Evidence base Agriculture – can we get there?

J. M Virgona[1] and G. Daniel[B,C]

[A]EH Graham Centre for Agricultural Innovation
Charles Sturt University, Wagga Wagga, NSW
[B]Group Manager, Growth Farms Australia
[C]'Camoo' Tumbarumba NSW.

Abstract

This opinion paper presents the case for making evidence the basis for decision making in agriculture. We briefly survey the phenomenon of evidence base medicine and conclude that elements of its approach would be beneficial to modern agricultural practice. The current need for an evidence basis is highlighted by considering the adoption of practices/ideas that are not underpinned by sound evidence and the non-adoption of practices that are. An example of a policy to ensure that evidence is central in decision making in commercial agriculture in provided. Finally, we propose that there is a role for grassland societies and other producer-based bodies, rural industry research corporations and scientific journals to work together to produce well researched reviews that lead to practical evidence-based guidelines that can be implemented on farm

Introduction

Evidence is a critical element in successful decision making. Unfortunately it is often either not present or inadequate when important farming decisions are made. Conversely, sometimes these decisions are made while evidence is ignored. This paper is about the role of evidence in management of grazing systems and agriculture more broadly. Our prime objective is to propose a decision making framework that has evidence at its centre. This does not mean that all decision making should cease in the absence of evidence – clearly such a proposal would be unrealistic. Instead, as we shall see with the example of evidence-based medicine, evidence needs to be integrated with the experience of the decision maker in order to minimise the risk of making poor decisions.

It may appear that a paper on the role of evidence in decision making (eg. adopting a grazing system, utilising a particular type of fertiliser or follow a particular weather forecast….etc.) is passé. But if that were true then it would be hard to explain the myriad of products, management systems etc. that are marketed successfully despite the absence of hard evidence supporting associated claims. It is noteworthy that in reviewing the field of extension theory and practice, Black (2000) concluded that "there still was a need for access to reliable scientific information…". Disappointingly, the use of reliable scientific information is not always a feature of modern agricultural practices – often resulting in poor performance in terms of agricultural profitability or natural resource management. It would be difficult to calculate the extent of the lost opportunities. For instance, how has the non-adoption of phosphate fertilisation of pastures (see below) cost the livestock industries over the past 30 years? One of us has built a successful farming system based on well fertilised pastures and efficient use of the resulting feed produced (Daniel 1995; 2009). And then there are the products for which outlandish claims have been made without any demonstrated benefit. These could include a range of animal health and nutritional products, various soil amendments and the list goes on.

Lack of evidence is not just confined to attempts to sell some of the 'snake oil' like products that are a persistent feature of commercial agriculture. Lack of evidence is also characteristic of many of the current "controversies" like the potential to store soil carbon, climate change, biological agriculture and soil "health" to name a few. To catalogue the array of products and practices that should not be adopted on the basis of poor evidence would be a mammoth task and fraught with legal difficulties, an example of which is described below. There is something to learn from examining the nature of the information that is made available on technologies (which will also be addressed below) but our central aim is to provide an evidence-based framework for the evaluation of practices in agricultural enterprises. Before examining the need and nature of evidence in agricultural systems we will briefly survey the phenomenon of evidence based medicine (EBM) and whether or not there are lessons for modern agricultural practice.

Evidence Based Medicine – in brief

It is now about 20 years since the term "evidence based medicine" was first used. It is not as if medical treatments before the 1990s were not based on evidence – evidence that vaccinations prevented disease, that penicillin could be used to treat infections that smoking caused lung cancer etc., there is no doubt that medical science had made great leaps forward particularly since the early 20th century. But medical practice has never been simply the application of scientific findings to the management of patients. Clinical experience of the practitioner also has had a wide influence on the course of treatment that was applied to a patient. And then there is the question of the quality and range of evidence – epidemiological studies, randomised trials, non-randomised trials, clinical case studies etc. On top of all this the mammoth size of the medical literature and its continued growth presents a clear problem not only for your local GP but in hospital departments as well. The pioneers of the evidence based medicine idea recognised this and promoted the need for evidence to be central in the decision making process. They defined evidence based medicine as "conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients" (Sackett et al.1996). This definition is oft quoted but it should always be cited along with the statement that immediately followed it in that article: "The practice of evidence based medicine means integrating individual clinical expertise with the best available external clinical evidence from systematic research". Most critics of EBM gave ignored this.

In practice, evidence based medicine has led to the development of practice guidelines that synthesise the best evidence from the medical literature (for a summary of the current state of EBM see Timmermans and Mauck 2005). This is done by reviewing all the evidence that currently exists in the area of interest – a review may then appear in a publication like Evidence Based Medicine which has clear guidelines that establish the quality of evidence required (this varies depending on the subject being covered eg. diagnosis, prognosis, etc.). Furthermore, reviews can be available on-line via the Cochrane Collaboration and are written " to help providers, practitioners and patients make informed decisions about health care, and are the most comprehensive, reliable and relevant source of evidence on which to base these decisions" (http://www.cochrane.org/). So it is not only medical professionals that can make use of this information but patients can also be involved. If, for instance, you were interested in the effect of caffeine on asthma then there is a review for it (http://www2.cochrane.org/reviews/en/ab001112.html) and about 4000 others besides! In short, the evidence based movement in medicine has developed to:

- give primacy to evidence in decision making,
- ensure that evidence is integrated with clinical experience
- recognise that there are different standards of evidence that are acceptable depending on the nature of the subject being investigated (for instance you will not find a randomised trial on the effects of smoking – it would be difficult to get through an ethics committee!)
- provide reviews that are available not only to medical specialists but also to the public that are strictly evidence based an cover a wide range of medical topics.

So from this brief (and incomplete) survey of evidence based medicine is it possible to apply any of its features to agriculture in general? Overall the answer to this question is yes, but given the nature of decision making in agriculture compared to the medical field, there are also major areas where the practices of EBM can only translate in a limited way. On the whole, we would suggest the following:

1) As with EBM there is a clear need in agriculture to ensure that evidence is central in the decision making process. At various levels, agricultural management is as beset with non-evidence based approaches as is health management.
2) In general, there is neither the breadth nor depth in the literature available at a 'clinical' level in agriculture that would allow a direct application of the practices of EBM to agriculture. For instance, how could practice guidelines be written for the various climates, soil types, pasture

species, animal species and production systems involved in livestock production? The range of decisions that need to be made by the consultant/farmer compared to the physician cover areas that include agronomy, soil science, animal science, economics….and the list goes on. The vast sum of funds invested into medical R&D also produces a massive concentration of literature that provides a very strong basis for an evidentiary practice in medicine involving a a comparatively narrow range of decisions. In agriculture, while good evidence will exist to guide some of the decisions that have to be made, for other challenges extensive evidence will not be available. So, as every agricultural practitioner knows, there will be an element of educated guess work involved – a predicament we would rather avoid when under medical care!

3) If we can't directly mimic all the practices and methodology of EBM, there is a strong case to make sure that we able to appreciate that evidence can occur in many forms depending on the nature of the subject at hand. Evidence can be of the highest possible quality (eg. randomised trials that have been correctly statistically analysed and carried out in an agricultural system very similar to the one in which the information is being applied) at one end to anecdotal observation at the other. The reliance on evidence, and the quality of that evidence, will be influenced by the level of risk involved when making the decision. Naturally, one would think that the greater the level of risk then the more reliant we should be on evidence of the highest standard. Importantly, given the propensity for commercial organisations (and some public ones) to promote evidence that is of dubious worth, it is important to develop the ability to smell a 'statistical rat'. In other words, is the evidence that is provided of any use or is it misleading. Below we will offer some helpful guidelines by which simple judgements can be made.

The current need for evidence in agriculture

It would be reasonable to assume, that after over 100 years of agricultural science and the development of statistical techniques which have enabled scientists to state the level of confidence (usually 95%) that differences between treatments occur, there was an established and unshakeable role for evidence in modern agriculture. If that were true then there would be few examples to report where evidence was wanting. It is not the case as the following will show. The Edmeades-Maxicrop case (see Menzies et al. 2009) involved a soil scientist who claimed (after carrying out the appropriate scientific investigation) that a fertiliser which was a seaweed based product known as Maxicrop did not improve yield (Edmeades 2002). Edmeades eventually won the case at considerable personal cost by proving to the courts in New Zealand that his conclusion was justified by the evidence. Edmeades used a novel method of presenting the data to show that by chance alone a false positive result can occur if enough experiments are conducted. But these are just details – thankfully evidence won out.

Edmeades (2002) subsequently published a review on the efficacy of a range of liquid fertilisers derived from "natural" products (28 in all) and concluded that "there was no evidence to support the conclusion that at least some product-types or products were effective on some crop-types, crops or cultivars" This review is of the type that is a definite parallel to what is produced from EBM – a broad survey of the all research results that could be obtained and a conclusion that could be readily used by practitioners. How many of these products are still in use? We know that some are and are still openly promoted.

A second example that deals with what is sometimes referred to as the 'Albrecht' system has been highlighted in a recent review by Koppitke and Menzies (2007). The issue dealt with in this review was whether there is any reliable evidence that the base cation saturation ratio (BCSR) could be used to determine fertiliser policy. Despite only meagre and obscure evidence, a group of US soil scientists had developed the concept of an 'ideal' soil where (for instance) the ratio of calcium (Ca) to magnesium (Mg) was more important the absolute levels of the cations present. An ideal soil was defined as having a base saturation ratio, Ca:Mg:K, in the ranges of 60-75%:10-20%:2-5%. The review by Koppitke and Menzies (2007) systematically demolishes the concept by following the development of the BCSR idea and demonstrating the absence of evidence supporting it. Yet, despite the fact that there is no such thing as an ideal soil conforming to a defined BCSR, the BCSR or 'Albrecht system' is still promoted in some quarters and, more alarmingly, 90-95% of all fertiliser recommendation in the turf industry in Australia are made using it (Koppitke and Menzies 2007).

A third example can be drawn from the work of Vizard et al.(2005) on the use of seasonal weather forecasts made by the Bureau of Meteorology. For a time series of data from 1997-2005 covering 262 towns across Australia, Vizard et al.(2005) found that the forecasts for a dry (rainfall in the lowest 33% of historical occurrences) season were effectively useless as the outcome was as likely to be 'dry' as 'wet' (rainfall in the top 33% of occurrences). The findings of this work have largely been ignored as seasonal forecasts are still widely reported – as if they could be utilised in decision making or, at least, the subject of much fruitless speculation.

The three examples above refer to the problems involved in the adoption of products/ideas that have little or no evidentiary support. However, non-adoption of evidence-based technology is also a feature of modern agriculture *but* is more problematic as non-adoption is the result of many factors not just the quality of evidence (eg. Pannell et al.2006). However, where the non-adoption of appropriate technology occurs solely on the basis of misinformation or misunderstanding of the evidence then this too is a major problem. Relevant to the grasslands, a clear example of non-adoption is under-use of Phosphate (P) fertilisers. As noted above, one of us has built a farming system in which the judicious evidence-based use of P fertilizers (Daniel 1995) has played a major role. Despite highlighting the importance of P in improving pasture productivity in such campaigns as the Grasslands Productivity Program (see Trompf and Sale 2000) and the decades of research that preceeded it, survey results on randomly chosen paddocks reveal that a high proportion of these operate at well below adequate soil P levels. For instance in 1996, surveying 53 paddocks across the cropping and higher rainfall zones of southern NSW, Bowcher (2002) found 89% of the paddocks had Olsen-P below 16 μg/g and 43% of the had levels below 5 μg/g. A more recent survey of 61 paddocks in the higher rainfall zone of southern NSW (Virgona and Hildebrand 2007) found that Olsen-P was below the critical level of 15 μg/g (see Gourley et al.2007) in 63 % of paddocks and below 10 μg/g in 27% of the paddocks – all of which had been sown to 'improved' pasture species. There may be many reasons behind the non-adoption of appropriate levels of P fertilisation but it is clear that evidence cannot be one of them.

Evaluating evidence – some guidelines

A summary of the previous section would simply be that evidence is still a key ingredient in good decision making. Whether avoiding the products that simply don't work, or disregarding forecasts of limited 'skill' or even adopting rational fertiliser strategies, evidence is a basic necessity. Yet, the search for evidence is rarely completely satisfying – especially in agriculture. This is because agriculture is a biological system that deals with a multitude of organisms in a spatially and temporally varying environment. And that is before you add the human element! So there is no way we will be able to subject all decision to the best forms of evidence. By "best forms of evidence" we simply mean well conducted experiments at a scale and scope that are directly applicable to the production system being considered. It is not possible here to provide a definitive guide to forms of evidence. Instead we offer a practical guide as to what you should look for and ask about when considering a new product/idea in your production system.

1) *Publication* . Has an experiment been published which will satisfy you that the appropriate data has been obtained? Note here that you, and/or your advisor, need to have access to details of this work *not* just be assured that it has been carried out. Quality is an important aspect and to ensure quality scientists will publish in peer reviewed journals. The peer review process (which is not always perfect – presumably Fleischman and Pons (1989) publication on cold fusion was peer reviewed but ended up being discredited). Even if the science has not been peer reviewed it may be valid – but the onus is on the reader to make that judgement and few of us should be put in that position.

2) *Analysis.* Whether published in the official channels or not – the data needs to be analysed. Many of the statistical techniques applied in modern agricultural studies are now well beyond what the authors were taught as undergraduates. Nonetheless, regardless of complexity there should always be an indication that some form of statistical analysis has been performed. To help we offer the following handy hints:
    a. Experimental design must always be acceptable. Usually, any experimental study that does not have treatments replicated and randomised is of little or no worth. It is true that some of these studies (such as paired catchment comparisons) have been published in the scientific literature but this should be regarded as an aberration rather than a post-hoc justification. It is also important to be wary of what statisticians call pseudo-replication. An example of this would occur in a paired-paddock comparison of fertiliser use. If the paddock was sampled 20 times for dry matter, each sample is not a replicate and could not be analysed as such.
    b. Any table or graph that does not have some indication of error on it should be regarded as worthless. For instance if there is a bar graph with no error bars or letter indicating differences between treatments then it is only reasonable that you suspect the significance of what is being presented. Error bars give an indication of how much statistical certainty there is about the result. Similarly, when you see letters associated with figures in tables or bars/points in graphs they are indications that tell us which of the treatments are different, i.e. if treatments have the same letter then they are not significantly different. So if there is no indication of statistical significance you should assume that there is none and pay no any further attention to any associated claims.
    c. Scale of graphs can be misleading. Even where the appropriate analysis has taken place it is always important to pay attention to the scale on any graph. Sometimes to highlight the difference between treatments the left hand axis (or y-axis) is interrupted. This is an accepted practice and is often used visually highlight differences between treatments. The reader should beware, however, that while there may be statistically significant differences, the magnitude of these differences may well be minor.
    d. When authors report that there is no statistical difference between treatments but add further observations on "trend" in the data then the reader is justified in being sceptical. Again, despite the peer review process, this often occurs and readers need to be wary about commentary on non-significant effects. To be on the safe side it is better to disregard any such commentary.
    e. In some studies the statistical analysis will be difficult to understand. To be frank, the analysis performed by Vizard et al. (2005) to which we referred above is not one that we are familiar with. If in this situation it is best to seek advice if you do not understand what has been done. If it means ringing the scientist involved then why not?

3) *Testament.* There are times when the best forms of evidence are not available and you are in the position of having to evaluate a testament. Many times we have heard the claims of practitioners of alternative agriculture with respect to their production systems, sometimes these are outlandish and other times they can seem to be reasonable. However, any testament should at least include some *measure* of the impact of the management strategy being applied. The measure could simply be in terms of profitability, benchmarking or physical change in the system (eg. more perennial grasses) *but* there must be some concrete basis to any claim being presented. Pictures of happy families, claims of a more relaxed lifestyle are all very well but if there is not enough information made available to allow you to judge at what costs these may have been obtained then the testament is of little worth.

4) *How do you know that?* Finally, if you are engaging a consultant to report on a new product/idea then it is only reasonable that evidence of the type described above be produced to justify any action. One would hope that the relationship between consultant and client

could be robust enough for the client to pose questions regarding the sources of evidence drawn upon. Simply put, the question "how do you know that?" would hopefully be met with a sensible, evidence-based reply. We know that this sometimes is not the case. For instance, in the survey conducted by Virgona and Hildebrand (2007) farmers were asked to give details of what species/cultivars they sowed and what their source of advice was when pastures were last established in these paddocks (61 in total). Many farmers had sown white clover and perennial ryegrass in rainfall zones that were not suitable (according to NSW Industry and Investment advice) and these species had failed to persist. It was found that much of this "incorrect" advice had originated from consultants (Table 1). Had that simple question, "how do you know that?" been asked then it is possible that the incorrect practice may have been avoided and the money saved spent elsewhere (Virgona and Hildebrand 2007).

Table 1. Sources of advice for paddocks sown 'incorrectly' (ie. below recommended NSW I&I rainfall boundaries) to perennial ryegrass and white clover

	Number who incorrectly* recommended sowing:	
Source of advice:	Perennial ryegrass	White clover
Consultant	10	13
Retailer	2	4
Self	3	4
Total	15	21

A practical decision making framework – based on evidence

The above discussion has highlighted the need for evidence, the types of evidence and some of its limitations. On a practical level, evidence would be integrated with the experience of the practitioner (as in the EBM definition). A policy that is now in operation is that used by Growth Farms Australia (GFA), a corporate farming entity that explicitly relies on evidence, wherever possible, in the evaluation of new technologies. This means that a strong premium is placed on verifiable trial results over all other sources of information. This approach, combined with the integration of new technologies into practical farming systems will lead to high and continuing productivity gain. Furthermore, this approach will lead to a far reduced risk of failure when adopting proposed technology. Given the difficulties of identifying the efficacy of various options the following guidelines are offered. Hence, for a technology to be of interest it must satisfy, or be likely to satisfy the following four criteria: plausibility, veracity, applicability and cost benefit.

Plausibility

- Product claims consistent with other verifiable knowledge obtained from the relevant scientific discipline. There are some claims that are simply ridiculous that conform to no known scientific law or theory and can be discarded without further consideration
- Circumstances in which technique is to be applied are similar to other circumstances where verifiable results have occurred.
- Obviously not all techniques require experimentation (clearly, most will not) before being adopted in a particular farm situation. Often there will be overwhelming evidence that in similar situations on other farms (e.g.; plant response to P on low P soils) the technique will work. Judgment and recourse to expert opinion will often be required.
- Likely to be of interest in an economic context

Veracity

- The argument leading to the claims must be able to be backed up by current knowledge based upon well designed and repeatable experiment or survey.
- Claims made on the basis of statements such as "it works" or "trust me" should be tested under the plausibility and cost/benefit criteria. If the claim seems plausible, and there is likely to be a cost benefit, an attempt to verify the claim may be justified. As an example Menzies et

al.(2009) recommended farm scale experiments with products designed to increase phosphate solubilisation (for example) and gave advice on how these could be conducted.

Applicability to the Farming System

- The new technology should be considered in the context of the farming system and any flow on effects application of the technology may have in other parts of the system. This should be viewed with particular reference to the overall profitability of the system, and the risks around this profitability.

Cost/Benefit

- The product, if shown to be likely to be effective in some way, must be the cheapest alternative to obtain that response, and must show a positive cost benefit.

Conclusion

It is our contention that if the simple guidelines above were followed rigorously then many fewer mistakes would have been made in agricultural production systems in recent history. Many of the products that are still currently being marketed would have fallen by the wayside and profitable practices would have been more widely adopted. There are elements of an evidence-based movement alive and well in agricultural science and management today. We have highlighted the recent publications by Edmeades (2002), Koppitke and Menzies (2007) and Menzies et al.(2009) to draw attention to the continuing need to run a critical eye over practices and products. While the nature of agricultural problems solving is such that an evidence based medicine approach would be difficult to mimic, it is critical that all involved in the production and consumption of information on products and practices should ensure that evidence is the basis for action. We propose that there is a role for grassland societies and other producer-based bodies, rural industry research corporations and scientific journals to work together to produce well researched reviews into areas of contention in agriculture that lead to practical evidence-based guidelines that can be implemented on farm. In doing so we would be taking positive steps towards evidence based agriculture.

References

Black AW (2002) Extension theory and practice: a review (2000). Australian *Journal of Experimental Agriculture* **40**, 493-502

Bowcher AJ (2002) Competition between temperate perennial pasture species and annual weeds: the effect of pasture management on populations dynamics and resource use. PhD thesis. Charles Sturt University.

Daniel F (1995). Putting it all together – getting pasture and animal nutrition right. In ‘Pasture – use it or lose it, Proceedings of the 36h Annual Conference of the Grassland Society of Victoria

Daniel G (2009) Disentangling management from farm ownership. In "Take Up the Challenge ", Proceedings of the 50th Annual Conference of the Grassland Society of Southern Australia,

Edmeades DC (2002) The effects of liquid fertilisers derived from natural products on crop, pasture, and animal production: a review. Australian Journal of Agricultural Research **53**, 965-976.

Fleischmann M and Pons S (1989), Electrochemically induced nuclear fusion of deuterium. *Journal of Electroanalytical Chemistry* **261 (2A)**, 301–308,

Gourley CJP, Melland AR, Waller RA, Awty IM, Smith AP, Peverill KI , Hannah MC (2007) Making better fertiliser decisions for grazed pastures in Australia. Department of Primary Industries, Victoria.

Koppitke PM , Menzies NW (2007) A review of the use of the basic cation Saturation ratio and the “ideal” soil. *Soil Science Society of America Journal* **71**, 259-265

Menzies N, Bell M , Dart P (2009) Soil additives to stimulate N fixing and P availability – Science, Myth and legend. Dubbo Grains Research Update, GRDC. Pp172-188.

Pannell DJ, Marshall GR, Barr N, Curtis A, Vanclay F , Wilkinson R (2006) Understanding and promoting adoption of conservation practices by rural landholders. *Australian Journal of Experimental Agriculture* **46**, 1407-1424.

Sackett DL, Rosenberg WMC, Gray JAM, Haynes RB, Richardson WS (1996) Evidence based medicine: what it is and what it isn’t. *British Medical Journal* **312**, 71-72.

Timmermans S and Mauck A (2005) The promises and pitfalls of evidence based medicine. *Health Affairs* **24**, 18-28.

Trompf JP and Sale PWG (2000) The paired-paddock model as an agent for change on razing properties across south-east Australia. *Australian Journal of Experimental Agricultur*e **40**, 547-556

Virgona J and Hildebrand S (2007) ‘Biodiversity and sown pastures: what you sow is not what you get’. In "From the Ground Up", Proceedings of the 48th Annual Conference of the Grassland Society of Southern Australia, Victoria, Australia

Vizard Al, Anderson GA and Buckley DA (2005) Verification and value of the Australian Bureau of Meteorology township seasonal rainfall forecasts in Australia, 1997-2005. *Meterological Applications* **12**, 343-355