Chapter 24
Case Studies on Food Production, Policy and Trade

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24.1 Native Animals in Food Production

George Wilson

Few native animals, other than fish and crustaceans, are used in food production by the humans who recently arrived in Australia. Even Aboriginal Australians have now become reliant on introduced species which evolved elsewhere. In part, this is due to cultural dominance, first of the British and then other western perspectives in last 200 years. It is also because introduced species generally have higher production rates following centuries of agricultural selection and recently, energy-intensive farming practices. But it need not always be that exotic species are superior, particularly in the context of climate change. Replacing cattle and sheep on the rangelands

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with well-adapted species such as kangaroos and making greater use of them just as Aborigines did for 40,000 years, is a prospect worthy of further investigation.

More than 75% of Australia is broadly defined as rangelands (ANRA 2009). The area includes a diverse group of ecosystems such as tropical savannas, woodlands, shrublands, and grasslands whose role in food production is based on extensive grazing of native pastures. Grasses and shrubs on the rangelands are converted into meat protein by herbivores, making a valuable contribution to food production in an area in which broadscale cropping and cultivation generally cannot take place. At the moment most of the production which comes from the rangelands and which is available commercially, comes from exotic animals.

In the future, climate change and rising carbon dioxide levels have the potential to alter vegetation including on the rangelands. If rainfall decreases in southern Australia in winter and spring, some cropping and irrigation areas will be replaced by grazing and rangeland animal production (DCC 2002). Thus rangelands are likely to increase, although at the same time some currently marginal pastoral areas could be expected to become unproductive.

Aboriginal Australians again have title to much of Australia's rangelands (Altman et al. 2007). If they choose to, they have an important role to play in supporting a return to greater use of native animals in food production that is adapted to these environments. They managed the land for this purpose for thousands of years (Gammage 2011). It is axiomatic that Australian wildlife has adapted to the Australian environment and its highly variable and erratic climate. Animals introduced in the last 200 years have not yet acquired these attributes (and are never likely to through natural selection). For example, kangaroo reproduction responds to droughts which occur with regularity with minimal impact on the adult (Newsome 1975). Kangaroos are able to move significant distances with minimal energy expenditure (Baudinette 1989) to take advantage of their preferred green grass following isolated showers and patchy storms. On the other hand, introduced livestock are managed under regimes which restrict movement behind domestic stock fences, confining animals to areas from which they might otherwise move as seasonal conditions deteriorated.

This observation raises one of the key issues constraining greater use of kangaroos by landholders—a lack of ownership and landholder capacity to benefit. To address the issue there needs to be a regional approach to wildlife management and decision-making capacity by landholders about kangaroo harvesting levels across property boundaries (Ampt and Baumber 2010).

Kangaroos are shot in the field at night using a high-powered spotlights and rifles by certified and licensed shooters. A Code of Practice requires head shots and instantaneous death (NRMMC 2008). Most carcasses are processed to human consumption standard and kangaroo meat is currently exported and sold in Australia to the food service industry, retail outlets and also as pet food (Kelly 2005). Kangaroo skins are valued for their high strength to weight ratio. Quotas are set to ensure harvests are sustainable. They are based on research and rigorous monitoring of population numbers and breeding patterns and are only set for species which are abundant and not threatened or endangered. Populations remain high in areas where commercial hunting is most intense. Endorsement of the management program from professional ecologists and wildlife managers and their associations has been consistent (Lindenmayer 2007).

Kangaroo harvesters are generally independent small businesses paid per kilogram for the kangaroo carcasses they supply to processors. They have access to properties with the permission of the landholders who nevertheless do not gain any benefit from the animals taken from their properties. At Mitchell in central Queensland a different model of managing kangaroos is being tested following an investment 5 years ago by the Rural Industries Research and Development Corporation (Wilson and Mitchell 2005). Further support for research and innovation is needed to continue this opportunity. Under the banner of the local Landcare Association, landholders have formed a cooperative with kangaroo harvesters to purchase and process kangaroos, thus demonstrating that kangaroo production can be integrated into farm productivity and income without needing to muster and transport live kangaroos. In 2011 the cooperative was humanely harvesting 500 kangaroos per week from free-ranging populations across cooperative land.

From this relatively small scale, the cooperative has opportunities to expand by bringing on more landholder participants, improving the quality of the product, and marketing it directly down the value chain. However a lack of information about the financial impacts of land use change and other scientific and technical issues is limiting the growth in membership and interest by potential investors.

Under the sustainable use scenario, the primary aim of management is meat production and may require continuation of management practices such as provision of artificial water, selective harvesting of males and possibly predator control because high dingo numbers are associated with lower kangaroo numbers. The process proposed has parallels in other countries, taking advantage of uniqueness of locally evolved species, and a capacity to deliver comparative advantage and diversity to the marketplace.

In other countries, landholder involvement in wildlife management has increased populations on private lands and encouraged maintenance of habitats in their natural state. In southern Africa, wildlife industries are replacing cattle production (Bothma and Toit 2010) and in Europe and North America game species thrive on private lands integrated with conventional agricultural production (Deer Commission for Scotland 2008). Equally, iconic species and national symbols—springbok in South Africa, (Conroy 2007), red deer in Scotland, (Scottish Venison Partnership 2012) and bison in the United States (Turner 2008) are in expanding production systems.

Some people object to utilizing national icons for commercial gain. They are opposed to private ownership and value for wildlife for ethical reasons because they believe it will threaten species. Such opposition need not be insurmountable. Wildlife scientists have published scientifically based responses promoting the notion of conservation through sustainable use (Cooney et al. 2009). The conservation benefits of less livestock more kangaroo could include not only more kangaroos but improved soil conservation, increased capacity of vegetation to respond after drought, reduction in damage cattle and sheep do to riparian environments, improved water quality, and long-term sustainability of vegetation used in production processes.

The case for greater use of adapted native species such as kangaroos which are widely distributed across Australia becomes even stronger in a climate change context, both from the perspective of capacity to adapt to change and emissions reduction. Kangaroos produce low levels of methane compared to other domestic herbivores. The source makes up 11% of all of Australia's emissions and is two-thirds the size of the transport sector. Greater use of kangaroos would reduce this liability (Wilson and Edwards 2008). The concept is worth investigating and the Carbon Farming Initiative (DCCEF 2011) of the Australian Government creates an incentive for landholders on the rangelands to take advantage of this and mitigate methane by producing low-emission meat by utilizing kangaroos. It would also prepare for the day when there is full coverage of agriculture in national carbon accounting and carbon pricing in agriculture exposes cattle producers to the substantial liability generated from domestic livestock.

In addition, the Australian rangelands have been subject to considerable modification by livestock. Grazing damage to native ecosystems has contributed to the extinction of at least 20 species of mammals (Lunney 2001) and continues to threaten around one quarter of the plant species listed as endangered (State of the Environment Report 2006). Although the proposal for greater use of kangaroos is for an increase in kangaroo numbers, the net planned effect is for a lower grazing impact and for maintenance of kangaroo and other wildlife habitat. It is probable that the kangaroos' adaptations to Australia's erratic, variable climate, and recurring droughts will bring a range of environmental services such as biodiversity, water and healthy soils in addition to offsets in the carbon market. Monitoring the effects on biodiversity would be an essential part of such a transition and would indicate the extent of the co benefits of the change.

Landholders, Landcare groups, and governments need to know more about these and other scientific and technical issues such as what are the total emissions from kangaroo production compared with beef/sheep (including transport), and whether closer management of product, maintenance of quality and accuracy of description of the product as low-emission meat can increase the value of the product. Landholders also need practical support and training on how to enter the carbon market with minimal cost and risk. To enable such innovative land use change to expand and generate useful results for wider application, further investment in capital equipment, infrastructure and research is also needed.

Research is also needed to test if reducing cattle numbers can produce the same amount of meat from the kangaroos and generate offsets which can be traded in the carbon market and whether there is increased soil C sequestration, biodiversity, and other landscape benefits to be traded as those markets develop. Research could also assess further the human health benefits of greater use of kangaroo meat which is reputed to be a healthier source of red meat.

The case presented here is for greater use of adapted species and indeed for landholders to use kangaroos as a primary source of meat production compared to the exotic introduced animals. The change could lead to a more stable and resilient agriculture and enhanced food security.

24.2 The Role of Australia's Native Food Plants in Food Security: History and Opportunities

Maarten Ryder

Australia's Aboriginal people lived on this continent for more than 40,000 years before European people brought with them new species of plants and animals for their own sustenance. Aboriginal people had long ago learned the value of hundreds of Australia's native plants for both food and medicine. This knowledge, in a variety of locally specific forms, was spread across the continent with its huge range of climates, soils and, consequently, plant species. Early white explorers also became familiar with some of these plants out of necessity, often after learning their uses from Aboriginal people. Many native food plants continue to be used by Aboriginal people to this day, and are often a popular part of the diet. For example, the 'bush tomato' (*Solanum centrale*) that is native to the arid regions of central and western Australia is harvested by large numbers of Aboriginal people, mainly women and children, when seasonal conditions are suitable (Walsh and Douglas 2009). Much of the fruit is sold to the wider native food industry based in capital cities but the 'bush harvest' activity also contributes to the food security of Aboriginal Australians. Many senior Aboriginal women are very passionate about the food plants of their region and they continue to hold detailed knowledge about these important species.

While some native food plants such as the quandong (*Santalum acuminatum*) have been used for many decades by white Australians, most of the useful species remain under-utilized in present-day Australian society. This means that there is a considerable wealth of natural resources that could be developed in the future.

With the exception of *Macadamia* species, the modern native food industry in Australia is quite a small part of the whole food industry. The *Macadamia* industry is a mature part of Australia's horticultural production capability, whereas 50 years ago this industry was in its infancy. There is much potential for development, and in the next 10–50 years we could have more native food industries on the scale of *Macadamia* if we put our collective minds, energies and resources into it.

There are a number of reasons why it will be beneficial to develop more native food plant industries in the future, several of which relate to food security.

- Within the huge range of native food plant species there are many useful characteristics. Some of these characteristics could be important for future food security. Drought tolerance is one of the key properties of Australia's arid zone food plants. Included in any list of drought tolerant plants are a range of *Solanum* and *Acacia* species (for wattleseed) as well as the desert lime. Bush tomato (also known as desert raisin), wattleseed and *Citrus glauca* (grafted on to conventional Citrus rootstocks) are all being grown and harvested in a wide range of dry climate conditions across Australia. Of course water is still required for a healthy crop of any species of plant, but the ability to withstand dry periods gives an insurance against crop loss until water again becomes available, whether through rainfall or irrigation. Salt tolerance of crops is another characteristic that is likely to become more important in the future, with changes in climate and with land degradation. We have evidence for high levels of salt tolerance among some of the arid zone native food species. These characteristics are useful in enabling crops to be grown under difficult conditions, and the Australian native species could also be useful as subjects for research into improving the salt tolerance of other major crops.

- New crops based on native food species can contribute to food security by providing greater opportunities for diversification in fruit, nut and vegetable production. Most of the native food species under development still require optimization of planting material (yield, flavour, quality) and production systems but the questions are eminently answerable with targeted research and development programs (RIRDC 2008a, b).
- The fruits of many native food plants contain high levels of compounds such as antioxidants that are beneficial to human health (Netzel et al. 2006; Konczak et al. 2010). This is another aspect of food security—the ability of foods to help maintain or improve our health. Many of the highly pigmented native fruits contain very high antioxidant levels (much higher than for blueberry) and the fruit of Kakadu plum (*Terminalia ferdinandiana*) has the highest known concentration of vitamin C of any plant. Edible wattleseed have a low glycaemic index (GI) and can therefore be useful in diets requiring a low GI.
- Aboriginal people, in family and community groups, are establishing income streams from their traditional native foods (Bryceson 2008). This type of activity appears to be increasing, and often with a view to presenting native foods in a cultural setting.
- It is very likely that if we do not develop native food species in Australia, then other countries will take up the opportunities, as happened initially with *Macadamia* and also with many Australian species of wildflowers. The more the intellectual property in new varieties of Australian food plants is held in Australia, the stronger our position will be.

Several of the subtropical Australian native *Acacia* species that produce edible seed including *Acacia colei*, *A. torulosa* and *A. tumida* have in the past 20 years contributed significantly to food security in parts of sub-Saharan Africa. This story has been well documented and is worth noting because it is a clear demonstration of the positive contribution of wattleseed in improving the nutrition (dietary protein content) of people living in poverty (Harwood et al. 1999). Based on this example, there is potential for Australian food plant species to be part of global food security. Indeed many species are 'multiple use' plants that can provide timber, medicines and other useful products as well as food ingredients. In southern Australia there are ~50 species of *Acacia* that produce edible seed (Maslin et al. 1998).

Some challenges facing the native food industry include the question of shared 'industry goals' and how we can reconcile different approaches to industry development and information sharing among Aboriginal and non-Aboriginal people. These issues can be dealt with if we establish and maintain good communication channels among the various sections of the native food industry. Development and sharing of intellectual property is another issue worthy of consideration. There are models for successful sharing of Indigenous intellectual property in new plant cultivars in Africa (for example, see Leakey et al. 2003).

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In conclusion, native food species have the capacity to make a significant contribution to Australia's food security in the future. There is a large range of species to choose from for development and for inclusion in the mainstream diet. At the moment, the native food industry is focused on developing about 12 main species: bush tomato (also known as desert raisin, *S. centrale*), quandong (*S. acuminatum*), *Acacia* species for wattleseed, Kakadu plum (*T. ferdinandiana*), muntries (*Kunzea pomifera*), riberry (*Syzygium luehmannii*), lemon myrtle (*Backhousia citriodora*), aniseed myrtle (*Syzygium anisatum*), Davidson's plum (*Davidsonia* species), mountain pepper (*Tasmannia lanceolata*) and *Citrus* species including the desert lime and finger lime (RIRDC 2008a, b). These species originate from a range of environmental conditions, from the arid zone to the tropical or temperate rainforest. Native food plants can become crops, some of which have strong survival properties in adverse conditions, and native food ingredients contain a variety of constituents that can benefit health as well as nutrition. The development of native food industries offers continuing opportunities for Aboriginal and non-Aboriginal people to form fruitful partnerships.

24.3 Sustaining Crop Yields in a High CO_2 World

Glenn Fitzgerald, Michael Tausz, Robert Norton, Garry O'Leary, Saman Seneweera, Sabine Tausz-Posch, Mahabubur Mollah, Jo Luck, and Grant Hollaway

The Australian Grains Free Air CO_2 Enrichment (AGFACE) experiment is an outdoor laboratory located in Horsham, Victoria Australia which seeks to understand the effects of increased atmospheric carbon dioxide (CO_2) concentrations on wheat and field pea crop production under a range of environments. It was designed to raise CO_2 concentrations from the present 380 to 550 ppm which is expected to occur in 2050. The data gathered help validate current crop production models providing confidence that, when linked to climate change models, the estimates of future crop yields in other locations across the landscape can be more accurately predicted (Fig. 24.1).

Key adaptation objectives of this research include:

- Identifying plant traits responsive to elevated CO_2 (eCO_2), taking advantage of the intra-specific variability that can be incorporated into future breeding lines
- Identifying management changes that maximize cropping system response to elevated CO_2
- Understanding how yield and quality can be maintained while adapting to changes caused by increasing atmospheric CO_2

Carbon dioxide taken up by plants provides the building blocks to make roots, stems, leaves and the parts of plants we eat (e.g., grain). Increasing atmospheric CO_2 concentration means that more carbon is available for growth. The response of many

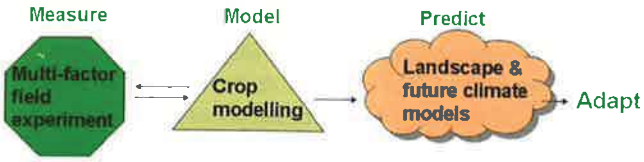

Fig. 24.1 AGFACE approach to extrapolating field data to landscapes using crop and climate modelling to assess impacts and analyse adaptation options

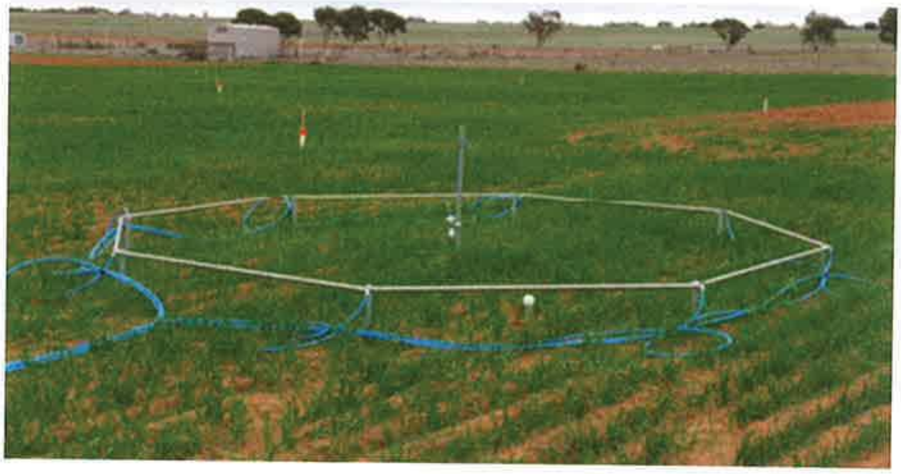

Fig. 24.2 Example of a FACE octagonal 'ring'. Pure CO_2 is injected upwind, whereby it is carried across the ring. Air is continuously sampled from the centre and a controller maintains central CO_2 concentrations at 550 ppm

C3 crop plants to eCO_2 (without limiting water or nutrient supply) is to increase biomass and yield. If these were the only consequences of increasing atmospheric CO_2, it would be a boon to global agriculture. However, future climate is predicted to have generally higher temperatures and altered rainfall distribution, intensity and amount. Thus, the interactions of CO_2 with water supply and temperature will cause changes to crop production, food quality and food security.

The FACE methodology allows measurement of crops under field conditions free from artefacts of enclosed chambers. Each FACE 'ring' is composed of eight horizontal pipes in an octagonal shape suspended on supports maintained just above the growing crop (Fig. 24.2). Each pipe has small holes through which pure CO_2 is injected into the prevailing wind, allowing the CO_2 to distribute across the ring. A computer monitors wind speed and direction and CO_2 concentration at the ring centre, maintaining central concentration at 550 ppm. The experiment is fully replicated and composed of eight elevated CO_2 (eCO_2) and eight ambient CO_2 (aCO_2) areas. A series of small plots with a range of treatments are encircled by the rings.

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From 2007 to 2008, at Horsham two cultivars of wheat were included and then in 2009 the rings were expanded to allow sowing of eight cultivars. There were two levels of irrigation (rain fed and supplemental), two times of sowing (typical and late) and one cultivar had two levels of nitrogen fertilizer applied. Additionally, a second site in a hotter, drier region in the Victorian Mallee (Walpeup) was run for 2 years. The time of sowing treatment and the hotter Walpeup site provided an indirect measure of the effect of increased temperature during the critical time of anthesis when the wheat grain develops. All together, these experimental treatments allowed a wide range of environments in which to measure and model wheat response to eCO_2.

In 2010, the experiment was altered to a long-term wheat-field pea rotation in which other questions concerning the effects of eCO_2 on a legume crop, nitrogen fixation processes and carry-over effects of soil N on wheat and legume grain quality could be addressed.

Key research questions have included the following:

- What are the impacts of eCO_2 on wheat and pea growth and yield?
- What are the effects of eCO_2 on grain protein, micronutrient composition and bread and noodle quality?
- How does water use efficiency change as a result of eCO_2?
- What are the long-term effects of the wheat-field pea rotation on soil and plant nitrogen?
- How do the wheat pests and diseases, crown rot, barley yellow dwarf virus and wheat stripe rust change under eCO_2?
- Are there any interactions between eCO_2, soil water levels and nitrogen fertilization on crop productivity?

It has been documented in other FACE experiments in wheat and other crops that there are distinct changes to growth, yield and quality. This has been confirmed in AGFACE and we have shown that under current temperatures and rainfall patterns:

- At Horsham, mean yield increased in wheat and peas by 24% and 22%, respectively
- Aboveground biomass of wheat and pea increased (mean of 27% for each crop)
- At Walpeup, the 2-year mean yield increase was greater than 50%
- Wheat grain protein decreased, depending on environmental conditions (mean of 5% at Horsham and 13% at Walpeup)
- Wheat nitrogen uptake increased due to increases in biomass (20% at Horsham, 32% at Walpeup)
- Wheat grain iron and zinc concentrations decreased by about 10% at Horsham
- Elevated CO_2 promoted tillering in wheat
- Elevated CO_2 increased grain yield through increased head number, grain number per head and single grain mass.

Crop modelling allows evaluation of the effects of future temperature increases and changing rainfall patterns on crop production. Thus, although eCO_2 by itself increases yield, increasing temperature is expected to erode this gain, leading to yield decreases as global temperature rises. Climate change models also indicate that rainfall amounts and timing will change and there will be more rainfall later in the season in Victoria. Preliminary modelling results suggest that by 2050, without adaptation there could be about 10–20% yield reduction in the drier Mallee and an increase of about 10–20% in high rainfall zones in southern Victoria. Thus, adaptation may include shifting to longer season cultivars and sowing later to take advantage of late season rainfall.

Pests and diseases in wheat have been studied in the AGFACE resulting in better understanding of how they will respond in a higher CO_2 world. For example, wheat crown rot was shown to have greatly increased fungal biomass under eCO_2 compared to aCO_2. This may be because this fungus overwinters in crop residues and the increased biomass from eCO_2 led to increased stubble. There was no effect from eCO_2 on wheat stripe rust pathogenicity, so this disease may become less serious under future climate.

The above results lead to the following adaptation possibilities and questions to ensure future food security:

- Tillering response can be incorporated in new breeding lines but the response must be matched to environment, since too many tillers may not lead to higher yields under rainfed terminal drought conditions
- Breeding for longer season cultivars and delaying sowing times may allow crops to take advantage of warmer conditions and late season rainfall
- Given that bread and noodle quality are likely to be affected by decreased wheat grain protein, protein quality and micronutrient contents under eCO_2, can cultivars be developed to overcome these limitations and be adapted to different regions?
- Can cultivars be developed that will maintain yield and quality in the presence of changing pest and disease dynamics?
- Will robust crop-climate models allow us to predict, within an acceptable degree of error, future crop yields?
- How will grain quality changes affect bread and noodle parameters and how will this effect marketability?
- How will people with limited access to meat maintain their intake of protein and micronutrients?

Current and future research will focus on cereal–legume systems to inform cultivar development and test crop management solutions to understand soil and plant nitrogen dynamics, while maintaining yields and grain quality under changing climate.

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