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Integrated Assessment Modelling of Complexity in the New Zealand Farming Industry

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Integrated assessment modelling of complexity in the New Zealand farming industry[1]

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Abstract

As New Zealand farming industry pursues more productivity this has implication for environment and makes land use and agricultural policy decision processes more complex for which integrated assessment modeling (IAM) can support. The purpose of this review paper is to propose means through which IAM can be improved specifically to minimize uncertainties and increase relevance, reliability, and utility of outputs of different models. Literature suggests that the general motivation for land use change is that farmers do consider the environment, but need to maintain profitability. There are handful decision support tools for land use and land policy decisions but one common feature of most of the models is that each seems suitable for only a part of the complexity. An appropriate framework for linking different models in an integrated assessment is still needed. As integrated assessment often goes beyond an individual researcher's role, research institutions need to align their research portfolio across the dimensions of the complexity by creating an appropriate mechanism to integrate individual research into integrated assessments while individual researchers need to present modelling results in a compatible format for integration into another model's application.

Keywords: integrated assessment, modeling, complexity, farming industry, New Zealand

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1. INTRODUCTION

Agriculture in New Zealand is, to an extent, becoming more productive and competitive, however, an emerging issue is that intensive land-use is putting the land, water and atmosphere under stress, and threatening the long-term sustainability of ecosystems and biodiversity. Barnett and Pauling (2005) relate increasing agricultural pollution (of water bodies) to the intensification in dairy farming as dairy farmers push for more production in the competitive market.

Consequently at farm level, considering both the economic and environmental impacts of land use options can be seen as becoming increasingly a policy requirement in farmers' decision-making processes in recent times. Examples include the targets set for the dairy farmers in the NZ Dairying and Clean Stream Accord (MfE, 2003). Interestingly, these requirements are becoming more and more driven by institutions in terms of policies to encourage environmentally friendly stock policies. A study by Shadbolt et al. (2010), which explored NZ farmers' perceptions of risk, shows that farmers rank local body laws and regulations as a source of threat that although is about as likely not to happen as it is to happen, but if it does happen it will have a relatively high negative impact within a season and in the longer term. Adding to the farm-level decision making complexity is that most of these regulations, especially in terms of property rights, do not adequately capture the diversity of values that farmers have for managing their farmlands (Fisher 2005). O'Connor (1993) envisaged this challenge and asserted that securing land tenure, and having access to investment capital, is not enough for successful land use. Farmers also have to meet the legislative, institutional and bureaucratic planning requirements.

It can likewise be complex for policy makers to encourage sustainable land use as the environment is complex in itself, having both time and space dimensions and meaning that the diversity of environmental effects of decisions made today are not always readily apparent. For example, Moller et al. (2008), while acknowledging that agricultural intensification negatively affects water biodiversity, argued that there is insufficient research evidence to confirm the impacts on land biodiversity in New Zealand. In addition, the number of stakeholders involved is diverse, making it more difficult to arrive at decisions to achieve desired outcomes of all stakeholders

(Qureshi et al. 1995). Another issue with land use policy that is not well informed is unintended consequences.

These complexities can at least increase the difficulty of decision making process at both farm- and policy-level. For instance, in addition to usual farm management questions, additional questions can include which land use option is appropriate for both profitability and environmental sustainability? Similarly to the policy makers, more questions can include which policy is appropriate for sustainable resource management, up-taking of sustainable farm management practices, etc. given various drivers that have different implications for agricultural profitability and competitiveness and sustainability.

What aroused interest in this topic is that while NZ farming industry tends to pursue more productivity, this has implication for environment and makes decision process more complex for which IAM can contribute. In addition, IAM being a developing discipline (Hisschemoller et al. 2001), there are more development needed to enhance its contribution to supporting decision making process around balancing economic and non-economic outcomes of options. According to McClean et al 1995, addressing the complexity in land use issues can undoubtedly be aided by applications of decision support tools. Jakeman and Letcher (2003) argue for the important role of IAM for informed decision making regarding land-use and policy options. However, the authors highlighted a number of challenges to IAM based on case studies of water resource assessment and management projects in Northern Thailand and Yass and Namoi catchments in Australia. One of the challenges is that most conceptual frameworks being used for analysis of decision options are problem specific rather than being integrative. Another challenge is limited credibility and use of relatively complex models as a decision support tools - these models are not easily validated. This sometimes is seen as gap between decision makers and model developers. These are challenges that have been earlier on perceived to persist for a long time especially when developing comprehensive models for integrated assessment (Malafant and Davey, 1996).

In addition to performing integrated assessment on specific problems, comprehensive model testing and characterisation of uncertainties in the applications of models to resolve the issues above, as suggested by Jakeman and Letcher (2003), the following literature reviews attempt to contribute to IAM by broadening awareness and giving reasons to justify the stance take on - what can help validation of component-based models and linking of such models in order to minimize uncertainties and increase relevance, reliability, and utility of outputs of different models – That is each model is useful (useful in its own scope) and complementary to other models (able to talk to and being talked to by other models).

This paper proceeds as follows: An overview of land use change and drivers of land use change in NZ is presented in Section 2 exploring the indicative drivers of land use change among NZ farmers. In Section 3, a catalogue of tools/models being used to analyze land use issues and support farm-level decisions and policy interventions is presented. Having set the scene, Section 4 explores further questions namely what is an appropriate framework for IAM? Is there a gap between science and decision makers? Is 'complex' model a panacea? And finally, answering these questions lead to leverage points for IAM.

2. OVERVIEW OF LAND USE CHANGE AND ITS DRIVERS IN NZ

New Zealand seems to have a history of land use change and change in farm management practices, an overview of which cannot be exhaustively presented here given the scope of this paper. Comprehensive situational analysis of factors that impact NZ agriculture by Manhire and Emanuelsson (2009), shows recent drivers of change in NZ agriculture to be diverse namely climate change, water constraints, energy constraints, commodity prices, associated exchange rate risk, etc. Meat and Wool New Zealand (2007) reported that profit, physical and financial risks were the main decision criteria among farmers in New Zealand. In this case, the physical risks in farming systems would encourage farmers to choose the best environmental management practices to manage risk, lower costs, raise profit and minimise nutrient leakage/loss (Dake et al. 2007).

Gray, et al (2008) reported that consideration of higher food and input prices, and labor supply, were important criteria for choice of farm management practices among dairy farmers. Newmann and MacMillan (2008) reported that the average cost of production played a major role in dairy farming, based on the 2005-06 DairyNZ economic survey.

Drivers of land use change in New Zealand

Environmental conditions, such as land degradation and pest infestations, have inevitably resulted in changes to land use away from the traditional pastoral production in some areas in the South Island high country communities. Likewise, in the East Coast Region of New Zealand, severe climatic events have been reported to have indirectly contributed to a long history of earlier land use change to pastoral agriculture, and a more recent change to commercial scale exotic plantation forestry in the region (Ministry for the Environment, 1991). Some landowners have tapped into the value of carbon sequestration through the government Permanent Forest Sink Initiative which started in December 2007. For example, MAF (2011) reported that about 1,000ha of the 7,141ha registered permanent forests between December 2007 and March 2011 was new forest as a form of land conversion.

A report by MAF (1998) shows specific changes in land use, from sheep and cattle farming to forestry. These changes have been attributed to changes in market demand and the need to manage the farm environment. Initial changes to forestry plantations were linked to government subsidies under the East Coast Forestry Project in an effort to encourage land protection. More pastoral farmers later diversified into farm forestry for economic reasons, and fear about the long-term viability of farming, coupled with increase in land costs as residential land use competed unfavourably with agricultural land use. Other reasons included flood control and the mitigation of soil erosion risk.

Drivers of change in farm management practice in NZ

Macgregor and Warren (2006), in a study of 30 farmers in a catchment, reported that farmers tend not to take responsibility for environmental outcomes, such as maintaining water quality, as they don't easily observe the links between farm practice and environmental outcomes. The studies therefore concluded that economics rather than environmental issues were the determining factors. While it is expected that farmers will have an intrinsic concern for the environment, given the wide range of benefits from quality farmland, there is an indication that farmers do use various management practices to improve both the economic and environmental outcomes of their land use.

Farmers have taken advantage of benefits that environmental friendly management practices have on their farm profits. Bewsell, Monaghan and Kaine (2007)'s study on the adoption of stream fencing among 30 dairy farmers in four New Zealand catchments, shows that the factors influencing dairy farmers' decisions to fence waterways on their farms includes farm contextual factors. For instance, while stream fencing targets were set by the industry as a code of practice to minimize damage to stream water quality from dairy farming, the farmers choose to do stream fencing mainly for the purposes of on-farm benefits. These included fencing boundaries, fencing for stock control, fencing to protect animal health, and fencing because of pressure to conform to local government guidelines or industry codes of practice rather than for stream water quality management. For a few farmers who fenced waterways on their properties, the studies reported that motivating factors included pressure from local government and/or industry, property redevelopment, and incentives from the council in the form of no-cost assistance.

Wilcock, et al. (2007) monitored five dairy farming catchment streams in New Zealand with high concentrations of N, P and faecal indicator bacteria resulting from poor riparian management. They later examined trends in management practices and water quality in these streams, and found little improvement in water quality attributable to improved land use management practices, over five years in three catchments (Waiokura, Bog Burn and Pigeon). However, in two catchments (Toenepi and Waikakahi) monitored over ten years, water quality improved significantly, and less significantly respectively, as a result of improved land use management practices. In a follow-up study, Monaghan, et al. (2008) conducted on-farm monitoring of water quality variables, nutrient and sediment yield estimates, over a four year period among the intensive pastoral farmers in a 5230ha Waikakahi catchment. They used a modeling framework to capture the economic and environmental components of farm systems, with a GIS calculation of N and P effluents to identify linkages between catchment water quality and farm mitigation strategies, in an experimental program on selected dairy farms in the catchment. The research further aimed to examine the effects of land management practices on farm business profitability and stream water quality in the catchment, to show that improved stream water quality would be generally desirable, and prescribe a number of cost-effective mitigation practices.

James et al (2008) reported that forest (planted) managers in New Zealand use management practices such as manipulating rotation length, species, etc. to maximize profit. There is more to learn about land use decision-making considering the claim by Milne (2009) that farm forestry offers both environmental and economic gains, and yet records show low rates of new planting. In an effort to promote farm forestry, the NZ Farm Forestry Association (NZFFA) conducted a number of case studies of what farm foresters farmers do and how they do it. The reasons given for growing trees included spreading financial risk, succession planning, shelter and landscaping to enhance the property, agro-forestry, a love of trees, control of soil erosion, fencing of water ways, and profit from poorer land.

In summary, profit is the main decision criterion for land use options. The general criteria and motivation are that farmers tend to take good care of the environment, but need to maintain profitability. Scientists, in an effort to help farmers and policy makers' decision-making processes do develop technologies and 'best' farm management practices to enhance productivity and environmental sustainability. These 'best' bets and policy options with a number of factors that affect outcomes are being analysed with the aid of models and decision support tools. Some of these tools and models are presented in the next section.

3. TOOLS BEING USED TO SUPPORT LAND USE CHANGE AND POLICY IN NZ

An earlier effort to raise awareness about the tools and models available to help farmers, policy makers and other stakeholders in decision-making was reported by MAF (1995). This report indicates that the tools integrate data on financial indicators, stock numbers, climate and natural resources to give insights on the short and long-term implications (mainly financial) of land use options. Although there has been improvement in most of the tools and models catalogued by MAF (1995), most models/tools give gross margin analysis that leaves farmers with difficulties in assessing multiple variables over long time periods or how different enterprises interact in the whole farm system. Rutledge, Fenton and Wedderburn (2010) reviewed the state of integrated decision support systems in NZ by undertaking a stock take of integrated decision support systems. The authors reported that few of the models/tools address cultural, socio-economic and environmental outcomes of decision making.

Another relevant scoping of models being used to study farm and agricultural policy issues is McGregor et al. (2001). The study presents a range of modelling approaches that have been used to specify decision-making at farm household level, on sustainable agricultural development. None of the approaches the authors reviewed used a multi-dimensional framework which led the authors to suggest that two or more methodologies should be integrated in order to leverage the complementarities and/or minimise the conflict between the results of different approaches. The authors based their conclusion on the integrated nature of the relationship between the farm household, the farming system and the environment. The authors believed that one method, tool or approach will not adequately capture the decision-making process and its subsequent impacts, and suggest a multi-dimensional approach in an integrated manner. However, they note that the assumptions behind each approach may be incompatible as results imply different solutions to a problem.

In this study, a summary list of models and tools being used to analyse land use issues in NZ are presented in Tables 1 and 2 in this section. Most of the tools presented used models in different forms, complexity or specialty to analyze agricultural production and policy at farm level, catchment level, regional and national level, and some a combination of one or two of these. While an attempt has been made in this study to make an inventory of tools and models being used to address NZ agricultural complexity, this is in no way exhaustive. It is difficult to cover all possible tools/models being used but the majority are covered in this study. The report by Rutledge, Fenton and Wedderburn (2010) gives comprehensive reviews and more details on these models.

The scope of the decision support tools covered in this study include models that present either a concept, method or an algorithm for undertaking decision support analyses such as scenario analysis, trade-off analysis, optimisation, land use allocation, visualisation, 'what-if' analysis, etc. In Table 1, most of the tools/models presented are usually used to inform farm-level decision making. The applications with their corresponding uses and few references are presented.

Table 1: Summary of tools/models being used to support farm-level land use decisions in New Zealand

Sn	Tools/models	Purpose and use	Reference and examples of application
1	ACRES	For strategic assessment of financial and environmental outcomes of integrated land management by land manager.	Rutledge, Fenton and Wedderburn (2010)
2	FOLPI - Forestry Oriented Linear Programming Interpreter	For decision-making in forest management to find an optimal solution in forestry estate planning.	Morenga et al. (2001), Manley et al. (1991), (MAF 2000).
3	FARMAX® suite	To explore the consequences of changes to farm stocking policy and feed planning.	White et al. (2010)
4	Be$tFeed™	To make decisions about short-term supplementary feeding requirements.	White et al. (2010)
5	OVERSEER®	Used by farmers to decide on balancing production and environmental outcomes of soil nutrient application.	White et al. (2010)
6	Dairy BMP toolbox	To evaluate both environmental and economic impacts of a range of on-farm management practices in pastoral farming.	Monaghan et al. (2008), Monaghan et al. (2009)
7	LUPIS	To identify a preferred land use or management regime from a number of competing management uses.	Foran & Wardle (1995)

Source: own compilation from literature

In Table 2, most of the tools/models presented are usually used to inform policy decisions at catchment and regional levels. Similarly to the models presented in Table 1, the applications with their corresponding uses and few references are presented. One common feature of the tools/models presented in Tables 1 and 2 is that each tool or model is developed and applied in a specific context and to a specific objective. This is often the case as each research or application of the tools/models always has limited scope and this is unlikely to change.

Table 2: Summary of tools/models being used to support policy decisions on land use in New Zealand

Sn	Tools/models	Purpose and use	Reference and examples of application
1	CLUES - Catchment Land Use for Environmental Sustainability (CLUES) model	For in integrated assessments of progressive effects of land use change on water quality in lakes, rivers, and coastal regions.	Woods et al. (2006)
2	GTAP CGE model	To analyse the commodity markets and supply-demand relationships in an economy.	Sue & Anton (2001), Rae et al. (2008)
3	Q-Sort	To produce reliable and valid interval measurements of people's perceptions of landscape visual quality through photographs.	Swaffield & Fairweather (1996); Greer & Kaye-Blake (2009)
4	AFEDSS - Agriculture and Forestry Economy Decision Support System	To simulate and analyse the complex processes of agricultural and forestry economies in reasonably short computational times and with less subjective uncertainty.	Zhu et al. (2007)
5	Input-Output models	To analyse regional or national economy by describing flows to and from industries and institutions.	Dake et al. (2009), Cole et al. (2007)
6	Causal maps	To display and solve spatial problems.	Greer & Kaye-Blake (2009)
7	Deliberation Matrix	To allow community stakeholders to evaluate the outcomes of policy decision and deliberate the suitability of the outcomes from their perspectives.	Wedderburn et al. (2009)
8	SDSS - Spatial Decision Support Systems	To explore alternative futures. Eg. Waikato Integrated Scenario Explorer.	RIKS (2008)
9	Influence Matrix	For cross impact analysis.	Cole et al. (2007)
10	Kyoto compliance equation	To account for national compliance requirement to international policy (Kyoto Protocol: 2008–2012).	Ministry for the Environment, (2007), Cairns (2009)
11	CLIMPACTS	For examining climate-related thresholds and how these thresholds relate to different rates and magnitudes of climate change.	Kenny et al. (2000)
12	PSAM template	To facilitate common understanding between stakeholders in policy and innovation system in order to arrive at better collaborative strategies.	Parminter et al. (1999), Morriss et al. (2006)
13	Life Cycle Analysis	For identifying and evaluating environmental impacts of a product or service for its whole time of existence. It's being applied to agricultural commodities as agriculture contributes significantly to global warming potential (GWP).	Basset-Mens et al. (2009), Paragahawewa et al. (2009)
14	LURNZ - Land Use in Rural New Zealand Model	LURNZ - is an econometric model used to predict spatial and changes in rural land use based on future price scenarios.	Hendy et al. (2007)

Source: own compilation from literature

Van den Belt et al. (2009) present a set of integrated assessment modeling frameworks being used in NZ as advisory tools to the regional authorities. The tools include Geographic Information System (GIS), Input-Output models, Computable General Equilibrium (CGE) models, Agent Based Models, Bayesian Belief Network models, Integrated Spatial Dynamic System Supports, Multi-Criteria Analysis and Mediated Models. Most of these modeling frameworks have a trans-disciplinary approach, however, the models have varying degrees of integration (of issues but not necessarily with each other) in a continuum, and this calls for synergies between the tools in the way they are used in research. This is believed to provide more comprehensive results to the users. The authors reported that these modeling frameworks are demanding not only in time but also in capability. The authors further reported on a number of factors that determine the use of these types of modeling framework among the regional authorities to support their policy decisions. According to the authors, the most common determinants of use of these types of modeling frameworks are an inability to assess if and how a model adds value to land use policy decision, monetary cost of acquiring and applications of these modeling frameworks and time cost of their applications.

In summary one common feature of all the models is that each seems suitable for only a part of the complexity and an appropriate conceptual framework for linking different models in an integrated assessment is still needed. Sampson (1992) asserts that it is possible to achieve public value on private land, but that we need to integrate useful models (useful in their own scope) and policy instruments in a framework. The leverage points to this integration are explored in the next section.

4. TOWARDS INTEGRATED ASSESSMENT MODELING

Contemporary research on integrated assessment methods includes IAM on a larger scale (CIESIN 1995). This involves exploring the potential of multiple research tools (models – modeling; systems – systems thinking, etc.) that allow the explicit integration of socio-economic, biophysical and political variables relevant to the issues in question (Jakeman & Letcher 2003; Olubode-Awosola & Van Schalkwyk 2007). This is based on the principle that most integrated assessments involve consideration of a broader set of information from diverse fields of study in research activities (CIESIN 1995). Using a model to unpack and/or pack scientific knowledge to assist policy making, Hisschemoller et al. (2001) term this integrated assessment approach “integrated assessment modeling". This approach is mainly implemented through the development of component-based models, and linking such models into a ‘mega’ model to analyse the complexity, uncertainties and interactions between natural and social systems of farming industry. The models capture the diversity and dynamics of the drivers and the consequences of change and innovations. These methods integrate knowledge and make it available for learning and decision-making on the current and foreseeable issues, specifically climate change and other outcomes of land use practices.

The development of ‘mega’ integrated assessment models is partly researchers’ response and contribution to understanding the emerging challenges, especially to help decision-making on national obligations to global issues such as climate change, and take advantage of international trade opportunities as well as live up to global trade requirements. Examples of such ‘mega’ models include Framework for Evaluation and Assessment of Regional Land Use Scenarios (FEARLUS), World Integrated Assessment General Equilibrium Model (WIAGEM), Integrated Climate Assessment Model (ICAM), Integrated Model to Assess the Greenhouse Effect, (IMAGE), System for Environmental and Agricultural Modeling - Linking European Science and Society (SEAMLESS), etc. Development of these integrated assessment models is being carried out in different countries, under specific projects for integrated impact assessments. The integrated assessment modeling exercise involves the pulling together of small or specialized models and tools to achieve some level of end-to-end integration, with particular focus on climate change, global trade agreements, etc.

Although these ‘mega’ models are very useful and gaining popularity, their development is not without challenges. Jakeman and Letcher (2003) highlighted a number of such challenges based on case studies of water resource assessment and management projects in Northern Thailand and Yass and Namoi catchments in Australia. The two main challenges earlier on stated as the focus of this paper are deemed important to integrated assessment project. The remaining part of this section explores leverage points for IAM by addressing the two challenges to IAM namely first, most conceptual frameworks being used for analysis of decision options are problem specific rather than being integrative; second, there is limited credibility and use of relatively complex models as a decision support tools as these models are not easily validated.

Robust conceptual framework

A conceptual framework, being a research tool, is a set of ideas and principles taken from relevant fields of enquiry and a structure for discussion and presentation of research findings (Smyth 2004). There is potential to adapt a conceptual framework, but there needs to be a common language from which to describe the situation under investigation and to report the research findings. This can be a series of guiding principles against which judgments and predictions might be made; a series of reference points from which to locate the research questions within contemporary theorizing and a structure within which to organize the content of the research and to frame conclusions within the research context. A conceptual framework for linking different models for an integrated assessment model seems difficult to conceive, especially when different tools are being integrated in a model, and even more so because each tool or model has a unique conceptual framework for researching a specific issue in detail. More principles that can help to arrive at an appropriate framework are discussed below.

Multi-disciplinary research approach

Literature on IA research seems to focus on considering the complex relationships between socio-economic and environmental implications of resource use activities in a multi-disciplinary approach. The value of the multi-disciplinary research approach to integrated assessments of farming issues cannot be overemphasised. One recent and comprehensive review of concepts of integrated research is Burton et al. (2008). The authors reported on a number of concepts of integrated research, ranging from the nature of integrated research, its contemporary critiques, elements of 'best practice' in integrated research and suggestions for constructing an integrated research alluding to systems thinking, geography, economics, ecology, landscape studies, etc. in the context of multidisciplinary, interdisciplinary and trans-disciplinary research projects. For example, Moller et al. (2008) asserted that long-term solutions to the impact of intensification on the environment needs long-term multi-disciplinary research of agro-ecosystems. Similarly Cocklin and Wall (1997) reviewed literature on regulation for rural change and transformation as a basis for analysing social contestation of the East Coast forestry project in NZ. The authors drew attention to how concepts of place (geography), the role of local agency (governance) and private regulation are important in policy formulation for sustainable natural resource development and use.

The need for a multi-disciplinary research approach stems from the fact that the range of factors driving land use change is dynamic and widening. For instance, in a case study, Johnsen (2003) and Johnsen (2004) took a holistic conceptual approach to the family farm and reported that farm-level experiences of agricultural restructuring, during (and after) the rural downturn, were contingent upon a much greater array of factors. These were the characteristics of the farm enterprise, household and property; actors' individual attributes; and the local context's biophysical, economic and cultural fabrics. In another example, spatial factors have influenced interpretations of sustainable management as indicated in the Resource Management Act which is used to guide decisions on allocation and use of natural resources in New Zealand (Furuseth 1995).

Research that will help the decision-making process, both at farm and policy levels, would be expected to consider a whole range of factors, i.e. biophysical, socio-economic and demographic. For instance, attitudes, values and beliefs of the public, including farmers, evolve and change over time, place and culture (Small 2007). MacLeod and Moller (2006) reviewed and used principal components analysis of 35 New Zealand agricultural statistics from the past 40 years to identify two main patterns of change in land use, production and farm inputs. One main conspicuous pattern is agricultural intensification with little diversification. Forty nine percent of this change is evidenced in an increase in stocking rates and yields, an increase in fertiliser, pesticide and food stock inputs, a change to more intensive forms of agriculture, and a diversification into forestry and deer farming. A second group of variables, which explained 22% of overall variation, reflects the major shift in agri-economic policy that removed farm subsidies around 1982/83. Among the second group of changes is some slimming down in agriculture (especially in sheep farming) and its associated inputs. These trends and patterns suggest that the factors behind these change and their environmental impacts are not well understood.

Participatory research approach

Bryant and Snow (2008) reviewed nine simulation models of pastoral farms and reported that a pastoral farm is a complex agro-ecosystem with many interacting components which simulation modelling can best handle in research. The complexity goes beyond dynamic soil nutrients and spatial variation in soil properties, to prioritising many interacting components in most models, given limited time and resources for science of modelling. Most of the models lack consideration of newly recognised components, including management practices which the authors accorded high priority in simulation modelling of a pastoral farm. Joseph et al. (2001) conceptualised a descriptive model of agricultural and rural community change. They used the model as a framework for an integrative analysis of change in the rural sector, based on key informants' case studies of the rural communities of Taumarunui and Tirau. The authors reported that interactions between changes in farm and rural communities in New Zealand are not only evolving, but the trends are also complex and ambiguous. Hence, as the range of factors keeps unfolding and diverse, participatory research approach can help to recognize and prioritize the concerns of various stakeholders as well as critical factors of land use decision. That is one value of participation is narrowing a set of broader factors to a set of relevant factors for consideration in integrated assessments. Even when it is not possible to include all factors within a specific study, omitted factors should still be considered when analysing the data.

Hisschemöller et al. (2001) argued that proper integrated assessment in environmental studies should combine a modeling approach with participatory methods in order to leverage integrated assessment. Fig. 1 shows both overlapping interaction and the central role of participatory modelling in identification of drivers, problems, solutions through to communication of results. It strongly indicates the importance of participatory modeling in integrated assessments, although the authors acknowledged that this is easier said than done. For effective integrated research, there is a need for greater interaction between scientists and institutions such as governance bodies and policy makers (Burton et al. 2008), and the farmers. Such integrated assessments will include determining the economic, social and environmental impacts of policy options.

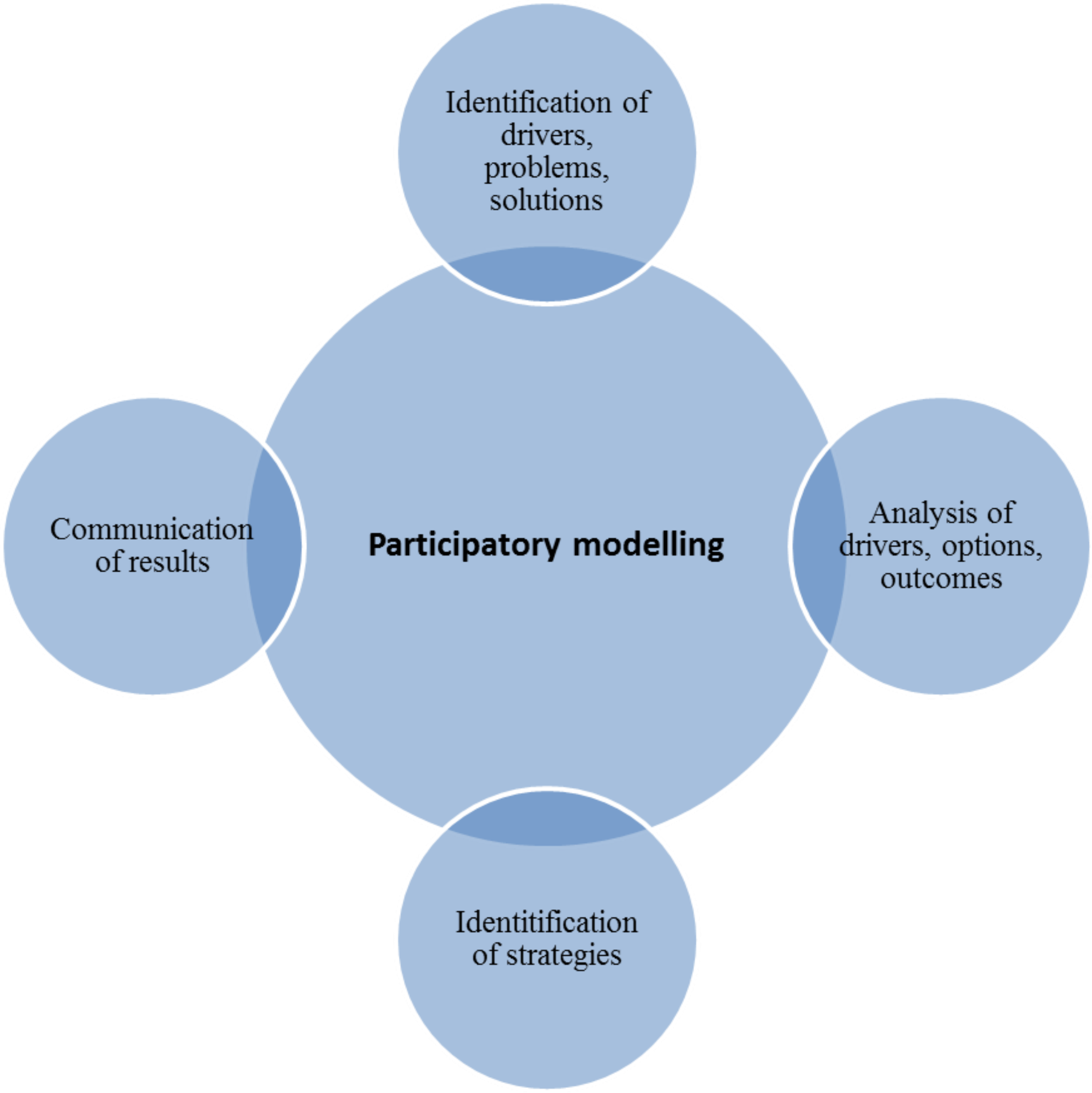

Figure 1: Overlapping roles of participatory modelling in IAM

Source: adapted from Hisschemollor et al. (2001)

Parkes and Panelli (2001) argued that understanding the relationship between catchment development, environment and health requires consideration of complex bio-physical, socio-economic and public health factors, and hence an integrative assessment of the relationship. The authors demonstrated that participatory action research can contribute to integrated assessments of catchment and community health management in a case study of the Taieri River Catchment. Similarly, Woodward et al. (2008) argued for stakeholder participation in problem definition, model design and testing, and policy design and evaluation phases of model-based research of innovation process.

Building applied research on basic research

Resources are always limited, which in turn limits researchers from being able to offer a 'fit for all' answer to all the research questions of all stakeholders, so it is important to conduct an integrated assessment that will allow easy access to and use of information from related methods. This looks possible within a maintained and continuous, but not necessarily linear, framework (as in Fig. 1) in a continuum. The continuum in this context refers to a continuum within the level of innovation, from idea or opportunity identification, to the scaled-up application of results in a continuous loop.

As relatively simple models are easily calibrated and validation, building applied research on basic research can help with calibration and validation of corresponding models being developed and used. The concepts presented in Acreman (2005) provide the potential for improved and robust calibration of integrated assessments models. Acreman (2005) studied decisions and research in water resource management by exploring different forces driving decision-making and science. The author convincingly concluded that there is no real gap between science and decision-making, but rather there is a continuum of expertise from basic to applied scientists through to decision-makers. Fig. 2 puts this in the perspective of a research to knowledge transfer or technology adoption continuum showing how to integrate knowledge/feedback, and making it available for learning and decision making – specifically by building applied research and application on fundamental basic research. This is because different disciplines that can support decision making through modelling has different level of expertise and often do use different gears which is depicted in figure 2. Yet it is desirable for outcomes of one modelling informs or be informed by outcomes of other modelling. Van Delden and McDonald (2010) analyzed four different integrated models for policy support that include economic and land use change models. The authors convincingly argued for creation of ideas and learning as key components of models integration. The authors believed this has potential to link the models together. This concept can be explored if basic and fundamental models are developed in such a way to create ideas and learning for the development of applied models useful for policy analysis.

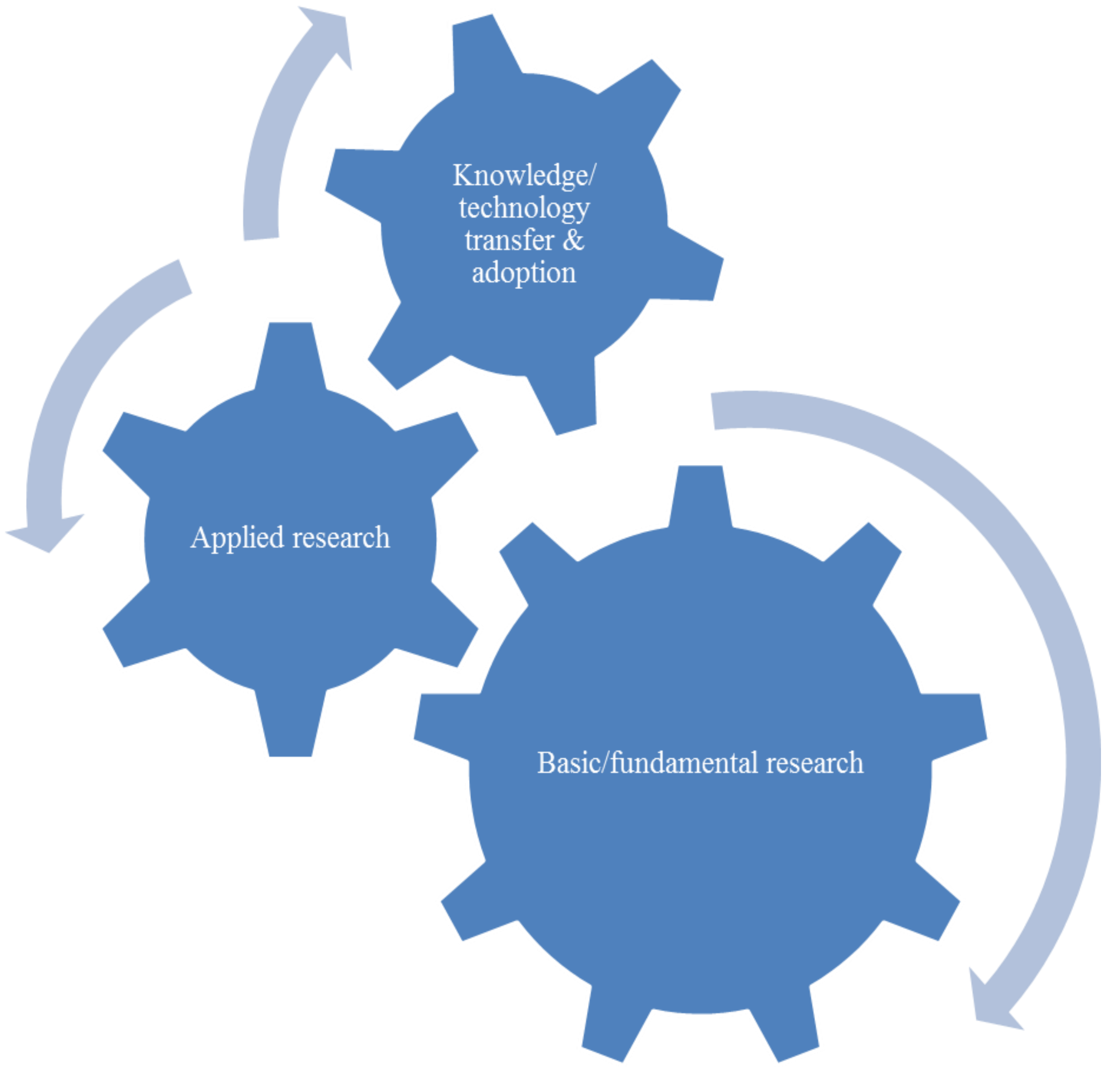

Figure 2: An implicit process of integrated assessments: Research-practice change continuum

This concept was exemplified in Van Ittersum et al. (2008)'s component-based integrated assessment of agricultural systems at multiple scales. The authors apply a component-based framework in which agronomy plays a significant, but a partial role using the SEAMLESS model to assess effects of a trade liberalization proposal on the EUs' agriculture. This approach involved linking micro and macro analysis, assessing economic, environmental, social and institutional indicators, reusing standalone model components for field, farm and market analysis and their conceptual and technical linkage. As core disciplinary research is required, research continuum will allow more and more core disciplinary research which will always be needed but applications of results of such model will be usefully if research at different level are well linked on a continuum.

Standardise modelling indicators

Another helpful principle of integrated assessment will be consistency in the use of analysis tools and the interpretation of outputs such that understanding of fundamental issues is linked to the applied decision and discussion support tools needed by users (farmers and policy makers). There is potential in each work to build on the works of others, and with learning over time, to come to comparable conclusions as a mechanism for integrated assessment. Disciplinary knowledge and information should be standardised to help link models in a modelling chain that underpins integrated assessment. It will be easier to build applied research on basic research if there is standardisation of the indicators of land use change outcomes, especially if research at all levels and scope is consistent, both in terminology and calculations of key outcome indicators. If all these principles, among other things, are observed in modelling land use change and its potential impacts, comprehensive information will be available for informed decision at various levels of decision-making. Standardised indicators, metrics, terminologies will also contribute to increasing measurement information which are increasingly needed about system behaviour as land use issues become complex. In addition, this can also contribute to development of software platforms for IA process such that different dimensional data are integrated with modelling and facilitate model use, reuse and integration.

Concluding remarks and recommendations

Rather than presenting hard and fast conclusions, we would rather here present concluding remarks and recommendations. This will include summing up of the views taken on; of course based on the information gathered from the reviews presented above.

Researching land use change and its diverse impacts needs an integrated assessment approach like IAM. There are diverse tools and models being used for integrated assessment of agriculture in NZ. While these models have been improved over time, one common feature of most of the tools/models is that each seems suitable for only part of the complex system for which decision is needed. Development and application of most models is context and issue driven. Contemporary research on integrated assessment methods includes integrated assessment modeling. This involves linking component-based models in integrated assessments modeling. However, an appropriate conceptual framework for linking different models for an integrated assessment is needed mainly because each tool/model has a unique conceptual framework for researching a specific issue in detail.

While researchers will always be limited in the scope of integration extent of models being developed, linking component-based models has the potential to broaden the scope of integrated assessment modelling. This can be easier done using a combination of models in an appropriate framework. One of the common issues researchers must confront all of the time is the inability to consider other related factors. For a robust conceptual framework, a multi-disciplinary research approach is recommended to allow for a set of broader factors to be considered. In integrated assessment modeling; a participatory research approach has the potential to narrow the set of broader factors to a set of relevant factors. Even when it is not possible to include these factors within a specific study, such factors should still be considered when analysing the data. In addition, as resources are always limited, research is confined to the development of smaller, focus-specific integrated assessment models and tools. Therefore the development of smaller, issue-specific integrated assessment models will continue indefinitely, but for such models to be useful to other field of enquiry and analysis, there is a need to standardize both input and output indictors from such modeling efforts. This will facilitate building an applied research on basic research outputs. It will also facilitate the integration of these models into a more comprehensive, but not necessarily complex, IA model, laden with black or gray boxes.

Adopting the concept of research development to practice change/adoption continuum may add value to the integrated assessment of complex agricultural issues. This is based on the insight that integrated assessment will go beyond an individual researcher's role. However, a research institution could align its research portfolio across the dimensions of the complexity by creating an appropriate mechanism to integrate individual research into integrated assessments. The individual researchers' role would include presenting a model's results in a compatible format for integration into another model's application. The mechanism could be an information framework which integrates the outcomes of the assessments being developed by different researchers, technical agencies, disciplines, etc.

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