Crop scientists as change agents

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Abstract

Crop scientists as change agents is an ambiguous title. For many, the title promises to document the impressive impacts achieved through crop science and the efforts of its practitioners. An alternative interpretation is that it is more aspirational than reality. In adopting the latter view, I suggest that the conundrum for crop scientists is to balance the traditional performance criterion of knowledge generation with the new imperative for realising impacts. The drivers of change are seen as continued rural poverty, heightened environmental concerns and increasing criticism of our profession's willingness to achieve purposeful benefits.

Whilst acknowledging the past achievements of crop science, this paper argues that the problems of today, as well as the opportunities for tomorrow, may be best met through reorientating our profession towards a more participative research paradigm where the intended beneficiaries of research are integral contributors to the research process and outcomes. What evidence is there to justify such reorientation? Disappointingly little if sought from the crop science literature. Therefore, documented case studies demonstrating successful implementation of participatory action research, its impacts and contributions to innovative science, will greatly enhance the attraction for the broader adoption of such approaches to crop science issues. In this paper, institutional and personal performance indicators are given for successful participatory action research both in terms of the published experience of others and my own experiences.

Media summary

Crop scientists need to be interventionist in applying science innovation as our comparative advantage in the market place of agricultural change.

Key Words

Participatory action research, on-farm research, change agents, FARMSCAPE.

Introduction

"An academic career puts a young man into a kind of embarrassing position by requiring him to produce scientific publications in impressive quantity – a seduction into superficiality which only strong characters are able to withstand." Albert Einstein[1]

I feel fortunate to have started work in the 'good old days' of agricultural research in Australia, where insights into crop physiology provided both personal and institutional rewards. Twenty years on, at times, I am envious of researchers in those countries and institutions where research outputs are still largely judged against the traditional criterion of innovative science. On the other hand, I admire those researchers who have devoted careers to achieving realised benefits to farmers, and especially those who not only see the circumstance of resource-poor farmers in developing countries as agricultural science's greatest challenge but who also devote their lives to tackling this challenge. In a quiet moment, I worry about the future for young crop scientists who enter a profession where there is confusion, even conflict, between these dual foci of innovation and impact, knowledge generation and making a difference.

The proposition that there may be conflict between investment in science innovation versus a focus on achieving real-world impacts may be contentious to many crop scientists. For most of us, conducting excellent science which generates knowledge for current or potential future use is the reason we were attracted into a science career. However, there are strong drivers of change, mostly external to our profession, which are forcing a shift in emphasis in agricultural research to achieving real-world impacts. Continued rural poverty in developing countries and environmental concerns in more developed countries are the key drivers. Also, reduced public funding for research, greater accountability to research funders, and strong criticism of our traditional research paradigm for failing to deliver expected benefits can be seen as added pressures for change.

This paper is written in support of the view that crop scientists need to be at the forefront of accepting the challenges facing agriculture by striving for innovative solutions. I support the proposition that agricultural science is primarily about realising benefit from our science and that we crop scientists need to take responsibility for achieving such benefits and not defer this task to others. In thinking about this paper, I found it impossible to be impersonal in tackling a topic with the proposition that 'crop scientist act as agents of change'.

What credentials do I have in addressing you on a topic which purports to have a view on how our profession should behave? Only that I have called myself, at various times in my career, a crop physiologist (Carberry and Campbell, 1985; Carberry et al., 1993), a crop modeller (Carberry et al., 1989; 2001) and a farming systems researcher (Carberry et al., 1996a; Carberry, 2001; Carberry et al., 2002). Most of these experiences have been in Australia, but I have a long historical association with India (where I did my PhD field work) and Africa (Carberry et al., 1996b; 2004). Here I write as a crop science practitioner, attracted into crop physiology and agronomy by the allure of science innovation, but now wanting to pass the 'so what?' test in realising some consequence from my efforts.

You will read in this paper a personal perspective, hopefully informed by experience and reflections of others. Although appreciative of the efforts of those who have based similar arguments grounded in the philosophy of science (Maxwell and Randall, 1989; McCown, 2001), I am incapable of arguing from this perspective. Rather this paper presents my experience in trying to achieve both innovation and impacts in practice. If you judge that this outcome is indeed achievable, then our profession may both attract talented researchers and achieve expected benefits. This is the challenge and goal of this paper.

Drivers of change

It is difficult to argue against the position that the practices of many farmers world-wide have benefited from the collective and individual actions of crop scientists. Investment in agricultural research, development and extension (RD&E) has been well documented as beneficial to farmers and consumers (Falvey et al., 1998; Maredia et al., 2000; Hafner, 2003; Brennan et al., 2003). Much of this success has been associated with technologies which have relieved constraints, most notably through breeding for improved yield and disease and pest resistance (Maredia et al., 2000; Brennan et al., 2003). For example, by analysing trends in maize, rice and wheat yields for 188 nations over 40 years, Hafner (2003) showed linear growth in yields in more than half of all nation-crop datasets. The benefits of research were clearly seen in the finding that those nations with the highest rates of yield increase were those with already high yields.

What is disturbing in the report by Hafner (2003) is that those nations with minimal or negative yield growth were associated with lower per-capita gross domestic product, fertiliser usage and latitude. Likewise, Maredia et al. (2000) list a number of studies which demonstrate high rates of return to crop improvement research in Africa, but they add several qualifications – particularly the lack of widespread impacts and the fact that such benefits are often captured by commercial farmers and in high potential regions. The benefits of agricultural research clearly have not reached many of the rural poor. While continued rural poverty in Africa has multiple causes (Kitching, 2000; Ekboir, 2003), a greater return on the estimated $US100 billion investment in agricultural research over the past 30 years on behalf of developing country farmers could be expected (Matlon, 2003).

The issues confronting agricultural RD&E are increasingly associated with natural resource systems and their management by farmers whether in developing or developed countries. Attributable success in this area is more difficult to demonstrate (Krall, 2003). Whether you read the local newspaper or formal research evaluation literature, it is apparent that agricultural RD&E is under pressure to deliver impacts. Tackling rural poverty (Byerlee, 2000), the degradation of natural resources (Lovering and Crabb, 1998; Robertson, 2000), loss of biodiversity (Briggs and Taws, 2003), falling public trust in science (Maxwell and Randall (1989), societal fears about science (Frewer, 2003), diminishing public funding (Falvey et al., 1998; Maredia et al., 2000), declining agricultural graduates (Rowarth and Caradus, 1998) and finding a role in the information age (Da Silveira, 2001) are a number of the current challenges for our profession.

Failure to progress on many of these challenges, especially in developing countries, has led to reflection on how we are conducting our science. Criticism of the paradigm of crop scientists concentrating on innovation, through generation of new knowledge and technologies, transferred to farmers by extension services is led in the literature by systems thinkers, evaluation economists and extension scientists (Jiggins, 1993; Pretty, 1995; Ison et al., 1997; R?ling and Jiggins, 1998; McCown, 2001; Ekboir, 2003; Vanclay, 2004). In Australia, an even more telling critique of our practice has come from farmers and agribusiness (Wylie, 1992; McClelland and Eyres, 2001). A significant indicator of dissatisfaction of public funded RD&E institutions in Australia has been the increasing number of proactive, organised farmer groups who are competing as RD&E providers on the basis that traditional RD&E institutions are failing to meet their needs (Carberry, 2001).

Such criticism of agricultural RD&E has been raised for decades, yet its impact on research practice has not seen the radical revolution called for by some (Cox et al., 1996; Wood et al., 1997; R?ling and Wagemakers, 1998; Packham, 2003). In fact, in some countries it is difficult to see significant change in the way agricultural RD&E is funded and practised. Huffman and Just (1999) reported some shift in traditional funding for agricultural research in a number of developed countries, from assured government allocations to increasingly competitive grant programs, but this proportion remains relatively small in countries such as the United States.

In Australia, however, there are clear indicators of a reformation in research practices. CSIRO[2], Australia's national research organisation (and my employer), has a stated primary function of conducting scientific research and its application. The organisation's strategic plan elaborates by stating that "*it is not enough just to have a great idea, we must have impact, solve problems and make a difference…Great science is our foundation. Getting it out there is our aim*" (CSIRO, 2003). The organisation has adopted 'Service from Science' as one of its key change messages, demanding "*a culture of uncompromising customer focus – delivering great service from excellent science*". Publication of scientific papers is explicitly referred as one of a number of secondary functions.

Crop scientists are under pressure to deliver increased benefits to our industry and community clients. Innovative science, as judged by disciplinary peers, can no longer be the chief criterion for continued support. Unfortunately, some are ignoring this contemporary reality.

Changes in thinking and practice

I don't believe that there were strong external drivers which forced me from a career in crop physiology and modelling to farming systems research and beyond. On reflection, three significant influences are most likely. Firstly, a personal desire to explore whether the crop models I started developing in the early 1980's could be used in real-world farm management – I had always intended a return to the family farm before becoming distracted by a science career. The record of past failure for decision support systems (DSS) was seen as a challenge, along with an arrogant desire to do better. Secondly, my personality is suited towards engagement and I most enjoy agronomic and social interactions with farmers. And, thirdly, the influential leadership of Bob McCown, who led our team's evolution both in our systems thinking and practice (McCown, 2001; 2002; McCown et al., 1985; 1994; 1996; 1998; 2002a,b). Not being an extensive reader nor a natural systems thinker, I benefited enormously from his mentoring and challenging which strongly influenced my own thinking and practice.

When the Agricultural Production Systems Research Unit (APSRU) was formed in 1991, it was given a mandate to develop and deliver DSS for use by farmers. This was despite the lack of local or international success for their adoption (McCown et al., 2002a). Rather than dutifully developing more DSS, our team decided instead to address questions such as 'Why don't farmers use seemingly useful tools such as crop models?', 'Is there any farmer who values access to our science models?' and 'If so, how then can model outputs be delivered cost-effectively?'. Addressing these questions clearly leads towards a different type of research than that practised in crop physiology and model development!

FARMSCAPE (Farmers, Advisers, Researchers, Monitoring, Simulation, Communication And Performance Evaluation) has been a 13-year program of participatory research with farming communities around Australia. It initially involved research to explore whether farmers and their advisers could gain benefit from tools such as soil characterisation and sampling, climate forecasts and, in particular, simulation modelling. Its current focus is facilitating the implementation of commercial delivery systems for these same tools in order to meet industry demand for access to them.

Carberry et al. (2002) provide a detailed account of the FARMSCAPE experience and report the impacts and learning from working with farmers and their advisers on the monitoring and modelling of their soils and crops. Here, the significant contributions of colleagues need to be recognised in reference to FARMSCAPE implementation and reporting (e.g. McCown et al., 1998; Dalgliesh and Foale, 1998; Hochman et al., 2002; Robertson et al., 2000; Foale et al., 2004).

An alternative research paradigm

A research career focussed on crop physiology, model building and normative simulation analyses represented a 'hard' systems research approach. Systems boundaries, goals and analyses can be defined technically and are independent of real people. I have undertaken a multitude of simulation scenarios run under hypothetical management situations and, as a consequence, recommended how farmers should farm (eg. Carberry et al., 1996a,b). In fact, most justifications of a role for modelling refer to context-free analyses (eg. Meinke et al., 2001; Hammer et al., 2002; Matthews and Stephens, 2002) with few, or no, examples on where farming practices have benefited from a hard systems-based modelling approach.

A significant learning for me was introduction to the concept of 'soft' systems, where people become an integral component of a socially constructed and negotiated human activity system (Checkland, 1999). Our FARMSCAPE research program represented my introduction to soft systems research and, led by the inquiry of McCown (2001), it opened up the option of an alternative research paradigm. We wanted to participate with farmers in exploring their own real-world issues using on-farm research and systems simulation. However we did not want to simply abandon our research interests for a role in extension. Participatory Action Research (PAR[3]) provided the soft systems research paradigm which enabled credible research outcomes to be sought in the context of real-world farming.

I particularly like the definition of action research of Zuber-Skerritt (1993) which describes it as being:

- participative and collaborative – a researcher is not an outside expert but rather "a co-worker doing research with and for the people concerned with the practical problem and its actual improvement";
- practical – "the results and insights gained from the research are not only of theoretical importance to the advancement of knowledge in the field, but also lead to practical improvements during and after the research process";
- emancipatory – "all people concerned are equal participants contributing to the enquiry".
- interpretive – "solutions are based on the views and interpretations of the people involved in the enquiry (with) research validity achieved by rigorous methods";
- critical – participants act as "critical and self-critical change agents … (they) change their environment and are changed in the process".

I dare not attempt here to summarise the body of literature on systems thinking and its linkage to the social sciences. Instead I refer those interested to the early chapters in Jackson (2000) for an excellent introduction to hard and soft systems approaches and methodologies.

Participatory Action Research in practice

Having adopted Participatory Action Research as a research approach we have followed the route of many critics of the hard systems research paradigm. Over the past 20 years, more than thirty participatory methodologies have been promoted and implemented (Black, 2000), differing mostly in terms of the balance between hard and soft research approaches (Farrington and Martin, 1988; Biggs, 1989; Jiggins, 1993; Okali et al., 1994; McCown et al., 1994; Martin and Sherington, 1997; Petheram and Clark, 1998; R?ling and Jiggins, 1998; Collinson, 2000; Black, 2000; Pound et al., 2003).

I suspect that, for a crop scientist contemplating participatory methodologies as a research approach that can generate innovative science alongside real-world impacts, a review of these published experiences would not be enticing nor compelling. Much of this work is long on the rhetoric of participation and short on its achievements (Okali et al., 1994). Added to this are the realities of participatory research methods which include the high time cost of participation, dependence on qualitative data, difficulties in quantitative data collection and analysis, inadequate evaluation procedures, difficulties in publication and lack of rewards (Martin and Sherington, 1997).

Helpful in contemplating participatory methodologies in practice, Okali et al. (1994), Martin and Sherington (1997) and Sumberg et al. (2003) distinguished between ‘research-driven’ and ‘development-driven’ farmer participation, where the former is aimed at making research more effective and the latter about empowering farmers. Sumberg et al. (2003) raise the concern that the proposition that ‘more participation is always better’ is an attack on formal agricultural RD&E and that such pressure will impact negatively on scientists’ ability to serve the agricultural sector. Even more strongly, they believe those preaching the empowerment argument are confused as to the purpose of research. Loss of rigour in research can be a unfortunate consequence.

The FARMSCAPE program of farmer engagement is research-driven – it incorporates farmers, their advisers and researchers working together in using soil and crop monitoring and simulation to learn about their farming systems, to widely communicate what is learnt, and to utilise performance evaluation for both assessing impacts and guiding future research. I believe it demonstrates a successful implementation of participatory action research with outcomes in terms of both science innovation and industry impacts. We have been able to address many of the technical and resource difficulties raised by Martin and Sherington (1997) and others, as well as meet the personal aspirations of most participants.

Clearly, case studies which demonstrate successful implementation of Participatory Action Research will greatly enhance the arguments for the broader adoption of such soft systems approaches. In the following sections, a number of performance indicators and issues with participatory methodologies are addressed, both in terms of the published experience of others and our own experiences in FARMSCAPE.

Science innovation

Science innovation, encapsulating research inquiry and its publication, has not been a high priority in many participatory research efforts. In truth, it is not difficult to see why traditional agriculturalists have regarded farming systems research / farmer participatory research as ‘vague’ and more extension than research (Biggs, 1989; Petheram and Clark, 1998; Murray, 2000). In my reading of published attempts to promote participatory research through reports of on-ground case studies (eg. Biggs, 1989; Okali et al., 1994; Pound et al., 2003), I can find little by way of new knowledge generation, let alone its publication. There are some who even argue that findings from often location-specific, participatory research are not in principle concerned with, nor expected to generate, innovations with potential for wide adoption or applicability (Okali et al., 1994; Martin and Sherington, 1997). This is disappointing and likely a real deterrent for crop scientists to adopt such research approaches.

A major reason for a lack of scientific reporting from participatory on-farm research is that such trials are often plagued by variability, they are normally specific to the location where the work was done and their analysis is hampered by the lack of any standard methodologies (Biggs 1989; 1995; Okali et al., 1994; Carberry, 2001). Ashby (2003) makes it even more difficult by suggesting that the standards for reliability and validity have to be negotiated with stakeholders and often researchers have to accept compromises. A daunting task for a science-trained researcher.

The FARMSCAPE program of on-farm research has generated new biophysical knowledge which is both locally and more broadly applicable. Some examples include:

- Robertson et al. (2000) describe a research approach involving researchers, farmers, advisers and grain traders in which on-farm monitoring of spring-sown commercial mungbean crops, combined with systems simulation, was used to establish evidence that a spring-sown crop after a winter fallow was not only feasible but profitable.
- Hochman et al. (2001) developed close relationships between the plant available soil water content (PAWC) of farmers' soils and soil type, crop species and soil depth. This work utilised soil data collected as part of an extensive on-farm monitoring program (Dalgliesh and Foale, 1998).
- Foale et al. (2004) report on the collective efforts of farmers and researchers to test whether measured changes in soil water and mineral N on commercial farms can be simulated. This participative research resulted in revelations about the behaviour of mineral N in shallow clay soils which in turn challenged the specifications of the simulator.
- Murray-Prior et al. (2004) report on-ground attempts by farmers to incorporate lucerne within their crop rotations. Results from participatory on-farm research, biophysical and economic modelling demonstrated that lucerne improved some sustainability indicators but reduced profitability.
- Whish et al. (2004) report results from both on-farm participatory research trials and the monitoring of commercial sorghum crops grown in different row configurations. As a consequence, new science was incorporated into the APSIM simulation model to account for the difference in water usage between alternative row configurations.
- Brennan et al. (2004) describe case studies of farmers interested in incorporating recycled effluent water within their farming systems. The approach used farming system and economic models specified for specific farms to enable analysis of the likely economic and environmental benefits and risks of investing in recycled water.

Many more examples of good science emanating from this program are available, although much is currently reported in the grey literature of industry and conference publications. Difficulty in publication is an issue for participatory on-farm research – for a 13-year effort, our publication record is not extensive. However, international journals appear to be increasingly receptive of such work.

In dealing with issues of rigour and relevance from our on-farm research, systems simulation has played an essential role. The Agricultural Production Systems Simulator (APSIM) is a powerful systems analysis tool (McCown et al., 1996; Keating et al., 2003), which not only provides an innovative way of making sense of on-farm data but it also becomes the receptacle of new science generated from such analyses – these two uses are evident in most of the above examples. I am astounded that simulation has not been more prominent in the recent reports of on-farm research (e.g. Pound et al., 2003).

Innovation in science must include insight and lessons about our own RD&E practices in order that we continually improve what we do. The original questions which triggered FARMSCAPE were about learning how we as scientists, with our science tools, could intervene in the human activity systems of farming. We have published some experiences and insights on this front (McCown, 2001; 2002; McCown et al., 1994; 1998; 2002a,b; Hochman et al., 2000; 2002; Carberry, 2001; Carberry et al., 2002; 2004). Such learning has informed our own practices and, through publication, hopefully has helped others addressing similar issues. Thus we have joined many who have published views on how our science should be practised. What pleases me is that we have based our writings and lessons on hard-won experiences. One may detect a small niggle here with those science theorists who preach from a pulpit and not from a field – a complaint I hear also from other practitioners.

Impacts

Ten years ago, Okali et al. (1994) published a reflection of the then status of farmer participatory research and subtitled it rhetoric and reality. The contradiction to which they refer related to a perceived gap between the level of intellectual discussion on participatory and emancipation processes of such research versus the reality of impacts on practices of farmers in the field. Okali et al. (1994) provided eleven case studies with evidence of collaborative farmer involvement, but on-ground impacts were, at best, mostly promises. In reviewing this book, Stroud (1996) concurred with the view that it focussed too much on details of implementation strategies and too little on outcomes and impacts. Despite this, Martin and Sherington (1997) use this same reference to overstate the opinion that "*participatory trials and programmes result in more productive (higher yielding) technologies*".

A decade later, Pound et al. (2003) published another set of 23 case studies of participatory R&D in natural resource management with the promise of uniting science and participation, of bringing "*practical reality to bear on generalised concepts*". Although conscious of the limited reporting on each case study, my assessment is harsh – it seems the rhetoric continues. Many (but not all) of the cases are devoid of stated research questions and inquiry, they concentrate on 'development-driven' farmer participation and they are still at the stage of aspiring to achieve impacts rather than reporting evidence of such. Given the long history of attempting participatory R&D, I was keenly hoping for a better advertisement. For example, in the same book, Ashby (2003) reported on the work of Pretty and Hine (2001) who analysed 208 cases of sustainable agriculture from 52 countries, involving nine million farmers and 30 million ha, and concluded that participatory approaches involving farmer experimentation were the foundation of their cases which they judged to be 'successes'.

The achievements of the FARMSCAPE program in bringing benefits to both industry and the broader research agenda in Australia over the past 13 years have been significant and demonstrable. To borrow from Carberry (2001) and Carberry et al. (2002), FARMSCAPE has

- helped change how the soil resource is viewed by farmers and agribusiness – soil water is now commonly referred to, in private and public extension material, as depth of water in millimetres measured by a soil core as opposed to depth of wet soil measured by a push probe.
- contributed to the establishment of soil monitoring as a routine management practice – many farmers and agribusiness nationally are now deep soil coring for water and nitrogen measurement as evidenced by the number of deep soil samples being commercially analysed.
- increased industry acceptance of modelling as a source of management support – farmers in several regions of Australia are now routinely using simulation-derived information as provided by private consultants.
- helped promote the use of the Southern Oscillation Index (SOI) in seasonal climate forecasting – the SOI is now routinely sourced and used by farmers and advisers nationally .
- contributed to achieving innovative changes in farming practice – the introduction of spring-sown mungbean as a new management option and renewed interest in dryland maize are two recent examples.
- contributed to increases in crop yields and profitability – our evaluation activities have identified many examples of such benefits attained by farmers.
- established commercial delivery mechanisms for FARMSCAPE – agronomists have been trained and accredited in our tools and APSIM simulations are now accessed from an on-line commercial web service called the 'Yield Prophet'.

Farmer participatory research clearly is difficult to implement and to achieve impacts, let alone document such successes. I am conscious that most participatory research efforts have been attempted with smallholder farmers in developing countries where socio-economic and political aspects add complexity to the ambition of achieving real-world impacts. Achieving the claimed impacts within FARMSCAPE are relatively easier because of the agricultural environment of Australia. Nevertheless, proponents argue for such approaches on the basis of real-world benefits and so should be assessed against this criterion.

Monitoring and evaluation

Few agricultural RD&E activities have incorporated explicit monitoring and evaluation activities either to assess their impact (summative evaluation) or to inform future activities (formative evaluation) (Okali et

al., 1994; Martin and Sherington, 1997; Dart et al., 1998; Murray, 2000; Horton & Mackay, 2003). One reason is that assessing impacts from management-oriented research is difficult and so most effort in agricultural RD&E is directed towards the impacts of breeding (Cox et al., 1996; Maredia et al., 2000; Krall, 2003). Another reason is the problem of attribution, as causality can only be attributed to a range of causes and rarely to a single influence (Ekboir, 2003). Yet another reason is that most impact assessments and evaluation studies are seen to have little influence either on research management or to the achievement of development impacts (Krall, 2003; Horton & Mackay, 2003). All these excuses hold as to why researchers do not invest in evaluation. But I see this as a real deficiency within our profession, whether in the hard or soft science paradigm.

An attractive benefit from using a participatory action research framework is the explicit requirements for activities conducive to achieve evaluation outcomes. In fact, Participatory Action Research is often depicted by the action research cycle consisting of iterative cycles of planning, action, observation, reflection, replanning and so on (Zuber-Skerritt, 1993). From the very earliest research activities within FARMSCAPE we have attempted to document and reflect on our experiences (Carberry et al., 2002). A significant investment in evaluation processes is now regarded as an essential ingredient to our research.

Organisational learning and change

Collinson (2001) firmly lays the blame of low adoption of research results by smallholder farmers in developing countries as a fault of the traditional applied research paradigm and its research institutions. He argues that scientists and managers give their allegiance to their commodities, their disciplines and their institutions rather than to beneficiaries as the appropriate drivers of research programming and organisation. This view and the consequent call for organisational learning and change within our agricultural profession and its institutions is a persistent and strong recommendation from many practitioners in the field (Okali et al., 1994; Biggs, 1995; Woods et al., 1997; R?ling and Jiggins, 1998; Ashby, 2003; Chambers, 2003; Ekboir, 2003; Matlon, 2003; Horton and Mackay, 2003).

Traditional science and its organisational arrangements are important because they embed practices which have proven useful over many years (Ison, 1998). However, sticking with tradition also runs the risk of lacking critical reflection and if crop scientists are uninterested in critique then we will become increasingly irrelevant (Ison, 1998, Carberry, 2001). Unfortunately, questions will then follow on the ethics and values underpinning agricultural RD&E and the willingness and capacity of researchers to improve the situation of rural people (Woods et al., 1997).

FARMSCAPE has benefited and blossomed under the organisational support it has received from CSIRO over the past 13 years. While Biggs (1989) suggested that research systems have not rewarded scientists for working directly with farmers, I do not believe my career has been hampered because of this commitment. In fact it has been significantly enhanced, both in terms of career progression and recognition but more importantly from the learning and friendships gained. However, I do believe that many researchers who choose to work for the benefit of farmers are penalised by institutional and disciplinary reward systems which favour peer recognition and publication record over industry and community impact. Rewarding researchers who take this route is a real challenge for our profession.

Conclusions

I found it difficult to write this paper on the issue of ‘crop scientists as change agents’. Difficult because I respect our agricultural science tradition and its many achievements. Difficult because, despite the call for greater impacts from our research, continued investment in our disciplinary sciences and in strategic research are essential. Difficult because I know well there are crop scientists who have been agents of change under current RD&E systems. Difficult because much of the push for a changed approach is driven by the lack of progress in developing countries. Difficult because I am writing about my profession and offering an opinion on how it should operate.

The only way I could deal with this difficulty was to review the alternative paradigm of participatory research and record what was learnt within our FARMSCAPE experience. Farming systems research /

farmer participatory research, and their many permutations, have been attempted for over 20 years and clearly critics of these approaches have raised issues of concern, especially on its cost-effectiveness. Within FARMSCAPE, we have found a participatory action research approach beneficial in grounding our research in real-world activity systems. Knowledge generation and innovation remain important components of this approach.

In reviewing the literature cited in this paper, the statement about which I feel most strongly is the view of Biggs (1995) who identified the importance of individual actors in making commitments to addressing local problems, by taking risks, finding resources and by influencing their own institutions to gain appropriate support. This paper's title of 'crop scientists as change agents' is way of stating that our profession needs to be interventionist in our practice and that this will require committed individuals. Science innovation is our comparative advantage in the market place of agricultural change. Crop scientists acting as agents of change will deliver benefits to farmers and their communities.

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[1] Quotation given to the author by Bob McCown when he joined CSIRO.

[2] Commonwealth Scientific and Industrial Research Organisation

[3] As a crop physiologist, PAR had always represented photosynthetically action radiation. Changing paradigms requires changing one's jargon!