomic Model of a Dryland Farm System, Pudoc, Wageningen, 64-73.

6. Pannell, D.J. and Falconer, D.A. 1988. Agricultural Systems 26, no. 1, 1-17.

7. Ewing, M.A. and Pannell, D.J. 1985. Proceedings of a Review Conference on Pasture Research in Southern Australia. Australian Wool Corporation, Melbourne.

8. Ewing, M.A., Pannell, D.J. and Morrison, D.A. 1986. Proceedings of the Fourth International Lupins Conference, Geraldton, Western Australia, 152-160.

9. Salerian, J.S., Malcolm, C.V. and Pol, E. 1987. Technical report (56), Division of Resource Management, Western Australian Department of Agriculture.

10. Campbell, C. and Morrison, D.A. 1988. Agricultural Economics and Marketing Division, Western Australian Department of Agriculture.