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Learning from past adaptations to extreme climatic events:

A case study of drought

Part B: Literature Review

June 2008

2020 SCIENCE
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MAF Policy – Climate Change

CC MAF- POL 2008 – 17 (124-3)

Climate Change 'Plan of Action' Research Programme 2007/2008

Learning from Past Adaptation to Extreme Climatic Events: A Case Study of Drought.

Part B: Literature Review

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1. Executive Summary

The potentially damaging impact of drought on agriculture and human populations is not a recent phenomenon but has been observed for almost as long as we have records of human civilisation. In the modern world drought remains a serious issue despite improvements in agricultural technologies such as irrigation and plant genetics.

Historically agricultural drought in New Zealand has not been uncommon and this trend will continue. In fact, climate models have predicted that under global warming drought conditions will extend northwards to cover the entire east coast of New Zealand and droughts that were 1 in 20 year events could soon become 1 in 5 year events. As a result, developing strategies for coping with agricultural drought is likely to become a critical part of New Zealand agriculture and agricultural policy in the coming decades. There is therefore an urgent need to examine responses to specific drought events to aid in the development of adaptive capacity in New Zealand.

Understanding how New Zealand's farmers have historically adapted to extreme climate events will play a critical role in developing effective adaptation plans for the future. While the temperate climate in New Zealand has meant that much of the country has not been subject to frequent, widespread or prolonged climatic extremes, farmers in certain areas of New Zealand *have* needed to respond to climatic events on their farms and have developed many coping strategies accordingly.

This report focuses on these past adaptations of farmers to the extreme climatic event of drought. First, a literature review will provide a critical overview of drought adaptations in an international context. Second the research will explore the 'strategic responses' of farmers in the regions of North Otago and South Canterbury, areas which have previously experienced extreme drought events. Lastly, having gained an understanding of what farmers have done historically to cope with drought events, this research aims to use this knowledge to develop future adaptive strategies for New Zealand's farmers.

Most importantly this will also lead to the development of suitable methodologies to enable future applications of more extensive and broader investigations – covering additional climate responses such as flooding and cyclone events. Thus this study will contribute towards building adaptive capacity in New Zealand's farming systems to cope with extreme climate events.

2. Contents

3. A literature review of drought adaptation strategies

3.1 Introduction

The potentially damaging impact of drought on agriculture and human populations is not a recent phenomenon but has been observed for almost as long as we have records of human civilisation. For example, Russill (1998) refers to the “great drought” of 1276 and 1299 that occurred in the southern USA and lead to the abandonment of many local indigenous settlements. Similarly Haug et al. (2003: 1732) observe in a study of northern Venezuela “Our data show a clear link between the chronology of regional drought and the demise of the Classic Maya culture” between 760 and 910 AD. In the modern world drought remains a serious issue despite improvements in agricultural technologies such as irrigation and plant genetics. In fact, predictions suggest that if global warming continues many parts of the world are likely to experience increased frequency and severity of drought events – and this includes increase of drought along the east coast of New Zealand (IPCC, 2001).

3.2 Drought

What is a drought? The basic concept of a drought is clear. As the New Shorter Oxford Dictionary suggests, drought for many people is a “Dryness, aridity, lack of moisture” or “(A spell of) continuous dry weather; (a) prolonged absence of rain”. However, while it could be argued that a lack of precipitation is the ultimate cause of all droughts, the literature suggests there are many different types of drought. Three types of drought are of key importance to agriculture: meteorological droughts, hydrological droughts, and agricultural droughts. *Meteorological drought* is defined on the basis of precipitation or the degree of dryness, in comparison to a normal or average amount of rainfall, and the duration of the dry period. This is commonly a set precipitation level over a set number of months. Definitions of meteorological drought must be region-specific since the atmospheric conditions that result in deficiencies of precipitation are highly variable (Wilhite, 2002; Isendahl & Schmidt, 2006; UN/ISDR, 2007). *Hydrological drought*, on the other hand, refers to a persistently low discharge and/or volume of water in streams and reservoirs, lasting months or years and often leading to deficiencies in subsurface supplies. (LeHouereu, 1996; Wilhite, 2002; Isendahl & Schmidt, 2006; UN/ISDR, 2007).

While hydrological and meteorological droughts form the basis of all drought events, the main focus of this study is on *agricultural drought*. Agricultural drought links meteorological and hydrological drought to agricultural impacts, focusing on factors such as precipitation shortages, differences between actual and potential evapo-transpiration, soilwater deficits, and reduced groundwater or reservoir levels. Plant water demand depends on prevailing weather conditions, biological characteristics of the specific plant, the stage of growth, and the physical and biological properties of the soil such as infiltration rates and water holding capacity (Wilhite, 2002; Isendahl & Schmidt, 2006; UN/ISDR, 2007). Essentially, if the evapotranspirational needs of the plant cannot be met through existing water supplies – be they meteorological or hydrological – and this leads to a dramatic reduction in vegetative production then a drought may be said to be occurring. Irrigation from a sustainably replenishable aquifer is one way in which agricultural drought can be eliminated regardless of the meteorological conditions at the time. As LeHouereu (1996) observes, there is also a spatial and temporal element to agricultural drought as, to be classified as drought conditions, the deficit should be present over one or several years and over an extended area (rather than a small part of a watershed).

Historically agricultural drought in New Zealand has not been uncommon. For example, Johnsen (2004) notes that North Otago suffered two severe droughts during the 1980s and, looking back into the 19th century, Holland and Mooney (2006) observed that in 1878 lowland areas of Canterbury received half their normal rainfall and, as a result, grain yields were so low that it was not economic to reap the crop. He (2000) observes through the calculation of a drought index that the most severe drought in North Otago since 1867 occurred in the late 1880s through to the early 1890s – a meteorological/hydrological drought considerably larger than the extremely disruptive agricultural drought of 1997-99. Drought was such a problem in the early 20th century that one of the primary goals of the Department of Agriculture in 1910 was the development of grass species that were resistant to drought (Star & Brooking, 2007).

Climate models have predicted that under global warming that these drought conditions will extend northwards to cover the entire east coast of New Zealand (IPCC, 2001)[1] and droughts that were 1 in 20 year events could soon become 1 in 5 year events (Fitzharris, 2007). As a result, developing strategies for coping with agricultural drought is likely to become a critical part of New Zealand agriculture and agricultural policy in the coming decades.

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[1] The presence of an agricultural drought in the Hawkes Bay in 2007 (Hawkes Bay Regional Drought Committee, 2007) may be the forbearer of more to come.

3.3 Adaptation to drought

While there is no specific definition of adaptation to agricultural drought, Bradshaw et al. (2004: 119) define 'adaptation' to climate change as "those responses by individuals, groups and governments to climate change or other stimuli that are used to reduce their vulnerability or susceptibility to adverse impacts or damage potential." Risbey et al. (1999: 138) take a more narrow (farm centred) perspective of climate adaptation, defining it as "the process of maintaining various farming objectives (e.g. yield, production, profitability, sustainability) in the face of changes in external conditions". There are many forms of adaptation that can be characterised by attributes such as social level (individual, community, governmental), intent and purposiveness (spontaneous versus planned), timing and duration (reactive, concurrent or anticipatory), and scale and responsibility (localised or widespread) (Klein & Maciver, 1999; Smit & Skinner, 2002). Drought adaptation thus occurs on a number of interacting social layers (individuals, communities and governments) and may have a combination of any number of response characteristics (e.g. spontaneous-concurrent-localised or planned-anticipatory-widespread).

Early studies of drought adaptation focused on biophysical resource assessments using scenario-based climate modelling approaches. This has had two key influences on our current understanding of adaptation to drought. First, as a result of focusing on economics and modelling there is a "fundamental gap" in our understanding of agricultural decision-making issues with respect to climate change adaptation (Chiotti & Johnston, 1995). Second, the role of non-agricultural factors (such as non-farming demand for water, family influences or community influences) in influencing drought response is poorly understood (Smit et al., 1996). Despite the observation that "how farmers, their associations, the crop insurance industry … mediate between external stimuli such as climatic change and actual results in terms of agricultural change" is an essential ingredient in the adaptation process, we still have a fairly limited understanding of the role of human agency in climate adaptation – although recent research has moved away from modelling approaches to examine at farmer adaptation more empirically and directly (Bryant et al., 2000: 182).

One issue that emerges repeatedly in the literature is that the complexity of agricultural droughts means there is no single optimal adaptive strategy. In addition to every farmer's situation being unique (e.g. farm size, livestock, soil type, debt level), each drought event is also unique. For example, the geographical extent of the drought can vary considerably (Bryant et al., 2000). In the case of a localised drought farmers are likely to have the ability to access fodder or agistment from neighbouring regions relatively cheaply. A widespread drought on the other hand means that this can be prohibitively expensive because of transport costs. Another example is the nature of the local community surrounding the farm, with strong local communities providing support for individual farmers (e.g. in terms of labour assistance or machinery sharing) not available to farmers in areas with weak community structures (e.g. Stehlik, 2003a). Other areas where droughts may differ include the economic situation (commodity prices at the time); the extent, intensity and periodicity of the drought (as McKee et al. (2000: 16) suggest "there appears to be no such thing as a 'typical' drought pattern"), and the past history of drought and its impact on land uses of the region at the time. Thus drought adaptation is highly individualised and context dependent (Bradshaw, 2004; Topp & Shafron, 2006).

This creates a problem for the investigation of drought adaptation and the development of effective policy for coping with drought in New Zealand. While there is plenty of direct advice available to farmers for coping with drought events (e.g. MAF, 2008; Topp & Shafron, 2006) this advice is often generic rather than presenting a systematic response to drought adaptation. In addition, there are few reliable studies that examine (in a systematic fashion) context dependent farmer response to drought. There is therefore an urgent need to examine responses to specific drought events to aid in the development of adaptive capacity in New Zealand. It may be argued that an alternative solution is possible. Some studies have asked farmers how they would respond to hypothetical droughts. However, Topp & Shafron (2006) observe that the limitation of asking farmers 'proposed' drought response strategies is that self assessment of what 'ought to happen' only provides an assessment of what farmers intend to do, whereas the practice may be dramatically different. In part this is also the result of the variability of factors influencing drought as mentioned above – farmers may not know how they will respond until they are immersed within the drought and are informed of all the conditions.

3.4 The literature review: methodology

This review of literature is intended to form the basis of our study of drought adaptation in the North Otago region of New Zealand – an area commonly hit by droughts (e.g. Johnsen, 2004; He, 2000). The objectives are twofold:

- First, it aims to develop a greater understanding of the social and environmental conditions leading to the choice of drought response strategies as well as exploring drought response options themselves.

- Second, the knowledge generated in the first objective will be used for informing the field study to be undertaken as the next stage of this project and will ensure a solid theoretical basis to this stage of the work.

While it would be desirable to focus solely on New Zealand studies, reliable literature is very scarce – even on the global level. As a result, this review focuses on international droughts and drought responses in industrialised agricultural regimes (predominantly Canada and Australia) both large continental land masses where meteorological drought is a persistent problem. There are two areas of the drought adaptation literature that have been largely excluded. First, literature on drought adaptation in tropical regions is not included because of fundamental differences in the climate, resource base and (often) social organisation. Second, literature on the impact of government policy on drought adaptation is also not extensively covered. While government policy undoubtedly plays a major part in any drought response where aid is given (e.g. McLeman et al, 2007; Stehlik, 2003a) the focus of this review is on farmers' and farm communitys' responses themselves – rather than responses at a governmental level. As the objective here is to promote the creation of resilient systems, this review focuses on adaptive responses of farmers and communities to drought rather than the potential for state intervention (the reader is directed towards Botterill & Fischer 2003 for further details on government responses to drought in the Australian context).

This review comprises two main components. The first (Section 2.5) will review empirical findings from specific droughts, general empirical studies of drought preparedness, and advice documents prepared for members of the farming community. This essentially restricts the section to literature reporting empirical findings directly from farmers (largely academic studies) and literature from expert sources providing advice directly to farmers. The second section (Section 2.6) will focus on two specific case studies of droughts: The 'dust-bowl' drought of the 1930s USA (and its Canadian equivalent) (McLeman et al., 2007) and the Australian drought of 1991-1995 (Stelhik, 2003a & b). Examining these cases of specific droughts will enable the review to look more at how the context of the drought influences the response and examine potential adaptations should New Zealand be the subject of droughts of similar intensities.

One issue that might be raised as a criticism is the validity of studies that focus on historical drought events. In particular, as recent exposure will make an event more readily obtainable from memory (Moser and Kalton, 1971; Miller, 1985) the reliability of the data on drought response is inversely related to the time since the event occurred. Asking questions about historical droughts therefore suffers from a potential memory bias. However, as Moser & Kalton (1971) contend, ability to accurately recall any event is related to its significance – with highly significant events being more easily recalled than those of low significance. Thus, providing the drought events are of high significance to the farmers (as is undoubtedly the case in the dust bowl and Australian droughts) the impact of any memory bias should be minimised. In terms of general studies, the technique of asking farmers to recall management changes in a historical context has been used successfully in past studies of farm decision-making (e.g. Marsden et al., 1989; Burton & Walford, 2005) – providing support to the validity of the approach.

3.5 Farmers' response to drought

Even a brief scan of the literature will reveal that there is an enormous range of potential adaptive responses to cope with drought. For example, Austen et al. (2002) found 33 different management approaches for coping emerging from interviews with 62 farmers. Their study (as with many studies of adaptive response), however, focused only on the farm-management responses to drought without considering the potential social adaptation responses. To extend our understanding of drought further, therefore, this section is divided into two parts, looking at both the individual on-farm (managerial) responses to drought, and social responses at the family and/or community level.

3.5.1 Individual farm level responses

Adaptation to climatic variations at the individual farm level is a standard part of farm management and, as such, early responses to drought may be little more than an extension of normal farm behaviour. However, at some stage in the development of a drought, farmers must first detect and then respond to the drought. Risbey et al. (1999) suggest that this involves a four stage process. First, signal detection where the farmer must distinguish a drought signal from the 'noise' of other hydrological, managerial and economic events. If no signal is detected, no response is forthcoming. Second, the farmer follows an evaluative stage where the signal is interpreted and its potential consequences are evaluated. Third, having evaluated the potential consequences, the farmer makes a decision concerning how best to adapt the system to cope with the problem at hand and begins implementing a drought adaptation strategy. Fourth, the farmer monitors the outcomes of decisions to assess if they are effective and adapts the system if the desired goals are not being met.

Risbey et al. (1999) further contend that response can be made on two levels; tactical and strategic. *Tactical decisions* are short-term decisions (based on immediate climatic/hydrological conditions) such as when to sell animals, when to plant crops, how much fertiliser to use, when to harvest, or whether to sow fodder crops or not. *Strategic decisions*, on the other hand, are long-term decisions made on the basis of climatic interpretations over a longer time frame and involve adjustments such as building up sheep or beef enterprises, taking a bank loan, altering soil management practices, diversifying farm enterprise, purchasing crop insurance or installing irrigation systems (Smit & Skinner, 2002; Bradshaw et al., 2004). The key difference between tactical and strategic decisions is that, whereas tactical decisions are an immediate response within the existing system, strategic decisions involve making changes to the system itself in order to survive drought over a longer time period (two seasons or longer – Smit & Skinner, 2002)[2].

3.5.2 Tactical responses

Table 1 summarises the adaptive options either observed in studies of adaptation, or presented as part of advice to farmers by farming experts (in the form of extension activities). Note that this table is not exhaustive, but it does highlight the four main categories of tactical response – providing feed for livestock, livestock management, fiscal prudency during the drought, and the management of water resources.

Tactical responses
Feeding livestock
Cut more hay/silage (in a good season) (Austen et al., 2002 - AUS) (Topp & Shafron, 2006 – AUS)
Use stored fodder (Topp & Shafron, 2006 – AUS)
Forward fodder contracting (Topp & Shafron, 2006 – AUS)
Ration pastures (Austen et al., 2002 - AUS)
Crop pasture land (in a good season) (Austen et al., 2002 - AUS)
Feed supplements (Austen et al., 2002 - AUS)
Buy in feed (Smit et al. 1996 - US) (Topp & Shafron, 2006 – AUS) (HBRDC, 2007 - NZ) (Marwick & Davies, 2006 – AUS)
Graze fodder paddock (Austen et al., 2002 - AUS)

[2] Risbey et al. (1999) suggest another category of adaptation – *structural decisions* – decisions made at a higher level to deal with drought issues. An example may be the Alberta Government's decision in the 1920s to change farm land uses and relocate population to try to lessen the impact of future drought events (Marchildon et al., 2007). While this is undoubtedly important as noted above, this study focuses on farm adaptations and thus looks at tactical and structural decisions only.

Managing livestock Change mob sizes (Austen et al., 2002 - AUS) (Stehlik, 2003 – AUS) Sell stock early (Austen et al., 2002 – AUS)(MAF, 2008 – NZ) Put stock on agistment (Topp & Shafron, 2006 – AUS) (Marwick & Davies, 2006 – AUS) Destock surplus stock (Austen et al., 2002 - AUS)(Topp & Shafron, 2006 – AUS)(HBRDC, 2007 - NZ)(Marwick & Davies, 2006 – AUS) Sell stock early (Austen et al., 2002 - AUS) (Smit et al. 1996 - US) (Topp & Shafron, 2006 – AUS) Buy stock if prices good (recovery measure) (Austen et al., 2002 - AUS) Humane destruction (Marwick & Davies, 2006 – AUS) **Fiscal prudency** Adopting tighter accounting (Stehlik, 2003 - AUS) Reduce inputs to drought stressed pasture (Smit et al. 1996 - US) Reduce maintenance and general costs (Topp & Shafron, 2006 – AUS) Temporarily lay off staff (McLeman et al., 2007 – US) (Stehlik, 2003 – AUS) (Topp & Shafron, 2006 – AUS) **Water management** Ensure water supplies for livestock (Topp & Shafron, 2006 – AUS)(Marchildon et al., 2007 – Canada) Purchase additional water allocation (Topp & Shafron, 2006 – AUS) **General** Taking action early (Topp & Shafron, 2006 – AUS)

Table 1: Tactical responses to drought

Feeding livestock: a key problem during drought events is how to maintain feed supplies to livestock. A variety of responses to feed problems are reported in the literature involving both pre-emtive measures such as maintaining higher stocks of food in good season or forward fodder contracting, to responses to immediate problems such as using stored fodder, grazing fodder paddocks, buying feed, or using feed supplements.

Managing livestock: Another way of adapting to drought is to reduce the pressure on feed by managing the animals differently or changing the composition of the flock/herd. This involves managerial decisions such as whether to put stock on agistment or sell stock. Stock management may also provide a useful means of reducing labour requirements – for example, by running stock as a single mob. An important issue for farmers to consider here is the order in which to sell stock as a means of keeping the capability of the farm to respond quickly once the drought is over. As a last resort, farmers may consider the humane destruction of livestock to alleviate suffering and preserve pastures.

Fiscal prudency: Economising during drought includes measures such as reducing inputs onto pastures suffering from drought stress, reducing maintenance and temporarily laying staff off. Farmers may also adopt tighter budgetary controls in order to maintain control over gross margins. One advice document based on interviews with ‘successful’ or ‘top’ farmers (MAF, 2008) suggests also that farmers should focus on maximising income rather than reducing costs as “Top farmers spend relatively more on productive inputs” – however, this is contradicted by other sources such as Smit et al. (1996) and Topp & Shafron (2006) [3].

Water management and other issues: Ensuring adequate water supplies is clearly key to minimising the negative impact of drought on pasture and animal health. This divides into two key areas – ensuring that animals have sufficient drinking water (water distribution) and securing water allocations (water access).

It is evident from the list that farmers have a considerable range of tactical options for dealing with drought (an ‘arsenal’ according to HBRDC, 2007 or “a suite of appropriate risk-management measures”, Wilhite, 2002 – also see Bryant et al., 2000). In order to respond to the individual circumstances (social, economic, environmental) of drought the farmer is able to select from a variety of possible response options. The key is choosing the right option, at the right time, for the right circumstances. For example, the decision whether (and when) to sell stock or buy in feed will depend on factors such as the price of feed, the price of stock at the time, the type of stock on the farm, transport costs, and the farmers’ strategy for drought recovery. Other decisions are taken at a level between tactical and strategic decisions, such as whether to incur losses during the drought in order to increase survival chances in the recovery stage – or whether to focus on maintaining a breeding unit or farm lot-feeding (Marwick & Davies, 2006).

An important element in determining the efficacy of the response is the timing of the adaptation response (Austen et al., 2002; Smit et al. 1996; Topp & Shafron, 2006; HBRDC, 2007). There are two (somewhat contradictorily) key areas of advice provided to farmers in the literature. The first is to make the decision on when to cut losses prior to the event (MAF, 2008). Once a loss has been made it is psychologically harder for the farmer to make tough decisions about drought response as those decisions will invariably involve taking a loss. The second is to be flexible with the timing of responses. As noted above, contextual variables around the

[3] A possible reason for this discrepancy lies in the selection of ‘key’ or ‘top’ farmers for interview. As noted above, the experience of drought is dependent on a number of contextual decisions. Topp & Shaffron (2006) suggest that there is some evidence that larger farms (in terms of their gross value of their production) are generally better prepared for drought and have more strategies for dealing with drought. Thus, one possibility is that ‘top farmers’ are in a better financial position than many farmers and that, consequently they have more options than it comes to response.

drought (e.g. commodity prices, government aid, family circumstances) are always changing – thus it is widely seen as good practice to review decisions on a relatively frequent basis (Marwick & Davies, 2006; MAF, 2008).

3.5.2.1 Strategic responses

Table 2 presents three main categories of strategic responses. Long-term crop and livestock changes, changes or investment in technology, and family and community responses. One important factor to observe from this table is that tactical and strategic responses can overlap. For example, a farmer may reduce labour in order to lower costs during a drought, however, following the drought, he/she may decide that a more mechanised system is likely to improve the capability to deal with future drought. Alternatively, as Stelhik (2003a) observed, managerial practices taken up during the drought (in her case the uptake of computer technology to aid in tighter budgeting) may be maintained after the drought. Lessons learnt at the tactical level can thus become strategic decisions if incorporated into long-term management plans.

Strategic responses
Long term crop/livestock changes
Change crop or livestock type (Smit et al. 1996 – US) (McLeman et al., 2007 - US) (Topp & Shafron, 2006 – AUS) (Muscroft-Taylor, undated – NZ)
Altering crop mix (Bryant et al., 2000 - Canada)
Agricultural diversification (Bradshaw et al., 2004 – Canada)
Changes/investment in technology
Increased use of forecasting (Stehlik, 2003a - AUS) (Topp & Shafron, 2006 – AUS)
Improve water use efficiency (Topp & Shafron, 2006 – AUS) (Kenny, 2005 – NZ) (Bryant et al., 2000 - Canada)
Change tillage practices (e.g. min. tillage) (Smit et al. 1996 - US)(Topp & Shafron, 2006 – AUS) (Bryant et al., 2000)
Increased computerised strategic planning (Stehlik, 2003a - AUS)
Family and community responses
Increased use of social capital (networks) (McLeman et al., 2007 – US) (Stehlik, 2003a – AUS)
Increasing involvement of farm wife (McLeman et al., 2007 – US) (Stehlik, 2003a – AUS)
Non-agricultural income diversification (McLeman et al., 2007 – US) (Stehlik, 2003a – AUS) (Topp & Shafron, 2006 – AUS) (Bryant et al., 2000 – Canada) (Bradshaw et al., 2004 – Canada)
General
Keep farm maintenance up to date (Topp & Shafron, 2006 – AUS)
Tree planting (Kenny, 2005 – NZ)

Table 2: Strategic responses to drought

Long term crop/livestock changes: Changing the type of crops grown or livestock reared on a property can provide a very effective means of drought adaptation. This can vary in scale from changing the production system completely where the existing production is not fully suited to the local climate (e.g. McLeman et al., 2007; Marchildon et al., 2007) to changing the grass mix to one that is more capable of withstanding drought conditions. In addition, farmers also make strategic decisions about the mix of crops and livestock and the types of crops/livestock produced on the farm (agricultural diversification[4]).

Changes/investment in technology: Advances in technology can be particularly useful in the combating of drought. For example, recent improvements in irrigation and tillage practices (particularly the introduction of minimum tillage) were precipitated by improvements in the available technology. The uptake of computer technology can also aid adaptation through enabling better access to climate forecasts[5] and other predictive data and improving farmers ability to manage finances.

Family and community responses: While managerial and technological changes are particularly useful in strategic planning, the ability to cope with an extended drought is greatly assisted by the response of both the family and wider community. Key here is the changing role of the family as the drought progresses, with the farm wife in particular taking on more farming roles, taking tighter control of finances and being the most likely family member to get an off farm job or engage in income diversification[6] (Stehlik, 2003b). Strategic adaptation may also occur at he community level as members of the rural community make increased use of social networks to support each other through the drought.

Farm maintenance: Keeping the farm maintenance up-to-date ensures that when a drought occurs, maintenance costs are kept low. The farm can also be made more resistant to drought through measures such as tree-planting.

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[4] The problem with crop diversification, as observed by Bradshaw et al. (2004) is that farmers weigh the additional drought resistance such a measure may provide against the potential economic dis-benefit caused by a loss of economies of scale. In the case of Bradshaw's study in Canada (of over 20,000 farmers), the need to create economies of scale appeared to outweigh any benefits that crop diversification may have – meaning that crop diversification was negligible on all farms except the very large (which could diversify and operate economies of scale simultaneously).

[5] Austen et al (2002) suggest that climatic forecasts are of increasing importance to drought adaptation strategies. These are of two types. Short term forecasts which enable farmers to make immediate decisions to optimising their farm management – (e.g. when to cut hay, spray or irrigate) and longer range seasonal forecasts predicting climate over a period of 3-6 months which enables farmers to adjust stocking or selling policies according to the predicted conditions. The authors suggest that with adequate long range warning of dry climate conditions farmers can make informed decisions about stocking numbers – potentially reducing them before soil or pasture damage occur or before stock decline in condition.

[6] Diversification is a key potential adaptation for farmers, as it is seen as a means of risk spreading in to cope with increasingly volatile climate conditions (Kelly & Adger, 2000; Bradshaw et al., 2004).

3.5.2.2 Social responses to drought

Examining social response to drought is likely to become increasingly important in developing resilient systems for coping with climate change. Investigating family adaptations is particularly important. As farm sizes increase farm managerial systems generally become more diffuse, either to cope with a range of diversified enterprises (often the role of the farmer's wife, Marsden et al., 1993; Wilson, 1996; Morris and Evans, 1999) or to distribute management responsibilities for separate blocks or enterprises to separate family members. Thus, while in the past, studies have been able to focus on the decision-making of a single individual, increasingly adaptation is likely to be the result of a collective effort on family farms.

Families have a number of direct impacts on the nature of the adaptive responses chosen. First, farmers are frequently seeking to achieve social goals – such as succession (e.g. Taylor et al., 1998) or generating cultural capital in the community (e.g. Burton et al., 2008) – as well as economic goals (see also Stehlik, 2000). Thus the adaptive strategy may be chosen to meet family goals (such as succession) as much as economic goals. Second, strategies to diversify the farm away from reliance on agriculture are generally dependent on the labour of other family members while the main farmer focuses on the farm business (Hjalager, 1996; Ilbery et al., 1996). Third, it is often the farmer's wife who is responsible for accounting and budgeting and this plays a key role in successful drought adaptation (Stehlik, 2003a). Fourth, as the drought progresses, the farmer's wife often takes on new roles on the farm – particularly if there is a shortfall of hired labour as a result of economising (Stelhik, 2003a). Inclusion of the family is particularly important at the level of strategic decision-making. As Muscroft-Taylor (undated) suggests to droughted farmers, "Whatever decisions you take with your farming future, involve your partner and children. They are vital in choosing the correct decision".

The local community (or social networks) can also play a key role in adaptive responses to drought. Kenny (2001) suggests (in a New Zealand context) that a "vibrant healthy community" is essential for the health and wellbeing of farmers and farming during drought events. MAF (2007: 1) produced an advice document for dealing with climatic events. They observe that "Community members need to work together to manage local and regional adverse events" with a community consisting of "a small group of farmers living in an isolated valley, or all of the people occupying a district or a region." While in this case the authors refer to formal community organisations (such as Federated Farmers, Rural Women, etc) in many cases the adaptation is likely to be at an informal level with farmers simply supporting each other during the drought (Stehlik, 2003a). The extent to which these informal networks are used is little understood but studies of major past droughts have suggested that social networks can be very important for the survival of prolonged droughts at least (e.g. McLeman et al., 2007).

A key aspect of effective response is the level of social capital built up within the community. Social capital can be defined as "Those characteristics of social structure or social relations that facilitate collaborative action and, as a result, enhance economic performance" (Johnston et al., 2000: 746). One important characteristic is trust – particularly when it comes to either taking advice on drought response or providing direct aid to others in the form of assistance. For example, at the family level, (Ziervogel et al., 2006) gives the example of one farmer for whom trust in the son and family network "was what prompted that particular adaptation strategy." At the community level, McLeman et al. (2007) suggest that trust played a key role in determining farmers' ability to receive credit from banks or merchants – with the trust relationship having been established through length of residence in the area, the extent of kinship ties and the borrower's history of repaying debts (see Section 5.1 below). Similarly, Stehlik (2003b) observe of drought in Australia that:

> Building social capital in times of climatic variability to ensure that community capacity building has a sustainable future and community resiliency is supported, requires trust-based partnerships between individuals, community stakeholders and the public sector. *It cannot be undertaken by individuals alone* (emphasis added).

The level of social capital is also important in the relationship between farmers and the government – although, studies throughout the world have suggested that during drought, the level of trust is low, and that active engagement is required by government and supporting institutions to build faith in government decision-making (O'Meagher et al., 1998; Alston, 2006; McLeman et al., 2007). The key here is that if government is to play a central role in helping farmers adapt to drought (e.g. through providing advice) it must be trusted by the local farming community.

3.6 Historical case studies of drought adaptation – Oklahoma (1930-1936) and Australia (1991-1995)

While historical – and even recent – studies of adaptation to specific droughts in Western agricultural regimes are rare, examples are beginning to emerge as scientists seek to learn more about how farmers adapt to climate change. In this section we will review two studies of historical adaptations. These are the 'dustbowl' drought between 1930 and 1936 in Eastern Oklahoma, USA (McLeman et al., 2007) and the more recent Australian El Niño drought of 1991-1995 (Stehlik, 2003a). These provide useful case studies because the seriousness of and response to any drought event is heavily context dependent (Bradshaw, 2004; Topp & Shafron, 2006) – and our understanding of the role of non-climatic forces in influencing drought response is poorly understood (Smit et al., 1996). Examining these studies will enable us to develop a greater understanding of the role of context in determining adaptation.

3.6.1 The dust bowl drought in eastern Oklahoma in the 1930s.

The dust bowl drought of the 1930s is perhaps one of the best known agricultural drought events of the 20th century with thousands of farmers displaced over a time period of almost a decade. What is interesting, however, is that meteorological droughts that were equally as severe as the dust bowl era have since been experienced in the same region – with the most recent severe drought occurring in 2006 (McLeman et al., 2007). Further, climatic predictions for the region suggest that the conditions prevailing during the dust bowl event will become the norm over the next few decades (Rosenzweig & Hillel, 1993; Seager et al., 2007) – thus the adaptation of the system has been essential for the survival of agriculture. Studying the causes of the 1930s drought event and looking at how farming has changed in the area as a result may provide us with clues as to why meteorological drought has failed to become agricultural drought in the decades following the main event.

3.6.1.1 McLeman et al.'s (2007) study

McLeman et al. (2007) interviewed 19 (elderly) farmers who had been farming in Oklahoma during the dust bowl era with a view to understanding how they had coped with the drought. A number of key results emerged. The first concerns the fact that the drought was not driven solely by the meteorological or hydrological conditions being experienced – but also by key external drivers impacting on the industry at the time.

1. *The impact of commodity prices*. One of the reasons the dust bowl drought was so severe was that the commodity price for cotton hit record lows in the early stages of the drought (1930-31). As a result of this, farmers had little money to invest in technologies such as mechanised equipment or irrigation systems in order to overcome the drought.

2. *The lack of opportunities for off-farm income generation*. The timing of the drought with the stock market crash and depression of the 1930s meant that, whereas farmers would normally have been able to earn income externally to survive, at the time of the drought there was little external work to support their families. This forced them to continue intensive farming practices leading to soil erosion and land degradation.

3. *The lack of security in tenanted farms*. Farmers in the region at the time were on relatively small tenanted farms. When the drought occurred and the cotton price simultaneously dropped the response was to work the land harder, again leading to soil erosion and land degradation. In addition, with no money to invest in fertilizers, the fertility of the soil rapidly declined.

The second key finding was the lack of changes in farming practices that occurred during the drought. In addition to the issue of lacking the capital to fund improvements, farmers also failed to make managerial changes on their farm during the drought. Rather, the main response was to intensify existing practices. The managerial options open to farmers were not taken up for the following reasons.

1. *Changing location of crops on the farm*. Farmers in the region were growing corn and cotton. Although corn is the less drought tolerant of these crops, this could not be moved to different fields because the corn was already being planted on fields with the highest soil moisture content as part of their standard farm management. In other words, corn was at the limit of its growing range.

2. *Changing to drought resistant crops*. This was not done because of a combination of factors. First, farmers continued to need to produce corn as feed for both their draft animals and livestock. No money to purchase corn meant it had to be grown regardless of the drought. Second, the infrastructure supporting farming in the region was dominated by cotton thus there was little support for other types of production. Again, during a drought changing such systems without a large capital input is likely to be extremely difficult. Third, cotton production was "what Sequoyah County farmers knew and did best". Farmers' cultural links can provide a strong motivation for continuing with a form of production despite the existence of economically more viable alternatives (Burton et al., 2008).

The third key finding was that the main response of the farming community to the drought was a social response – to work more as a community. In this environment non-economic forms of capital (cultural and social capital – see Bourdieu, 1983) became critical to survival in drought conditions. This was in the following ways:

1. *Increased cooperation within the community*. During the drought the lack of capital to hire labour meant that farmers increasingly relied on the help of each other to survive the drought. Community bonds were thus strengthened as an adaptive response to the extended drought conditions. McLeman et al. (2007) observe that in some cases farmers pooled their capital in order to import feedstuffs in bulk.

2. *Increased role for farm women*. During the drought farm women's activities became increasingly critical in terms of raising external income, growing food around the homestead, and preserving food (for example, canning culled cattle).

3. *Increased use of barter systems*. A lack of cash income meant that bartering goods became more common during the drought event – although it was generally not the case for large purchases associated with agriculture (e.g. seeds, equipment).

4. *Using social capital to obtain credit*. Farmers observed that during the drought event the value of the social capital of a farm was often critical in terms of obtaining needed credit. Factors such as the length of the borrower's residence in the area and the extent to which the family was tied in with the community became important for merchants to decide who would and who would not be provided with credit.

3.6.1.2 Why are droughts no longer an issue in the region?

McLeman et al. (2007) contend that the key reason agricultural drought has not been an issue recently in eastern Oklahoma is simply that the land is no longer used for cotton or corn production – in fact, it is reported to be 60 years since any cotton was harvested in the county. Instead, the current land use is extensive pastoral beef farming with row crops only found on the most fertile lowlands and, even then, the crop is soybeans rather than corn or cotton. In the recent severe drought of 2005-2006 the response of the beef industry was simply to purchase supplementary feed for the animals and, as the drought wore on, farmers either sold off stock or paid to truck water to the animals. As discussed above, the problem in this case was not with farming, but with the type of farming that was being practiced in the area. Matching the production systems with the meteorological/hydrological conditions experienced is thus a key factor in avoiding agricultural droughts.

Perhaps the optimal example of survival of agriculture in a drought-prone region is that described by Le Houereu (1996: 146) as occurring in some regions of the Sahara. Through careful management, he observes, some areas of the Sahel have managed to maintain agricultural production through a 25 year drought without any ‘visible long-term harmful consequences’. In other words, through careful land management farmers were able to maintain production while simultaneously maintaining the capacity to produce – albeit at a low level.

While the Oklahoma area responded to the drought by a change in land use towards ranging systems, in other areas of the mid-west farmers who were already in ranging systems also experienced serious drought. By 1950, however, a meteorological drought that was almost as serious as the dust bowl years went almost unnoticed amongst livestock farmers. Kassas (1987: 394) lists a number of changes that had assisted livestock farms in the region to become more resilient. These were: (a) government investment in and legislation on soil conservation in the region, (b) a change in the cattle variety to more drought resistant species (particularly the Texas Longhorn), (c) expansion of transport networks allowing cattle to be moved between summer and winter grazings, (d) the use of cattle fencing for improved range management, (e) improved access to water through technological advances and major large-scale water management projects (e.g. the Grand Coulee dam), (f) advances in the science of ecology to help with soil conservation and range management, and (g) development of effective extension, advice and vocational training services to farmers (also see McKee et al., 2000).

3.6.2 The Australian El Niño drought of 1991-1995

3.6.2.1 Stehlik’s (2003a) study

The Australian drought of 1991-1995 occurred as the result of the occurrence of four consecutive El Niño years – leading to particularly dry conditions in Queensland, northern New South Wales, and parts of central Australia. The drought is estimated to have reduced agricultural production by 8% and ended with the advent of heavy rain in 1995 and 1996 (Lindsay, 2003). In 1996-1998 Stehlik (2003a; also see Stehlik et al., 2000) conducted an in-depth examination of 56 farm properties’ (103 interviews in total with family members) experiences of and adaptations to the drought of 1991-1995.

The context of this drought was that it occurred while many families were still recovering from the drought of the early 1980s. Unlike the dust bowl drought where the cropping system was unsuited to the climatic conditions, in the Australian case farms were mainly under extensive pastoral management at the time of the drought – a system more capable of withstanding drought. In this case Stehlik (2003a) found that the length of the drought and the scattered nature of the farming community meant that community cohesion was not enhanced by the drought (as had been the case for the dustbowl). This was problematic as many of the government support policies were predicated on the notion that farmers pull together into a ‘collective mentality’ at times of drought. Instead, as farmers begin to experience stress and lay off staff many simply ceased to participate in community events.

Stehlik’s focus was predominantly on the adaptation to drought at the family and community level – rather than specific farming behaviours used to manage the drought threat. Nevertheless, two key managerial responses in response to the drought were detected.

1. *Increase the level of strategic planning on farms*. There were two main adaptive responses. First, it prompted a strong growth in the uptake of information technology as a farm management tool. In particular, farmers who had been sceptical of climate indices related to El Niño events re-educated themselves and used the indices to make decisions in advance such as when to sell stock. Second, the drought led to the reorganisation of farm accounting practices. In particular, it led to a rapid growth in the uptake of information technology and software for farm budgeting (often innovatively led by spouses rather than the male farmer) – in order to keep a much tighter reign on costs and income.

2. *Divest the farm of hired labour*. Many farmers divested the farm of casual or hired labour in response to the drought – leaving family members to undertake more of the farm tasks. As the drought progressed the laid off labour increasingly left the region, meaning that, even if labour could be afforded, there was often nobody to undertake the work. This, in turn, placed more pressure on families to undertake the farm-work themselves and, in order to do this, many simplified their farming systems.

The farm level response to the drought showed both similarities to the dust bowl drought of Oklahoma.

1. *Increased role for farm women*. Partnerships were very important in providing resilience to drought. Stehlik observed that the woman's role on the farm changed during the drought with women taking on greater responsibility for stock and undertaking more physical work on the farm. They were also likely to become more directly involved in decision-making and provided an important buffer between the farmer and potential sources of financial stress (the bank, creditors, and accountants).

2. *Increased use of existing friendship networks*. While on some farms the main adaptation was in terms of the role of the spouse, in others farmers drew heavily on their friendship networks (social capital) established over many years.

3.6.2.2 Why are droughts continuing to be a problem in the region?

The reason agricultural drought continues to be a problem in Australia (with another occurring in 2003-2007) is that in the Australian case production is already extensive leaving limited capacity to adapt. Risbey et al. (1999: 160) observe that "from the demographics of Australian agriculture, it is apparent that most farming in Australia is more or less optimally located to reduce climatic variability". Thus, while in the Oklahoma case, farmers were able to adapt to the drought by simply changing the production use of the land the areas experiencing drought in Stehlik's (2003a) study were already based on extensive grazing and, as a consequence, there was no easy alternative approach.

3.6.2.3 Other droughts

Findings from other droughts support the findings of the Oklahoma and Australian case studies. In particular, the uniqueness of each drought and the impact of the climatic and commodity price conditions before and during the drought cannot be underestimated. For example, in the most recent Australian drought of the 2000s Topp & Shaffron (2006) observe a difference between the position of farms in Queensland (which had experienced dry conditions throughout the 2001 to 2003 period) and other drought affected areas where favourable agricultural conditions and commodity prices had led to farmers having stores of both fodder and capital at the time of the drought. However, external (non-agricultural) conditions can mean that preparedness is not always sufficient to alleviate drought. In Victoria, while dairy farmers were prepared for the drought, an underlying hydrological drought (caused by a long period of low rainfalls) combined with concerns about the drought conditions (partly by the urban population) led to their access to water being cut and, as a result, the only way to maintain milk production was to purchase fodder. The impact of a combination of low irrigation water supplies and high fodder prices, Topp & Shaffron (2006) note, was not anticipated by many farm managers and created problems with adaptation.

In another study, Marchildon et al. (2007) looked at adaptation to drought in the Great Plains of Alberta and Saskatchewan (Canada) between 1914 and 1939. Although this study did not involve interviews with members of the farming community at the time, it nevertheless makes an interesting observation on the response to drought during this particular period. Whereas the Alberta local government carried out an extensive program of land use change following localised droughts in the 1920s (converting farms into ranches and relocating the population) the Saskatchewan government took no action. When the dust bowl drought hit in the 1930s, farmers in Alberta suffered a significantly lower drop in incomes to those in Saskatchewan (61% compared to 72%) which Marchildon et al. (2007) cite as evidence of the success of the policy. The authors further contend that the impact on agriculture by the severe drought of 2000-2001 "would have been much worse without the lessons learnt from the earlier droughts".

In a study of drought conducted in New Zealand, He (2000) looked at the 1997-99 and other historic droughts in North Otago. While the study was of hydrological/meteorological drought there are nevertheless some implications for farmers. The 1997-99 drought lasted 32 months and was widespread along the east coast of the country including Marlborough, North Canterbury, and the Hawkes Bay bringing record breaking temperatures and low river flows. For farmers, this meant voluntary irrigation restrictions and even irrigation bans – but even this was not sufficient to raise the Kakanui and Shag rivers above the consent limits. Despite it's lack of focus on agriculture, He's (2000) study is important as it identifies the periods of 1988-89 and 1997-99 as two of the most severe droughts in the North Otago region. The severity of the 1988-89 drought is confirmed by McGann (1991: 56) who suggests that the drought, up to that stage had been "one of the worst that has occurred there".

3.6.3 Lessons for promoting effective drought adaptation

The Australian drought of 1991-1995 was different to the dust bowl drought in a number of ways. First, in the case of the dust bowl the drought was partly driven by the recent incursion into the area of cotton and corn farming – an activity not suited to existing environmental conditions. As a result, while the outcome of the dust bowl drought was a change in the regional produce from cotton to extensive grazing, in

Australia, extensive grazing continues to dominate. Second, the Australian drought occurred shortly after a drought in the 1980s and thus farmers may already have resilience measures into their farming systems (even though it was one of the most severe in Australian history – Stehlik et al., 1997). Third, at the time of the Australian drought computer technology was becoming available and this enabled farmers to better cope with the drought through both improved farm accounting/management practices and use of long-range forecasting. Finally, whereas the impact of the Oklahoma drought on social cohesion was to strengthen it, in the case of the Australian drought, it tended to weaken. There are a number of possible explanations for this ranging to research effects (i.e. Dust bowl drought survivors holding an idealised image of Oklahoma communities in the 1930s) to structural differences such as the dispersed nature of population in the Australian drought or the larger farm sizes in Australia – resulting in less time for social networking.

In both the Oklahoma and Australian cases, however, the researchers noted the growing importance of the contribution of farmers' wives to farm survival throughout the drought as a strategic response. Droughts often leave farmers with few adaptive options for their main production activities – particularly as the drought progresses and the capital and response options diminish. Instead, adaptation appears to move towards family changes – such as on- or off-farm diversification activities or changing roles of family members to cope with new demands for labour, efficacious management and fiscal prudency.

One interesting finding of Stehlik's (2003a) study was that the main impact of the growing number of experts providing advice to farmers was to increase the stress on farmers – particularly where this advice was counter to farmers' own experience. Farmers preferred to work out their own systems for drought management based on experiential knowledge. It could be argued that extension is applicable mostly at the early stages of the drought – but that once the farm is in a prolonged 'critical' state, it is all farmers can do to hold on to what they have. New ideas are not effective when there is neither capital nor labour to activate them. Investment and guidance in accounting systems (targeted at the farmers' spouse), on the other hand, may provide direct benefits for the affected farmers in the middle stages of a prolonged drought. At later stages of the drought Stehlik observed that the biggest issue was the breakdown of social capital and community links (observed in the case of the dust bowl drought as key factors in maintaining farming).

3.6.4 Implications for dairying in drought regions

One issue of concern that should be raised by this examination of past droughts is that of the expansion of the dairy industry into drought prone regions of New Zealand. As Kenny (2001) observes:

> The vulnerability of the dairy industry to drought could increase if the planned expansion into Canterbury occurs. In the 2000/01 season Canterbury dairy farmers faced irrigation bans, which led to high supplementary feed costs. The situation could be repeated with greater frequency in future because of increased water demands for expanding and more productive farms, even without considering the effects of climate change. (P7).

While there is no suggestion of a hydrological drought as of yet it is clear that within a drought vulnerable region such as North Otago/South Canterbury, such farms are in a similar position to the corn and cotton farmers of Oklahoma – or the dairy farmers of Victoria in the recent Australian drought. Unlike extensive livestock production which, as the evidence suggests, is better adapted to drought, dairy farmers could find themselves increasingly vulnerable. As observed by Topp & Shafron (2006) dairy units that are reliant on irrigation systems are vulnerable to hydrological droughts – particularly in cases where there may be competition for water resources by urban users. The authors suggest that dairy farmers in Victoria survived because of the abundance of fodder available as the result of good years prior to the drought – meaning fodder was available for purchase when water supplies were reduced. However, *if* the meteorological/hydrological drought had have occurred at a time when farmers had few financial reserves, the impact could have been far more severe.

The temptation to expand production into fundamentally unsuitable climate zones on the basis of high commodity prices was one of the fundamental problems behind both the 1930s dust bowl drought and the Canadian drought of the same era (driven by high cotton and wheat prices respectively). The scale of upheaval experienced in these areas is unlikely to occur in New Zealand simply because the climate is less continental and the same westerly wind flows that will lead to drought on the east coast of New Zealand may lead to greater rainfall in mountain areas – potentially lessening the chance of hydrological drought (Fitzharris, 2007). However, as McLeman et al. (2007) conclude "adaptive responses must be developed when conditions are favourable" and the example of the efficacy of the Alberta government's program of conversion away from unsuitable land uses outside of drought years provides a salutary example. As a pre-emptive means of coping with climatic events farmers in New Zealand should carefully consider the climate risks prior to purchasing land or changing land use (MAF, 2008).

Another lesson is that, in preparing for drought, consideration should not only be given to all eventualities – but all combinations of eventualities (see Bradshaw et al., 2004). For example, response to a period of meteorological drought and low irrigation water supply (hydrological drought) will be different to response to low irrigation water supply, low fodder availability, high commodity prices – and the temporal and spatial distribution of these factors will also influence the adaptive response. Further, as Marchildon et al. (2007) observe, the ability to cope with drought is a function of experience with drought. The rapid expansion of the dairy industry suggests that many farmers are unlikely to have the direct experience with drought (on dairy systems) to be able to cope easily. Only time will tell whether dairying is sustainable in drought prone regions of New Zealand or whether, like the cotton farmers in Oklahoma, dairying will ultimately prove unsustainable. As Topp & Shafron (2007: 9) comment of the recent spread of dairy farms to drought vulnerable areas in Australia (and reliance on irrigated pasture):

> Many dairy farms in Australia are now much more exposed to the adverse effects of drought than they were in the past, particularly when a severe drought leads to a combination of higher fodder prices and a decrease in the supply of water for irrigation.

The impact of the growth in dairy is also likely to impact on the sheep/beef sectors' ability to respond to drought in New Zealand. Topp & Shafron (2006) observe that drought in Australia led to a considerable spike in fodder demand in 2004 – and a consequent spike in the price of fodder. The current situation in New Zealand is that dairy farming is hugely profitable while beef and sheep production have suffered low commodity prices in recent years. The occurrence of a major extended drought in the coming 2 or 3 years could thus see dairy incomes pushing up fodder prices considerably – potentially beyond a level affordable by cash-strapped beef/sheep farmers. The impact could therefore be that buying in feed for stock becomes simply unobtainable for sheep/beef farmers. Such an event would, however, also offer opportunities as sheep/beef farmers would now be have the option of selling fodder (and increasing the level of destocking) as a means of drought survival.

3.7 Conclusions

This analysis of the literature has critically reviewed drought adaptation studies in an international context. Lessons for drought adaptation have been learnt from both studies of farm level and social responses to drought, and two case studies of drought in Australia and the USA. Analysing this data allows us to construct a conceptual model for classifying drought response and this is presented in Figure 6.1.

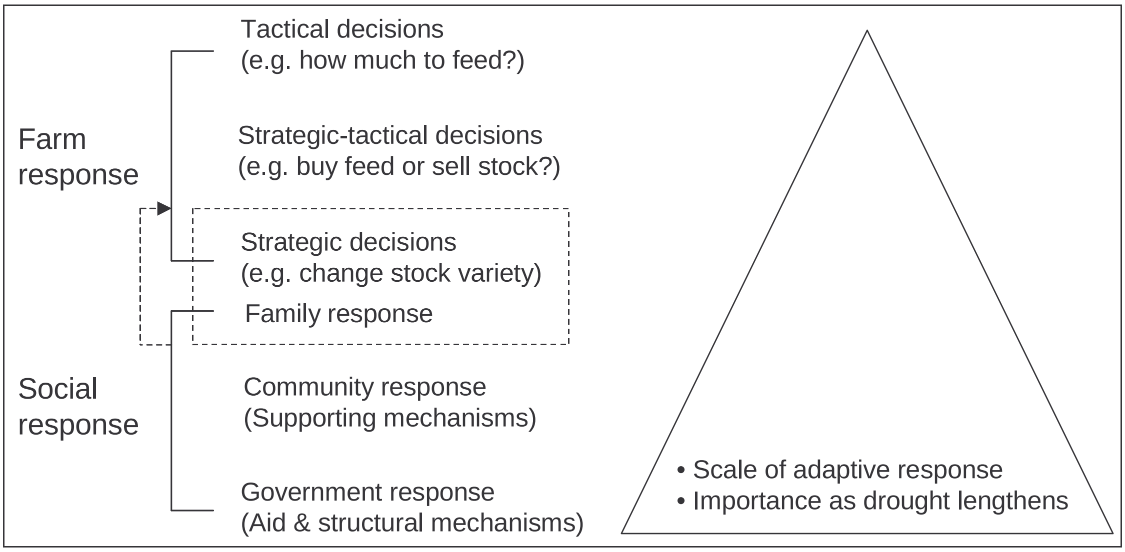

Figure 1: A classification of drought adaptation strategies

Figure 1 builds on the heuristic 'tactical' and 'strategic' response framework of Risbey et al. (1999). It suggests that there are three levels of farm response 'tactical' 'strategic tactical' and 'strategic'. The 'strategic-tactical' category is added to incorporate the notion that many tactical decisions have strategic elements and, as discussed above, many tactical decisions can eventually become part of the strategic response. For example, the decision whether to buy feed or sell stock has implications for strategic planning on the longer term – possibly years. The conceptual framework also adds a new category of response – that of social response. This is at three levels – collective *family responses* (such as diversification, changes in the role of the farm wife and labour reallocation), *community responses*[7] (such as increased use of social networks during drought, the use of barter systems, and the emergence of community based assistance groups), and *government responses* (such as the provision of direct aid to the farming community and the implementation of structural change).

While the diagram suggests that social responses comprise their own distinct adaptation grouping, it does not suggest that social response and farm response are

[7] Note that this includes members of the local business community who may support farmers during droughts through extending credit and so forth.

entirely separate. Farm response (tactical and strategic decisions) are almost always farmed in the context of social responses such as family goals, available government aid, or the support of the local community. As observed at the right hand side of the diagram, it may be useful to consider these adaptations as temporally variable. Tactical decisions concerning farm management are likely to be made without any necessary recognition of drought conditions – but rather simply in response to feed shortages due to a lack of grass. As the drought extends, the desirability of specific tactical options will change. For example, Marwick & Davies (2006) observe that in a short drought maintenance feeding is likely to be a low cost strategy. However, as the drought lengthens it can become very expensive – particularly as feeding resources within the region become depleted. Eventually as the drought becomes more critical the farmer needs to pay more attention to the strategic consequences of tactical decisions as many will have implications for the future recovery of the farm. At this stage the farmer moves into a 'strategic-tactical' response.

If these conditions persist further, the farm family may then look towards more strategic decisions to cope with drought – i.e. reducing their long-term vulnerability to drought. This may occur either during the drought (e.g. taking on off-farm employment) or after the drought on reflection (e.g. changing the crop/animal varieties) and, as noted above, may be the result of tactical responses becoming permanent. As the diagram indicates, these decisions are often made at the family level as the solutions such as diversification or changing enterprise may require the agreement and participation of the whole family.

Beyond the family level, community responses (such as the increased use of the bartering system observed by McLeman, 2006, or the increased use of social networks observed by Stelhik, 2003a) are likely to increase further as the drought progresses. Farmers increasingly need to cooperate to cope and, as this need increases, the community response gains in importance. Finally, when farmers or communities are completely unable to cope with the drought, local or national government may intervene in the drought response. In its ultimate form, government adaptation can involve installing policies to initiate a complete change in land use as occurred in Alberta following drought in the 1920s (Marchildon et al., 2007). It should be noted, however, that as government is involved in many ways within the farming community even in non-drought situations, that the impact of government measures is likely to be felt across all scales of adaptive response – social and farm based.

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