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Review

An integrated biophysical and socio-economic framework for analysis of climate change adaptation strategies: The case of a New Zealand dairy farming system☆

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ABSTRACT

The development of effective climate change adaptation strategies for complex, adaptive socio-ecological systems such as farming systems, requires an in-depth understanding of both the dynamic nature of the systems themselves and the changing environment in which they operate.

To date, adaptation studies in the New Zealand dairy sector have been either bottom-up, qualitative social research with farmers and communities, or top-down, quantitative biophysical modelling. Each of these approaches has clear benefits as well as significant limitations. This review considers concepts and approaches that support the potential for different disciplines to complement each other in developing a more in-depth understanding of farming systems and their adaptive potential. For this purpose, a Mixed Methods Framework is presented, using examples from a pilot study of a New Zealand dairy farm to illustrate the complementarities between the two current approaches.

By presenting this methodology in a specific context, the review provides the theoretical basis for a practical way to integrate quantitative and qualitative research for climate change adaptation research.

1. Introduction

Analysing the future sustainability of a complex system such as a dairy farm in the context of climate change presents significant challenges. The impact of climate change on agriculture will depend on factors such as scale, location and the vulnerability of the people and activities concerned (Adger, 2006; Aydinalp and Cresser, 2008). There are many uncertainties around the degree to which global and regional climate could change, and many of the effects are unpredictable and depend on complex feedback cycles that are still poorly understood (Fowler et al., 2007; Parry et al., 2007; Solomon et al., 2007; Swart et al., 2009). Uncertainty is further increased by the complexity of pastoral agro-ecosystems (Bryant and Snow, 2008) as specific effects of climate change, such as rising atmospheric CO_2 concentrations, may have an impact in different ways on different aspects of the farm system.

Traditionally, adaptation studies have focussed on the analysis of specific risks under climate change scenarios. There are two dominant approaches to climate risk assessment and adaptation studies: 'Top-down' approaches, which feed down-scaled climate scenarios into impact models in order to calculate probable impacts and test potential adaptation measures; and 'bottom-up' approaches, which generally focus on ways to reduce the vulnerability of a community to climate events based on past experiences, often following an extreme event or disaster (Wilby and Dessai, 2010).

Integrated models, such as the DairyNZ Whole Farm Model (WFM) (Beukes et al., 2011) referred to in this review, provide a useful basis for assessment of climate change adaptation options, allowing the manipulation of management options under future climate scenarios and providing both biophysical and economic outputs. Although mostly characterised by a top-down methodology, such models provide an effective means to integrate key aspects of farm systems performance with estimates of climate variability.

Despite these advantages, the use of integrated models like the WFM in top-down studies has a number of limitations when applied to the analysis of adaptation. There are biophysical uncertainties, as currently no models are available that include a fully comprehensive range of biophysical processes important in the analysis of climate change adaptation options, such as pests and diseases, pasture species competition or soil carbon dynamics.

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Models do not always include 'softer' elements in their system boundary, such as socio-economic factors, limiting their value for the practical evaluation of some climate change adaptation strategies (Dynes et al., 2010). In addition, such complex integrated models are not usually directly accessible to farmers, and in many cases these key farm decision-makers are excluded from the model development and application process. Thus implementing management decisions in practice necessitates collaboration between stakeholders and researchers. This aspect has also been emphasised by others, e.g., by Martin et al. (2011), whose scenario approach focused on encouraging participatory involvement of farmers in managing adaptation to climate variability, and which also connected the science with feasible farm applications.

A pivotal question is how to accommodate and synthesise different perceptions of the farming system and the 'soft' and 'hard' components of the system. Participatory bottom-up, qualitative research can provide a more direct reflection of the on-the-ground reality that farmers face in making management decisions. However, for any proposed adaptation measure, there are biophysical impacts that need to be evaluated, trade-offs to be made in present and future costs and benefits. Social research, by nature, is unable to adequately quantify these impacts and trade-offs.

This paper argues that in order to understand and address properly the available adaptation options and the context in which those options would be useful, an interlinked approach utilising both qualitative and quantitative research methods is necessary. This is neither 'bottom-up' nor 'top-down', but an interdisciplinary process that develops plural and conditional assessments of the trade-offs inherent in different management strategies. This paper presents a conceptual framework using a New Zealand dairy farm system as a working example, with concepts from resilience approaches and soft systems methodology as one way to facilitate the working together or synergy of two different methodologies for achieving a dynamic and inclusive analysis of complex farming systems.

2. Approaches to climate change adaptation assessments

Since the early 1990s, there has been a rapid expansion of research on adaptation to environmental change (Nelson et al., 2007). One of the earliest frameworks for the assessment of impacts and adaptation was provided by the Intergovernmental Panel on Climate Change (IPCC) (Dessai et al., 2005), which is also considered the standard approach (Burton et al., 2002). This approach defines seven steps: 1) Problem definition; 2) Selection of the method; 3) Testing of the method (e.g. sensitivity analysis); 4) Selection and application of climate change scenarios; 5) Assessment of biophysical and socio-economic impacts; 6) Assessment of autonomous adjustments; and 7) Evaluation of adaptation strategies. This framework provides for the systematic quantification of the severity of climate change impacts on a pre-defined biophysical or human system (Parry and Carter, 1998).

Many assessments still follow the broad IPCC framework. However, such assessments are heavily focussed on the development of climate change scenarios and the assessment of potential impacts from these scenarios (Dessai et al., 2005), rather than on current vulnerabilities or on adaptation options (Burton et al., 2002). Because of this, the results of such assessments can be highly sensitive to the uncertainties in the climate models (Dessai and Hulme, 2007), stimulating the development of increasingly sophisticated models for the purpose of adaptation assessments (Burton et al., 2002; Dessai et al., 2005).

More recently, risk management has become a central concept in many climate change assessments, particularly in light of the projected increases in extreme weather events. A core concept in risk assessment for climate change is the need to analyse not only average changes, but also the potential frequency of major losses (Yakushev, 2009). However, while there is broad agreement that the management of uncertainty and concepts of risk management are important, there are a wide range of approaches to risk assessment and each community of practitioners has adopted a different definition of the process (Dessai et al., 2005). The quantification of risks in the context of climate change adaptation research is particularly challenging due to the high level of uncertainty associated with climate change projections and difficulties in attaching probabilities to different development pathways, as well as the global nature of the problem (Dessai and Hulme, 2004). Stirling (2010) highlights the dangers of an overly narrow focus on specific, quantified risks, suggesting that it is an inadequate and oversimplified response to incomplete knowledge. He suggests that a more rigorous approach to incomplete knowledge is required, which takes into account less quantifiable aspects of uncertainty as well as "the deeper challenges of ambiguity and ignorance".

A broad criticism levelled at adaptation studies to date is that they have a tendency to be rather prescriptive and normative about specific management practices. Particularly for top-down, scenario-based assessments of adaptation options, the options evaluated tend to focus on areas where immediate benefits can be gained. For this reason, there is often little progress in removing the more persistent and intractable vulnerabilities (Nelson et al., 2007). In addition, because adaptation is considered in relation to specific risks, the assessments are often static in nature, i.e., measuring the levels of risk before and after adjustments have taken place (Nelson, 2011; Nelson et al., 2007). In the context of agricultural systems, prescriptive recommendations about management practices may have limited usefulness. Because systems are not static entities, but dynamic in space and time, there will be ongoing changes in the sensitivity and adaptive capacity of systems (FAO, 2008). Risk management perspectives continue to evolve to take into account the surprise, uncertainty and the long-term nature of climate change adaptation, as well as the multiple sources of stress and risk (Nelson, 2011).

A parallel conceptual development in adaptation research has been a focus on more systems-oriented 'resilience' approaches (Folke et al., 2010; Nelson et al., 2007). Farms are considered as 'complex socio-ecological systems'. Such systems do not change in a linear fashion but rather incrementally as they reach particular thresholds (Briske et al., 2010), often to the (negative or positive) surprise of those trying to manage them (Nelson et al., 2007). This is closely aligned with the emerging 'non-equilibrium' perspective (Scoones, 2004), which embraces the complexity of systems and encourages more flexible and dynamic adaptive responses to climate change. In the case of New Zealand farming systems, it has been noted that "equilibrium is not an option and, if achieved, is short-lived" (Beijeman et al., 2009).

Given the uncertainties surrounding the assessment of adaptation measures, it has been suggested that it is now timely to allow the appraisal of adaptation options to take centre stage, rather than the climate change scenarios themselves (Wilby and Dessai, 2010). The safest approach to adaptation is to aim for flexible and diverse systems that are resilient to shocks (FAO, 2008). This approach focuses on ways to build a system's ability to cope with adverse effects rather than on the effects themselves, which remain highly uncertain. By concentrating on the system, rather than on the problem, and assessing adaptation options in the context of their contribution to the overall resilience of the system, the outcomes have a much stronger chance of being 'no-regrets' (Wilby and Dessai, 2010). However, the level of flexibility or diversity required for sustained adaptation so far has been difficult to ascertain.