

Climate change adaptation for peri-urban horticulture: a case study of the Adelaide Hills apple and pear industry

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Abstract

Despite a growing body of climate change adaptation research, translating findings into action remains a challenge. The need for early intervention looms as a significant problem for horticulture industries in Australia's peri-urban regions where competing demands for resources generate land use conflicts. Tools and methods that help stakeholders and decision-makers understand climate risks and adaptation options at a more strategic level provide a mechanism to bridge the gap between research and action, enabling stronger, collectively planned responses. This paper describes and then revisits the outcomes of a research project developed to assist the Adelaide Hills apple and pear industry understand and respond to projected climate risks. A participatory research method was implemented using critical stakeholder discussion and GIS representations of climatic, natural resource, and land use data to inform an analysis of risks and planning needs for the apple and pear industry. By working closely with practitioners and decision-makers during the development of a spatial model of climatic risks to the industry, key parameter and data selection decisions and various assumptions, as well as the values and limits of the approach could be reflexively understood and critiqued by all participants. Several years after its completion, key stakeholders were invited to reflect on the project and its influence. While the original project generated useful information and provided insights into climatic risks to South Australian pome fruit production, it has had limited influence on industry planning, which highlights the challenges confronting adaptation in multiple use landscapes.

As the evidence for climate change increases, so does the need for approaches that can assist decision-makers to plan responses to anticipated impacts (Adger et al., 2005; Morecroft et al., 2012). Adaptation research is a burgeoning field, as demonstrated in Australia by the National Climate Change Adaptation Research Facility (NCCARF, 2014) and a range of other initiatives within government, universities, and private organizations. However, generating useful knowledge and then translating research findings into effective local-scale plans and actions remains a

challenge (Moser, 2010; Tang et al., 2010; Measham et al., 2011; Sheppard et al., 2011; Berkhout, 2012). A review of adaptation research in the Australian primary industries sector has made the pointed observation that 'not only does research need to be integrated, synthesized and practice-oriented [...] it needs to be communicable to others' (Rickards, 2013, p. 16). The 2013 National Adaptation Research Plan (NARP) for Primary Industries similarly nominated 'clear and accessible information [...] at a geographic and time scale relevant to stakeholder needs' as a key issue for

the sector (Barlow et al., 2013, p. 11). For researchers and stakeholders about to embark on adaptation planning, these observations have important implications for the tools and methods they choose to develop and employ.

It is in this context that we describe and briefly review the outcomes of a participatory research project, 'Room to Move,' developed between 2006 and 2008 to assist apple and pear (pome fruit) producers in South Australia's Adelaide Hills learn about adaptation issues facing their industry (Houston and Rowland, 2008). During the project, industry leaders, and other stakeholders collaborated with researchers to construct a Geographic Information Systems (GIS) model to investigate how climate change will affect resource availability for pome fruit production. Because the Adelaide Hills are a bio-climatic 'island' of relatively high rainfall and cool-climate conditions in a mostly semi-arid State, and as the district is subject to encroachment from metropolitan Adelaide, stakeholders were also interested in the potential roles of land use planning in any adaptation response.

The NARP has identified the need in Australia for 'information, tools and knowledge to support decisions about adaptation in multiple use landscapes (i.e., primary industries, water production, conservation, tourism, etc.)' (Barlow et al., 2013, p. 11). That statement embodies three reasons why the 'Room to Move' project is likely to be of interest to adaptation researchers and practitioners. First, peri-urban regions, such as the Adelaide Hills, require planning to understand competing priorities and to overcome conflicts in land use through adaptation planning. Second, GIS-based participatory research methods are emerging as an effective approach for supporting decision-makers and stakeholder groups, not only to understand the likely impacts of climate change but also in encountering the practical and local political dimensions of adaptation. Third, the 'space as a proxy for time' concept at the heart of the GIS model appears to have untapped potential as an inexpensive and accessible tool for communicating the implications of climate change and helping stakeholders compare adaptation options.

Our aims in this undertaking are twofold. First, we reintroduce the project for the benefit of researchers contemplating methods to make adaptation research more communicable to stakeholders. Second, after asking stakeholders to reflect upon the original project, we make some observations about project design and implementation to inform a discussion about adaptation planning for primary industries. Much of what follows is particular to the Adelaide Hills or to adaptation planning in the primary industries sector

but will be of interest to climate change researchers and land use policy practitioners working on the spatial and land use dimensions of adaptation.

The Australian climate change adaptation context: horticulture industries, peri-urban regions, and the potential role of participatory research methods

The gap between research and action is clearly evident in the Australian horticultural sector (Jones et al., 2005; Darbyshire et al., 2011). Because climate change will alter patterns of resource availability for climate-sensitive horticulture (Hannah et al., 2013), adaptation responses often have spatial land use dimensions, involving progressively migrating or re-locating production in response to shifting climatic conditions (DPI, 2007; Barlow et al., 2013; Rickards, 2013). However, there is still limited evidence of such measures being implemented, and little if any consideration of the need to reserve suitable areas for this purpose (Bardsley and Pech, 2012; Rickards and Howden, 2012).

The Garnaut Climate Change Review (Garnaut, 2008), for example, emphasized the importance of incremental, in situ, adaptation at the farm enterprise and farming systems level. According to this prescription farmers will autonomously adapt by 'adjusting primary production practices and technologies [and] changing primary production systems' (Barlow et al., 2013, pp. 28–30). Emphasizing adaptation at the farm level is consistent with the prevailing neo-liberal paradigm of Australian primary industries policy (Pritchard and Tonts, 2011). Many individual businesses will respond autonomously in a timely and efficient manner during the early stages of climate change to collectively help to build regional adaptation capacity (Bradshaw et al., 2008; Lereboullet et al., 2013). However, the scope of anticipated changes to rainfall, temperature, evaporation, heat waves, and water resource conditions (MSSI, 2015) demand something more purposeful from public policy (Palutikof et al., 2014). In order to adapt in the long-term, horticultural sector will also need collectively planned responses framed at industry, regional, and even national scales (Howden et al., 2007; Nelson et al., 2010). This will be especially true in Australia's peri-urban regions, home to a significant share of Australian horticultural production (Lesslie et al., 2011; ABS, 2012), yet also inherently problematic for adaptation planning.

Continuing urban encroachment into peri-urban regions, especially in the form of scattered rural

residential development, poses a number of resource management issues for primary industries, urban water supplies and biodiversity protection (Land and Water Australia, 2007; Argent et al., 2011; Buxton et al., 2011; Commonwealth of Australia, 2012). Intensive horticultural systems are already subject to a unique range of difficult circumstances such as land use conflicts, declining support services, and escalating land values (Jewell, 2008; OSISDC, 2010; Drew and McEvilly, 2011). Implementing planned responses that pre-empt urban encroachment pressures will be a technical, methodological, and political challenge. It will require decision-makers to understand future climate risks to regions and industries, and to integrate relevant adaptation concepts and principles into project and policy design (O'Brien and Wolf, 2010; Biesbroek et al., 2013). In peri-urban regions, where spatially-framed responses may have implications for vested interests, it also requires an awareness of stakeholder motives and aspirations (Bulkeley, 2006; Webb and Stokes, 2012). This type of challenge is best met when decision-makers work with researchers and stakeholders to develop and test knowledge about climate change risks in a participatory manner (Collins and Ison, 2009; Bardsley and Rogers, 2011).

Participatory research methods (PRMs) provide mechanisms for simultaneously dealing with complex data uncertainty, the need for contextual relevance and local ownership of risk. Rather than mere compromise or deference to experts, PRMs aim for social learning where different forms of knowledge are recognized and new, hybrid forms are created to enable shared understandings and mutual decision-making (Shaw et al., 2009; Tarnoczi, 2011). An important variation on this theme is Participatory GIS (PGIS) in which participatory methods are used in combination with spatial modeling tools (Dunn, 2007). PGIS acknowledges that complex spatial data on uncertain, technical issues that may have major impacts on peoples' lives can hinder decision-making if presented without adequate contextual subtlety (Adger et al., 2005). Accordingly, it seeks to complement positivist research and spatial modeling with the inclusion of local insights that arise from stakeholder engagement and deliberation (Hobson and Niemeyer, 2011; Henly-Shepard et al., 2015). While challenges remain in the application of these approaches to decision-making (Elwood, 2006; Preston et al., 2011; Brown and Donovan, 2014), PRMs and PGIS are emerging as important tools for guiding climate change adaptation.

Natural resource management, land use planning and apple production in the Adelaide Hills

South Australia's *Natural Resources Management Act 2004* defines eight Natural Resources Management (NRM) regions for the purposes of 'promoting sustainable and integrated management of the State's natural resources'. One of those NRM regions, the Adelaide and Mount Lofty Ranges (AMLR) (Fig. 1), comprise the Adelaide metropolitan area and its peri-urban hinterland, including the Mount Lofty Ranges (AMLR NRM Board, 2008). The ranges, and especially the more elevated Adelaide Hills district, experience relatively high rainfall, cool-climate conditions that underpin a number of climate sensitive, natural resource-based functions, including primary production, biodiversity protection, and catchments for Adelaide's main drinking water supply (AMLR NRM Board, 2008, 2013a). In an otherwise mostly semi-arid state that is projected to experience increased warming and drying (Suppiah et al., 2006; MSSJ, 2015) this feature holds considerable strategic significance. To guide climate change adaptation planning within the AMLR, the regional NRM Board commissioned an assessment of the vulnerability of its various natural resource-based production and environmental management systems (Bardsley, 2006). Horticultural industries were identified as being particularly vulnerable and specific research projects were subsequently developed for a number of industries, including the Adelaide Hills apple and pear industry (Bardsley and Sweeney, 2010).

While not as well-known as its higher profile neighbors, the Barossa Valley and McLaren Vale, the Adelaide Hills are a vital element in South Australia's agri-food system. The cool-climate district generates about 75% of South Australia's total apple production and 80% of its pear production (PIRSA, 2012), including most premium, export quality pome fruit (ABS, 2012). A combination of favorable soil, rainfall, and temperature conditions, along with reliable groundwater, has led to the Lenswood Valley becoming the major production district. The Adelaide Hills, and Lenswood Valley in particular, account for most of the AMLR region's 1,500 hectares of pome fruit orchards worth \$44.2 million in 2011 (PIRSA, 2012). The presence of those orchards has led to the establishment of an extensive local support infrastructure, including technical expertise and a strong industry culture (Government of South Australia, 2013). These features enable Adelaide Hills apple and pear growers

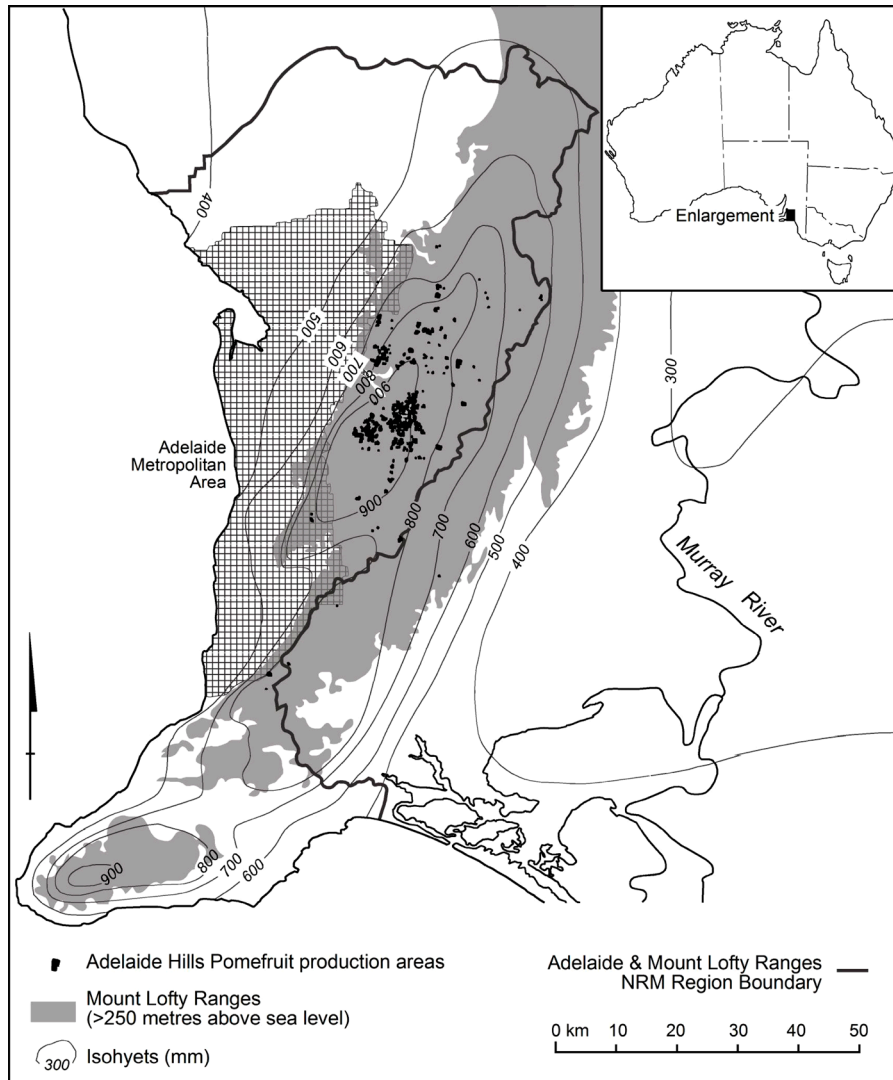


Figure 1: The Greater Adelaide region showing Adelaide Hills pome fruit production areas.

to remain viable despite rising production costs and global competition, with several producers exporting fruit into Asian and European markets (Walmsley, 2013). No other parts of South Australia enjoy this same combination of favorable circumstances for high quality pome fruit production.

Climate change poses no immediate threat to pome fruit production in the Adelaide Hills because existing on-farm management systems provide scope for coping with near-term variations in temperature and water availability (Suppiah et al., 2006; Bardsley and Rogers, 2011; MSSI, 2015). However, projected longer-term risks are substantial as cool winters are necessary for vernalization and fruit set, and extreme heat can inhibit fruit development. Furthermore, adequate water resources, which are

critical for managing heat stress are increasingly constrained; not only due to declining spring rainfall but also due to tighter regulations. For example, Water Allocation Plans for the AMLR region cap the resource availability for orchards (AMLR NRM Board, 2013b), to secure metropolitan water supplies and protect ecosystem functions (EPA, 2007). By themselves these circumstances would make climate change adaptation a difficult enough proposition. However, analysis showing a 30% increase in the number of dwellings on land zoned for primary production across the region during the period 1985 to 2005 also suggests an increasingly amenity-focused local community (Houston and Baldock, 2007). This is likely to create friction as growers seek to adopt incremental, in situ adaptations at the farm enterprise

level, such as permanent orchard netting that is shown to protect pome fruit from extreme weather events (APAL, 2009).

On the other hand, South Australian planning has long-standing commitments to protect land for primary industry in Adelaide's peri-urban region (DHUD, 1993; Government of South Australia, 2010). Most recently the State Government has established Character Preservation districts for the Barossa Valley and McLaren Vale, and an Environment and Food Production Area across the balance of the Greater Adelaide Region's rural land (Rau, 2017). These special designations overlay land use policies in the Adelaide Hills Council Development Plan that nominate the bulk of its rural land as a Primary Production Zone (Government of South Australia, 2016). Such complex policy arrangements illustrate the importance of participatory, local adaptation research in multiple use landscapes. In the case of the Adelaide Hills apple and pear industry, they also underline the importance of understanding bio-physical resource availability suitable for high quality pome fruit production and finding ways to maintain access to those resources as climate change unfolds.

The room to move project, 2006 to 2008

The project aimed to work with industry stakeholders to determine where high quality pome fruit production would remain possible under warmer and drier conditions and whether land use policy could reserve key resources. The research sought to clarify and document the relationship between bio-climatic conditions and apple production to enable an informed assessment of the regional context for adaptation. Horticultural data on the soil, water, and climatic conditions that currently enable high quality apple production in the Lenswood Valley were also gathered and GIS techniques used to identify a bio-climatic envelope with similar conditions across the AMLR region.

The second objective was to understand likely changes to future resource availability due to climate change. Ordinarily this would be difficult given the absence of fine resolution climate projections (Suppiah et al., 2006) and insufficient regional-scale climate data to explain micro-climatic variation. However, a relatively small bio-climatic 'island' such as the Adelaide Hills, where climate and elevation are strongly correlated, lent itself to simulation. The project hypothesized that a future bio-climatic envelope for high quality apple production will shrink in a manner that can be inferred from current climate data and published climate change projections. Projected

warming and drying was mapped onto current regional patterns of temperature and rainfall to generate an alternative envelope simulating the spatial extent of future resource availability. This 'space as a proxy for time' approach is a technique that uses the experience of known production sites along a real or implied environmental gradient to anticipate future conditions (Ramírez-Villegas et al., 2011; Thomas et al., 2012). In association, the third objective was to analyze how peri-urban development pressures and other land use priorities may interact with and amplify the impacts of climate change on resource availability for apple production. GIS modeling provides a sub-regional scale perspective on how future resource availability might be affected through the addition of data sets describing land use demands related to biodiversity conservation and catchment management.

To pursue these objectives, a Project Team comprising officers of the then South Australian Department of Water, Land and Biodiversity Conservation (DWLBC) and the Department of Primary Industries and Resources SA (PIRSA)¹ was established in late 2006. The Project Team was supported by a Reference Group with expertise in commercial horticulture, climate science and soil science and stakeholder representation from the Apple & Pear Growers Association of South Australia (APGASA), the AMLR NRM Board and the Australian Bureau of Meteorology (BoM). Spatial data for the GIS modeling, including land capability assessments, elevation, groundwater salinity and yield were made available from State Government sources. Following initial data assembly, workshops with the reference group identified key bio-climatic and bio-physical determinants of high quality apple production including key parameters and criteria relevant to modeling current resource availability:

- the overriding importance of an adequate water supply for managing heat stress during summer;
- the need for minimum temperatures <7°C during autumn and winter months to provide sufficient chill for fruit set;
- susceptibility to frost during spring months;
- the desirability of a high diurnal temperature range in spring, summer, and autumn months;

¹These are now, respectively, the Department of Environment and Water (DEW) and the Department of Primary Industries and Regions SA (PIRSA). At the time of publication, NRM Boards are also about to undergo organisational change.

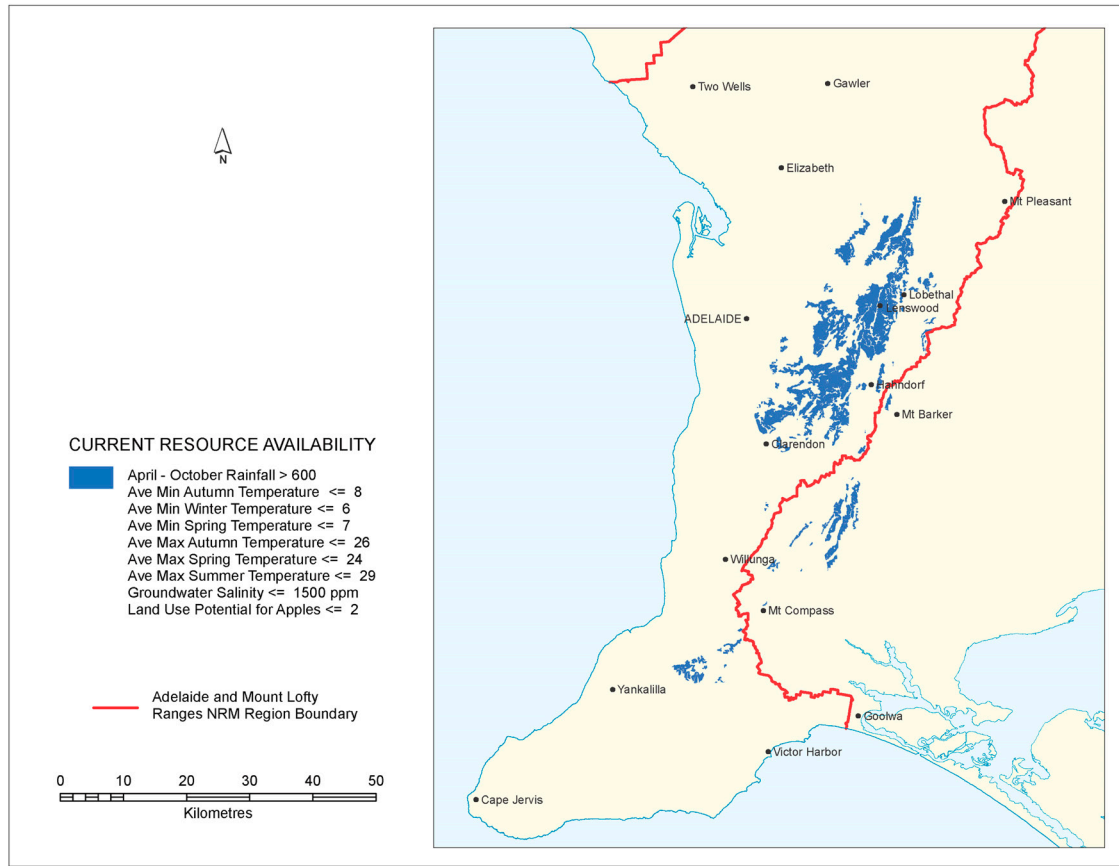


Figure 2: Current resource availability for high quality apple production in the Adelaide Hills.

- the undesirability of extended hot days $>35^{\circ}\text{C}$ during spring and summer months;
- the need for deep soils with good drainage and acceptable magnesium levels; and
- the desirability of slopes generally $<30\%$.

Some of these criteria translated readily into rules for GIS analysis, while others, such as susceptibility to frost were more difficult to incorporate. After some experimentation and feedback from the reference group, a set of agreed rules and data were created for the GIS model (Houston and Rowland, 2008). The resulting bio-climatic envelope encompassing conditions similar to the Lenswood Valley suggests that 20,300ha would be technically suitable for high quality apple production (Fig. 2). However, parts of the area are already used or reserved for other purposes and Water Allocation Plans effectively cap resource availability. Furthermore, the reference group raised concerns about data used in the model that meant the spatial finding could only be regarded as provisional, including:

- the extent to which temperature and rainfall modeling can describe local micro-climatic variability;
- the lack of insights into extreme weather events, such as extended heat waves and storms;
- the lack of recognition of the need for soil magnesium for successful apple production; and
- the lack of detailed understanding of groundwater salinity and yield.

The analysis assumed that existing Lenswood Valley production areas are at the threshold of the bio-climatic production envelope and thus provide a benchmark for high quality apples. The second assumption was that there is no significant intra-regional variability in climate attributable to either latitude or to maritime influence. Generalized assumptions, qualifications, and uncertainties such as these are common in environmental modeling but must be understood by those ultimately relying on the research. Importantly, by working closely with the reference group to develop the model and to identify key parameters,

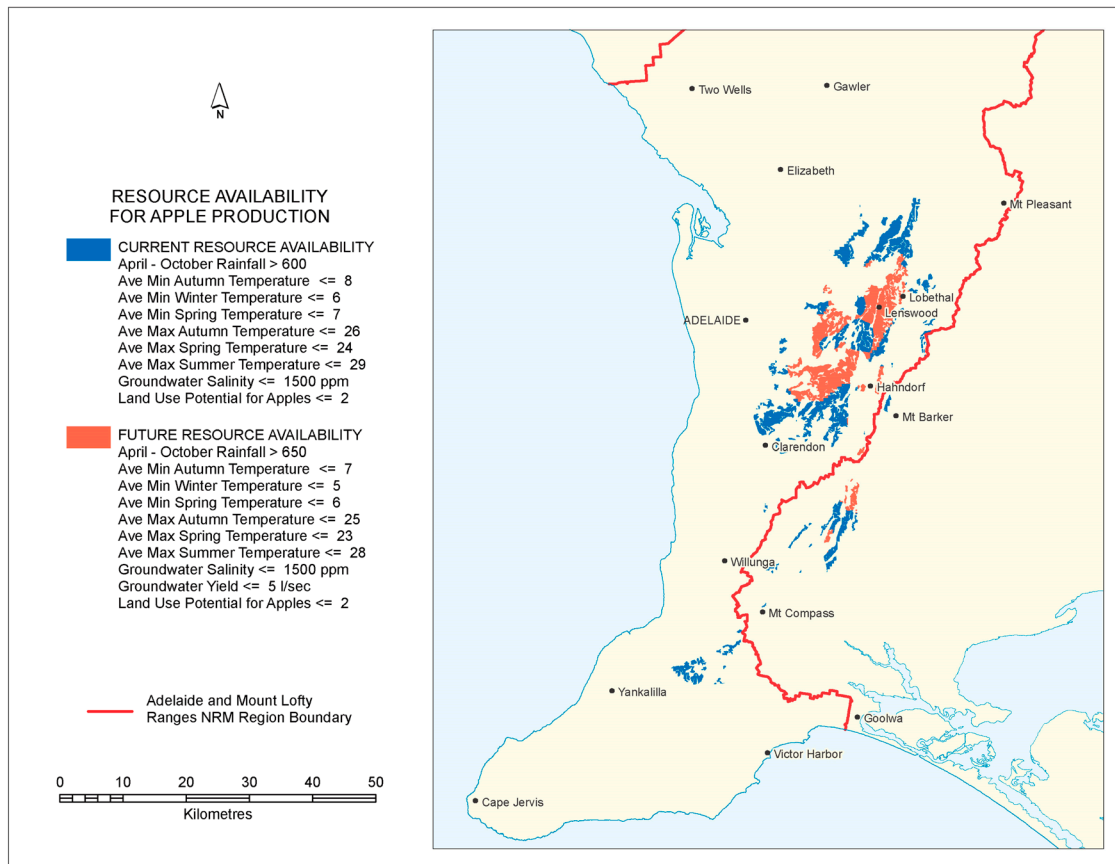


Figure 3: Comparison of current and future resource availability for high quality apple production.

data and assumptions, the limits of the approach were reflexively understood and critiqued by participants.

Having identified current resource availability, the project set about developing a scenario of future resource availability under projected climate change conditions. To account for projections of warming on average from 0.4 to 1.2°C and a 1 to 10% reduction in annual rainfall to 2030 (Suppiah et al., 2006), the modeling incorporated warming of 1°C and a reduction in key April-October rainfall of 50mm². This effectively involved mapping projected warming and drying onto the current patterns of temperature and rainfall across the AMLR region³. An additional GIS rule relating to

²Based on Suppiah et al. (2006), an annual warming of 1°C corresponded to upper-level projections for 2030 or mid-level projections for 2070. A reduction in April-October rainfall of 50mm equated to a mid-level projection for 2030 or a low-level projection for 2070.

³Rather than reclassify all of the temperature and rainfall data in the model, the modeling simply adjusted the GIS rules relating temperature and rainfall by +1°C and +50mm, respectively. Although counter-intuitive, the effect on calculation of the future bio-climatic envelope was the same.

availability of groundwater was also included in anticipation of an increased demand for supplementary irrigation by 2030. The resulting analysis suggested that by 2030, climate change will shrink the bio-climatic envelope suitable for high quality apple production in the AMLR region from 20,300ha to about 9,000ha (Fig. 3).

It was necessary to adjust and qualify this finding consistent with the project's third objective by taking into account existing non-agricultural land use and land use policies. After excluding urban areas, rural residential development, public land, and zoning likely to restrict commercial-scale horticultural development, the assessments of current and future resource availability shrank to 13,100ha and 4,950ha, respectively, not including current production areas (Fig. 4). Further quarantining of remnant natural areas, where approval of native vegetation clearance for horticulture development would be unlikely, reduced the size of the current and future bio-climatic envelopes to 11,400ha and 4,200ha, respectively. Exclusion of other areas, such as zones of high water pollution sensitivity in catchment areas (EPA, 2007) would modify these findings even further.

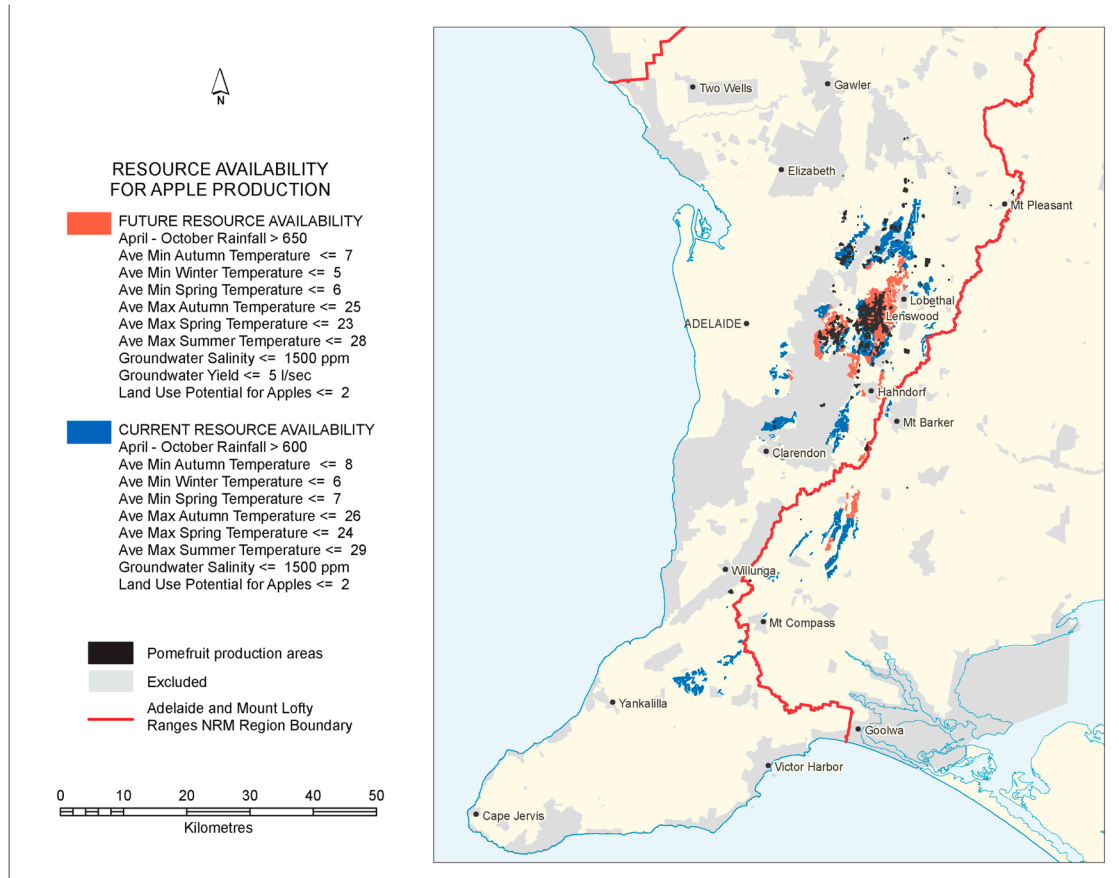


Figure 4: Current and future resource availability for high quality apple production including excluded areas and existing orchards.

Figure 5 illustrates the modeled relationship of current and future resource availability, excluded areas, rural residential development, remnant native vegetation and current production areas specifically for the Lenswood Valley. An important feature of this land use pattern for climate change adaptation planning is the extent of inter-mingling of different land uses and consequent edge-effects, giving rise to an increased likelihood of land use conflict.

Finally, it needs to be noted that the assessments of current and future resource availability were made independent of wider land use trends. Available evidence suggests a fundamental inability of conventional land use policy to control rural dwelling construction in the AMLR region (Houston and Baldock, 2007), so residential development is likely to progressively narrow the space available to the apple industry. The ad hoc spread of rural residential development suggests that primary production will be further constrained by land prices and by attitudes that may restrict farming activities.

In summary, and noting all of the above assumptions, the model suggests a potential halving of the area suitable for high quality apple production in the Adelaide Hills by 2030, with a significant proportion of current orchards falling outside the future bio-climatic envelope. Existing land use commitments, other environmental priorities and evolving peri-urban development pressures will further diminish resource availability. The results were reviewed with the reference group and a wider audience of apple growers and NRM stakeholders in separate workshops and, consistent with Rickards' (2013) observations about the benefits of scenario planning, participants agreed that the GIS model provided them with a useful tool for better understanding the implications of climate change. For the short and medium term, the model describes a gradient along which growers and decision-makers will have a changing array of adaptation options and timeframes for action. For the longer-term it provides a case for land use policy intervention both to maintain access to existing

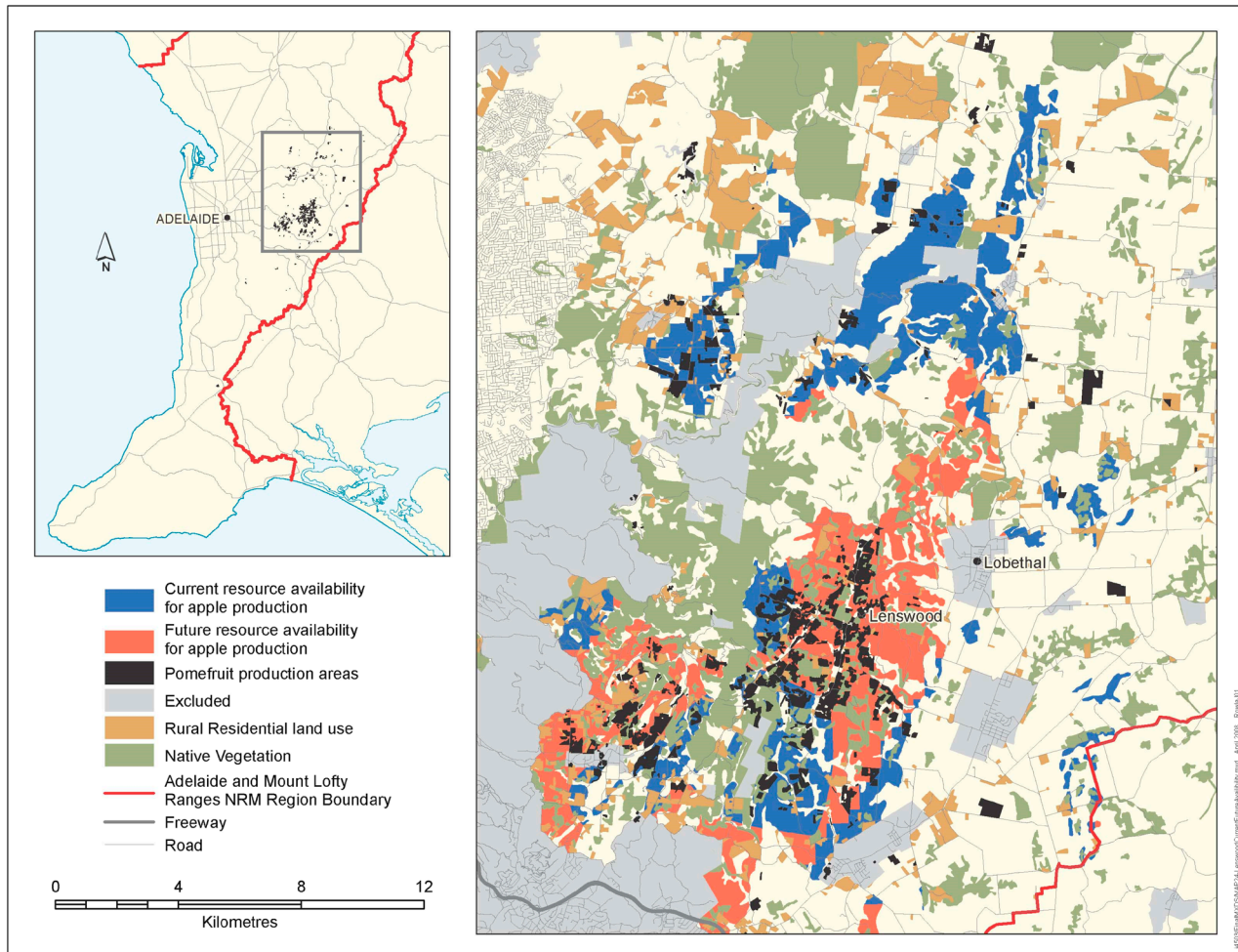


Figure 5: Current and future resource availability for high quality apple production in the Lenswood valley.

resources and enable reconfiguration of orchards within the future bio-climatic envelope (Houston and Rowland, 2008).

Revisiting room to move, 2014

There are substantial opportunities to utilize more technically sophisticated modeling than was undertaken here (e.g., Kriticos et al., 2012). We are also mindful of more recent research on the climate vulnerability of the apple and pear industry nationally (Putland et al., 2011), and of recent assessments of warming and drying and their effects on Australian agriculture (MSSI, 2015). Likewise, AMLR regional planning arrangements have changed, especially those related to rural land use, water allocation, and water quality. Nevertheless, with the NRM Board revisiting climate change adaptation in the context of

a new regional Plan (AMLR NRM Board, 2013a) and the NARP drawing attention to stakeholder information needs (Barlow et al., 2013), an appraisal of the impact of the research was timely. To inform the review of the use of the knowledge, we conducted a brief survey of key stakeholders' perceptions of the project's impact on adaptation planning and practice in the AMLR NRM region. Respondents (numbers in parentheses) included representatives of the APGA-SA (1), DEWNR (1), the AMLR NRM Board (3), and the Adelaide Hills Council (1). Only two of the participants had been directly involved in the original project. The survey questions asked respondents about their:

- awareness of the original project;
- understanding of how it has been used in climate change adaptation planning;
- assessment of its influence;

- assessment of whether the type of information produced, and the type of forum set up for the project were useful for climate change adaptation planning; and
- views on whether there are issues that may have affected how the report was used.

Since 2008, there have been a number of positive spin-offs from the 'Room to Move' project and the wider AMLR NRM adaptation research program of which it was part (AMLR NRM Board, 2008; Bardsley and Sweeney, 2010). The identification of gaps in climate data across the region has seen additional automatic weather stations installed by the NRM Board and industry groups (AMLR NRM Board Representative, pers. comm., July 17, 2014). Also, interest generated by the project, especially amongst neighboring Adelaide Hills cherry growers, led to two reference group members participating in an adaptation project for the Australian cherry industry (Thomas et al., 2012). However, only those respondents involved in the original exercise, or currently working on adaptation planning for primary industries on behalf of the AMLR NRM Board knew of the research, with representatives of the APGASA and the Adelaide Hills Council unaware of the project. Of those who were aware, all indicated that it had been used in subsequent regional adaptation planning efforts, although this appears to have been a minor and indirect role (AMLR NRM Board, 2013a).

None of the respondents believed the project was being used by industry. Although all respondents recognized value in the highly participatory process, they emphasized that planning rarely responds to a single source of information. Any influence of the work was clearly hindered by a lack of planning representation during a period of substantial planning reform. As one respondent suggested 'the complexity of the region is a major impediment to implementing climate change adaptation activities, but there is also a major issue around land use planning and the [limited] influence the NRM Board has in this area.' Perhaps what is required is the regular reiteration of important climate change adaptation knowledge to generate a groundswell of responses – and in fact, all respondents viewed positively the prospect of revisiting a similar project in the future. Given the sobering results of the review, and other observations about the distance between knowledge creation and its implementation in the policy arena (Dovers, 2002; Gregory et al., 2006; Bardsley and Sweeney, 2010), adaptation planning research and engagement premised on changes to land use policy must be prepared for an extended campaign.

Discussion

A decade after it began, the 'Room to Move' project may appear to be a modest undertaking by contemporary standards of climate research, GIS modeling and PRM practice. However, the research anticipated an approach that combines spatial tools to allow stakeholders to better understand future scenarios and developed participatory methods that enabled social learning and shared decision-making. The research demonstrated an adaptation planning approach for Australian primary industries that appears directly relevant to contemporary concerns in the NARP about stakeholder information needs and the challenge of adaptation in multiple use landscapes (Barlow et al., 2013; Rickards, 2013).

It is the model of GIS-based participatory research, built around the 'space as a proxy for time' (SAAPFT) concept, that we believe has most to recommend it for local studies of climate change impacts. Along with 'homoclimes' (Dry and Coombe, 2004) and other climate analogue concepts, SAAPFT is part of a group of analytical techniques being used for climate change adaptation planning (Ramírez-Villegas et al., 2011; Lowe et al., 2013). In Australia, it has been used mainly in the broadacre cropping sector, but it is applicable to any climate-sensitive production system (Nidumolu et al., 2012; Thomas et al., 2012). In addition to the values of engaging stakeholders with regular meeting and the intuitive appeal of SAAPFT, it is an inexpensive tool to deploy and gives spatial form to climate change impacts in a way that is helpful for adaptation plans predicated on the possibility of land use policy interventions. It may be especially useful in situations where the critical role for policy will be to secure scarce combinations of land, water, and climatic resources that provide spatial adaptive capacity for climate-sensitive land uses and functions generally.

The applied research provided, for the first time, a mechanism for understanding future resource availability for high quality apple production across the AMLR NRM region. Besides helping the apple and pear industry understand its own adaptation options, the project required them to consider the potential for multiple land use tensions in landscape planning. That was only achieved because information was provided and deliberated on at a scale and in a form directly relevant to stakeholder needs. Indeed, the model was capable of sufficient spatial resolution that, when project findings were presented to apple growers and other stakeholders in late 2007, it was possible to illustrate where existing orchards will sit relative to sim-

ulated warming and drying across the region (Fig. 4). This outcome is similar to the local contextualization of projections advocated by Shaw et al. (2009, pp.447-449), who believe it ‘allows people to encounter the possible impacts of climate change and make them more meaningful [by demonstrating those impacts] in people’s backyards’.

The GIS-based participatory research described here was a practical example of what Stirzaker et al. (2010, p. 600) describe as the ‘requisite simplicities [necessary] to help negotiate complex problems.’ Research is consistently emphasizing the importance of generating knowledge that is developed with and communicable to stakeholders to inform responses to uncertain future risk (Campbell, 2008; Hobson and Niemeyer, 2011; Sheppard et al., 2011; Henly-Shepard et al., 2015). In that context, the approach represents a readily accessible ‘entry-level’ research pathway for those governance organizations that wish to initiate adaptation planning with industries, regions, and communities using publicly available data and unsophisticated GIS facilities. Of particular importance, given that local governments are expected to shoulder much of the burden of adaptation planning (Measham et al., 2011; Mukheibir et al., 2013), the approach guides stakeholder-led adaptation planning by increasing climate change literacy and the understanding of available options. The next step might be to develop and apply sophisticated land use planning tools and concepts, such as tradeable development rights, to ensure priority spaces in the landscape are retained for high-value agriculture (Harman et al., 2013).

Conclusion

The ‘Room to Move’ project had only modest success influencing local climate change adaptation. Nevertheless, reflecting on the experience a decade on provides a number of insights relevant to emerging themes in the contemporary adaptation research agenda. The combination of GIS-based participatory research with simple scenario planning and climate simulation techniques made adaptation research communicable to stakeholders and provided information relevant to their needs. The same combination of tools and methods also demonstrated potential to support decisions about adaptation in multiple use landscapes by helping stakeholders understand competing priorities. Given its low development costs and ease of assembly, this approach represents a viable pathway for informing local adaptation planning. The project also shed light on underlying problems for agricultural adaptation to climate change in Australia’s peri-urban regions. Land use policy ap-

pears to hold significant potential to assist adaptation in these circumstances, in particular by securing critical resources that provide spatial adaptive capacity for climate-sensitive land uses and functions. However, to achieve those goals, important research questions are still to be answered about the details of effective integration of land use policy with primary industries adaptation planning at different scales.

Acknowledgments

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