FARMING SYSTEMS IN AUSTRALIA

Rohan T. Jayasuriya*

* Resource Management Economist, NSW Agriculture, 161 Kite Street, Orange 2800, Australia.
Telephone: +61-2-63913343 Fax: +61-2-63913650 E-mail: rohan.jayasuriya@agric.nsw.gov.au
The views expressed are those of the author, rather than those of NSW Agriculture or the NSW Government.

CHARACTERISTICS OF THE REGION

Australia, the smallest of the continents – and the world's largest island – is a compact land mass measuring approximately 3900 km from east to west at its widest point and about 3220 km from north to south. The total land area in Australia is 7,617,266 sq km (762 million ha). Native forest cover is estimated at 22% (164 million ha). Approximately one-third of the continent is classified as arid (receiving less than 250 mm average annual rainfall) and another third as semi-arid (250 to 500 mm). However, Australia's northern, eastern, south-eastern and south-western areas with climates ranging from tropical to temperate and Mediterranean-style usually are well-watered, with regular rainfall. These areas have become the main agricultural regions, although Australia also has developed techniques for farming in drier areas. Total agricultural land is estimated to be 200 million hectares (approximately 25% is cultivated with equal areas on crops & sown pastures) out of which only 1% is irrigated though irrigation contributes 26% of the gross value of farm production (NLWRA, 2001). Irrigation has offered opportunities for agricultural intensification, greatly enhanced yields and the substitution of low value crops with higher value enterprises. Without irrigation, a significant proportion of Australia's agricultural industries would either not exist or be greatly diminished. About two thirds of Australia's agricultural production from irrigation is derived from the Murray-Darling Basin, producing rice, cotton, cereals, soybean, fruit and vegetable crops. Outside the Basin, irrigation is used mainly for dairy pastures, seed, fodder, cereal, horticultural crops and sugar cane production. There were approximately 146,400 establishments engaged in agricultural activity that reported an estimated value[1] of agricultural operations of $5,000 or more in the year 2000 (ABS, 2001).

Australia has advanced in 200 years from a land without agriculture to one of the world's leading producers and exporters of food, natural fibres and livestock. This achievement has taken place in the face of harsh climatic and environmental conditions which necessitated the development of highly specialised agricultural systems, skills and technology. Agriculture and food production is Australia's largest and most diverse and most competitive industry. When the total chain from the farm and research laboratory to the processing plant, retail outlet and exporter is considered, it accounts for about 30% of the nation's total economic activity and directly/indirectly employs 20% of the Australian work force (National Farmers Federation, 1992 and 1998). Australia's gross value of farm production is $38 billion (5.5% of GDP) with an export value of $29.5 billion (forestry & fisheries an additional $2 billion each). Australia has a total population of 19.4 million of which 381,000 (4.1% national workforce) are employed in rural farm sector (forestry, fishing and hunting an additional 57,000) (ABARE, 2003). Today, Australia is the world's largest producer and exporter of wool; the largest exporter by quantity and the second largest by value of beef; and the third largest exporter of wheat. It is also the second biggest exporter of raw sugar to the open market and a significant overseas vendor of fruit and dairy products. Just over half of Australia's exports go to nations in the developed world, principally Japan and the United States, a further one quarter are sought by the centrally planned economies while the remainder are purchased by developing countries. The strongest growth in Australia's export markets has in recent years been concentrated in these latter two groups (National Farmers Federation, 1998).

The long term viability of the Australian agriculture depends on sustainable management practices and systems, that is, those that are within the capability of the resource base to support. The effects of unsuitable agricultural practices are well documented. Experience

[1] Unless otherwise indicated, the currency used is Australian dollars.

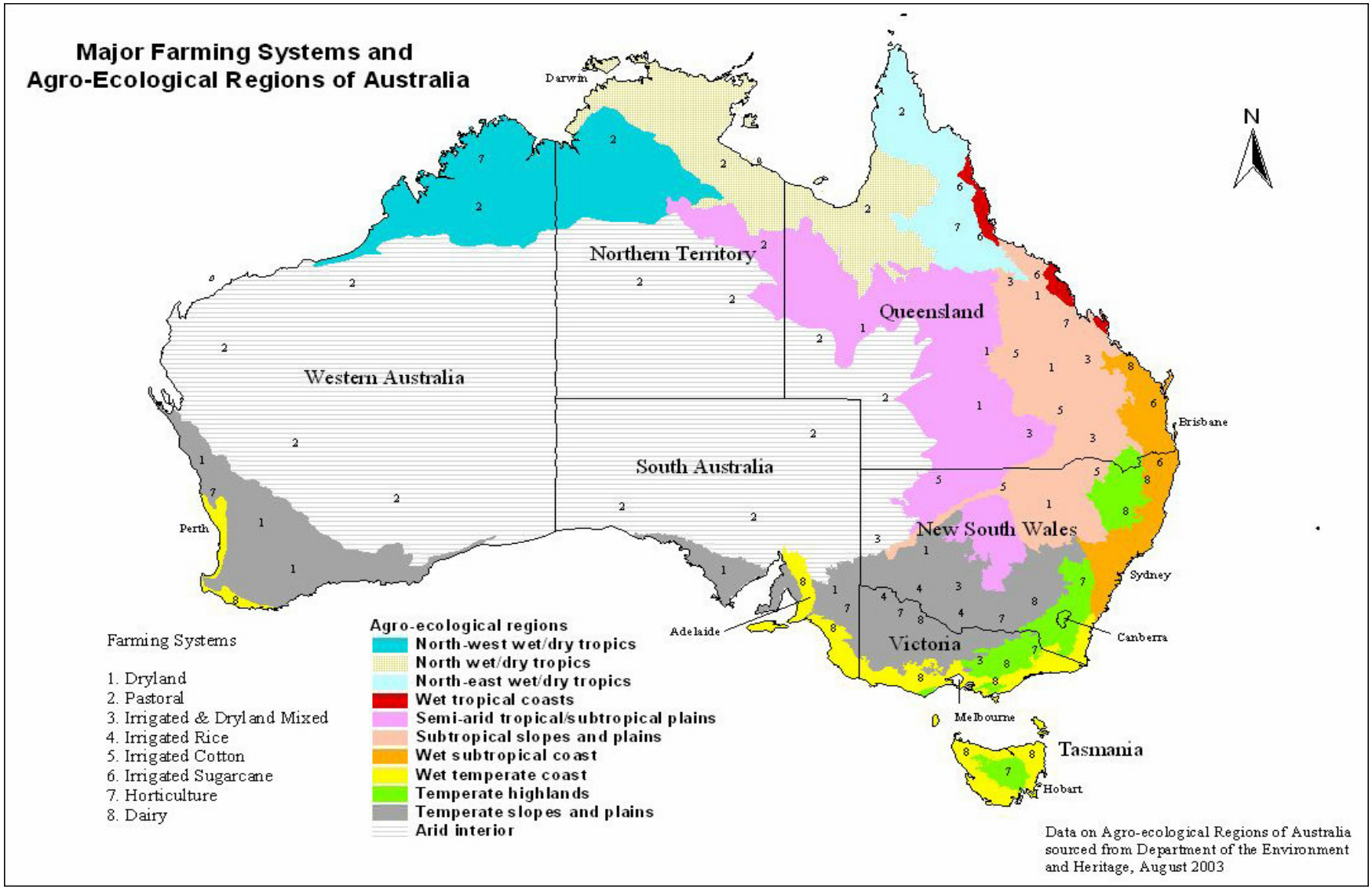
and research have assisted farmers in taking preventive and or remedial action to address many resource degradation problems. However, there is still a need for a better understanding of the relationships between natural resources and farming systems, which will facilitate improvements in sustainable agricultural practices.

MAJOR FARMING SYSTEMS IN AUSTRALIA

Eleven broad farming systems have been identified based on criteria discussed in Dixon et al, 2001. They are listed in the table below and the geographical distribution of eight of these systems is indicated on a layout of agro-ecological regions in the accompanying map. Each farming system is briefly described, followed by a discussion on region-wide trends. Finally, the main systems are analysed in greater depth.

Major Farming Systems in Australia

Farming Systems	Land Area / % of Country	Farm Families / People Employed	Enterprises
Dryland	15% of the country	33,200 families	wheat, sorghum or sunflower, wool, sheep meat, beef
Pastoral	45% of the country	not available	beef, sheep meat, wool
Irrigated and Dryland Mixed	not available	not available	maize, sorghum, soybeans, canola, wheat, barley, oats, pastures, sheep and cattle
Irrigated Rice	155,000 ha	2,000 families	paddy rice, cereals, sheep
Irrigated Cotton	459,300 ha	1,300 families	cotton lint & seed, other crops, sheep, cattle grazing
Irrigated Sugarcane	419,000 ha	6,900 growers 23,000 employed	sugar cane, raw sugar & by-products molasses, bagasse & fibre
Horticulture	annual vegetables & perennial fruit 136,500 ha each and wine grapes 128,000 ha	93,000 employed across 13,865 properties 4,500 wine grape growers	annual vegetables and perennial citrus, nuts, pome fruit, stone fruit, tropical fruit berry fruit, bananas, wine and table grapes, cut flowers
Dairy	3.5 million ha	13,900 farms employ 50,000 directly, another 50,000 provide related services	fresh milk and manufactured dairy products
Poultry, Swine & Goat	not available	poultry 1850 farms swine 3600 farms goat 2400 farms	broiler meat, eggs, pig meat, goat meat, milk & skin
Aquaculture	95% production in coastal waters	not available	marine & freshwater finfish, crustaceans and shellfish
Forestry	commercially 29.4 & 1.5 million ha of native forest & plantations	14,000 growers & harvesters 72,000 employed in processing	wood fibre (woodchip), sawlog, sawnwood, pulpwood


Major Farming Systems and
Agro-Ecological Regions of Australia
Darwin
Northern Territory
Queensland
Western Australia
South Australia
New South Wales
Victoria
Tasmania
Perth
Adelaide
Brisbane
Sydney
Canberra
Melbourne
Hobart
N
Farming Systems
1. Dryland
2. Pastoral
3. Irrigated & Dryland Mixed
4. Irrigated Rice
5. Irrigated Cotton
6. Irrigated Sugarcane
7. Horticulture
8. Dairy
Agro-ecological regions
North-west wet/dry tropics
North wet/dry tropics
North-east wet/dry tropics
Wet tropical coasts
Semi-arid tropical/subtropical plains
Subtropical slopes and plains
Wet subtropical coast
Wet temperate coast
Temperate highlands
Temperate slopes and plains
Arid interior
Data on Agro-ecological Regions of Australia
sourced from Department of the Environment
and Heritage, August 2003

Dryland Farming System

Dryland farming, also called rain-fed agriculture, is practised in regions where lack of moisture limits crop and/or pasture production to part of the year. This period is called the growing season and varies from a few months to about nine months in a 'normal' year. Rainfall is often low (250 to 500 mm) and variable but the more successful dryland farming systems have been established where rainfall (however low) is reliable and the start and finish of the growing season are fairly predictable. Successful systems are not restricted to the wetter end of the spectrum. Dryland farming systems combine crops, pastures and fallow periods based on rotations for the fundamental purpose of making efficient use of the limited water. Dryland agriculture based on integrated livestock (sheep and cattle) and cropping farms is important in most mainland States of Australia. Much of Australia's agricultural income comes from production of food and fibre on dryland farms. On these farms crops and pastures are grown in rotation and livestock graze pastures and eat stubbles and some grain. This farming system extends to three agro-ecological regions namely temperate slopes & plains, semi-arid tropical/subtropical plains and subtropical slopes & plains and this region is called the cereal/livestock region (the so-called wheat/sheep zone) of Australia. Wheat is the major crop often grown in rotation with grain sorghum or sunflowers after fallow periods, which sometimes last several months. Farms classified in the wheat and other crops industry are referred to as specialist grain farms, those in the mixed livestock-crops industry are referred to as mixed livestock-grain farms and the two categories combined are classified as grains industry farms. The combined industry grouping accounts for around 33,200 farms and around 95% of the total value of grain production of $10 billion - around a quarter of the total gross value of farm production (Hooper et al, 2003). The farming system carries most of the nation's 119 million sheep and about 20% of nation's 24 million beef cattle.

Pastoral Farming System

The basis for separating the pastoral region from the rest of Australia lies in its inability to be cropped for rain-fed grain. Arid and semi-arid rangelands total about 5,294,000 sq km that represent about 70% of Australia's land mass, providing a harsh environment for human habitation. Day temperatures are high; rainfall is low and erratic, soils generally are infertile and often poor in physical structure and recurring droughts are a feature of the environment. The pastoral system developed consists of low-density grazing of the natural vegetation (perennial grasses, shrubs and trees) with sheep and cattle. Much stock water is pumped from underground sources (artesian and sub-artesian) using pumps powered by wind. The low operating cost of wind pumps has enabled watering points to be strategically spaced, assisting preservation of rangeland vegetation. The regions carry most of the nation's 24 million beef cattle and about 22% of nation's 119 million sheep, representing an important breeding area for livestock.

Individual properties, generally called stations, are large throughout the region, often exceeding 50,000 ha held under leasehold tenure from government. Large enterprises tend to have a company or partnership structure. Firms with a number of stations move cattle by road transport between different holdings in various parts of the region, according to seasonal conditions. Cattle are produced for sale direct to export abattoirs in Australia, shipment live overseas or for sale as stores to be fattened on quality pastures in more favoured regions. Sheep properties more commonly are owner-operated and, in the event of difficult conditions, sheep are sold (particularly wethers and older ewes). As a last resort, all or part of the breeding flock may be sent on agistment (rented grazing) to be returned when

rain promotes new pasture growth. A similar procedure is followed on owner-operated cattle enterprises.

Mobility is a major feature of the pastoral farming system. As a result this farming system can be seen covering a range of agro-ecological regions including the wet/dry tropics, subtropical slopes & plains and temperate zones (beef cattle fattening). The property size varies from 13,000 to 300,000 ha in the wet/dry tropics (Department of Trade and Resources, 1982).

Irrigated and Dryland Mixed Farming System

Most major inland rivers in Australia are regulated which means their supply is controlled or augmented by releases from dams and weirs operated by the Government. Water is made available to irrigators through a system of individual entitlements and annual allocations. In addition, underground resources are also tapped on some individual farms as irrigation entitlements. Farms with access to such systems irrigate part of their land while the other part is maintained with dryland enterprises. Irrigation is mostly by flood and furrow systems and sprinkler and trickle irrigation systems are adopted on high-value crops. This farming system is present mainly in temperate slopes & plains as well as subtropical slopes & plains associated with Australia's Murray-Darling Basin river systems.

Crops such as maize, sorghum, soybeans, and pastures are irrigated while canola, wheat, barley, and oats are grown both with irrigation as well as without as dryland enterprises. Livestock (mainly sheep but cattle as well) and pasture often is integrated with crop production as a rotational requirement on the farms. Livestock is grazed on dryland perennial pastures as well as on crop stubble and irrigated pastures (lucerne) is used to make hay both for market as well as extra hand feeding of livestock when required. As expected there is a vast difference in yield levels between irrigated and non-irrigated crops.

Individual farm size is highly variable. As an example Lachlan Valley in New South Wales reported typical farm size ranging from 300 ha to 7500 ha with an irrigation component ranging from 4% to 50% of total farm size (Jayasuriya, 2004; Jayasuriya et al, 2001). Most of these farms are family owned while some larger farms are jointly owned by more than one family. The smaller farms are run by the owner/manager and family with some employment of casual labour during peak demand periods, while the large farms employ an additional unit of permanent hired labour. These typical farms reported whole farm gross margins between $93,000 and $443,000 and net farm incomes between $38,000 and $239,000 depending on their size and enterprise levels.

Irrigated Rice Farming System

Australian rice farming system is wholly located in the temperate slopes & plains in New South Wales, mainly on country irrigated from Murray and Murrumbidgee Rivers in the southern part of the State. Rice production is only allowed on extremely heavy clay soils that are tested to ensure they are impermeable to water leaking to the groundwater table. Rice is grown in water for much of the growing season and mostly on contour banks and in laser-landformed border checked bays. The crop is sown from late September to the end of October. Three sowing methods are used, the most popular of which is aerial broadcast by specialised aircraft directly into the bays that have been filled with water. Other methods include sod-seeding (directly drilled into pasture) and combine drill into a conventionally prepared seed-bed. New technology includes metering of fertiliser and herbicides into the irrigation water. Harvesting starts about mid-March, and if the weather is good, largely is

completed by the end of May. Self-propelled combine harvesters, similar to wheat harvesters are used for rice harvesting. Rice milling and marketing is entirely done through the Ricegrowers Co-operative Limited, where two-thirds of board members are elected by growers holding shares. Recent average figures indicate a total harvested area of about 155,000 hectares and an average paddy rice yield of 9.0 t/ha, the worlds highest (ABARE, 2003). Nearly 50% of production is exported, making the rice industry one of the major export earners of the State.

There are around 2,000 families operating rice farms. These farmers grow rice using a unique rotation cycle (with other enterprises) across the whole farm over four to five years. Generally the rotation consists of a rice crop followed by a cereal crop sown into the rice stubble to utilise the available moisture. This will generally be followed by subclover pasture and then back to rice. The pasture phase allows the farmers to run livestock (mainly sheep) and allows the soil to build up nutrients for the coming rice crop and the rotation system defeat weeds and breaks any pest cycles. There are two categories of typical rice farms in Murrumbidgee Valley; a 220 ha small farm and a 425 ha large composite farm (Jayasuriya, 2004; Jayasuriya and Crean, 2001). The small farm is run by the owner/manager and family with some employment of casual labour during peak demand periods, while the large farm employs an additional unit of permanent hired labour. These typical farms cultivate rice as the main summer crop (about 35% of total farmed area) together with wheat and subclover and additionally, canola and soybeans only on the large farms. These typical farms reported whole farm gross margins of around $124,000 & $265,000 and net farm incomes of $66,000 & $111,000 for the small and large farms respectively.

Irrigated Cotton Farming System

Cotton is grown in subtropical slopes & plains and semi-arid tropical/subtropical plains in northern New South Wales and in Queensland. Cotton is mostly irrigated but there is some rain-fed cotton (about 10%) as well. Recent 3-year average figures indicate a cotton area of 308,700 ha in New South Wales and 150,600 ha in Queensland with an overall average yield of 1624 kg/ha being the worlds highest (ABARE, 2003). In some Valleys, grower co-operative system has evolved into a fully integrated ginning, warehousing, shipping and marketing organisation. About 90% of the Australian crop is sold off-shore.

Almost all farmers who grow cotton also grow other crops and about 50% graze either sheep or cattle. This is due to both environmental factors (soil quality) and economic factors (spreading the risk) associated with cotton growing. Cotton growing operations range in size from a few hectares on mixed farms through to 45,000 ha farm in North West New South Wales. Approximately 1,300 farmers, 10 processing companies and six private merchants are involved in the production (National Farmers Federation, 1998). Although there is a number of large cotton producing enterprises, the majority of cotton is grown on family farms. Compared with other rural industries, cotton farming has high dollar turnover and is both capital and labour intensive. The average cash operating surplus of cotton farms in normal times is nearly six times higher than the average for all agriculture; and the average total asset value of cotton farms is more than three times higher than the average for all of agriculture (National Farmers Federation, 1998).

Irrigated Sugarcane Farming System

Sugarcane is cultivated in wet subtropical coast, north-east wet/dry tropics and dominates in the wet tropical coast, where it is by far the most important crop; not only in economic terms but also for the employment it creates. Queensland produces 95% of the Australian crop.

There are about 6,300 and 600 cane growers in Queensland and New South Wales respectively, employing a total of 16,500 workforce. Also, there are around 30 raw sugar mills that employ about 6,000 people during the crushing season, although this figure falls by about 20% during the off-season maintenance period (National Farmers Federation, 1998). Recent 3-year average figures show a harvested area of 419,000 ha with an average 82 t/ha of cane yield a year to make some 11.3 t/ha of raw sugar (ABARE, 2003). Around 75% of 4.74 million tonne total Australian raw sugar production is exported.

The average sugar-cane farm is about 48 ha in size, with about five-sixths in production at any one time with the rest in fallow, in transition to another crop, being grazed or sown to soil-improving leguminous green manure crop. Monoculture in sugar-cane is common and has had few adverse effects. The Australian sugar industry relies heavily on mechanical planting and cultivation, while all sugarcane is now harvested mechanically by specially designed harvesters. Both green cane harvesting and burnt cane harvesting methods are adopted. The harvester moves along the rows of cane, removing the leafy tops of the cane stalks, chopping the stalks and loading the pieces into bins for transport to the mill by road, light railway or a combination of both. Computer images are used to locate cane bins on the tracks and to manage their movements to ensure that no bin is in transit for more than 16 hours, to avoid cane deterioration (National Farmers Federation, 1998). In many areas, cane growers and mill owners form harvesting groups to ensure the harvest runs efficiently, and to minimise delays between harvesting and milling. The groups range in size from two to eight growers depending on the volume of cane to be harvested, the location of the field in relation to the mill, and the type of equipment available. By-product 'molasses' from sugar mills is in great demand for drought feeding of livestock, for introducing mineral supplements into farm animals and as the base for concentrated stock feeds. The other by-product 'bagasse' provides nearly all of the fuel required for steam and electricity generation at the mills.

Horticulture Farming System

Australia produces a diverse range of annual and perennial horticultural crops, including vegetables, fruits and nuts, and has a well established and expanding viticultural industry. About 100 crop types are produced over more than 80,000 enterprises (NLWRA, 2001). The products are mostly used as fresh vegetables (eg. beans & peas, onions, lettuce, tomatoes, potatoes and carrots) and fresh fruit (eg. apples, pears, citrus, stone fruit, bananas and grapes). Some are processed as frozen or canned, dried or made into beverages (wine and fruit juices). Most horticultural products are aimed towards the domestic markets, with less than 20% being exported.

The horticultural industry is distributed across a wide range of environments, but primarily restricted to irrigation water, quality soils and topography. Major production areas are concentrated in fertile regions with high annual rainfall or abundant water for irrigation. Perennial horticulture is distributed in temperate highlands, temperate slopes & plains, subtropical slopes & plains and in wet/dry tropics. Vegetable production is highly concentrated close to major towns and cities (urban based), where domestic water supplies are used. In 1997, equal areas of annual (mostly vegetables) and perennial (mostly fruit) crops were grown (~136,500 ha each) which were valued at $1.9 billion for the annual and $1.7 billion for the perennial crops. Much of this production was grown on 164,000 hectares of irrigated land, using 1,640 GL of irrigation water and an average return of $590 /ML of water use. In 1998/99, Australian horticulture employed more than 93,000 people across 13,865 properties and generated an average farm income of $59,000 for fruit growers and $44,000 for vegetable growers (NLWRA, 2001).

Additionally, the viticultural industry (wine, dried & table grapes) is valued at more than $1.5 billion in 2000-01 with wine grapes representing most of this - $1.2 billion gross value (ABS, 2001). Recent 3-year average figures indicate a grape production of 1.4 million tonnes with a wine grape area of 128,000 ha (ABARE, 2003). There are between 4,000 and 4,500 independent wine grape growers (82% with a turnover of more than $20,000 per annum) who produce about 70% of the crop, with winery owned vineyards growing steadily in both absolute hectares and also in relative terms. A typical independent vineyard is 25 ha or larger, with irrigation now being all but universal (National Farmers Federation, 1998).

Dairy Farming System

The Australian dairy industry is the nation's third largest rural industry in terms of the wholesale value of production ($2.8 billion). The industry operates in all States, providing milk and manufactured products of the highest quality at world competitive prices. The agro-ecological zones include temperate highlands, temperate slopes & plains, wet temperate coast as well as in the higher rainfall areas in subtropical slopes & plains and tablelands in wet/dry tropics. The farming system carries about 3.2 million milk cattle and the number of registered dairy farms is around 13,900 out of which 60% is located in the Victoria State. The industry employs some 50,000 people directly, while another 50,000 people provide related services (National Farmers Federation, 1998).

The average Australian dairy herd comprises 120 milking cows, but there is a trend towards larger herds, and herds of 200 plus are common. The typical farm occupies 183 ha. Most are family owned and operated and have only limited use of hired labour (National Farmers Federation, 1998). These farmers have milk quota contracts to supply a specific amount of whole milk to the controlling body. While pasture remains the primary feed source for dairy cows in Australia, extra hand-feeding of hay and grain during winter often is necessary to maintain production to the necessary levels. Many dairy farms are situated on coastal rivers and creeks, and the dairymen irrigate sown temperate pastures and lucerne in summer. Estimates by the Australian Bureau of Agricultural and Resource Economics (ABARE) indicate that in 1995/96 the average dairy farm had a gross income of $215,800 and cash costs of $114,900, resulting in farm cash income of $63,600.

Poultry, Swine and Goat Farming Systems

Most commercial poultry enterprises are intensive, highly mechanised units that occupy relatively small areas compared with conventional farming and are located close to urban areas. Both broiler (meat) and egg production are highly developed industries in subtropical slopes & plains in New South Wales and Queensland, temperate slopes & plains in Western Australia and South Australia and also temperate zone in Tasmania. Poultry producers operate within well organised structures, which ensure constant, guaranteed returns. Two large integrated companies supply about 75% of the day-old broiler chickens hatched and process about 70% of broiler chickens marketed in Australia. The balance of production is shared among several medium-sized companies, and a myriad of smaller processors and hatchery people. Approximately 850 growers produce about 80% of chickens under contract to processing companies. The balance is produced by a small number of large company farms. A typical family farm would house 60,000 broiler chickens and produce a total of 300,000 to 400,000 birds per year in several batches (National Farmers Federation, 1998). Because of the continuing high price of red meats, the broiler industry is expected to expand further. There are about 1,000 egg farms that vary in size with the average commercial farm

consisting of 10,000 hens. Free range and barn-laid production systems account 5% of total egg production.

Pig farming is practiced in temperate slopes & plains in Western Australia, South Australia, New South Wales and Victoria; subtropical slopes & plains in Queensland and also temperate zone in Tasmania. The majority of Australian pigs are housed indoors. Extensive pig keeping systems are expanding slowly in Australia. These systems appear attractive, with space for the pig to move around and with much lower capital expenses. However, pigs in these systems are more susceptible to disease, have poorer performance and can experience discomfort from both the sun and the rain. Pig production is centralised in cereal growing areas, because adequate supplies of the dry feeds that pigs require rely on large quantities of relatively cheap grain. Barley and wheat provide the main base rations. There are many large intensive piggeries, where pig meat production complements grain growing. Many smaller pig units are situated close to urban areas. Most commercial pigs are hybrids, generally crosses between Large White and Landrace. In 1995, approximately 3,600 farms produced pigs, with total farm-gate production worth $700 million (National Farmers Federation, 1998). Marketing methods for the pig industry have undergone changes in the past decade. More than 95% of pigs are sold directly to a meat processor or to a retailer either by consignment or by computer trading (electronic network for trading livestock including cattle, sheep, lambs etc.).

Feral goats are found throughout semi-arid pastoral areas of Australia with many thousands being domesticated or rounded up for slaughter each year. These animals and their progeny remain the main stay of the goat meat industry. The total goat population is estimated to be 5 million. There are around 2,400 goat producers. Live exports were conservatively valued at $45-50 million in 1996 (National Farmers Federation, 1998). In addition to meat production, goat farming produces goat milk and skins as well.

Aquaculture Farming System

Since 1980s, with declining production from wild fisheries and increasing demand for seafood products, there has been a surge in interest in aquaculture, particularly the farming of prawns in northern Australia. From an initial industry based on almost entirely on oyster and pearl production, aquaculture now covers marine and freshwater finfish, crustaceans and shellfish. Industries such as freshwater crayfish farming are dominated by small scale family operations, many operating as a secondary activity on a traditional farm. In contrast, industries such as abalone and tuna farming are multimillion dollar activities. The farming systems range from highly intensive, controlled systems through to low-capital, extensive production. The type of production system used depends on the type of species grown. Crustaceans (eg. yabbie production in South-eastern Australia and in Western Australia) tend to be produced in relatively extensive systems because they are bottom dwellers. Their density and production relates to surface area rather than volume, so large areas of water are utilised. Finfish (eg. trout, salmon and barramundi) tend to be produced more intensively as they can be stocked at higher densities and formulated feeds are available for many species. Recent developments have seen wild fisheries and aquaculture working together more closely, in particular with industries such as the sea ranching of tuna (semi-intensive production) in South Australia (Smallridge, 1998). In this industry, tuna are netted from the wild and brought back to a sheltered bay where they are transferred to sea cages.

Australian aquaculture production has risen rapidly during the last decade, at about 10% per year. Farm-gate production for the year 1999/2000 was valued at $695 million, which is

more than 30% of the total national production value of all fisheries (O'Sullivan and Dobson, 2001). The industry has concentrated on the production of high value products, primarily aimed at export markets. Future directions may come in the form of high volume production of lower value products and a greater emphasis on domestic markets. Although 95% of Australian aquaculture production is in coastal waters, the opportunities for expansion are more likely to be in off-shore waters beyond the sight of the beach, as part of inland irrigation schemes and in saline waters drained from salinised farm lands, of which there are currently 2.5 million hectares.

Forestry Farming System

Australia has a well established mature forest industry, historically resourced from native hardwood and plantation softwood forests. The Eucalypt species, unique to Australia, makes up about 80% of Australia's forests with the remainder consisting of a variety of acacia species, cypress pine (Callitris spp.) and paper-bark (Melaleuca spp.). The native forest cover is estimated to be 164 million ha out of which 70% are on private land but account for only around 29% of wood production. Most of the commercial quality forest is publicly owned (29.4 million ha of native forest and 632,000 ha of plantations). In addition, Australia has more than 900,000 ha of private plantations (about 400,000 ha of softwood and nearly 500,000 ha eucalyptus). Plantations provide about 57% of Australia's wood processing requirements. In 2000/01, total harvest removals were around 24.3 million m^3 – 10.3 million m^3 from native forests (mainly hardwood), 12.9 million m^3 of mostly exotic plantation softwoods and more than 1.1 million m^3 of plantation hardwoods (AFFA, 2003).

Forestry industry has a highly skilled workforce with 2,500 professionally trained foresters, 14,000 growers and harvesters, and about 72,000 people employed in processing. The industry has about 1140 sawmills. The majority are hardwood mills, producing high value, small volume products. The remaining 32% are softwood sawmills many at world scale levels of production, with timber predominantly used for structural manufacturing (AFFA, 2003).

To secure long-term timber supplies, some overseas companies are directly, or in partnership, entering into plantation establishment agreements in Australia. Australians, in response to forecasted improvements in timber prices and increasing domestic and international demand for timber, have invested in many prospectus based managed plantations. Within these schemes professional managers usually supervise all operations, while ownership of the plantation remains with the individual investor. Over 500,000 ha of plantation forest have been established under these schemes, with investments exceeding $2 billion. Plantation ownership also offers the ability to trade in environmental credits (carbon credits), an emerging market which is gaining international support. Several international investments within Australia have been made on the basis of obtaining carbon credits (AFFA, 2003).

REGION-WIDE TRENDS IN AUSTRALIA

Population, Farm Structure and Income growth

Farm numbers have decreased from 178,000 in 1982 to 146,400 agricultural holdings in 2000/01. The greatest reductions were in smaller holdings of less than 1,000 ha, and especially <100 ha. As a consequence, the size of farm holdings in some agricultural sectors increased in some regions. For instance during these years, the number of sheep and beef cattle farms with areas between 100 and 5,000 ha increased, as did grain cropping farms

having areas between 1,000 and 25,000 ha (NLWRA, 2001). This trend could be further expected to continue into the future. The number of people directly employed in the farm sector has decreased, mainly in the broadacre agriculture (sheep, beef and cropping industries). A declining farm labour force has contributed to the declining size of many rural communities and a corresponding loss of service infrastructure. The loss of services is impacting on rural communities. As a consequence, issues raised by rural communities include access to services such as health, education, finance and telecommunications, falling employment prospects and a decline in lifestyle. A broad understanding by rural women of significant issues facing the rural sector is bringing a diversity of ideas and solutions to these challenges. Rural women are actively seeking and finding new ways to influence both industry and government policy; their activism is leading to the establishment of rural women's networks at the State and Commonwealth levels (National Farmers Federation, 1998). The nature of farming in Australia continues to be dominated by family ownership, with only about 0.4% of establishments corporately owned, although these farms account for some 6.5% of the gross value of production. The top third of broadacre farmers produce 70% of output. On average, there are 2.5 partners per farm. Approximately 40% of all business partners in broadacre and dairy farms are women (ABARE, 1996).

The Australian grains industry has achieved substantial productivity gains over the past ten years. Between 1991/92 and 2001/02, the area sown to grains increased by 50%, while production expanded by over 90% (Hooper et al, 2003). The increase in the area sown to grains over this period in mixed sheep and grain producers was due to the farms reducing their sheep numbers as a response to low wool prices. Increased productivity has contributed to an increase in the profitability of grains production relative to livestock production in mixed farms. However, the reverse is predicted for the future with a projected decline in the area sown to grains due to fall in real grain prices and a switch in resource use as sheep producers expand their flocks in response to favourable wool and sheep meat prices. Rates of return to capital and management (excluding capital appreciation) for grains industry farms exceeded the average for the previous decade of 2% in both 2000/01 and 2001/02. At the national level, rates or return for grains industry farms averaged 7.5% in 2001/02. In addition, farms in all States recorded substantial capital appreciation during both 2000/01 and 2001/02 averaging over $170,000 at the national level and resulting in rates of return including capital appreciation of 7% and 14% respectively in 2000/01 and 2001/02 (Hooper et al, 2003). The average capital value for grains industry farms was an estimated $1.76 million in July 2002. For broadacre and dairy farms, farm equity ratios have on average remained at about 85%, as a result of increase in farm assets though the debt levels have increased in the recent past. Increased profitability permits increased investments in farm natural resources and infrastructure.

Natural Resources and Climate

Climate, soil quality, topography and the availability of irrigation water determine agricultural land use patterns and production potential in Australia. Development of agriculture has had to confront and overcome constraints imposed by an unreliable and generally semi-arid climate, and often fragile and infertile soils. Many Australian soils do not naturally have the qualities needed for sustained agricultural production without significant management inputs (NLWRA, 2001). Irrigated agriculture has expanded markedly in recent decades to over 2 million hectares. It now contributes about a quarter of Australia's gross value of farm production (total $38 billion). Major irrigation activity takes place in the Murray-Darling Basin (75% of irrigation), Queensland's Burdekin delta and Mareeba-Dimbulah areas and on the Ord River and Carnarvon in Western Australia.

Agricultural development has significantly changed Australia's landscapes and catchments and disturbed the rate and sometimes the direction of the ecological processes of natural landscapes. Vegetation cover has been altered, accelerating soil erosion and dryland salinity. Harvesting plants and animals has changed landscape nutrient balances. Rates of soil acidification have increased by addition of fertilisers. These unintended consequences of agriculture are often insidious but are now affecting farm production and reducing water quality in rivers and estuaries (NLWRA, 2001). The estimated cost of lost production from land degradation is about $0.6 billion (Chisholm, 1992) to $1 billion (Roberts et al, 1996; Lovering and Crabb, 1998) per year. Some types of degradation (eg. soil loss by erosion and dryland salinity) have long-term or irreversible consequences; other forms (eg. leaching of nutrients, surface acidification) can be remedied with appropriate management actions. Therefore, it has become important to adapt land & natural resource management practices to better suit Australia's environments. Farming systems need to be innovative, adopting new ideas and practices to reduce off-farm impacts while maintaining productivity.

Agricultural land use systems and farming practices have progressively evolved. They continue to move towards being more efficient in resource use and becoming sustainable. Integrating native vegetation and biodiversity management objectives with sustainable agricultural development and practice is clearly an important issue for the future of Australian agriculture. The recognition of the environment as a legitimate user of water and thus re-balancing of consumptive and environmental uses is a key element of the recent water reform framework. A series of water sharing plans have been developed by community based committees for water sources that include regulated rivers, unregulated rivers and groundwater aquifers. Environmental allocations attempt to provide environmental benefits in the form of improvements in water quality, the health of natural ecosystems and aquatic biodiversity. While the economic benefits attached to these environmental improvements may be significant, the extent of trade-offs associated with establishing environmental allocations and vegetation reforms is an important issue in catchments, which support large farming industries dependent upon secure irrigation and suitable land supplies.

Demand for land to satisfy the trend for urban development and rural subdivision for small farms is placing greater pressure on the limited area of soil suited to agriculture and has escalated land values in certain urban areas. As an example, this trend almost has eliminated dairying within 25 km of the coast in some areas in wet subtropical coast (Department of Trade and Resources, 1982). While some valleys and aquifers are fully committed in terms of irrigated agriculture, there are instances where potential exists elsewhere. As an example, in the Northern Territory, government resource planners estimate that the area of irrigated agriculture could sustainably expand 30 to 40 times greater than its present level. Based on an annual water consumption of 10 ML/ha, the area for potential irrigation in the 'Top End' was projected to be 85,600 and 27,500 ha respectively for surface and groundwater reserves (NLWRA, 2001). This assessment required no in-stream dams to be constructed; ensured adequate water allocations were available for environmental river flows (80% of stream flow and/or recharge) and required land clearances in river basins of less than 4%.

Considering the impact of drought on agriculture over the last decade or so, there is an increasing need to invest in climate forecasting to provide information that supports farmer decisions (eg. whether to crop or leave fallow, whether to stock or de-stock). Returns on investment in climate forecasting are likely to be high in terms of both increased productivity

and reduced reliance on drought relief (NLWRA, 2001). Warnings / alerting farmers to weather hazards can also help reduce stock losses through precautionary actions being taken.

Science and Technology

Australian agriculture has gone through phases of exploitation and expansion, adopted new technologies and dealt with issues such as pest invasions over the last century. Plants and all domesticated livestock in Australia originally came from overseas. They were selected, bred, improved and adapted to local conditions, ranging from alpine to tropical. The result has been steady growth in some land uses and productivity. Farming practices like minimum tillage maintains high crop yields of wheat and grain sorghum, reduces soil erosion and improves soil stability. It also reduces production costs, provides effective weed control and, in most years, leads to an increase in stored soil moisture, compared with traditional cultivation. Crop/pasture rotations have been developed to the point where, with rising fertiliser costs, legume-produced nitrogen has become increasingly valuable. The pasture phase of this key farming system is dominated by legumes and integrated with livestock production. Pasture species have been developed for seedling vigour and seed retention characteristics.

Livestock (beef & sheep other than dairy) are almost entirely run under extensive or open range conditions. The earliest livestock success story came with the introduction of the Merino sheep, the starting point for the greatest wool industry in the world. The early Merinos, shearing about 1 kg of wool each year, bore little resemblance to today's larger, more robust Merino which shears up to 7 kg or more each year, even in marginal areas with low, sometimes unreliable rainfall and only native grasses for feed in tropics (Department of Trade and Resources, 1982). Other breeds such as the wool-producing Polwarth and the prime-lamb oriental Poll Dorset have been established for Australian conditions. Substantial advances have been made in sheep breeding, particularly in regard to selection for commercial characteristics such as wool cut, yield, lambing performance and immunity to disease. Early introduction of cattle mainly were of British beef-producing types to the temperate zones. Except for the European dairying breeds, like the Friesian, Jersey and Guernsey, this trend continued until the embargo on imports, brought in as a protection measure against exotic animal diseases. However in the tropical regions, gradual infusions of *Bos indicus* blood produced crosses combining the meat production qualities of the British breeds with the ability of the Zebu and Brahman to tolerate heat, parasites and low-quality feed. Other significant breeds developed include Murray Grey beef cattle and the dairying Australian Illawarra Shorthorn. More recently, since importation of breeding materials resumed, there has been an influx of European breeds. These are being assessed by both graziers and researchers under a wide range of conditions to determine what contributions they can make to the national breeding and selection program. A major aid in breeding and selection is the computer-based National Beef Recording Scheme. Computers are finding an increasing place in Australian agriculture, particularly for keeping detailed records of breeding programs. The swine industry, with its rapid rate of genetic improvement, finds computers especially useful (Department of Trade and Resources, 1982).

Recent developments in techniques and machinery highlight the innovativeness of the farming sector. These developments have included rugged tillage machinery, seeding equipment including the air seeder, and spraying gear. The use of chemicals as part of minimum tillage farming is increasing and this has led to the development of a range of new seeding and spraying equipment. Strong productivity growth, a key factor in Australia's international competitiveness and farm profitability has resulted largely through better

production methods, new technologies and farm amalgamations. The average annual growth in productivity in Australian broadacre agriculture is in the range of 2.4% to 2.6%, while specialist grains farms reported a higher 3.6% (Mullen and Cox, 1996; Knopke et al, 2000). New systems, information and technologies continue to improve farm productivity and respond to market signals. Much was learned and is still being learned as land use systems and farming practices continue to evolve and adjust to the Australian environment.

Trade Liberalisation and Market Development

Australian agriculture industry had gradually shifted its focus from being production driven towards being market driven. The post war period in Australian agriculture was largely dominated by bulk exports of products such as wheat, beef, sheep and wool. Changing world markets and trade relationships, such as the entry of the United Kingdom into the European Union in 1972 and the growth in expenditure on export subsidies during the 1980s and early 1990 in both the European Union and the United States, created a need to develop new markets and diversify production. The other major factor affecting Australian agriculture in the post war period has been the globalisation of world markets; a process that has gathered even greater pace during the past decade. This has involved wider recognition and acceptance of brand marketing, the expanding role of supermarkets in food marketing and new approaches to supply chain management. These have placed emphasis on developing closer linkages between producers and marketers, providing higher levels of service and shortening the supply chain. These issues, together with changing consumer trends, increasing discernment among consumers in developed countries, increasing disposable income levels in developing countries and the emphasis on food safety and product integrity, have increased the need for Australian farmers to be more responsive to market developments.

Today, a diverse range of agricultural products is produced in Australia. These include new products that have not previously been commercially produced in Australia such as venison, Asian vegetables, native flora and fauna, aquaculture and essential oils. Industries also earn valuable export income by supplying a significant proportion of world trade in wool, meats, grains, raw sugar and more recently in wine. Value-adding secondary industries turn raw agricultural produce into food and fibre products. Australian agricultural commodities have competitive advantage in the world market due to the nature of low cost and efficient production systems. Increasingly the global trend is towards increased market access through trade liberalisation. Market liberalisation is expected to further encourage expansion in these commodities and also farm diversification – production and trade of higher-value products in most of the farming systems. Demand from domestic and export food and fibre markets for high quality products is a continuing challenge facing modern farming systems. Market signals linking processes from ‘paddock to plate’ are beginning to influence international trade in agricultural goods. Accreditation for the use of ecologically sustainable production systems is also increasing. Under these circumstances contemporary Australian agricultural industries are seeking new opportunities while attempting to minimise impacts on the natural resource base, delivering ‘clean and green’ products.

Policies, Institutions and Public Goods

Historically Australian agriculture has passed through many cycles of prosperity and recession, but was principally sustained by a favourable policy environment because the general public and national leaders both recognised that farming was fundamental to increases in the national living standard and to national wealth and prosperity. Agricultural industry development has been supported by transport (roads, rail and ports) and irrigation

infrastructures, an agricultural service sector, and a research and extension capability. In the past two decades however, with the growth of mining and manufacturing as a proportion of export income, the dwindling size of the farm population and urban drift, and the economic and social hegemony of the seaboard metropolises, agriculture has been relegated to a less significant role in overall national policy (National Farmers Federation, 1998). The result has been major reviews of several key areas or rural policy including statutory marketing, quarantine, drought assistance and rural research. These led to far reaching changes in the structure of traditional rural assistance mechanisms, notably a trend towards deregulation of statutory marketing and the corporatisation of rural research effort with increased emphasis on value-added food products. The challenges facing Australian primary producers as a result of the changing market environment as explained in the previous section have been heightened by this gradual reduction of government intervention. This process has been ongoing and extensive in Australia since the 1980s. In Australia, the best known example of reducing government intervention, the removal of the wool reserve price scheme, created significant adjustment pressures and challenges for a major segment of Australian agriculture. More recent examples include reducing tariff (since replacement of an embargo on importation in 1989) on sugar imports and the de-regulation of the dairy industry introducing a free market for the supply of milk in Australia.

Agricultural industries are confronting issues of resource degradation, following a 200 year 'experiment' in land use. Earlier short term economic gains must now be measured against longer term resource degradation and the costs of repairing rural landscapes (Lovering and Crabb, 1998). Salinity and water quality problems are widely recognised as a priority issue for natural resource management programs and policy. The National Land and Water Resources Audit and the Murray Darling Basin Commission Salinity Audit both highlight the alarming increase in salt loads in Australia's rivers and streams over recent decades. These trends are expected to continue, with the Murray Darling Basin Commission Salinity Audit suggesting that salt mobilisation to the land surface in the basin could double from 5 million tonnes a year in 1998 to 10 million tonnes in 2100 (MDBMC, 1999). Australia-wide, at least 2.5 million ha (5% of the cultivated land of approximately 50 million ha) is currently affected by dryland salinity and this could rise to 12 million ha (22%) at the current rate of increase. One third of Australian rivers are in extremely poor condition, and land and water degradation, excluding weeds and pests, is estimated to cost up to $3.5 billion per year (COAG, 2000). Achieving high water use efficiency in dryland (rain fed) and irrigated agricultural systems are of paramount importance for both maximising production and protecting the resource base. Surface and subsoil acidity exists in all Australian States, with an estimated total area of eight to nine times that affected by dryland salinity with 12 to 24 million ha categorised as extremely to highly acidic with pH values less than or equal to 4.8 which is considered as below optimum for the acid-sensitive agricultural plants (NLWRA, 2001). Attention needs to continue to be paid to nutrient status, monitoring and tracking changes in all farming systems. This needs to be done with dual objectives – maximising yields on-farm and minimising export of nutrients off-farm, with the consequent impacts on the quality of water bodies. Therefore, continuing investments are needed to develop more sustainable farming systems and to minimise or arrest their continued impacts into the future.

Agricultural industries and farming communities have responsibilities to ensure that land is maintained or enhanced for future generations and that land use impacts are not transferred to the wider catchment or downstream. Importantly, many agricultural industries and their supporting service industries have either established or are moving towards establishing codes of practice which promote quality assurance in the agricultural sector – quality on-

farm resource management and delivery of safe food and fibre products to markets – a process that could be styled 'product stewardship'. Renewed emphasis and farmer participation in government policy initiatives, such as National Landcare Program (Landcare) and implementing property management plans are most positive signals. Over the last decade, 'Landcare' encouraged rural communities and individual landholders to become more aware of and to participate in the conservation and repair of natural resources in their regions. In all States, community led catchment management bodies have also worked to plan and implement actions to ensure that significant resource issues are identified and their impacts minimised. Such initiatives are all about 'resource stewardship' implying that present resource users are trustees, not end-users. Announcement of the National Action Plan for Salinity and Water Quality in late 2000 (COAG, 2000) signifies that Australia is poised to tackle such critically important and complex natural resource management issues at national and regional scales. All these imply the need to manage agricultural systems to be both profitable and environmentally sound, through adoption of efficient and environmentally benign management practices. There is much research, development and extension to be done in improving farming practices and developing industry databases that monitor and report on progression in environmental and economic performance.

Information and Human Capital

Farmer awareness of the insidious nature of unintended consequences of agriculture has been heightened by research and extension programs at both State and Federal levels. Good progress has been made over the past decade to improve the land resource information base – particularly through the National Landcare Program and Natural Heritage Trust. Many farmers now monitor natural resource condition on-farm and manage to minimise impacts off-farm. Australian Agriculture Assessment 2001 (NLWRA, 2001) assessed key factors related to natural resource sustainability, including: soil loss off-farm and through rivers to estuaries and marine environments through water-borne soil erosion; nutrient balance, incorporating an assessment of all inputs and outputs in the production cycle; soil chemistry – particularly pH and soil nutrient status; and transport and delivery of nutrients through regional river networks. Access to information on natural resources provides opportunities for increased awareness and informed debate. This access has been improved through internet and database technology. The interactive web-based Australian Natural Resource Atlas presents products from the above Agriculture Assessment. It provides information to aid decision making across all aspects of natural resource management by geographic region (national, State, regional) and by information topic covering water, land, agriculture, people and ecosystems (NLWRA, 2001). The Australian Natural Resources Data Library supports the Atlas with links to Commonwealth, State and Territory data management systems. Australia is vast and a great deal remains to be done to meet the growing demand for high quality and resolution information. Resource constraints inevitably mean that information collected must be prioritised and targeted to areas of most significant need.

Agricultural activities can be broadly grouped into: (1) production – covering issues of rotations, enterprise mix, varieties and trends in yield performance; (2) produce quality – covering issues of food safety, meeting market specifications, processing, marketing, selling and transport; and (3) natural resource maintenance and protection – covering issues of on-farm resource management and off-farm impacts. Farming systems link these activities and therefore agricultural productivity and maintenance of the natural resource base needs to be managed as a 'package' in a catchment context. This demonstrates a need for contemporary Australian farm enterprises to develop their business and communication skills sufficiently to meet new challenges as they arise. While Australian agriculture has invested heavily in

technology and physical capital during the past decades, the need for farm business managers to invest in their human capital by way of education and training has also become an increasingly important factor in farm profitability and competitiveness. Successful producers will increasingly need to adopt demand driven business management approaches to meet changing circumstances. They will need to be skilled in market research, establishing and building relationships with new clients, and developing strategic alliances with other farmers and other players in the supply chain. They will also have to develop skills in appropriate methods of production and negotiating contracts and supply agreements. Community or grower networks make the task of learning new skills somewhat easier by sharing information, pooling the resources to secure expert advice and by developing individual grower expertise in particular areas. As an example, best practice guidance is provided to farmers through codes of practice for general agriculture and through the industry (rice, cotton, sugarcane etc) programme initiatives. These industries promote sustainability through self improvement approaches to water use, chemical and nutrient management and broadly building manager skills across the business enterprise. Co-operation between farmers and attention to partnerships and collaboration ventures are providing a basis for transition towards more sustainable and efficient production systems. Improved resource management is occurring on a broad scale as a result of these initiatives. A continuous information flow and investment in human capital is required in maintaining sustainability of these systems.

Selection of Farming Systems for Analysis

The main farming systems outlined in the previous section have been selected for further analysis on the basis of their economic importance and potential for agricultural growth in the coming years:

- Dryland farming System
- Irrigated Rice, Cotton and Sugarcane Farming (semi-intensive) Systems
- Horticulture Farming System
- Dairy Farming System

These farming systems contain the most of the value of agricultural production in the region. They are described in more detail in the following sections.

DRYLAND FARMING SYSTEM

Characteristics of the System

Australian dryland farming systems show some similarities with systems of the Mediterranean region, Western Europe and North America (Tow, 1991). These are based on climate, tradition and land development patterns out of which the main determinant is the seasonal distribution and level of rainfall. At the most general level, climates relevant to dryland farming in Australia are divided on the basis of rainfall distribution and amount available for use by crops and pastures. There are three main categories of distribution: winter-dominant, summer-dominant and transitional between summer and winter dominance (uniform). These determine whether winter-growing crops or summer-growing crops or a mixture of the two can be grown. Within each of these categories the amount of rainfall also determines the type of system and its components. At the dry end of the spectrum, the risk of crop failure due to inadequate rainfall is high and extensive grazing is the most appropriate system. At the wet end of the spectrum, there may be adequate rainfall and in fact, too much that may bring high risks of disease and interference with land preparation, sowing and harvesting. This environment is therefore most suited to intensive grazing enterprises. The

Australian dryland farming systems have also developed their own distinctive characteristics due to the importance of livestock (especially sheep) products and wheat as export commodities, the availability of pasture legumes for incorporation into crop rotations and the need for efficiency imposed by farm size.

Wheat became a profitable component of Australian dryland farming systems because of innovations which increased production per man as well as per hectare and reduced the costs of production and transport. It is a short season crop under subtropical conditions and has preference in cropping decisions, provided soil moisture is stored from summer rains and adequate sowing rains are received. Wheat generally is sown in May and June, after the first rains, and is harvested in November and December, mainly with high capacity, self propelled combine harvesters, often called 'headers' locally. These discharge into bulk-bin trucks which, in turn, discharge at railway sidings, through floor grids and elevators into substantial silos. Later, the grain is bulk-loaded into railway wagons for transport to the shipping terminals. The entire operation is geared to bulk-handling from farm to ship, with bags never used at any stage. Wheat has continued to attract higher prices in relation to sorghum. Maize and sorghum are the crops mainly used in livestock feeds. Grain sorghum yields satisfactorily in climates too severe for maize. Also, sorghum is considered a safe crop on properties which carry cattle, as in drought years, when grain production may fail, the standing crop can be grazed. Sorghum is considered as an excellent alternative crop to wheat, as similar machinery is used in all operations. Oats are grown as a grazing crop to fatten cattle. It is also an extremely useful grain both as a supplementary ration and for maintenance feed during drought. The crop often is stored in on-farm silos to provide a fodder reserve. Barley is grown especially in southern parts for local sale and export. Barley provides a suitable alternative to wheat because it can be grown on lighter soils, and if moisture is lacking, can be sown late in the season.

Cereals and sheep were integrated into the farming system in its early years because they tended to be complementary rather than competitive. For instance, the grazing of wheat and oats in winter provided sheep with feed and also improved the tillering of the crop, preventing it from lodging in spring. Only an upright crop could be harvested with strippers (Tow, 1991). Farms carry sheep, not only for income from wool and mutton, but also for cleaning up cereal stubbles and eating down pasture or weed growth on paddocks to be cropped. Sheep are preferable to cattle for reducing crop stubble; they are able to graze closer to the ground and pick up fallen grain; they also cause less treading damage through hoof compaction of the soil. It is also practice to rest wheat land regularly and use it for grazing. The plants in such a 'weedy fallow' have been annual grasses, legumes and herbs of Mediterranean origin. These provided good livestock feed and improved the soil nitrogen content for the following crop. In the cereal/livestock region (wheat/sheep zone), Merino ewes are joined with Border Leicester rams for lambing; the ewes are sold to prime lamb producers (to be bred as prime lamb mothers) and the wethers (castrated males) for their meat. Merino-Border Leicester cross ewes are joined with Poll Dorset or British-bred rams to produce prime lambs. Prime lamb production generally occurs in conjunction with wheat-growing on the slopes, or with cattle on the tablelands. To fatten lambs, perennial lucerne is the favoured pasture on the slopes, while phalaris, fescue, ryegrass and white clovers finish lambs on the tablelands. Although sizes vary, a typical farm in the temperate slopes and plains contains about 600 ha of land. Of this half is sown to cereal and half to pasture.

Beef cattle provide grain farmers with diversification and an alternative source of income. Cattle fattening on the fodder crops in the western slopes of New South Wales and

Queensland and improved pastures of the tablelands can be very profitable. Feedlots (large-scale holding > 10,000 head and small-scale holding < 1,000 head) are increasingly being used to 'finish off' cattle before slaughter in these areas; the location being ideal to obtain year-round access to a wide range of cheaper grains as feedstuffs.

Trends and Issues in Dryland Farming System

Most of the temperate zone's success in cereal cropping and livestock production can be attributed to the 'ley farming' system – the rotation of cereal crops with legume-based pastures integrated with sheep. Two annual legume types dominate improved pastures – subterranean clovers and medics (*Medigaco species*). These pasture legumes have had a very beneficial effect on the fertility of soils for cropping and on stock-carrying capacity during the pasture phase. Cereal yields have been substantially lifted, often doubled, by the nitrogen contributed by clovers and medics. Crops also benefit from soil structure improvement during the legume pasture phase. The higher protein content and digestibility of dry clovers and medics in summer has had a major influence on the stock-carrying capacity. The sheep obtain feed in the dry half of the year and reduce the volume of crop and pasture residues and also weed growth to assist in land preparation for the next crop. The annual legumes are self-regenerating from seed set each year and deposited in the soil. A high proportion of the seeds (especially those of annual medics) remain impermeable ('hard') for varying numbers of years before germinating, thus making self-regeneration possible after an intervening cereal crop. A package of management procedures is adopted to ensure the continued presence of the pasture species in the rotation.

Since the introduction of the ley farming system, large tracts of land have been opened up for crop production, particularly in Queensland, New South Wales and Western Australia. These systems have been characterised by relatively large farm size, the use of large machinery for timeliness of operations, and the aim of exploiting the initial high fertility of many of the soils. Unfortunately this exploitive phase has often been accompanied by soil degradation (particularly erosion and salinisation). Thus attempts are being made to include 'conservation farming' practices in the farming system (Tow, 1991). As yet however, few farms of the northern cereal zone have adopted a ley farming system. In most cases this is due to the lack of suitable pasture legumes and/or the higher profitability of crops than of livestock products.

Because of sustained high prices for wheat in world markets, the dryland wheat area continues to increase. Annual variations in wheat yields due to climate have reduced through development of drought tolerant species and disease control. Dryland wheat yields over the past 100 years have quadrupled, approaching 2 tonnes/ha, following the adoption of improved crop practices (eg. stubble mulching, crop rotation and soil fertility management). New varieties, improved plant nutrition and better weed control are expected to further raise average yields in the near future. Clearing of land and capacity to produce winter grain production means that wheat has continued to dominate total grain production.

Land development for grazing continues steadily, despite beef market fluctuations, and the beef cattle industry is capable of considerable expansion in years ahead. There has been a continued growth of cattle feedlot systems (fattening cattle before slaughter), centred around regions with reliable supplies of grain and breeding stock.

Priorities for Dryland Farming System

Dryland farming system needs to maximise efficient use of natural rainfall through crop and pasture systems that can respond to and work within the context set by rainfall variability. Farming inputs are geared to match expectations of yield; they range from being more conservative, lower input systems in the more arid, mixed farming regions to higher input, more diverse rotations in the more climatically reliable regions. In areas with waterlogging and dryland salinity, minimising deep drainage beyond the root zone is also an important consideration. Grazing is the main land use contributing to total soil erosion across Australian river basins, because of the vast areas involved and their location in northern Australia. Grazed land composed of woodlands as well as pastures – the basis of the beef industry in northern Australia. It is predicted that erosion under pasture lands has doubled from natural conditions, with a five-fold increase for improved pastures (NLWRA, 2001). Soil erosion is much harder to manage in grazing than in cropping areas because of the greater area, lower levels of inputs and smaller marginal returns on investment. Structural works and other soil conservation practices are usually impractical in these areas. The greatest scope for reducing soil loss is through good pasture and stock management aimed at maintaining adequate ground cover at all times. Establishment of trees, shrubs, perennial pasture species and legumes are considered as key management priorities. Ferguson et al (1991) has documented the importance in establishment of trees as shelterbelts and/or woodlots in Australian dryland farming systems with regard to the benefits achieved through increased sheep and wool production, reduction in soil erosion and salinity, provision of fuel wood and fencing, and improvement of aesthetic value etc.

Greater opportunities exist for intensifying and diversifying land use and enterprise mixes in these areas. Many farmers are now changing their rotations or systems of land use to produce a range of products that result in achieving greater and more sustained business profits (through more effective use of resources and capturing synergies between rotations); reducing financial risk (through enterprise diversification) or improving sustainability of the resource base (through reduced exposure to weeds and diseases or soil erosion through the adoption of minimum tillage and stubble retention practices). Examples include changing from wool to prime lamb or beef; undertaking more diversified cropping with less grazing; growing durum wheat, pulses or canola in rotation with traditional bread wheat varieties and introducing higher-input perennial and annual pasture systems (NLWRA, 2001). Dryland farming systems as expressed in rotation sequences are ever changing to meet economic demands and to keep farms viable. Maintaining the productivity of the existing farmlands has become the utmost importance as nowadays, opening up of new agricultural land has almost ceased to be an option under this farming system.

IRRIGATED RICE, COTTON AND SUGARCANE FARMING ('semi-intensive') SYSTEMS

Characteristics of the Systems

Australia's rice farming system is contained in the valleys of the Murrumbidgee and the Murray Rivers, in the region known as the Riverina. It was within this area that a vast irrigation system was laid out centred on these two rivers, linking irrigation to the big Snowy Mountains hydroelectric scheme. The crop is sown from late September to the end of October. Three sowing methods are used, the most popular of which is aerial sowing of pre-germinating seed. Other methods include sod-seeding (directly drilled into pasture) and combine drill into a conventionally prepared seed-bed. Fertiliser, herbicide and insecticide applications done by specialised aircraft. The rice fields are permanently flooded before sowing (for aerial sowing) or when seedlings are 5-10 cm high (for sod-seeding and combine

sowing). The water in the bays is 'locked up' in March and the crop will use up this residual water so that the soil is only moist when harvest commences. Rice is harvested with large, self propelled headers specially equipped with a peg drum to remove the grain from the panicles. The harvest is immediately delivered into aerated storage designed to keep rice at a suitable temperature and moisture level for milling by the industry's milling and marketing co-operative – Ricegrowers Co-operative Limited (RCL). The RCL mills and markets the entire Australian rice crop in six modern mills in the rice growing area. The co-operative also administers the industry's pure seed scheme and provides merchandising facilities for growers. The Ricegrowers Association of Australia formed in 1930 is the forum for the formulation of rice industry policy that is in the best interests of growers. The association has many interests and these are dealt with through an extensive committee system. Agronomic rice research and extension is funded primarily from levies collected from crop proceeds while product development and post harvest research is largely conducted by private funding from the RCL (National Farmers Federation, 1998). Recent average figures indicate a total harvested area of about 155,000 hectares and an average paddy rice yield of 9.0 t/ha, the worlds highest (ABARE, 2003). Nearly 50% of production is exported with the remainder being sold on the Australian market as table rice, broken rice & rice flour for food processing and a variety of value added by-products.

Cotton has been grown in Australia since the 1800s, although the modern cotton industry was not born until the 1960s, when the construction of large dams in northern New South Wales and southern Queensland made the development of irrigated production systems in these areas possible. By 1993, cotton had become Australia's fifth most valuable rural export (behind wool, meat, wheat and sheep) and placed Australia as the third largest cotton exporting nation in the world (National Farmers Federation, 1998). Cotton is mostly irrigated but there is some rain-fed cotton (about 10%) as well. Irrigation generally trebles the yield of lint and other cotton products. Australian cotton growers consistently achieve the highest yields of any of the world's large cotton producers. For example, for the 5 years from 1998 to 2002, the average yield on Australian farms was 1519, 1275, 1595, 1556 and 1720 kg/ha respectively (ABARE, 2003). Recent 3-year average figures indicate a total cotton growing area of around 459,300 ha. Australian cotton industry is also the second largest source of oilseed in Australia, second only to canola. The industry's peak grower body, the Australian Cotton Foundation, funded by a per bale levy from growers, represents the industry in areas including environmental management on and off farm, developing industry standards, producing educational materials, occupational health and safety issues, promotion of cotton value-added products and consultation with governments. In some Valleys, grower co-operative system has evolved into a fully integrated ginning, warehousing, shipping and marketing organisation. Cotton growers draw on a wide range of sophisticated risk management and price hedging strategies including futures and options trading or they may deliver to seasonal or minimum price pools and leave the selling and trading of futures and options to the discretion of the professional marketers (National Farmers Federation, 1998).

Sugarcane farming system is a major contributor to the Australian economy and earns more than $2 billion each year. It is Australia's second largest export crop and raw sugar stands as Queensland's second most valuable rural commodity. The crop is established using pieces of mature sugarcane or 'setts'. These setts are planted by a special machine that cuts the cane stalks, drops them into furrows, applies fungicide to prevent disease, adds fertiliser and covers them with soil. Each sett grows into a cluster or stool of about 8-12 cane stalks. After the crop has been harvested (mechanically) the stool remains in the ground and the next crop grows from it. These additional crops are known as ratoons. Throughout the industry it is

common for farmers to grow three or four ratoon crops before ploughing out the stools and either replanting the fields with setts, or leaving the ground fallow with a cover crop of legumes. Sugarcane grows for 12 months before being harvested from June or July of each season, the period when the sucrose content of the cane is highest. Harvesting is done mechanically and both green cane harvesting (without setting fire) and burnt cane harvesting methods are adopted. Recent 3-year average figures show a harvested area of 419,000 ha with an average 82 t/ha of cane yield a year to make some 11.3 t/ha of raw sugar (ABARE, 2003). Australia's sugar industry comprises several segments: cane growing, raw sugar production, bulk raw sugar storage, and refining. An important characteristic of the industry is its high level of vertical integration, particularly between cane growers and sugar milling. Canegrowers associations represent the growers with the aim of protecting, advancing and fostering the sugar industry and the cane growers engaged in the industry. Mills make a significant contribution to the local economies in which they operate and are major regional employers. Some mills are owned co-operatively by cane growers whereas the others are owned by proprietary companies. Other functions performed by mills include survey of cane fields, estimation and transportation of sugar cane, sampling and analysing of unprocessed cane, raw sugar delivery to bulk terminals, maintenance of accounts to allow pool payments to be made to cane growers and marketing by-product 'molasses'. The close relationship between growers and millers has resulted in the development of a legislative structure in Queensland that affects many aspects of the raw sugar industry's operation. The industry has a strong commitment to retaining its position as an internationally competitive, low-cost, customer focused raw sugar producer and has moved quickly to meet changing market conditions (National Farmers Federation, 1998). The Sugar Research and Development Corporation administers the research funds collected from the industry as a levy and also funds that are granted by the federal government.

Trends and Issues in Irrigated Rice, Cotton and Sugarcane Farming Systems

Irrigated areas under rice, cotton and sugarcane have all increased in the recent years. The successful rapid development of the irrigated industry has raised a number of environmental issues. The extended drought brought all irrigated crops and their level of water use and water management under close scrutiny. All three industries located in sensitive and land use competitive environments, have developed environmental codes of practice for their industry. Individual industries continue to develop environmental policies and guidelines aimed at minimising environmental impacts. These guidelines are supported by extension and research, enabling informed adoption of technology. Management practices are continually improving.

Rice production is only allowed on extremely heavy clay soils that are tested to ensure they are impermeable to water leaking to the groundwater table. Targets for water use levels have been agreed to stand around a maximum of 12 ML/ha though the documented mean application rates range from 12 to 13.9 ML/ha (NLWRA, 2001). Close attention to these environmental constraints as well as improvements in management and water use efficiency by growers (such as laser levelling of fields) has seen rice water usage drop by about 15% in recent years (National Farmers Federation, 1998). As evident more efficiency gains are to be obtained in the rice farming system.

The cotton industry's major environmental issue relates to its use of pesticides for controlling budworms (*Helicoverpa spp.*). These pesticides and other farm chemicals collect in waterways affecting fish, birds and human health. Other issues relate to efficient use of water and fertilisers that may affect the volume and quality of water available downstream.

Water problems are being tackled in a number of ways: the use of shorter season varieties, improved cultivation, the use of on-farm storage and tail-water recycling and irrigation methods that conserve water. The documented mean water application rates can range from 4 to 12 ML/ha depending on the location (NLWRA, 2001). Recognition of key challenges – pesticide use, land use and water use – arose through an industry-wide environmental audit and appropriate best management practices were developed (Williams et al, 2000). Adoption of these practices across country is progressing very well. Research and extension are targeted to ensure comprehensive adoption. Cotton growers are required to develop action plans that focus on the implementation of these best management practices, which help manage and improve their farming operations and minimise environmental impacts. The adoption of 'Ingard cotton' (genetically modified insect/pest resistant varieties) has not only increased productivity but also facilitated the widespread adoption of integrated pest management strategies, resulting in drastic reduction of farm chemical usage in the cotton industry.

A major environmental issue common to the sugarcane farming system is soil erosion, caused by seasonal floods and droughts that occur in the tropical regions where cane is grown. This problem is tackled through minimum tillage techniques and green cane harvesting (without setting fire) where suitable. Adding up of chemicals and fertiliser into waterways is of special concern with regard to impacts of outflows to the Great Barrier Reef Marine Park, located close to the sugarcane growing areas. These areas also have high habitat value ecological resources such as World Heritage Rainforest, floodplains, wetlands and estuaries and increasing human populations. Salinisation is also causing problems in some areas where salty groundwater levels have risen due to land clearing, poor drainage systems and long term irrigation. The mean water application rates can range from 3 to 11 ML/ha depending on the location (NLWRA, 2001). The industry itself is also concerned about lack of yield increases in many areas. Gains in total productivity within the industry regions relate mostly to increased use of mechanisation and increased scale of operation. The varietal situation is continually changing because of the introduction of newly-bred lines with higher yields, better disease resistance and resistance to cyclonic damage. The adoption of recommended practices is highlighted by the rapid adoption of green cane trash blanketing (to protect soil from eroding) that reflects the flexibility in harvest that green cane techniques provide. Other practices which are progressively improving towards the development of sustainable production systems are: waste disposal of chemicals, slashing techniques for headlands and grassed waterways, tail water drains, record keeping, trash management in ratoon crops and fallow, irrigation scheduling and chemical use and handling.

Priorities for Irrigated Rice, Cotton and Sugarcane Farming Systems

The highest rates of soil erosion are from intensively cropped lands, particularly tropical croplands. Sugarcane is of particular concern, as it is located in areas of high rainfall erosivity. Where they occur on sloping land, soil erosion can only be stopped by retaining good cover at all times. Considerable effort to reduce soil erosion potential in croplands includes minimum tillage, stubble retention and contour banking – practices that are widely but not universally adopted. The sugarcane industry reports 80% adoption of minimum tillage, green cane harvesting and green trash blanketing, reducing soil erosion rates on sloping land from the order of 100 t/ha/yr to 5-10 t/ha/yr (NLWRA, 2001). Tillage is still necessary when planting a new crop, creating a risk of accelerated soil erosion at these times. Riparian filter strips offer a last line of defence to soil erosion – protecting streams from sediment and attached nutrients lost from farm land. Attention has only recently been given

to riparian management as a means of mitigating against the impacts of some crop land use practices.

The expansion of the cotton industry into new areas in Australia will be largely determined by two things: the availability of water in new areas with the requisite temperatures and soils, and the prevailing perception of cotton farming practices by the community. While several localities across northern Australia fit the agronomic requirements, it is the social factors that provide the greatest challenge to individual cotton farmers and their collective industry organisations. Facing intense public scrutiny and criticism from the outset, cotton growing in Australia has evolved into an intensely research oriented, highly self regulated industry but gaining public recognition is still a very high priority. Direct expenditure on research and extension aimed at improving environmental sustainability is almost $6 million each year from Cotton Research and Development Corporation funds (NLWRA, 2001).

To address dryland salinity, for example, Australia needs to make major changes in water balance in many catchments. This will require changes in agricultural land use patterns and land management activities so that targets for protection of downstream land and water resources are met. It is essential to minimise deep drainage of water beyond the root zone. Major opportunities to increase economic activity, and at the same time enhance environmental and social benefits are generated by water resources through water resource development and improved water use efficiency. There is an increasing need to maximise efficient use of irrigation water supplies to provide a more secure (but still variable) source of water for irrigated agriculture. Improved water use efficiency and sustainable practices are imperative for optimising and sustaining irrigated farming systems.

HORTICULTURE FARMING SYSTEM

Characteristics of the System

The horticultural farming system is diverse and widespread. The system supports more than 100 crop types, categorised into 21 commodity groups. Based on similarity in natural resource management approach, these commodity groups broadly fall into two categories: annual horticulture (mostly vegetables) and perennial horticulture (mostly fruit) crops. Horticultural production occurs across a wide range of environmental conditions, with distribution restricted primarily by access to water, water quality, soil quality and by topography. Major production areas are concentrated in fertile areas with high annual rainfall or abundant water resources from rivers, streams or reticulated irrigation scheme areas. The horticultural industry is supported by the infrastructure such as packing sheds, processing plants and by an industry-funded marketing and promotion program valued at $6 million per year and a further $30 million per year (in 500 projects in some 40 different industries) on government and industry funded research and development (Horticulture Australia, 2003). Various grower associations represent the interests of commercial growers in their industries throughout Australia in matters of national importance including regulation/legislation, marketing, research and development. Fresh fruit sales in the domestic market are arranged by the grower or through the numerous packing establishments throughout the growing season. Wholesalers handle most sales at the major produce markets in State capital cities, but increasing business is now being done between packing houses and supermarket chain buyers. Supermarkets, fruit barns and green grocers are the major retail outlets for fresh fruit and vegetables.

The vegetable sector is the largest segment within the horticultural industry and produced over 2.9 million tonnes, with a gross value of over $1.8 billion in 2000 (Horticulture Australia, 2003). Vegetable farming system is essentially made up of single unit farming families who have several generations of experience as specialist vegetable growers. Average vegetable farm size is about 25 hectares, producing vegetables worth some $230,000 per annum at the first point of sale. It is estimated that there are about 15,000 commercial vegetable producers in Australia, with the majority being small to medium sized family farming units (National Farmers Federation, 1998). ABS (2001) reported 5300 establishments (with an estimated value of agricultural operations of $5,000 or more) growing vegetables with main enterprises being: potatoes 36,800 ha with a total production of 1.2 million tonnes; tomatoes 8,300 ha producing 414,000 tonnes; carrots 7,000 ha producing 283,000 tonnes; and onions 5,300 ha producing 247,000 tonnes.

The Australian apple and pear (pome fruit) industry is comprised of about 1500 growers who tend around 10 million apple and 1.5 million pear trees (Horticulture Australia, 2003). There are many growers with small orchards and a few large growers and co-operatives with access to more than 200 hectares. There has been recent consolidation in the apple industry, with a number of orchards either expanding or developing marketing alliances to provide volume produce for export (National Farmers Federation, 1998). The processing industry utilises about 40% of apple and pear production. In year 2002, Australia produced 320,000 and 145,000 tonnes of apple and pears respectively (Horticulture Australia, 2003).

Citrus fruits are grown commercially in all Australian States except Tasmania, and primarily along the Murrumbidgee and Murray Rivers. There are approximately 2500 growers who tend around 10 million trees covering 32,000 ha (Horticulture Australia, 2003). Current planting trends indicate an increase in plantings of Naval orange, mandarin and lime trees, a slight decrease in plantings of Valencia and other orange trees and a static situation in respect to lemon and grapefruit tree numbers. Although furrow irrigation method is still used extensively in some localities, permanent overhead and portable systems is losing favour, particularly where water quality (salinity), supply or cost problems exist. Limited interest was initially shown in trickle or drip irrigation, but under-tree microjets or mini sprinklers and, more recently, drip systems are now being installed extensively in new plantings or replacing existing systems (National Farmers Federation, 1998). Mobile power ladders for harvesting have been adopted widely, although harvesting platforms have not been accepted to any great extent. Bulk handling is now used throughout the industry both on and off the farm. Half-tonne bins are common and even larger capacity bins and road trailers are used by many growers. Disposal of the annual citrus crop normally results in about 55% of the crop being sent to processing factories, 30% being sold on the domestic fresh fruit market and 15% being exported as fresh fruit to overseas countries. In year 2000, Australia produced 510,000 and 85,400 tonnes of oranges and mandarins respectively (ABS, 2001).

There are about 1260 stone fruit (peaches, apricots and nectarines) growers in Australia. Spray or trickle irrigation systems are now widely used in the production. These range from fully manual operated systems up to computer controlled systems that are fully automatic (National Farmers Federation, 1998). Hand picking is usually practiced, however in times of labour shortages or a sudden ripening of the fruit, mechanical harvesting is used to harvest varieties grown for processing. Fruit grown for processing is harvested into large wooden bins that hold approximately half a tonne of fruit and is delivered straight to the cannery. Fruit destined for fresh market is picked into half sized bins to minimise pressure bruising and is placed in cold storage immediately after being harvested to prevent the fruit becoming

over mature. Once the temperature of the fruit is lowered to 1-2 degrees centigrade, it is then packed into trays and sent to the fresh fruit markets. This operation is usually done by the growers, many of whom have built their own cool stores for this purpose. In year 2000, Australia produced 86000, 20000 and 36000 tonnes of peaches, apricots and nectarines respectively (ABS, 2001).

Pineapples are big business in Australia, and getting bigger. The industry today is worth some $45 million annually, with 438 growers and close to 2,700 people directly employed. Nearly all this activity takes place in Queensland (National Farmers Federation, 1998). There are approximately 2800 ha under cultivation that produces 140,000 tonnes per year. About 78% of production goes into canning, with the remainder going into the fresh fruit market. Soil erosion is a recurrent problem on the sloping lands where farmers grow their pineapple crops. Mulching practices show great promise both for soil conservation and increased profits.

In 2002 Australia's 2100 banana growers produced approximately 227,000 tonnes of bananas (Horticulture Australia, 2003). Australian horticulture industry also produced 38,000 tonnes of mangoes, 24,000 tonnes of avocados, 15,000 tonnes of strawberries and 23,000 tonnes of macadamias in year 2000 (ABS, 2001).

The viticultural industry (wine, dried & table grapes) with nearly 6,500 growers is valued at more than $1.5 billion in 2000-01 with wine grapes (128,000 ha) representing most of this - $1.2 billion gross value (ABS, 2001). There are between 4,000 and 4,500 independent wine grape growers (82% with a turnover of more than $20,000 per annum) who produce about 70% of the crop, with winery owned vineyards growing steadily in both absolute hectares and also in relative terms. New entrants are appearing in both traditional areas and in new areas, some of whom are specialised winegrape growers, and some who are developing both a vineyard and a winery. A typical independent vineyard is 25 ha or larger, with irrigation now being all but universal. It costs at least $30,000 per hectare to develop a vineyard, which highlights the importance of expertise and care in all aspects of the investment (National Farmers Federation, 1998). Growers usually liaise closely with winery technical staff on specifications of fruit quality. Also, harvesting is scheduled to ensure that the fruit is picked when the winery wants it, in regard to the time of day, ripeness and also wine production scheduling. While contracts between growers and winemakers are common, a significant proportion of the annual harvest is also sold on the 'spot market' with growers seeking out wineries with unfilled intake requirements, and with winery buyers seeking out growers with grapes that have not been committed.

Cut flowers and flower seed growing establishments can be found from small or large, single specialised crop enterprises to those growing several different kinds of flowers, either as open field production or under cover (shade houses or fully automated greenhouses that incorporate sophisticated climate control equipment). The range of flowers to be found in production from the tropics to the cool temperate climate is many and varied. The total number of kinds of flowers grown is about 150, but when the number of varieties for each kind or type of flower is taken into account, the choice of colours and form is nothing short of tremendous (National Farmers Federation, 1998). The main kinds of flowers being offered for sale are the well known and popular Carnations, Chrysanthemums, Gladioli and Roses. There is increasing interest in Australian native flora for the cut flower industry, with a number of large flower growing enterprises now specialising in the production of native flora. A considerable proportion of this production finds its way onto the export market, with

the balance being sold locally. Flowers are usually harvested and packed by the grower, but there are a few central packing establishments that handle product from growers. Product distribution can be either to market wholesalers in the capital cities or sent direct to florists by growers. While florists have, and continue to occupy, a key position in the flower industry, supermarket sales of flowers has been steadily increasing (National Farmers Federation, 1998). ABS (2001) reported approximately 1130 establishments involved in cut flowers & flower seed growing and 2500 establishments dealing with plant nurseries which reported an estimated value of agricultural operations of $5,000 or more.

Trends and Issues in Horticulture Farming System

Strong signals for improved environmental management from the marketplace or from legislation are not common. Improved environmental performance is underway across all crop groups with industry changes being driven by:

- new and revised codes of practice (best management practices and quality assurance standards);
- an increasing focus on integrated solutions to pest and disease management;
- improvements to the structure, management and planning of industry organisations;
- greater investment in environmental research and development projects on an enterprise and regional basis; and
- specific development of industry awareness programs.

Not all crop groups and regions are progressing at the same rate, with the larger professionally managed groups being typically further advanced than others. However, the process of cultural change and improved environmental performance in terms of waste, chemical & soil management is evolving. Perennial crop groups are generally better prepared for improved environmental performance than annual crop groups.

The horticultural industry is generally ahead of other industries on quality assurance and equal with other industries for environmental management practice. However, its fragmented and multi-commodity nature creates barriers for introducing environmental initiatives. Variation between State legislative requirements inhibits a national approach to better environmental performance. Low grower membership of industry organisations is a limitation, creating difficulties for promoting industry-wide changes in practice (NLWRA, 2001).

Priorities for Horticulture Farming System

While codes of practice provide valuable guidelines for fruit and vegetable growers, the horticulture industry still faces serious environmental challenges. Optimising grower access to information about environmental issues and management options and establishing processes to monitor and report industry progress towards sustainability is important. The Horticultural Research and Development Corporation funds and manages research and development. It plays a critical role in linking the various industries to State agencies and in delivering the outcomes of R&D efforts. Ongoing research, management innovation and commitment will be required to:

- refine integrated pest management techniques;
- balance production requirements with native vegetation retention needs;
- protect crops from damage by native wildlife;
- improve water use efficiency and maintain access to increasingly expensive and limited water resources;

- manage the good neighbour interface between the industry and protected or world heritage areas;
- protect downstream land and water ecosystems from impacts generated by fruit and vegetable production;
- develop meaningful links to regionally driven natural resource management planning; and
- respond to a tightening regulatory framework for property and natural resource management.

Future expansion in the horticultural farming system would be constrained by access to viable markets and to water resources rather than by environmental limitations. Although accountability for food safety and environmental compliance will be increasingly important to future markets, the complexity of industry organisational structures inhibits close liaison and coordinated planning. Access to water resources is considered the key industry risk. However the relatively high water use efficiency of many horticultural crops, compared with other irrigated agriculture, means that horticulture is well placed to compete for increasingly expensive water entitlements. Given that the existing horticultural industry only occupies a total area of 401,000 ha, land is not expected to be a limiting factor, though it was reported that in recent times the horticulture industry is competing with the sugar industry for productive soil and water resources. Wherever expansion does occur, it will probably be achieved through the re-allocation to horticulture of existing agricultural land rather than clearing new land. An example to this effect is the ongoing significant conversion of general security water entitlements (used in broadacre agriculture) to high security status (with greater reliability needed for high value horticulture) in the middle reaches of the Murrumbidgee River in NSW. The scale of horticultural investments is likely to increase in the future, as technology and plant breeding become more integrated with consumer markets and supply chains serving domestic and export markets. Technology will be increasingly important to expansion of horticultural industries by providing rapid access to information on markets and innovations, and assistance in farm management and environmental practice.

DAIRY FARMING SYSTEM

Characteristics of the System

Dairy production systems are dominated by pasture grazing with herds also receiving grain and fodder supplements. With the exception of inland irrigation schemes, dairy pastures depend heavily on natural rainfall, although in most regions at least some supplementary irrigation is now being used. Dryland dairying areas are mainly located in the high rainfall, coastal and adjacent areas. Australian dairy industry's major advantage over producers in the northern hemisphere is year-round access to pasture – a relatively low cost form of feed. Australia's average per cow production is 4,700 litres per annum, lower than in countries where indoor and supplementary feeding is required under freezing conditions in the winter months. But the total production cost per litre of milk is significantly lower due to herds relying predominantly on pastures. For example, milk production costs in the US and European Union are generally regarded as about 50% to 100% respectively above Australian costs (National Farmers Federation, 1998).

The Australian dairy industry is vital to the national economy, providing domestic milk and dairy products and valuable export earnings. It also generates considerable regional employment and economic activity. Milk is produced for direct human consumption (market milk) and for the production of dairy products (manufacturing milk) such as cheese, milk

powders and butter. The increased production of milk in Australia has led to strong growth in the manufacturing milk sector of the industry, fuelled by increasing domestic consumption of milk based products and increased export sales. Approximately 18% of total production is used for market milk and 82% for manufacturing (~ 8.9 billion litres). About two-thirds of the dairy products from manufacturing milk are now exported (NLWRA, 2001).

The dairy industry is organised on local, State and national levels. Locally, the organisations are mostly dairy farmer groups and are usually component parts of larger State level bodies. Other State level organisations cover manufacturers, exporters, and milk processors. There are also national bodies representing these groups. In terms of statutory arrangements, there are State level milk authorities responsible for the regulation of such matters as milk promotion, distribution and quality. At commonwealth level, the Australian Dairy Corporation conducts export and domestic promotion and marketing activities, and a further statutory body, the Australian Dairy Research and Development Corporation (DRDC), is responsible for much of the industry's research and development activities. All Australian dairy farmers pay a research levy that is matched dollar-for-dollar by the Commonwealth government. The DRDC funds research and development projects conducted by research organisations such as departments of agriculture, universities and CSIRO.

Trends and Issues in Dairy Farming System

During the last 25 years, the number of dairy farms has declined consistently (from around 30,630 in 1974/75 to 13,900 in 1999/2000); the size of the national dairy herd has remained reasonably constant. An increase in the national herd size (currently 3.2 million) is reported in the recent years, reflecting growing confidence in the industry's future. The volume of milk produced has increased strongly to over twice that produced in 1980/81 (NLWRA, 2001). While pasture remains the primary feed source for dairy cows in Australia, more dairy farmers now improve productivity through supplementary feeding which is now commonplace in the Australian industry. The steadily increasing productivity per cow results from improved pasture and supplementary feeding techniques, better breeding techniques and general farm management practices. Herd performance recording identifies the better and poorer performers in a herd, and allows herd composition and breeding decisions to be adjusted accordingly. This practice is frequently combined with a program of artificial breeding, which allows for a more strategic and accurate meshing of genetics. Currently, performance recording is carried out regularly on more than half of the national dairy herd and artificial breeding programs cover approximately 50% of Australia's cows (National Farmers Federation, 1998).

During the 1980s and 1990s, Commonwealth and State governments regulated milk production, fixing a price for a guaranteed amount of milk to be supplied for direct consumption of market milk. Manufacturing milk was sold at an unregulated price and produced products such as cheeses and milk powders. From July 2000, the regulations in each State were removed, introducing a free market for the supply of all milk. Deregulation has been associated with an increase in marketing activities by companies in the market milk sector. Farmers relying on the sale of premium priced market milk were faced with a severe and immediate challenge on farm profitability (NLWRA, 2001). To assist the industry during this transition, the Commonwealth government introduced the Dairy Industry Adjustment Package. In the same way, Australian dairy manufacturing companies are now also restructuring, adapting their operations to remain internationally competitive. Associated with this development has been the steady trend towards amalgamation among industry operators, and this has seen a significant reduction in the number of dairy

manufacturing and processing plants in Australia, enabling significant production and efficiency gains.

Dairying is an intensive grazing industry, centred mainly in higher rainfall catchments, and irrigation areas, which necessitates high levels of environmental management. Located in sensitive and land use competitive environments, it has developed environmental codes of practice for the industry. Management practices are continually improving. Nationally, around 50% of dairy farmers surveyed in year 2000 considered dairying in their regions were having minimal impact on land and water degradation. Over 30% considered 'environmentally friendly farming' in their regions would reduce farm profits (NLWRA, 2001).

Priorities for Dairy Farming System

The health and condition of dairy farm soils is vital for feed production and for minimising any off-farm impacts from farming activities. The Dairy Industry Survey in year 2000 indicated a strong awareness of soil management issues by farmers, and when recognised, they responded by adopting best management practices to contain or overcome them. However, with 28% of farmers reporting no land management problems affecting their property, there is a question as to whether all soil health issues are recognised by farmers.

Effluent management is a high priority especially when high concentrations of waste are generated where dairy cows congregate in high numbers (eg. around milking sheds). Pond systems are the most common form of effluent management and nearly 80% of farms re-use their effluent, with more than half doing so by way of irrigation. Farms without formal effluent systems tended to be less intensive and used lower stocking rates.

Water is a key resource input and as a consequence, the industry has to increase its participation in the design and implementation of regional, catchment and waterway management to responsibly contribute to regional environmental needs. The industry needs to seek sustainable growth into the future by simultaneously optimising production, profitability and environmental benefits and outcomes. As the dairy industry intensifies to meet the challenges of deregulation, it is imperative that natural resource management issues are incorporated in on-farm development.

REFERENCES

ABARE. (1996). *Australian Farm Survey's Report 1996*. Australian Bureau of Agricultural and Resource Economics, Canberra, Australia.

ABARE. (2003). *Australian Commodity Statistics 2002*. Australian Bureau of Agricultural and Resource Economics, Canberra, Australia. Available at: http://www.abare.gov.au/

ABS. (2001). *Australian Agricultural Census 2000/2001*. Australian Bureau of Statistics, Canberra, Australia. Available at: http://www.abs.gov.au/

AFFA. (2003). *Australian Forest Products Industry*. Agriculture Fisheries and Forestry Australia, Canberra, Australia. Available at: http://www.affa.gov.au/corporate_docs/publications/pdf/forestry/forest_products_industry.pdf

Chisholm, A.H. (1992). 'Australian Agriculture: A sustainability Story'. *Australian Journal of Agricultural Economics*, 36 (1), pp. 1-29.

COAG. (2000). *A National Action Plan for Salinity and Water Quality*. Council of Australian Governments, Agriculture Fisheries and Forestry Australia, Canberra, Australia. Available at: http://www.napswq.gov.au/

Department of Trade and Resources. (1982). *Australian Farming Systems*. Australian Government Publishing Service, Canberra, Australia.

Dixon, J., Gulliver, A. and Gibbon, D. (2001). *Farming Systems and Poverty - Improving Farmers' Livelihoods in a Changing World*. FAO/World Bank, Rome, Italy.

Ferguson, I.S., Wilson, A.D. and Campbell, C.A. (1991). 'Farm Planning and Land Management'. In Squires, V. and Tow, P. (eds): *Dryland Farming - A Systems Approach*. Sydney University Press, Sydney, Australia, pp. 41-52.

Horticulture Australia. (2003). *Australian Horticulture Overview*. Horticulture Australia Limited. Available at: http://www.horticulture.com.au/

Hooper, S., Barrett, D. and Martin, P. (2003). *Australian Grains Industry 2003 - Performance and Outlook*. Australian Bureau of Agricultural and Resource Economics, Canberra, Australia.

Jayasuriya, R.T. (2004). 'Modelling the regional and farm-level economic impacts of environmental flows for regulated rivers in NSW, Australia'. *Agricultural Water Management*, 66 (1), pp. 77-91.

Jayasuriya, R.T. and Crean, J.J. (2001). *The on-farm impacts of environmental flow rules in the Murrumbidgee Valley*. Report to the Murrumbidgee River Management Committee, Economic Services Unit, NSW Agriculture, Orange, Australia. Available at: http://www.agric.nsw.gov.au/reader/17446

Jayasuriya, R.T., Crean, J.J. and Hannah, R.B. (2001). *The on-farm impacts of environmental flow rules in the Lachlan Valley*. Report to the Lachlan River Management Committee, Economic Services Unit, NSW Agriculture, Orange, Australia. Available at: http://www.agric.nsw.gov.au/reader/16815

Knopke, P., O'Donnell, V. and Shepherd, A. (2000). *Productivity Growth in the Australian Grains Industry*. ABARE Research Report 2000.1, Australian Bureau of Agricultural and Resource Economics, Canberra, Australia.

Lovering, J.F. and Crabb, P. (1998). 'Australia's 200-year experiment in agricultural sustainability'. *Agricultural Science*, 11, pp. 17-25.

MDBMC. (1999). *The Salinity Audit of the Murray-Darling Basin - A 100 Year Perspective*. Murray-Darling Basin Ministerial Council, Canberra, Australia. Available at: http://www.mdbc.gov.au

Mullen, J.D. and Cox, T.L. (1996). 'Measuring productivity growth in Australian broadacre agriculture'. *Australian Journal of Agricultural Economics*, 40 (3), pp. 189-210.

National Farmers Federation. (1992 and 1998). *Australian Agriculture - The Complete Reference on Rural Industry*. Third and Sixth Editions, Morescope Publishing Pty Ltd, Hawthorn East, Victoria, Australia.

NLWRA. (2001). *Australian Agriculture Assessment 2001*. National Land and Water Resources Audit – Volumes 1 and 2, Commonwealth of Australia, Canberra, Australia. Available in sections at: http://www.nlwra.gov.au/atlas

O'Sullivan, D. and Dobson, J. (2001). 'Status of Australian Aquaculture in 1999/2000'. In: *Austasia Aquaculture Trade Directory 2001*. Turtle Press, Hobart, Tasmania, Australia, pp. 3-19.

Roberts, I., Doyle, S., Stayner, R., Mues, C. and Gray, A. (1996). 'The future for Australian Agriculture: Important Issues to 2010'. In: *Proceedings of ABARE's National Agricultural and Resources Outlook Conference, Canberra, 6-8 February Outlook* 96 (2), pp. 55-75.

Smallridge, M. (1998). 'Aquaculture'. In: *Australian Agriculture - The Complete Reference on Rural Industry*. Morescope Publishing Pty Ltd, Hawthorn East, Victoria, Australia, pp. 79-84.

Tow, P.G. (1991). 'Factors in the Development and Classification of Dryland farming Systems'. In Squires, V. and Tow, P. (eds): *Dryland Farming - A Systems Approach*. Sydney University Press, Sydney, Australia, pp. 24-31.

Williams, A. and Williams, J. (2000). *Australian Cotton Industry Best Practices Manual*. Cotton Research and Development Corporation, Narrabri, New South Wales, Australia.