ROLE OF LOCAL INSTITUTIONS IN FORMULATING CLIMATE CHANGE ADAPTATION STRATEGIES FOR A LOW WATER FUTURE: A PUBLIC POLICY PERSPECTIVE[1]

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ABSTRACT: This paper examines the role of local institutions in supporting climate change adaptation action from a public policy perspective. While certain adaptation actions will provide public benefits, many others will offer private benefits. The paper argues that adaptation investments and assigning the adaptation responsibility across various actors should be guided by a clear public-private benefit framework. A case study of adapting to a 'low water future' in North East Victoria is used to discuss the role of local institutions and industries in formulating climate change adaptation strategies. The findings indicate that formulating adaptation strategies, at the local level, has been complicated by the existence of considerable uncertainty in the nature and magnitude of adverse climatic impacts. The planning problem is further exacerbated by considerable information asymmetries and moral hazard issues inhibiting climate change adaptation for reduced water supply by local institutions and industries.

KEY WORDS climate change, vulnerability, public-private benefits, regional planning, local governments, water supply

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1. **INTRODUCTION**

Adaptation is pivotal in the Australian water sector as it is highly vulnerable to adverse climate change impacts. The water sector characterises hierarchical institutional and policy frameworks, long-term capital investments and political economy issues. Understanding how climate variability impacts on both urban and rural water sectors is critical when formulating policies at the regional and local government level. Recently, significant investments have been made to understand and adapt to a low water future. For example, *Water for the future* project, the single largest climate change adaptation investment undertaken in Australia (A$12.9 billion), focused on four national priorities: taking action on climate change, using water wisely, securing water supplies, and supporting healthy rivers and wetlands (Commonwealth of Australia, 2010).

Numerous adaptation initiatives at the local level have been implemented in the water sector. For instance, there are programs in place to promote the use of water efficiency appliances, storm water harvesting, water efficient urban design and household standards, water efficient garden planting and watering, supplementing supplies with recycled water, watering restrictions, and appropriate pricing mechanisms (Department of Climate Change and Energy Efficiency, 2010). In addition, local government bodies play a role in enhancing community education and engagement in relation to water-related adaptation issues. Unlike mitigation, the public policy response to climate change adaptation is far less obvious. In particular, guidance on formulating adaptation strategies that maximise social welfare has received less attention.

Adaptation to climate change is inevitably a local phenomenon. It is important to understand how the local institutions can effectively respond to adaptation with appropriate institutional mechanisms and incentive structures, driving the behavioural change (Agrawal, 2008). Within each Australian state and territory, the Local Government Act provides the regulatory powers to formulate policy on climate change adaptation action. For example, in Victoria, the *Environment and Planning Act 1987* sets forth planning provisions for adaptation policy at the local level (Vasey-Ellis, 2009). Over the years, the local government bodies have been given increasing powers in this regard providing flexibility to respond to a myriad of local needs. However, the primary approach has been that of risk management. There are guidelines for local councils to identify risks and appropriate adaptation responses. For example, the framework for the assessment of risks associated with climate change is based on the Australian and New Zealand Standard AS/NZS 4360 Risk Management (Department of Climate Change and Energy Efficiency, 2010). Local councils and water authorities may be liable if they cannot show that they have taken preventive action against any threat to the health, safety and welfare of their communities. Therefore, local governments and water agencies consider it a priority to identify threats and implement strategies to prevent these threats.

This paper uses a normative economic framework to analyse adaptation actions at the local level. The framework explores incentives for action and distinguishes between adaptation investments by private and public agents. In particular, the role of local government institutions in shaping adaptation action in the water sector is examined. The paper is mainly based on secondary literature and a series of research reports from a climate change adaptation project conducted in North East Victoria. The paper highlights some of the challenges in formulating climate change adaptation plans at a local or regional level. Whilst it deals with the water sector in particular, the core findings are relevant to other sectors as well.

The paper is organised as follows. The following section 2 outlines a theoretical framework that can be used to understand the rationale and motivations behind adaptation action. The framework also guides the policy on assigning and facilitating adaptation action. Section 3 presents a case study of adapting to reduced water availability in North East Victoria. Localised impacts of reduced water availability and consequent vulnerability of economic sectors are discussed in this section. Adaptation options and policy instruments are described in section 4. Section 5 provides a discussion of some guiding principles for adaptation planning at the local government level. Some concluding remarks are offered in the final section.

2. THEORETICAL PERSPECTIVES ON ADAPTATION

Parry et al., (2007) define adaptation as the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Put simply, adaptation to climate change involves taking actions in anticipation of, or in response to, climate change impacts that cannot be avoided by mitigation policy (Garnaut, 2008). Climate change adaptation is equally important as mitigation although so far it has received comparatively less attention (Atkinson et al., 2007). Much of the research on adaptation to climate change focuses on understanding the concept of adaptation rather than drawing from other areas of study on adaptation (Aakre and Rubbelke, 2010). Climate change adaptation action is undertaken both by public and private actors through policies, investment in infrastructure and technologies and behavioural change (Fankhauser et al., 2008). A number of typologies have been developed to classify adaptation activities. These are based on timing (anticipatory vs. reactive), scope (short-term vs. long term; localized vs. regional), purposefulness of adaptation (spontaneous vs. planned) and adapting agent (private vs. public) (Fankhauser et al., 2008). This paper concerns the latter perspective of private vs. public adaptation. Public adaptation is also referred to as collective or joint adaptation.

Pannell (2008) presented a framework for selecting policy mechanisms to influence the individual landholder (private) behaviour with respect to adopting conservation measures. The framework can be used to analyse adaptation actions. The basic premise of the framework is that environmental managers can invest in a range of projects involving land use changes in private lands and these projects invariably generate different levels of private and public net benefits, including potentially negative net benefits (Pannell, 2008). Private net benefits are defined as benefits minus costs accruing to private entities (landholders, firms, etc.) and exclude transfers which are part of the policy intervention. Public net benefits refer to benefits minus costs accruing to everyone other than the private entity and exclude any costs borne by the government in the process of intervention (Pannell, 2008).

Figure 1 shows the policy space for possible government interventions with various levels of public and private net benefits. Depending on the mix of private and public benefit, any government intervention can be placed on the private-public net benefit matrix shown in Figure 1. Projects that fall under areas A, B and C represent overall positive net benefits (Pannell, 2008). For instance, interventions that fall in area A will have greater public net benefits than private net costs. For example, the establishment of riparian vegetation that promotes ecological connectivity to aid migration and dispersal of species would be too costly to a private landholder but the public benefits from this action far exceed the private costs. *Gondwana Link*, *K2C Link* and *Alps to Atherton Link* are some examples of establishing biodiversity corridors in Australia. In these situations, positive incentives using financial or regulatory instruments are justified. In area B, both the public and private entities accrue positive net benefits from the intervention. For example, the establishment of earthworks to reduce soil erosion or zero tillage may be beneficial to both private landholders and to the environment. In such cases, the most appropriate policy intervention would be to provide information on the benefits of intervention or extension service.

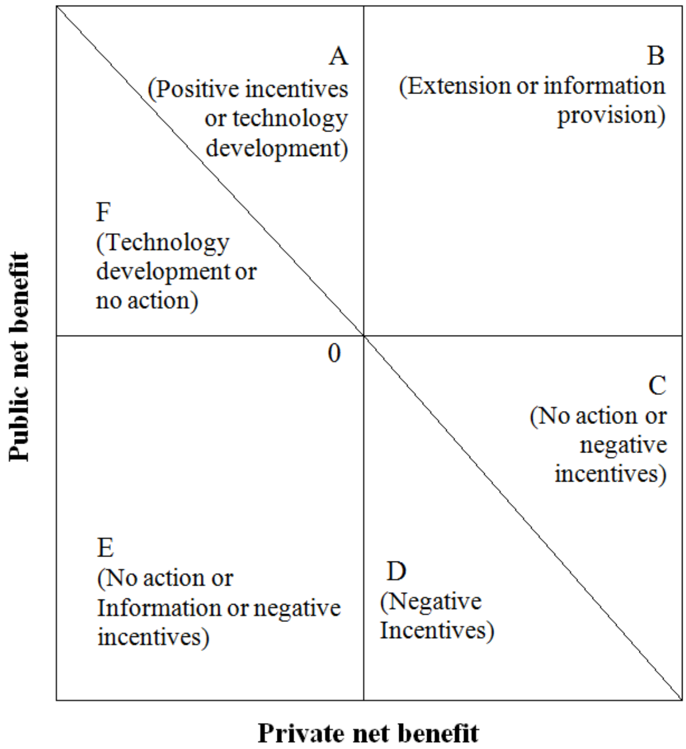

Figure 1. The Public-Private Benefit Framework.
Source: Pannell (2008)

The interventions that fall under area C, private net benefits exceed the public net costs (Pannell, 2008). For example, conversion of grazing land to a forest plantation would be profitable to the forestry firm but it causes reduced stream flows and downstream costs to the water users that may not outweigh the onsite benefits. Climate change induced reductions in rainfall can significantly reduce plantation timber harvests (Australian Bureau of Agricultural and Resource Economics and Sciences, 2011). Therefore, public net benefits of adaptation action to minimise losses far outweigh the public net cost of intervention. In this case, private benefits are sufficient to change the firm behaviour and therefore government intervention in terms of subsidies is unnecessary.

The framework contends that agents (firms, households and individuals) are likely to implement adaptation measures with positive private net benefits (areas B, C and D) provided that they are aware of such measures. Given this public-private dichotomy, the most appropriate policy mechanism to maximize the net benefits of intervention can be identified. The policy mechanisms to alter land-use are described in Table 1.

Table 1. Alternative Policy Mechanisms for Land-Use Change in Private Lands. Source: Adapted from Pannell (2008), p.226.

Category	Policy mechanism
Positive incentives	Financial or regulatory instruments to encourage change
Negative incentives	Financial or regulatory instruments to inhibit change
Extension or information provision	Education, communication, demonstrations, technology transfer and support for community network
Technology development	Mechanisms that alter the benefits of land management options such as strategic R&D, provision of infrastructure to support new practices and training to enhance the performance of existing technologies
No action	Informed inaction

3. CLIMATE CHANGE IMPACTS AND VULNERABILITY IN NORTH EAST VICTORIA

North East Victoria covers an area of about 19,000 square kilometres and is made up of five Local Government Areas (LGAs). The region has a diverse economy with service, manufacturing and tourism sectors making major contributions whilst the agricultural sector still plays an important role. There has been a significant restructuring in certain sectors owing to globalisation pressures and changing economic and social needs in the region and elsewhere. The data pertaining to climate change in North East Victoria are not only dispersed across many agencies but also circumscribed by uncertainty. The Commonwealth Scientific, Industrial and Research Organization (CSIRO) predicted climate change impacts for the region (CSIRO, 2006, CSIRO, 2008a, CSIRO, 2008b, CSIRO, 2008c). These predictions were of a low spatial resolution and predictions based on such a low resolution are of limited use for planning at the local level (see Annex Table 1 for regional-scale impacts on rainfall, temperature, snow, drought and fire incidence). Moreover, there are discrepancies in the predicted impacts of climate change on the water resources within the North-East Catchment Management Authority region of Victoria. The discrepancies in estimates are due to varying assumptions underpinning the development of climate change scenarios and different modelling techniques used. Modelling approaches are continually being refined and the production of consistent results from this type of analysis remains a challenge.

This research adapted the results of a climate impacts study carried out by Beverly and Hocking (2010) for the North East Victoria region scaled down to local government areas. Their methodology involved interpolating climate scenarios generated by CSIRO for the study area. The daily climate sequences were incorporated into existing surface water and groundwater models to assess the major impacts of climate change on water availability projections for 2030 and 2070. The modelling approach used a suite of farming system models and a fully distributed multi-layered groundwater model and is shown to offer fine scale, Catchment Management Area-wide regional estimates across a range of designated future climate scenarios (Beverly and Hocking, 2010).

The communities in the North East region are more likely to experience stressed water supply systems along with negative impacts due to reduced water availability to agriculture, tourism, water-intensive manufacturing, food processing and the like. Under the low 2030 climate condition, projected flows would be reduced by between 2% and 14% depending upon landscape position and dynamics (Beverly and Hocking, 2010). Under dry extreme condition, the flows would be reduced by between 10% and 25% across the North East Victoria region (Beverly and Hocking, 2010). The water availability progressively worsens for the region with low 2070 and dry extreme 2070 scenarios where flows would be reduced by 9-24% and 34-61%, respectively (Beverly and Hocking, 2010). Most noteworthy is the considerable variation in water flow forecasts within the region. According to the hydrological analysis, different local government areas would be affected differently.

The groundwater modelling carried out by Beverly and Hocking (2010) indicates that the study region is already being 40% over-allocated (Beverly and Hocking, 2010). This was a significant finding because up until then the general perception was that groundwater resource can be used as a fall back option in an event of acute water scarcity. The results of the hydrological modelling depicting sub-regional impacts of climate change for the region are summarized in Annex Table 2. In summary, the impact of climate change on rainfall and stream flows is highly uncertain and the level of uncertainty increases as we move from the national to local level.

Vulnerability Assessment

The climate change literature identifies a wide range of vulnerability assessment methods (Baum, 2008, Füssel and Klein, 2006, Füssel, 2007). The vulnerability method used in this research combines the dimensions of biophysical (natural) vulnerability and social vulnerability arising from reduced water availability. The preliminary vulnerability assessment focuses on assessing the extent of water supply dependence, the extent of anticipated water availability changes in different jurisdictions and the extent to which substitution opportunities are available in the short run (Crase and Clarke, 2010).

Translating the climate-induced hydrological effects into impacts on the community, businesses and individuals requires some understanding of the socio-economic make up of each local government area. First, the degree of water dependency of each sector or LGA for their activities is pivotal and determines the level of vulnerability of the sector. Second, the feasibility and availability of substitute low water dependence activities or alternative water sources at a low cost. In addition, an approximate timeframe to switch to these alternatives was also considered.

Crase and Clarke (2010) developed a qualitative scale in order to assess vulnerability to reduced water based on the level of water dependency, substitution options and lead time to switch to a preferred substitution option. In this scale, water dependency is rated from 1-3 with 3 indicating a high dependence on water given current technologies (Crase and Clarke, 2010). Substitution opportunities are negatively rated 1-3 with 3 indicating few substitution opportunities and 1 indicating many substitution opportunities, at least relative to current demands and patterns of consumption (Crase and Clarke, 2010). Lead time is designed around the decision-making time frame for important investment decisions. A score of 1 suggests that a ‘wait and see’ approach is not too costly and 3 indicates that decisions are relatively pressing in the present context (Crase and Clarke, 2010). An example of the vulnerability assessment for the Alpine Shire is presented in Annex Table 3.

4. ADAPTATION OPTIONS AND POLICY INSTRUMENTS

In this section, the theoretical framework presented in section 2 is applied to the case of adaptation in the water sector. The focus is on several economic sectors that will be affected by low water availability in the North East Victoria region. The reviewed industry sectors were agriculture, manufacturing, urban water, forestry, biodiversity management and tourism. Table 2 summarises adaptation options and policy tools for selected sectors in the study region.

Table 2. Climate change adaptation options and policy instruments. Source: the Author

Sector	Vulnerability	Adaptation options	Policy instruments	Type of action at the local level
Agriculture	Very high	Wine production – (a) The use of urban water trade to maintain production (B) (b) Sale of water allocations and/or entitlements to adjust to new varieties (B) Dairy industry – (a) Substitution of grain and fodder for irrigated pasture (B/C) (b) the transition to annual pastures with harvesting for silage or hay, since under some circumstances hay prices will be heavily correlated to water availability (C)	Institutional changes in the water market None	Water agencies facilitating water trade by lending their infrastructure to deliver water No action
Manufacturing	Moderate	Strategic relationships Better communication with the water utility about the water needs (B)	None	Water agency incorporating security of supply
Plantation Forestry	Very high	Short rotations (B) Increased fire detection and fire prevention Forward planning or even exiting the industry (B/C)	None	Information
Urban water (reticulated)	Low	Recycling (A) 3rd pipeline (F) Storage (F)	Regulatory and market-based instruments	Information Positive and negative incentives
Peri-urban	High	Groundwater bores (A) Community water supply (A/B)	Regulatory	Water agency installing supply infrastructure and positive incentives
Biodiversity	High	Riparian corridors (A) Captive breeding approaches (A)	Regulatory and Market-based instruments	Devise incentives and regulatory mechanisms to encourage change
Tourism	High	Snow industry – Snow making technologies (A) and developing off-season attractions (C)	None	Information

Note: The category that each adaptation option belongs to, in the Public-private benefit framework (Fig.1), is indicated in parenthesis.

Adaptation in the Agriculture Sector

The overall impact on agriculture is predicted to be negative as agriculture is the biggest abstractor of water in the region consuming about a two thirds of the total water supply. Livestock production is the largest contributor to the region's agricultural economy contributing $327m to the region's economy in 2006 (ABS, 2010). The major cropping enterprises include wheat, canola, oats and barley. Horticulture in the region includes grapevines, berries, apples and nuts. The agricultural sector is one of the sectors heavily affected by the low water availability in North East Victoria. Dryland farmers have experience and flexibility in adapting production plans to a range of contingencies including prolonged drought conditions, markets and technical change (Watson, 2010). However, not only is irrigated farming highly vulnerable to climate change effects of water supply but they are also less adaptable due to the rigidities imposed by high irrigation investments (Watson, 2010).

According to the region's economic make up, the grapevine industry is both an important activity in its own right and defines the character of the region to a great extent (Department of Primary Industries, 2008). The grapevine industry is also, to some extent, water dependent, although this is determined by the form of production, the age of the vineyard and the objectives of the producer. The recent drought has uncovered the capacity of wine growers to adapt. Several novel strategies have been adopted by wine growers in the region to deal with the low water availability and water dependency. These strategies include the use of the urban water market to maintain production and sale of water allocations and/or entitlements to adjust to new varieties in 2007-08 (Crase and Clarke, 2010). The regional urban water authority introduced a relatively straightforward mechanism for individuals and groups to access additional water without the expense associated with installing bores or carting water. This initiative was introduced to save the deterioration of community assets due to severe water restrictions applied amidst the ongoing drought at the time. The scheme was limited to organizations providing a community asset such as sporting fields (e.g. golf course) and businesses that were deemed to be water dependent. In simple terms, this amounted to a consumer purchasing a small volume of water from the water market and then using the urban water authority infrastructure to deliver that water. The costs of the water purchase and delivery charges were borne by the user. A wine producer adjacent to the urban water supply used this scheme to maintain the production during that year.

Arguably, without this innovative scheme, alternatives for this wine producer would have been severely constrained. Although using potable water may not be profitable in all cases, by changing institutional settings and allowing inter-sectoral water trade, the adaptation options were invariably broadened. Clearly, the government's role (the water agency, in this case) here is to remove impediments and restrictions to trade thereby facilitating climate change adaptation. Private benefits, in this case, are sufficient to trigger the behavioural change and the government does not have to make large investments (Area B in Fig. 1).

Dairy farmers in North East Victoria have been relying on perennial pastures to meet the nutritional requirements of dairy cattle. The cost associated with feeding dairy cattle varies significantly depending on the location and management regime. Substitution of grain and fodder for irrigated pasture in dairy enterprise under various scenarios has been researched extensively (Griffith, 2010). Transition to annual pastures with harvesting for silage and hay is another adaptation strategy in the dairy industry. Some dairy farmers were able to sell their water allocations and buy grain and fodder as a substitute for perennial pasture. However, the feasibility of such adaptation action largely depends on the grain and fodder prices (Crase and Clarke, 2010). Although the state government can play a role in assisting research and extension into substitution possibilities, the local governments' role in terms of direct intervention is limited (Area B in Fig. 1).

Adaptation in the Manufacturing Sector

The manufacturing sector is a prominent water user in the region. Two manufacturers in the region, in particular, are amongst the North East Victoria's top ten water users (Ananda, 2010). Water-intensity of manufacturing is one area that local governments must pay careful attention when enticing new manufacturers to the region. The available evidence indicates that water is an important input in the production process. However, utility costs including water, waste and electricity comprise less than 10% of the total production cost and raw materials and labour accounted for the lion share of the total production cost (Crase and Clarke, 2010).

Although water costs are relatively modest, the ability of manufacturers to respond to higher water prices depends on the degree of competition in its output market. If the firm is in a highly competitive market with low profit margins then it may not be able to handle larger water cost increases. Moreover, if the firm in question sells its output in the export market, exchange rate fluctuations can further exacerbate the problem.

One of the manufacturing firms interviewed for the study was a member of the advisory board of the water utility in the region and used its strategic relationship to inform the water needs of the firm and to deal with the risks associated with water supply interruptions (Crase and Clarke, 2010). The water utility would appear to be responsive to the potential needs of the manufacturer, at least to the extent that an emergency supply could be located in close proximity to the plant. If short term interruptions to water supply were to occur the plant would be forced to cease operation immediately and clearly this is not in the interest of the manufacturer or the water utility. This raises the issue of who should bear the water supply security risks – the beneficiary or the water utility? In this case, clearly, the water utility bears the supply security risk by incorporating alternative supply augmentation options such as water recycling. The local planning agencies that oversee the future expansions of manufacturing in the region must take into account the potential supply security issues when they attract water-intensive manufacturing businesses. The government action with regard to facilitating inter-sectoral water trade would enhance adaptation options and costs.

Urban and Peri-Urban Water Sector Adaptation

The responsibility for providing water and wastewater services remains with local institutions i.e. either the local government or water authorities. Several institutional configurations exist in water and wastewater service provision in Victoria ranging from fully public to state-owned corporations. Most of the government responses to scarce water supply have been driven by a rationale of supply security, particularly with regard to drinking water. However, the consensus on an acceptable level of supply security in drinking water remains elusive. Fortunately, the effects of climate change on the region's reticulated water supply will be moderate and in some cases benign. North East Victoria enjoys a relatively high security of water supply compared to some other regions of Victoria because of its proximity to regulated river systems and large storage facilities. This location advantage also provides scope for water trade to meet most demands of the regional towns in North East Victoria. However, the volume of water received in the region has progressively declined during the last decade. Rainfall is predicted to fall by as much as 7.2% by 2030 and 18.3% by 2070 (Beverly and Hocking, 2010). Water inflows into the upper catchment are probably more pertinent insomuch as the regulation structures (dams) upstream of Wodonga are the main drivers of water availability.

Securing the region's water supplies in the medium to long term period involves dealing with significant climate and policy-related constraints (Ananda, 2010). Compared to the reforms in the irrigation sector, where a more rigorous market mechanism has been proposed, the urban water sector relies on mandated and assisted behavioural changes such as water restrictions, incentives for water saving devices and recycling (Crase and Dollery, 2006). The effectiveness of these regulatory instruments has been questioned on both efficiency and equity grounds. Such discrepancies epitomize the use of different institutions within the water sector where policy makers trust market institutions such as water trade for irrigation management and regulation for urban water management. This discrepancy in water policy has negative implications for climate change adaptation.

The urban water supply throughout Australia is heavily reliant on rain-fed dams. Diversification of water sources has been proposed as a risk minimization and adaptation strategy (PriceWaterhouseCoopers, 2010). However, for most water utilities this is easier said than done because of the lack of access to alternative water sources. Moreover, artificial volumetric restrictions imposed on the inter-sectoral water trade constrain the urban water utilities' security of supply. For instance, in Victoria, there is an annual volumetric restriction of 4% on the purchases of irrigation water by urban water utilities (PriceWaterhouseCoopers, 2010). Instead of advancing policy reforms and demand management, the urban water sector is heavily focused on technological and manufactured supply augmentation options such as desalinisation plants, long-distance pipelines and recycling to address the urban water supply security (Areas A and F in Figure 1).

In contrast to urban water users, the more severe effects of climate change will be on small peri-urban communities (certain localities in Wangaratta and the Alpine LGAs) who do not have access to reticulated water supplies. Historically, these communities have been reliant on bore wells that tap the deep water aquifer below the Ovens Valley (Crase and Clarke, 2010). With predicted population and climate change impacts, the water level of this aquifer is expected to decline and the water utility has adopted a 'self-reliant households' approach which is quite contentious on equity grounds (Crase and Clarke, 2010). As an emergency measure, in severe water shortages, the water agency has transported potable water into these localities in the past. Households in these communities face weak incentives to make further capital investments in their own infrastructure. Essentially, the risk of water scarcity and the cost of transporting water to non-reticulated areas have been borne by the urban water uses in the more populous localities. This has been a challenging dilemma for water agencies as public policy should ensure a social safety net for vulnerable households who fall into the category of severely disadvantaged and below the generally accepted social norms (Crase and Clarke, 2010).

Adaptation in the Forestry Sector

The North East Victoria region has a significant forest plantation industry which supplies sawlogs, veneer and pulpwood to industries dispersed throughout the region. The sector faces considerable vulnerability due to reduced stream flows. Forest plantations use a substantial amount of groundwater although the forest industry has not yet been required to purchase extant water entitlements or allocations. Climate change resulting in reduced water availability will reduce the biological productivity and growth potential of standing forests and increase the extent to which they are exposed to forest fire risks. The latter is particularly important since forests that are harvested over long rotations can be devastated by forest fires. It is contended that fire risks do not substantially affect management practices on forests in terms of selecting harvesting schedules. The increased risk increases discount rates and only marginally reduces desired rotations (Crase and Clarke, 2010). The plantation operators clearly have an incentive to minimise losses due to reduced stream flows and biological productivity. Short rotations, increased fire detection and prevention and better forward planning or even exiting the industry are plausible adaptation strategies. These strategies clearly offer positive private net benefits (Area B in Figure 1) and hence the local governments, in this context, may assume a greater information provision role.

Adaptation in Biodiversity Management

There are major challenges in the management of biodiversity resources in the North East region. Biodiversity resources in the region have received less attention in the adaptation debate although there are good reasons for maintaining such an emphasis. The region has rich fauna and flora species which are labelled as 'nationally endangered'. They include the Box-Ironbark forests of Chiltern and parts of the Warby Range State Park. The consequences of climate change induced reductions in rainfall will invariably threaten the viability of these endangered ecosystems in the region. A reduced rainfall will reduce the food supplies, particularly blossom in flowering trees and hence the breeding success of rare and threatened species such as Regent Honeyeater, Turquoise and Swift Parrot, Peregrine Falcon, the Brush-tailed Phascogale and Squirrel Glider (Crase and Clarke, 2010). Adaptation options to improve the resilience of biodiversity include establishing wildlife corridors and captive breeding approaches in extreme situations (Clarke, 2007). Such adaptation actions construe the provision of public goods and are the most compelling cases for public intervention (Area A in Fig. 1). Public biodiversity adaptation action is a classic example of a 'No regrets' strategy. 'No regret' actions are actions that will accrue net benefits regardless the type or magnitude of climate change that occurs. If climate change predictions are accurate, the loss of biodiversity resources valuable to society will be minimised and if the threat of climate change has been overestimated, society still gains positive benefits from adaptation action.

Adaptation in the Tourism Sector

The region's tourism industry relies heavily on large water bodies (rivers, lakes and creeks), forests, parks, snowfields and grapevine production that provide numerous recreational opportunities. In particular, the hospitality industry (accommodation & food industry) is the largest employment provider in the Alpine Shire, reflecting the importance of major ski resorts such as Falls Creek, Mount Hotham, and Mount Buffalo for tourism. The accommodation and food industry accounted for 14.6% of the total employed whereas manufacturing and retail trade sectors accounted for 11.2% and 10.7% of total employment, respectively (Ananda, 2010). According to CSIRO forecasts, the areas with 60 days of snow cover per year will decline by 18-20% by 2020. The sector is highly vulnerable to climate change-induced water scarcity. Adaptation options in the snow resorts may include improved snow making technologies and/or developing off-season attractions for the site (Bicknell and Mcmanus, 2006, Lynch et al., 2009, Pickering and Buckley, 2010). These actions entail significant private benefits for the resort operators and fall under the areas of A and C in the public-private benefit framework discussed previously. Hence, in this instance, leaving adaptation responsibility at the discretion of the private sector is socially beneficial.

5. DISCUSSION

This section discusses several core considerations when formulating local government strategies in climate change adaptation. The local-level public institutions can play a major role by providing necessary information and supporting relevant research activities. This constitutes either indirect local government action supporting efficient adaptation activities in the private sector (i.e. individual households, firms, etc.) or direct adaptation policies where the government itself is the adapting agent. However, the distinction between these two categories is often blurred. For example, a local government program of adaptation education can be considered as direct intervention, but it also assists the private sector to adapt more efficiently.

Information Provision as a Policy Tool

One of the most intractable challenges for local government institutions is to find high resolution (both spatially and temporally) climate change impact forecasts. Without proper understanding of climate change impacts, it is difficult to carry out a meaningful vulnerability assessment. Even when forecasts are available, reconciling the discrepancies of climate change impacts between various forecasts has been difficult. Uncertainty and imperfect information about the consequences of climate change also create uncertainty about the benefits of adaptation. Hence, agents are reluctant to invest in adaptation options. Given this uncertainty, it is prudent to consider ‘No Regrets’ policy options.

Providing information on climate forecasts (short-term, medium-term and long-term) and impacts is one the core policy tool that local governments can use. Households and firms can reduce vulnerabilities and adapt when they have better and timely information. An important instrument of anticipatory adaptation is research and the dissemination of information (Fanhauser et al. 1999). Spreading better information concerning future climate, climate variability and benefits and costs of adaptation options has public good characteristics. Moreover, local institutions can promote the use of, and access to, climate change information among the community. Supporting research related to climate change adaptation enables expansion of the technical menu increasing the number of options available to firms and households when dealing with adverse impacts of climate change.

Local governments can also play a coordinating role in formulating regional adaptive governance processes and strategies. Inputs from many different local institutions are needed for adaptation planning. These may include water utilities, bulk water businesses, catchment management authorities, local departments of environment, planning and rural development, local councils and shires, local businesses, community groups, famers and landholders.

Moral Hazard Problems

The positive externalities imposed by climate change mitigation action are quite clear and they warrant a coordinated public policy response. In contrast, agents that take adaptation actions often benefit from such actions and the role of public policy response is far less clear (Crase and Clarke, 2010). In fact, public policy responses may inadvertently create moral hazard problems for firms and individuals who are interested in adaptation action. Moral hazard is defined as the actions of economic agents in maximising their own utility to the detriment of others in situations where they do not bear the full consequences or do not enjoy the full benefits of their actions due to uncertainty or incomplete contracts (Kotowitz, 1987).

The amount of autonomous adaptation to some climate change-related events may be lower if there is a perception that the government will reimburse economic agents for much of the damages arising from such events. Flood assistance, disaster relief subsidies, bushfire recovery assistance, ‘exceptional circumstances assistance’ etc. should be minimal and in line with addressing immediate basic needs of the affected community rather than prolonged compensation type payments which create a moral hazard and restrict behaviour modification. It may also crowd-out or reduce the need for private insurance for climate change adaptation. It would be sensible to look at removing perverse government policies that limit the capacity to adapt in the community.

Lowering Vulnerability Through Infrastructure Investment

Long-lived infrastructure investments that offer capacity to adapt are critical to adaptation planning. Often infrastructure decisions have been characterised as decisions taken on the run rather than after giving careful consideration to their short-term and long-term implications. Since infrastructure spending is politically attractive, they tend to be subject to less rigour and scrutiny and depart from least cost solutions. Most urban water infrastructure expenditures such as water storages, pipe capacity, water plants and treatment plants tend to be lumpy and cyclical. They are also location and firm-specific.

Another important characteristic is that once committed all infrastructure costs become sunk costs. One example from the study region is the proposal to build an extra water supply pipeline to deal with extra water demand in areas that cannot reply on local supplies. This type of infrastructure investment will only be provided by government because of the natural monopoly or economies of scale characteristics of the public supply of water technology. Compared to dam constructions and desalinisation plants, this type of investment does not require long lead time in planning. If the project does not require longer lead time in planning, then it is better to take a cautious approach and wait and see what climate and water supply outcomes do eventuate before committing to expensive infrastructure projects. In this context, the recently commissioned desalinisation plant at Wonthaggi, where public monies were hastily committed, provides a classic example. The plant was established under a public-private partnership between *AquaSure* Consortium and the Victorian Government with a capital cost of $3.5 billion (Edwards, 2012). According to an analysis by *PriecWaterhouseCoopers*, Victorians will pay *AquaSure* a service payment of $654 million per year from 2012-13 onwards even if no desalinisation water is taken (Tomazin and Millar, 2011). A staggered development or a ‘wait and see’ approach would have been economically efficient as the Victorian Government declared that it does not need water from the desalinisation plant for 2012-13(Millar and Schneiders, 2012).

6. CONCLUDING REMARKS

Since the prospects for a binding agreement on climate change mitigation are uncertain, policy makers increasingly attach more importance to the topic of adaptation. Although critical, adaptation decision making at the local level is less guided. Given the financial resources and potential perverse incentives that the government policies could create, it is important that local government institutions fully appreciate the range of issues at play when formulating local and regional adaptation strategies.

One notable approach to adaptation at the local government level is the risk management approach. This approach is primarily driven by future liability concerns that may arise from breaches of duty of care by the local government. On the other extreme, large public funds have been committed to adaptation projects without careful planning. This paper examined the role of local institutions in adaptation planning for reduced water supplies from a public policy perspective. It did not attempt to identify specific high-priority policy options, but rather analysed the policy rationale for direct and indirect government intervention offering some insights on potential policy tools to encourage adaptation investments.

The analysis indicates that the region's agricultural and plantation forestry sectors are the most vulnerable sectors to a reduced water supply due to climate change. Although certain types of agriculture such as dairy farming may potentially substitute grain and fodder for irrigated pastures, their prices largely determine the economic feasibility of such adaptation. Since there are significant net private benefits from this type of adaptation, direct intervention by the government may be sub-optimal. However, institutional reforms facilitating water trade can enhance adaptation options for the agriculture sector. In the plantation forestry sector, there are private incentives to adopt shorter rotations, increased fire detection and better forward planning to a low water future. Local governments, in particular have a role in addressing information asymmetries related to these adaptation options.

The manufacturing sector adaptation to reduced water supplies prompts the question – who bears the water supply security risk? Currently, neither the responsibility of urban water supply security nor its articulation to water customers is clear cut. Hence, the local governments are ideally placed to facilitate better collaboration and communication between water-intensive manufacturing firms and water utilities. Urban and peri-urban sector adaptation also requires clarity on the appropriate level of water supply security. In these cases, the reliance on rigorous market mechanisms than mandated behavioural changes such as water restrictions has more merit. Removing the artificial barriers to inter-sectoral water transfers such as the volumetric restrictions would invariably enhance private adaptation options. Adaptation measures for managing biodiversity resources present the most compelling case for public intervention as they can be justified by a 'no-regret' philosophy. Tourism sector adaptation actions clearly entail private net benefits and public investments must be limited to the provision of high resolution climate impact information which is vital to make better adaptation decisions.

A comprehensive water resource planning is critical for water businesses and local governments delivering water services. Urban water businesses have 3-5 year planning cycle during which they formulate water plans that outline water supply demand strategies. This entails significant lag time in infrastructure development and pricing changes. Nevertheless, adaptation to climate change must be fully integrated into water resources planning and management. Prudent infrastructure management that addresses supply security is another area that local governments and water businesses must focus on. It may be worthwhile for local governments and urban water authorities to pay more attention to behavioural changes than solely relying on engineering solutions.

The findings of the paper provide several policy implications for drought assistance, bushfire and flood assistance schemes. In all three cases, public policy may inadvertently create moral hazard problems for firms and individuals who may be interested in private or autonomous adaptation measures. A cautious approach to infrastructure investments aimed at reducing the vulnerability to natural disasters is warranted given the presence of considerable uncertainty.

A public policy approach to climate change adaptation can help answer important research questions. It helps the policy maker to identify the cases where local government intervention is desirable and where it is not. In most of the economic sectors analysed, provision and distribution of information about regional climate change impacts are central and they are necessary tasks of the local government because information related to adaptation is a classic public good. In certain cases, the optimal policy would be to take no action or adopting a ‘wait and see’ approach. If the private net benefits of adaptation exceed the public benefits, direct intervention by the government may not be needed. However, it is important to establish adequate safety nets for marginal communities who are most vulnerable to adverse impacts of climate change-induced water shortages.

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Annex Table 1: Climate change impact predictions for North East Victoria. Source: Department of Sustainability and Environment (2008)

Variable	Changes
Temperature	• Annual warming of 0.3 to 1.6°C by 2030 and 0.8 to 5.0°C by 2070 • Daytime maximum temperatures and night-time minimum temperatures are likely to rise at a similar rate • Warming is likely to be greater in spring and summer • 10-60% increase in the number of hot days (≥35°C) by 2030 and 20-300% increase by 2070 on the plains. Rate of increase will greater in the mountains • 0-50% reduction in the number of frost days by 2030 and a 50-100% decrease by 2070
Rainfall	• Annual rainfall decreases are likely (changes of +3 to -10% by 2030 and +10 to -25% by 2070 • Extreme daily rainfall events are likely to become more intense
Snow	• Area with at least 1 day of snow cover per year is likely to be reduced 10-40% by 2030 with 22-85% by 2050 • Area with at least 60 days of cover shrinks 18-60% by 2020, and 38-96% by 2050 • At Mt Hotham, peak snow depth declines 10-50% by 2020, and 25-95% by 2050
Drought	• Droughts are likely to become longer and more frequent, particularly in winter-spring • Rainfall deficiencies that currently occur once every 5 winter-spring may occur once every 3-5 years by 2030 and once every 2-3 years by 2070 • Due to hotter conditions, droughts are also likely to become more intense
Fire	• 10-40% increase in the frequency of days with extreme fire-weather risk by 2020, and 20-120% increase by 2050 • 4-25% increase in the frequency of days with very high and extreme fire-weather risk by 2020, and 15-70% increase by 2050
The climate of Wangaratta	• A 1°C warming and a 5-10% annual rainfall decrease (a moderate scenario for 2030) would make the climate of Wangaratta more like the current climate of Cowra in NSW

Annex Table 2. North East LGA future climate percentage change in water balance. Source: Beverly and Hocking (2010)

	1995-2005	2030 Low	2030 Medium	2030 High	2070 Low	2070 Medium	2070 High
Alpine Shire							
Rainfall	-5.8	-1.2	-2.5	-4.1	-3.8	-8.3	-14.3
Runoff	-3.0	-21.8	-26.1	-31.2	-29.4	-41.6	-51.6
Evapotranspiration	2.1	0.1	0.7	1.3	1.3	2.6	2.4
Recharge	-11.1	-4.0	-6.8	-10.3	-9.8	-19.0	-30.1
Streamflow	-14.8	-2.0	-5.5	-9.7	-9.1	-20.5	-33.7
Total flow	-17.6±3	-3.1±1	-7.2±2	-12.3±3	-11.6±2	-25.3±5	-41.2±8
Indigo Shire							
Rainfall	-1.4	-3.5	-4.9	-6.6	-6.3	-11.2	-17.8
Runoff	2.6	-11.6	-15.5	-20.0	-18.8	-29.9	-40.3
Evapotranspiration	2.3	-1.3	-1.6	-2.1	-2.0	-3.9	-7.8
Recharge	-8.3	-7.3	-10.8	-15.1	-14.3	-25.3	-37.3
Streamflow	-8.6	-7.6	-11.3	-15.7	-15.0	-26.2	-38.2
Total flow	-10.7±2	-9.4±2	-14.1±3	-19.5±4	-18.6±4	-32.5±6	-47.5±9
Towong Shire							
Rainfall	-2.0	-3.5	-4.7	-6.2	-6.0	-10.3	-16.1
Runoff	-2.5	-29.4	-34.3	-39.9	-37.8	-50.9	-60.9
Evapotranspiration	2.5	-0.2	0.1	0.3	0.4	0.4	-1.4
Recharge	-8.0	-8.8	-12.1	-16.1	-15.5	-25.9	-37.2
Streamflow	-9.4	-8.7	-12.6	-17.3	-16.7	-29.0	-42.6
Total flow	-11.4±2	-10.9±2	-15.6±3	-21.3±4	-20.6±4	-35.5±6	-51.9±9
Wangaratta Shire							
Rainfall	-4.5	-1.4	-2.8	-4.5	-4.2	-9.1	-15.7
Runoff	-1.5	-20.0	-24.9	-30.4	-28.1	-41.0	-50.0
Evapotranspiration	1.8	-1.0	-1.1	-1.2	-1.1	-2.1	-5.0
Recharge	-13.6	-4.2	-8.0	-12.5	-11.8	-23.8	-37.3
Streamflow	-16.8	-0.7	-4.7	-9.6	-8.9	-21.4	-35.1
Total flow	-20.2±3	-1.8±1	-6.8±2	-12.7±3	-11.9±3	-27.4±6	-44.4±9
Wodonga Shire							
Rainfall	-1.2	-4.1	-5.5	-7.2	-6.9	-11.7	-18.3
Runoff	-5.1	-6.4	-11.0	-16.5	-15.4	-28.8	-41.1
Evapotranspiration	2.3	-2.5	-2.9	-3.4	-3.4	-5.5	-9.8
Recharge	-9.1	-7.5	-11.2	-15.7	-15.0	-26.2	-38.2
Streamflow	-9.4	-7.6	-11.6	-16.5	-15.7	-27.9	-40.5
Total flow	-11.7±2	-9.5±2	-14.4±3	-20.4±4	-19.5±4	-34.5±7	-50.1±10

Annex Table 3. Preliminary vulnerability assessment – Alpine Shire. Source: Crase and Clarke (2010)

Activity	Water Dependency	Predicted Decline in Streamflow by 2030		Substitution Opportunities	Lead time requirements	Other comments
		Low	High			
Tourism	2	2.0%	9.7%	1	1	Snow making technologies may be required. Attention to development of off-season attractions at discretion of private sector.
Forestry	3			3	3	Processing unlikely to be directly at risk but contraction of forested area probable.
Agriculture	2			2	2	Varies depending on mix of perennial and annual activity.
Manufacturing	3			1	1	Almost all manufacturing has access to potable supplies with accompanying planning.
Urban reticulated	3			1	1	Planning and consideration of alternatives generally sufficiently advanced. Reliance on groundwater as an emergency supply also warrants review give current over-allocation identified in Deliverable 1.
Peri-urban	3			2	2	Categorization of 'self-reliant households' requires additional policy and planning consideration. Reliance on groundwater as an emergency supply also warrants review give current over-allocation identified in Deliverable 1.
Environmental assets	3			3	3	Refuge and biodiversity aspects appear vulnerable. Integration with tourism and other activities suggest advocacy role by local government, at least.