Horticulture Australia Council & Horticulture Australia Ltd

Submission to the House of Representative's Standing Committee on Primary Industries and Resources Inquiry into the role of Government in assisting Australian farmers to adapt to the impacts of climate change

Horticulture Australia Council (HAC) and Horticulture Australia Limited (HAL) welcome the opportunity to provide this submission to the Parliament of Australia House of Representatives Standing Committee on Primary Industries & Resources, on the role Government can have in assisting Australian horticultural growers adapt to the impacts of climate change. Consultation on this submission has been made with the across-horticulture Industry Management Committee, with HAL and HAC members.

The Terms of Reference for the submission were to examine the role of government in assisting Australian farmers to adapt to the impacts of climate change. Specifically:

- Current and prospective adaptations to the impacts of climate change on agriculture and the potential impacts on downstream processing.
- The role of government in:
  - Augmenting the shift towards farming practices which promote resilience in the farm sector in the face of climate change;
  - Promoting research, extension and training which assists the farm sector to better adapt to climate change.
- The role of rural research and development in assisting farmers to adapt to the impacts of climate change.

Submissions are due Friday 20th March 2009[1] to: pir.reps@aph.gov.au

For further information on this submission please contact:

Alison Turnbull
Natural Resources & Climate Manager
Horticulture Australia Limited

[1] Note that an extension to this submission was granted – revised due date is Friday 6th April 2009

EXECUTIVE SUMMARY

Climate change and increased climate variability will present a number of challenges for horticulture and natural resource management in Australia over the next 30 to 50 years. Growers and communities will need to make decisions that increase resilience, allow for adaptation and seek approaches for mitigating greenhouse gases. This requires R&D that promotes innovation in science, tools development and policy development.

Horticulture in Australia is intensive, generally irrigated, agriculture. Horticulture is a diverse industry, spread across the continent in a wide array of climates. Horticulture is the second-largest and fastest growing industry in agriculture; with some 30,000 businesses nationally, and a farm gate value of ~$9 billion. The industry contributes positively to the economic, social and environmental elements of the Australian community.

The Australian horticulture sector has historically been successfully adapting to the challenges of changes in climate, water availability and weather extremes, and the industry continues to value improvements in production efficiencies and best management practices as approaches to managing ongoing variability and change.

The horticulture industry is nevertheless at risk to the impacts of climate change and climate variability. Climate change has already or has the potential to result in:

- Enterprise structure and location
- Crop selection/mix
- Irrigation management
- Changes in crop windows
- Soil management practices
- Management of pest and disease
- Business size/location
- Increased public and political pressure on the use of resources

These impacts vary to other agricultural industries, but will also vary between and within commodities, regions. The greatest impacts will not just be physical challenges, but rather the implications of climate change policy.

There will be an impact of the Australian Government's Carbon Pollution Reduction Scheme on the horticulture industry, with or without agriculture's involvement in the CPRS, as industry is exposed to high compliance costs, increases in input costs and the financial impact of flow-on costs from the supply chain that supports it.. There is a need for Government to acknowledge the impacts and to help HAL & HAC assist industry to adapt to these challenges.

Horticulture will have to contend with not only these direct climate change implications, but also the pressure of providing for increasing world food demand, coupled with an increasing demand for productivity growth. However, this rate of growth will be limited by the land

availability, distribution channels (effective supply chains) and domestic food security responses. Coordinated research response is required to better understand and inform responses to ensure no perverse outcomes as a result of these issues.

Due to the diversity of the industry and the anticipated impacts climate change poses for horticultural businesses, the research responses that industry is and will need to continue to implement to manage and adapt to climate change are varied.

Industry has invested approximately $18.8 million into research projects that are helping horticultural growers adapt to climate change – including projects on water use efficiency, surviving the drought, pest management, best management practices and climate variability projects (see attached spreadsheet of projects). In comparison with the extensive climate change and climate variability R&D conducted in broad-acre agriculture and the grazing industries, this investment by horticulture is smaller and mainly involves more recent investments as a result of the drought.

There is a significant amount of research already undertaken, but there are still gaps in climate change research relevant to horticulture, and further investment is required. Uncertainties include:

- limitations in modeling,
- impacts,
- adaptation responses and
- policy.

The Horticulture Climate Change Action Plan (HCCAP) has been recently developed specifically to identify urgent RD&E needs for the area of climate change/variability within the HAL Environment Portfolio. The HCCAP has three strategies:

1. Adaptation,
2. Mitigation, and
3. Information, Awareness and Communication.

Overall, the best defence against future climate change is to continue to develop the capacity and knowledge so that growers can make effective business decisions, minimize risk, and manage our response to current climate variability more effectively. This will ensure both the long-term viability and sustainability of our industry, and continued availability to consumers of fresh and health-giving horticultural outputs.

To this end;

- It is critical that government co-sponsoring of horticultural research be continued and to prepare for the challenges of climate change, be increased.
- A list of research areas that would help horticulture understand and adapt to climate change (under the HCCAP) is provided in the document and should be supported.

- It is vital that Government supports the collaborative approach to managing climate change already being supported by primary industries– through the Climate Change Research Strategy for Primary Industries (CCRSPI) program.

- The government needs to work with horticulture to help it adjust to the significant impacts expected by climate change and the introduction of the government's Carbon Pollution Reduction Scheme

To ensure the continued viability of the Australian horticulture industry, HAL and HAC very ready to explore the recommendations further with the Australian Government and other stakeholders if/when appropriate.

Table of Contents

Introduction to the Australian Horticulture Industry

Horticulture Australia Limited & Horticulture Australia Council

HAC is the peak national umbrella organisation representing the Horticulture sector; and currently has nineteen members (national peak industry bodies for the various horticultural commodities, and state grower associations). HAC was formed as a not-for-profit association to effectively deal with the increasing number of critical issues that are threatening and challenging the livelihood of horticultural industry stakeholders. HAC's intention is to speak with one clear, strong voice in order to better promote the worth and importance of the horticultural industry both in Australia and overseas.

HAL is the industry's national rural research and development corporation (RRDC) for the horticulture industry and has an annual expenditure of $80 million in projects in partnership with the horticultural sector and governments. HAL manages more than 1,200 projects annually across a wide diversity of topics to fulfill its mission, of investing in programs that provide benefit to Australian horticultural industries and the producers whose levies make up a significant proportion of its funding.

Value of horticulture

Horticulture in Australia is intensive, generally irrigated, agriculture. Horticulture is a diverse industry, spread across the continent in a wide array of climates. Horticulture is the second-largest and fastest growing industry in agriculture; with some 30,000 businesses nationally, and a farm gate value of $9 billion. Total horticulture exports (including fresh fruit, vegetable, nuts and plants including flowers) were $751m (12 months to May 2008). As the most labour intensive of all agricultural industries, Horticulture employs around one-third of those employed in agriculture.

Horticulture includes vegetables, fruit, grapes (dried, fresh and wine grapes[2]), nuts, mushrooms, nursery, turf, cut flowers and extractive crops.

The industry is the principal driver of many local communities and economies in rural and regional Australia (the average multiplier for horticulture in regional and rural Australia is x factor of 5). Members of the horticultural industries take seriously their responsibilities to operate within the constraints of environmental and climatic conditions; significant research and extension work has taken place within the industry over the past decade to ensure that horticulture's Water Use Efficiency (WUE), for example, is world's best practice.

The major growing regions in Australia include the Goulburn Valley of Victoria, the Murrumbidgee Irrigation Area of New South Wales; the Sunraysia district of Victoria/NSW; the Riverland of South Australia; northern Tasmania; southwest Western Australia; the coastal strip of northern New South Wales; and Queensland. In broad terms, approximately one-third

[2] Note however that viticulture is NOT one of HAL/HAC members, and is covered by the Grape & Wine Rural Research and Development Corporation.

of Australian horticulture is located in Queensland, with another third along the southern Murray Darling Basin (MDB). Amenity horticulture (nursery and turf production, landscaping and urban green spaces) generally occurs in, and close to, metropolitan centers.

For further information on the breadth of the horticulture industry, including the top five fruit and vegetable crops by value of production and total of production and the estimated value of horticultural production by state, please see appendix 1.

The significance of the horticulture Industry to the Australian economy is not limited to the value of the production of the industry. The horticulture Industry is also a significant supplier to, and consumer of the products of, other industries.

As a supplier, the horticulture industry provides raw inputs to a range of Australian industries. For example, the Fruit and Vegetable Product Manufacturing Industry and (to a lesser extent) the Other Food Manufacturing Industry, both depend on horticulture produce[3Error! Bookmark not defined.]. The horticulture industry also purchases inputs from various sectors of the Australian economy. For example, the fertiliser industry depends on demand from horticulture enterprises, while the horticulture industry uses a significant amount of transport and storage services.

In Australia there is a wide diversity of enterprises (scale and nature) involved in horticultural production. The range is from hobbyists who regard horticulture as a secondary source of income or producers whose turnover is less (often significantly less) than $100K per annum, up to family-owned and large corporate holdings who have sales in excess of $40 million per annum. Thus the industry contributes significantly to regional communities and development of employment opportunities.

Horticulture also provides significant social and health benefits to the Australian community. Eating plenty of fruit and vegetables not only contributes to good health, but also protects against a number of diseases and helps maintain a healthy weight. For consumers there is a level of trust and an expectation that they can purchase safe and healthy products that are produced in a sustainable manner.

The industry also contributes to the environmental, physical and psychological benefits, through urban greenlife. The importance of the outdoor room has become entrenched in contemporary life-styles and building design. Outdoor rooms are adding value to homes, as renovators and homebuyers place increasing importance on this home design feature. Recent consumer surveys show that the two most popular views that express homeowners associations with their garden were "relaxing in their garden" (75%) and "entertaining with family and friends" (68%)[4].

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[3] Horticulture Australia Limited (2005) "Final Horticulture Sector Submission to: Ensuring a profitable and sustainable agriculture and food sector in Australia" (Agriculture and Food Policy Reference Group White Paper)

[4] Freshlogic (2008) "Australian Garden Market Monitor – for the year ending 30 June 2008"

For all the benefits the horticulture industry provides, it also strives to ensure it has a relatively small environmental impact. Australia's horticulture producers are already leading the way in environmental management. The horticulture industry is reliant on natural resources, especially water for irrigation, and as such is focused on implementing best management practices to reduce its impact on these resources. Horticultural crops account for only 17 per cent of total irrigation but produce more than 40 per cent of Australia's irrigated production. Figures suggest that for every 100 mega litres of water used in horticulture $250,000 and four jobs are generated at the farm gate and approximately $0.5 billion injected into the economy.

Horticulture emissions equate to just 1% of agriculture's emissions, or some 0.2% of Australia's total emissions.

This low level of emissions is due in part to the type of crops grown. The mixture of perennial crops such as tree fruits, tree nuts and vine fruits, combined with seasonal vegetables and herbs provides carbon storage above ground. The fact that minimal tillage is involved further helps to build up and contain carbon in the soil.

Improvements in natural resource management and in productive capacity over the past decade have shown that horticulture can meet consumer and community expectations for sustainable production, both now and over the longer term. The horticulture industry acknowledges environmental stewardship as an industry priority and has invested heavily in improving environmental management.

Impacts of climate change in horticulture

The Australian horticulture industry has been, and will continue to be, impacted by climate change and variability. Due to horticulture's dependence on natural resources, especially irrigation, it is inherently vulnerable to climate change and variability. Furthermore, all horticultural crops are sensitive to temperature, and most have specific temperature requirements for the development of optimum yield and quality[5].

Aside from the physical impacts of climate change on horticultural products and businesses, the industry will also be impacted by the global demand for food, increasing demand for productivity growth in response to this global demand, and the impacts of climate change policy.

These impacts are detailed further below.

Physical impacts

Global climate change scenarios for medium- to long-term changes in climate can vary considerably at regional scale, but all commonly predict Australia's climate to become hotter, drier and even more variable than current averages.

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[5] Deuter, P.L. (2008). "Defining the Impacts of Climate Change on Horticulture in Australia." For the Garnaut Review – Feb 2008. – http://www.garnautreview.org.au/CA25734E0016A131/pages/all-reports--resourcescommissioned- reports (accessed 8th Dec 2008).

Many horticultural regions have already seen a rise in both maximum and minimum temperatures compared with the 1961 to 1990 base period. As a result of these changes, growers have already experienced up to 1˚C rise in temperatures, and have successfully adapted to these changes.

The drought – most particularly the Irrigation Drought – has also had severe impacts across most horticultural production regions (including the MDB).

Nevertheless, there is still uncertainty as to the extent of the impacts climate change will have on individual horticultural businesses because:

- Impact assessments for broad-acre agriculture, especially for the wheat industry have been published widely. This is not the case for horticulture, except for viticulture; and as a result, there are currently no scientifically validated or published assessment tools available which have been designed specifically with the requirements of horticultural industries in mind.
- Thresholds, such as temperature extremes, for the large range of horticultural crops are also not well known, especially for the vegetable sector.
- Arriving at an understanding of the effects of climate change is made even more complex by the large number of commodities classified as horticultural crops (over 100 in Australia), and the wide range of regional climates which exist.

The extent and timing of direct physical impacts of climate change on horticultural businesses may not be quantified, but include all of the following:-

- Changes in the suitability and adaptability of current cultivars as temperatures change, together with changes in the optimum growing periods and locations for horticultural crops
- Changes in the distribution of existing pests, diseases and weeds, and an increased threat of new incursions
- Increased incidence of physiological disorders such as tip-burn and blossom-end rot
- Greater potential for downgrading product quality e.g. because of increased incidence of sunburn
- Increases in pollination failures if heat stress days occur during flowering
- Increased risk of spread and proliferation of soil borne diseases as a result of more intense rainfall events (coupled with warmer temperatures)
- Increased irrigation demand especially during dry periods
- Changing reliability of irrigation schemes, through impacts on recharge of surface and groundwater storages

- Increased risk of soil erosion and off-farm effects of nutrients and pesticides, from extreme rainfall events

There is the potential that increased atmospheric CO^2 concentrations will benefit productivity of most horticultural crops, although the extent of this benefit is unknown. There is also the high probability that these benefits will only be felt with the lower-range predicted temperature increases, and that in the long-term these will potential growth benefits will not continue.

Extended drought conditions and reduced resilience

The availability of water for irrigation is currently (and perhaps for the foreseeable future) the most limiting factor in horticulture production (and agriculture in general), especially within the Murray Darling Basin. As a consequence, the impacts associated with limited irrigation water availability include:-

- Water security and capacity to deliver water (channel system) is, and will continue to have an effect on which crops can be grown
- It is estimated that 30% of water is lost in the delivery system (earth channels). Changing this by lining or piping could make a very significant difference to the amount of water available to growers
- Improved water use efficiency might be achieved by using other methods of irrigation e.g. drip/trickle. This will depend on other changes as well, including the need for on-farm storages, or a changed delivery mechanism
- Drip/trickle irrigation may also provide other advantages over traditional irrigation methods, including more timely agronomic operations which are independent of irrigation timing – i.e. furrows are not wet, so operations such as pesticide application can be carried out at any time; irrigation can be continued up to harvest if necessary – furrow irrigation must be discontinued sometime.

The extended drought in nearly all regions of Australia or at least in some regions over the last five years, has caused considerable irrigation water shortages which in turn has either stopped crops being planted, crops failing, or in some cases trees or vines being removed or dying.

In the previous irrigation season (2007/08) up to 20% of permanent plantings within the Murray Darling Basin were 'dried off'. For those that could afford to, over 267,000 ML of water was purchased by horticultural businesses in Sunraysia and South Australia at a cost of up to $1,200/ML. This extremely expensive water was purchased to sustain permanent plantings to avoid 3 to 7 years lost income and the large capital cost for replanting.

The most important message and lesson from the previous irrigation season (2007/08) has been that harvest was disappointingly low in many tree and vine crops. Most irrigators put this down to under-watering during critical spring periods such as flowering, and/or crops being allowed to get too dry at the end of last year (when a zero percent allocation was forecast). As a result, minimal watering over previous years and low winter rainfall meant that subsoil

moisture was not built up. Subsoil moisture was too low throughout this season and there were insufficient moisture reserves to cope with warmer conditions when they arrived. It is believed that this contributed to small fruit on tree crops and massive berry collapse in grapes (especially table grapes). This effect has been highly variable according to the extent of under-irrigation.

The long-term impact of this 'irrigation drought' continues. There will continue to be a hangover of high debt and less income, there will be growers afraid to replant due to insecure future water, a decline in property values to water value only, as well as production impacts such as tree health, productivity, quality etc.

Economic impacts

Introduction of the CPRS

Greenhouse gas emissions (GGE) management is predicted to be the next big expense for agriculture, with or without agriculture's involvement in the Carbon Pollution Reduction Scheme" (CPRS). Primary industries are exposed to both increases in input costs and the financial impact of flow-on costs from the supply chain that supports it.

Coupled with the fact that for Australian agriculture, there is seems to be little benefit in the CPRS, due to primary industries not being eligible for carbon certificates.

It is therefore felt that the mitigation policies pose a greater challenge for agriculture, including horticulture, than the physical impacts of climate change itself.

The horticulture industry acknowledges the need for mitigation of emissions as an urgent national action – the horticulture industry is extremely vulnerable to temperature and weather extremes posed by climate change scenarios and therefore supports action to mitigate and reduce emissions at a global and national level.

However, there is a need to ensure that any climate change policies that are implemented take into account the differences between agriculture and other industries and the differences within agriculture as well. Otherwise, there is the potential for perverse outcomes from the implementation of regulatory approaches, such as the CPRS.

The horticulture further acknowledges that it has a part to play in mitigating the nation's emissions.

Agriculture in Australia was responsible for 16.5 per cent of Australia's GHG emissions in 2004 - making it the nation's second largest emitter (after energy sector). The Australian agricultural and land use sectors have already made a significant contribution towards Australia's commitment to reduce its greenhouse gas emissions to 108 per cent of 1990 levels by 2012, principally through reduced land clearing. Agricultural activity can influence the atmospheric level of three of the major greenhouse gases - carbon dioxide (CO2), nitrous oxide (N2O), and methane (CH4) - both as a source and a sink.

It is important to acknowledge the difference between emissions from horticulture and the rest of the primary industries. Horticulture's contribution to these emissions is small –

approximately 1% of agriculture's GGEs, which equates to ~0.2% of total national emissions. Emissions from horticulture production result mainly through nitrogen release from fertilisers.

Horticulture has a limited ability to mitigate compared to other primary industries – the industry is a small emitter and reduction of these emissions will mainly come from improvements to fertiliser management and application. The emissions reductions from these improved practices will be much smaller than potential emissions gains in the livestock industry.

At present, agriculture is not due to be included in the CPRS. However, that does not exclude agriculture being included in the future.

Due to the media interest in this issue, industry members are becoming increasingly interested in the perceived opportunities such as carbon sequestration and trading in offsets. But is there really an opportunity for industry in the CPRS?

There is a need to ensure that industry members are aware of the difference between the perceived opportunities and the actual realities of what the CPRS will mean for them. This includes clarifying terminology to dispel confusion, assessing the actual amounts of emissions produced through horticulture production (such as through carbon footprinting and/or life cycle analysis) and determine practices to reduce GGEs cost effectively (mitigation) where appropriate.

There is also a need to better understanding the economic implications of the introduction of a CPRS can have on horticultural business.

For example the cost of freight, packaging, pesticides and fertilizer will increase as a result of greenhouse gas mitigation activities, and the increasing costs of fossil fuels. Post-harvest cooling costs for most vegetable and fruit crops will also increase as additional field heat will need to be removed prior to transport to market.

Recent economic modeling by the Australian Farm Institute and the Centre for International Economics identified that the CPRS will reduce the value of agricultural production, with focus on the beef, wool, sheep, meat, pork and dairy sectors[6]. There is a need to better understanding the compliance costs, increase in input costs and identify potential opportunities to offset these negative economic impacts of the CPRS for horticultural commodities.

Increasing competition for resources

As a result of drought in some areas across Australia, water entitlement costs have increased by over $1,000 per ML (in some areas), although in a number of irrigation systems there has been no or limited water supplies available at any cost. This has resulted in some cases in the loss of tree crops and very limited production of annual crops we estimate approximately 50% exit of growers in the Riverland by the end of the 2007-08 season; and current forecasts show

[6] Australian Farm Institute (2009) "Some impacts on Agriculture of an Australian Emissions Trading Scheme"

a decrease of 50% in wine-grape growers, and perhaps 30% in citrus growers in the Sunraysia by the end of the current season.

The multiplier effect is that more irrigation (water) will be required into the future, because of higher evapo-transpiration demand, for preventing tip-burn (lettuce) and other induced disorders such as blossom-end rot (tomatoes).

Increases in input prices over the last five years as a result of drought and the inability to pass any or a significant proportion of these costs onto the growers' customers, has impacted significantly on farm profitability. Without farm profitability, horticultural businesses are being forced to consider whether to exit the industry, or to continue to farm in an environment of steadily increasingly input costs.

Social impacts

The current situation for many in Horticulture during the current drought (particularly in, but not limited to, the deepening crisis in the lower MDB) has resulted in an unprecedented process of unplanned structural adjustment on a massive scale. Unfortunately, there has not to date been a strategic or systemic response to the crisis from governments; particularly in regard to community resilience and social infrastructure.

Drought is an inherent part of agriculture in Australia. There has been a long history of general community expectation that governments should provide assistance when droughts become 'exceptional'. However, there is no consensus as to how best this might be done. Nor is there uniform agreement on what is meant by 'drought', let alone what form of intervention governments should provide in the event that an 'exceptional drought' does occur. Indeed, current

Commonwealth-State approaches to drought are too complex, lack consistency, are inefficient, and do not deliver assistance that is needed when and where it can do most good, particularly for horticultural enterprises.

Consequences of drought directly impact on growers, farming families, local businesses and regional communities. It is not possible to clearly separate economic sustainability of producers and regions from the social impacts on those regions and communities, and the multiplier for horticulture is estimated, on average, as a factor of five (5).

For the first time ever horticulture producers across the country have been seriously impacted by this drought. This has resulted in outcomes that are outside those usually experienced by farming operations and the communities that support them. Horticultural production units are far more intensive than broadacre operations, and are in the main irrigated. The impacts of drought on perennial plantings have been devastating. As large labour users, the resultant business consequences have been dire not just for our growers, but also for the communities which rely on them as key economic drivers.

Consequences of drought directly impact on growers, farming families, local businesses and regional communities. Horticulture is inextricably linked with the economic, social and cultural vigour and sustainability of significant numbers of regional communities spread widely across

the country. It is not possible to clearly separate economic sustainability of producers and regions from the social impacts on those regions and communities, and the multiplier for horticulture is estimated, on average, as a factor of five (5).

As Cyclone Larry's impact on north Queensland's communities or the deepening crisis in the MDB amply illustrate, it is not possible to view economic or social consequences of drought or disaster in isolation.

In March this year, the Victorian Department of Sustainability and Environment's executive director (Campbell Fitzpatrick) reported that the Victorian towns located along the Murray that are irrigation-dependant - such as Mildura and Swan Hill - will be impacted significantly by climate change, through the removal of water from those locations. This human aspect of climate change, already a reality in South Australia's Riverland, is a real risk for horticulture and the significant regional and rural communities it supports.

Impacts on health and well-being

The emotional toll on growers, their families and communities of climate change impacts to date (such as increased incidence of drought and reduced water availability), is increasing for horticultural businesses which have large investment in their irrigation-reliant crop system.

The low irrigation allocations have created a level of uncertainty throughout the industry; and changing allocations and inconsistencies between regions do not provide growers with the confidence in their water security. Some families have increasingly needed to seek off-farm income to remain viable. The WinHort (Women in Horticulture) Network no longer exists nationally, but some attempts have been made to enable local networking and encourage growers to socialize and share their issues in a casual setting. However, this local movement is not always successful as people under stress tend to withdraw. Uncertainty, increasing workloads and increasing debt all contribute to the stress of growers. This will have significant impact on future communities, employment in rural areas, and the health and well-being of those current members of the industry.

Case study: Evidence of impacts of climate change in horticulture

There has been a single across-horticulture project undertaken recently in an attempt to quantify and better understand the impacts of climate change on individual horticulture businesses through grower workshops/interviews. The aim of this review was to better inform the research, development and extension (RD&E) response required to help horticultural businesses adapt to these impacts.

The following are the responses by citrus and vegetable growers in the Central Riverina district to the question, "What are the impacts of the past and future changes in temperature on your farm/business/crop/industry?"[7]

[7] Deuter, P.L. (2009) "AH06019: Australian horticulture's response to climate change and climate Variability"

- Earlier maturing crops (citrus/grapes) by about 10-14 days. This has had a positive effect – earlier on the market.
- Earlier maturing crops (vegetables – sweet corn and rockmelons) by about 14 days.
- Higher cost of grading and marketing due to the effects of sunburn and frost on both fruit and vegetables – costs of removing increased amount of blemished fruit, as well as the reduced marketable yields associated with damage from sunburn and frost.
- Higher costs of irrigation under hotter conditions.
- Poor rind colour development in citrus (navels) under higher temperatures, especially autumn night temperatures.
- Vegetable varieties may not be as appropriate for the current environment, as they are not as adaptable to the higher temperatures as varieties available 10-15 years ago.
- Poor pollination in many seed crops (lettuce, sweet corn, cucurbits and carrots) and commercial crops (sweet corn and cucurbits).
- Long-season varieties of citrus are more subject to the effects of a hotter climate (longer period of time for the risks associated with a hotter climate to have a negative effect on yield and quality).
- Scale and mites pests - increase in the occurrence and appearance earlier in the season, because of dryer and dustier conditions.
- Higher temperature effects on parasites (scale parasites in citrus) and other beneficial (trichogramma in vegetables).
- Potential for new pests which currently are not able to survive in the colder winter – e.g. Queensland Fruit Fly.
- Increased wind damage to crops has been observed (there is insufficient historical data on wind speed and direction to validate this observation).
- As other production districts become warmer in the winter, it is possible for them to be encroaching on winter production from the Riverina. – e.g. the Central West of NSW currently produces lettuce only in the spring and autumn. Warmer winters in the Central West will allow lettuce production to run through the winter as well.

Climate Change Impacts on Horticulture - Summary:

- *The horticulture industry has been, and will continue to be vulnerable to impacts of climate change and climate variability*
- *Impacts vary between horticulture and other agricultural industry as well as within horticultural commodities and their growing regions. There can even be variability in impacts within a business. There is a need for Government to consider horticulture separately from other agricultural industries when considering policy responses to climate change*
- *Aside from the physical impacts of climate change, the main threat to horticultural industry currently is the extent of the policy impacts of climate change, including the introduction of the CPRS due to compliance and increased input costs without the ability to pass on those costs*
- *Improved understanding of these impacts is required to inform RD&E responses*
- *The ongoing drought in many key horticultural regions has had an immediate significant impact and will reduce the long-term resilience of the horticultural industry. Climate change will continue to impact on water resources into the future*
- *It is recommended the Australian government introduce a commercially complementary insurance-based risk management system and funding for rural sector natural disasters 'preparedness' as well as the development of social infrastructure in each region that is preparing for the next 'event'*

Horticulture Climate Change Action Plan

The Horticulture industry has invested approximately $18.8 million into research projects over the past 5 years that are helping horticultural growers adapt to climate change – including projects on water use efficiency, irrigation technologies, integrated pest management (IPM), best management practices and climate variability studies.

In comparison with the extensive climate change and climate variability R&D conducted in broad-acre agriculture and the grazing industries, this investment by horticulture is smaller and mainly involves more recent investments as a result of the drought (including projects on survival during severe water shortages).

The majority of these projects, therefore, have been focused on improving on-farm management practices for the efficient use of natural resources to maximize yields and productivity. The investment in RD&E in horticulture has allowed the industry to continue to adapt to the challenges of changes in climate, water availability and weather extremes.

Due to the diversity of horticultural commodities and their geographic locations and micro-climates, and the fact that the impacts of climate change and variability are business specific, the research responses industry is implementing to managing and adapt to climate change are varied. Hence there is still an urgent need to implement RD&E to further respond to challenges posed by climate change and variability.

The vision of the HAL Environment Portfolio is therefore to:

VISION: By 2010, Australian horticulture will be recognised internationally for its widespread adoption of commonly agreed good management practices, which both conserve and enhance the natural resource base, and promote a long-term viable industry.

This includes empowering industry leaders, facilitating meaningful partnerships, encouraging innovation and adoption of research, informing policy and positioning the industry.

The **Horticulture Climate Change Action Plan** (HCCAP) has been recently developed specifically to identify urgent RD&E needs for the area of climate change/variability within the HAL Environment Portfolio.

The HCCAP has three strategies:

1. Adaptation,
2. Mitigation, and
3. Awareness and Communication.

See below for more detail on these strategies or Appendix 2 for the full Action Plan.

Adaptation

One of the desired adaptation outcomes for Australian horticulture is the existence of resilient and adaptive horticultural production systems which are less vulnerable to climate change and climate variability.

One of the priorities for Australian Horticulture in achieving this desired outcome will be to identify and build on successful strategies of adaptation by the horticultural sector to climate changes already experienced.

Actions addressed by this priority, are intended to answer the question: "*Do horticulture producers (and their advisors) have appropriate tools and an understanding of climate change and variability issues, to avoid the risks and/or take advantage of the opportunities of a variable and changing climate*?"

Mitigation

Two of the desired mitigation outcomes for Australian horticulture are further reduced greenhouse gas emissions from horticultural production systems, and profitable horticultural production systems which contribute to greenhouse gas abatement.

Two of the priorities for Australian Horticulture in mitigating greenhouse gasses are to determine the contribution ("Carbon Footprint") which all horticulture (and specific regions and commodities) make to N^2O and CO^2 emissions, and to identify and promote horticulture-specific Best Management Practices (BMP) which minimize N^2O and CO^2 emissions, and at the same time promote the simultaneous goals of productivity, sustainability, adaptability and abatement.

Actions addressed by this priority are intended to answer the questions: "*Do we understand how to reduce greenhouse gas emissions from horticulture cropping systems?*" and "*Are current fertilizer management practices in horticulture appropriate for managing N^2O emissions?*"

Information, Awareness and Communication

Two desired outcomes for Australian horticulture are:

1. A clear understanding of climate change and climate variability issues by stakeholders in horticulture, and

2. Horticulture producers and their advisors having sufficient understanding of climate change and climate variability issues to be able to make appropriate risk management decisions.

Priorities for Australian horticulture for informing growers, scientists, politicians and the community are to develop information products which promote horticulture specific messages to the community as well as to stakeholders in horticulture; and develop and disseminate specific information to raise awareness in the most vulnerable industries and regions.

Actions addressed by this priority are intended to answer the questions: "*Do horticulture producers (and their advisors) have appropriate tools and an understanding of climate change and variability issues, to avoid the risks and/or take advantage of the opportunities of a variable and changing climate?*"

Current horticulture climate change research projects

Some of the current projects with which the industry is engaged in meeting the climate change challenge are:

National Collaboration - CCRSPI

CCRSPI, the Climate Change Research Strategy for Primary Industries network, is a collaborative partnership between all the RRDCs, the primary industry departments of State Governments, experts from the universities sector and the Federal Government, through Department of Agriculture, Forestry and Fisheries and CSIRO. The three pillars of CCRSPI are collaboration, coordination and communication of information, knowledge and research focused on climate change in primary industries. CCRSPI is managed by Land & Water Australia (LWA).

HAL is a partner of CCRSPI and has been a strong supporter of the need for coordinated research and sharing of knowledge between primary industries in this important topic.

The strategies within the HCCAP are aligned with the joint strategy and HAL will continue to work with LWA into the future to invest in climate change and variability issues that will ensure horticulture is able to adapt and remain viable into the future.

Carbon footprinting in the Vegetable industry

The project "Environmental footprint analysis of salad producer, for development of an industry greenhouse gas calculation tool" is an example of the vegetable industry being the first of many fresh produce groups beginning to measure its environmental impact. The project is being undertaken By Houston's Farm in Tasmania, supported by an innovation grant from Woolworths and matched Government RDC investment (through HAL). Project collaborators include Pitt & Sherry, RMIT Centre for Design (Victoria) and the University of Tasmania. The Reference group members included representatives from DPI Queensland, Landcare Research (New Zealand), Australian Farm Institute, Meat and Livestock Australia, and the Food Climate Research Network (Surrey).

The project is designed to develop a preliminary carbon footprint calculation tool and standard protocols for tailoring of the tool for the Australian vegetable industry, using the Houston's Farm enterprise as a test case business.

In order to achieve these objectives, Houston's Farm broke down the project in to specific subsets:

- Determine the Houston's Farm environmental footprint;
- Consider the major contributors to Houston's Farm environmental footprint;
- Use the Houston's Farm environmental footprint analysis to develop a tool which was capable of calculating carbon (greenhouse gas) and the impact of identified opportunities to reduce major contributors;

- Develop an interpretative document to outline the scope, inclusions/exclusions and science based methodologies included in the tool.

It is hoped from this project that the tool and protocol can be transferred to the rest of the vegetable industry. Stage 1 of the project is almost complete; and roll-out to the rest of the industry is currently in negotiation.

Houston's Farm has a fundamental philosophy to produce sustainable products. This has been built into their growing and processing functions over many years, and understanding their carbon (greenhouse gas) emissions and where they can work to reduce these is an important part of their strategic focus moving forward.

Banana industry desktop study

This project is focused on better understanding and identifying the threats and opportunities posed by climate change for the banana industry.

The banana industry has recently completed their Strategic Investment Plan for RD&E activities. It was identified, within this strategic process, that the issue of climate change and its impacts for the banana industry was not well understood. This project has hence been commissioned to better understand these issues and to identify key research needs for the banana industry in response to the impacts of climate change.

Critical thresholds ('tipping points') and climate change impacts/adaptation in horticulture

This project is a partnership between and the Managing Climate Variability Program[8].

All horticultural crops are temperature sensitive and most have specific temperature requirements for optimum yield and quality. Climate indices and critical temperature thresholds of significance are poorly understood so the impact of climate change on businesses and cropping systems in specific regions has not been well documented, and the resilience of the system cannot be properly assessed.

This project will investigate:

- if exceeding the thresholds (tipping points) will, on their own, effect significant changes in land use or production systems, and
- the adaptive capacity (resilience) of producers and production systems.

A review of the literature and industry consultation is required to document critical thresholds for major horticultural commodities, as well as understand the broader risks associated with climate change and the resilience of growers and industries.

[8] MCV Program is a strategic collaboration of the rural Research and Development Corporations and the Australian Government Department of Agriculture Fisheries and Forestry. It is managed by Land and Water Australia on behalf of the partners. MCV II is currently underway.

Horticulture Climate Change Action Plan - Summary:

- *A climate change Action Plan has been recently developed for the horticulture industry to help prioritise urgent R,D&E needs. The HCCAP has three themes:*
    - *Adaptation*
    - *Mitigation*
    - *Information, Communication & Awareness*
- *The industry has invested $18.8 million in adaptation activities over the past 5 years, but this is small investment when compared to other primary industries and when considering that the majority of this investment has been focused on drought – related activities such as water use efficiency during severe water shortages.*
- *The industry acknowledges the need for further investment to address knowledge gaps – through existing RD&E frameworks like CCRSPI and the Horticulture Climate Change Action Plan.*
- *The horticulture industry continues to value improvements in production efficiencies and best management practices as approaches to managing ongoing climate variability and change.*

Response to Inquiry Terms of Reference

Current and prospective adaptations to the impacts of climate change on horticulture

Current adaptations

With increasing temperatures and changes to rainfall patterns which are currently uncertain (impacting on availability of water for irrigation), climate change adaptation strategies will continue to be employed by growers.

Flexibility has been the key to adaptation in horticulture to date, and is likely to continue to be an important component of adaptation strategies as climates continue to change[9]. Growers have been able to manage climate variability reasonably well, although major improvements could be made if tools to assist with the management of climate variability, both temperature and rainfall, were designed specifically with the needs of horticultural growers and industries in mind.

The current drought has provided opportunities for some growers who have been able to shift production to where water for irrigation is available. Those who have done this successfully will be in a much better position to also manage climate change successfully.

There is evidence that the horticulture industry has been adapting to climate change already. However the majority of these adaptation responses have been implemented as a result of incremental (i.e. small changes over a long period of time) and often because it is sound business management to implement them, for example water use efficiency practices are often implemented for the economic reason of reduces input cost for water rather than an environmental reason. The challenge for horticulture will come when greater and more extreme climate change occurs as:

- The easy-to-implement adoption measures will have already been implemented; driven by sound business management. Hence greater and more expensive adaptation responses will be required over time
- Ongoing impacts of climate change on on-farm infrastructure such as irrigation systems and trellising will impact on farm debt. The increasing level of farm debt will over time limit the ability of businesses to cover more expensive adaptation options
- Research will need to be implemented for long-term transformational adaptation measures, such as new cultivars, are available to growers when they are most required

[9] Deuter, P.L et al (2008) "The development of adaptation strategies for the most vulnerable horticultural regions in Australia"

To date, adaptation actions have been good business management. In the future adaptation will fundamentally be an issue of risk management.

There are a number of risk management approaches already being developed and/or roll-out to horticulture industry members, including Horticulture for Tomorrow – Guidelines for Environmental Assurance for Australian Horticulture, through HAL, and the Farm Management System, through Growcom. There are also a number of industry-specific best management practices available such as the Ecohort program for Nursery industry.

Specifically in response to climate change, there are a broad range of management practices that are currently being implemented, including:

- Diversification into shorter duration crops, to reduce the potential risks associated with higher temperatures, and reduced availability of irrigation water.
    - Growers of cucurbits in particular, are already making their first plantings earlier in the spring, because they perceive (or know from experience) that there is less risk of cold and/or frost damage because of higher temperatures in the spring. Similarly for the last plantings in the late summer – these are being made later, because of the reduced risks associated with cold and frost damage.
- Adoption of Integrated Pest Management (IPM) – identification, registration and use of new pesticides to manage pest and disease pressures exacerbated by climate change.
    - A project currently being funded by HAL and vegetable levies is looking into the benefit of landscape-scale IPM - the identification of beneficials for pest management and the promotion of appropriate habitats for those beneficial through the choice of native vegetation buffers.
- Improvements to infrastructure and use of windbreaks – such examples include:
    - Shading of some crops is already being undertaken by some growers in the Riverina, to reduce temperatures.
    - Introduction of windbreaks to reduce the effects of wind damage.
- Choice of cultivars and varieties – there is evidence of diversification of plant varieties being utilised by growers to 'hedge their bets'. Through the use of cultivars with different characteristics and resilience, growers are able to diversify their operations and thus ensure a successful crop.
- Exploration of niche markets – growers and industry are exploring ways to gave higher price for their products (and therefore be able to withstand rising input costs) through niche markets, and/or more creative marketing for crops.

Proposed adaptations

If climate change impacts exceed growers' adaptation capacity at a specific location, more adaptation responses will be required. A southward shift of production following the southward shift of agri-climatic zones is then more likely to occur if growers are to maintain profitability through appropriate market timing, market access and market share (though this will likely be off-set by northward shifts – towards more reliable and accessible water supplies for irrigation – in other crops (particularly permanent plantings).

As mentioned above there are a number of Farm and/or Environmental Management Systems (FMS/EMSs) available within the horticulture industry currently to help growers adapt the climate change impacts.

There is a need for any programs that support adaptation to climate change to be given incentives to increase adoption. It is imperative that regulation is not chosen as the method for enforcing climate adaptation – this would have the potential to cause perverse outcomes and compliance costs will detrimentally impact on the viability of businesses.

A partnership between industry and Government is required to assist industry deliver their own extension, through Farm and/or Environmental Management Systems (FMS or EMS).

There is also a need to understand and map the most appropriate tools and decision support information on how to manage the risk of climate change and variability and the potential actions that can be taken should be investigated.

Issues related to decision support tools for horticulture include:

- Temperature tools are currently not available – a 'day degree calculator' for horticulture would allow for changes to temperature that relate to weather extremes to be monitored on farm. Issue is the forecast length, i.e. would need to be scaled down and forecasts for both long-term and short-term predictions needed.
- There is a need to revise current seasonal forecasts and decision support tools as we gain increasing knowledge and certainty – improvement of models is better than constantly creating new models (and less costly)
- Need to ensure integration of tools into existing management practices and tools
- Training around interpretation of tools – no forecast tool will ever be 100% accurate and should be interpreted with context

Horticulture's activities in this area of adaptation needs to link in with other national scale activities, such as the Managing Climate Variability Program and Australian Government Australian Farming Future.

Specific adaptation strategies that require further investigation include (also see appendix 3 for full list and details of each):

- Annual crop planting decisions – through cultivar choice or change in planting times or durations. These require good information on seasonal forecasts
- Property acquisition – through acquisition of property in a different location
- Improved crop management – through adoption of best practice and continuous improvement processes, adoption of integrated pest management
- Improved resource management – adoption of Water Use Efficiency measures including trickle irrigation where appropriate or irrigation scheduling using latest techniques and appropriate technology.

It is vital that any adaptation responses are integrated with mitigation. Adaptation and mitigation are intimately linked – the horticulture industry is extremely susceptible to the impacts of climate change/variability and as such strongly supports the need for mitigation and reduction of emissions to reduce the potentially catastrophic impacts of climate change. At the same time, it is important for horticultural growers and businesses to undertake a risk management approach to better understand the potential impacts and appropriate actions required to response to those impacts.

Reducing GGE is an important part of the actions that should be taken by businesses to improve environmental performance. Nitrogen applications are responsible for most of the nitrous oxide (NO2) released. NO2 can be reduced through change in farming practices to limit air exposure to nitrogen, such as minimum till and/or supplying nitrogen more efficiently through drip fertigation or controlled-release fertilisers.

Planting trees or investing in forest sink emission offsets can be an effective way to reduce GGE into the atmosphere. However, the current evidence suggests that there is still a lot of research and work to be done prior to sequestration, within orchards or soils, becoming a big opportunity for individual growers.

The following are the responses by vegetable and fruit growers in the Lockyer Valley to the question – "*What are you doing (or what can be done) about these impacts of the past and future changes in temperature on my farm/business/crop/industry?*"[10]

- Provide shade to vulnerable crops through (a) shade netting, (b) companion cropping / intercropping that will provide a natural canopy for smaller crop species, (c) use of shade houses. (NB companion cropping / intercropping would require a reconfiguration of planting arrangements and densities to manage competition and machinery logistics.)
- Use of anti-transpirants to reduce transpiration rates.

[10] Deuter, P.L. (2009) "AH06019: Australian horticulture's response to climate change and climate Variability"

- Use varieties that are more suited to warmer temperatures and increased pest populations and species.
- Reduce risk through relocating some production to other areas (this would include moving to other regions in Australia and moving to increased altitudes) to address (a) reducing water availability, and (b) climate change.
- Change in planting dates to optimize the time and potential of pollination.
- Introduction of increased populations of pollinator species.
- Genetic modification.
- Consumer and supermarket education to encourage the consumption and sale of crops outside the present narrow definition of acceptable quality.

Further research is required to improve the potential for adoption of adaptation strategies with the horticulture industry. R, D&E must be implemented to answer the questions:

- Are we aware of, and do we understand the adaptation strategies which growers have successfully employed to manage their enterprises in an already changing climate?
- Do horticulture producers (and their advisors) have appropriate tools and an understanding of climate change and variability issues, to avoid the risks and/or take advantage of the opportunities of a variable and changing climate?
- Are current climate change scenarios sufficiently regionally specific to enable appropriate vulnerability assessments for horticultural commodities and/or production regions?
- What are the changes in distribution and abundance of pests, diseases and weeds under a changing climate?
- What are the impacts for managers of pests, diseases and weeds, of a changing climate?
- Are there new market opportunities (domestic and export) as a result of climate change effects in Australia and overseas?
- Are the current scenarios sufficiently regionally specific, for horticulture to respond appropriately with adaptation and mitigation strategies which are practical, effective and profitable?
- What are the tools, which are being used by managers of agricultural systems to manage climate risk, which can be improved/ modified to have an application in horticulture?

- What is the level of understanding in the R&D community of the special research needs for farm management (decision support) tools in horticulture?

Specific adaptation research responses that are required:

- Crop management techniques – such as:
    - Windbreaks - There is a real need to understand the cost effectiveness of windbreaks - how much wind damage reduction can be achieved; what are the negative effects of planted windbreaks on adjacent crops (water and nutrient requirements especially); and what are the costs of establishment and maintenance.
    - An increase in the intensity of rainfall will increase the potential for erosion events and the export of nutrients and sediments from fields, affecting water quality and impacting other ecosystems such as the Great Barrier Reef. This will require practices aimed at intercepting raindrops and runoff, e.g. residue and stubble retention.
    - An increasing awareness of climate change will increase the need for growers to use carbon neutral practices and reduce practices that are deemed detrimental to the environment.
- Integrated Pest Management - There is a need for new options for the control of pests – IPM will become the norm. In general, higher temperatures will increase pest and disease activity, alter their development rate, including that of host crops, and increase survivability of some organisms, especially in warmer winters. Changing rainfall amounts and patterns will modify this temperature effect for each organism. There will be an increased need to take advantage of new pesticides which are being registered in other crops (e.g. cotton), so that registrations will be encouraged in appropriate situations in horticulture as well.
- Cultivar selection - There is a need for better adapted varieties in vegetable crops especially – changing to a better adapted variety is relatively simple to do, all other factors being equal. For fruit crops, the capacity of growers to change to better adapted varieties (if better adapted ones were available) is limited by the costs and the time from planting to first harvests in fruit crops. The other limitation is about knowing what varieties would be adapted to the changed environment – this would need to be extrapolated from other production regions. The costs of getting it wrong are very high.
- Communication - Most of the anticipated climate changes point towards the need for a very high standard of crop management in order to respond to the challenges that expected changes pose. Industry and farm managers will need to distinguish between 'old climate expectations' and 'new climate realities' in determining and implementing new adaptation strategies or options.

- Improved understanding of production timing - Crops will develop more rapidly and mature earlier (taking less time from planting or fruit set to harvest). Vegetable growers producing summer crops in temperate regions will have the additional option of planting earlier, and later, therefore extending the production season. In tropical and sub-tropical regions, vegetable growers producing winter crops will be negatively impacted as the winter production season will be shortened.

- Improved understanding of the impact of climate change on Greenhouse production - Increasing temperatures will impact greenhouse production, especially production in sub-tropical regions, where current summer temperatures restrict production to the cooler months of the year, because temperature thresholds are often exceeded. Additional technologies for cooling greenhouses will be required for these production systems to continue. Greenhouse production in temperate (or highland) regions will be impacted less, and for summer production the impacts may not be felt for many years, especially where temperature thresholds are much higher than current maximum temperatures. Positive impacts on reduced costs of heating for winter production will o

- Improve seasonal forecasting tools specifically for horticulture - Currently the limitation on the use of tools (climate applications for managing climate variability) in horticultural industries, is the lack of information – at the micro-climate/regional level - that addresses the lead-time and season requirements of the horticultural industry. The combination of long season (3 months) and short lead-time (zero), which are appropriate for other agricultural industries, is a significant constraint to the use of forecasting tools in horticulture, where a much shorter season length (several weeks to one month in some cases), and a much longer lead-time (3 to 4 months), would be much more useful. Given a sound forecast system that meets the requirements of the industry the appropriate tools can be produced. There are no forecast systems based on the SOI and SST's which have been extensively tested for longer lead-times and shorter seasons.

Role of Government

The horticulture industry would seek acknowledgement from Government regarding the anticipated impacts of climate change on horticulture.

The horticulture industry is keen to see increased Government investment in climate change R, D&E for primary industries. This investment should be undertaken in collaboration with primary industries, through RDCs.

It is vital that Government supports the collaborative approach to managing climate change already being supported by primary industries– through the Climate Change Research Strategy for Primary Industries (CCRSPI) program.

For the horticulture industry specifically, we would support increased investment by Government into the area of climate change to ensure adaptation outcomes for horticulture:

- Resilient and adaptive horticultural production systems which are less vulnerable to climate change and climate variability
- Improved resilience to changes in pest and disease incidence
- Increased ability to capitalise on new market opportunities
- Regionally specific climate change scenarios, which are very relevant to managers of horticultural enterprises
- Practical tools available to horticultural growers and their advisors to better manage climate change and climate variability

See the recommendations section for further actions.

Role of rural research development corporations

The horticulture industry strongly supports the current rural research and development corporation (RDC) model. The structure allows for co-investment by industries and Government for implementation of research to improve the resilience of primary industries into the future.

The horticulture industry is supportive of the collaborative approach to managing climate change – through the Climate Change Research Strategy for Primary Industries (CCRSPI) program. HAL will continue to work with Land & Water Australia (the secretariat for CCRSPI) into the future to invest in climate change and variability issues that will ensure horticulture is able to adapt and remain viable into the future.

There is strong support by industry for the role of Horticulture Australia Limited (HAL) and Horticulture Australia Council in strategically addressing the issue of climate change for horticulture.

Climate scenarios are predicting that future adaptation by industry will be required. It is therefore vitally important that Government continues to support adoption of best practice and implementation of research to continue to identify and propose ways for industry to continue to adapt to the risk of climate change impacts on-farm. Further R, D&E is therefore required. The Horticulture RRDC, specifically through the HAL Environment Portfolio, is well-placed to be able to collaborate with industry and Government on future work.

Specifically for the area of climate change/variability, further work should fit under the three strategies of the Horticulture Climate Change Action Plan - Adaptation, Mitigation, and Awareness and Communication.

Recommendations

Horticulture is a unique and dynamic primary industry

- Horticulture has been, and will continue to be impacted upon by climate change and variability. These impacts vary to other agricultural industries, but will also vary between and within commodities, regions.
    - **Action: Improved understanding of the impacts on horticultural industries and individual businesses is required. A framework of impacts versus potential adaptation and mitigation options should be developed to help industry prioritise investment.**
    - **Action: Acknowledgement by Government of the differences between horticulture and other primary industries regarding the impacts and the adaptation/mitigation responses to climate change. Horticulture should be considered separately to other primary industries in future investment and policy responses.**

Engagement of industry in Government climate change policy

- The greatest impacts will not just be physical challenges, but rather the implications of climate change policy. Horticulture will not only have to contend with the direct climate change implications, but also pressure of providing for increasing world food demand, coupled with an increasing demand for productivity growth. However, this rate of growth will be limited by the land availability, distribution channels (effective supply chains) and domestic food security responses.
    - **Action: Government should ensure that any policy responses to climate change, such as the CPRS, do not limit the flexibility and resilience of the horticulture industry.**
- There is no 'ready' solution to climate change, but the urgency of information and action is new. Government and industry need to work together to communicate and respond to the implications of climate change.
    - **Action: a process for effective two-way flow of information/needs/actions between industry (via both the CCRSPI process and peak industry bodies) and Government is required.**

The need for effective collaboration and investment through existing research models

- The horticulture industry strongly supports the current rural research and development corporation (RDC) model. The structure allows for co-investment by industries and Government for implementation of research to improve the resilience of primary industries into the future.
    - **Action: Government should continue to support, and indeed increase, investment in research, development and extension (RD&E) through the Rural Research and Development Corporations.**

- Collaboration is the key. In the past, climate change research has been fragmented; across all areas of innovative technologies, biological systems and communication/education.
    - **Action: Government should continue to support, and indeed increase, investment in research, development and extension (RD&E) especially in the area of best practice/productivity advances.**
    - **Action: Any further climate change research investment must be channeled through existing agricultural research models, such as the Rural Research Development Corporations and the Climate Change Research Strategy for Primary Industries network.**

Research priorities addressing impacts of climate change for horticulture

- Horticulture has developed an Action Plan for addressing the issue of climate change and variability for industry – the Horticulture Climate Change Action Plan (HCCAP). HCCAP has three strategies - Adaptation, Mitigation, and Awareness and Communication. The Horticulture RRDC, specifically through the HAL Environment Portfolio, is well-placed to be able to collaborate with industry and Government on future work through HCCAP.
    - **Action: Government investment and support is sought for implementation of research priorities within the Horticulture Climate Change Action Plan, including adaptation, mitigation and communication priorities**

- Adaptation can take many forms – horticultural growers to date have implemented adaptation responses proactively, however future climate change adaptation will more

than likely be reacting to extreme events. Incremental adaptation will not be appropriate in the long term. Therefore, for the horticulture industry the cost of non-mitigation is too high. Mitigation with adaptation must be addressed together to reduce the potential negative impacts of climate change/variability and increase industry's resilience to change at the same time.

  - **Action: Government support is required to monitor and evaluate adaptation & mitigation actions over time, to assess uptake and outcomes of adoption. Success of adaptation and mitigation strategies should equate to increased resilience of primary industries.**

- Climate change cannot be considered separately from other business risk. Furthermore, adoption of these risk management approaches should be supported through incentives, i.e. rather than regulation. Adaptation and mitigation can be actions within a management framework, through existing systems such as the Farm and Environmental Management Systems.
  - **Action: Government support is requested to further roll out the Farm / Environmental Management Systems to industry.**

- Good science is essential in informing policy development. There is a significant amount of research already undertaken, but there are still gaps in climate change research relevant to horticulture, and further investment is required. Uncertainties include:
  - limitations in modeling,
  - impacts,
  - adaptation responses and
  - policy.
  - **Action: Government should implement an ongoing consultation process with horticulture industry leaders to discuss industry needs and research outcomes that relate to the areas of resource management and climate change.**

Structural priorities to address impacts of climate change for horticulture

- The ongoing drought in many key horticultural regions has had an immediate significant impact and will reduce the long-term resilience of the horticultural industry. Climate change will continue to impact on water resources into the future.
    - **ACTION: It is recommended the Australian government introduce a commercially complementary insurance-based risk management system and funding for rural sector natural disasters 'preparedness' as well as the development of social infrastructure in each region that is preparing for the next 'event'**
    - **ACTION: It is recommended the Australian government ensure that current EC eligibility criteria - which still exclude growers from accessing the Exit Package - need to be amended to provide equity for horticulture (and other intensive irrigated industries) with farmers from the dryland agriculture sector (talk to me about this if you need to).**

Addressing barriers to adaptation

- Timescales are a problem – in terms of modeling scales and forecasts, adoption of adaptation approaches and the effectiveness of adaptation & mitigation, and the policy demands
    - **Action: Government support is sought to link region-specific seasonal and long-term forecasting requirements appropriate to horticulture, through existing programs such as models managed by Bureau of Meteorology and CSIRO.**

- Communication and landholders engagement is just as high a priority as investment in straight climate science (i.e. modeling). Communication on climate change needs to be improved to better meet the needs of the intended audience.
    - **Action: Any future climate change projects and programs should seek to engage with peak industry bodies to ensure landholder engagement.**
    - **Action: Government should support coordinated communication for primary industries through the CCRSPI process.**

Appendix 1: Production statistics – top five fruit and vegetable crops and by state

Table 1: Production of Australia's Top Five Fruit and Vegetable Crops, 2005

Fruit	Production (t)	Vegetables	Production (t)
Citrus	504,610	Potatoes	1,333,159
Pomefruit	438,147	Tomatoes	424,950
Bananas	313,314	Root vegetables	401,323
Tropical fruit	192,621	Onions and garlic	294,790
Summerfruit	162,015	Brassicas	226,398

Source: HAL (2006)[11]

Table 2: Value of Australia's Top Five Fruit and Vegetable Crops, 2005

Fruit Value	($ million)	Vegetables Value	($ millions)
Pomefruit	$453	Potatoes	$485
Bananas	$415	Root vegetables	$236
Citrus	$331	Tomatoes	$230
Table grapes	$278	Onions and garlic	$194
Summerfruit	$266	Brassicas	$167

Source: HAL (2006)[11]

Table 3: Value of production, by State, 2005 (Includes Cut Flowers & Nursery)

State Value	($ millions)
NT	$54
WA	$545
SA	$1,349
TAS	$222
VIC	$1,581
NSW	$1,070
QLD	$1,534
Total	$6,355

Source: HAL (2006)[11]

[11] THE SIGNIFICANCE OF THE HORTICULTURE INDUSTRY TO THE AUSTRALIAN ECONOMY (2006) Econtech Pty Ltd (Prepared for Hassall and Associates on behalf of Horticulture Australia Limited)

Appendix 2: Horticulture Climate Change Action Plan

Horticulture Climate Change Action Plan

March 2009

Objective

The objective of the *Horticulture Climate Change Action Plan* is to commence answering the question – *"What are the Impacts of climate change on selected horticultural regions and production systems in those regions, and what Adaptation Strategies will be useful in addressing these impacts?"*

For individual growers, outcomes of the Action Plan can start to answer the question - *"What does climate change mean for my farm and my business?"*

Strategies

The three strategies identified for the horticulture industry are:

1. **Adaptation**
2. **Mitigation**
3. **Information, Awareness and Communication**

These are discussed in more detail below.

1. Adaptation

One of the desired adaptation outcomes for Australian horticulture is the existence of resilient and adaptive horticultural production systems which are less vulnerable to climate change and climate variability.

One of the priorities for Australian Horticulture in achieving this desired outcome will be to identify and build on successful strategies of adaptation by the horticultural sector to climate changes already experienced.

A question which actions, addressed by this priority will answer is, "Do horticulture producers (and their advisors) have appropriate tools and an understanding of climate change and variability issues, to avoid the risks and/or take advantage of the opportunities of a variable and changing climate?"

Desired Adaptation Outcomes for Australian Horticulture

- Resilient and Adaptive Horticultural Production Systems which are less vulnerable to climate change and climate variability.
- Improved industry resilience to changes in pest and disease incidence.
- Increased ability to capitalise on new market opportunities.
- Regionally specific climate change scenarios, which are relevant to managers of horticultural enterprises.
- Practical tools available to horticultural growers and their advisors to better manage climate change and climate variability.

Priorities for Australian Horticulture in Adapting to Climate Change

- Identify and build on successful strategies of adaptation by the horticultural sector to climate changes already experienced.
- Obtain regional climate change scenarios (downscaling) for all Horticulture regions (to 2030) – update as improved scenarios become available.
- Develop Impact Assessments for all or major commodities in these regions.
- Assess the Vulnerability of all or major regions and/or horticultural commodities and Identify current "at risk" production sites (regions) and/or industries.
- Identify the long-term (2030 and 2070) opportunities and threats to horticultural regions and cropping systems, as a consequence of climate change - long term adaptation.
- Develop (in consultation with growers and their advisors), Adaptation Strategies which are appropriate, practical, and economically sound.
- Review and/or develop where necessary, Best Management Practices (BMP) for horticulture, which include adaptation and mitigation components.
- Assess the economic benefits of agri-forestry in horticulture as well as the benefits it might bring for adaptation and mitigation.
- Document the effects of climate change for major overseas production regions, especially in those countries that are major competitors to Australian production.
- Identify additional export opportunities for Australian growers

- Identify alternative regions that may be suitable for production, to take advantage of these market opportunities.
- Investigate the "food miles" concept and the effects decisions on markets and production opportunities for horticulture.
- Develop horticulture specific forecasting tools that can be used for climate change and climate variability (especially temperature variability) related decision making at a farm and regional scale.

Some Questions which these Actions will answer

- Are we aware of, and do we understand the adaptation strategies which growers have successfully employed to manage their enterprises in an already changing climate?
- Do horticulture producers (and their advisors) have appropriate tools and an understanding of climate change and variability issues, to avoid the risks and/or take advantage of the opportunities of a variable and changing climate?
- Are current climate change scenarios sufficiently regionally specific to enable appropriate vulnerability assessments for horticultural commodities and/or production regions?
- What are the changes in distribution and abundance of pests, diseases and weeds under a changing climate?
- What are the impacts for managers of pests, diseases and weeds, of a changing climate?
- Are there new market opportunities (domestic and export) as a result of climate change effects in Australia and overseas?
- Are the current scenarios sufficiently regionally specific, for horticulture to respond appropriately with adaptation and mitigation strategies which are practical, effective and profitable?
- What are the tools, which are being used by managers of agricultural systems to manage climate risk, which can be improved/modified to have an application in horticulture?
- What is the level of understanding in the R&D community of the special research needs for farm management (decision support) tools in horticulture?

Urgent/immediate recommended priorities for Australian Horticulture in Adapting to Climate Change:

1. Work closely with CSIRO scientists to obtain regional climate change scenarios (downscaling) for all Horticulture regions (to 2030) – update as improved scenarios become available.
2. Assess the vulnerability of all or major regions and/or horticultural commodities; identify current "at risk" production sites (regions) and/or industries; and identify the long-term (2030 and 2070) opportunities and threats to horticultural regions and cropping systems, as a consequence of climate change (long term adaptation).
3. Review and/or develop where necessary, Best Management Practices (BMP) for horticulture, which include adaptation and mitigation components (short term adaptation).
4. Document the effects of climate change for major overseas production regions, especially in those countries that are major competitors to Australian production, and identify additional export opportunities for Australian growers.

2. Mitigation

Two of the desired mitigation outcomes for Australian horticulture are reduced greenhouse gas emissions from horticultural production systems, and profitable horticultural production systems which contribute to greenhouse gas abatement.

Two of the priorities for Australian Horticulture in mitigating greenhouse gasses are to determine the contribution ("Carbon Footprint") which all horticulture (and specific regions and commodities) make to N^2O and CO^2 emissions, and to identify and promote horticulture specific Best Management Practices (BMP) which minimise N^2O and CO^2 emissions, and at the same time promote the simultaneous goals of productivity, sustainability, adaptability and abatement.

Two of the questions which actions addressed by this priority will answer are, "Do we understand how to reduce greenhouse gas emissions from horticulture cropping systems?" and "Are current fertilizer management practices in horticulture appropriate for managing N^2O emissions?"

Desired Mitigation Outcomes for Australian Horticulture

- Reduced Greenhouse Gas emissions from Horticultural Production systems.
- Profitable horticultural production systems which contribute to greenhouse gas abatement.
- More energy efficient horticultural production and marketing systems.
- Increased ability to capitalise on consumer perceptions and new market opportunities.
- Cost effective biofuel usage and production in horticulture.
- Biosequestration applicable to horticultural cropping systems.

Priorities for Australian Horticulture in Mitigating Greenhouse Gasses

- Determine the contribution ("Carbon Footprint") which all horticulture (and specific regions and commodities) make to N^2O and CO^2 emissions.
- Develop on-farm measures of N^2O and CO^2 emissions (indicator tools for GHG emissions), which are scientifically consistent and verifiable for measuring greenhouse gas emissions from each of the cropping systems and regions of horticultural significance.

- Identify and promote horticulture specific Best Management Practices (BMP) which minimise N2O and CO2 emissions, and at the same time promote the simultaneous goals of productivity, sustainability, adaptability and abatement.
- Identify the gaps in our understanding and the ability of current BMP's to sufficiently mitigate greenhouse gasses.
- Assess Controlled Traffic/Minimal Till systems in vegetable production systems for energy efficiency as well as issues associated with reduced greenhouse gas emissions.
- Assess the economic benefits of agri-forestry in horticulture as well as the benefits it might bring for adaptation and mitigation.
- Review and/or develop where necessary, Best Management Practices (BMP) for horticulture, which include adaptation and mitigation components.
- Investigate the "food miles" concept and the effects decisions on markets and production opportunities for horticulture.
- Develop on-farm measures of energy use (energy audit tools) that identify areas where cost reductions and environmental benefit can be obtained.
- Assess the potential cost efficiencies of bioenergy and renewable energy sources for the horticultural sector.
- Investigate the profitability of bioenergy crops as alternative and rotation/fallow crops in horticulture cropping systems

Some Questions which these Actions will answer

- What contribution does horticulture in Australia make to greenhouse gas emissions?
- Are they different for each commodity/cropping system?
- Are they different for each production region?
- Do we understand how to reduce greenhouse gas emissions from horticulture cropping systems?
- Are current fertilizer management practices in horticulture appropriate for managing N2O emissions?
- Can soils under horticultural crop management be net sequesters of Carbon?
- What opportunities exist for horticulture to become more energy efficient on farm?
- What opportunities exist for horticulture to become more energy efficient along the supply and demand chain?
- Are there new market opportunities (domestic and export) as a result of climate change effects in Australia and overseas?
- Are consumers willing to preferentially purchase "low carbon" fruit and vegetables?
- Can horticultural cropping systems play an important role in emissions trading?
- Are there any crops which can be grown as part of horticultural production systems which can have economic benefits to farmers, whilst providing a feedstock for biofuel production?
- Can horticultural cropping systems play an important role in emissions trading?
- Can horticultural cropping systems play an important role in biosequestration and emissions trading?

Urgent/immediate recommended priorities for Australian Horticulture in Mitigating Greenhouse Gasses

1. Determine the contribution ("Carbon Footprint") which all horticulture (and specific regions and commodities) make to N2O and CO2 emissions, and develop on-farm measures of N2O and CO2 emissions (indicator tools for GHG emissions), which are scientifically consistent and verifiable for measuring greenhouse gas emissions from each of the cropping systems and regions of horticultural significance.
2. Identify and promote horticulture specific Best Management Practices (BMP) which minimise N2O and CO2 emissions, and at the same time promote the simultaneous goals of productivity, sustainability, adaptability and abatement, and identify the gaps in our understanding and the ability of current BMP's to sufficiently mitigate greenhouse gasses.

3. Information, Awareness and Communication

Two desired awareness outcomes for Australian horticulture is a clear understanding of climate change and climate variability issues by stakeholders in horticulture, and horticulture producers and their advisors having sufficient understanding of climate change and climate variability issues to be able to make appropriate risk management decisions.

Two of the priorities for Australian horticulture for informing growers, scientists, politicians and the community are to develop information products which promote horticulture specific messages to the community as well as to stakeholders in horticulture, and develop and disseminate specific information to raise awareness in the most vulnerable industries and regions.

A question which these actions addressed by this priority will answer is, "Do horticulture producers (and their advisors) have appropriate tools and an understanding of climate change and variability issues, to avoid the risks and/or take advantage of the opportunities of a variable and changing climate?"

Desired Awareness Outcomes for Australian Horticulture

- A clear understanding of climate change and climate variability issues by stakeholders in horticulture.
- Horticulture producers and their advisors having sufficient understanding of climate change and climate variability issues to be able to make appropriate risk management decisions.

Priorities for Australian Horticulture for informing growers, scientists, politicians and the community

- Develop information products which promote horticulture specific messages to the community as well as to stakeholders in horticulture.
- Develop and disseminate specific information to raise awareness in the most vulnerable industries and regions.

- Communicate climate change issues to growers and their advisors, by taking (making) opportunities to present climate change information (including results of R&D) and engaging in discussions and motivating to consider the implications of climate change for their businesses, society and the environment.
- Communicate scientifically based information on observed climate trends, climate change projections and possible impacts to key industry sectors.

Some Questions which these Actions will answer

- Do we know which commodities and/or regions are most at risk from climate change?
- Are horticulture growers and their advisors aware of the implications of climate change to their industries and businesses?
- What are the important messages which will increase climate change awareness amongst stakeholders in all horticulture industries?
- Do horticulture producers (and their advisors) have appropriate tools and an understanding of climate change and variability issues, to avoid the risks and/or take advantage of the opportunities of a variable and changing climate?

Urgent/immediate recommended priorities for informing growers, scientists, politicians and the community

1. Develop information products which promote horticulture specific messages to the community as well as to stakeholders in horticulture.
2. Communicate scientifically based information on observed climate trends, climate change projections and possible impacts to key industry sectors raise awareness in the most vulnerable industries and regions.

Background

Nature of the problem

To date there has been limited research into climate change and climate variability in the Australian horticulture sector, in comparison with the extensive R&D conducted in broad-acre agriculture and the grazing industries. In 2005/06 HAL funded the project – "VG05051: Scoping Study - Climate Change and Climate Variability - Risks and Opportunities for Horticulture". This one-year scoping study focused on the gathering of knowledge on work already undertaken in the area of climate variability and climate change, and the potential for the Australian vegetable industry to capitalise on tools and programs currently available.

The Final Report "Climate Change and Climate Variability – Risks and Opportunities for Horticulture" identified key issues and provided recommendations specifically for the vegetable industry, including conclusions for the horticulture industry as a whole. In summary, the steps in addressing climate change in horticulture in Australia should include identifying those industries and/or specific locations which are most at risk from climate change, followed by the development of adaptation strategies for those industries and regions at risk. At the same time, climate variability (particularly temperature) will continue to challenge managers of horticultural supply and demand chains (production and marketing). Forecasting tools need to be developed, with the requirements of horticultural industries and managers specifically in mind.

There is a large amount of climate information available to grazing and cropping industries, but much of this is not in a form which is useful to horticulture. There is an opportunity to develop and disseminate climate information with specific application to the horticulture sector.

The Scoping Study identified the following climate change priority issues worthy of investigating:-

- What are the climate change impacts for the most vulnerable crops and regions?
- How vulnerable are horticultural crops and regions to climate change?
- Where are the knowledge gaps preventing adaptation to climate change?
- What are the potential adaptation strategies for crops and regions?
- What are the costs and benefits of these adaptation strategies?
- How practical and acceptable are these strategies and what is the capability of industries and individual growers to implement these strategies?
- What are the barriers to adoption?

For horticultural industries to successfully adapt to increasing temperatures and changing rainfall patterns there will be a need to understand the impact of climate change on specific regions and cropping systems, how vulnerable these regions and cropping systems are, and then develop both pre-emptive and reactive adaptation strategies or options.

Research undertaken

There is a focus on understanding how to improve the management of climate variability from a horticulture perspective, with an emphasis on temperature variability. A review was conducted (AH06019) of 27 projects previously funded by the Managing Climate Variability Program (MCVP) across a range of agricultural industries, of which 15 projects provided information or were capable of delivering an outcome which could have application in horticulture.

Currently the limitation on the use of tools for managing climate variability in horticultural industries is the lack of climate science understanding that addresses the lead-time and season length requirements of horticultural industries. The combination of long season (3 months) and short lead-time (zero), which are appropriate for other agricultural industries, is a significant constraint to the use of forecasting

tools in horticulture, where a much shorter season length (several weeks to one month) and a much longer lead-time (3 to 4 months), would be much more useful. Given a sound forecast system that meets the requirements of the industry the appropriate tools can be produced.

There are no forecast systems based on the Southern Oscillation Index (SOI) and Sea Surface temperatures (SST) which have been extensively tested for longer lead-times and shorter seasons.

There are many tools which have been developed for the management of rainfall variability, but none which address the need for a greater understanding of temperature variability. Temperature variability is the main parameter which affects the performance of most horticultural crops.

Major research findings and industry outcomes

Tools used in managing climate variability, have in the main been designed and constructed for a specific purpose and for a specific agricultural or pastoral industry. None of these tools have been designed specifically with any horticultural industry or application in mind. Some examples:

- Bureau of Meteorology (BOM) – Seasonal Temperature Outlook – http://www.bom.gov.au/climate/
- LongPaddock – http://www.longpaddock.qld.gov.au/
- Madden Julian Oscillation (MJO) – http://www.apsru.gov.au/mjo/ or http://www.bom.gov.au/climate/tropnote/tropnote.shtml
- AgClimate - http://www.agclimate.org/
- Rainman StreamFlow version 4. - http://www.dpi.qld.gov.au/rainman/
- Southern Oscillation Index (SOI) – http://www.bom.gov.au/climate/glossary/soi.shtml or http://www.longpaddock.qld.gov.au/SeasonalClimateOutlook/SouthernOscillationIndex/index.html or http://www.longpaddock.qld.gov.au/SeasonalClimateOutlook/RainfallProbability/index.html
- Sea Surface Temperatures (SST) http://www.longpaddock.qld.gov.au/SeasonalClimateOutlook/SeaSurfaceTemperature/index.html
- The Predictive Ocean Atmosphere Model for Australia (POAMA) is a state-of-the-art seasonal to inter-annual seasonal forecast system based on a coupled ocean/ atmosphere model and ocean/atmosphere/land observation assimilation systems – Experimental Products are available on the web - http://poama.bom.gov.au/experimental/poama15/map_rt.html - the "Monthly Spatial Map Forecasts" provide temperature forecasts, as a spatial output for all of Australia.

Different predictive system delivering forecasts with a longer lead time and short season length, which are required for horticulture, are more likely to be achieved using dynamical modeling techniques than previous statistical methods used in other agricultural industries. For this to occur, horticulture needs to engage with climate scientists developing these newer systems, and provide them with details of the specific climate dependant needs of horticulture in Australia.

Future climate change will deliver impacts to horticulture as a consequence of increasing temperatures and changes to rainfall patterns. The most easily accessed and managed adaptation strategies will be employed and are currently being employed by growers, and these will be the use of more adaptable cultivars and a range of cultural practices which enable growers to maintain current production in current locations – i.e. adapt to the 'new' climate in the current location. This will be driven in the first instance to maintain profitability through market timing, market access and market share.

If climate change impacts exceed growers adaptation capacity at a specific location, then a southward shift of production, following the southward shift of agri-climatic zones, is more likely to occur if growers are to maintain current crop production and profitability through appropriate market timing, market access and market share.

Most of the anticipated climate changes point towards the need for a very high standard of crop management in order to respond to the challenges that expected changes pose. Industry and farm managers will need to distinguish between 'old climate expectations' and 'new climate realities' in determining and implementing new adaptation strategies or options.

Previous assessments of climate change adaptations have been made for agricultural industries other than horticulture. One of the general conclusions from these analyses is that the best defence against future climate change is to continue to develop the capacity and knowledge to manage our response to climate variability more effectively.

Climate change is occurring and there are two options; ignore it in the hope that it will go away and accept the consequences; or develop strategies to adapt to and manage the impacts of climate change.

Climate Change in Australia

Most of the anticipated climate changes point towards the need for a very high standard of crop management in order to respond to the challenges that expected changes pose. Industry and farm managers will need to distinguish between 'old climate expectations' and 'new climate realities' in determining and implementing new adaptation strategies or options.

Climate affects Australian horticultural industries in a range of ways through impacts on industry location, plant growth, pest and disease risk and product quality (Howden, et al., 2003). Amongst many other considerations, management and infrastructure decisions attempt to account for these climatic effects and risks. Such decisions will usually use the historical climate as a guide to future conditions, as there are no scientifically validated or published tools available which have been designed specifically with the requirements of horticultural industries in mind.

There is increasing evidence that human activities are already changing the global climate, and that more change seems likely. Consequently, historical conditions may become increasingly less pertinent as a guide to industry activities or industry adjustment.

Vulnerability to climate change is a function of the impacts of climate change on regions or farming systems, and the adaptive capacity of the farming systems in these regions. i.e. a particular region or farming system would be considered to be highly vulnerable to climate change, if there is little or no capacity to adapt to (or negate the effects of) the impacts of future climate change.

Vulnerability = Impacts – Adaptive Capacity

The IPCC defines vulnerability as "The extent to which climate change may damage or harm a system" (IPCC, 2001). A vulnerable system is one which is sensitive to changes in climate variables (impacts) and a system which is not able to readily adapt (low adaptive capacity) (Olmos, 2001).

Rainfall

Since 1900, Australian annual average rainfall shows a moderate increase (7.9mm/decade), but it is dominated by high year-to-year variability (Smith, 2004). While north-eastern Australia has become wetter since 1950, much of eastern and southern Australia has become drier. This is due to a weakening or southward shift of the frontal systems that bring most rain to these regions (Marshall, 2003). Rainfall intensity in eastern Australia has increased from 1910 to 1998, but has decreased in the far southwest of Australia (Haylock and Nicholls, 2000) over this same time period. Over New South Wales, extreme daily rainfall intensity and frequency has decreased from 1950 to 2003 (Hennessy et al., 2004b).

The frequency of tropical cyclones in the Australian region has decreased since 1967 (Hennessy et al., 2004c), along with an increase in cyclone intensity, possibly as a result of a shift in areas of formation. Explosively developing cyclones, including east coast lows off the New South Wales coast, have increased between 1979 and 1999 (Lim and Simmonds, 2002).

There appear to be many potentially significant impacts of climate change on horticultural industries, some of which may be positive, some negative. It will be essential in reducing the impact of climate change, that a clearer understanding of what these impacts are, and that management strategies be identified and implemented to either offset the negative impacts, or to take advantage of positive responses. Previous assessments of climate change adaptations have been made for other industries (e.g. Howden et al., 2003). One of the general conclusions from these analyses is that the best defence against future climate change is to continue to develop the capacity and knowledge to manage our response to current climate variability more effectively.

Temperature

Australian annual mean temperatures have increased by 0.9oC since 1910, with significant variations from region to region (CSIRO, 2007; Smith, 2004), with night-time temperatures increasing faster than daytime temperatures. Night-time (minimum) temperatures have particularly risen sharply in the northeast of Australia. There are also trends from 1957 to 2003 of increasing frequency in hot days (35oC or more) of 0.08 days per year and a decreasing trend in cold nights (5oC or less) of 0.16 nights per year (Hennessy et al., 2004a).

"The best estimate of annual warming over Australia by 2030 relative to 1990 is about 1.0ºC for the mid-range emissions. Warming will be a little less in coastal areas and a little more inland. The pattern varies little seasonally, although warming is less in winter in the south. The range of uncertainty due to differences between models is about 0.6ºC to 1.5ºC for most of Australia, with the probability of the warming exceeding 1ºC by 2030 being 10-20% for coastal areas, and more than 50% for inland regions." Department of Climate Change (2007). Mean temperature change is likely to be greatest inland and least on the coast. Most warming is expected to occur in spring and summer, and least in winter.

Climate change is occurring and there are two options; ignore it in the hope that it will go away and accept the consequences; or develop strategies to manage climate change.

All horticultural crops are sensitive to temperature, and most have specific temperature requirements for the development of optimum yield and quality (Deuter, 2008).

Climate change will impact horticultural commodities and regions through all of the following:-

- Changes in the suitability and adaptability of current cultivars as temperatures change, together with changes in the optimum growing periods and locations for horticultural crops

- Changes in the distribution of existing pests, diseases and weeds, and an increased threat of new incursions
- Increased incidence of physiological disorders such as tip burn and blossom end rot
- Greater potential for downgrading product quality e.g. because of increased incidence of sunburn
- Increases in pollination failures if heat stress days occur during flowering
- Increased risk of spread and proliferation of soil borne diseases as a result of more intense rainfall events (coupled with warmer temperatures)
- Increased irrigation demand especially during dry periods
- Changing reliability of irrigation schemes, through impacts on recharge of surface and groundwater storages
- Increased atmospheric CO2 concentrations will benefit productivity of most horticultural crops, although the extent of this benefit is unknown
- Increased risk of soil erosion and off-farm effects of nutrients and pesticides, from extreme rainfall events
- Increased input costs – especially fuel, fertilisers & pesticides
- Additional input cost impacts when agriculture is included in an Emissions Trading Scheme (ETS)

With increasing temperatures, and changes to rainfall patterns which are currently uncertain, the simplest adaptation strategies will be employed and are currently being employed by growers. These adaptation options are likely to be closely associated with management options already well understood by growers (Howden et.al., 2007). These are the use of more adaptable cultivars and a range of cultural practices which enable growers to maintain current production in current locations – i.e. adapt to the 'new' climate in the current location. This will be driven in the first instance to maintain profitability through market timing, market access and market share.

If climate change impacts exceed growers adaptation capacity at a specific location, then a southward shift of production following the southward shift of agroclimatic zones is more likely to occur if growers are to maintain profitability through appropriate market timing, market access and market share (Kingwell, 2006).

Climate Change and Adaptation Strategies

With increasing temperatures and changes to rainfall patterns which are currently uncertain, the simplest adaptation strategies (autonomous and assisted adaptation) will be employed and are currently being employed by growers. These will be the use of more adaptable cultivars and a range of cultural practices which enable growers to maintain current production in current locations – i.e. adapt to the 'new' climate in the current location. This will be driven in the first instance to maintain profitability through market timing, market access and market share.

If climate change impacts exceed growers adaptation capacity at a specific location, more transformational adaptation responses will be required. A southward shift of production following the southward shift of agri-climatic zones is then more likely to occur if growers are to maintain profitability through appropriate market timing, market access and market share.

Flexibility has been the key to adaptation in horticulture to date, and is likely to continue to be an important component of adaptation strategies as climates continue to change. Growers have been able to manage climate variability reasonably well, although major improvements could be made if tools to assist with the management of climate variability, both temperature and rainfall, were designed specifically with the needs of horticultural growers and industries in mind.

The current drought has provided opportunities for some growers who have been able to shift production to where water for irrigation is available. Those who have done this successfully will be in a much better position to also manage climate change successfully.

The following are desirable climate change adaptation outcomes for horticulture, which are consistent with the adaptation strategies suggested by other researchers (ABARE, 2007) :-

- Resilient and adaptive horticultural production systems which are less vulnerable to climate change and climate variability
- Improved resilience to changes in pest and disease incidence
- Increased ability to capitalise on new market opportunities
- Regionally specific climate change scenarios, which are very relevant to managers of horticultural enterprises
- Practical tools available to horticultural growers and their advisors to better manage climate change and climate variability.

Integration with other agricultural climate change plans

NACCAP

The National Agriculture Climate Change Action Plan (NACCAP) - www.daff.gov.au/_data/assets/pdf_file/0006/33981/nat_ag_clim_chang_action_plan2006.pdf was developed for the Natural Resource Management Ministerial Council in 2006. The NACCAP focuses on research and development to build knowledge, solutions and tools that will assist managers to deal with the impacts of climate change. The outcomes sought are practical methods of climate change adaptation and mitigation for all of Australian agriculture. The NACCP was developed with four (4) Focus Areas – Adaptation; Mitigation; R&D; Awareness and Communication.

For simplicity, this Horticulture Climate Change Action Plan has incorporated the R&D Focus Area into both the Adaptation and Mitigation areas – leaving specific Actions which Australian Horticulture needs to address under three (3) Focus Areas – (1) Adaptation, (2) Mitigation, (3) Information, Awareness & Communication.

CCRSPI

HAL is involved in the Climate Change Research Strategy for Primary Industries (CCRSPI).

The strategy has been developed and aims to answer these questions:

- What is happening with climate change?
- What does it mean for primary industries, businesses and regions?
- What can we do about climate change?
- How can we best prepare for future climate change?

The strategy includes Six Themes (under two sub-headings):

Underpinning Research

1. Understanding Future Climates
    - What it will do: Understand how climate change will influence the future of Australia's primary industries – both long-term and seasonal forecasts
    - What it will not do: Support industry-specific scenarios
    - Rationale for collaboration: Expensive, long-term, consistency of models, identification of primary industry output requirements
    - Relevance to horticulture: HIGH
2. Managing Emissions
    - What it will do: Identify options for primary industries to manage and reduce emissions while supporting the development of production systems with low emissions
    - What it will not do: Directly influence Government climate policy or enforce adoption of or develop industry-specific tools
    - Rationale for collaboration: Similarities in measurement, reporting and issues such as soils, offsets, biofuels, reduced energy use
    - Relevance to horticulture: HIGH/URGENT
3. Preparing Industries
    - What it will do: Improve understanding of the timeframes and implications of climate change to inform adaptation strategies
    - What it will not do: Tailoring of practices to specific industries or delivery of extension programs
    - Rationale for collaboration: Info sharing, coordinate investment in topics such as pest, disease and weed risk and elevated CO2
    - Relevance to horticulture: MEDIUM

Enabling Research

4. Accessing Information
    - What it will do: Establishment of info 'hubs' for information relating to climate change
    - What it will not do: Replace existing websites or communication programs
    - Rationale for collaboration: Encourage awareness and debate, identify gaps, consolidation and consistency of reporting
    - Relevance to horticulture: MEDIUM
5. Facilitating Change
    - What it will do: Improve understanding on how to best encourage and drive practice change/adaptation responses to climate change
    - What it will not do: Deliver practice change on-farm
    - Rationale for collaboration: Share success stories, link researchers to industries, consolidate social research
    - Relevance to horticulture: MEDIUM
6. Linking Decision Makers
    - What it will do: Promote partnerships between policy, industry and researchers to better align research
    - What it will not do: Lobby Governments
    - Rationale for collaboration: Inform future priorities, promote debate, improve linkages and increase investment
    - Relevance to horticulture: MEDIUM

Benefits of collaboration through CCRSPI for primary industries:

- Access to ideas, inputs to policy
- Access and exchange of information, including existing high quality research data
- Increase research capacity and long-term relationships between partners – continued access to this capacity for primary industries
- Reduce duplication of RDE activity
- Along the RDE value chain, linking researchers to end users
- Enabling cross sector and cross region issues to be addressed
- Identify who is best able to 'lead' research programs

HAL

The vision of the HAL Environment Portfolio is to: *By 2010, Australian horticulture will be recognised internationally for its widespread adoption of commonly agreed good management practices, which both conserve and enhance the natural resource base and promote a long-term viable industry.*

This includes empowering industry leaders, facilitating meaningful partnerships, encouraging innovation and adoption of research, informing policy and positioning the industry.

Specifically for the area of climate change/variability the three strategies are Adaptation, Mitigation, and Awareness and Communication.

Appendix 3: Adaptation Strategies table

Table 1. – How might Climate Change affect management decisions in horticulture AND what are some appropriate Risk Management Options (Adaptation Strategies)?

Decision Issue	Tools or Adaptive Methods	Decision Maker	Possible Impact	Certainty of Impact	Some Risk Management Options (Adaptation Strategies)
Annual Crop Planting Decisions	• Cultivar Choice	Grower and Seed suppliers	Cultivars which are more adaptable to higher temperatures, **are not** available from Australian seed suppliers	Possible – vegetable cultivars are sourced (in the main) from overseas.	Extend the season by growing in other regions (purchase, lease or 'contract' production to supply the market).
	• Production Period & Production Timing	Grower (and Advisors)	Cultivars which are more adaptable to higher temperatures, **are** available from Australian seed suppliers.	Possible – more likely for some species e.g. lettuce and brassicas	Lobby seed companies and Peak Bodies to have appropriate cultivars available to the industry
			Crops maturing earlier resulting in a shorter production season (reduced by several weeks).	Probable – especially if more adaptable cultivars are not available.	Extend the season and maintain position in the market by growing in other regions (purchase, lease or 'contract' production to supply the market).
Property Acquisition	• Location of Production	Grower (and Advisor)	Higher temperatures will force some relocation of production to more suitable production region.	Possible – more likely for some species e.g. lettuce and brassicas.	Maintain position in the market by growing in other regions (purchase, lease or 'contract' production to

					supply the market).
Crop Management .	• Cultural Practices	Grower (and Advisors)	Higher temperatures will have adverse effects on product quality of many crops.	Probable – especially if more adaptable cultivars are not available.	Maintain position in the market by growing in other regions (purchase, lease or 'contract' production to supply the market with high quality product).
			Higher temperatures will increase pest and disease activity for many crops.	Certain.	Continuous improvement in the effectiveness and adoption of IPDM systems.
	• Pest and Disease Management	Industry Peak Bodies, R&D providers and RDC's	Higher temperatures will increase pest and disease survivability, and extend their range to more southerly regions.	Certain.	Awareness of the potential for movement of 'new' and exotic pests and diseases into production regions; and continuous improvement in the effectiveness and adoption of IPDM systems
Water management	• Inputs (amount and costs)	Grower (and Advisors)	Higher temperatures will increase the need for more efficient irrigation systems, and/or more irrigation.	Possible – more likely for some crops and especially in southern production regions.	Water Use Efficiency measures including trickle irrigation where appropriate. Irrigation scheduling using latest techniques and appropriate technology.
Marketing Arrangements	• Production Period & Production Timing	Grower and Marketers	Crops maturing earlier (i.e. shorter duration from planting or flowering to	Probable – especially if more adaptable cultivars are not available.	Maintain position in the market by growing more adaptable cultivars OR

			harvest).		growing in other regions (purchase, lease or 'contract' production to supply the market).
			Increased post-harvest costs.	Probable – especially if more adaptable cultivars are not available.	Maintain position in the market by growing more adaptable cultivars OR growing in other regions (purchase, lease or 'contract' production to supply the market).
			Reduced product quality and/or yield.		

** Adapted from Clark, A., Barratt, D., Munro, B., Sims, J., Laughlin, G. and Poulter, D. (2006) – Climate Change – Adaptation in Agriculture. Science for Decision Makers – Bureau of Rural Sciences, Department of Agriculture and Fisheries - www.acera.unimelb.edu.au/materials/brochures/SDM-**Climate**%20**change**.pdf (downloaded 17/3/2008).