Lessons from an ag-focused agent-based model

Fraser Morgan

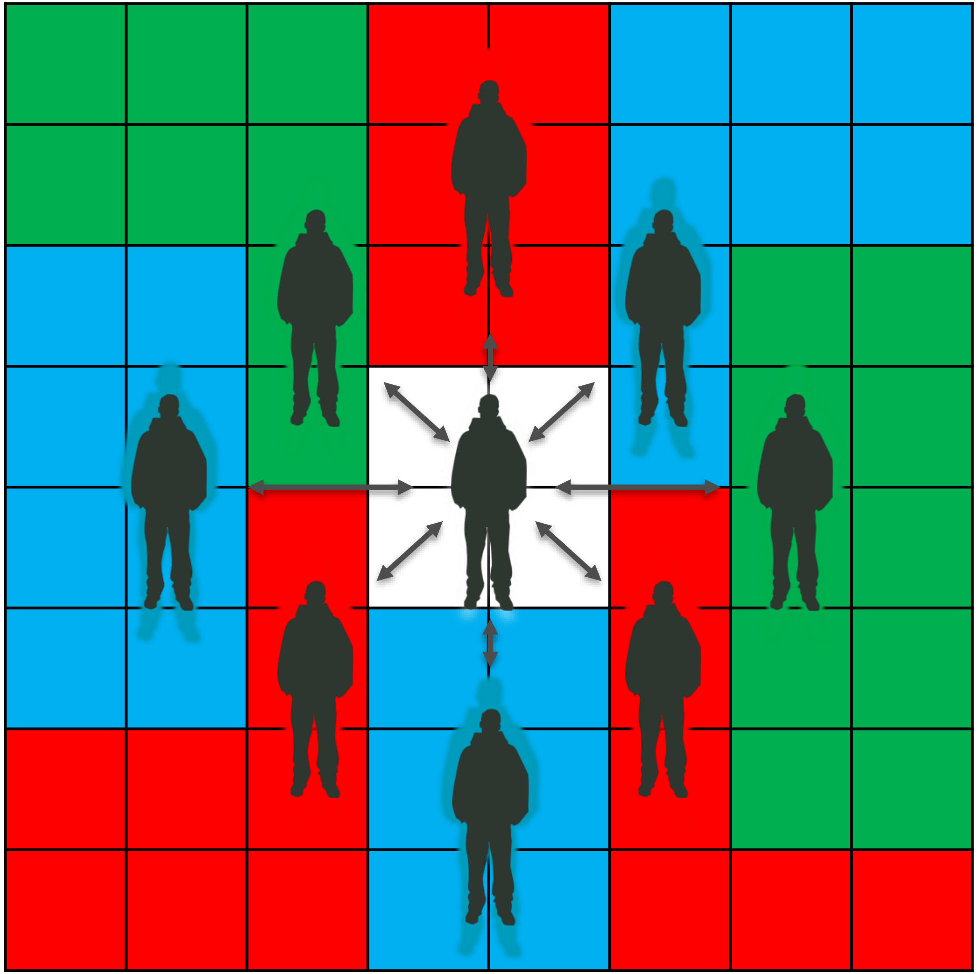
Manaaki Whenua Landcare Research

The University of Maine
Adam Daigenault

University of Cambridge Department of Land Economy
David Gawith (Castalia)
Ian Hodge

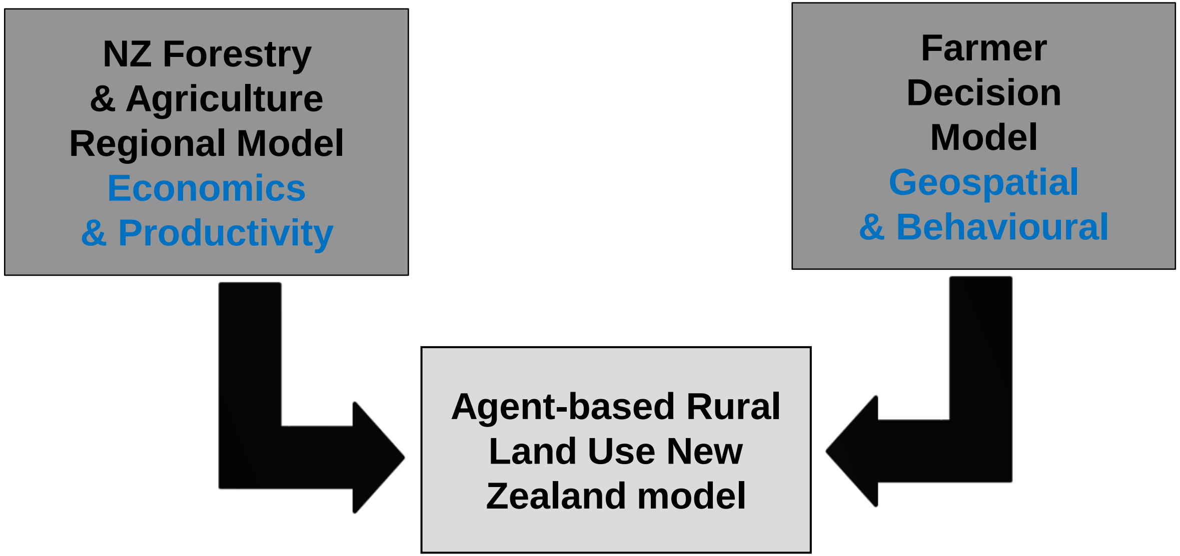
Manaaki Whenua Landcare Research
Pike Brown
Suzie Greenhalgh

Te Pūnaha Matatini
Data ▪ Knowledge ▪ Insight



Lesson 1:
When creating policy, design it with individuals in mind

ARLUNZ – Overview



PLOS | ONE

RESEARCH ARTICLE

Estimating Impacts of Climate Change Policy on Land Use: An Agent-Based Modelling Approach

Fraser J. Morgan*©, Adam J. Daigneault©

Landcare Research, Auckland, New Zealand

© These authors contributed equally to this work.
* morganf@landcareresearch.co.nz

OPEN ACCESS

Citation: Morgan FJ, Daigneault AJ (2015) Estimating Impacts of Climate Change Policy on Land Use: An Agent-Based Modelling Approach. PLoS ONE 10(5): e0127317. doi:10.1371/journal.pone.0127317

Academic Editor: Krishna Prasad Vadrevu, University of Maryland at College Park, UNITED STATES

Received: December 22, 2014

Accepted: April 13, 2015

Published: May 21, 2015

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Funding: FM and AD were supported by Landcare Research through their Capability Fund (CF1112-83-02 and CF1011-83-11). FM was also supported by the New Zealand Ministry of Business, Innovation and Employment under the "Building biodiversity into an ecosystem service-based approach for resource management" project (C09X1307). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Abstract

Agriculture is important to New Zealand's economy. Like other primary producers, New Zealand strives to increase agricultural output while maintaining environmental integrity. Utilising modelling to explore the economic, environmental and land use impacts of policy is critical to understand the likely effects on the sector. Key deficiencies within existing land use and land cover change models are the lack of heterogeneity in farmers and their behaviour, the role that social networks play in information transfer, and the abstraction of the global and regional economic aspects within local-scale approaches. To resolve these issues we developed the Agent-based Rural Land Use New Zealand model. The model utilises a partial equilibrium economic model and an agent-based decision-making framework to explore how the cumulative effects of individual farmer's decisions affect farm conversion and the resulting land use at a catchment scale. The model is intended to assist in the development of policy to shape agricultural land use intensification in New Zealand. We illustrate the model, by modelling the impact of a greenhouse gas price on farm-level land use, net revenue, and environmental indicators such as nutrient losses and soil erosion for key enterprises in the Hurunui and Waiau catchments of North Canterbury in New Zealand. Key results from the model show that farm net revenue is estimated to increase over time regardless of the greenhouse gas price. Net greenhouse gas emissions are estimated to decline over time, even under a no GHG price baseline, due to an expansion of forestry on low productivity land. Higher GHG prices provide a greater net reduction of emissions. While social and geographic network effects have minimal impact on net revenue and environmental outputs for the catchment, they do have an effect on the spatial arrangement of land use and in particular the clustering of enterprises.

Introduction

Agriculture and Forestry are a significant part of New Zealand's economy, generating 70% of its export merchandise earnings and about 12% of its GDP [1]. As the sector strives to maintain

Land **2015**, *4*, 914-937; doi:10.3390/land4040914

OPEN ACCESS
land
ISSN 2073-445X
www.mdpi.com/journal/land/

Article

Simulation *vs.* Definition: Differing Approaches to Setting Probabilities for Agent Behaviour

Fraser J. Morgan [1,*], Philip Brown [2] and Adam J. Daigneault [1]

[1] Landcare Research New Zealand, Private Bag 92170, Auckland Mail Centre, Auckland 1142, New Zealand; E-Mail: daigneaulta@landcareresearch.co.nz
[2] Landcare Research New Zealand, P.O. Box 69040, Lincoln 7640, New Zealand; E-Mail: brownp@landcareresearch.co.nz

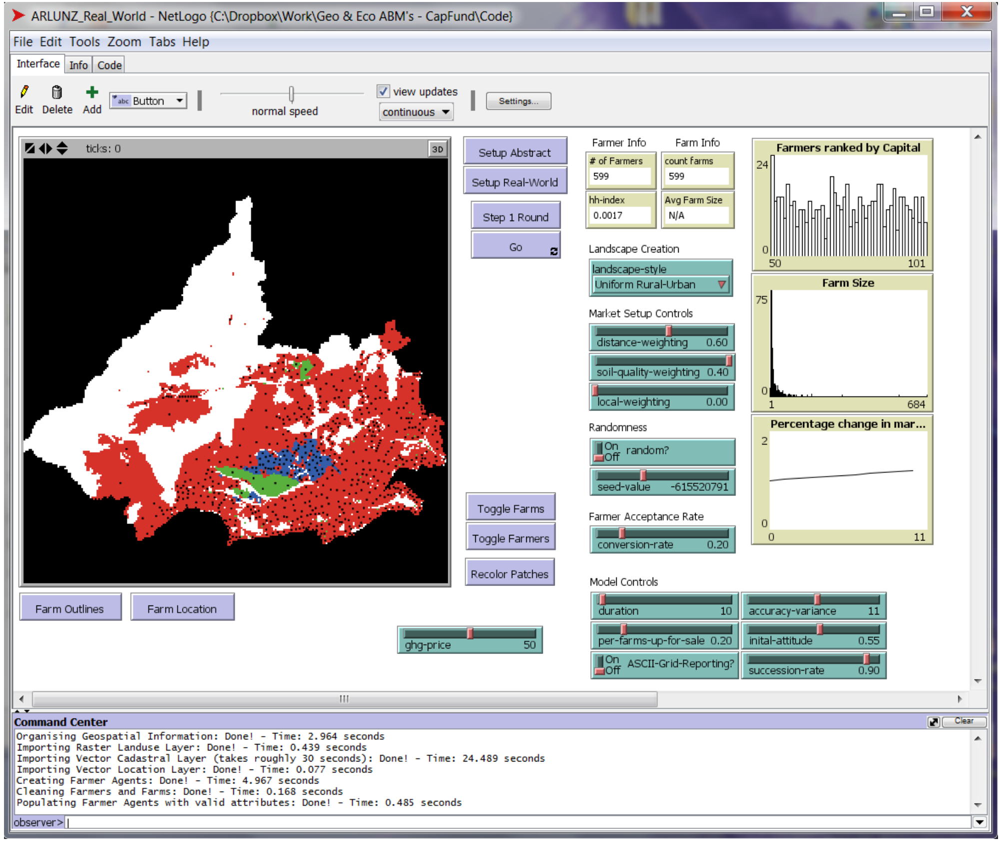
* Author to whom correspondence should be addressed; E-Mail: morganf@landcareresearch.co.nz; Tel.: +64-9-574-4149; Fax: +64-9-574-4101.

Academic Editors: James Millington and John Wainwright

Received: 30 April 2015 / Accepted: 23 September 2015 / Published: 25 September 2015

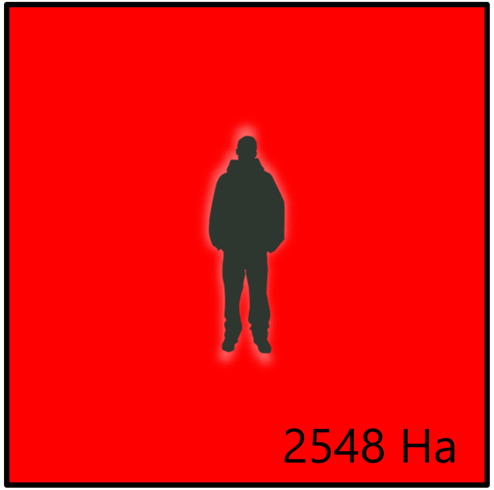
Abstract: While geographers and economists regularly work together on the development of land-use and land-cover change models, research on how differences in their modelling approaches affects the results is rare. Answering calls for more coordination between the two disciplines in order to build models that better represent the real world, we (two economists and a geographer) developed an economically grounded, spatially explicit, agent-based model to explore the effects of environmental policy on rural land use in New Zealand. This inter-disciplinary collaboration raised a number of differences in modelling approach. One key difference, and the focus of this paper, is the way in which processes that shape the behaviour of agents are integrated within the model. Using the model and a nationally representative survey, we compare the land-use effects of two disciplinary-aligned approaches to setting a farmer agent's likelihood of land-use conversion. While we anticipated that the approaches would significantly affect model outcomes, at a catchment scale they produced similar trends and results. However, further analysis at a sub-catchment scale suggests the approach to setting the likelihood of land-use conversion does matter. While the results outlined here will not fully resolve the disciplinary differences, they do outline the need to account for heterogeneity in the predicted agent behaviours for both disciplines.

ARLUNZ – Model



Lesson 2:
Understanding people, is really hard to do

ARLUNZ – Data to inform



Rural Decision Makers SURVEY2019

Land Use	Sheep and Beef
Size	2548 Ha

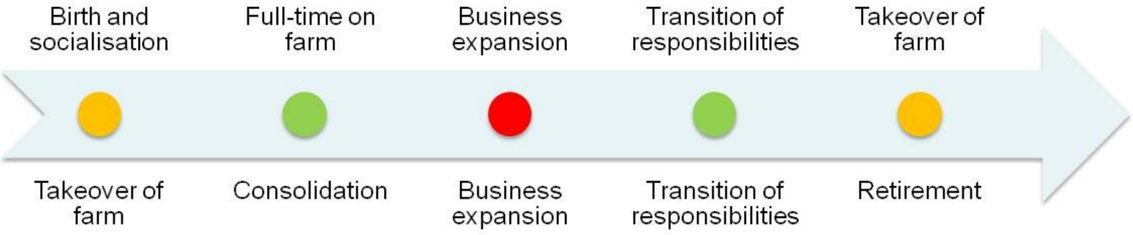
Age	57 Years
Experience	29 Years
Education	High School
Productivity	5.4
Profitability	Yes
Network Size	> Median
Risk	6.9

Intensify	0.19659
De-Intensify	0.24512

Real processes being modelled

Overlapping Generational Model

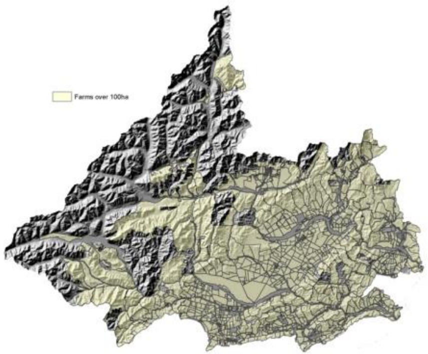
Successor



Incumbent

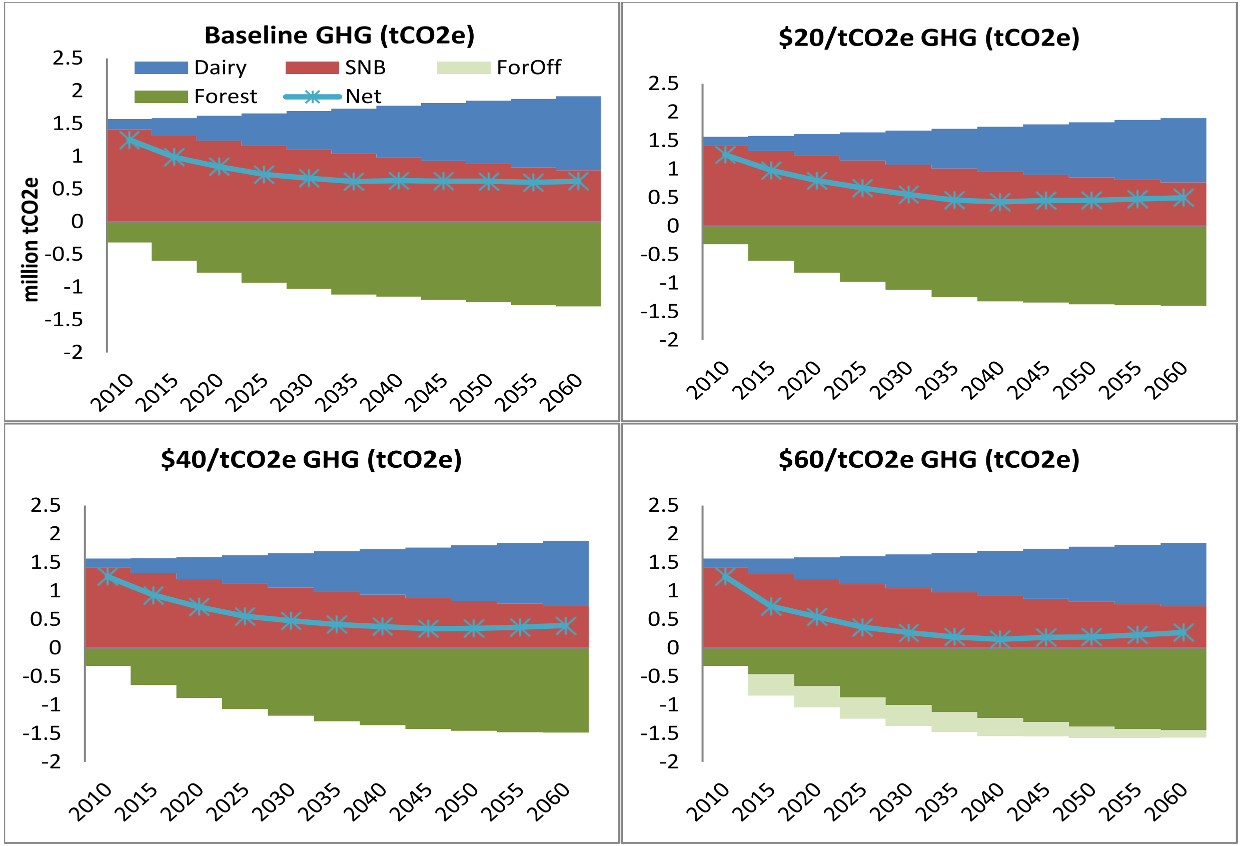
Information Networks

Social Network



Geographical Network

ARLUNZ – Carbon Pricing



Lesson 3:
Individual's goals vs their reality, don't usually align

Submitted to Ecosystem Services

Enhancing decision-making through incorporating ecosystem service approaches in participatory processes and land use modelling

Suzie Greenhalgh[a] and Fraser Morgan[b]

[a] Manaaki Whenua – Landcare Research NZ, 231 Morrin Rd, St Johns Auckland, 1072, New Zealand. greenhalghs@landcareresearch.co.nz (corresponding author)

[b] Manaaki Whenua – Landcare Research NZ, 231 Morrin Rd, St Johns Auckland, 1072, New Zealand. morganf@landcareresearch.co.nz

Abstract

There has been an upsurge in the use of ecosystem service concepts to assist decision making globally, particularly in the use and management of natural resources. Both public and private institutions are exploring how ecosystem service approaches can enhance the sustainability of their decisions. New Zealand, a country of abundant yet diminishing natural resources, is no different, with business, local government and researchers alongside communities and landowners seeing how this concept can be applied in practice. To test these approaches, a participatory process, the Biodiversity and Ecosystem Services assessmenT (BEST) framework, was developed along with an agent-based land use model to assess the economic and ecosystem services impacts of alternative future land use scenarios in the Rangitāiki catchment in New Zealand. This paper outlines the BEST framework and how it was used in a catchment context to explore future land use decisions as well as highlighting some of the outstanding challenges yet to be resolved when using this approach. These include, among others, incorporating indigenous values, maintaining flexibility within participatory processes, and the communicating information and modelling results.

Key words: ecosystem service assessment, agent-based modelling, scenario analysis, land use futures, human behavior, catchment planning

Highlights

- Participatory processes and ecosystem service concepts enhance land use planning
- Individualistic land use decisions mean meeting catchment goals need interventions
- Agent-based modelling or similar shows more realistic land use development pathways
- Ecosystem service impacts highlight wider impacts of land use development

1. Introduction

Making choices about how to manage our land, water and ocean resources is becoming more challenging as our natural resources are becoming scarcer and the conditions under which we operate are changing. To name just a few, fresh clean water is becoming scarce in summer, water quality is under pressure, our soils are being pushed, aquatic life is no longer abundant, weather patterns are less predictable, pests are prevalent, and markets

BEST Programme – Rangitaiki catchment

1. Introduction
- ***Building a common platform***
- *Share knowledge and build a common understanding in the group around the Rangitāiki catchment and the ecosystem services approach*

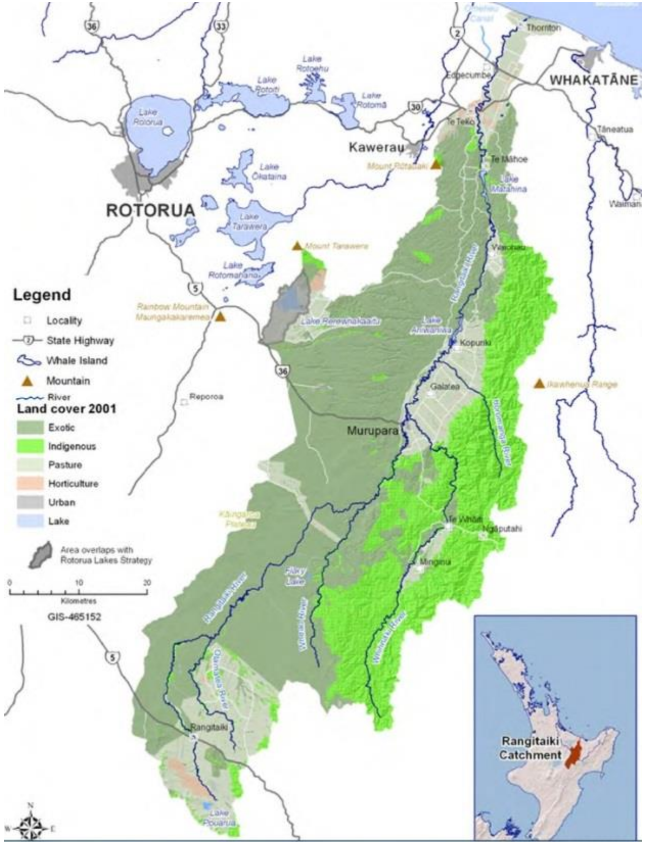
2. Field trip
- ***Exploring the catchment***
- *Further extend collective knowledge and understanding of the catchment and the ecosystem services it provides*

3. Prioritise
- ***Recognising ecosystem services***
- *Identify the local natural resources, current uses and associated services critical for delivery of the groups objectives*

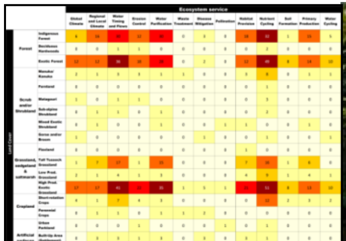
4. Future scenarios
- ***Scoping future landscape scenarios***
- *Identify future drivers, translate these drivers into possible alternative future land use and management scenarios for the catchment*

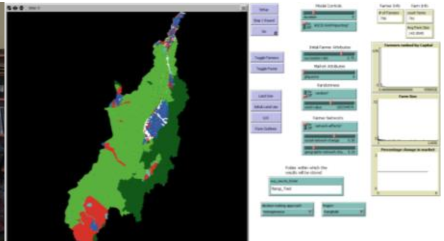
5 & 6. Future forecast
- ***Exploring the scenarios***
- *Discuss scenario findings based on modelling*

7. Strategise
- ***Strategising***
- *Identify decisions/options for future actions*



	Scenario D	Scenario E1	Weak network Low succession	Normal network Normal succession	Strong network Normal succession
Profit	28%	30.5%	14.7%	18.4%	20.9%
Net GHG Emissions	-5.8%	-10.4%	8.5%	8.9%	8.8%
N Leaching	2.7%	7.4%	-0.9%	7.6%	9.8%
P Loss	1.0%	0.9%	-24.7%	-13.3%	-10.1%
Sediment	0.7%	1.2%	-6.1%	-5.9%	-6.1%
E.coli	-13.7%	-13.4%	-29%	-30%	-27%
Labour*	~182%	~186%	~49%	~46%	~51%



Lesson 4:
Just because individuals could change, doesn't mean that they ***will*** change

Ecological Economics 173 (2020) 106636

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

ELSEVIER

Analysis

Climate change costs more than we think because people adapt less than we assume

David Gawith[a,*], Ian Hodge[a], Fraser Morgan[b,c], Adam Daigneault[d]

[a] Department of Land Economy, University of Cambridge, 16-21 Silver St, Cambridge CB3 9EP, United Kingdom
[b] Manaaki Whenua – Landcare Research, 231 Morrin Rd, St Johns, Auckland 1072, New Zealand.
[c] Te Pūnaha Matatini, University of Auckland, Private Bag 92019, Auckland 1011, New Zealand
[d] School of Forest Resources, University of Maine, Old Town, ME 04468, USA

ARTICLE INFO

Keywords:
Adaptation constraints
Adaptation deficit
Adaptation costs
Loss and damage
Climate change
IAMs

ABSTRACT

Human behaviour is commonly optimised in economic models of adaptation to climate change. These models assume that people work to maximise profit, subject to financial and technological limitations. In effect, these models simulate adaptive potential. In reality, adaptation falls short of this potential. This shortfall is conceptualised as the adaptation deficit, and it has been causing increasing concern.

This study demonstrates the impacts of the ways by which people's real-world adaptive behaviours depart from those assumed under pure optimisation. These departures, known as adaptation constraints, are formalised as numerical preference functions based on an empirical case study in New Zealand, and they are used to constrain an agent-based model of climate change adaptation. We show that these empirically-specified adaptation constraints reduce profits relative to an optimised specification by roughly one third. This demonstrates that unconstrained economic models are likely to significantly underestimate the costs of adaptation to climate change, the benefits of reducing greenhouse gas emissions, and the residual loss and damage that climate change will cause.

1. Introduction

Near-term climate change is now inevitable (Kirtman et al., 2013; Rogelj et al., 2016), and adaptation will be essential. Despite improvements in physical scientific projections of environmental change, we remain highly uncertain about people's adaptive behaviours (Noble et al., 2014; Adger and Barnett, 2009; Di Falco and Sharma, 2018). Much work has been done to understand the adaptive potential of people and communities. In many developed counties, there is a widespread presumption that people will be able to adapt to climate change (Dilling and Moser, 2007; Repetto, 2009). Even in vulnerable countries, a number of studies have shown that people often have sufficient potential to adapt to climate change (Gawith et al., 2015; Iglesias and Garrote, 2015; Nordhagen and Pascual, 2013). These studies suggest that individuals *can* adapt to climate change, however this does not necessarily mean that they *will* adapt.

Despite our adaptive potential, many studies report a lack of adaptive *action* (Berrang-Ford et al., 2011; Davidson, 2016; Lesnikowski et al., 2015; Burke and Emerick, 2016). For example, empirical evidence shows that farmers' responses to long-term changes in climate differ little from their short-term coping strategies (Burke and Emerick, 2016). Furthermore, the considerable damage currently caused by climate-related events is evidence of an adaptation deficit (Noble et al., 2014; Burton, 2004; Burton and May, 2004; Fankhauser and Mcdermott, 2014; Parry et al., 2009a), defined as "the gap between the current state of a system and a state that would minimise adverse impacts from existing climate conditions and variability" (Noble et al., 2014, p.839). While this adaptation deficit is recognised to be large in specific sectors and places, there is little knowledge about its scale globally (de Bruin and Dellink, 2011). And, as climate change outstrips the implementation of adaptation, it is clear that the deficit is growing (Burton, 2004; Burton and May, 2004; IPCC, 2012; Eisenack et al., 2014).

The adaptation deficit results from individual preferences, behavioural traits, or barriers that make adaptation more difficult, but that can, in principle, be overcome (Klein et al., 2014; Moser and Ekstrom, 2010; Fankhauser, 2017; Simões et al., 2017). These are conceptualised as adaptation 'constraints' or 'barriers' in the climate change literature (Bisaro et al., 2018). While these constraints are expected to result in considerable residual damages under climate change (Parry et al.,

* Corresponding author.
E-mail address: gawith@gmail.com (D. Gawith).

https://doi.org/10.1016/j.ecolecon.2020.106636
Received 23 May 2019; Received in revised form 15 January 2020; Accepted 26 February 2020
Available online 19 March 2020
0921-8009/

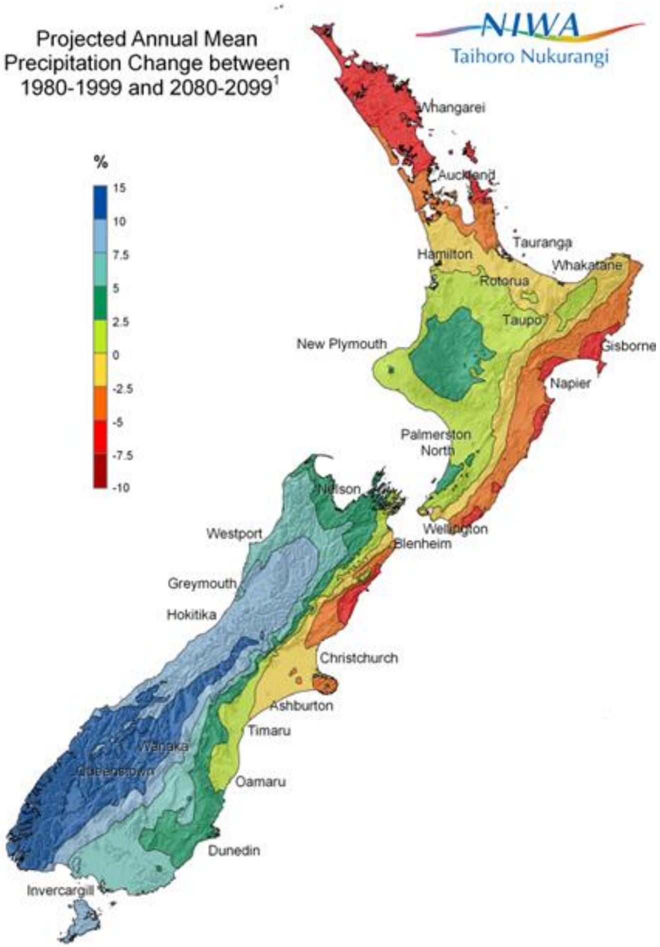
Adaptation gap

- Hikurangi Catchment

- ‘Can population ‘X’ adapt to the changes in climate projected for their area?’

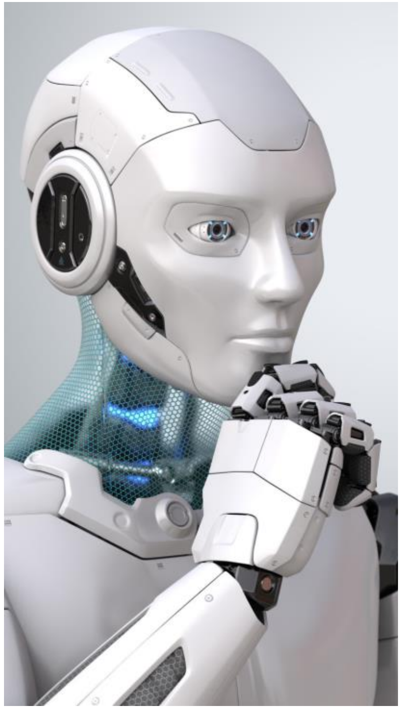
- Agricultural sector
  - If conditions changed, could they change land use? (Almost always YES)

  - If conditions changed, ***would*** they change land use? (?????)



How ‘optimised’ are farmers in their decision making

One in which adaptation is optimised.



Vs.

One in which adaptation is constrained

Adaptation constraints

Ad Hoc Constraints (Interviews)	Quasi Objective Constraints (Surveys/Regression)
Minimum Cash Flow	Risk Aversion
Lifestyle Preference	Disaster Experience
Kaitiakitanga	Dairy Path Dependence
Cultural Identity	Self Efficacy
Regulation	Technical Expertise
Response Lags	Agricultural Information
Labour Constraints	
Social Information	
Forestry Path Dependence	
Scale	
Climate Change Information	

Gawith, D. and I. Hodge (2018). "Moving beyond description to explore the empirics of adaptation constraints." Ecological Indicators **95**: 907-916.

Results

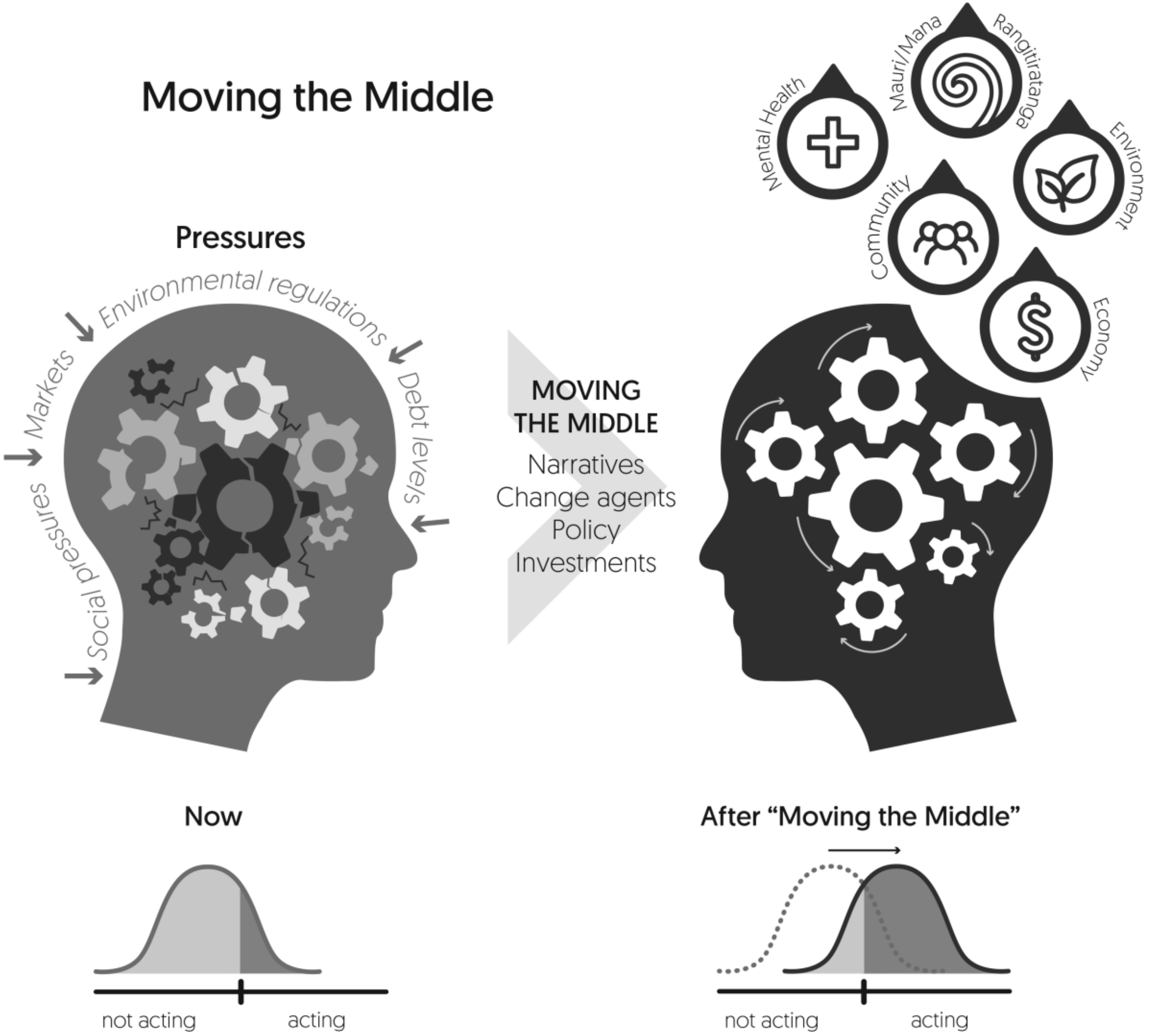
Total Catchment Profit 2010-2085	
'Optimised'	NZ$18.3bn
'Constrained'	NZ$12.1bn
'Optimised' – 'Constrained'	NZ$6.2bn

= NZ$89,600 per farm per annum

Total catchment profit is **33.8%** lower in the constrained scenario than in the optimised scenario.

- We have been underestimating the costs of adaptation.
- We have been underestimating the loss and damage that climate change will cause.

Moving the Middle



Thanks and Questions?

Manaaki Whenua
Landcare Research

Ministry of Business, Innovation & Employment
HĪKINA WHAKATUTUKI

1865 THE UNIVERSITY OF MAINE

Ministry for Primary Industries
Manatū Ahu Matua

UNIVERSITY OF CAMBRIDGE
Department of Land Economy

Ministry for the Environment
Manatū Mō Te Taiao