

How limiting factors drive agricultural adaptation to climate change



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ABSTRACT

Consensus is growing that agriculture is vulnerable to climate change and adaptation responses are necessary to minimize impacts. Nonetheless, the diversity of potential impacts, agro-ecological contexts and regional capacity for change make understanding adaptation behaviors challenging and ensure that climate change adaptation will not be the same across all contexts. Considering this heterogeneity, this paper aims to develop a theoretical approach to connect agro-ecosystem diversity with farmer decision-making in the context of agricultural adaptation to climate change. We combine the ecological principle of Liebig's Law of the Minimum with the Psychological Distance Theory to suggest how adaptation behaviors vary across regional contexts. We argue with our limiting factors hypothesis that limiting factors within a farm system (water or temperature impacts) influence the adoption of adaptation practices differently across regions and farm systems. Limiting factors varied across farm systems and regions, based on historical climate changes, agro-ecological contexts, infrastructure and adaptation capacity. Using farmer survey data from New Zealand we show that limiting factors mediate the effect of past climate experiences on the adoption of adaptation strategies differently in two regions with water acting as a limiting factor in Hawke's Bay and water and temperature as a limiting factor in Marlborough. This suggests that farmers perceive and respond to climate change in part due to their personal experiences with climate change and the limiting factors within their system. Such results are relevant for the development of regional adaptation strategies, effective policies and targeted climate change communication.

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1. Introduction

There is emerging consensus that agriculture is vulnerable to climate change and that adaptation strategies are urgently needed to assist in minimizing climate impacts (Rosenzweig et al., 2013). Increasing the adaptive capacity of agriculture requires a better understanding of the drivers and barriers for adoption of climate-smart practices (Howden et al., 2007). While a significant body of research exists to assess the adoption of innovations (Rogers, 2003) and conservation practices in agriculture (Prokopy et al., 2008), growing research seeks to understand what drives the adoption of climate change adaptation and mitigation practices among farmers (Barnes and Toma, 2012; Arbuckle et al., 2013a,b; Wood et al., 2014).

A major challenge is that climate change adaptation is not a one-size fits all phenomenon; adaptation strategies and farmer responses will vary across regions (Berry et al., 2006) based on agro-ecological contexts, socio-economic factors (Adger et al., 2009), climatic impacts, and existing infrastructure and capacity. Despite this heterogeneity, there remain gaps in our psychological understanding about how farmer experiences and concerns for varying ecological impacts differentially influences farmer decision-making on adaptation strategies across different farm systems and regions. This paper aims to address this gap by theoretically linking the agro-ecological context of climate change with farmer decision making across farm systems and regions. We focus on the drivers and barriers for adopting adaptation strategies to assist communities and policymakers in devising targeted adaptation strategies (Howden et al., 2007).

We link the agro-ecological system and farmer decision-making by combining a classic ecological principle, "Liebig's Law of the Minimum" with the Theory of "Psychological Distance" (Lieberman and Trope, 2008) to suggest that adaptive behaviors within an agricultural system are influenced by the most limiting factor.

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Based on these existing theories, we develop and apply a “Limiting Factors Hypothesis” that assesses how farmers’ past climate experiences influence their concern for future climatic limiting factors (water and temperature) and in turn, their likelihood to adopt adaptation behaviors. This hypothesis became evident from our previous work with California farmers, which demonstrated that adaptation decisions were most responsive to experiences and concerns about water availability (Haden et al., 2012), which historically is the most limiting factor in California’s Mediterranean climate (Tanaka et al., 2006; Schlenker et al., 2007).

Here we more systematically develop the limiting factors hypothesis and apply it in two regions of New Zealand that have different agro-ecological and climate contexts, and therefore different limiting factors that translate into farmer adaptation decisions. We focus on two New Zealand farming regions (Marlborough and Hawke’s Bay) and farm system types (sheep/beef and viticulture), which have had varying climatic changes and infrastructure responses. We predict that in Marlborough, a region known for its wine production, temperature will be a key limiting factor for climate change given previous temperature-related climatic changes, wine’s temperature sensitivity, and its already established irrigation infrastructure. Conversely, in Hawke’s Bay we hypothesize that water will be the climatic limiting factor given a history of drought, and the prevalence of sheep/beef systems that lack irrigation and water infrastructure. We compare these two farm system types across both regions using quantitative data from a comparative survey to develop statistical models (multiple mediation models, a form of path analysis) to test for the direct and indirect effects of limiting factors, global climate concerns, and climate change experiences on adaptation behaviors (Fig. 1).

2. Connecting ecological and psychological theories

Liebig’s Law of the Minimum, originally applied in agriculture but now broadly used in ecological research, states that an organism’s growth is limited by its most scarce resource (von Liebig, 1855). We argue that an agricultural system’s adaptation to climate change is fundamentally hindered by, and vulnerable to, the most limiting factor within the system. In this study there is a clear link between limiting factors and productivity in a climate change context because both water and temperature impacts can fundamentally impact the growth potential of a crop or animal. However, limiting factors will vary across regions and agro-ecological systems.

In fact, climatic factors are just one type of limiting factors that farmers contend with and farmers certainly make decisions based

on other agronomic and socio-economic limiting factors. For example, a farmer’s debt load may have a profound effect on their ability to implement irrigation, which may help them respond to water as a limiting factor. We hope that future work can assess the interaction of these potential factors and examine the limiting factors hypothesis in other agronomic and socio-economic contexts as well. The limiting factors hypothesis is consistent with the idea that farmers must adapt to multiple constraints in order to maximize their productivity and desired outcomes (Lubell et al., 2013). As such, it can be considered a subset of the broader work in adaptive management of agricultural systems, for it enables understanding about the link between climatic variables and farmer decision-making.

We connect Liebig’s Law of the Minimum with the Psychological Distance Theory to suggest that limiting factors will have a strong influence on climate change attitudes and behaviors because they are psychologically “closer” to the community that must contend with them. Psychological distance and the related Construal Level Theory (Liberman and Trope, 2008) suggests that events perceived to be “closer” to an individual (temporally, geographically, socially, and in certainty) are more salient and have a stronger proximate influence on individual decisions (Spence et al., 2012). Many have argued that reducing the psychological distance of climate change and making it more personal and relevant can increase the potential for behavior change (Kates and Wilbanks, 2003; Nicholson-Cole, 2004; Lorenzoni and Pidgeon, 2006; Leiserowitz, 2007; Scannell and Gifford, 2013). As such, personal experience with climate events can influence climate change attitudes and behaviors (Brody et al., 2008; Spence et al., 2011; Haden et al., 2012). Emerging research also suggests that recent climatic and weather events can strongly influence individuals’ climate change perceptions and beliefs (Hamilton and Stampono, 2013; Rudman et al., 2013; Zaval et al., 2014).

Here we argue that a farmer’s future climate concerns are oriented towards the most limiting climatic factor within their system as informed by previous weather and climate events. Because farmers must repeatedly contend with limiting factors in a particular agro-ecological context, their attitudes have a higher cognitive “availability” (Kahneman, 2011). These limiting factors in turn mediate the relationship between past climate experiences and potential adoption of adaptation practices.

3. Place context and hypotheses

3.1. Water as a limiting factor: Hawke’s Bay New Zealand

Hawke’s Bay sits on the central east side of New Zealand and is the 5th and 3rd largest region for sheep and beef production respectively in New Zealand. It also produces horticultural crops and is the 2nd largest wine grape growing region, though it produces four times fewer grapes than Marlborough (Statistics New Zealand, 2012). Hawke’s Bay has been historically plagued by water shortages in part because it is bordered by mountain ranges, which shelter it from prevailing westerly winds, resulting in a fairly low mean annual rainfall (less than 1000 mm). It has one of the lowest number of rain days in the North Island of New Zealand (Fowler et al., 2013). Despite this climate, Hawke’s Bay doubled the amount of hectares given permits to take surface water between 1999 and 2010 (Hawke’s Bay Regional Council, 2014). The region has also proposed the development of the Ruataniwha water storage scheme, a project with 91 million m³ storage capacity to address chronic water shortages in the area.

These regional water shortages have been exacerbated in recent years as Hawke’s Bay contended with four years (2006–2009) of consecutive droughts (Hawke’s Bay Regional Council, 2014). Rainfall records were significantly below average particularly for

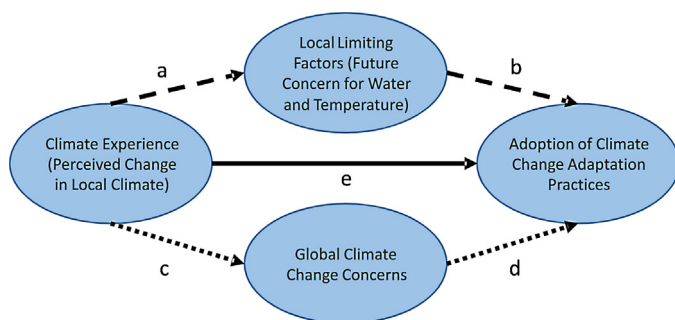


Fig. 1. A sample multiple mediation model. The “Limiting Factors Pathway” (dashed (a, b)) is hypothesized to be significant and tests for the indirect effect of local limiting factors (future climate concerns for either water or temperature impacts shown in Fig. 2) mediating climate experience on adoption of adaptation practices. The dotted “global pathway” below (c, d) tests for the indirect effect of global concerns mediating climate experience on adoption of adaptation practices. The solid line (e) tests for a direct effect of climate experiences on the adoption of adaptation practices.

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