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Integrated assessments of climate variability and change for Australian agriculture – connecting the islands of knowledge

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Abstract: Key clients for regional or national assessment capabilities are government and industry policymakers, who must deal with constantly changing policy questions. For instance, adaptation to climate change has relatively recently come onto the policy agenda, as has the interaction between adaptation and greenhouse gas mitigation. 'Integrated assessment' has therefore become a common approach that attempts to demonstrate the policy relevance of science. It is intended to inform policies that ultimately lead to better risk management of agro-ecosystems (amongst other objectives). Increasingly policy stakeholders also demand realistic assessments of uncertainties that are associated with the scenarios underpinning such integrated assessments. This requires quantitative, probabilistic evaluation of risks and opportunities associated with specific scenarios that need to supplement the overall, qualitative assessments. Such evaluations can help to cut through the complexity of policy related issues without sacrificing the holistic perspective needed to maintain policy relevance. Using climate change as an example, we explore the role of quantitative models for integrated assessments and argue that a nested modelling approach (eg. climate model – biophysical model – socio-economic model – engagement model) to address all relevant disciplines, stakeholders and scales not only provides the quantitative information needed, but is also a valuable process to negotiate the complexities of the policy domain. This process might help us move more quickly from impact assessments (ie. unadapted responses) to well-structured scenario planning with adaptation, a process that is both policy and response informing.

Keywords: Integrated assessment; APSIM; simulation model; climate change; policy

1. INTRODUCTION

According to CIESIN (1995) 'integrated assessment' can be defined as *the presentation of knowledge derived from research to help individuals with responsibilities evaluate possible actions or think about a problem*. This is only one of many possible definitions of an area of research that can be considered a discipline in its own right (Toth, 2003). It is a practical expression of adaptive governance concepts that are increasingly informing the science/policy interface (Holling, 1978; Ostrom, 1999). We do not wish to further enter into these debates – for our objectives a simple definition is sufficiently succinct to explain why 'integrated assessment' has become the approach of choice when attempts are made to demonstrate the policy relevance of science. It is a means to provide decision-makers with quantitative answers to assist them in solving real-world problems.

Key clients for regional or national assessment capabilities are government and industry policymakers. However, while this client base is stable, the policy questions they need to answer are constantly changing. For instance, adaptation to climate change has relatively recently come onto the agricultural policy agenda, long after managing with climate variability had become a feature of Australian agriculture (Meinke et al., 2003) and after the discussions about mitigation needs to reduce agricultural greenhouse gas emissions had started during the 1990s (eg. Howden et al., 1994). For science to remain relevant in such a changing policy environment requires a wide range of tools and the ability to respond rapidly to changing demands. Although much of the uncertainty in human-environment interactions is irreducible, knowledge of all kinds (informal, local and scientific) can assist in the management of this uncertainty (Dietz et al., 2003).

Due to the multiple dimensions of policy, many integrated assessments are limited in their usefulness and often do not provide insights into the emergent properties of complex systems. Intractability of cause and effect, which is often a feature of complex systems, can be perceived as devaluing scientific contributions to the policy debate. A careful investigation of policymakers' needs as well as an explicit, ex-ante analysis of the costs and benefits of the assessment process might assist in reducing this dimensionality, resulting in fewer, but better targeted scenarios that address stakeholder needs more effectively. Lowe (2002) describes this dilemma and argues that the *limits of our present knowledge mean that scientific knowledge could be described as islands of understanding in oceans of ignorance*. He challenges us to find ways to use valuable, existing component knowledge in a way that is relevant at a higher, holistic level. This will require realisation and acceptance by scientists and policymakers alike that although we cannot predict the future, we are well equipped to prepare for it. *Politicians will have to accept that fuzzy answers may be the best expression of expertise; scientists will have to learn that the identification of the fuzzy borderline between knowledge and ignorance may be the sign of real competence* (Walker and Marchau, 2003).

Integrated assessments based on scenario planning are usually conducted using a quantitative modelling approach. However, experience shows that quantitative models that try to answer all questions that arise as part of the integrated assessment process usually answer none of them well. Additionally, attempts to sum reductionist approaches to understand the emergent properties of human-environment interactions tend to be enormously costly and slow, and are quickly overtaken by changing circumstances (Holling 1978). Hence, we argue that it is not just a range of models that is required, we also need a well-designed and flexible process that combines and uses these models with social engagement processes in order to answer pertinent policy questions: exploring human-environment issues requires human-quantitative model interactions.

Fig. 1 depicts a process-oriented, multiple model approach, ranging from a purely physical interpretation of data via a climate model, to a modelled interpretation of the bio-physical consequences, to an economic impact and risk assessment and ultimately to a participatory engagement model that uses all these different levels of interpretation and complexities to engage with decision makers and seek their feedback, thereby refining the process and starting again.

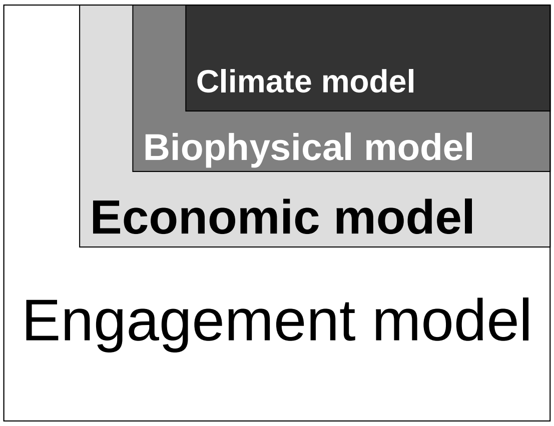

Figure 1: A nested modelling approach for integrated assessments.

It is important to note that we use the term 'model' in the widest possible sense, eg. the 'climate model' in Fig. 1 can be anything, from a simple analysis of historical data to a fully coupled ocean-atmosphere model. Such a nested or polycentric modelling approach (i) provides the necessary flexibility to adapt the process to the constantly changing policy questions; (ii) allows the generation of knowledge at the various levels of integration without the need to disregard uncertainties (iii) helps to design the process in an iterative, transparent fashion that facilitates stakeholder engagement, provides contextualised, relevant information and (iv) creates the confidence and trust amongst stakeholders in the approach and ultimately the advice arising from the integrated assessment process (Ostrom 1999, Turnpenny et al., 2003; Cash and Buizer, 2005).

Using a simple case study from Australia we will i) highlight how issues relating to temporal and spatial scales might be overcome and ii) discuss issue of transferability of influence/responses up and down scales, ie. feedbacks and dialogues between policymakers and practitioners, particularly considering the pre-eminence of temporal variability in Australian agricultural systems. We hope that lessons learned from this case study will improve the efficacy of future efforts.

2. A CASE STUDY OF AN ACCIDENTAL INTEGRATED ASSESSMENT

This is the story of an integrated assessment that was neither intended nor planned – it simply happened. It is also unfinished. However, we believe it to be sufficiently instructive to be discussed here and now. Although the beginnings are hard to pin-point and have their origin in the extensive work on climate variability and agricultural systems analysis (eg. Hammer et al., 2000), the main story begins in 2001, following the release of the IPCC's Third Assessment report (IPCC, 2001). At that time, debate in Australia about evidence of climate change and its impact began to intensify. Industry, as well as public policymakers, began to demand 'hard evidence' that climate change was occurring, many of them remaining unconvinced that climate change was real and would affect their interests. Discussions with farmers drew responses ranging from 'don't waste your time talking to me about climate change – I need to know what is going to happen on my farm this season' (farmer at a scientific conference in Hobart, 2001, pers. com.) to expressions of suspicion or even hostility. Some industry leaders even privately expressed fear of government regulation should they acknowledge that climate change was already affecting their businesses.

Evidence, particularly in relation to temperature impacts, began to mount and data showing trends in historical climate records were increasingly published and discussed in the media. The take-home messages emanating from the application of climate analyses and models were generally negative or even alarming.

Based on this information, some government agencies and R&D corporations started to invest in small impact studies. Using the systems simulation model APSIM (Keating et al., 2003; Holzworth et al., these proceedings), Reyenga et al. (2001) showed that increases in CO_2 levels were likely to compensate to a substantial extent for losses associated with increased temperatures and/or reduced rainfall for wheat grown along a transect in South Australia. Likewise, Howden et al. (2001), showed similar trends for wheat and beef production in Central Queensland. Although these studies highlighted some of the positive aspects of climate change for the wheat and beef industries, the general public, including the rural sector, saw climate change as a problem beyond their influence. Although our science had important messages to convey to the industry (such as 'change will continue to happen and you can prepare yourself and maybe even capitalise on it'), this message remained buried in scientific papers and on WEB sites. We, the scientific community, had failed to get the message across.

Following a major report to the Australian Greenhouse Office on the adaptive capacity of the Australian agricultural sector (Howden et al., 2002), Howden et al. (2003) took a slightly different approach: knowing that frost risk for wheat is one of the major production constraints in the northern Australian wheat belt, they conducted a simple, historical analysis of trends in temperature records and found strong evidence of warming, particularly for minimum temperatures. Using, again, a modelling approach based on APSIM, they found that the frost risk for wheat in this region had declined from about 10 weeks in 1900 to about 2 weeks in 2000 (Fig. 2). When they carried this through to an economic analysis, they found that on average an adaptive strategy that takes these changes into account would be worth about \$18 ha^{-1} annually. Based on this, they concluded: *The documented* (temperature) *trends are likely to continue and wheat producers could benefit from taking such information into account. However, the industry is currently not proactively engaged with the issue even though changes in their own practices suggest that they have already responded autonomously*.

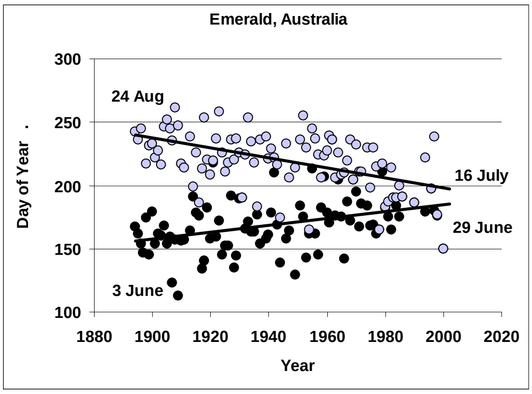

Figure 2: Changes in the dates of first and last frost (closed and open symbols, respectively) at Emerald during the last century based on historical climate data (after Howden et al., 2003).

Howden's et al. concluding statement was obviously intended to provoke a reaction from the industry, which failed to materialise. Although the work integrated outputs from a climate model, a bio-physical model and an economic model (see Fig. 1), and although the paper was presented at a major conference and subsequently published, it failed to provide a basis for action. However, as a consequence of this and similar publications, the authors and their three home institutions (CSIRO, Australia's federal research organisation and two Queensland Government Departments, namely DPI&F and NR&M) became increasingly recognised as change agents capable and willing to provide scientifically relevant input into complex policy discussions (here we stress that the Howden et al. paper was only one small, but important contribution to this development – many other authors and agencies contributed to this, as did other papers and presentations by those authors and their colleagues).

By early 2005 public debate about adaptation options in relation to climate change had reached a level that demanded policy responses. In April 2005, the Queensland Farmers Federation[1] (QFF) co-hosted a public forum in Brisbane titled 'Acclimatising Agriculture for Climate Change: Minimising risks and maximising opportunities', www.qff.org.au/weekly.asp?dbid=13), where senior scientist from the three abovementioned Government organisations as well as representatives from the Australian Government presented their latest findings and engaged with rural industry stakeholders in an open discussion. The outcome from the forum was the establishment of a rural industry roundtable on how best to adapt to a changing climate. This roundtable was informed by scientists from the Queensland Government and provided a venue to discuss all issues in a non-threatening, confidential environment. This included detailed discussion on interactions between potential changes to mitigation policy and their consequences on adaptation measures available to rural enterprises.

In parallel, the Queensland Government developed an adaptation discussion paper (www.nrm.qld.gov.au/science/climate_smart.html). On 10 November 2005, the same day the Queensland Government released it's discussion paper, QFF issued a press release on the outcome of the roundtable (*Rural sector must adapt to climate change*; www.qff.org.au/media.asp?dbid=28). In this statement, QFF acknowledges that Queensland's changing climate is affecting the industry and welcomes the release of the discussion paper as evidence that the Queensland Government is starting to act. Following is an extract from this press release: *A changing climate has variable implications for Queensland's rural industry, depending on the exposure and sensitivity to changes in climate patterns, its adaptive capacity, adverse implications, and the potential to benefit. To truly address the problem, a response must encompass not just the reduction of greenhouse gases but also adaptation strategies driven by opportunities.… last month* [QFF] *convened a rural industry roundtable on how best to adapt to a changing Queensland climate. …. Like all changes, a changing climate brings both risks and opportunities. Those who better understand the changes can adapt effectively to avoid the risks and seize the opportunities. The smart ones plan and prepare.*

[1] QFF is a rural industry organisation in Queensland representing thousands primary producers through 14 diverse member organisations, ranging from cane growers and fruit and vegetable growers in the north, to cotton growers in the central-west, to prawn farmers in the east and dairy farmers in the south.

3. DISCUSSION

As we pointed out in the introduction: none of this was planned, the tale continues and the causal connections we have drawn are tentative and non-exclusive. In this sense it has the hallmarks of autonomous adaptive governance systems that have been documented around the world (Ostrom 1999). Obviously, many other factors also played an important role in getting industry and government to act based on the best scientific advice available. However, as part of this process we learned a few lessons that might prove valuable in achieving future outcomes more quickly.

3.1 The importance of salience, credibility and legitimacy

Cash and Buizer (2005) argue that for climate information to translate into real-life action requires salience, credibility and legitimacy:

- 'Salience' relates to the perceived relevance of climate information: Does the system provide information that these users think they need, in a form and at a time that they can use it?
- 'Credibility' addresses the perceived technical quality of information. Does the system provide information that is perceived to be valid, accurate, tested, or, more generally, at least as likely as alternative views to be "true".
- 'Legitimacy' concerns the perception that the system has the interests of the users in mind or, at a minimum, is not simply a vehicle for pushing the agendas and interests of other actors'.

In our simple case study some 'salience' was gained when Howden et al. (2003) translated historical temperature trends into an economic analysis quantifying the value of proactive adaptation to climate change. This was salient for at least two reasons: i) because it used a management strategy that was already well established and ii) because it provided a positive example of what people can do when previously the issue was only seen as a problem beyond their influence.

Credibility developed slowly by demonstrating scientific integrity via publications, by conducting interdisciplinary research involving many agencies and by engaging in discussions with government policymakers and industry leaders. This is an example of science gaining credibility by facilitating analytical deliberation between stakeholders to negotiate policy objectives and sharing of residual uncertainty (Dietz et al., 2003).

Legitimacy is about trust and integrity that must be developed and maintained (Turnpenny et al., 2003). In our case, the engagement model (Fig. 1) became the most critical part to obtain legitimacy. This was achieved by engaging with stakeholders and providing evidence that the information provided was i) policy informing, rather than policy prescriptive ii) all stakeholders – government as well as industry – had equal access to the information and iii) it was obvious to all that the science was untainted by advocacy. This allowed all stakeholders to begin discussions about policy options that were informed by the same relevant, scientific information.

3.2 The importance of common tools across different scales

Engaging a range of stakeholders with often very different information needs has proven difficult. This is the key reason for the on-going disconnect between the 'climate variability science' and the 'climate change science' communities. Fig. 3 depicts this problem and shows why the information needs between government and industry policymakers differ: they are largely interested in outcomes at vastly different scales.

Traditionally, climate change science has focused strongly on larger scales at higher levels of integration – temporally, spatially and economically. This scale focus had two consequences: firstly, it primarily attracted government policymakers and, to a lesser extent, large corporations in the private sector, who all have considerable interests at i) timescales of generations or longer, ii) spatial scales ranging from regional to global and iii) economic scales ranging from industry to sectors. This left rural practitioners and their representatives disenfranchised and with a feeling of inevitability, as there was no guidance on how they might be able to influence outcomes. Secondly, because of this scale focus, the issue of mitigation dominated their 'climate change agenda'.

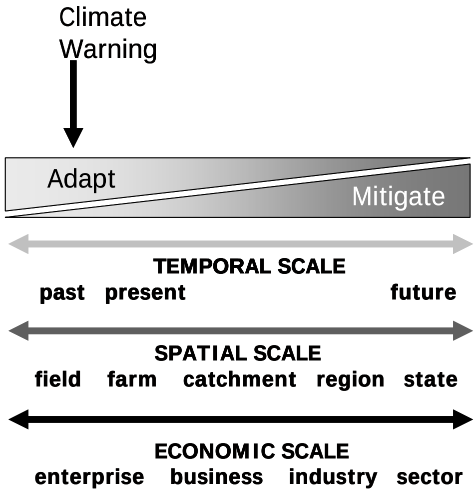

Figure 3: Negotiating multiple scales for integrated assessments

On the other hand, climate variability science focused very much on short temporal scales (eg. the ENSO phenomenon) at the field/farm level addressing issues relevant to specific enterprises and business. The managerial tools developed to deal with climate variability are well established and accepted by rural practitioners (Meinke and Stone, 2005). They are also ideally suited to address adaptation options (Howden et al., 2000), which in agriculture often have to be implemented 'on-farm'.

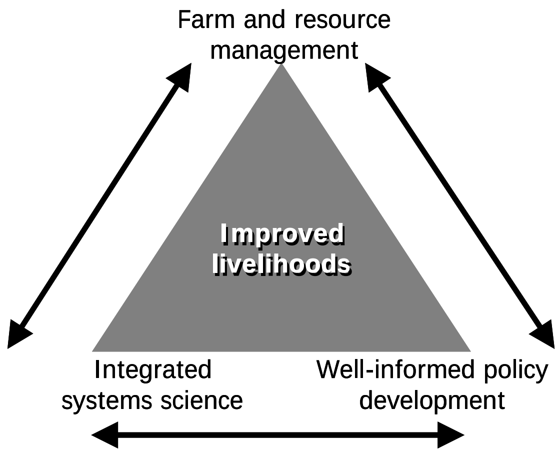

Figure 4: Integrated systems science simultaneously informing different stakeholders, thereby providing quantitative information as input into dialogues between business managers and policymakers about policy options and their consequences.

3.3 Integrated assessments based on integrated systems science

Providing an objective basis for all stakeholders to engage in a dialectic discourse is critically important for an integrated assessment process. With effort, integrated systems science can, via the application of common tools and approaches, be policy as well as response informing, thereby enabling such discourse (Fig. 4). This requires awareness of the scale issues and a willingness to learn and engage by all participants. Hopefully this will lead to the required adaptive policies that are needed to negotiated competing interests in an unpredictable and rapidly changing world (Walker and Marchau, 2003). After all, this is the purpose of integrated assessments.

3.4 Communicating our knowledge as well as our ignorance

Scientists have a responsibility to communicate their degree of knowledge as well as their ignorance (WMO, 2005). Modelling always involves the use of simplifying assumptions about complex situations – characterising, understanding and reducing complexity are the main reasons for modelling. However, this process contains the danger of disregarding the inherent uncertainties, thereby at best providing incomplete information and at worst misleading information to decision makers regarding the nature, level and location of the uncertainty (Walker and Marchau, 2003). Hence, responsible scenario analysis has to provide probabilistic rather than deterministic information (Meinke and Stone, 2005): it needs to embrace and acknowledge uncertainty, not ignore it (Fig 5). This is complemented by governance systems for appropriately sharing residual risk and uncertainty between participants (Ostrom 1998). Within appropriate governance structures, integrated assessment can provide useful frameworks for handling complexity and uncertainty that can be quantified, thereby improving decision making at all levels (Brouwer et al., 2003). Using quantitative modelling tools to address fuzzy, real-life issues covering multiple dimensions will always lead to fuzzy, but hopefully useful, answers.

4. CONCLUSION

Climate is one of the key risk factors for agro-ecosystems. However, many of the pressing problems posed by climate variability and change have not been adequately addressed because as scientists we are used to applying narrow, specialised knowledge to complex systems, thereby answering some component questions very well but often ignoring the high level issues – traditional, reductionist science has the tendency to create 'islands of knowledge in a sea of ignorance'. Integrated assessment needs to be complemented by adaptive governance structures that connect and increase these 'islands of knowledge'. Within appropriate governance structures, we found that nested modelling approaches can usefully address issues at a range of temporal, spatial and economic scales. Appropriate governance requires stakeholder engagement that demonstrates relevance (salience), credibility (good science and the communication of inherent uncertainties) and legitimacy (fairness, no advocacy). Such an approach can provide a platform to generate knowledge that is policy as well as response informing.

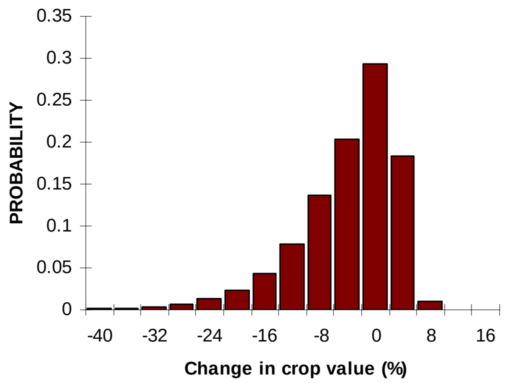

Figure 5: Probabilistic assessment of change in gross value of the Australian wheat crop from historical baseline values for the year 2070 as a result of increase in CO_2 and change in temperature and rainfall assuming no adaptation (Howden and Jones 2004).

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