CSIRO Submission

Issues of sustainable natural resource management with particular reference to the impact of climate change

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Terms of Reference

This inquiry is a current Legislative Assembly inquiry conducted by the Natural Resource Management (Climate Change) Committee.

The Committee was first established in 2003 as the Legislative Assembly Standing Committee on Natural Resource Management to inquire into issues in the sustainable management of natural resources in NSW. The Committee was re-established on 21 June 2007 as the Legislative Assembly Standing Committee on Natural Resource Management (Climate Change) to inquire into issues of sustainable natural resource management with particular reference to the impact of climate change and, in particular, to report on the following terms of reference:

a. The likely consequences of human-induced climate change on land (including salinity), water and other natural resources;

b. Options for ensuring ecologically sustainable natural resource use, taking into particular account the impacts of climate change;

c. Approaches to land and water use management practices on farms and other natural resource management practices, having regard in particular to the role of such practices in contributing to climate change or as a tool in helping to tackle climate change;

d. The effectiveness of management systems for ensuring that sustainability measures for the management of natural resources in New South Wales are achieved, having particular regard to climate change; and

e. The likely consequences of national and international policies on climate change on natural resource management in New South Wales.

Contents

Acronyms Used

APSIM	Agricultural Production Systems sIMulator
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EC	Electrical Conductivity (a measure of salinity)
IPCC	Intergovernmental Panel on Climate Change
MDB	Murray Darling Basin
ML	Mega litres (millions of litres)
NRC	Natural Resources Commission
NSW	New South Wales
NRM	Natural Resource Management
PMSEIC	Prime Minister’s Science and Innovation Council
R&D	Research and Development
tCO2e	tonnes of carbon dioxide equivalent

Executive Summary

This submission has been prepared by a team of scientists from across CSIRO with experience and international recognition in many facets of climate and natural resource management (NRM) research. In this submission, we briefly review the issue of sustainable NRM with particular reference to climate change and bring to the Committee's attention relevant conclusions, based on past and current research. Adaptation of agriculture to climate change is a particular focus of this response, given the significant portion of land in Australia (and New South Wales (NSW)) under agricultural management.

The likely consequences of human induced climate change on land, water and other natural resources in NSW are significant. Agriculture and NRM are highly vulnerable to climate change and the projected drying trend across southern Australia will make agriculture in NSW more difficult as we move into the future. There may also be some opportunities for some agricultural activities to benefit from climate change. Building the capacity to capitalise on these opportunities will be important as will be the capacity to manage increasingly challenging climate conditions for most of the NSW agricultural zones.

Across NSW there are considerable pressures on both water quality and water quantity. Climate change is one of the multiple stressors impacting these water systems. Other stressors are increasing consumptive demands (including increased groundwater pumping, additional river water allocation and the increased use of existing water licences), reduced quantity of inflows (including the increased water inception from farm dam development, increasing forest plantations and overland flow harvesting) and increasing pollutant loads (including changes to salt loads from groundwater and increased wash off of pollutants from the land surface)

Future climates will impact on the temporal and spatial patterns of rainfall. These changes to rainfall are the primary driver for climate change related changes to streamflow. Predictions for 2025 indicate that reduced rainfall due to climate change and the development of new farm dams are the largest risks to streamflow and account for 4.6% and 3.8% respectively of the total reduction of 11.5 % of the current mean annual surface water inflows to the Murray Darling Basin (MDB).

Historic upward trends in stream salinity in the MDB will be exacerbated by climate change, with recent comprehensive analysis indicating that by 2030 climate change will result in modest (1-10%) reductions in salt load, which translate to small increases in stream salinity when combined with the forecast reduction in streamflow quantity. Managing this salinity requires vegetative and engineering approaches including salt interception schemes and upland plantings.

Climate change will impact on biodiversity in a complex way depending on location, level of other stressors in the system, and interactions at species, community and landscape scales. In NSW, different studies have identified significant potential impacts of climate change on biodiversity in the rangelands, highly fragmented areas, the alpine zone, rivers and wetlands, coasts (near-shore through to salt marshes), the western slopes and the south eastern region. Most studies have focussed on how species many respond to changes in temperature and rainfall, rather than how ecosystem processes and threats to biodiversity may change.

Options exist which take account of climate change in ecologically sustainable resource use, including land and water use management on farms. Currently a lack of underlying information about resource availability hinders adaptation in NRM. This issue is exacerbated by poorly organised information systems for NRM in NSW.

There are, in principal, a number of potential options for agriculture and the way we manage natural resources to adapt to climate change. Many of these options are extensions or enhancements of existing activities that are aimed at managing the impacts of existing climate variability. Practicable and financially-viable adaptations at the farm level will have very significant benefits in ameliorating risks of negative climate changes and enhancing opportunities where they occur. However, there is a limit to incremental adaptation using new technologies and management strategies and for some industries and regions transformational change will be required to adapt to climate change.

Reliable information on the character and distribution of soil resources across NSW is essential for understanding how climate change will affect current land use and define opportunities for future systems. The soil information base for NSW is deficient and cannot be used for this purpose – it requires urgent investment to reach the standard necessary for regional assessments of land use options under changed climate.

There is a wide range of technologies for reducing water consumption in the irrigation industries, including on-farm measures such as conversion to drip irrigation, and off-farm measures, such as channel lining. Some of the reservoirs in NSW have a very large surface area for their storage volume by world standards. All of the reservoirs have a high rate of evaporation.

The impacts of climate change on biodiversity lead to a range of implications for the strategic approach to managing native species and ecosystems. Policy and management strategies need to accommodate significant and continuous changes in species and ecosystems, rather than attempting to prevent change. The overarching strategy for biodiversity conservation should increasingly focus on managing a range of general and unpredictable changes in species and ecosystems, as opposed to managing particular future changes in individual species and ecosystems.

There is a range of policy and management options for enhancing the conservation of biodiversity under climate change: Ensuring that the possible changes resulting from climate change (including changing abundances and distributions and changing threats) are considered in policy and management plans; aiming to conserve a high diversity of native habitats, as well as a large area of habitat; anticipating how the action and impact of various threats to biodiversity many change in order to be better prepared to respond to them in ways that minimise losses to biodiversity; and increased coordination of different conservation and NRM programs would enable improved management at landscape and regional scales

In terms of emissions reduction, carbon trading and renewable energy, significant opportunities and challenges exist for Australian agriculture. The introduction of offset programs will be strongly influenced by national policies on carbon emissions.

Introduction

CSIRO and climate change impacts on natural resource management

CSIRO is a leading internationally recognised research and development (R&D) provider in the field of climate change and adaptation. It is, has been, and will continue to be, engaged in R&D partnerships with climate researchers and managers across the world. CSIRO has conducted research pursuant to the terms of reference of this inquiry including: climate modelling, climate forecasting, natural resource management science, agricultural sustainability, biodiversity conservation and management and adaptation to climate change.

This submission has been prepared by a team of scientists from across CSIRO with experience and international recognition in many facets of climate and NRM research. In this submission, we briefly review the issue of sustainable NRM with particular reference to climate change and bring to the Committee's attention relevant conclusions, based on past and current research. Adaptation of agriculture to climate change is a particular focus of this response, given the significant portion of land in Australia (and NSW) under agricultural management.

CSIRO's climate adaptation research

In recent times the climate challenge facing Australia has become more severe and more urgent. Australia is experiencing the worst drought in recorded history and consequentially, is in the grip of a water crisis. These issues have brought to the public mind appreciation of the reality of global climate change, of the massive impacts that it is likely to have upon our continent, and of the opportunities and challenges stemming from those impacts.

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment report (2007) has reinforced the evidence that most of the warming observed in the past 50 years is attributable to human activities, that there will be considerably more warming in the 21st Century, and that this warming will be accompanied by many other changes in the global climate system, including changes in wind, precipitation and weather extremes.

The seriousness of the challenge requires a response that must deal with both the extreme variability of Australia's climate and the longer term alteration of our climate associated with climate change. Australia has been at the forefront in the development of strategies to deal with climate variability but these will not be enough to cope with climate change. For example, overseas estimates of the costs of climate change into the future range from 3-7% of global GDP with poor countries suffering costs in excess of 10% of GDP. If more serious climate feedbacks are included this could rise to 20% of global GDP (Stern 2007, Nordhaus 2006)

The scale and gravity of climate variability and change are such that R&D must be marshalled to assist in the national response. Science can add significant value to how we adapt to climate change through informing responses.

The National Research Flagships Program is delivering scientific solutions to advance Australia's most vital national objectives. Flagships are partnerships of leading Australian scientists, research institutions, commercial companies, CSIRO and selected international partners. CSIRO has recently formed the Climate Adaptation Flagship which aims to minimise the economic, social and environmental impacts of climate change as well as maximise new opportunities in response to climate change and variability. In addition, the Water for a Healthy Country Flagship is determining the impact of climate change on our most stressed water supplies and how these challenges in water availability may be addressed.

Addressing the Terms of Reference

a. The likely consequences of human induced climate change on land (including salinity), water and other natural resources

(i) Climate projections

The consequences of human induced climate change are a current research focus in Australia and around the world. CSIRO has contributed to projections of climate change for NSW (Hennessy et al. 2004a, 2004b), as well as for Australia (CSIRO 2007a). Evidence is clear that climate change is happening now and that human activity is a contributor to climate change. Projections indicate a warming climate with changes in temperature extremes, precipitation and wind, along with an increased frequency of drought and extreme fire weather and sea level rise.

The most recent climate change projections for Australia can be found at http://www.climatechangeinaustralia.gov.au .

For NSW, the best estimate projection of temperature increase for 2030 under the most likely scenarios of moderate to high emissions is 0.6-1^{o}C for the southern half of the state and 1.0-1.5^{o}C for the northern half of the state. For 2070, where emission scenarios are much less certain, the temperature increase ranges from 1.5 to 5^{o}C.

The projections suggest a drying trend for rainfall with the decrease in rainfall ranging from 2-5% for 2030 and 5 to 20% for 2070 for low to high emission scenarios.

These climatic trends will have significant consequences for agriculture, water resources and NRM, as described below.

(ii) Agriculture

Studies have shown that Australian farming systems are highly vulnerable to the climate changes likely over the next decades (Howden et al. 2003, Pittock 2003, Reyenga et al. 2001). The IPCC Fourth Assessment Report (2007) and the Prime Minister's Science, Engineering and Innovation Council (PMSEIC) Independent Working Group report on climate change in Australia (2007) summarised the impacts of climate change for agriculture in Australia and New Zealand and the relevant impacts for NSW as being:

- reduced crop, horticultural, pastoral and rangeland production over much of southern and eastern Australia with much of this arising from anticipated reductions in rainfall as well as temperature conditions less suited to specific activities such as the growing of stone fruits;
- reduced grain and grape quality in particular caused by increases in carbon dioxide levels and high temperature conditions;
- reduced dairy milk production due to increases in heat stress as well as threats to pasture production, particularly in systems that rely on irrigation to grow pasture;
- a southward shift of pests (e.g. cattle tick) and disease vectors (such as the carrier of the bluetongue virus) caused by overall temperature increases with the risk increasing with increasing levels of globalised trade. However, there are some pest species such as the light brown apple moth that may decline in importance;
- increased fire risk for forests and other industries and ecosystems;
- heavy precipitation events causing damage to crops and increasing soil erosion;
- increased temperatures may also increase the range of crops that can be grown, provided that irrigation water is available or rainfall is not overly reduced. For example, cotton and/or sugar cane may be able to grown in more southerly regions than they have been historically, whilst options may increase for inclusion of summer crops into crop rotations. There may also be reduced lamb mortalities if low

temperature extremes decline. The growth rates of cool temperate forests may also be increased;

- prolonged heatwaves will, in contrast, reduce crop yields and quality and increase heat stress in livestock. Heat stress conditions can impact particularly on intensive livestock operations, reducing productivity, increasing the need for capital investment and raising increased issues in terms of animal welfare; and
- agriculture in marginal climatic environments will become increasingly challenged, perhaps requiring re-evaluation of the enterprise mix. However, there may be increased demand for the skills and experience of farmers in such environments from farmers in historically more humid areas.

In summary, agriculture and NRM are highly vulnerable to climate change and the projected drying trend across southern Australia will make agriculture in NSW more difficult as we move into the future. There may also be some opportunities. Building the capacity to capitalise on these opportunities will be important as will be the capacity to manage increasingly challenging climate conditions for most of the NSW agricultural zones. This increase in adaptive capacity is dealt with in Term of Reference b) ii).

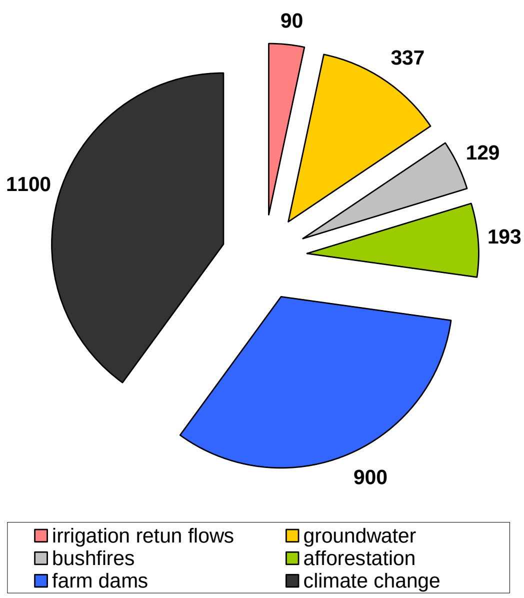
(iii) Water resources and stream salinity

Changes to water resources are normally described in terms of the impacts upon consumptive and non-consumptive uses. For stream flow, the quantity of water flowing down a river over the cycles of rainfall events, seasons and years can be thought of as a flow regime. All of the rivers in NSW are highly variable in their flow rate. The flow regime is closely tied with the ecology of the stream and the stream environment (Cullen, 2002). Where constructed storages on rivers exist, it is the volume of water stored for downstream use, which is a key indicator. This water may be managed to improve water security for consumptive use while providing some environmental flow regime. A further significant descriptor of water resources is the quality of the water and its consequent suitability for various purposes. Key pollutants for consideration in NSW rivers are salinity, turbidity and nutrient levels (National Land and Water Resources Audit 2007). Pollutants may be measured as the concentration of the problem substance (mass per unit volume) or as a load carried by the river (mass per unit time). The mean concentration of the pollutant (or the surrogate measurement, EC, in the case of stream salinity) is most commonly used a fit-for-use measure for both consumptive and non-consumptive uses along the river systems.

Across NSW there are considerable pressures on both water quality and water quantity. Climate change is one of the multiple stressors impacting these water systems. Other stressors are increasing consumptive demands (including increased groundwater pumping, additional river water allocation and the increased use of existing water licences), reduced quantity of inflows (including the increased water inception from farm dam development, increasing forest plantations and overland flow harvesting) and increasing pollutant loads (including changes to salt loads from groundwater and increased wash off of pollutants from the land surface). These stressors may, or may not be additive and in some instances may be compounding (van Dijk et al. 2006). For instance, climate change frequently reduces the flow of rivers and new plantations of forests also reduce stream flow. Herron et al. (2002) found these effects to be similar in magnitude for plausible plantation development scenarios in the catchment of the Burrendong Dam on the Macquarie River.

Future climates will cause changes to the temporal and spatial patterns of rainfall. These changes to rainfall are the primary driver for climate change related changes to streamflow. Predictions of streamflow should also take into account secondary factors including increased evapotranspiration and increased water demand due to temperature and humidity changes. Jones and Durack (2005) and Chiew (2006) provide up-to-date assessments of the methods suitable for making climate change-related streamflow predictions in the Australian context. A rule of thumb that is widely agreed by hydrologist in Australia is: For every 1 percent change in the rainfall there will be a 2 percent change in the streamflow.

In a recent study of the MDB, van Dijk et al. (2006) provided an analysis of six “risks” to the surface water resources and the related flow regime of the river. Figure 1 provides a summary of the findings that relate to the quantity of water inflows for 2025. It is noted that climate change and the development of new farm dams are the largest risk terms and account for 4.6% and 3.8% respectively of the predicted total reduction of 11.5 % of the current mean annual surface water inflows to the MDB.



> Figure 1. Best estimate of the impact of the range of risks on total Murray-Darling Basin surface water (24000GL) inflow in the next 20 years (reproduced from van Dijk et al. 2006)

At the time of writing the CSIRO is engaged in a major study of the available water resources in the Murray Darling Basin (CSIRO 2007b). The results for the majority of NSW MDB river sub-basins are not yet available. These results will provide a far more comprehensive analysis of the impact of the stressors on the surface and ground water resources, with details of several scenarios provided for each of the sub-basins.

While the quantity of water fundamentally limits the sharing of water between various consumptive and environmental uses, water quality is an increasingly important factor. In the comprehensive analysis of salinity trends in the MDB, Jolly et al. (2001) found the historic levels of stream salinity to be highly variable with few being of immediate concern for consumptive demands. The most significant rising trends in stream salt concentration were in the 500-800 millimetre per year rainfall zone in the southern and eastern dryland region of the MDB.

These historic upward trends will be exacerbated by climate change. Zhang et al. (2005) found that the forecast climate change resulted in increasing stream salinity for catchments in the Victorian portion of the south east MDB. A further, more spatially comprehensive analysis of these changes across the MDB has been completed and is currently in review. These analyses find that by 2030 climate change will result in modest (0 to 10%) reductions in the salt loads carried by the rivers of the MDB. However, when these results are combined with the forecast reduction in the quantity of streamflow, all forecasts are for small increases in stream salinity concentrations.

Managing stream salinity:

It is widely accepted that managing stream salinity requires both vegetative and engineering-based approaches. Groundwater systems that carry mobilised salt have response times that vary between 10 and 10 000 years, so that methods to reduce the mobilisation of salt will not result in short term improvement in stream salinity (Walker et al. 2003). Furthermore, very large masses of salt are currently mobilised that should be intercepted before reaching stream environments. For these reasons CSIRO and its research partners have developed a combined engineering (short term) and vegetative approach (long term) approach to managing salinity.

Salt interception schemes comprise saline groundwater pumping, interception drains and salt disposal basins. Leaney et al. (2000) provides guidelines for the sustainable operation of these basins. These schemes are suitable where large saline regional groundwater systems approach the river and are currently being extensively used in the riverine environments of the lower Murray River.

In upland environments the planting (or regeneration) of deep rooted perennial vegetation (trees, shrubs, and lucerne) can significantly reduce the mobilisation of salt. For this strategy to be effective, revegetation must be sited in locations where the hydrogeology is suitable for a response in terms of stream salinity (Walker et al. 2003). Van Dijk et al. (2007) provides an analysis of the potential locations for revegetation across the MDB.

(iv) Native species and ecosystems

Globally, there is overwhelming evidence the climate change is already affecting thousands of species. The most easily observed and best documented impacts are changes to the timing of life-cycle events (typically early spring flowering and migration) and shifts in the distribution of species (typically shifts up-hill or towards the poles in the “cool” boundaries of distributions). A very wide range of other changes to species and ecosystems have been observed and predicted, including changes to:

- the physiology of plants (e.g. carbon: nitrogen ratios, allocation of carbon, water use efficiency, growth) and animals (life cycles, mortality, gender of offspring, behaviour);
- interactions between individuals and their environment leading to changes in reproductive success, resource use, growth, survival, mortality;
- the genetic composition, abundance and distributions of populations;
- the composition, structure and functioning of ecosystems (including types of vegetation communities, nutrient and hydrological cycling);
- the benefits that flow to society from species and ecosystems (including preservation of biodiversity, cultural and aesthetic values, services such as pollination, pest control, water storage and purification, and provision of food, fibre and timber).

Species and ecosystems will be affected directly by impacts cascading from individuals to populations to ecosystems, and indirectly via changes to the interactions between species, provision of habitat, regulation of ecosystem processes and feedbacks on the climate. In addition, climate change will exacerbate the impacts of many threats to species (habitat loss and degradation, invasive species, altered stream flows).

Importantly, observation and modelling studies consistently report that the details of the impacts vary considerably between species, ecosystems and regions. And, while it is clear that we can expect many types of changes (including changes in abundance, distribution, interactions, ecosystem processes and threats), the details cannot be predicted at level of specific species and ecosystem due to the many complex interactions in ecosystems.

In Australia, different impacts may predominate in different regions, but it is difficult to say which regions’ biodiversity will be more affected or less able to cope with climate change. In NSW, different studies have identified significant potential impacts in the rangelands, highly fragmented areas, the alpine zone, rivers and wetlands, coasts (near-shore through to salt marshes), the western slopes and the south eastern region (Howden et al. 2003, Pittock 2003, IPCC 2007). Most studies have focussed on how species many respond to changes in temperature and rainfall, rather than how ecosystem processes and threats to biodiversity may change.

b.&c. Options for ensuring ecologically sustainable natural resource use, taking into account particular account of the impacts of climate change; and Approaches to land and water use management practices on farms and other natural resource management practices, having regard in particular to the role of such practices in contributing to climate change or as a tool in helping to tackle climate change.

(i) Information about the underlying resource base

Reliable information on the character and distribution of soil resources across NSW is essential for understanding how climate change will affect current land use and define opportunities for future systems. The capacity of different soils to store water and supply nutrients strongly controls the suitability of land for different uses. The large cropping areas in NSW cannot simply migrate east under a drying climate because most soils on the slopes and tablelands are of inferior quality (e.g. less fertile, prone to degradation). Likewise, the potential of soils to sequester carbon depends on climate, land use and their chemical and physical properties.

Some Australian states (e.g. Western Australia and South Australia) now have sufficient information on the distribution of soil and land resources to make defensible assessments of the likely impact of climate change on agricultural systems. The soil information base for NSW is deficient and cannot be used for this purpose – it requires urgent investment to reach the standard necessary for regional assessments of land use options under changed climate. The same information, when combined with a strategic monitoring program, is also essential for predicting carbon biosequestration across the state. Again, the lack of investment in natural resource information over several decades is now seriously constraining informed land planning and management across NSW.

(ii) Agriculture

There are, in principal, a number of potential options for Australian agriculture to adapt to climate change. Many (but not all) of these options are extensions or enhancements of existing activities that are aimed at managing the impacts of existing climate variability. However, less than a dozen of these potential adaptation options have been evaluated for their utility in reducing the risks or taking advantage of climate change impacts. Only a couple of adaptations have been evaluated in relation to the broader costs and benefits of their use. The engagement of stakeholders in these responses (farmers, regional management, industry bodies and government policymakers) is still in its infancy.

These few analyses show that practicable and financially-viable adaptations at the farm level (see Table 1) will have very significant benefits in ameliorating risks of negative climate changes and enhancing opportunities where they occur. The benefit to cost ratio of undertaking R&D into these adaptations appears to be very large (indicative ratios greatly exceed 100:1). The adaptations studies are, furthermore, a small subset of those possible.

Climate change adaptation R&D needs to be undertaken in a participatory way with industry groups so as to deal effectively with their key concerns (particularly NRM), draw on their valuable expertise and also contribute to enhanced capacity in the agricultural community. This R&D also needs also to draw on the large knowledge and skill base of the science community, particularly when it has been formalised in farming systems simulation models such as APSIM which allow reliable integration of the biophysical consequences of given changes in climate, carbon dioxide concentration and management actions.

Given the uncertainty in projected climate but the certainty of ongoing technological, cultural and institutional change, there is a need to use an active adaptive management approach for adaptation so as to ensure sustainable natural resource use. This approach requires directed change in management or policy that is monitored, analysed and learnt from, so as to iteratively and effectively adjust to ongoing climate changes (Howden et al. 2008).

Successful adaptation to climate change will need both strategic preparation and tactical response strategies, operating at farm to governmental scales, dealing with the full range of options from technological innovation to institutional re-design. Adaptation measures will have to reflect and enhance current ‘best-practices’ designed to cope with adverse conditions such as drought. Adoption of these new practices will require, amongst other things;

- confidence that the climate really is changing;
- the motivation to change to avoid risks or use opportunities;
- demonstrated technologies to enable change to occur;
- support during transitions to new management or new landuse;
- altered transport and market infrastructure; and
- improved monitoring and evaluation systems (Howden et al. 2008).

There is a clear role for policy in all of these.

A summary of the key priorities for climate change adaptation strategies for the main Australian agricultural sectors (based on Howden et al. 2003 with additions from Pittock 2003) is presented in Table 1. Mid-latitude regions have many options available for adaptation to climate change, in terms of crop types and animal production systems drawn from other climatic zones provided that there are adequate water supplies and rainfall does not decline too much.

> Table 1: A summary of priorities for climate change adaptation strategies for the main Australian agriculture sectors (based on Howden et al. 2003, with additions from Pittock, 2003).

Priorities for climate change adaptation strategies for Australian agricultural sectors
Cropping
• Develop further risk amelioration approaches (e.g. zero tillage and other minimum disturbance techniques, retaining residue, extending fallows, row spacing, planting density, staggering planting times, erosion control infrastructure) and controlled traffic approaches – even all-weather traffic • Research and revise soil fertility management (fertiliser application, type and timing, increase legume phase in rotations) on an ongoing basis • Alter planting schedules to be more opportunistic depending on environmental condition (e.g. soil moisture), climate (e.g. frost risk) and markets • Further develop warning systems for likelihood of very hot days, drought and high erosion potential • Select varieties with appropriate thermal time and vernalisation requirements, heat shock resistance, drought tolerance, high protein levels, resistance to new pest and diseases and perhaps varieties that set flowers in hot/windy conditions
Livestock industries – grazing and intensive
• Research and promote greater use of strategic resting of paddocks • Develop regionally safe carrying capacities i.e. constant conservative stocking rate • Modify timing of mating based on seasonal conditions • Develop water use efficiency strategies to manage potentially lower irrigation water availabilities • Research intensive livestock management in tropical environments particularly dealing with heat stress • Further selection for cattle lines with greater thermoregulatory control
Horticulture
• Change varieties so they are suited for future conditions and re-assess industry location • Research on altering management to change bud burst, canopy density, etc., in fruit trees • Undertake risk assessment to assess sustainability in more marginal areas (e.g. chilling requirements)
Water resources
• Increase monitoring of water use in terms of production and climate rather than area • Develop probabilistic forecasts of likely water allocation changes • Develop tools that enhance crop choice (maximise efficiency and profit per unit water) • Build climate change into integrated catchment management, relevant strategic policies and new infrastructure • Incorporate climate change into long-term water sharing agreements
Pests, pathogens and parasites
• Systematically map vulnerability of plants and animals to endemic and exotic pests, pathogens and parasites • Select animal breeds and plant varieties resistant to pests, pathogens and parasites already in Australia • Strengthen quarantine measures within Australia and at ports of entry

In addition to these sectoral adaptations, there are several adaptation options that are common across industries (Howden et al. 2003). These include:

- ‘mainstreaming’ climate change into other policies such as those dealing with NRM;
- enhancing communication of industry-specific and region-specific information;
- maintaining effective climate data collection, distribution and analysis systems;
- developing the capacity to respond flexibly via suitable R&D and capacity development in industries and regions;
- investing in the new technologies (e.g. varieties and breeds) needed;
- maintaining or improve quarantine capabilities, sentinel monitoring programs and other management of pests, diseases and weed threats; and
- increasing water use efficiency via technologies, infrastructure and policies.

(iii) Water resources

For water, planned adaptation opportunities lie in the inclusion of risks due to climate change on both the demand and supply side (Allen Consulting Group, 2005). For rural activities, more flexible arrangements for allocation are required, via expansion of water markets, where trading can increase water use efficiency (Beare and Heaney, 2002). Attitudes toward water pricing and difficulties with structural adjustment are significant barriers, although recent federal government investment in water security is moving to address these issues.

CSIRO continues to be involved in many water-related projects aimed at addressing the problems described above. A few key outcomes are briefly described here to provide a sample of the methods available.

Conserving existing water resources:

There are a wide range of technologies for reducing water consumption in the irrigation industries, including on farm measures, such as conversion to drip irrigation, and off-farm measures, such as channel lining. Khan et al. (2004) and Khan and Akhtar (2007) provide analysis of these measures and find that cost effective approaches are available and can be targeted to have greatest impact. The upgrading of irrigation infrastructure and incentives for existing irrigation enterprises to change to water efficient practices are key priorities.

Reducing the evaporation from reservoirs is also a priority. Some of the reservoirs in NSW have a very large surface area for their storage volume by world standards. All of the reservoirs have a high rate of evaporation. Some control measures are available and others are under development (D. McJannet CSIRO – pers. Com.).

Addressing the risks to water resources in NSW

Following the report of van Dijk et al. (2006), some of the risks to water resources are locally manageable. It is widely recognised that further development of farm dams causes a significant threat to the overall security of river water. Recent regulation may address this issue, though the effectiveness of these measures has not been assessed by CSIRO and may benefit from further evaluation.

Future plantation development is an issue that has received much discussion in the rural community. Recently, some provisions within the National Water Initiative have been proposed that may address this risk. Brown et al. (2006) provides a tool for assessing the impact of planned plantations on streamflow.

The regulation of further draws on fresh water groundwater resources would be a further approach to address the trends in water availability across the overall water system.

Creating more available water resources

There are a range of methods to create more water resources than currently exist. These methods include cloud seeding and runoff enhancement schemes. No comment is made on cloud seeding here as CSIRO is not currently conducting R&D on this method. Runoff enhancement is widely used in the south west of Western Australia to provide local water for new and existing irrigated horticulture. These systems involve treating the land surface so a greater portion of rainfall becoming runoff which is harvested for use on an adjacent irrigated enterprise. Hairsine et al. (2007) describes the prospects for using these systems in eastern Australia. They suggest there is scope to establish trials of such systems where water values are moderately high.

(iv) Native species and ecosystems

The impacts of climate change on biodiversity lead to a range of implications for the strategic approach to managing native species and ecosystems.

- It is suggested that policy settings and management strategies need to accommodate significant and continuous changes in species and ecosystems, rather than attempt to prevent change. For example: pre-European vegetation types will not be suitable long term benchmarks for vegetation; ecological communities will change, some will disappear and new ones will form as different species respond in different ways; and observed declines in species abundance and distribution will not necessarily indicate a threat to viability, especially at the local scale.
- Many different aspects of biodiversity will be affected, including the relative abundance of different species, species distributions, ecosystem processes and threats to species and ecosystems; and, in general it will be very difficult to predict the details of changes, which types of changes will dominate, and which are most important from a management perspective. This suggests that the overarching strategy for biodiversity conservation should increasingly focus on managing general and unpredictable changes in species and ecosystems, as opposed to managing particular future changes in individual species and ecosystems.
- Climate change will interact with existing threats. Climate change will have many direct and indirect impacts on species and ecosystems that may threaten the persistence of some species. However, it is more useful to consider how climate change will affect existing threats and their impacts, rather than to think of climate change as a threat to be managed separately.

Considering these issues, there is a range of policy and management options for enhancing the conservation of biodiversity under climate change (Dunlop and Brown 2007).

- Ensure that the possible changes resulting from climate change (including changing abundances and distributions and changing threats) are considered from a policy and management plan perspective. In particular, ensure such plans are not based on an assumption that species and ecosystems will or should remain static (i.e. as they were 200 years ago). In doing so, it will be necessary to understand what types of changes and how much change might be "acceptable"; this will have both scientific and societal dimensions.
- Aim to conserve a high diversity of native habitats, as well as a large area of habitat. As ecosystems and habitat requirements change, increasing the diversity of habitat (or ecosystem) types that are protected will increase the opportunity for a large number of native species to adapt to climate change and persist in the long term. The comprehensiveness and representativeness criteria applied through the Interim Biogeographic Regionalisation of Australia (as used in the National Reserve System) is a very effective framework for identifying and protecting habitat diversity (Parks Australian 2007). Indeed such criteria almost certainly provide a more strategic and effective basis for protecting as many species as possible in the long term than any criteria based on individual threatened species. The framework could also be used to prioritise private conservation, habitat restoration and incentive schemes.
- Anticipate how the action and impact of various threats to biodiversity many change. Four threats in particular are likely to be affected by climate change:
    - altered fire regimes;
    - changed land use (habitat loss and degradation);
    - establishment of new exotic and native species; and
    - altered hydrological regimes.

  By anticipating how these threats may change, society and managers will be better prepared to respond to them in ways that minimise losses to biodiversity.
- Many ecosystem processes and many of the changes that occur to biodiversity and threats will do so at large scales. Increased coordination of different conservation and NRM programs would enable improved management at landscape and regional scales. In some situations increasing the connectivity of native habitat will increase the ability of species to adapt to climate change;

however, increasing connectivity may add pressures for some species by facilitating colonisation of competitors, pathogens, predators and fire. Hence, isolated habitat patches will also be of conservation value, especially if they add to the diversity of habitats protected.

(v) Mitigation

A CSIRO report to the Agricultural Alliance on Climate Change (Hatfield-Dodds et al. 2007) outlines mitigation opportunities for the Australian agricultural sector, including through biosequestration. The report suggests a large potential for creation of offsets via vegetation sinks, dependent on clear policy and improvements to accreditation arrangements. Establishing new plantation forest at around double the average annual rate of the last decade would offset 18 million tCO_2e per year after 15 years (equivalent to one fifth of direct agricultural emissions in 2005), and could yield gross carbon revenues of $360 to $920 million a year, or more. The impact of such plantations on water availability, biodiversity etc is an area currently under investigation. The introduction of offset programs will be strongly influenced by national policies on carbon emissions and these aspects are covered in section (e) below.

d. The effectiveness of management systems for ensuring that sustainability measures for the management of natural resources in New South Wales are achieved, having particular regard to climate change.

The Natural Resources Commission (NRC) document *Recommendations: State-wide Standards and Targets* (September 2006) lists seven macro-environmental targets and six specific priorities under the themes of biodiversity, water, land and community. These standards have been adopted by the NSW Government and have been developed to inform and support all natural resource management across NSW (NSW Government 2006). The 13 Catchment Management Authorities across NSW provide a focal point for monitoring, evaluating and reporting progress toward meeting NRM objectives for their regions. There are two overarching community targets developed to monitor and evaluate natural resource decisions. These are defined as:

- *Target 12. Natural resource decisions contribute to improving or maintaining economic sustainability and social well-being.*
- *Target 13. There is an increase in the capacity of natural resource managers to contribute to regionally relevant natural resource management.*

Understanding the capacity of natural resource managers to contribute regional natural resource management is an important indicator of how vulnerable a region may be to both future environmental and climate pressures.

Work is underway with CSIRO, NSW Department of Environment and Climate Change, NSW Department of Primary Industries and regional Catchment Management Authorities to develop tools to practically assess the capacity of agricultural land managers to effectively manage natural resources.

e. The likely consequences of national and international policies on climate change on natural resource management in New South Wales.

As mentioned above, mitigation via vegetation offsets is an area where policies on carbon emissions will have strong influence. A CSIRO report commissioned by the Australian Agricultural Alliance on Climate Change (2007) addresses this issue for Australia as a whole and includes the following major findings:

“ (a) The introduction of emissions trading offers a range of important opportunities for agriculture (including profitable chances to supply offsets and renewable energy, increased demand for existing agricultural products, and substantial potential permit revenues for agricultural programs that provide greenhouse benefits) but also involves some potential challenges;

(b) The net impacts of emissions trading on competitiveness will depend on the details of policy implementation and accompanying measures. The Allen Consulting Group (2006) found that emissions trading would boost domestic agricultural demand at low levels of carbon prices. The Australian Farm Institute (2007), however, argues that under higher carbon prices emissions trading will increase the cost of energy and other key inputs, reducing export competitiveness. Our analysis suggests that these cost increases are likely to be small (less than 3% by 2025), and could easily be offset by other policy benefits.

Assessing the magnitude of net competitiveness impacts and engaging policy makers on this issue is a priority;

(c) Achieving a clean, renewable electricity target, such as a renewable energy target of 25% by 2020 appears challenging but feasible, and could provide significant benefits to rural Australia. A substantial increase in clean electricity generation would be possible and cost effective with the introduction of a strong clean, renewable energy target or an ambitious medium-term emissions reduction target, and it is likely that a range of clean energy technologies will be able to meet projected demand for peak and base load power to 2050 and beyond;

(d) Renewable energy offers significant financial and other benefits to landholders and rural communities. Previous reports imply wind and bio-electricity could generate total annual revenues of $300-1000 million by 2020 with an ambitious emissions reduction target or other policy support for renewable energy. Estimates undertaken for this report suggest potential wind royalties of up to $150 million a year, or more.

(e) Biofuel supply is expected to exceed the Government's target of 350 ML by 2010, and significant further expansion of domestic biofuel production in the medium term would be possible with step changes in production technologies or specific policy action in addition to the introduction of emissions trading. Realising the benefits of increased production and use of biofuels will require all stakeholders to be involved in developing practical pathways for commercialising biofuels that are environmentally sustainable and do not disrupt food and fibre production, along with significantly increased research and development into prospective second generation biofuels that are relevant to Australia;

(f) There is a strong case for government support for programs that demonstrate and deliver mitigation in advance of the inclusion of direct agricultural emissions in an emissions trading scheme. However, farmers should not assume that emission trading will allow the creation of tradable credits through reductions in agricultural emissions relative to past levels.

(g) The potential for creating offsets through vegetation sinks is very large, but realising these benefits will require clarification of policy settings and improvements to accreditation arrangements. Establishing new plantation forest at around double the average annual rate for the last decade would offset 18 million t CO_2e per year after 15 years (equivalent to one fifth of direct agricultural emissions in 2005), and could yield gross carbon revenues of $360 to $920 million a year, or more.

(h) Environmental stewardship payments have the potential to address climate related pressures on both landholders and ecosystems. Implementing an ambitious voluntary stewardship scheme could more than double the area of actively conserved native vegetation through total outlays of $740 to $1,630 million per year, some of which might be funded through the carbon value of the native vegetation protected."

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