Developing Collaborative Planning Support Tools For Optimised Farming In Western Australia: A Methodology

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Abstract

A model called MOLups – multiple objective land-use planning – has been developed as a planning support tool for optimising land-use decisions in Western Australia. The model is capable of assessing land-use capabilities at farm level (which may later be incorporated into regional decision-making) to achieve satisfying solutions which reconcile competing objectives such as profit maximisation while minimising the impact of the production system on the environment. This paper describes the development of MOLups and illustrated its usefulness in supporting whole farm decision-making process.

Keywords

multiple-objective land-use planning, modelling, MOLups, decision-making

Introduction

The main purpose of whole farm decision-making is to determine optimum land-use management applications for different farming enterprises (e.g. crop production, animal production and pastures) in the context of the entire farm, based on its resources. It is an approach that supports farmers in achieving their goals as well as ensuring the farm sustainability (Kemp, 1996). The process itself is a complex one to perform. It involves procedures incorporating numerous, at times interrelated, factors and aspects such as land-use management elements (e.g. crop type, fertilising application, spraying application, and sowing date), climatic and market conditions. Climate and market move constantly and may alter the course of farming decisions as the growing season develops, resulting in uncertainty. Essentially, decision-making at a farm level requires sufficient skills and knowledge in a broad range of fields such as biology, agronomy, mechanics and marketing. Decision makers need to be alert and ready to make decisions anytime for the whole sowing year. Farm decision-making can be visualised in a dynamic environment, with a cone-like shape. At the beginning of the sowing year, the future is unknown and uncertainty in terms of climate and/or market is high. Moreover, a lack of constraints on land-use management elements means there is an enormous number of possible farm management options. As the year progresses the decision-maker is required to take a decision based on the information being made available (e.g. climate, market). This will pose some sort of constraint on land-use management elements, reducing the amount of available options. Furthermore, as time goes by the occurrence of climatic and economic events will reduce the uncertainty, offering more confidence in the decisions to be adopted.

Model Description

MOLups was developed to work as a decision support system which is capable of assessing land-use capabilities at the farm level to achieve satisfying solutions x which reconcile competing objectives (F_1, F_2), such as maximisation of profit P and minimisation of environmental impact E of the production system:

$$F_1(x) = \max\{P(x)\} \text{ and } F_2(x) = \min\{E(x)\} \tag{1}$$

The solution is based on the most suitable combination of paddock management options (e.g. sowing date, crop type and fertilising activities) constituting the whole farm management option.

MOLups was developed based on multi-objective decision-making techniques where the optimum management is determined by an exhaustive search of the possible outcomes. The optimum result is reached by using Pareto optima, ensuring each individual objective is met without compromising any of the others. The MOLups model goes through three stages: input, search and optimisation, and output. In the input phase, land-use management, predicted weather and predicted market price for the agricultural products are asserted as input in a crop simulator model and environmental impact simulator to evaluate the returns of a particular crop production under specific paddock constraints, the expenses used, and the likely impact on the environment as result. The WA Wheat-Beverley (Fisher *et al.*, 2002) is used as the crop production simulator, while the Grains Environmental Data Tool (GEDT) (Narayanaswamy *et al.*, 2002) was used for evaluating the environmental impact caused by selected applications, such as fertiliser, spraying and transportations instigated by a crop product life cycle. Furthermore, Monte Carlo simulation is used for modelling the risk and uncertainties inherent to the whole decision-making process. The data distribution utilised by Monte Carlo is based on the existing historical data. The search-and-optimisation phase encompasses a suitable search and selection technique to locate feasible optimal solutions. In the output phase, the solutions are processed in such a way that the user recognises the most satisfying solutions for a particular case. Hybrid exhaustive heuristic search and Pareto Optimal techniques are employed to search for promising solutions. A pre-selection heuristic method is employed to determine Pareto optimum options for each paddock, limiting the search into promising regions. A limited amount of options are then used to permutate and find the best combination for the whole farm land-use management option. Once again, Pareto optimisation is employed to discover most satisfying final solution for the user.

MOLups provides output for each farm management options, including overall profit (estimated and distribution), environmental impact (estimated and distribution), estimated proceeds on each crop products produced, and paddock per paddock management activities (i.e. sowing date, crop type, fertilising activities, yield production, expenses and environmental impacts caused). The output is presented in such a way, it facilitates understanding the comprehensive information provided (Figure 1).

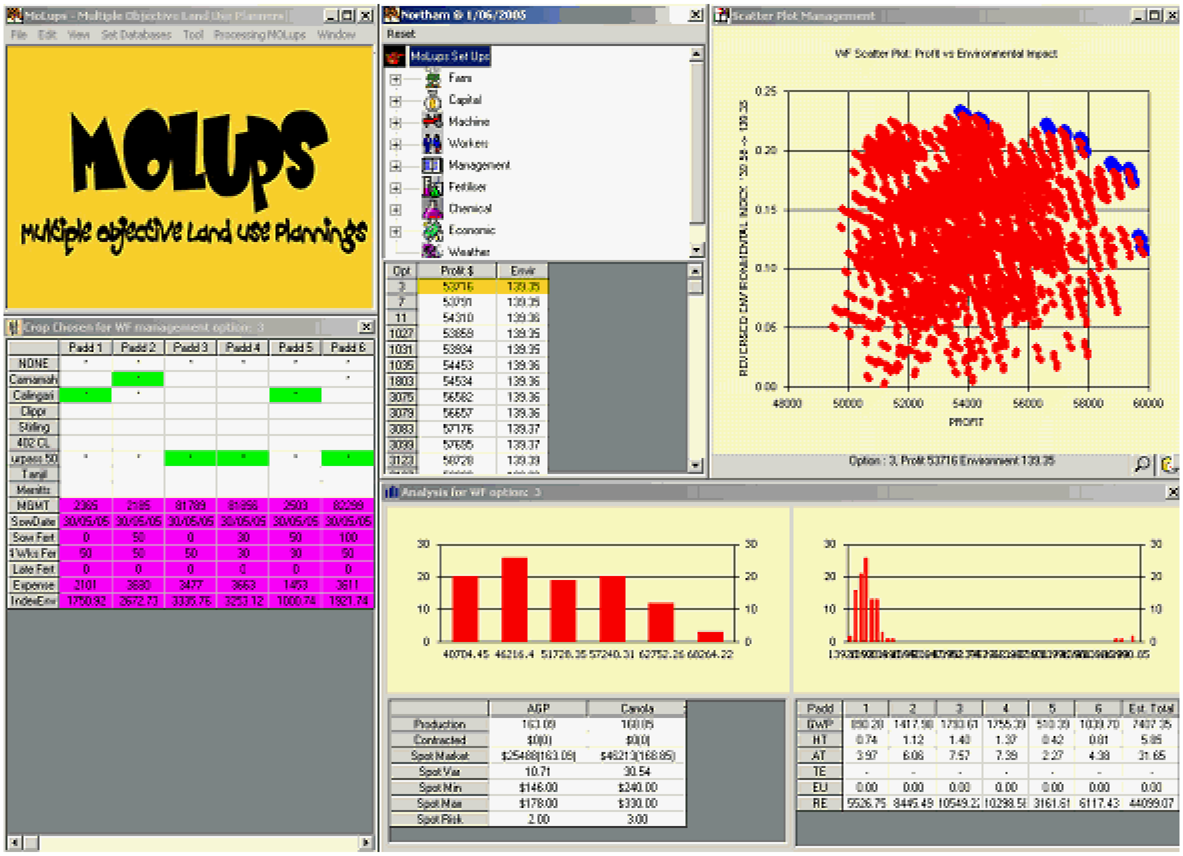

Figure 1 MOLups output

Conclusion

MOLups is a multiple-objective decision-making tool that attempts to mimic the way a decision maker reasons his/her decisions through the growing season. At the beginning of the year the solution space is a huge open space. However as the time passes and decisive events occur, the confidence level increases narrowing down the solution space. In addition, the uncertainty elements within the decision-making process are adequately accounted for by utilising Monte Carlo simulation. Furthermore, MOLups is designed to be used in various different situations, like during planning, decision-making and monitoring farming stages. Subsequently, MOLups can be a very useful tool in supporting farmers in determining most suitable management options for their farm.

References

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