

# ***CLIMATE CHANGE IMPACTS AND PRIORITY ACTIONS IN THE AGRICULTURE SECTOR: BACKGROUND PAPER***

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## ***Introduction***

This paper assumes that climate change in NSW over coming decades is likely to conform to the ‘hot, dry’ scenario analysed at the NSW DPI Climate Change Risk Management workshop in December 2006 (Department of Primary Industries 2007). All climate change projections for NSW predict an increase in average annual and seasonal temperatures so the ‘hot’ part of this scenario is not controversial (CSIRO, BoM & AGO, 2007). Under a ‘best bet’ scenario (50<sup>th</sup> percentile projection with medium emissions) increases in average temperature of 1-1.5°C will be widespread across NSW in summer, autumn and spring by 2030 while in winter the increase will be lower though still positive. Greater increases in temperature are indicated in the longer term (by 2050 and 2070), and for higher emission scenarios.

Rainfall projections to 2030 for the same scenario suggest decreases in average annual rainfall of 2-5% over most of NSW, with decreases of 2-10% in winter, widespread decreases of 5-10% in spring, little change in summer rainfall and decreases of 2-5% in autumn though only in the northern half of the State. Decadal-scale natural variation in rainfall is comparable to the projected changes to 2030 so that natural variation may mask or significantly enhance the greenhouse-forced changes (CSIRO & BOM, 2007). Again, greater impacts are evident in longer term projections or with higher emissions.

Associated with the ‘best bet’ scenario would be generally small decreases in relative humidity, small increases in potential evapotranspiration, and increased frequency of extreme events related to temperature, rainfall intensity (except in winter and spring) and drought (CSIRO & BoM 2007).

All of these changes would be associated with, and underpinned by, an increase in atmospheric CO<sub>2</sub> concentration.

## ***The agricultural sector in context***

The agriculture sector in 2005 contributed 87.9 Mt CO<sub>2</sub>-e to Australian greenhouse gas emissions, representing 15.7 % of the total, almost unchanged from 1990 (AGO 2007). This contribution is now substantially greater than that from the Land Use, Land Use Change and Forestry sector (6% of national emissions in 2005) which has declined substantially (by 73.9% since 1990) due to the cessation of broad scale land clearing.

Within the agriculture sector, livestock industries are by far the greatest source while emissions from agricultural soils (arising from soil management, cultivation and fertiliser use) are also significant (Table 1). It seems unlikely that the NSW Government’s target of a 60% reduction in emissions by 2050 could be achieved without attention to these sources, especially given that reductions in the agriculture sector may be achieved more cost effectively than in other sectors (Keogh 2007).

**Table 1. Greenhouse gas emissions from Australian agriculture by source.**

Source	Emissions Mt CO <sub>2</sub> -e		Change in emissions (%) 1990-2005
	1990	2005	
Enteric fermentation	63.9	58.7	-8.1
Manure management <sup>1</sup>	2.07	3.4	66.3
Rice cultivation	0.49	0.22	-56.0
Agricultural soils (non-CO <sub>2</sub> gasses)	14.4	16.6	15.2
Savannah burning	6.6	8.7	30.9
Agricultural residue burning	0.29	0.35	20.6
<b>Total</b>	<b>87.7</b>	<b>87.9</b>	<b>0.2</b>
<sup>1</sup> Emissions from livestock manure in intensive industries eg piggeries (50%), feedlots (30%) and dairies (20%)			
Source: AGO 2007 quoted by Keogh 2007			

### ***Identified risks***

The December 2006 workshop identified and prioritised a number of risks posed for various agriculture sectors (or ‘elements’) by the ‘hot, dry’ scenario outlined above. Existing controls that tend to reduce the likelihood of a risk occurring, or limit its consequences if it does occur, were also noted (Table 2). These controls include a number of regulatory, policy and planning instruments as well as current R,D&E activities within NSW DPI.

### ***Identified R&D priorities***

The *Draft Discussion Paper: Climate Change Research Priorities for NSW Primary Industries* (Fairweather and Cowie 2007), prepared for the Ministerial Advisory Council on Primary Industries Science, has already identified broad R&D priorities for NSW DPI under the headings of modelling, mitigation and adaptation. Those relevant to the agriculture sector are summarised in Table 3. Broadly, it is argued that development of new agricultural systems aimed at mitigating climate change must consider their life cycle greenhouse gas and energy balance, their impact on other environmental attributes and their adaptability to future change. Those aimed at adaptation must result in the development of resilient agricultural production systems with increased capacity to cope with climate variability, trends in climate variables, and indirect impacts (eg fire, pests) anticipated under climate change.

At the technical level, the priorities listed in Table 3 are compatible with the ‘potential next steps’ identified under the focus areas of Adaptation, Mitigation and Research & Development by the national workshop on climate change (Campbell 2007) convened to progress the *National Agriculture and Climate Change Action Plan 2006-2009* (DAFF 2006), and also with the ‘potential areas of action’ identified for the Agriculture, Fisheries and Forestry sector under the Council of Australian Governments’ *National Climate Change Adaptation Framework* (COAG 2006). Adoption of these priorities should thus position NSW DPI appropriately to engage in collaborative programs developed through the recently announced Australian Centre for Climate Change Adaptation.

### ***Implications for agricultural sub-sectors***

While there is thus broad agreement on the risks to agriculture posed by climate change, and the priority areas for R,D&E, the identification of specific projects requires a sub-sectoral analysis.

#### ***Intensive livestock industries (Dairy, pigs and poultry)***

##### ***Likely climate change impacts***

The NSW dairy industry is based on the supply of a constant volume of milk year-round to processors for the domestic market. Feed is a major component of the cost of production (up to 80% of the

**Table 2. ‘Extreme’ and ‘high’ priority risks and controls identified for agriculture sectors (NSW DPI workshop, December 2006)**

<b>SECTOR</b>	<b>RISK and (PRIORITY)</b>	<b>CONTROLS</b>
Rainfed extensive agriculture (rainfed broadacre cropping)	Significant reduction in production and increased annual variability (quality and quantity); impact on export earnings and viability of rural communities (High)	Demand for ethanol feedstocks Experience and technology for managing for variable climate (eg zero till) Planning processes Alternative feed sources Current level of activity limited by Native Vegetation Act Plant breeding for quicker season and drought tolerant varieties
	NSW DPI unable to support stakeholders as changes take hold (service delivery issue) (High)	Work in hand Initiatives yet to be undertaken by producers
	R&D priorities locked into historical practices and dominant industries which might not be relevant to future. (High)	Strategic planning framework
Irrigated agriculture/ horticulture	Increased conflict for water leading to reduced economic and/or environmental sustainability (Extreme)	Water Act National Water Initiative
	Significant reduction in production and increased annual variability (quality and quantity); impact on export earnings and viability of rural communities (Extreme)	Growing adoption of new technology Imported sources
	Loss of confidence in water trading market (High)	National water Initiative
	Increased range of tropical pests and diseases leading to increased control costs (High)	Regulation, legislation, surveillance Research
	Dislocation of industries, infrastructure & regional economies as current crops cease to be viable (High)	State Plan Structural adjustment programs
	Increased loss of crops and infrastructure from extreme natural events (High)	New technology (hail netting, flood levies) Climate forecasts
Intensive livestock (including dairy on irrigated pastures)	Insufficient water to sustain existing highly water dependent industries (eg dairy operations) (Extreme)	Water efficient crops available (still need water) Options to adapt to alternative farming systems
	Dairy, pig and poultry (meat & egg) production no longer viable as feed prices rise and sources dry up (High)	Potential to import feed Individual farmers’ responsiveness (adoption of different systems)
	Yields decline as high temperatures suppress appetites & production (NB ‘hot less dry’ scenario will produce even worse outcomes due to high humidity) (High)	Temperature control Relocation of operations
	Increased grain production overseas drives low cost meat production to compete with local product. (High)	Nil

**Table 3. NSW Primary Industries research priorities relevant to the agriculture sector (after Fairweather and Cowie 2007)**

<b>ACTIVITY AREA</b>	<b>SPECIFIC RESEARCH PRIORITIES</b>
Climate change modelling	Development of regional climate change models through downscaling global climate projections.
	Development of a Geographical Information System (GIS)-based framework for assessing the risk of climate change for primary production systems.
	Vulnerability assessment of key systems to test the capacity for the coping range to be extended by proposed adaptation strategies.
	Assessment of the socio-economic impacts of climate change.
	Development of decision support systems to assist primary industries to cope with enhanced climate variability.
Climate change mitigation	Full lifecycle analysis of current and alternative farming systems, including direct and indirect emissions and removals.
	Development of sustainable production systems with enhanced carbon sequestration and lower life cycle emissions, that have capacity to adapt to climate change.
	Methods to reduce methane emissions from ruminant livestock, manage emissions from manure in intensive livestock industries, and reduce nitrous oxide emissions from applied fertiliser
	Use of char and other recycled organics as a soil amendment.
	Development of technologies for production of bioenergy and other products from biomass, including evaluation of feedstock and energy conversion options, socio-economic impact of a bioenergy industry on other NSW primary industries, and potential to produce high value chemicals from biomass.
	Development of the underpinning science to facilitate mitigation through emissions trading, including development of improved models of soil carbon dynamics under a range of management practices, and development of greenhouse accounting methods for use in inventory calculation and emissions trading.
Climate change adaptation	Breeding for faster grain filling, reduced chilling requirement and tolerance to higher temperatures, shorter growing seasons and reduced water availability.
	Evaluation of the interactive effects of increased atmospheric carbon dioxide in a water- and nutrient-limited environment on growth of major crop and pasture species.
	Impacts of climate change on product quality, pests and diseases.
	Development of strategies for minimising water losses, both on-farm and at regional scale.
	Improving water use efficiency for irrigated agriculture, while minimising increased energy requirements.

variable costs in northern NSW) and farms with the most home-grown feed (grazing + conserved hay and silage) tend to have the lowest variable costs and the highest operating profit per cow (Murphy *et al.* 2006). Impacts of climate change on the feed base will therefore be of major importance to the future economics of dairy production. These impacts will arise both through direct effects on the biology of forage species, through the availability of irrigation water on which the industry is critically dependent in most areas, and on the availability and price of grain which has now become an integral part of a previously pasture-based production system. Indeed the dairy industry nationally is the now single largest consumer of feed-grains in Australia, using over \$500M/annum.

In the sub-tropical dairy system of northern NSW, tropical grass pastures oversown with annual ryegrass provide the basic feed base for the dairy industry. This system is already showing signs of stress as increasing temperatures effectively reduce the period of rye grass growth and exacerbate feed gaps. The effect is evident both in the autumn, when the persistence of higher temperatures delays rye grass sowing and reduces early winter production, and in the spring as temperatures rise earlier above 29°C (the critical temperature for growth of ryegrass) and terminate the growing period. The result is an emerging spring feed deficit and an extension of the usual autumn deficit into early winter.

A number of alternatives are feasible to address these feed gaps including forage *Brassica* species, forage oats and perennial temperate grasses with the capacity to persist over the summer (eg prairie grass and tall fescue with novel endophytes) combined with perennial herbs such as chicory and plantain (Slack *et al.* 2000, Fulkerson *et al.* 2000, Slack 2004, Slack and Fulkerson 2004). However, further work is required to evaluate the many new forage *Brassica* species and cultivars currently available, and to refine management requirements for new pasture systems at farm scale.

Availability of irrigation water will have a substantial impact on the industry throughout much of the state. Inland areas such as the Riverina and the Macquarie, which are totally or largely reliant on river flows for irrigation, could face serious competition for water from other industries (eg horticulture) and may have a poor outlook for future expansion. On the coast, the availability of water for irrigation varies from valley to valley (e.g. relatively unrestricted in the Shoalhaven; overcommitted for irrigation in the Richmond valley) but reduced river flows or capacity to fill on-farm storages will affect dairy production in all areas. It is important to note in this respect the impact of a dryer climate on runoff is expected to be much greater than on rainfall *per se*. At the same time, irrigation requirements for forage crops and pasture could increase with increasing temperatures although changes to relative humidity will also be important in determining potential evapotranspiration.

Reliance on imported grain from the wheat belt is likely to become less viable as price and availability change with adjustments in the extensive cropping industries, and promotion of the bio-fuels industry increases competition. Dairy producers will ideally need to grow a range of pasture types, forages and crops in order to be as self-sufficient as possible and if necessary may rely more on contract cropping of maize and cereals from the mid-north and (to a lesser extent) the far north coast than on importation of grain from the wheat belt.

Direct effects of heat stress on the dominant Holstein-Friesian breed may be expected, including increased water intake, depressed feed intake, decreased milk yield and components, elevated somatic cell count and increased risk to clinical mastitis, increased body temperature, weight loss and reduced reproductive performance. In extreme cases excessive heat stress may result in the death of high producing cows. At a Temperature-Humidity Index (THI) > 72 conception rate falls rapidly and a THI>80 indicates extreme heat stress with loss of milk production and reproductive failure (Davison *et al.* 1996, Tranter 2007). Casino in northern NSW already experiences more than 185 days per year with THI> 72 and more than 30 days with THI >80.

Strategies for dealing with heat stress may include crossbreeding Holstein with Jersey or Brown Swiss to obtain a cow more suited to a hotter environment, 'cut and carry' feeding on covered feedpads, avoidance of mating in the hotter part of the year, and provision of shade and sprinklers. These strategies involve a penalty in increased labour and reduced production when milk prices are high.

Increased incidence of eye cancers in Holstein Friesian cows has already been noted by farmers (J Crawter, pers. comm.). Increased prevalence of cattle ticks and buffalo fly may also be expected.

Future trends in the dairy industry may be towards animals with lower genetic potential grazing a more diverse range of pastures, supplemented with conserved summer fodder crops and with grain depending on availability and price. Alternatively, changes in the economically optimum balance of grain, pasture and water inputs will result in reduced suitability of some areas for dairy production and a degree of relocation to more suitable environments.

The intensive pig and poultry industries, which are increasingly supplying the world's animal protein needs at the expense of meat from ruminant animals, are both heavily reliant on cereal grains such as wheat and barley as their principal feed component. Climate changes affecting the extensive grains industry will therefore also pressure the pig and poultry industries. These have traditionally been located in the cropping zones, or between the cropping zone and the urban market, to balance transport costs of raw material and product. Three changes can be foreseen with climate change, being (1) a scaling back of production if grain price climbs (2) relocation, in the long term, in the wake of shifts in cropping locations and (3) increased demand for water, particularly for pork production, if producers need to provide more in-shed cooling to maintain the production microclimate. Together, these factors indicate that climate change will alter the utility of current sites for pig and poultry production. The high level of vertical integration within the corporates currently dominant in these industries does provide a level of flexibility and protection from short term market forces, and a capacity to manage climate driven change all along the industry pipeline.

Government policy on such issues as water entitlement and charges, electricity costs and release of high nutrient effluent and greenhouse gases from manures may also affect location of these industries in the future.

#### ***Current and recent relevant research in NSW DPI***

Little if any climate-related research in the poultry industry has been undertaken by NSW DPI. Some engineering research on solid separation waste treatment for piggeries has been completed but involvement has been limited. Research relevant to the dairy industry has related primarily to development of seasonal risk management tools and related extension (Project 2.7), improvements in water use efficiency (Projects 1.22 and 2.14) and collaborative efforts with QDPI&F to improve the quality of kikuyu pastures, though not primarily for mitigation purposes (Project 1.11).

#### ***Gaps and opportunities***

Both the pig and poultry industries have their own R&D corporations and a high (though not all-inclusive) level of vertical integration. Their future prosperity in the face of climate change will not be dependent on R&D within NSW DPI where current expertise is limited to poultry health and pig growth and physiology (EMAI). The industries are only small emitters of greenhouse gases so that NSW DPI involvement will be justified only by assisting adaptation to changing climate, rather than by a focus on mitigation of emissions. NSW DPI does have a substantial advisory role to the NSW dairy industry, performance recorded dairies that could be used in adaptation research, expertise in dairy pasture R&D, and developing expertise in seasonal risk management in the dairy industry.

Of the specific priorities identified in Table 3 those most relevant to the intensive livestock industries, particularly the dairy industry, and the more detailed issues that they encompass are:

Development of regional climate change models through downscaling of global climate projections:

- Evaluation of suitable methods for downscaling of climate projections in coastal regions (where temperatures may vary greatly on relatively small spatial scales).

Development of decision support systems to assist primary producers cope with enhanced climate variability:

- Evaluation of climate change effects on the dairy feed base using the DairyMod model
- Determine THI trends for coastal and inland dairy locations to assess future exposure to heat stress.
- Further development of tools to assist producers manage seasonal risk (eg extension of the approach develop in Project 2.7, Appendix 2 to other dairy regions).

Methods to reduce emissions from livestock, manure and fertiliser:

- Determination of nitrous oxide emission factors appropriate for the dairy industry (following Edmeades 2004, Eckard 2007)
- Evaluation of the use of nitrification and urease inhibitors to reduce emissions.
- Managing diet quality to reduce methane emissions.
- Ecological manipulation of the rumen to reduce methane production
- Breeding to match cows with high feed conversion efficiency to a low input, pasture-based environment (Clarke *et al.* 2007).

Breeding for faster grain filling, reduced chilling requirement and tolerance to higher temperatures, shorter growing seasons and reduced water availability.

- Improving the quality of tropical grass pastures. A two-year study has commenced with the long-term aim to reduce lignin in tropical grasses (QDPI & F and NSW DPI).

Evaluation of the interactive effects of increased atmospheric carbon dioxide in a water- and nutrient-limited environment on growth of major crop and pasture species.

- Evaluation of more heat tolerant grasses and herbs as part of the dairy feed base.
- Interaction of nutrients, water, CO<sub>2</sub> and temperature in determining growth of C<sub>3</sub> and C<sub>4</sub> dairy forages (particularly C<sub>4</sub> species which have received little attention to date).

### ***Critical linkages***

Projects in the pig and poultry industries would require interfacing with Australian Pork Limited, Australian Egg Corporation Limited and RIRDC (chicken meat). There are currently no CRC's likely to support work in these industries.

A strong collaborative linkage already exists with QDPI & F in relation to the dairy feed base and linkages with DPI Victoria and University of Melbourne are developing.

### ***Extensive livestock industries (Beef and sheep)***

#### ***Likely climate change impacts***

Pastures in the rangelands and parts of the wheat sheep zone are likely to be more severely affected by anticipated climate changes than in the high rainfall zone since below a threshold of about 300-500 mm per annum the effect of elevated CO<sub>2</sub> in offsetting the impact of reduced precipitation through increased water use efficiency is diminished (Harle *et al.* 2007 and references therein). The feed base for the extensive livestock industries in the drier parts of the State may thus be expected to show increased variability in terms of quantity. The effect on feed quality may be variable but could often be negative as elevated CO<sub>2</sub> coupled with warming has been shown to exacerbate nutrient deficiencies in systems which are already deficient in nitrogen (Scholes and Howden 2003). Elsewhere in the wheat sheep zone, and in the high rainfall zone, pasture production is less likely to be impacted by climate change, and forage quality in grass-legume pastures may even be enhanced, although changes in seasonal growth patterns (eg a shortening of the growing season for temperate species) may reduce production in some areas (Harle *et al.* 2007). Where irrigation contributes to the feedbase, increasing variability of rainfall, and amplified effects on stream flow and runoff into farm dams, is likely to reduce feed availability.

In addition to the effects on dry matter production of individual species, elevated CO<sub>2</sub> and associated changes may influence community composition. However, the effects of these impacts are likely to be small relative to the capacity of management and other factors to regulate such changes. Effects could include an expansion and thickening of woody plants in grass dominated ecosystems (Archer *et al.* 1995), and altered distribution of C<sub>3</sub> and C<sub>4</sub> species although Howden *et al.* (1999) found that any southward migration of the zone dominated by C<sub>4</sub> plants was likely to be limited.

In higher rainfall environments it may be possible to adapt to climate change, in terms of forage quantity and quality, by breeding of adapted lines of key forage species or by carefully selecting existing genotypes to suit more clearly differentiated niches in a heterogeneous landscape. In rangelands, however, the capacity of native communities to continue to support economic levels of livestock production will depend critically on the capacity of species to cope with the interaction between grazing and changed environmental conditions, particularly given the increasing adoption of shedding sheep breeds in the Western Division with the reputed capacity to survive at very low levels of forage availability. Understanding the phenotypic plasticity of major species, or if possible vegetation communities, in the light of this interaction is critical to understanding the capacity of the pastoral industry to survive in its current form and thus the need for any further policy initiatives to secure its orderly transformation, and the avoidance of the '9<sup>th</sup> episode' of rangeland degradation (McKeon *et al.* 2004).

Harle *et al.* (2007) concluded that while the Australian wool industry would be affected by climate change to 2030, through effects on the feed base as well as impacts on water resources, land carrying capacity and sustainability, animal health, and competition with other sectors (particularly cropping), as a whole it was likely to be fairly robust to it. They considered that early adaptation through development of low emission grazing systems, more sustainable management especially in the rangelands, and improved management of climate variability could significantly reduce the downsides of climate change impacts.

Impacts on the beef industry will result from changes to the feed base discussed above, and may also include increased ectoparasite impact due to the increased incidence of tick and buffalo fly, and heat stress. The result could be reduced levels of growth, reproduction and age at slaughter. There is likely to be concomitant change in other factors to compensate. These could include infusion of appropriate genetics (e.g. for heat tolerance, feed efficiency, resistance to warm climate ectoparasites and walking ability) and change to supplementation patterns and the materials used (eg less cereal grain and more biofuels by-products).

Heyhoe *et al.* (2007) estimated the impact of climate change at 2030 on total factor productivity and production of broadacre industries for the central west slopes and plains of NSW, as well as the impact of adaptation technologies. The approach was to derive a pasture growth index (essentially an index of biological productivity) under assumed climate change scenarios, use that index to derive a measure of change in total factor productivity for selected industries, and determine the corresponding changes in commodity outputs and gross regional product by means of the ABARE AusRegion economic model. Application of adaptation technologies was simulated by assuming increases in agricultural productivity of 0.05-0.15% pa (compared with long term average productivity growth in broadacre agriculture of about 2% pa), without specifying particular technologies. The results (Table 4) are necessarily subject to a number of caveats but they do indicate the potential for negative impact on regional economies (although considerably less than for the northern and eastern wheat belt case study area in WA), the potential of mitigation strategies to reduce these impacts, and the greater impact on crop industries than on livestock industries.

**Table 4. Economic impacts of climate change at 2030 on broadacre industries in the Central West Slopes and Plains of NSW. (Results are expressed relative to a reference case assuming no climate change and are presented only for the ‘low rainfall’ scenario. Climate changes are based on a midrange emissions scenario, SRES A2. Data derived from Heyhoe *et al.* 2007)**

Industry	Change in total factor productivity (%)		Change in economic output (%)	
	Without adaptation	With adaptation	Without adaptation	With adaptation
Wheat	- 4.2	-2.1	-6.8	-3.4
Beef	-1.7	-0.8	-0.9	-0.5
Sheep meat	-1.8	-0.9		
Wool	-2.2	-1.1		
Wool & sheep meat			-2.1	-1.1
Gross regional product			-1.1	-0.5

Increased riskiness of cropping, implied by Table 4 and consistent with the projected trend towards drier (and more variable) winters and springs, may prompt a resurgence of livestock (particularly sheep) production in the wheat-sheep zone as a risk management measure.

#### ***Current and recent relevant research in NSW DPI***

Current (Appendix 1) and recent (Appendix 2) NSW DPI projects relevant to extensive livestock production (projects 1.6, 1.10, 2.2, 2.3, 2.9, 2.10, 2.11, 2.12) have focussed primarily on development and extension of seasonal risk management tools, some breeding of pasture varieties suited to lower rainfall zones, development of methodology for measuring livestock methane emissions and assessment of the potential for reduced livestock emissions through rumen manipulation. These projects do not include the substantial work undertaken in the area of net feed efficiency of beef cattle which has demonstrated, as a correlated response, a substantial reduction in emissions from cattle selected for low net feed intake. No attempt has yet been made to quantify the aggregate emissions resulting from alternative livestock management systems, including genetic reduction through increased feed efficiency, despite the overwhelming importance of enteric fermentation to total agriculture sector emissions and the dominance of grazing as a land use over large parts of both NSW and Australia.

#### ***Gaps and opportunities***

There has to date been little research to explicitly address the modelling, mitigation or adaptation issues as they relate to extensive livestock production. This area now displays some significant gaps but also provides substantial opportunities for NSW DPI.

The need for Emissions Intensity Benchmarking has been agreed by COAG (AGO 2006) and presents NSW DPI with the primary opportunity to undertake the benchmarking that can underpin the climate credentials of extensive agriculture in NSW. Funding from both State and Federal sources could be expected to support co-investment by NSW DPI to document the current emission and sequestration levels occurring in the agricultural enterprises of NSW. Such benchmarking would be a logical foundation investment for climate change R&D in the agriculture sector and would provide the basis against which the impact of emerging mitigation options and alternate management strategies could be assessed.

Of the specific priorities identified in Table 3 those most relevant to the extensive livestock industries, and the more detailed issues that they encompass, are:

Full lifecycle analysis of current and alternative farming systems

- Emissions intensity benchmarking for the major agricultural (particularly extensive livestock) industries and production systems;

Methods to reduce emissions from livestock, manure and fertiliser

- Role of rumen modifiers or dietary supplements in reduced emissions
- Quantification of the (permanent) reduction in methane emissions achieved by selection for low net feed intake (in beef cattle) so that permanent and quantifiable reduction could be claimed in an emissions trading context.

Development of the underpinning science to facilitate mitigation through emissions trading

- Development of whole-farm systems models for livestock and mixed farming systems that allow the impact of mitigation and adaptation options on whole farm emissions and sequestrations to be quantified.

Evaluation of the interactive effects of increased atmospheric carbon dioxide in a water- and nutrient-limited environment on growth of major crop and pasture species.

- Interaction of grazing, CO<sub>2</sub> and water stress on population dynamics of key pasture (particularly rangeland) species;
- Grazing ecology of shedding sheep breeds in the rangelands, particularly as related to the issue above;
- Ecological and system models of the effect of climate change on future productivity of the livestock industries at current or alternate locations (cf. Hall *et al.* 1998).

Impacts of climate change on product quality, pests and diseases.

- Effects of climate change on susceptibility to blow fly strike
- Potential range expansion of key weed species (eg Mesquite and Prickly Acacia) and quarantine protocols that might be appropriate to restrict spread to NSW.

Development of decision support systems to assist primary industries to cope with enhanced climate variability.

- Continued refinement of decision support tools, particularly ones that reduce reliance on historical probabilities
- Development of a web-based capacity to provide seasonal risk assessments for pasture growth at property or paddock scale.

Development of the underpinning science to facilitate mitigation through emissions trading.

- Quantification of the sequestration implications of management of 'invasive native scrub' in the semi-arid zone.

### ***Critical linkages***

Key linkages in relation to Emissions Intensity Benchmarking are with the Australian Greenhouse Office (AGO) and the NSW Greenhouse Office as major potential co-investors. Key funding agencies for mitigation research include the AGO and Meat & Livestock Australia.

There is no world leader in agricultural GHG modelling, but collaborations with the NZ based networks should be developed and University of Melbourne in the first instance. Strong links already exist with the Queensland Climate Change Centre of Excellence in relation to pasture growth modelling under climate change and will be maintained.

### ***Broadacre cropping***

#### ***Likely climate change impacts***

Table 4 indicates that the economic impact of climate change on broadacre cropping is likely to be greater than for the livestock industries but that adaptation which achieves even quite modest increases in productivity can substantially reduce this effect. Dryland broadacre croppers in NSW have always experienced significant seasonal variability and the farming systems they currently use incorporate a range of management factors and technologies to reduce this risk. While these industries may be

particularly exposed to the greater seasonal variability associated with climate change they also have the capacity and experience to allow them to adapt their systems relatively quickly to these changes. One factor facilitating this adaptation for many will be the experience of those already farming in more marginal environments. Farmers can be expected to look to their colleagues ‘further west’ to gain insights about how to handle future climate scenarios in their own district and indeed this is already happening. For those already at the margins, however, adaptation may not be feasible.

Perhaps the biggest risk for dryland croppers under the ‘hot dry’ scenario is that the variability of the seasonal break will increase even further, and be combined with unreliable spring finishes. The reduced possibility of an early autumn break will restrict the range of crops that can be grown (e.g. canola may be taken out of the rotation completely because of its requirement for an early break). With a reduced range of rotation options farmers may revert to the easy-to-grow cereal on cereal system which will bring with it the attendant risks of soil fertility decline, disease and weed build up etc. Indeed, a trend in this direction has already occurred in the last 5 years with the continuing drought conditions in southern NSW.

In addition to effects on rainfall, the future climate will probably include greater unpredictability of frost occurrence and the associated effects of late frosts on crops at flowering and in the early stages of grain filling. In terms of total cost to the grains industry the value of production lost due to frost is small. However, for an individual grower the cost can be devastating. Overall, a greater frequency of failed crops could be expected in the southern cropping regions, resulting in more forage available for livestock either directly or through hay production. Combined with the greater economic resilience of livestock industries (Table 4) this would suggest an increased role for livestock in mixed farming systems.

The emergence of weeds and diseases that are not currently a major problem may also be anticipated. An example in southern NSW is the emergence of deep rooted summer perennial weeds such as nightshade that have not been a problem in past decades.

While the ‘CO<sub>2</sub> fertilization’ effect has been well documented, Heyhoe *et al.* (2007) quote several studies that have shown that the benefits will only partially offset the more negative impacts of climate change on agricultural productivity. While many broadacre producers will no doubt be able to adapt to the changed environment some redistribution of the grains industries could be expected with a contraction from the more marginal environments where livestock production could displace cropping.

#### ***Current and recent relevant research in NSW DPI***

Howden *et al.* (2006) identified strategies for coping with climate change at the farm level including diversification of varieties, species change, shifting planting seasons, changed crop management practices (e.g. spacing, tillage and rotation), nutrient, erosion and salinity management, moisture conservation, pest management and application of seasonal risk assessments. These options are part of the normal range of crop management practices. While not specifically designed to deal with climate change, therefore, the considerable number of current projects (not listed in Appendix 1) aimed at developing ‘agronomy packages’ for a range of crops are among the most relevant since the capacity to match crop genetics (i.e. variety) to a particular management system and region is one of the most effective ways of dealing with environmental changes. Many other current and recent projects will also provide tools that will be applied to manage the impacts of climate change. The development of zero-till and controlled traffic farming systems, for example, has provided critical technology for conserving soil water and has provided producers in the northern cropping zone particularly with management options not otherwise available to spread seasonal risk.

Other relevant projects within NSW DPI have dealt mostly with the development and extension of seasonal risk management tools (Projects 1.7, 1.8, 1.9, 1.10, and 2.9). Development of a system to predict the onset and impact of blackleg and *Sclerotinia* in canola (not listed in Appendix 1) is an example of technology that can usefully assist with production risk management

Some attention has been given to the incorporation of perennial grass and shrub pastures into mixed farming systems (Projects 1.5 and 1.19) where they will offer advantages, in a more variable climate, over annual pastures and complement the already widespread use of lucerne pastures.

### ***Gaps and opportunities***

Continuation of current lines of agronomic and farming systems research will do much to assist broadacre producers cope with a changing climate, as with the example of non-till farming noted above. Complementary to these developments will be ongoing development of adapted varieties, including in the long term (by 2015-16) lines of wheat and barley with high nitrogen-use-efficiency requiring as much as 50% less fertilizer (<http://www.farmonline.com.au> ; 17 October 2007).

Of the specific priorities identified in Table 3 those most relevant to broad scale cropping and the more detailed issues that they should encompass are:

Development of decision support systems to assist primary industries to cope with enhanced climate variability.

- Development of decision tools with web-based access to assist fertiliser decisions in relation to seasonal climate outlooks.

Development of sustainable production systems with enhanced carbon sequestration and lower life cycle emissions, that have capacity to adapt to climate change.

- Incorporation of perennial grasses and shrubs into mixed farming systems. The capacity of perennial species to cope better with more variable and drier climate should allow for a more sustainable pasture phase in a crop/pasture rotation. Alternatively, they may also allow less productive cropping land to be taken out of production and sown down to long term pastures.
- Improved water use efficiency of crop and pasture species through management systems that enhanced soil water holding capacity and plant available water.

Impacts of climate change on product quality, pests and diseases.

- Development of systems for assessment of weed, pest or disease risk in relation to seasonal climate outlook.

Extension programs designed determine the factors limiting the uptake of zero till and /or controlled traffic farming system will need to be strengthened.

### ***Critical linkages***

Extensive linkages are already established with organisations involved in broadacre farming systems research. Additional linkages that should be established, though not necessarily with a view to collaborative projects, are with:

- plant breeding programs (e.g. CSIRO, Australian Centre for Genetic Resources) that are searching for genes for drought tolerance, disease tolerance etc;
- national FACE (Free Air Carbon Dioxide Enrichment) experiments that are investigating the impact of raised CO<sub>2</sub> levels on a range of agricultural systems. (FACE is a field based technique to raise the level of carbon dioxide in the air around growing plants. The FACE technique is used internationally at more than 30 sites);
- research programs in the emerging area of “canopy management” (mainly CSIRO) which seek to optimize yields and inputs by managing the green surface area of the crop canopy. Maintaining a more open canopy, for example, may allow better management of leaf diseases;
- GRDC, the major R&D funding provider for the broadacre cropping industries. GRDC is a major partner in the national Managing Climate Variability program which provides tools for growers to better manage within-season climate variability. These predictive tools such as Yield Prophet and Whopper Cropper, using information from the APSIM model, are already

used by the industry. Linking such tools more effectively with climate prediction tools would greatly benefit growers.

### ***Irrigation industries***

Only about 1.5% of agricultural land in NSW is irrigated annually but this area accounts for approximately 30% of the total value of agricultural production (NSW Irrigators 2002). Nationally, irrigated farm profit contributes over 50% of total agricultural profit (CRC IF 2006).

The major crops are cotton, most of which is irrigated, and rice which is entirely irrigated. Together, these crops usually contribute over \$1 billion to the NSW economy (CRC IF 2006) but their contribution has been substantially reduced in recent years (to a total of approximately \$678 M in 2004-5) due to reduced water availability. Most cotton growing regions in NSW started the 2006/07 season with announced allocations of around 20% or less, and some regions had 0%. In addition, 83% of vegetables, 75% of fruit and 83% of grapes grown in NSW are produced under irrigation. The irrigated sector thus represents an important source of fresh food production, especially in times of drought, and also provides some stability for regional livelihoods.

### ***Likely climate change impacts***

Increased variability of rainfall and, particularly, river flow due to climate change will reduce the reliability of water supply for the irrigation industries. This reduced reliability has already been experienced in the inland irrigation areas where the current drought has seen a return to rainfall conditions more typical of the early years of the 20<sup>th</sup> century, in contrast to the second half of the century when most irrigation areas were developed and average rainfall over the State was about 100mm higher than in the first half (BoM 2007).

Reduced reliability of surface water supply is likely to prompt irrigators to be more flexible in the ways in which they generate income. They may, for example, rely on a 'core' allocation of water for permanent crops, but make opportunistic use of "normal" water (100% of allocation plus any supplementary water available in the local water sharing plan) which may be available for 1 – 4 years. Since the 'core' allocation may be derived from various forms high security water, which tend to be characteristic of individual irrigation districts, the changes in enterprise mix might occur on that scale.

Reduced reliability of supply also has flow-on effects on the certainty of investment in the irrigation industry. This is particularly relevant to the on-farm investment required by the National Water Plan for water security. If 'normal' water is only available infrequently only those irrigators with flexible or low cost infrastructure will be able to make use of it. Many inefficient but flexible flood/furrow type systems, already established, can be maintained at costs which are relatively minor compared to the cost of new investment in more intensive and/or efficient systems. Similarly, reduced reliability of supply limits the options for alternative cropping systems, some of which may require large capital investments. Compared with alternative crops, cotton has one of the highest returns per ML of water used and growers are therefore unlikely to move away from irrigated cotton production in the short term.

Changes in river flow are also likely to physically challenge investments in more sophisticated irrigation systems. For example, it is likely that the most advanced irrigation management system (Martinez Open Hydroponics) will have limited application due to infrequent riparian supply.

Variations in the size of an industry, as could be expected with more variable water supplies, lead to capacity constraints in both the input supply and the product/market sides of the farm system. The irrigation industry will not be unique in this respect but it does rely heavily on high technology and intensive systems which need to be established and maintained. Opportunities for new industries or products may be missed because variability in production cycles cannot be matched with demand (e.g. a current opportunity for high quality pulse crops for human consumption, which would require

irrigation and the establishment of a domestic processing plant, may be missed if the risk associated with variable water allocations is too great).

Most irrigation in NSW is supplementary to rainfall to some extent, even if the rainfall only provides a leaching fraction to manage salinity in the root zone. From an agronomic perspective, rainfall can mitigate problems of limited wetted area which develop under some irrigation systems. Reduced or more variable rainfall under climate change may create a more challenging soil-water system.

An additional complication already apparent in rural communities is the loss of skilled labour. The reduced certainty resulting from climate change can only exacerbate this problem. Further challenges to the skill base will place irrigation managers in a difficult position, trying to operate in a changing climate where the solutions rely on higher levels of technology.

The water market in NSW and Australia is in its infancy and there is still a great deal of uncertainty about the capital value of permanent water and hence the equity in the irrigation industry. There is very little historical market information available, and recent climate shifts have resulted in distortions through interventions in the water market. Many irrigators have not worked through the recent history of the permanent water market let alone considered climate change.

Given the increased uncertainty associated with surface water supplies irrigation from groundwater sources may be viewed in a new light. The history of groundwater use is not one of high technology, and there have already been examples of over-allocation and subsequent intervention to reduce allocations. Groundwater irrigation into the future will require more sophisticated systems which are built on volumetrically sustainable supplies.

#### ***Current and recent relevant research in NSW DPI***

Current (Appendix 1) and recent (Appendix 2) NSW DPI projects (most directly) relevant to the impact of climate change in the irrigation industries (projects 1.7, 1.22, 2.6, 2.13, 2.14 and 2.15) have focussed primarily on water use efficiency and risk assessment. In addition, as a partner in the CRC for Irrigation Futures (CRC IF) NSW DPI is directly involved in research related to:

- The impact of more efficient irrigation systems, and increasing re-use of water, on salt concentration in the root zone;
- Use of new polymer formulations to reduce evaporation from water storages (in conjunction with the CRC for Polymers);
- Development of technology for more responsive irrigation management both on-farm and by water supply companies (eg plant-based sensors of water stress; estimation of evapotranspiration at farm and catchment scales);
- Development of economic and financial models appropriate to a water-limited rather than a land-limited environment;
- Physical protection structures for high-value crops (eg. shade cover for broad-acre irrigated vegetables).
- Harmonising the social, economic and physical constraints of an irrigation area through the establishment of Regional Irrigation Business Partnerships.

Other areas of irrigation research will be considered under horticultural industries below.

#### ***Gaps and opportunities***

Of the specific priorities identified in Table 3 those most relevant to the irrigation industries, and the more detailed issues that they encompass, are:

Development of regional climate change models through downscaling global climate projections.

- Impact of climate change on water availability and allocation. This is a priority issue and NSW DPI should actively collaborate with current initiatives in this area (e.g. the South

Eastern Australia Climate Change Initiative (SEACI) and the CSIRO Sustainable Yields project), particularly in the interpretation of likely impacts on NSW irrigators.

Development of sustainable production systems with enhanced carbon sequestration and lower life cycle emissions, that have capacity to adapt to climate change.

- Precision management of soil moisture to optimise sequestration of CO<sub>2</sub> and minimise emission of nitrous oxide;
- Testing of crop factors/coefficients for water use under increased or more variable temperature regimes.

Breeding for faster grain filling, reduced chilling requirement and tolerance to higher temperatures, shorter growing seasons and reduced water availability.

- Effect of elevated temperatures on GM varieties, particularly in the cotton industry. Temperature sensitivity has been suggested as an explanation of the variable expression of Ingard gene technology. Irrigation industries, particularly cotton, are becoming more dependent on GM technology. To some extent this issue will be addressed by the commercial providers of the technology.

Improving water use efficiency for irrigated agriculture, while minimising increased energy requirements.

- Development of efficient but less energy-intensive irrigation systems. The cost of energy can be expected to increase with greenhouse gas abatement programs. Technology is required to reduce the link between increased technical efficiency of irrigation schemes and increased energy use.
- Re-evaluation of the economic efficiency of fertiliser use (increased cost of production due to increased energy costs, contribution to emissions).

Assessment of the socio-economic impacts of climate change.

- Development of more sophisticated methodologies for economic evaluation of investment in water supply and on-farm infrastructure. Improved methodologies will need to consider longer investment cycles than the short term production optimisation decisions which are currently thought to drive decision making, together with decreased reliability of water supply, rapidly changing markets and volatile commodity prices.

Extension opportunities

Irrigators are likely to need more flexible scaleable technology to manage in the future climate. IrriMATE technology is a good example, involving small relatively low cost sensors which can be relocated from site to site, and are backed up by external consultants. Manual retrieval of data may offer a means of reducing the cost per site in scaleable systems compared with telemetry (e.g. G Bugs compared with C-probe for soil moisture sensing) but may also be constrained by labour availability. The essential point is that adoption of new technology will be enhanced by the promotion of flexible systems, not necessarily capital intensive systems.

Improved management of climate variability will mean providing irrigators with better information which can be readily used, and the availability of practical systems to utilise it. An example is the provision of weather information in the form of a quantitative value of evapotranspiration (ET). The challenge for irrigators is to have systems which can utilise improved ET information, together with the appropriate crop factor or coefficient.

### ***Critical linkages***

Critical linkages for the management of climate change impacts on the irrigation industries include:

- The network of NSW DPI irrigation extension officers;

- The Federal Department's responsible for the implementation of the National Water Initiative (National Water Commission) and the National Plan for Water Security (Department of Environment and Water), particularly with respect to the responsibility for water data management that has been assigned to the Bureau of Meteorology;
- Intra- and inter-State agencies engaged in relevant research activities.

### ***Intensive cropping (Horticulture/viticulture)***

Total value of production for the Australian horticultural industry is \$6.9 billion, believed to be \$1.3 billion in NSW. The industry covers fruits, vegetables, nuts, nursery, extractive crops, cut flowers and turf. It is Australia's fastest growing agricultural industry with more than 17,000 enterprises covering all geographic zones and employing 64,000 people.

The Australian wine industry has expanded rapidly since the mid nineties, the total area under vines doubling in the last ten years to 168,791 ha in 2006, with 23.8% in NSW. The expansion was mostly driven by export. About 50% of wine production is exported with a value was \$2.82 billion in 2006. Grape production in 2007 was reduced by about 30% due to the impact of drought and frosts. (Australian Wine Industry Directory 2007).

### ***Likely climate change impacts***

Reduced water availability and increased temperatures will affect zones suitable for growth, flowering, fruit set and ripening of perennial horticultural crops in particular. Eventually this will shift production zones, leading to the dislocation of industries, infrastructure and regional economies. Operators with the resources and knowledge may enter other horticultural and/or agricultural sectors more suited to the new environment. Since in general it is only the highest quality product that is exported reduced yield and quality will result in a net reduction of horticultural exports, and reduced viability of rural communities.

Higher temperatures (and their effects on plants e.g. earlier or extended ripening) will increase the distribution of existing insect pests and are conducive to establishment of new pests in wider areas, resulting in reduced production and increased control costs. For example, Queensland fruit fly (Qfly) has acclimatised to the horticultural production areas of inland NSW and an Exclusion Zone protects the market access of \$350 million worth of product grown in this area. Increased average temperatures and changes to host tree phenology would expand the range of Qfly and accelerate the expansion of a vast range of other tropical fruit fly species.

Higher temperatures together with increased rainfall, CO<sub>2</sub> and humidity can increase expression of disease, the persistence of pathogens in the environment, and the cost of control. For example, disease caused by infection with *Phytophthora* species and postharvest rots caused by *Glomerella* species in apples are currently evident in Bilpin but rarely occur in cooler production areas

Grape production will be similarly affected by climatic changes, although there is more adaptability to altered conditions, due to the wide range of varieties available for production in different climatic zones. Higher temperatures will lead to larger canopies, offsetting the improved water use efficiency due to higher CO<sub>2</sub> content of the atmosphere so that overall the water requirements will increase. Increased temperature will also alter the growing season. An earlier start to the season will result in higher frost risk and less than optimal growing conditions for the current varieties. Earlier harvest will result in reduced grape quality of the currently grown varieties. Alternative varieties better suited to the warmer conditions are available but might have marketability difficulties.

Increased frequency and range of extreme weather events (eg hail storms) will increase losses of crops and infrastructure (including greenhouses), increase spread of diseases (eg citrus canker is known to be spread by hurricanes in the USA) and insect pests (which also vector viral diseases).

The need for improved water use efficiency may drive field production sector (e.g. vegetables and ornamentals) and perennial crops (e.g. grapevines and citrus) to protected cropping systems. However, on the positive side, greenhouse systems offer opportunities for improved climate control, integrated pest and disease management, nutrient recycling etc which may improve sustainability. Large-scale shade house structures may have some application in warmer areas to reduce impacts of heat and reduce water demands of high value crops. Water allocations might also move to higher value horticulture crops from some broad acre agricultural crops.

### ***Current and recent relevant research in NSW DPI***

Most current and recent projects relevant to climate change in the horticulture and viticulture industries have focussed on irrigation management and water use efficiency, or the interaction of water and fertiliser use (Projects 1.12, 1.20, 1.21, 2.6, 2.17, 2.18, 2.20, 2.21). One project has focussed specifically on identification of risks to the horticulture industries from climate change, potential adaptation mechanisms and research challenges (Project 2.8) Some work has also focussed on matching of varieties to potential production areas using heat unit mapping techniques (Projects 2.16 and 1.13). A considerable amount of extension activity has also focussed on water management, particularly in the context of the current drought (Projects 1.14, 1.15, 2.19). In addition, field investigations are ongoing into the viability of large scale shade structures for production of heat sensitive vegetable crops in non traditional locations (Project 1.16).

### ***Gaps and opportunities***

Of the specific priorities identified in Table 3 those most relevant to the horticulture and viticulture industries, and the more detailed issues that they encompass, are:

Assessment of the socio-economic impacts of climate change

- Assessment of the marketability of grape varieties suitable for hotter climates and better water use efficiency.

Development of sustainable production systems with enhanced carbon sequestration and lower life cycle emissions, that have capacity to adapt to climate change

- Development of vineyard management strategies to counteract the negative impact of higher temperatures and water availability;
- Use of shading, netting, mulches to control microclimate.

Breeding for faster grain filling, reduced chilling requirement and tolerance to higher temperatures, shorter growing seasons and reduced water availability

- Development of varieties with low-chilling requirement, tolerance to higher temperatures, reduced water requirement etc.

Impacts of climate change on product quality, pests and diseases.

- Impact of climate change on product quality and post harvest handling.
- Development of new integrated management strategies to control the range of pests and diseases experienced with increased use of netting over tree fruit crops

Evaluation of the interactive effects of increased atmospheric carbon dioxide in a water- and nutrient-limited environment on growth of major crop and pasture species.

- Understanding the impact of increased temperatures and CO<sub>2</sub> levels on vine phenology, partitioning and grape quality.

### ***Critical linkages***

Critical linkages for the management of climate change impacts on the horticulture and viticulture industries include:

- Better networking within NSW DPI – horticulture is exceptionally diverse and covers a much wider range of issues than other commodities.

- Victorian DPI and CRC National Plant Biosecurity have existing projects modelling effects of climate change on significant plant pests and pathogens.
- International collaboration needs to be further strengthened and developed with institutions working on climate change in viticulture for a longer period.

### ***National Emissions Trading Scheme***

The National Emissions Trading Scheme, a ‘cap-and-trade’ scheme proposed by the Prime Ministerial Task Group on Emissions Trading (quoted by Keogh 2007) to operate from 2011 or 2012, will have significant implications for the entire agriculture sector.

In the short term agriculture will be impacted by increased energy costs along the supply chain due to the increased costs imposed on major energy producers (including wholesale fuel suppliers as well as electricity generators) who will compulsorily participate in the scheme. While agricultural businesses may be able to generate income by the sale of carbon offsets to scheme participants there appears to be no provision for any compensation for reduced international competitiveness arising from the additional costs, as will apply to participants in the scheme itself (Keogh, 2007). In the longer term, agricultural industries may be compulsorily brought into the scheme ‘as practical issues are resolved’.

These ‘practical issues’ relate particularly to the rules surrounding the incorporation of agricultural emissions and sequestrations into the trading scheme and the means by which they will be measured. Keogh (2007) has argued the need to have these issues resolved, particularly in relation of sequestrations or offsets, before the introduction of the scheme if the agriculture sector is to be able to offset the additional costs from inception.

The Prime Ministerial Task Group (2007) has summed up the situation by noting that ‘the main focus for the agriculture sector at this stage in emission trading is to increase its capacity to deliver low-cost abatement, initially by the provision of offsets. This suggests that research effort should be enhanced to develop greater understanding of practical abatement opportunities ... and to improve enterprise measurement of agricultural emissions.’ The piloting of these R&D activities ‘at farm level’ is foreshadowed as a precursor to any inclusion of agriculture into the scheme. The Group also noted that ‘Given the shortcomings in the existing international methodologies for offsets, there is clearly scope to improve on these approaches. By establishing and demonstrating offset methodologies that work and are relevant to a range of global circumstances Australia would be well positioned to influence the evolution of international rules in this area....’

These statements, in conjunction with the COAG commitment to Emissions Intensity Benchmarking noted above, raise significant imperatives for NSW DPI at a number of levels. Technically these are, initially, to ensure that the agriculture sector is well positioned by 2011 to offer offsets to the initial participants in the national scheme and, subsequently, to be able to estimate the level of emissions from agricultural systems in anticipation of incorporation in the national scheme.

A number of relevant research projects are already in train or have been recently completed. These relate to:

- evaluation of Biochar as soil ameliorant capable to sequestering carbon as well as providing production or environmental benefits (Projects 1.3 and 2.1);
- carbon sequestration under alternative management systems or best management practices (projects 1.1, 1.2, 1.4, 1.17, 1.18, 2.4 and 2.5) or
- development of methodology to estimate the C sequestration and emissions in agricultural systems (projects 1.1 and 1.18).

Some of the gaps and opportunities highlighted by the foreseeable establishment of the scheme have been mentioned in other industry sections above. In terms of the specific priorities identified in Table 3 these may be summarised as:

Development of the underpinning science to facilitate mitigation through emissions trading

- Quantification of the impacts of management practices on soil carbon, particularly in major cropping and mixed farming systems  
This requirement should be incorporated in all farming systems research projects whether or not aimed primarily at climate change issues.
- Emissions intensity benchmarking for the major agricultural (particularly extensive livestock) industries and production systems;
- Development of whole-farm systems models (particularly for livestock and mixed farming systems) that allow the impact of mitigation and adaptation options on whole farm emissions and sequestrations to be quantified.  
This action will need to build on the projects and linkages already established to extend modelling capacity to incorporate livestock production systems which account for most emissions from the agriculture sector.
- Development of protocols for incorporation of non-permanent sequestrations (which may be lost if management changes) into the emissions trading systems or greenhouse accounting.
- Development of protocols to allow pooling of agricultural offsets (e.g. amalgamation of small tree lots across properties) to facilitate practical operation of emissions trading.

Assessment of the socio-economic impacts of climate change

- Contribution to development of policy regarding compensation for loss of international competitiveness by agricultural industries resulting from compulsory emissions trading.

A credible response to the imperatives of national emissions trading will require a considerable expansion or redirection of resources within NSW DPI. Collaborative linkages with DECC, CSIRO Land & Water, CSIRO Sustainable Ecosystems, RMIT, AGO, UNSW, U of Western Sydney and Massey University/Landcare Research New Zealand will need to be maintained or strengthened.

### ***Emerging themes***

The conclusions to be drawn from this background in terms of priority actions for NSW DPI will be determined by the workshop on 25-26 October. However, some themes can be discerned in the preceding analysis and we have attempted to draw out at least some of them even though to do so, given the complexity of the issues, may be to invite criticism from some sub-sectoral interests.

- First, this analysis has validated the Fairweather and Cowie priorities (as defined in Table 3) since none of the actions identified at a sub-sectoral level could not be easily accommodated within this general framework. The implication is that the framework can serve as a useful template against which to assess the wider benefits of projects not specifically related to climate change but with potential for corollary benefits in this area. Much of the future R&D effort within NSW DPI, including plant breeding programs, will fall into this category.
- It is essential that NSW DPI initiate or extend programs, in conjunction with other appropriate agencies, which will position the agriculture sector to capitalise on the opportunities offered by the establishment of a national emissions trading scheme, and prepare it for eventual inclusion in the scheme. This will involve the development of technology for tradeable emissions offsets, development of the modelling capacity to estimate emissions and sequestrations from whole farm systems, and active contribution to the development of the rules and administrative procedures that will apply to traded offsets and, in the longer term, producer participation in the national scheme.
- The early establishment of a program of Emissions Intensity Benchmarking would seem to be a logical first step in this direction. Given the major contribution of ruminant livestock to total agricultural emissions these industries must be the primary focus of any such program.
- An emissions trading scheme will impose additional costs on the agriculture sector and NSW DPI should consider its potential to contribute to any debate regarding compensation for reduction of international competitiveness.
- Climate change impacts will almost inevitably lead to some industry restructuring and impacts on regional economies. A need for policy development could be foreseen in some industries

particularly those already at the margin (e.g. the rangelands pastoral industry, the marginal wheat belt) and programs aimed at developing a sound scientific basis for this development would seem a priority.

- Irrigation industries and regional economies dependent on them would seem to be particularly vulnerable given the expected greater impact of climate change on runoff and stream flows than on rainfall. NSW DPI is not responsible for water management but should ensure that its efforts in development and delivery of improved on-farm water management systems are effectively integrated with reforms at other levels.
- Much of NSW DPI's effort to date has focussed on the development of risk management tools. While these are important, and need to be further extended and developed (particularly to remove reliance on unstable historical probabilities), improved risk management alone is an inadequate response to climate change.
- Biosecurity issues have been identified in a number of sub-sectoral analyses but no clear pathway for response, other than through on-going production based R&D, has yet emerged.
- A credible response to the themes sketched above will be demanding in terms of resources. It will also require effective integration across administrative boundaries and technical disciplines within DPI, and between DPI and a wide range of other organisations.

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## ***Appendix 1. Current NSW DPI projects, and their objectives, relevant to climate change adaptation and mitigation in the agriculture sector***

### **1.1. Soil Carbon Assessment and rehabilitation: Landholders Develop; and Implement New Practices**

1. To understand the nature of carbon fractions in farming soils under various best management practices in the northern rivers. The project will quantify the origin of carbon in soil (e.g. historical bushfires, decaying organic matter, farm inputs such as compost). Derive the importance of these soil carbon sources in relation to soil health and BMPs.
2. To measure and account for greenhouse gas emissions (CO<sub>2</sub>, N<sub>2</sub>O) from farms using existing management practices.
3. To implement, test, demonstrate and promote a technology (application of agrichar) that results in significant carbon gain in soil, while at the same time significantly reducing emissions of N<sub>2</sub>O to the atmosphere. This technology holds significant potential for rehabilitation of degraded land through rapid enhancement of stable and high surface area carbon.

### **1.2. Increasing soil carbon sequestration of NSW agricultural soils by better managing pastures**

1. To quantify the magnitude of soil carbon sequestration of pastures under a range of management practices in central and southern NSW,
2. To estimate the soil carbon sequestration potential of pastures and to identify the management practices to achieve them in different farming systems in central and southern NSW.

### **1.3. Assessment of Biochar for agronomic benefits and greenhouse gas abatement**

Quantify and optimise the carbon sequestration and greenhouse gas (GHG) mitigation by black carbon (BC), pyrolytic chars through developing and understanding of:

- (1) the effect of BC addition to soil characteristics, especially in regard to sorption of organic matter (OM) and influence on GHG relevant species
- (2) the physical and chemical surface structures of different forms of char and how these relate to the molecular mechanisms involved in the processes observed in the soil systems
- (3) the long-term C-storage and GHG mitigation potential of BC in soil.

### **1.4. Carbon sequestration under summer/winter response cropping in north western NSW**

1. Measure changes in soil carbon under perennial pastures and six cropping systems including response cropping which differ up to two-fold in biomass productivity from a field experiment (1994-2000) conducted on the Liverpool Plains
2. Compare soil carbon stocks from paired sites (conventional/zero-tillage cropping vs native vegetation) in north western NSW .
3. Measure changes in soil carbon under response and conventional cropping on two Liverpool Plains farming properties which were initially sampled in 1998.

### **1.5. Perennial forage grass improvement for low-medium rainfall recharge environments to improve sustainability and profitability**

The specific objectives for the NSW component of the project are:

- a) to develop a persistent summer active tall fescue so as to extend its area of adaptation into lower and less reliable rainfall regions receiving a high proportion of their annual rain in summer (500-700) mm per year; and
- b) to develop genotypes of sub-tropical grasses suitable for profit driven adoption in temperate and Mediterranean climatic regions.

### **1.6. Drought tolerant white clover cultivar for dry margins environments**

By December 2008 develop new productive and persistent white clover cultivars adapted to low rainfall grazing conditions in the dry margins of the Temperate Perennial Pasture Zone.

### **1.7. Development of a Climate Change Adaptation Risk Assessment Tool in a GIS Framework**

1. Understand the impacts of various climate change scenarios for specific agricultural sectors and geographical regions and identify risks and opportunities.
2. Inform the agricultural sector of the risks and opportunities that will need to be responded to over the next 5 -10 years in the light of climate change and variability to ensure viable agricultural industries into the future.
3. Define the agricultural and geographical areas most sensitive to climate change to inform and prioritise appropriate responses.
4. Inform the agricultural sector of the most appropriate adaptation responses to meet the challenges and opportunities presented by climate change and potentially increased climate variability.

### **1.8. Climate Change and Soil Health Workshops**

1. Head off inappropriate responses to climate change such as low flow pumping and excessive on farm water storage.
2. Provide training in strategies to improve rainfall utilisation which do not significantly impact catchment flows.
3. Provide training tailored to landscapes and soils that will allow landowners to maintain sustainable production in reduced rainfall seasons.
4. Promote measures that contribute to carbon sequestration and soil health.
5. Integrate training with the Community Support Officers and available incentive funding to promote the maximal conversion of plans into on ground works.

### **1.9. CropMate - climate information for crop production**

Develop a tool (CropMate) that collates and analyses timely climate, weather, crop, soils and economic data in a risk assessment framework to enable growers to make more informed decisions relating to crop production and educate farmers and advisers on climate variability at local, regional and state scales.

### **1.10. Farmers Guide to the Climate workshop**

Provide education and training on accessing and using climate and weather information in risk management on farm to all regions of NSW.

### **1.11. Improving the quality of kikuyu by reducing the lignin content using marker selection** (Collaborative project with QDPI &F)

1. Increase the quality of kikuyu by 15%
2. Improve the knowledge and understanding of the lignin biosynthesis as a means of improving quality in tropical grasses
3. Generate a elite high quality kikuyu breeding population and ultimately a new kikuyu cultivar

### **1.12. Management of high density citrus plantings** (funding terminated by data collection continues)

1. Develop optimum management strategies for high density citrus plantings.  
Data collected on seasonal growth patterns and effects of tree spacing and dwarfing viroid inoculation on the development of shoot flushes, flowering, fruit set, fruit growth and yield. Water use efficiency measured under two irrigation systems - drip and under-tree sprinkler.

### **1.13. Increasing citrus production in Pakistan and Australia through improved orchard management techniques.**

1. To improve nursery production practices and production incorporating quality assurance (QA) procedures for maintaining disease free material and to introduce germplasm to extend the marketing season based on the climatic suitability to specific growing areas.
2. To demonstrate 'Best Practice' orchard management focussing on tree spacing, crop management, nutrition and irrigation management.

3. To enhance research, extension and production capacity of Pakistan citrus institutions and industry.

**1.14. Irrigation Management Training** (Extension project).

Approximately 650 of the 800 horticulturists on the NSW side of Sunraysia have been through the Waterwise Irrigation Training course. This is linked to financial incentives for irrigation upgrades and improving irrigation monitoring and practices. Advanced courses on drip irrigation and filtration systems have also commenced. The major infrastructure upgrades on the NSW side of Sunraysia (underground piping of water delivery), along with the Irrigation Training and Incentives program, have produced major, measurable changes in water use efficiency, water table depths and water lost to drainage basins.

**1.15. Seminar programs on drought survival strategies for citrus and grapes.** (Extension project)

Seminar program for 2007/08 is ready for delivery from early October in Sunraysia and the Riverland of South Australia.

**1.16. Covered cropping in semi arid regions.**

Field investigations are ongoing into the viability of large scale shade structures for production of heat sensitive vegetable crops in non-traditional locations. A shade structure near Griffith growing melons and capsicums has been monitored for the past 2 seasons and will continue in 2007/08.

**1.17. Impact of recycled organics on soil carbon** (from Cowie 2007; not listed in Projects on the Web)

1. Determine the total, labile and recalcitrant fractions of soil organic matter before and sequentially after amendment with recycled organics;
2. Assess the efficacy of different recycled organics in increasing and maintaining soil carbon stocks over time; and
3. Maximise the role of recycled organics in the long term enhancement of soil carbon.

**1.18. Land management to increase soil carbon sequestration in NSW** (from Cowie 2007; not listed in Projects on the Web)

1. Develop capacity to use a rapid and cost-effective method for measuring soil C based on mid-infrared spectroscopy;
2. Assess macro- and micro-scale variability of soil C stocks in diverse landscapes to aid quantification of soil C stock;
3. Examine the dynamics of soil C sequestration as a result of land management changes, including revegetation, altered crop rotations and grazing management;
4. Examine the ability of organic amendments, particularly bio-char, to increase soil C stocks; and
5. Contribute experimental data to calibrate and parameterise the carbon accounting model FullCAM, to improve our capacity to estimate the potential for changed land management to increase soil C stocks, and to provide a calculation tool for emissions trading.

**1.19. Grain & Graze Regional Initiative - Central West/Lachlan**

1. Develop more profitable/sustainable farming systems through research and collation of existing farmer knowledge;
2. Improve environmental outcomes from mixed farming systems, by reducing the leakage of water and nutrients, and by identifying opportunities for better biodiversity outcomes;
3. Increase the capacity for better and more confident decision making in the mixed farming community by providing networking, training and extension opportunities relating to production and natural resource management.

The most relevant sub-projects are:

5. Eastern zone pasture cropping systems - an evaluation of the costs and benefits of pasture cropping in the higher rainfall parts of the project area;
6. Western alley farming systems - an evaluation of the costs and benefits of incorporating old man saltbush into farming systems in the western parts of the project area.

### **1.20. The water relations of Semillon vines.**

The study had confirmed the high water demand of this variety under hot conditions; the next step is to develop management strategies to improve water use efficiency. 2005-2008

### **1.21. Optimising resource use and protecting the environment.**

A large section of this project aims to match seasonal irrigation schedules and fertiliser application to vine requirements. 2006-2010

### **1.22. Development of a more suitable forage base for the dairy industry**

1. To determine the water use efficiency (WUE), measured as production of digestible energy per mm of water used, and quality of 30 dairy forage species when provided with optimal and less than optimal water availability.
2. To incorporate data on WUE and forage quality into a model to develop the most profitable whole-farm feed plan considering the seasonal growth pattern of forages, cost of alternate feeds, climate and availability of irrigation water.

## ***Appendix 2. Recently completed NSW DPI projects, and their objectives, relevant to climate change adaptation and mitigation in the agriculture sector***

### **2.1. Evaluation of chars as soil amendments**

To evaluate char products as possible soil amendments for Australian soils by

- (i) characterizing the physical chemical and biological properties of the chars.
- (ii) identifying the optimal conditions for their application.

### **2.2. New methods for measuring greenhouse gas production and energy expenditure by ruminants**

1. Quantify the precision of enteric methane production estimation made using recently developed high-flow SF<sub>6</sub> permeation tubes.
2. Quantify the precision of enteric methane production estimation made using propane-releasing permeation tubes.
3. Training of local staff by an international expert in the establishment and use of animal respiration facilities.
4. Establish whether intraruminal permeation tubes can be used to measure carbon dioxide (CO<sub>2</sub>) production and oxygen (O<sub>2</sub>) consumption by ruminants, and so measure energy expenditure.
5. Develop total greenhouse gas (GHG) emissions profiles for cattle on grain and on roughage diets.

### **2.3. Reduction of methane emissions and enhanced productivity from sheep by elimination of rumen protozoa**

- 1) To evaluate alternative means of eliminating or managing rumen ciliate protozoa.
- 2) To explore natural variation in protozoal populations among livestock.
- 3) To determine the effects of short-term defaunation on animal productivity and methane production.

### **2.4. Economic potential of land-use change and forestry for carbon sequestration and poverty reduction**

- (1) determine the most appropriate land-use change and forestry systems for capturing carbon-credit payments and assisting in poverty reduction.
- (2) estimate the transaction costs of actual projects and identify principles of project design to minimise these costs.

### **2.5. Maintaining profitability and soil quality in cotton farming systems**

Determine the long-term effects of rotation crops and stubble management on soil quality, carbon storage, deep drainage and nutrient leaching; and growth, yield and profitability of succeeding cotton.

### **2.6. Australian vegetable crops - maximising returns from water**

Provide the vegetable industry with

- An accurate description of current water use practices in the major vegetable production regions in Australia.
- Objective measures, where possible, of the high productivity achieved by the industry for water used including water use efficiency.
- An indication of where knowledge and technology gaps to achieving high water use efficiency exist.
- Recommendations back to industry of an agreed set of water related research priorities which address those existing knowledge gaps.

### **2.7. Seasonal climate forecasts to improve subtropical dairy farmers' feedbase management**

1. To investigate the opportunity for dairy farmers to use climate variability and seasonal forecasting data in their feed management strategies.
2. To evaluate in collaboration with dairy discussion groups, dairy service providers and advisers the skill and usefulness of integrating climate variability and SCF with a feed modelling capability, for

investigating seasonal pasture and fodder production options for the sub-tropical dairy region.

3. To provide to dairy farmers an education and training package on accessing and using climate and weather information.
4. To develop and deliver a learning package on feed management options in association with SCF to sub-tropical dairy farmers, their advisers and the dairy industry sector.

### **2.8. Scoping Study - Climate Change and Climate Variability - Risks and Opportunities for Horticulture.**

The project aims to:

- \* Identify tools which the Vegetable (and wider Horticultural Industry) could use to its advantage in better managing Climate Variability.
- \* Document Projected changes in climate which are likely to affect Horticultural industries.
- \* Identify potential adaptation mechanisms for Horticultural industries and growers to be able to cope with these potential changes.
- \* Document key research challenges for the next five years.

### **2.9. Tools to reduce the impact of climate variability in South Eastern Australia**

1. Increased and more stable economic performance of South-Eastern Australian farming systems through the development of tools that integrate seasonal climate forecasts, climate variability and management options.
2. Different climatic forecast systems for seasonal rainfall and extreme temperatures based on global indices, i.e. Southern Oscillation Index (SOI), Sea Surface Temperature (SST), or in local patterns of rainfall distributions, i.e. persistence, will be evaluated for several locations. In collaboration with farmer groups, the most appropriate forecast system will be used to assess management options.

### **2.10. Improved seasonal forecasts for wool producers in western New South Wales for the climate sub-program of Land, Water and Wool**

To investigate the skill and operational usefulness of seasonal climate forecasts (SCF) in the NSW pastoral zone and the adjacent marginal cropping zone.

2. To work with graziers to develop protocols for incorporating SCF into management decision making, including the identification of critical dates/periods.
3. To develop and deliver, in conjunction with graziers, a learning package on use of climate forecasts in grazing management systems

### **2.11. Delivery of climate risk management information to woolgrowers in the sheep/wheat and high rainfall zones of Australia**

1. Develop an appreciation for the current level of understanding of climate risk management within the wool growing community in the sheep wheat and high rainfall zones in Australia.
2. Document the key decision points that wool growers perceive could be enhanced with the input of climate information.
3. Collate available data, tools and information that can provide input into the identified key decision points.
4. Develop a suite of products that identify the information, tools and data available for each of the key decision points.
5. Make recommendations to Land, Water & Wool (LWW) on the most appropriate method to distribute the products.
6. Develop networks for ongoing delivery and uptake of the tools and services for improved climate risk management for high rainfall and wheat sheep region wool producers.

### **2.12. Climate science for better NRM in western NSW**

1. Develop a capacity to predict regional trends in total ground cover, and provide early warning of potential degradation events, by linking AussieGRASS products and seasonal climate forecasts.
2. Demonstrate the potential of the PaddockGRASP model to support sustainable Natural Resource Management (NRM) at the property level.

3. Develop protocols to allow the PaddockGRASP model to be readily parameterised for individual properties.

**2.13. Extension for improving rice yields and water use efficiency**

1. To increase rice yields and water use efficiency (WUE) by 5%.
2. To assist farmers achieve targets in the Rice Growers Association Environmental Champions Program.

**2.14. Water Use Efficiency Project, Taree and Deniliquin**

1. To measure dry matter production and water use efficiency of dairy forages in New South Wales to derive their water use efficiency (WUE).
2. To develop management practices that increase water use efficiency of NSW dairy farms.

**2.15. Determining 'whole of system' water use efficiencies for selected NSW river valleys**

1. Improved understanding of 'whole-of-system' water balances within selected valleys.
2. Greater definition of irrigation delivery and application systems, and their interaction at farm, region and valley levels.
3. Assessment and prioritisation of opportunities for increased water use efficiency.
4. Quantification of potential water savings through increased farm, sub-catchment and valley-wide efficiency in Macquarie and Murrumbidgee valleys of New South Wales.
5. Documentation of the critical factors required for successful whole-of-system water use efficiency assessment.

**2.16. North West NSW Citrus development initiative.**

1. Heat Unit determination for potential production areas, citrus variety selection and probable maturity periods for those areas.
- NSW DPI will maintain an involvement in climatic suitability for citrus production through the ACIAR funded project in Pakistan.

**2.17. Improving vineyard soil and water management using minimum tillage and drip irrigation**

Drip irrigation volumes applied to the trial at Dareton (1994-99) were low and considered unsustainable by some industry representatives. With more conversions to drip and installations of high - tech soil moisture monitoring the figure of 4 -5 Ml/ha/yr for grapes under drip irrigation is now an achievable volume for drip irrigated grapes.

**2.18. Improving Water use Efficiency** (collaborative with CSIRO Plant Industry and SARDI)  
Research development and information dissemination from 2000 – 2003.

**2.19. Irrigation Benchmarking Study** (extension project; collaborative with DPI Victoria)

1. Measure changes in water use efficiency, predominantly in winegrapes. (1999-2002)

**2.20. Nutrition and irrigation strategies to minimise vineyard inputs, reduce environmental impact and improve grape quality.**

The investigation showed that the irrigation strategy can impact on water uses efficiency, nutrient uptake and berry composition. 2000-2003

**2.21. Influence of irrigation and fertiliser management on movement of water and nutrient within and below the rootzone of vines for sustainable grape production.**

The project emphasised the importance of soil monitoring and has lead to more appropriate water application in vineyards, reducing also nutrient losses. 2003-2006