The evolving role of crop modelling in agronomy research

Michael Robertson[1] and Peter Carberry[2]

[1] CSIRO Sustainable Ecosystems, PMB5, Wembley PO, WA 6913, Australia
www.csiro.au Email Michael.Robertson@csiro.au
[2] CSIRO Sustainable Agriculture Flagship, PO Box 102 (203 Tor St) Toowoomba, Qld. 4350, Australia.
www.csiro.au Email Peter.Carberry@csiro.au

Abstract

The role of crop modelling in agronomic research has evolved in the last 20 years from a fringe activity often criticised by many agronomists to a tool now used routinely for agronomic research. We chart this evolution through a survey of the published literature of the last 10-20 years in Australia, New Zealand, Europe and North America. Papers were classified according to focus on development vs. application; the issue the models were being applied to (production, environmental impacts, or both); type of extrapolation (spatial, temporal or both); scale of interest (single paddock over one season, rotations over multiple season, or enterprises at the farm scale). They were also classed according to whether the justification for the work was either decision support system (DSS) development or systems analysis. Results showed that production concerns dominate most applications, although there is a notable growing emphasis on environment and policy dimensions. Models, at least in Australia, are being used as research tools for systems analysis rather than prototypes for decision support systems and with a greater emphasis on 'big picture issues' such as crop rotations, environmental impacts and livestock integration. In Australia, the percent of papers devoted to modelling increased from <5% in the early 1990s to ca. 15% in 2008. In countries other than Australia, there is an on-going stream of new model development, despite the well-established suite of systems models now publically available. In New Zealand, DSS development dominates the rationale for model development, driven by a focus on production impacts of crop agronomic management over single seasons.

Key Words

Simulation model, decision support system, systems analysis

Introduction

In the pursuit of scientific enquiry the development of predictive knowledge is seen as a natural step following the accumulation of empirical understanding. In agronomic research, the formalisation of such knowledge has more often than not taken the form of the mathematical relationships embodied in simulation models. The development and use of models was encouraged to enhance the efficiency of field research through extrapolation beyond the limits of site, season and management. Their development has also been driven by the perceived need to disseminate computerised decision support systems, based on such mathematical models, for farmers and advisors (McCown et al. 2002;, Stone and Hochman 2004).

The role of crop modelling in agronomic research has evolved in the last 20 years from a fringe activity often criticised by many agronomists (Passioura 1996) to a tool now used routinely for agronomic research. In Australia in the 1960s and 1970s, there was some isolated development and application of simple cropping-system models and since then there has been the evolution of crop-soil models, cropping-systems models and crop-pasture-livestock-soil models (Carberry et al. 1998).

The aim of this paper is to document the evolving role of simulation modelling in crop agronomy via a survey of the published literature. Through this we attempt to answer the following questions: (1) Has there been a trend in the number of papers developing and/or applying crop simulation modelling?, (2) How has the motivation for modelling and type of application changed?, (3) What have been the trends in the diversity of crop modelling platforms in use?, and (4) in what context are there differences between

Australia, New Zealand, Europe and North America? For the purposes of this paper we concentrate on agricultural production simulation models (and their DSS derivatives).

Methods

Our research questions were asked within the Australian, New Zealand, North American and European contexts by targeting our search to local journals/conferences that publish agronomic research on arable crops. In the case of Australia and New Zealand, the proceedings of the agronomy societies in each country were searched. For Europe, the European Journal of Agronomy was targeted. Issues were manually inspected and papers classified on the basis of titles and abstracts. For North America, the Agronomy Journal was electronically searched using the terms “model” and / or “simulation” in the title or keywords.

Papers were classified as having a focus on either development, evaluation and testing, or on application. Application papers were further classified as having a focus on agronomic management, genotype x environment (GxE) or policy. The particular model being developed or used was also recorded. Papers were classified in terms of whether the models were applied to production or environmental impacts or to both; type of extrapolation (spatial, temporal or both); scale of interest (single paddock over one season, rotations over multiple season, or enterprises at the farm scale); and the justification for the work being for DSS development or systems analysis. Searchers covered 1992-2008 for Australia, 1988-2009 for New Zealand, 1990-2008 for America and 2002-2009 for Europe.

Results

The percent of papers devoted to crop modelling ranged from 7% for New Zealand, 8% for North America, 9% for Australia and 22% for Europe (Table 1). In Europe and America about two-thirds of modelling papers were devoted to development, while there was a 50:50 split between development and application in Australia and New Zealand.

Traditional agronomy was the focus of most application papers (>80%). With respect to other applications, policy was dominant in Australia, while there was an even split between policy and GxE applications in Europe and North America. APSIM dominated papers from Australia (75%), CERES/GRO was dominant in North America (27%) while in Europe a wide variety of models were developed and applied (Table 1).

In the proceedings of the Australian Agronomy Society the percent of papers devoted to modelling increased from <5% in the early 1990s to ca. 15% in 2008 (Figure 1). There was a noticeable spike in model development papers in 1996 followed by a trend towards applications. There was an increased emphasis on policy at the most recent conference of the Australian Society of Agronomy in 2008.

Table 1: Numbers of papers devoted to crop simulation modelling and classification into development vs. application, type of application, and type of model used.

	Australia	*North America*	*Europe*	*New Zealand*
Period searched	1992-2008	1990-2008	2002-2009	1984-2008
Total papers searched	2097	3248	490	438
Percent devoted to crop simulation modelling	9%	7.6%	22%	7%

Type of use				
Model development	46%	70%	61%	45%
Model application	54%	30%	39%	55%
Agronomy	43%	22%	22%	55%
Policy	10%	1%	8%	0%
GxE	1%	7%	9%	0%
Type of model used				
APSIM	75%	6%	9%	
CERES/GRO	1%	27%	17%	
CROPSYST	1%	2%	7%	
EPIC		2%	2%	
RZWQM		7%		
GOSSYM		2%		
Other	23%	54%	64%	100%

In the Australian and New Zealand literature, production was the main focus of modelling studies, although in Australia 26 % of papers contained an environmental focus (Table 2). Both spatial and temporal extrapolation was a justification of using models. In New Zealand nearly all papers were concerned with single paddocks, while 35 % of Australian papers concerned rotations or enterprises (e.g. livestock and cropping). The development or application of decision support systems was a major driver for New Zealand work, while this was the reverse in Australia, where a research emphasis on systems analysis dominated the aims of papers.

Discussion

These results point to a number of drivers in the development and use of simulation models in agronomy. (1) Production concerns dominate most applications, although there is a notable growing emphasis on environment and policy dimensions. (2) Models in Australia are being used as research tools for systems analysis rather than prototypes for decision support systems. This use is no doubt linked to the disenchantment with the lack of success with agricultural DSSs (McCown et al. 2002). These lessons either do not seem to apply or have not registered in New Zealand, where a healthy demand for DSSs seems to drive modelling. This demand may be consistent with a focus on production aspects of crop agronomic management over single seasons, whereas in Australia there has been a greater emphasis on environmental dimensions, crop rotations, environmental impacts and livestock integration. (3) In countries other than Australia there an on-going stream of new model development, despite the well-established suite of systems models now publically available (e.g. APSIM, CERES/GRO, CROPSYST, EPIC). This suggests to us an on-going need by agronomists to develop their own models for specific purposes, but the question remains whether research effort is being squandered by the re-invention of established approaches without significantly improving predictive capability.

Table 2: Classification of justification given for using / developing models in papers based on categories of system impact, extrapolation, scale of interest, end use.

		Australia	*New Zealand*
System driver	Production	74	90
	Environment	6	0
	Both	20	10
Extrapolation	Spatial	2	0
	Temporal	13	38
	Both	85	62
Scale of interest	Single paddock	65	97
	Rotations	24	0
	Farm / enterprise	11	3
End use	Decision support system	25	66
	Research – systems analysis	75	33

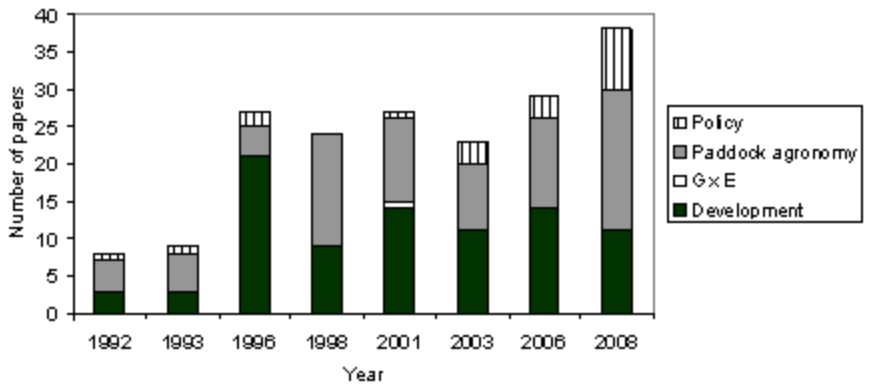

Figure 1: Trends in type of modelling use from papers presented at the Australian Agronomy Conference between 1992 and 2008.

The results show an increasing use of simulation modelling in Australia, with strong emphasis on production agronomy and the management of individual crops or sequences, despite the promise of modelling to tackle policy questions and genotype selection and management (Hammer 1998). The increased use has no doubt been driven by funding shortages for field research and the consequent need to extract greater value from experimental activities and to facilitate collaboration. A further driver has been an impetus to extrapolate beyond site and season and address wider systems implications such as environmental impacts, and hence the dominance of systems models that can address issues such as the impacts of crop sequence, soil erosion or pest incidence on production, soil fertility or water quality. While the use of APSIM dominates Australian studies, in only 40% of papers were the senior authors members of the Agricultural Production Systems Research Unit (data not shown). This may indicate the proliferation of APSIM throughout the Australian agronomy research community.

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