OVERSEER® NUTRIENT BUDGETS
- THOUGHTS ON DEVELOPING A DECISION SUPPORT TOOL

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Summary
'On-farm decision support tool' is a frequently used term and generally means something that will assist a farm manager in achieving the best outcome for a set of goals, be they 'personal/business' (e.g. farm productivity or financial targets) and/or 'imposed' (e.g. N leaching targets). OVERSEER®[1] Nutrient Budgets (*Overseer*) provides users with a tool to examine the impact of nutrient use and flows within a farm on nutrient use efficiency and on possible environmental impacts.

This paper uses *Overseer* as an example of a continually developing decision support tool and highlights some of the key scientific and operational challenges in building and maintaining such a tool. These include: maintaining a strong science base to the model; maintaining the correct balance between simplicity and complexity; maintaining and upgrading software to maintain reliability; providing users with support so that the model is applied correctly.

In summary, although investment in the quality of the science underpinning a decision support tool is critical, there are numerous aspects that need to be considered to ensure it is widely taken up by the agricultural industry so that full value from the investment is obtained. Furthermore, it could be argued that if the tool was also to be used to underpin policy, even greater rigour in all of the aspects is required.

Introduction
A Decision Support System (DSS) can be defined as 'an interactive [often software-based] system intended to help decision makers compile useful information … to identify and solve problems and make decisions' (Anon., 2010a). DSS or 'tools' are increasingly used on farms to assist a farm manager in achieving the best outcome for a set of goals, be they 'personal/business' (e.g. farm productivity or financial targets) and/or 'imposed' (e.g. environmental targets).

Decision support can operate at a range of spatial scales (e.g. paddock, farm) and temporal scales (e.g. daily irrigation need, annual nutrient balance) and can support either strategic or tactical decision making. Advice can also be delivered in a number of formats based on paper (e.g. booklets, leaflets, press updates) or electronic (e.g. software, text alerts and websites) media. While not all DSS are delivered as a computer model, models do, however, offer a way of synthesising complex information and can be an efficient way of interacting with the user.

Agricultural science research programmes sometimes identify as their goal or endpoint a DSS or Expert System; such a system is seen as a way of assimilating complex research findings

[1] OVERSEER is a registered trademark and is jointly owned by AgResearch, MAF and FertResearch

into a tangible output for the research investment. However, to maximise return on the investment, the DSS not only has to be developed, but also has to be taken up by the agricultural industry and used; the more widely it is used and for longer, the greater the return on the investment in science. This return on investment can be measured by many means; for research supported by public funds, for example, it could well be the improvement in productivity of the agricultural sector (increased export revenue) and/or improvement in environmental quality (measured by defined environmental indicators).

There is a significant body of opinion that agricultural DSS have failed to deliver tangible benefits to date (Matthews et al., 2008), generally failing at the implementation phase (McCown, 2002). Thus, science programme managers and funders need to be aware that the end point should not be just the development of a DSS; there is a sustained effort required afterwards to encourage and maintain use of the DSS. Various approaches can be adopted in this implementation phase, which moves the project beyond scientific development into sustained use by stakeholders. New Zealand's nutrient budgeting tool, OVERSEER® Nutrient Budgets (*Overseer*) is a good case in point. Its development started in the 1990s and today it is widely used by the pastoral sector and increasingly used by other sectors.

The aim of this paper is to use *Overseer* as an example to highlight some of the scientific and operational challenges associated with (a) developing a DSS and (b) ensuring that it continues to be relevant to and for the industry.

Background to OVERSEER Nutrient Budgets

Overseer provides users with a tool to examine the impact of nutrient use and flows within a farm (as products, fertiliser, effluent, supplements or transfer by animals) on nutrient use efficiency and on possible environmental impacts (Wheeler et al., 2003). The software is freely available and can be downloaded from the *Overseer* website or can be provided on a CD (see www.overseer.org.nz).

The model calculates a nutrient budget for the farm and blocks within a farm, taking into account inputs and outputs and some of the internal recycling of nutrients around the farm. It covers dairy, sheep, beef, deer; and a wide range of vegetable, arable and horticultural crops. It deals with a wide range of nutrients (N, P, K, S, and Ca, Mg, Na and acidity), and it calculates maintenance fertiliser nutrient and lime requirements for a block. An increasingly important feature is that *Overseer* estimates environmental impacts of the farm (N leaching/runoff, P runoff and risk index and gaseous emissions, including the greenhouse gases CH_4, N_2O, $\mathbf{CO_2}$). The model is also able to represent a wide range of management options and mitigation practices and enables the user to analyse "what if" scenarios.

The following principles have been central to its development:

- *Farmer-friendly inputs*. The model structure was based around using inputs of readily obtainable farm information (e.g. number of animals, milk production) or data that are readily available from commercial sources (e.g. soil nutrient tests).
- *Ease of use and flexibility*. Express and Detailed versions of the pastoral model have been developed (with a number of simplifications and assumptions in the Express version) to allow for different levels of user experience and knowledge. Similarly, within the detailed version, a user has the option of choosing an 'Advanced mode' for a range of key inputs for increased detail and accuracy.

- *Representation of the farm system.* The model can be used to account for different management blocks and the important nutrient flows and transfers within farm e.g. the fate of nutrients in imported feed and in farm dairy effluent.
- *A wide range of management practices.* This aspect is important in that users want to be able to accurately represent their farm within the model, which in turn gives them confidence in using the model.
- *Inclusion of mitigation practices.* This aspect has become increasingly important with the recent emphasis on reducing nutrient losses, particularly N and P to waterways and greenhouse gases. Associated with this has been a focus on the ability to assess and compare effects of alternative management or mitigation practices with the current farm system.
- *Validation against paddock- or farm-scale research.* Following model development based on research on specific nutrient processes, the model has been validated using summaries of NZ paddock and/or farm scale research on nutrient flows and losses.

Uses and users of Overseer

Overseer and previous incarnations (see below in 'Model development timeline') were developed to assist farmers in nutrient management, either by producing fertiliser recommendations or using the farm budget to identify inefficiencies. More recently, however, its use has extended to a regulatory role because of its facility to estimate farm losses of nutrients (N and P) to water and GHG emissions to air. For example, *Overseer* is being used to underpin regulations in the Lake Taupo catchment, where there is concern about leaching of N from farmland to the lake (Shepherd et al., 2009).

Farmers do not, routinely, construct *Overseer* nutrient budgets but they will be responsible for implementing nutrient management plans and therefore need to be familiar with the principles on which *Overseer* operates and be able to discuss with their advisors the relationships between their farm system and *Overseer* data entry and interpretation of nutrient budgets. Rural professionals, regional council compliance officers, fertiliser salespeople and farm advisors are those who will mostly construct the *Overseer* nutrient budgets and nutrient management plans for land managers and therefore require the greatest in-depth knowledge of the model.

Given all of this, there is a wide range of users of *Overseer* with widely differing needs; at one extreme an expert user fully conversant with its functioning at the other extreme, a general awareness of its capability as summarised in Table 1.

Table 1: Summary of potential 'users' of Overseer (adapted from training workshop notes produced by MAF)

Who	Level of understanding required
Agricultural/environmental researchers	High: need to be able to understand its working for one of two purposes: • *Applying* the model in research projects • *Developing* the underpinning science
Expert users, e.g. fertiliser company field officers,	High: must be able to apply the model to farm data to produce consistent results and understand the impact of

Who	Level of understanding required
consultants and auditors of process, data quality and compliance	uncertain or incorrect data on the *Overseer* calculations. Using *Overseer* for mitigation analysis/NMPs[2]. Experts in use of *Overseer* and farm systems and interpretation of outputs.
Trainers	High; must be able to train others; requires in-depth knowledge of *Overseer* AND farming systems.
Regulation implementers	Medium: those setting policy need to have a good understanding of the use of *Overseer*, its value and its limitations. High: those using *Overseer* for regulation need to be able to benchmark accurately.
Policy writers/ legislators	Low/medium: must understand (a) how *Overseer* might be used to support policy and (b) the policy implications of using a model to assess a biological system.
Delivery agents and allied industry	Low/medium: not actually preparing NMPs, but need to be able to interpret them.
Growers and farmers	Low/medium: not actually preparing NMPs, but need to be able to interpret them. Should be aware and able to implement best management practices.
Farm employees	Low: can impact on farm and influence decisions on farm. Should be aware of *Overseer* and what it does. Should be aware and able to implement best management practices.
Central government, Trustees, CEOs, Councillors	Low: can impact on farm and influence decisions on farm. Should be aware of *Overseer* and what it does.

Model development timeline

Prior to the development of a Computerised Fertiliser Advisory Service (CFAS), fertiliser recommendations were largely based on ‘rules of thumb’, published experimental results and local knowledge. The CFAS scheme was the first attempt to summarise all available information for fertiliser recommendations and to develop a computerised fertiliser advice scheme.

In the early 1990s, information from databases of P, K and S fertiliser trials conducted in New Zealand was developed into the computer model called ‘Outlook’. This model included econometric information as part of a decision support tool for making economic fertiliser recommendations. Information on lime was added, resulting in the PKSLime model being released. This model still exists as a proprietary economic model available to fertiliser companies.

In the late 1990s, environmental issues were starting to be recognised, and this resulted in the development and release of *OVERSEER* 2 in 2000. The model has continued to evolve over time, starting as a nutrient budget linked to fertiliser advice through to a decision support tool that uses nutrient budget information to produce environmental indicators.

Funding from bodies such as FRST, MAF and FertResearch allowed the model to be gradually improved and additional features added as new science became available. Funding and development focused largely on capturing existing farm and farm management systems.

[2] Nutrient management plans

However, the funding was generally of an *ad hoc* nature and short-term; whilst this allowed development of *Overseer* to progress, this approach to funding also brings risks:

- Difficult to sustain a long-term strategic vision for the model
- New features/ models fall behind the need for them: i.e. model less relevant to users
- Limited scope for investing in key elements of delivering a software product (e.g. support documentation, testing, training and maintenance)

Current governance
The issues identified above, however, have recently been addressed. Through formal agreement, *Overseer* is now jointly owned by MAF, FertResearch and AgResearch ('the Owners'), with MAF and FertResearch planning substantial financial investment in maintaining and improving the model. The Owners have developed a vision for *Overseer*:

> *A robust, science-based decision support tool and policy support tool that is widely used for improving farm profitability, optimising nutrient use and minimising impacts on air, soil and water quality.*

Given the background to *Overseer* and its strategic importance to New Zealand pastoral agriculture, it provides a useful case study for highlighting the challenges in maintaining a DSS or Expert System.

Scientific and operational challenges

Maintaining a strong science base
The strength and reputation of *Overseer* both rely on the quality of the science that underpins the model. *Overseer* covers a wide range of farming systems and a wide range of nutrients. Nutrient cycling through these systems is complex, which means that expertise from a number of disciplines needs to be called upon to provide the underpinning science. Figure 1 represents the typical 'development process' for integrating new or improved science into the model, once a decision to implement a change has been made.

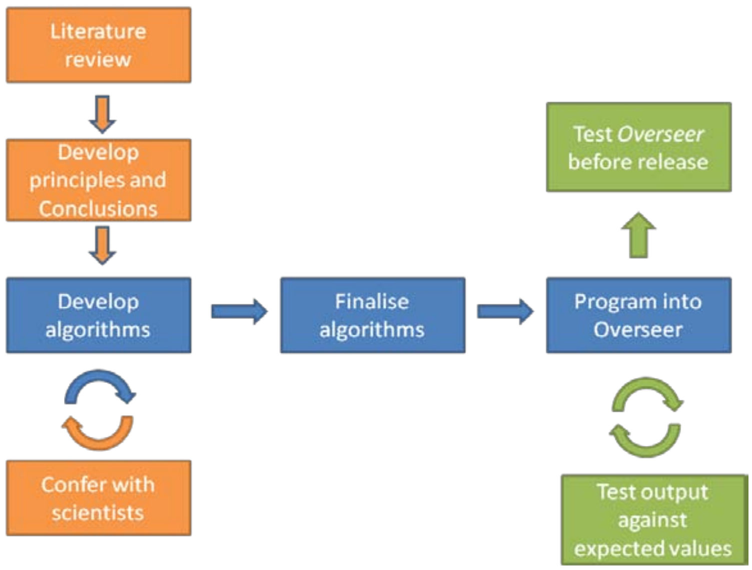

Figure 1: The development process, converting scientific knowledge into Overseer, *after identification of the need for development*

This process is nothing new, and would be the standard approach to any model development. The challenge for keeping a DSS relevant and applicable, however, is ensuring that the model is regularly updated with the best available science; ongoing investment is required to do this, as is funding for reviewing and improving the model. Whilst that challenge is not insurmountable, two other issues often perplex developers:

(a) Adequate data for new features

Overseer continues to evolve to reflect changes in farming practices. Two recent examples of new features added are (a) capability to include fodder crops grown on the farm for additional supplement (e.g. maize) rather than simply relying on pasture or imported supplements and (b) use of the nitrification inhibitor dicyandiamide (DCD) on paddocks to decrease N leaching and increase production. Both were added because they were becoming increasingly common practice on farms; without their addition, *Overseer* would have been less useful for the industry. However, there is a balance between adding the new features because of user demand and having adequate information to ensure that the new feature is scientifically robust. The two examples cited above are contrasting cases in point.

Recognising the need to include fodder crops, a rudimentary preliminary model was developed from first principles until a model based on the upgraded cropping model (Cichota et al., 2009) could be implemented. This approach was deemed acceptable for *Overseer* use as a nutrient management tool. However, once *Overseer* started to be increasingly used in a regulatory role (Shepherd et al., 2009), then the preliminary nature of the output, and the potential change is results after a more complete model has been implemented, has to be factored into policy.

In contrast, for inclusion of DCD as a mitigation technique within *Overseer*, a joint committee between industry and science was commissioned to review the evidence and develop an appropriate model (Anon., 2010b). Even so, given the amount of data available at the time, a precautionary approach to the level of effectiveness had to be taken, and further underpinning science is ongoing, with a plan to review new data in 12-18 months time.

(b) Extrapolation to ‘extreme’ scenarios

One use of models is to extend application to situations where there are few data. Generally, however, models will perform best within the ranges of the data against which they have been calibrated/validated. This is the same for *Overseer*. Validation at the block level against a range of dairy and sheep/beef enterprises has been undertaken, for example Ledgard et al. (2006) reported comparison with data from DairyNZ’s farmlet study in Hamilton. However, because experimental data for validation at a farm systems level are exceedingly expensive and difficult to collect, such datasets tend to focus on the most common production systems, soils and climates. Although the validation dataset probably covers 80% of soils and climates for dairy production, when other particular soil/climate/topography combinations start to become a significant minority, then validation data to reflect these situations becomes essential for continued development of *Overseer*. Two examples are shallow irrigated soils (e.g. Canterbury) and high rainfall areas on the West Coast.

Software development

It is the experience with *Overseer* that a move towards providing a reliable DSS widely used by the industry will require re-allocating resources or finding additional resources to develop and maintain software to a high standard. An unreliable program that regularly crashes frustrates the user and is a barrier to uptake. This emphasis on software will often represent a step change for science teams who have developed the original model.

The *Overseer* model has not until now been a software development project; rather, it has always been a model development project that uses software to distribute the results of this development. Generally, to date, 'pure' software development has comprised a small percentage of project resources. However, as the model has evolved and more features have been added, *Overseer* is becoming increasingly complex in its structure, with a need for greater emphasis on software development. Furthermore, Owner and User requirements in the future mean that it is likely to become even more complex.

Placing a greater emphasis on software development has advantages that include greater reliability of the model for the user through: updated software architecture and the deployment of software industry standards for development and testing prior to release. One approach to implementing this, and this is the case with *Overseer*, is to link with a commercial software developer.

The key point to make, however, is that although the emphasis has to be on developing good software, its maintenance and regular updating can be resource-hungry. Then, assuming that resources are limited (as is nearly always the case!), then it is a question of balance between science and software.

Simplicity versus complexity
The continual challenge in developing a workable DSS is achieving a balance such that the model is relevant and useful for users but is not so complex in input demands that it is unusable. This challenge can be formidable and this is certainly the case with *Overseer* where we are trying to accurately represent the management of complex farming systems with many internal interactions in that system.

The first step in meeting this challenge is to accept that *Overseer* is an 'Expert System', requiring and assuming user knowledge of farming systems. The next step is to provide a hierarchy of data inputs, such that users can choose the level of detail that they want to enter, since the model is supported by a series of default values. The model also requires methods to capture management systems that may only apply to some farms (e.g. supplement importation, use of the nitrification inhibitor DCD).

At the greatest level of detail, farms have a large number of optional inputs and a range of stock management input systems such that several hundred inputs can be made. For straightforward pasture farms, there is a 'small block' version of the model that requires few inputs (c. 20) that will provide a general estimate of the nutrient budget. In reality, most users fall somewhere in between these two extremes.

An analysis of a previous version of *Overseer* (v 5.2.6) by Woodward et al. (2008) made some assessment of the sensitivity of input data to the nutrient budget calculation for pasture farms. This enables the user to identify where effort is best spent in collecting reliable farm data. Table 2 provides a sensitivity analysis for the calculation of N leaching; the list of sensitive inputs will change for other outputs such as P loss or greenhouse gas emissions.

The analysis also highlighted that some inputs can have a large impact on the calculated outputs but they are difficult to quantify accurately. This particularly applies to the pasture development status (affecting N immobilisation) and the clover level (affecting atmospheric N fixation). In these cases, the limitation to better representing these inputs is not the model itself but the level of scientific understanding that underpins the model. Thus, continued investment in science to make incremental improvements in a model is essential. A sensitivity analysis such as that detailed in Table 2 is a good way of prioritising scientific direction.

Table 2: Summary of the main data input requirements affecting calculated N leaching from Overseer and an assessment of the likelihood of a user knowing the values (adapted from Woodward et al., 2008)

Chance of knowing	Inputs with high impact on calculated N leaching loss
High	Region; No. of dairy cows; stock replacement policy; presence of an over-wintering pad; total stock units; N fertiliser additions; use of N fertiliser in winter; rainfall
Medium	Level of farm grown supplement; ratio of beef and sheep; irrigation rate; soil type; soil drainage status; form of N fertiliser
Low	Pasture development status; pasture composition; pasture ME; clover level; soil water holding capacity

Quality assurance

Quality assurance procedures help ensure that the model gives the output and that the software is reliable. Thus, a quality plan has to address not just the scientific development, but also model development and model integration (Figure 2).

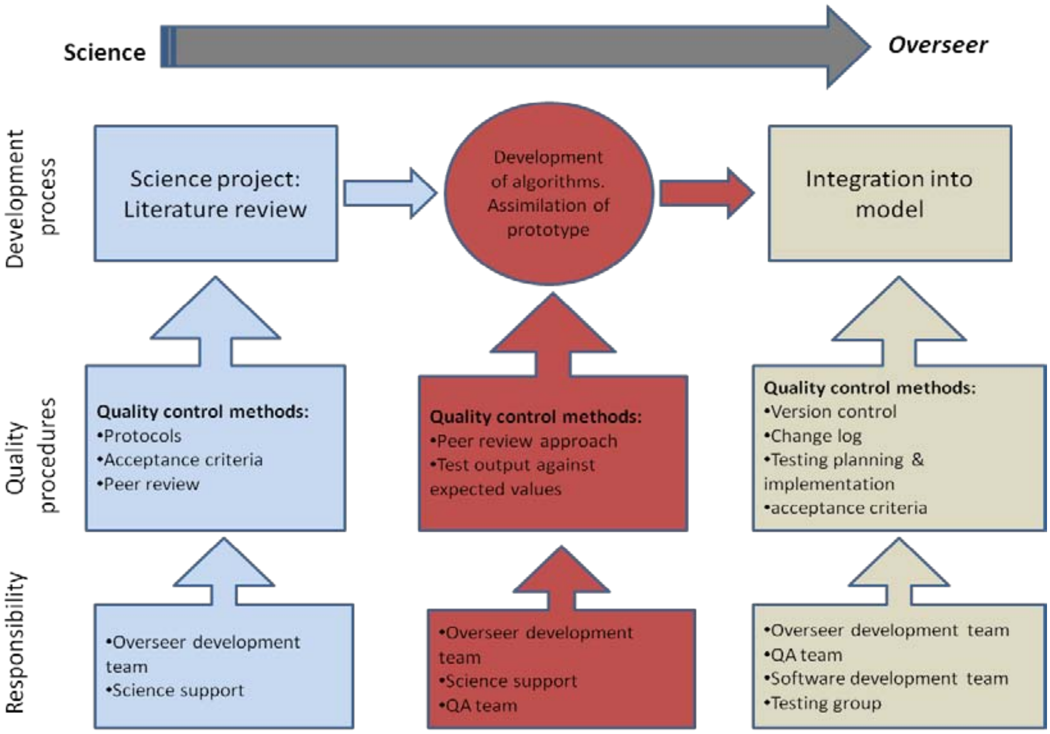

Figure 2: Quality processes involved in managing the science to model continuum

For the science development (generally a literature review and synthesis of the information), the key processes are: specifying the information that is required of the scientists at the outset (protocol and setting acceptance criteria); working with the scientist to obtain the information; ensuring it is to the required quality (peer review and publishing) and ensuring that it is consistent with the *Overseer* model structure and philosophy.

Converting the information into model algorithms involves peer review ('is the approach valid, based on the available information?'), building a prototype and testing that this gives the expected answer.

Once the model approach has been accepted, this then needs to be built into *Overseer*, both into the science model and the interface supporting the model. Here, standard software development procedures become relevant including planning and implementation of testing, as has already been discussed.

The key point, however, is that again there is a discipline and impact on resource requirements that result from a move from a research model to a fully functioning DSS that is readily available to the industry.

User competence and support
Overseer is required to represent complex farming systems. Therefore, correct use of the model is not a case of simply learning which buttons to press on a piece of software; more important is the expert, in-depth knowledge of agriculture and farming systems and of nutrient processes within those systems. Without this understanding, the adage 'rubbish in, rubbish' out will almost certainly be true.

Reliable output from the model is essential for the farmer whose business decisions may well be based on the outputs; in terms of nutrient management for production or to meet regulatory requirements. Reliable outputs are also essential for the reputation of the model and its continued use by the industry with confidence – as inaccurate outputs are almost always blamed on the model rather than the user. The use of *Overseer* in a regulatory role can add the requirement of another level of rigour to the term 'Expert User'.

The correct use and application of *Overseer* is seen as so important by the industry that it has started to set up its own training initiatives. The fertiliser companies such as Ballance Agri-Nutrients and Ravensdown have a 2 year ongoing training programme for fertiliser advisers including formal training and mentoring. The industry representative body, FertResearch, is also investigating auditing procedures for training and for the nutrient management plans. Massey University, through their Fertiliser and Lime Research Centre, run two courses on nutrient management which require use of *Overseer*, but do not specifically train users in its use.

Whilst this training is of value on its own, there is still a need for the *Overseer* development team to support this through additional interaction with end-users. This includes:

- Documenting the model and the principles behind it. One criticism is that the structure and workings of the model have not been well explained, so users cannot have complete faith in the 'black box'. It also increases the chances of them using it inappropriately.

- Providing a User-Manual
- Providing a website to provide supplementary information and allow interaction with end-users
- Providing time to support other training initiatives
- Interacting with end-users to capture their evolving requirements of *Overseer* so that we can assess whether these can be accommodated in the model.

Clearly, from Table 1 it can be seen that a particular challenge is meeting the information needs of users with widely differing levels of knowledge and widely different requirements in level of understanding of *Overseer*.

Discussion

According to Matthews et al. (2008), there is a significant body of opinion holding to the view that agricultural DSS developed to date have failed to deliver tangible benefits since there are few examples of a sustained use of a DSS by land managers. We would claim that *Overseer* is one of the exceptions to this general opinion, given that it is the industry-standard nutrient budgeting tool with New Zealand, widely used by consultants, fertiliser advisors and increasingly by regulators.

Some of the failure of agricultural DSS can be attributed to the problem of implementation, i.e. lack of sustained used by stakeholders (McCown, 2002). One criticism is that there has been too much emphasis on technological factors rather than ensuring that tools developed are credible with decision makers and able to integrate software into particular decision making milieu. Projects that have concentrated on building credibility with stakeholders and on DSS deployment have fared better (Matthews et al., 2008).

The credibility of the information being provided by a DSS is critical to its success (McCown, 2002). To this end there has been a long-term investment in the science that underpins *Overseer*. Furthermore, the development of the model and addition of new features has been market-led, i.e. there has been a continual effort to ensure that it remains relevant to the industry. Linking the model to fertiliser company software systems has also ensured that it is widely implemented.

The analysis of Matthews et al. (2008) makes two further points around development and implementation of agricultural DSS that we would agree with; funding and software development.

Regarding software development, the point made is that IT costs are high and are usually underestimated in the planning phase. Furthermore, the *ongoing* maintenance of tools represents a significant cost for upgrades, bug fixes, help-desks and support documentation. We would concur; these are not one-off tasks but ongoing activities that need annual investment. Certainly, this shift for *Overseer* from a development project using software to a more rounded software product brings the need for new disciplines to the development team as well as the challenge in balancing resources between science and other activities.

Regarding funding, some failure of DSS development has been attributed with a general shift from ‘research sponsorship’ to ‘research purchasing’; the latter tends to result in a more inflexible approach to delivering DSS projects built around *specify-build-deliver-use* which, historically has not been successful. We would argue that with *Overseer*, although funding for development over the years has sometimes been *ad hoc*, the relationship with the main funders (MAF and the fertiliser industry) has been more based around research sponsorship. This certainly is the case going forward as new Governance and long-term funding arrangements have just been agreed, as explained earlier.

Acknowledgements

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