Paying for Our Keep: Grasslands Decision Support in More-Developed Countries

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Paying for our keep: grasslands decision support in more-developed countries

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Key points

1. A survey of decision support (DS) tools in grassland agriculture illustrates the diversity of decisions supported and of delivery technologies that are used. Larger, whole-enterprise planning tools are undergoing a period where their user interfaces are being adapted to better reflect the requirements and practice of advisory users.
2. The history of use of GrassGro, a 'versatile simulator', is used to illustrate how versatile tools attract a diverse range of users and uses. Lessons learnt by the GrassGro team are discussed.
3. Uptake rates of DS tools in grasslands are generally lower than was expected a decade ago. Nevertheless, if return on investment is used as the criterion then some DS tools – especially smaller ones – are clearly successful. Uptake for educational use can be much more rapid.

Keywords: GrassGro, planning tools, versatile simulators

Introduction

"Models in grassland science have come to stay, and so they must be made to pay for their keep. To do that, it will be necessary to improve their scientific sophistication and their management relevance..." (Seligman, 1993).

Decision support (DS) tools in grassland agriculture have also come to stay. This review will examine the ways and means by which DS tools are being made to pay for their keep, with a focus upon DS efforts from the last decade and on the lessons that arise for those who develop DS tools for grasslands. A survey of the present state of grassland DS is presented, and a case made that there are grounds for modest optimism. As a more detailed case study, the history and impact of GrassGro (a simulation-based DS tool that has been in use since 1997; Moore *et al*., 1997) will be revisited. Lastly, some trends in technology and practice that will determine the effectiveness of DS tools in the coming decade will be examined. Throughout the review, the focus will be on those parts of the world where agriculture is well developed; consequently the term 'grasslands' should be read with this geographic caveat. A companion paper (Donnelly *et al*., 2005) addresses a number of technical issues in DS tool development and expands some points that are only touched on here.

Current trends in grassland decision support: a survey

The following survey of grassland DS tools is intended to be illustrative rather than complete. The selected tools show the diversity of adoption strategies and technologies that have been utilised in recent years, and general lessons for the practice of DS tool development. However, the survey is restricted to tools that have been released at the time of writing, and consequently a number of problem domains – especially provision of advice to policy makers – receive little attention.

'Niches that remain promising': McCown's critique of agricultural decision support

In an important paper concluding a special issue of *Agricultural Systems*, McCown (2002) applied theory from the wider discipline of management science to a series of case studies of agricultural DS efforts. He proceeded from a position that DS in agriculture has fallen far short of expectations. His analysis posited that the future of agricultural DS lies in only four directions:

- small tools ('decision calculi') that assist a decision-maker with a self-contained and highly structured task;
- use of models by consultants to aid farmers with both tactical and strategic decision-making;
- use of models as the basis of a facilitated learning process (a 'flight simulator'); and
- provision of formal frameworks that support regulatory objectives in constraining and documenting agricultural practice.

The second and third of these uses depend upon scientific knowledge being embodied in what McCown calls a 'versatile simulator'. A simulator is differentiated from a traditional research model as follows: "the primary aim in making a simulator is not to mimic system *process* but rather system *function* and *performance*, and to do so cost-effectively. Flexibility and ease of specification are key simulator attributes."

This author does not entirely agree with McCown's assessment of agricultural DS nor with his view of the feasible paths to success. The case studies on which he bases this conclusion are mainly concerned with cropping systems, and the authors of the two grazing-lands case studies to which he refers (Donnelly *et al*., 2002; Stuth *et al*., 2002) are conspicuously more optimistic. Nevertheless, McCown's categories provide a useful starting point for examining, and in many cases understanding, recent developments amongst grassland DS tools.

The decision calculus in grasslands: feeding, fertilizer and forage choice

There are a wide variety of small DS tools available for graziers in the more-developed countries. These tools are engineering rather than scientific artefacts, so literature citations are uncommon; this section is therefore mainly based on a survey of the World Wide Web and on personal communication with developers and distributors. Internet addresses for the tools discussed here are given in Table 1.

Tactical animal nutrition - Full accounts of the GrazFeed and NUTBAL animal nutrition tools can be found in Donnelly *et al*. (2002), and Stuth *et al*. (2002); these are well-established products that are now in a period of incremental change and accruing benefit to industry. They have been joined by a number of other tools, in particular a DS implementation of the Cornell nutritional model (Fox *et al*., 2004).

Fertiliser and manure - It is not surprising that choice of fertiliser and application rate is a decision area with considerable activity. The fertiliser tools all follow a common operating method: specification of soil attributes, pasture type and time of year is followed by the computation of a static yield model, with regulatory constraints taken into account where necessary.

Table 1 Some decision calculi for grazing lands, and their location on the World Wide Web

Tool	Purpose	Website (or citation if no site)
GrazFeed	Nutrition of sheep & cattle	www.hzn.com.au/grazfeed.htm
NUTBAL	Nutrition of sheep & cattle	cnrit.tamu.edu/ganlab
CNCPS	Nutrition of sheep & cattle	www.cncps.cornell.edu/cncps/main.htm
Diet Check	Nutrition of dairy cattle	Heard *et al.* (2004)
N Decision Tools	N fertilizer rates	www.nitrogen.unimelb.edu.au
EMA Fertilizer	Fertilizer & manure rates[1]	www.herts.ac.uk/natsci/Env/aeru/ema/
Cayley & Kearney	P fertilizer rates	Cayley & Kearney (2000)
fencepost.com.nz	Fertilizer rates[1]	www.fencepost.com/fertiliser/ft_main.jhtml
Phosphorus for sheep & beef pastures		www.dpi.vic.gov.au/dpi/nrenavh.nsf
M-CLONE4	Manure management	farmcentre.com/english/farmsoftware/start.htm
NMAN	Manure management	www.gov.on.ca/OMAFRA/english/nm/nman/default.htm
OVERSEER	Farm nutrient budgeting	www.agresearch.co.nz/overseerweb/
Forage Species Selection		www.forages.org
Greenhouse Accounting Tools		www.greenhouse.crc.org.au/calculators
StockPlan	Drought management	McPhee *et al.* (2003)
Pl@nteInfo	Yield prediction†	www.planteinfo.dk

[1] Part of a larger tool or suite

They are notable, however, for the variety of technologies and distribution channels that they use. Stand-alone software, Web applets, spreadsheets and paper-based systems are all employed, as are distribution via commercial CD (EMA), Internet download (N Decision Tools) and mass mailing (the tool of Cayley & Kearney, 2000). The Nitrogen Decision Tools product (Eckard *et al.*, 2001) uses three different means of deployment, and so provides an interesting example of the way that different user groups exhibit preferences for different means of dissemination. Dairy farmers – the ultimate decision makers – prefer lookup tables, while their advisors tend to prefer a downloadable spreadsheet. For this small tool, online calculation is not favoured by users (R.J. Eckard, *pers. comm.*).

The other side of nutrient management – managing excess nutrients (especially in manure) has also seen considerable DS effort. Tools from New Zealand (OVERSEER, Wheeler *et al.*, 2003), and from the United Kingdom (the nutrient budgeting module of the EMA product, Lewis & Tzilivakis, 2000) are decision calculi: they seek to inform producers about the nutrient balance of their enterprise, not to control it. In Ontario, on the other hand, the decision calculus approach has been overtaken by the fourth category identified by McCown (2002): use of DS tools to satisfy regulatory demand. The MCLONE4 software, developed in Ontario, is a decision calculus for use by advisors. Uptake of MCLONE4 has virtually ceased since 2002, and been replaced by NMAN, a tool specifically designed for the preparation of mandated nutrient management plans. Some of the science used in MCLONE4 has been re-used in NMAN (J. Ogilvie*, pers. comm.*).

Forage species choice - While it is not widely used, the Forage Species Selection Tool developed at Cornell University demonstrates an important technological opportunity for decision calculi. By employing a database (in this case a spatial data set of soil attributes linked to maps and aerial photography), the selection tool tailors its information to specific circumstances (a particular field); because it is deployed across the Internet, the application can proceed despite the large size of the underlying database.

In a previous review, Donnelly & Moore (1999) suggested that many small tools would be oriented to learning and designed to have a limited lifespan. There is some evidence of the former (e.g. StockPlan, McPhee *et al*., 2003), but the latter does not seem to have happened. Instead, decision calculi tend to be archived on the Internet, awaiting occasional future users at minimal cost. An example of this phenomenon is the greenhouse gas calculator tool of R.J. Eckard and colleagues (Table 1).

Information bases for decision support

A significant number of structured information bases for grassland agriculture have emerged in recent years. Examples include the Forage Information System (forages.oregonstate.edu), Agricultural Databases for Decision Support (www.adds.org) and the Agricultural Document Library module of EMA (Lewis & Tzilivakis 2000; www.herts.ac.uk/natsci/Env/aeru/ema/). These tools require a capacity to distribute and access large quantities of information; the compact disc seems to have been the initial enabling technology, but a clear shift toward Internet delivery is now under way. These tools are vehicles for self-directed, rather than participative, learning. Knowledge is expressed in the form of documents rather than models, which may be why McCown (2002) did not take them into account. The EMA example is of particular interest as it once again shows the value of placing decision calculi (fertiliser and pesticide application tools) into a learning context (the information base).

Tactical grazing management: the problem child of decision support

Allocating resources to optimise production was one of the earliest problems addressed by operations researchers. The classic problem of this kind in grassland agriculture is feed budgeting: the tactical allocation of grazing livestock to fields and other sources of feed. Given the obvious potential for benefit to graziers, it is no surprise that a number of DS efforts have been devoted to this decision area.

The success of these efforts has been mixed at best. Rickert (1998) reports the FEEDMAN project for Queensland graziers as a failure: despite a genuinely participative approach to development, uptake was low and FEEDMAN now appears to be in Internet archive. Rickert (1998) explains this failure in terms of insufficient ongoing commitment by the developing organizations. The technically very similar PRO PLUS tool (McPhee *et al*., 2000) has been successful within a limited market: an evaluation showed that 60% of graziers provided with PRO PLUS continued to use the software (A.K. Bell, *pers. comm.*). Release of PRO PLUS has been deliberately restricted to participants in a grazing management-training course. This has allowed the developers to find a niche market of users, whose attitude and aspirations predispose them to make use of the technology. The contrasting history of these two tools illustrates two lessons of general importance in DS tool construction: that participative development processes are a necessary but not a sufficient condition for success, and that embedding a tool in a learning process increases the likelihood of success.

The evaluation of PRO PLUS made it clear that a major reason for non-adoption was the time cost involved. Feed budgeting and feed planning have two major costs to a grazier: time spent in first describing the enterprise, and ongoing time spent monitoring pasture and livestock. Below a certain economic enterprise size, the setup cost makes these tools impractical; above a certain geographic size, the cost of monitoring is prohibitive. This explains why New Zealand, with its high ratio of economic size to geographic size, is where feed budgets are most popular.

Whole-enterprise planning: supporting the consultant

The four strategic planning tools in Table 2 share two important features. All are the outcome of DS efforts continuing over more than a decade; and they have all undergone extensive user interface changes in recent years. StockPol (Marshall *et al*., 1991) has transformed into a new service called FARMAX; the GPFARM tool (Shaffer *et al*., 2000) is being upgraded to accommodate risk analysis under the name iFARM (L. Ma, *pers. comm*.); GLA has been ported to a Web-server application, webGLA (Stuth *et al*., 2002). There is a common thread to these changes: a closer alignment of the tools with the requirements and practice of advisors.

In the FARMAX project, the simulator underlying StockPol has been implemented within two distinct interfaces: a strategic-planning interface for consultancy use, and a simplified interface that is intended for use by the grazier. Both interfaces share common data files, which are set up in an advisor-mediated strategic planning process. Grazier use of FARMAX is therefore critically dependent upon the prior involvement of an advisor; this connection underpins the FARMAX business model. From a technological point of view, this re-use of a model within different interfaces parallels the approach of the GRAZPLAN group (Donnelly *et al*., 2002).

Table 2 Some whole-enterprise planning tools for grasslands

Tool	Origin	Purpose and website
FARMAX	New Zealand	Farm planning service: flock and herd structure, seasonal decision-making (paddock allocation, livestock trading). www.farmax.co.nz
GrassGro	Southern Australia	Evaluation of various strategic and tactical management options for sheep and cattle enterprises (see below) www.hzn.com.au/grassgro.htm
iFARM	Great Plains, USA	Analysing 10-50 year production plans for mixed cropping & livestock enterprises: water, nutrient and pest management. Gpsr.ars.usda.gov
webGLA	Texas	Grazing Lands Application: conservation planning, inventory of forage resources and design of grazing plans.

The webGLA application differs in two important ways from the rest of the tools in Table 2. First, despite its evident viability and although it is intended for consultancy use, it is not centred on a simulation model; it therefore does not fit the typology of potentially successful DS tools identified by McCown (2002). Second, it is unique in being implemented as a Web application. Both the unique structure and implementation arise because GLA exploits the information in a set of extensive databases of plant and land attributes.

GrassGro: a versatile simulator encounters versatile users

GrassGro (Moore *et al.,* 1997) is a DS tool designed to evaluate various strategic and tactical management options for sheep and cattle enterprises. It incorporates simulation models of the grazing ruminant (Freer *et al.*, 1997), soil moisture, growth of multiple pasture species and enterprise management (Moore *et al.*, 1997). Users describe a grazing system in terms of the models and then conduct simulations, from which they draw their own conclusions as to the best course of action to follow. GrassGro is part of a larger effort that included the unequivocally successful GrazFeed DS tool for tactical nutrition of sheep and cattle (Freer *et al.*, 1997; Donnelly *et al.*, 2002).

GrassGro fits squarely within the definition of a versatile simulator (McCown, 2002). Its original intended use was as a tool for consultants, and during development of the software a great deal of effort was expended in building an interface that would make GrassGro ‘easy’ for consultants to use. Since its release the GRAZPLAN group has trained about 200 people to use GrassGro, most from the high-rainfall zone of southern Australia or the wetter parts of the cereal-livestock zone. Figure 1 shows the growth in user numbers; the distinct pulses are associated with the release of new versions of the software. Practically all users belong in one of three groups: advisors, university educators and researchers who use GrassGro for scientific or policy applications. Different lessons have emerged from our interaction with these distinct user groups.

Advisors

When GrassGro was released, it was intended that advisors would be the primary group of users. Figure 1 shows that this expectation has not been borne out; only 40% of those trained have been advisors. About half the advisors trained in the last two years have been from the private sector, compared with one in four during the first two years.

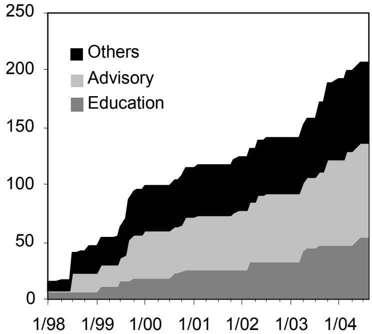

Figure 1 Growth in the number of trained GrassGro users since release

It was recognized that GrassGro users would require significant training, and so a workshop-based process was adopted in which small groups of users gathered twice. At the first workshop, users were exposed to the underlying models – especially the limits of their applicability – and to the software interface. During the interval between workshops, each new user conducted an analysis with GrassGro that was subsequently shared with the group during the second workshop. The second workshop also provided an opportunity to clear up any technical problems that users had encountered. A dedicated GrassGro specialist conducted all workshops, and over time a ‘resource kit’ for GrassGro users has evolved containing printed help and technical information.

A detailed account of the process by which GrassGro was evaluated is provided by Donnelly *et al*., (2002). These evaluations facilitated the identification of key needs of advisory users that were not met by the GrassGro package:

- Simulations needed to match the clients' situation more closely. Users requested that more management options be available, and that more pasture species be included for use in simulations. Successive releases of GrassGro have incrementally added management options such as more flexible descriptions of grazing management policies, and new parameter sets have been added to the underlying library of pastures (although fewer than demanded). The lesson learnt is that if a tool is versatile, users will always want more from it.
- An imbalance in the training was identified: its focus needed to shift away from technical issues and toward imparting the general technique of using simulation analysis to solve problems. With hindsight, it can be seen that this problem arose because experience gained with GrazFeed (a decision calculus) led the development team to assume that advisors would see for themselves how to use GrassGro (a versatile simulator). To remedy this problem, the training workshops and the resource kit now concentrate much more on the steps of specifying, analysing and reporting on a problem.
- While the 'easy-to-use' software interface was consistently well rated by users, drawbacks emerged when it was put into practice. Those who resumed working with GrassGro after a break often found that re-establishing their skills was difficult. Much of the work of converting simulation results into reports for clients had to be repeated manually, using up time that is an advisor's most valuable resource. These drawbacks have not stopped advisors from using GrassGro, but they have made its use less efficient.

Market research prior to release would not have identified these issues. Given the fragmented nature of the market and the fact that advisors have to learn how to exploit GrassGro, it is clear that the strategy to release the product, get the simulator into use and then to proceed by iterative prototyping (as described by Stuth *et al*., 1993) was the correct one to follow. The GrassGro interface is currently being completely re-developed to focus on the problem-solving process. The main element of the interface no longer represents a single simulation; instead it becomes an 'analysis', which is a *set* of simulations coupled with pre-defined reports (Figure 2). Locally specific combinations of initial conditions are stored as 'scenarios' that can be added to an analysis in a single action. Analyses can therefore be re-used quickly across different circumstances. A user can design an analysis and then transmit it to others, further increasing the value gained from the time spent designing it.

Educators

Tertiary educators form a quarter of the GrassGro user group, and are probably the most active users. This unexpected but welcome outcome is largely due to Jim Scott of the University of New England (UNE), who saw the opportunity and started developing a project to introduce GrassGro to UNE's undergraduate programme within months of GrassGro's release (Daily *et al*., 2000). GrassGro is now used at all levels of the UNE agricultural science degree and in both agronomy and animal production. Teaching exercises with GrassGro have proven to be a unique way of conveying a systems perspective to students. A second project (Daily *et al*., 2005) has disseminated the expertise developed at UNE to other institutions and deployed GrassGro through an innovative internet-based distribution channel. By 2004, over 500 students were learning from GrassGro at 8 of the 11 Australian institutions with tertiary courses in agriculture. The public investment in educational use of GrassGro now approaches the size of the investment in supporting its use by advisors. At the time of writing, the first GrassGro-aware graduates are beginning to appear amongst advisors and their clients.

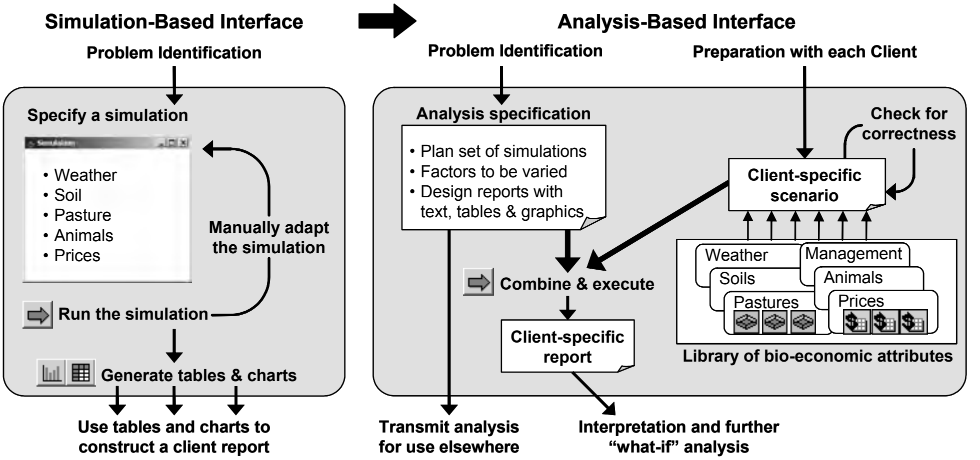

Figure 2 Changing from a simulation-based to an analysis based user interface for the GrassGro simulator. The shaded area denotes actions that are carried out by the GrassGro software

From a technical viewpoint, the GrassGro software has turned out to be well adapted to teaching use. Despite its drawbacks for advisors, a simulation-oriented user interface is a virtue when teaching higher-level undergraduates, because it means that they must learn the problem-solving process as part of the teaching exercise. The very detailed output options that GrassGro provides enable students to explore the basis of a simulated production outcome in plant or animal physiology. From a sociological viewpoint, the success of GrassGro in tertiary education provides an interesting twist on McCown's (2002) category of a versatile simulator used for facilitated learning: 'mutual learning' in a university setting involves students learning about the agricultural system, and lecturers learning how to teach it. Our experience in teaching use has parallels in the experience of the webGLA developers (Stuth *et al*., 2002).

Scientific and policy users

GrassGro has been used in a variety of ways by scientists, including extrapolation of experimental results (Cayley *et al*., 1998; Cohen *et al*., 2004), analysis of climatic variability (Clark *et al*., 2003; Donnelly *et al*., 2005) and studies of potential new production systems (Donnelly *et al*., 2002; Moore *et al*., 2004a).

Two of these research applications are of particular interest: drought assessment and the assessment of deep drainage from farming systems. Both issues are of pressing concern to Australian agricultural policymakers, since the cost of relief measures during drought is high, and excess deep drainage can lead to dryland salinity in much of the Australian agricultural landscape (Lambers, 2003). The GRAZPLAN development group applied GrassGro to both these problems in relatively small, point-based studies (Donnelly *et al*., 1998; Cresswell *et al*., 2002); it was then taken up by others and applied across entire landscapes (Crichton, 2001; Beverly *et al*., 2003). Applying a point-based model at the landscape scale presented challenges, both in managing the weather, soils, and management inputs required to create the simulations, and in executing multiple simulations with a user interface designed to execute small numbers of runs. In the drought assessment work of Crichton (2001), the spatial resolution was quite coarse (~40 unique areas) and it was feasible to manage the volume of inputs, simulations and outputs manually; however, GrassGro was adapted to accept up-to-date weather data automatically. The landscape water balance study of Beverly *et al.* (2003), on the other hand, involved several management systems and hundreds of unique geographic areas. To support this project, the GrassGro simulator had to be extracted from its user interface and the research team provided with a different interface that could run large batches of simulations.

While GrassGro has been used in diverse ways by a significant number of researchers outside of the development group, the proportion of researchers trained in GrassGro who have then gone on to apply it is about one in four – noticeably lower than for advisors and educators. Why this should be so is unclear. One possibility is that researchers are relatively more willing to invest time in training, just in case GrassGro might prove to be useful in the future. A contributing factor is that both the advisor and educator user groups have benefited from access to dedicated technical support that continues past the initial training process.

‘Success’ and ‘failure’ of grassland DS tools

Do the tools in Tables 1 and 2 (and others omitted due to space constraints) together “fall far short of expectation”, as McCown (2002) would have it? The answer depends upon what is expected. If the criterion is a radical transformation of the practice of grasslands agriculture, then it clearly has not been met. Impact is only partly determined by user numbers, but the uptake rates of all the tools that have been assessed are too small to form the basis of any such radical change. The only products that can be identified as having directly reached more than 20% of graziers in a large region are those that have been mass-mailed (e.g. the P fertiliser tool of Cayley & Kearney, 2000). A best estimate suggests that GrazFeed is used (directly or via an advisor) by 10-15% of Australian graziers. Adoption rates for simulator-based tools, although increasing steadily (see Figure 1), are lower still: less than 2% for both GrassGro and FARMAX when the ultimate clients (graziers) are used as the basis.

If on the other hand DS tools are expected to “pay for their keep” (Seligman, 1993), then limited adoption and resounding success can go hand in hand. A formal evaluation of GrazFeed has shown an expected benefit:cost ratio of 79 (Moore *et al.,* 2004b), despite its relatively low adoption rate. Many of the decision calculi in Table 1 must have similarly high returns to investment, given their low cost of implementation. In education, however, it is possible to aim for more than a low but useful adoption rate: as discussed previously, the majority of degree students studying grassland agriculture in Australia are now learning from GrassGro.

Critical factors for the future

What factors will determine the impact of DS efforts for grasslands in developed countries over the next decade? In broad terms, the same factors that have applied in the last decade (Donnelly & Moore, 1999): provision of useful user interfaces and client-specific inputs, commitment by the developing organization, effective evaluation, and above all focussing on the place of a DS tool in the operations of the client. Advances in technology and the accumulation of experience have changed the DS landscape in the intervening years. However, nothing has changed with respect to organizational commitment: only the simplest decision calculus will succeed with a short-term investment.

If McCown (2002) is correct, and much of the future of models and DS tools in agricultural decision-making lies with versatile simulators, then a major question facing developers is how to construct interfaces to such simulators that are efficient for the user. Re-casting of GrassGro to be problem-centred, and the transformation of StockPol into the two-tiered FARMAX interface represent attempts to address this question; only time will tell whether these attempts will succeed.

The set of delivery channels for DS tools has broadened considerably in the last 5-10 years. As shown by examples in the preceding sections, it is now possible to deliver via the internet in a variety of ways, such as download from a Web site, writing Java applets for execution over the Internet or using one of a range of server technologies. Internet delivery has clear advantages, especially where a tool is likely to be updated frequently or carries other significant maintenance or distribution costs (e.g. information bases), but the choice of delivery channel should always follow an analysis of the other fundamentals.

The experience of the GRAZPLAN group supports McCown's (2002) contention that grassland managers demand credibility from models before they will base decisions upon them. Scientific sophistication is thus a key element of management relevance. Those who model grasslands are few, and their efforts are fragmented; there is a need to find better ways to share insights and sub-models. In this context, modular simulation frameworks (David *et al*., 2002; Hillyer *et al*., 2003; Donnelly *et al*., 2005) will be an enabling technology that must be adopted.

The most critical factor determining the success of grassland tools is, and will remain, the ability to identify how new models and information can be situated in the operations of the client. New technologies for delivery, a better appreciation of management theory and participative processes of development and application will all be useful, but each by itself is insufficient. The way forward for tool developers must be to bring scientific opportunities, technological advances and social understanding together.

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