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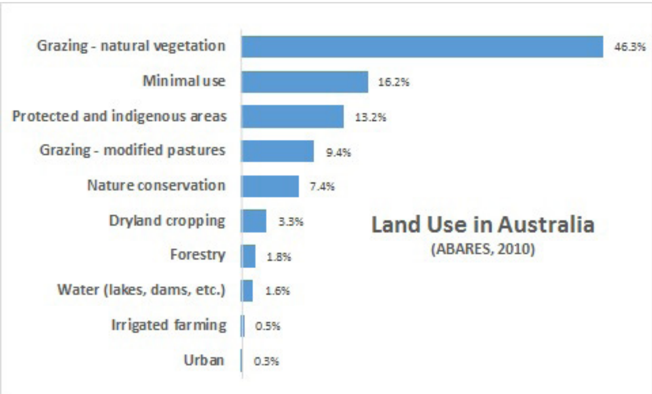
Agriscience tames an alien land

Agricultural science has been an essential component of Australia's evolution as a major agricultural exporter. It has improved stock yields, helped grain grow in hostile environments, and improved soils lacking many essential nutrients. Lindsay Falvey examines the development – and importance – of agriscience in Australia.

Until the 1950s agriculture still comprised 70 to 80 per cent of Australia's exports. The proportion is now much smaller, but the value and volume of Australia's agricultural output, and its agricultural exports, have continued to increase. The drop in agriculture's share of the economy has not been because agriculture has declined, but because of the massive growth other industries such as services, finance, telecommunications and mining.

Australia is one of the world's top ten reliable food exporters. The total farm value of produce now exceeds $50 billion, of which about $40 billion is exported. Added to this the value of food processing – around $100 billion – and retailing of around $140 billion, and we find that the agricultural, food processing and related service and retail sectors employ more than half a million people.

As the following diagram illustrates, our farmers manage more than 400 million hectares, half of the continent's land area. Just 32 million hectares is for crops, of with which 2 million hectares is irrigated with eight gigalitres of water annually. Agriculture continues to be absolutely critical to Australia's economic, social and environmental wellbeing.



Demand for Australia's agricultural produce and food products continues to rise exponentially, and tastes in our major export markets continue to change with growing population and wealth in Asian nations. The global demand for food is estimated to increase by 70 percent by 2050, with fully three-quarters of that demand coming from Asia. This defines a new era of efficiency for Australia, with further rural adjustments, and the need for public education, additional capital and constant innovation.

Yet, as indicated in the following diagram, Australia provides only about 3 per cent of the global food trade, which can feed only about 2 percent of the Asian population. So much for the 'food bowl of Asia' idea – Australia simply does not have the capacity. The secret to our export success is quality, not quantity.

We have good soils in eastern Australia – Ferrosols, Vertosols, Dermosols, Chromosols, Kandosols and Tenosols – and we also have many highly weathered soils. These are manageable, but historically our major constraints have revolved around variable rainfall and market isolation.

Modern communications and transport mean the isolation factor is no longer as relevant, but 'droughts and flooding rains' mean trying to farm Australia as if it were Europe, as the early settlers did, does not work.

The new environment meant Australia's early farmers quickly realised they needed to innovate and develop new technologies that enhanced production. Sometimes they needed to do this merely to survive.

Science and innovation

Innovation, born of necessity, evolved into a highly efficient system of agricultural research and development. It is an ethic that has led to Australia producing a disproportionately high number of world-leading agricultural technologies, scientists and managers. It has been an amazing achievement to make Australia's often harsh environment so productive.

Some examples include: the underpinning science that has produced the most Nobel Prize winners per head of any nation; the similarly disproportionate number of agricultural consultants and managers engaged in the international development sector, and leaders in the world's CGIAR 'Green Revolution Centres'; technologies as varied as refrigeration, mechanical sheep shears and the rotary hoe, tank-farming of tuna; practical in-vitro fertilization; permanent-press wool, and the myriad advances that the Australian invention of the atomic absorption spectrophotometer allowed.

Beginning with wool and dairy, and then with grains, Australia became a significant force in global agriculture and in global agricultural science. Once fostered by the exacting realities of the bush, the resources that produced this rise to power must now be cultivated from research, science and education. In this new world, the themes that dominate Australian agriculture include a market focus shift from Europe to Asia, the urban population's isolation from agriculture, increased environmental awareness, and developments in science and technology. The many facets are increasingly integrated, with a growing focus on the importance of agricultural science, or agriscience.

Agriscience has traditionally been based on an integrated understanding and application of science to soils, plants, animals, business, markets and people. This has been supported by such disciplines as biochemistry, genetics, physiology, pathology, nutrition, management, microbiology, sociology and economics.

The field has served Australian agriculture efficiently by conceiving of it as part of the environment; by adapting to it, changing it, or constantly managing according to it. The principles remain the same today, although growth in knowledge has increased specialisation and consequently made integration even more important. This can be illustrated by considering the standard factors of economic production – land, labour and capital. Agriscience has produced efficiencies in the use of each of these, and in doing so has highlighted the fact that its technologies can substitute in part for land and labour, relying on capital to fund continuous innovation.

In establishing agriculture in Australia we have made many mistakes. We introduced rabbits, foxes and a host of weeds. We mistook native grasslands for pastures. We subdivided lands into farms assuming stable rainfall. We cleared forests and scrub unmindful of soil conservation. Periodically we even delude ourselves that we are a major global food producer.

Such was our fervour for development, it became unAustralian to worry about soil conservation or land clearing, or to value our native grasslands. Agriscience has countered these and other views, and has enhanced our awareness of the land in which we live. A culture of developing techniques has come to characterise our approach to agriculture.

Watering our soils

A continuing theme has been management of water. In this dry continent, we have logically developed our more intensive agriculture in the better-watered areas, notably the Murray-Darling Basin. Covering about 15 per cent of

Australia, the Basin produces one fifth of our vegetables, half our fruit and nuts and more than 60 per cent of our grapes. But this has meant that extensive irrigation has reduced river flows in the Basin by perhaps 75 per cent over time. This has concerned many, but agriscience helped us understand that periodic floods from very wet seasons continue to flush out the 2 million tonnes of salt that is constantly washed out of our old landscape.

Agriscience works comprehensively, from farm technologies through to the integrated policy advice that is inevitably tempered by political feasibility. In water planning, a sustainable approach must begin to include not only rainfall and surface waters but the groundwater that constitutes 95 per cent of our fresh water.

Profligate water use has finished. Today serious farmers seek the maximum sustained production from each drop. Agriscience allows this through such innovations as breeding water-efficient crops. Today's wheat and similar crops are many times more water efficient than a century ago. Water losses in irrigation delivery continue to be reduced, and water application techniques have led to further savings of 70 per cent of water per unit of production. This has all been supplemented by improved purpose-designed rain forecasting, and particularly the 'nowcasting' that can inform farm management within ever smaller areas.

In addition to water, soil security is critical to sustainable agriculture. Soil is vital for nutrients, water, climate, recycling, biodiversity, ecosystem health, carbon sequestration as well as physical plant support. We have many good soils, and we use them well with support from agriscience. We also have soils that are highly weathered, saline, sodic, acidified, compacted, eroded, depleted or have reduced organic matter, biological activity or structure.

It is on both good and poorer soils – most of which have unpredictable rainfall – that agriscience has produced our agricultural success, and ongoing research continues to widen our knowledge of all of soil types. The innovations that continue to allow Australia to be a major agricultural nation rely on the expertise from and integration with our universities and research institutions, which are among the best in the world.

Australia's agricultural expertise

Originating in the agricultural colleges that arose from 1885 from departments of agriculture in South Australia and Victoria, Australia's first Faculty of Agriculture opened in 1905 at the University of Melbourne.

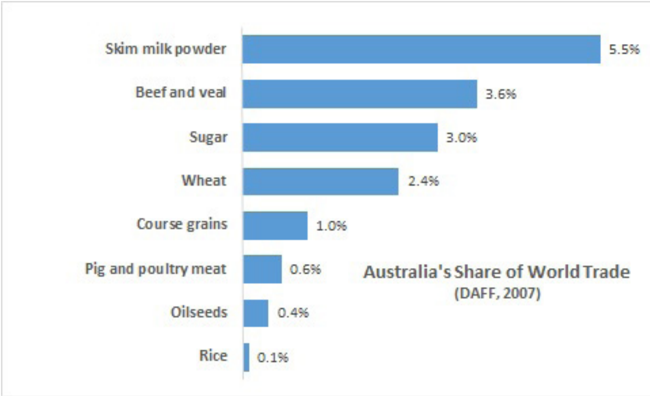
Organised agricultural research in Australia is generally dated from 1916, when the Commonwealth Advisory Council of Science and Industry became the Council for Scientific and Industrial Research (CSIR), which was initially oriented to agricultural production. By the time CSIR had evolved into CSIRO in 1949 it had a broader mandate spanning most fields of technology. This suits modern agriculture, which now relies on every field of science.

The agriscience expertise of CSIRO, working with universities and state government agencies, has regularly provided new practical inventions. These have included:

- 1920s – Horticultural techniques, extended storage life for chilled beef, improved quality of both frozen and dehydrated meats, prickly pear biological control, and economic entomology.
- 1930s – Systematic plant crossbreeding, skeleton weed control, tobacco selection, worm control in sheep, identifying sheep cobalt deficiencies, and understanding of rumen function.
- 1940s – Tropic-proof canned butter, innovative food preservation techniques, sheep external parasite control, the nucleus of the National Herbarium, log pealing lathes, poppy morphine estimation, drug extraction techniques, and timber research.
- 1950s – Atomic absorption spectroscopy, rabbit biological control, merino genetics, wool chemistry, textile technologies, tropical pasture establishment, wildlife surveys, and permanent-crease wool fabrics.
- 1960s – Tropical pasture management, white muscle disease remediation, fly control through dung beetles, sirex wasp control, mechanised cheese manufacture, viticulture improvement, wool dyeing, and stored-grain quality assurance.
- 1970s – Wool spinning advances, chemical defleecing, poultry virus isolation, shrinkproof wool, non-flammable wool, salvinia control, buffalo ecology.
- 1980s – Calicivirus control of rabbits, transgenic sheep, aphid resistant lucerne, climate change understanding, orchard lice control, Johne's disease management, Asian food taste testing, and recombinant DNA gene shears technology.
- 1990s – Bushfire dynamics, nano-diagnostic devices, milk product diversification, salinity dynamics, water quality monitoring, and plant genetic manipulation.

It is an impressive list, and it continues to grow. Since 2000, agriscience in Australia has continued with world-leading research and applications even though its research budgets have declined in proportion to other industries. This tradition of research has produced such Nobel Laureates as Peter Doherty and Elizabeth Blackburn for their contributions to immunology and molecular genetics, as well as equally significant Australian agriscientists working both here and abroad. It is such expertise that also allows us to participate in the highest levels of global science, such as climate change, which may well affect us more than most developed nations.

Climate change is real. It has been a focus of agriscience for a century in its continuous quest to adapt agriculture to new environments. The imperative now is to continue our research to adapt plants and animals to the new environments induced by climate change. This requires expertise in the same agriscience fields as the past – breeding, nutrition and management – supported by new meteorological means of anticipating weather. Serious farmers today base their crop schedules on sophisticated interpretations of ocean temperatures and atmospheric science. And thus all aspects of agriscience are a global effort.



Global participation

Research has allowed global crop and livestock yields to increase in parallel with agriscience investment. During the 1970s, 80s and 90s research investment in developing nations continued yield and production increases, but it has often relied on adapting outputs from developed nations' agriscience. With population and wealth driving food demand, a sustained investment profile is required. But this has not eventuated despite agriscience now being a global activity. Reductions in the level of global research participation relative to national wealth can be a costly saving in terms of both increased regional instability and spin-off technologies applicable at home.

Since agriscience relies on complex training, much research is conducted jointly with international laboratories in major universities. Continued support for research education is a simple indicator of sustained export potential. In addition, sharing one's international development responsibility becomes a field that feeds knowledge back into agriculture.

Proportionate to its size and wealth, Australia has been a particularly strong participant in international agriscience activities. These activities were formalised in 1982 with the establishment of the Australian Centre for International Agricultural Research (ACIAR). Bridging Australia's agriscience and international aid from a wealthy Western nation with temperate, subtropical and tropical climates relevant to developing countries, ACIAR supports research partnerships with the Consultative Group for International Agricultural Research (CGIAR) Green Revolution Centres. This support has been of huge benefit to developing nations. In turn, benefits to Australian agriculture have significantly outweighed our investment.

In fact, independent evaluation of the ACIAR has indicated benefit cost ratios for developing nations as high as 67:1 with a conservative overall estimate of at least 5:1. Some of the outstanding contributions have included; rodent control in rice crops in Laos; eucalyptus production in China; banana skipper control in Papua New Guinea; pig genetics in Vietnam; footrot control in Nepal; Newcastle disease vaccine for chickens, and rendering rice straw useful in buffalo and cattle diets.

Often overlooked, this modest aspect of Australian agriscience has produced major national benefits such as: protecting our status as the world's only bee mite-free nation; allowing a viable sandalwood industry in the Ord River region in northern Australia; keeping fruit flies at bay; introducing pest resistant sorghum and water efficient wheat; safeguarding us from pathogenic livestock diseases such as avian influenza and swine fever; improved protein in northern cattle diets; improved citrus rootstocks, pest control in mangos and post-harvest fruit quality. These and other benefits of agriscience can be illustrated by two industry examples: wheat and dairying.

Becoming a major wheat exporter

Australia is one of the world's top three wheat exporters. 38,000 farms produce about 40 million tonnes of wheat each year, which allows us to export about 14 per cent of globally traded wheat – even though we produce only 5 percent of the global total. It is not just the $9 billion income and abundance of clean wheat product in our foods that benefits Australia, but in exporting to food-poor regions we contribute to global stability, as grain shortages are a major source of conflict and emigration.

We have learned a lot from our experience, our innovation and our excellent agriscience, as the following diagram illustrates. Following the red line of running averages, it is clear that initially we mined soil nutrients causing wheat yields to decline until phosphate fertilisers and plant breeding gained back some of the initial potential.

Australia's leading role in the rotational use of natural nitrogen fertilising legumes then combined with engineering advances to continue yield increases, which were extended further by application of disease-breaking crops and nitrogen fertilisers. Average wheat yields more than halved from 1850 to 1900, to less than 0.5 kilograms per hectare, as the soil's natural nutrients were exhausted, but they have risen steadily since 1900 and now stand above 2 kilograms per hectare.

Improvements have been made in pasture management, fertilisers, cultivation equipment and mechanisation, and wheat strains. Droughts have meant variability year on year, but agriscience is now addressing water usage.

Our forebears quickly learned about rainfall variability, and ploughed regularly to control weeds that sucked soil moisture during the summer. Resultant soil erosion and percolation-induced salinity thus became subjects for agriscience. Today, moisture, nutrients and soil are conserved by use of biologically benign weed sprays and retention of the harvest stubble previously burnt off.

Adapting space and engineering developments, agriscience applied global positioning system (GPS) technologies to sophisticated tractors that accurately position sown seeds between stubble at the optimum depth. Precisely placed, and protected from drying winds by last year's stubble, seedling emergence and survival increased. With precise routes and reduced tractor traffic, ploughing is less necessary to break up soil compacted by machinery. This too has increased yields.

At the same time, agronomy determined means of reducing disease transmission across years by introducing commercial fallows of crops with such break crops as canola, leading to wheat yield increases of up 20 percent. One of the next innovations from plant breeding will likely use genetic variants that can be sown in summer at greater depth into moist subsoil to emerge with even greater resilience to Australia's erratic rainfall.

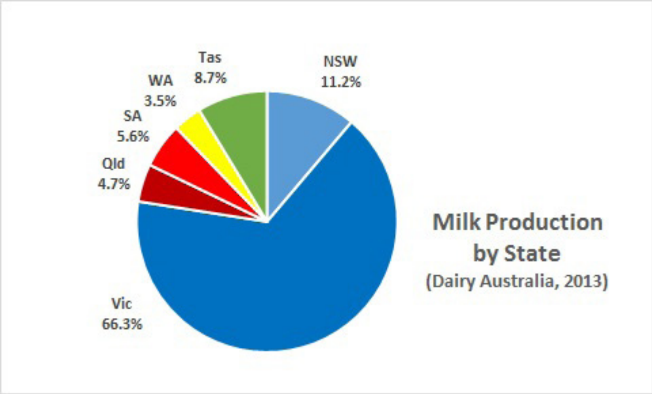
In the process of such research, agriscientists noted high yielding crops used more water to transport nutrients and photosynthesise. Water-use efficiency then developed into a leading area of agriscience in Australia based on land-based nuclear or electromagnetic sensory equipment, and molecular techniques for selection of water-efficient varieties of wheat and other plants.

As the public comes to realise the variable nature of Australia's rainfall and climate change, they are learning agriscience has successfully worked on both for decades to ensure an efficient and resilient agricultural industry. This is how good agriscience works, and Australia has been a leader, and to maintain that lead, we must breed new strains of plants and animals even better suited to our land.

Early varieties of many crops introduced to Australia struggled, and more suitable strains were bred from the few that survived. The rate of such genetic improvement has continually accelerated, to the extent that it is a constant process that facilitates resistance to diseases, enhances water and nutrient use efficiency and raises yields.

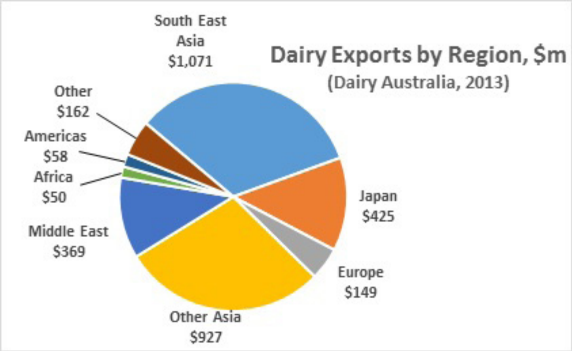
Today complex science isolates DNA markers of desirable genes, evaluates traits and analyses billions of data sets. This science has developed from those early observant farmers and their laborious pollination in systematic field plots with thousands of samples, to radioactively-induced variations to arrive today at the study of minute gene sequences. The general process has been the same throughout and today allows integration of genetic material from wild relatives. Inclusion of genes inherited by a plant's descendants has mainly been used in Australia to confer resistance to benign herbicides and to insects and diseases.

Other applications include enhanced drought and salinity tolerance and reduced pesticide and fertiliser requirements. Globally, and incidentally also involving Australian expertise, other genetic innovations that provide huge improvements in human health include means of overcoming vitamin A and iron deficiencies and their debilitating effects.



How dairying benefits

The role of agriscience in Australia's wheat industry is mirrored for livestock in dairying. As our third largest agricultural industry and with a major export orientation, the industry provides about $4 billion income to farmers – around 10% of our agricultural value – and vastly more in value added dairy products. Dairy is our largest processed food export, and needs reliable rain or irrigation, nutritious feed, integration with processing and sophisticated scientific and management expertise.



Until the 1830s, Australian dairying struggled with unsuitable soils in unreliable rainfall areas, but then expanded, with development of suitable lands to service larger settlements with farm-produced butter, cheese, cream and milk. The next big advance was in the 1880s with the invention of practical refrigeration in Geelong, and the introduction of exotic pasture species.

By the turn of the 20th century, farmer-cooperative butter factories had replaced farm manufacturing and the industry expanded profitably. Pasteurisation enhanced milk life and safety, and milking machines were introduced, although uptake was slow in the absence of electricity.

Then for most of the 20th century the industry enjoyed fixed priced exports to the UK until it joined the European Economic Community in 1973. The slow unravelling of intricate protective regulations then began and agriscience became an even more essential partner of dairying across its spectrum from soils to marketing processed product. Deregulation, long overdue, led to application of new technologies, infusion of essential capital and consolidation of farms into more economic sizes. These changes improved Australia's competitiveness to reliably become the fourth largest dairy exporter after the European Union, the US, and our dairying neighbour New Zealand (where even the corner stores are called 'dairies').

Australia's dairy exports today are ten times higher than they were in 1980, and the industry is continuing to modernise its business structure. Based on the natural advantages of our southern soils, rainfall and climate as indicated below, agriscience is now enhancing yields and extending the range of profitable dairying.

Australia's southern climate allows cows to be pastured all year on good soils, with marked benefits to the health and the welfare of the animals themselves. Australian milk yields are only 60 per cent of that of housed cows in the US, but Australian dairy farms enjoy higher profitability and closer proximity to major Asian markets. Milk product exports have also stimulated related industries to export dairy equipment, expertise, hay and dairy breeding stock. Often in cooperation with New Zealand, our agriscience has underpinned dairying's continuous goals of efficiency though innovations in endocrinology, electronics, engineering, health, genetics, nutrition management, pastures, robotics and welfare.

Examples of recent innovations include heat identification, robotic milkers and individual cow identification to record movement, weight, blood, milk and rumen parameters linked to automatic allocation of cows to different paddocks, feeds and treatments. We maintain our competitive advantage of outdoor pasturage through constant assessment of feed availability, growth rate and quality to inform strategic pasture use and supplementary feeding to optimize individual cow nutrition.

Australia's herd recording details lactation status, optimal time for sale of retiring cows, prescriptive therapies for dry cows, selection of replacement heifers and reproductive performance as a component of Australian Breeding Values and Herd Improvement. Incorporating biosecurity management, welfare practices for bovine wellbeing and improvements in milking shed design from research have further enhanced our continuation of a humane and profitable industry. Each innovation has required capital, often associated with expansion of farm size.

Our markets for dairy products are overwhelmingly in Asia, as the chart shows. Asia is also starting to contribute to that deficiency of most of our agricultural industries: serious capital investment. This investment can be linked to markets, allowing continuous introduction of new technologies. Thus Asia begins to contribute to our major missing ingredient.

Capital – the missing ingredient

The history of Australian agriculture is a history of addressing deficiencies. Australia has suffered from poor levels of soil nutrients, low moisture and unpredictable rainfall, the depredations of introduced species, and the necessity of developing suitable management techniques to address these problems.

One commonly overlooked and continuing deficiency is capital. Australia has a much higher per capita income than most countries, yet investment per hectare of agricultural land remains low by international standards. This relative lack of investment is limiting our ability to apply many of the new technologies essential to continued advances in efficiency.

In addition, we have shown a reluctance to invest urban wealth into agriculture, such that our main concentrations of wealth – superannuation funds – have meagre agricultural investments. The likes of VicSuper's valued presence in the sector is dwarfed by the total of foreign pension funds including, Canada's Public Sector Pension Investment Board, The Netherland's Stichting Pensioenfonds, Switzerland's Adveq Real Assets, the US Municipal Employees' Retirement System, Denmark's Danica Pension Fund, Sweden's Forsta AP-fonden as well as other German and Scandinavian funds. There are two lessons in this: the first is the obvious one that we as a nation can invest more. The second is that we rely now, as we always have, on large-scale foreign investment.

Land, labour and capital are the three key factors in agricultural production. Technology can make up some deficiencies in the first two but is ultimately reliant on the third – capital.

Wither Australian agriculture?

Looking back over the last 150 years we can see trends that inform future changes in agriscience, rural society, global and community demands, as well as apparent limitations. For example, our focus on water use may stimulate developments in northern Australia and a reduction in agriculturally marginal areas. Alternatively, such benefits might accrue from inefficient pasture irrigation being switched to intensive crops. Some even consider that landscape will be valued above agriculture and lead to perennial revegetation for extensive grazing, forestry and conservation.

Whatever transpires, it is unlikely to be a continuation of the 150-year trend of exponential agricultural land expansion. It will also be integrally related to international trends. Farmers around the globe are implementing major changes in farming practices and structures, such as precision farming (greater monitoring and crop management), increased automation, farm consolidation, and a general increase in professionalism.

A 2013 National Farmers' Federation survey of Australian opinion on the global and domestic factors that are now driving change has found the following; population growth, urbanisation, climate change, price volatility, labour, telecommunications, R&D investment, profitability, trade restrictions, foreign ownership, urban farming, cultural changes, biofuel, economic growth, energy costs, farm social adjustment, consumer and regulations.

When these factors are applied to Australian agriculture it is easy to see we require increases in agriscience, competitiveness, market access, labour availability, urban linkages, environmental practices and adaptability to change. These are consistent with the consolidated views from Europe, and both may be placed within the earlier diagram of drivers of change in Australian agriculture.

As we broaden our view beyond the past and look to Australia's competitive advantages we will also apply agriscience to existing and new industries. Some rising industries include exotic horticulture; game birds; goat and kangaroo meat; aquaculture; value-adding in the hide industry, and mechanisation in tea and coffee production.

The annual value of these new and fast-growing industries is now approaching $1 billion. While absolute values are low compared to traditional industries, significant environmental benefits also accrue from industries that reduce feral pigs and camels, reafforest with native species (such as oil mallee or wildflowers) and reduce salinization. Tourism is also associated with such new industries as truffles, olive oil, goat and sheep cheese, green tea and marron. Just as agriscience is an integrated part of the total agricultural landscape, so our future agriculture will be integrated across many business sectors.

But the largest foreseeable gains will be made in our existing major industries. The Australian Academy of Technological Sciences and Engineering notes: "Australia's agrifood industries are at an important crossroads due to a fortuitous confluence of geography and history. Do we respond to the immediate challenge of meeting the food and fibre demands of the emerging middle class of our near neighbours, who will express their new wealth in the clothes they wear and the foods they eat, or do we continue to be a price taker for bulk commodities into the future?

"To meet this new opportunity the Academy identifies the need for a long-term strategy for growth and value-adding that enhances our competitive advantage in clean green food. And this relies on reinvigorating innovation through globally-linked agriscience."

Australia is in agricultural transition. Symptoms include the cost-price squeezing of farmers, increased global investment interest in reliable agricultural enterprises and ongoing social adjustments. Our long history of innovation serving adaptation to new environments, new markets and new values that has produced the miracle of Australian agriculture will serve us well as we move further into the new era.

About the author

Professor Lindsay Falvey FTSE was Dean and Chair of Agriculture at the University of Melbourne. He is a Director of the major Qatari-owned investment in Australian agriculture Hassad Australia, and is Chair of the Board of the International Livestock Research Institute one of the CGIAR Green Revolution Centres. His PhD, higher doctorate (D.Agr.Sc.) and honorary doctorate are all related to agricultural science, technology and development. He is the author of several books and many papers on the agricultural and food processing industries.

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