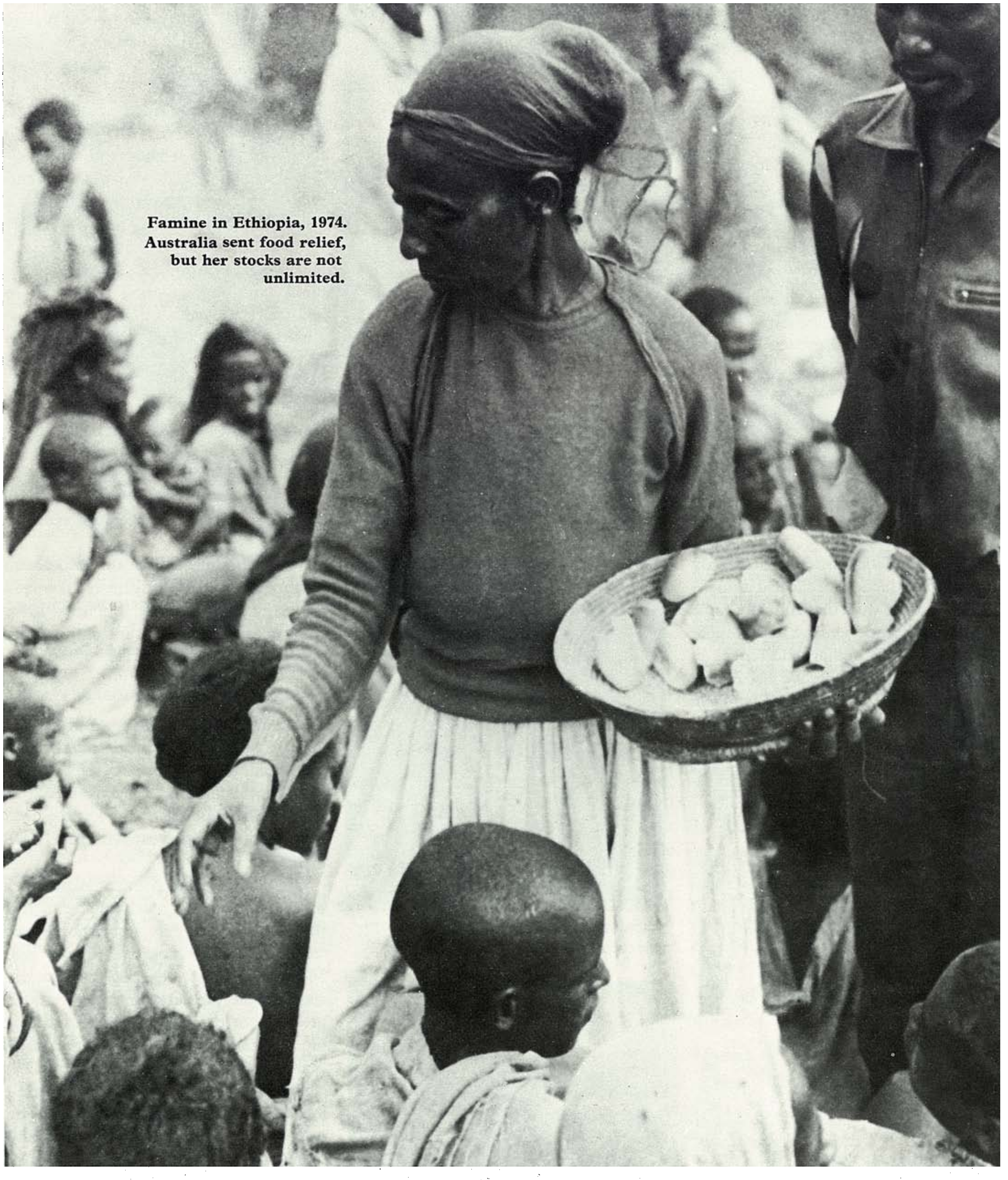
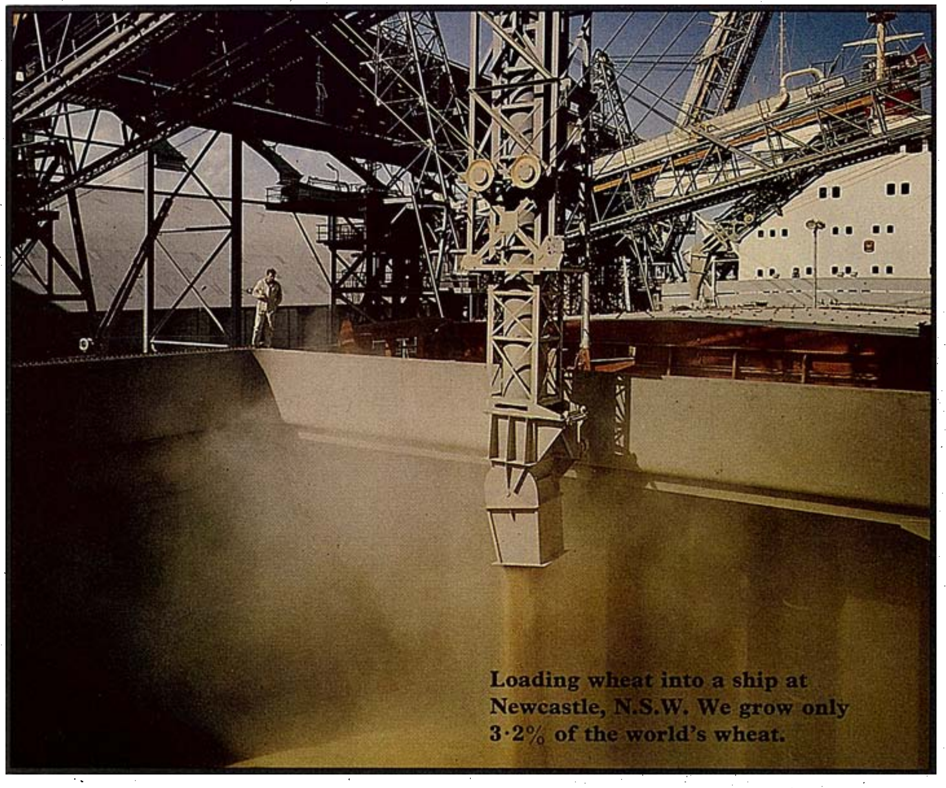


Famine in Ethiopia, 1974. Australia sent food relief, but her stocks are not unlimited.

On food and the future

Australian agriculture has always been unusual. Within 10 years of the arrival of the First Fleet it was producing a surplus, and it has done so ever since. Our population has remained so small compared with what we can produce that the prosperity of our farmers has always depended on what they can sell overseas. Most other countries grow their produce to feed and clothe their own people.



Loading wheat into a ship at Newcastle, N.S.W. We grow only 3·2% of the world's wheat.

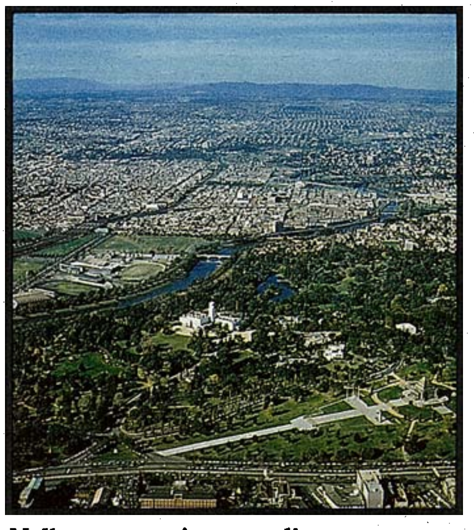
Today, 13 million Australians still only use about one-thirtieth of the 850 million-odd kilograms of wool that annually come off the sheep's back, and we export more than half of the 8 million-odd tonnes of wheat we grow each year. We also export more than half of our beef. All is gloom and misery when world prices are low.

So our agriculture certainly does supply our needs, but it has the other major function of supplying foreign exchange to support our exceptionally high standard of living.

As long as our population remains comparatively small we have a lot of room for manoeuvre, if we want it. We don't have to cultivate every available hectare of land. If we choose, we can preserve land in its natural state as a reserve or national park. We regard agricultural land as expendable—the extraordinary sprawl of Australian cities bears witness to that.

It won't always be like this; our population will grow, and our surpluses may well evaporate. In addition, we live in a hungry world, which pricks the nation's conscience now and then. If the need arises how much food will we be able to grow? Or if we decide to do it now, how much extra food can we grow to support the hungry nations?

Without doubt Australia could grow much more food if the demand arose. But it seems unlikely that there will be pressure to produce much more to feed the local population during the lifetime of any living person. Estimates vary on how many people our present agriculture will comfortably support. The most recent, by Dr Roger Gifford and his colleagues in CSIRO, suggests that right now we have food enough for about 35 million people at our present standard of living.



Melbourne—a city sprawling over agricultural land.

By many yardsticks we're an over-fed nation. We each eat about three times more protein than we need.

In the First Report of the National Population Inquiry, Professor W. D. Borrie of the Australian National University suggested that, without immigration, our population could be about 16 million in the year 2001, or some 17½ million if immigrants arrived at a rate of 50 000 a year. At present Australia seems to be faithfully following the trends to lower fertility visible in the other industrial countries. By mid 1974 no less than 21 of the 31 countries usually classified as 'highly developed' had birth rates lower than the replacement level. Australia's net replacement rate in 1974 was 1·12 per head of population, compared with 1·39 in 1971 and 1·65 in 1961.

Incidentally, in 1932, during the depression, the net replacement rate fell to 0·97.

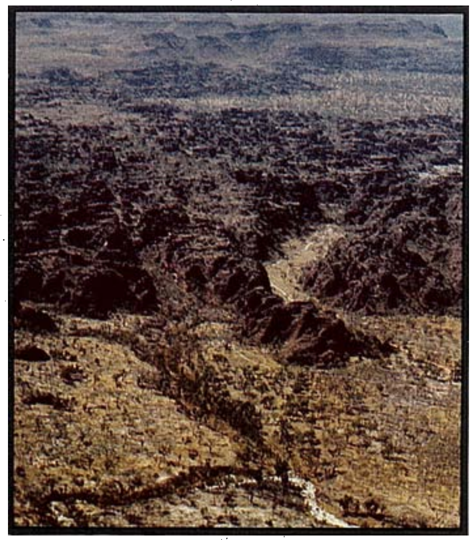
So our local needs probably will not be putting increasing pressure on the land for many years to come. But what if we want to grow more food for our own use or to feed other countries?

Food and the environment

You can increase the amount of food you grow in two ways: by increasing the area cultivated, or by increasing the quantity of a crop coming off a fixed amount of land. Either approach can have serious repercussions on the environment if mismanaged.

Of course, the 'environment' has many aspects. For much of our native plant and animal life, for example, the 'ecological crisis' came many years ago. Most of our continent has been under considerable pressure for many years to produce our exports, with the result that much of the land suitable for agriculture is already in use. Profound changes in the landscape—brought about by clearing forests for grazing and cropping, and by competition from sheep, cattle, and rabbits—have reduced many native animal species to remnants of their former selves. A few have become extinct. Some others like the red kangaroo and euro have thrived in the changed conditions.

Agriculture after all is a way of channelling the natural resources of sunlight, soils, and water to produce food or fibre for Man. This must happen at the expense of the natural fauna and flora. Good farming maintains a stable, but artificial, system so that the same piece of



Our tropical north is not a land of milk and honey waiting to be cultivated. Much of the Kimberleys and Arnhem Land look more like this.

Agriculture changes the environment. The red kangaroo has benefitted. Most of the native fauna has not been so lucky.

land produces food and fibre for as long as possible. This means using management systems that maintain a fertile soil (and even create it), that prevent erosion, and that don't have side-effects—like nitrate or pesticide pollution of waterways—that affect ecosytems beyond the area farmed.

Big country, limited land

How much of Australia is suitable for agriculture? Over the years agricultural scientists have made a number of estimates of the area of as-yet-unused land that could be cultivated. They have come up with a variety of figures that range between 6 million hectares and 102 million. Probably the most thoroughly researched estimate of 25–30 million ha came from Mr Henry Nix of the CSIRO Division of Land Use Research.

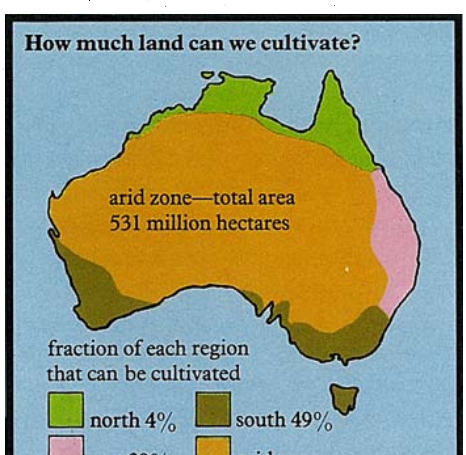
In the context of Mr Nix's calculations, 'cultivated' refers to those areas suitable for intensive dryland agriculture. In other words, he means those areas that can be periodically cropped and sown to improved pastures.

Australia has an area of 786 million ha, a large proportion of which is very arid. The drier areas can be and are used for sparse grazing, but not without incurring environmental costs (see *Ecos* 8). They aren't worth cultivating without irrigation.

Using the constraints of climate alone, Mr Nix calculated that only 237 million ha fall in the region that can be cultivated. That's an area a little larger than the whole of Mexico—a country lying is similar latitudes to Australia, but not one with which we often compare ourselves.

By no means all this land could be cultivated. Even though we don't have high mountains, the terrain and soils limit what we can do. This applies particularly in the north, where it's so rocky and the soils are so poor that only 3 million of the climatically suitable 73 million ha could conceivably be cultivated using our type of agriculture.

Taking just the terrain into account, Mr Nix's sums showed that only 132 million ha could be cultivated. Take out the areas of unsuitable soil and the figure drops again by nearly half to 77 million ha—that's just over twice as much land as can be cultivated in Mexico, or only about four times the area currently cultivated in the State of Iowa in the extremely fertile corn belt of the United States. Currently we farm some 40 million ha in some way.



Of Australia's 786 million hectares, only 77 million can be cultivated. That's one-sixth of the land available in North America.

Incidentally, Dr Bruce Davidson of the University of Sydney calculates that some 7 million ha of Mr Nix's farmable land can't be used, since it includes inland waterways as well as land that has already been lost beneath cities, roads, and railways.

Much of the land that can be cultivated in the southern region of Australia is already in use, and as already mentioned the north cannot be regarded as a wonderful piece of real estate for food production. Much of the remaining 25–30 million ha that could be used occurs in the subtropical eastern region of the continent away from the coast.

European traditions

Having the land available for cultivation is one thing. Being able to use it in such a way that productive agriculture can continue, preferably in perpetuity, is quite another.

In the south we have succeeded quite well in adapting our traditional European agriculture to the somewhat different environment. With careful management the two main forms of agriculture—wheat-growing and grazing—should be able to continue without a reduction in productivity.

We are learning to farm the subtropics, and have made strides in the higher-rainfall parts towards developing a stable

William Farrer, the now-familiar face on our $2 notes. He solved the problem of making wheat yield under Australian conditions.

and productive cattle industry based on planted pastures. We know much less about cropping.

We don't know how to farm much of the tropics on a long-term basis—either for crops or for even reasonably productive grazing.

Australia's agricultural history has been one of a small population steeped in the traditions of European agriculture adapting to a huge, hot, and very dry continent. That we have succeeded best in the south probably reflects our background as much as anything else. Sheep-grazing succeeded during the middle of last century because the animals needed a minimum of attention and the wool they produced could be transported across the world without spoiling.

Early attempts to grow wheat failed because the available European wheats weren't adapted to the latitudes of southern Australia. In Europe the wheats ripen in autumn as the days become shorter. Here they are grown in winter and must ripen during the lengthening days of spring. It wasn't until the 1880s that William Farrer overcame this problem by crossing Indian and British wheat varieties.

However, with time wheat yields fell. Cropping was using up the never-very-great fertility of the soil. The solution came during the 1930s. It was to regularly replace wheat, oats, or barley crops with short-term sown pastures (known as leys) containing subterranean clover or other legumes. The usual rotation now used is pasture for 2–3 years followed by cropping for about the same time.

We live in a hungry world, which pricks the nation's conscience now and then.

Maintaining a fertile soil

The problem was that the soil was becoming short of nutrients—nitrogen in particular. The legume in the pasture ley replaces this element by fixing nitrogen from the air. In addition it increases the fertility of the soil by adding organic matter. Superphosphate fertilizer added to make the legume grow also increases the levels of phosphorus and sulphur in the soil.

The sheep grazing the pasture probably have little effect on the system, since they recycle the nutrients they graze, and comparatively little goes off in the wool. The main function of the sheep is to provide the farmer with cash while his land is recovering its fertility.

Modern legume leys stem from the discovery in 1907 by Amos Howard, a South Australian farmer, that his sheep did better on paddocks containing an annual clover. In addition, he noticed, the clover could be easily spread once the land had been topdressed with superphosphate. Now known as the familiar subterranean or sub clover, this plant had not previously been used in agriculture. It came to Australia by chance from near the Mediterranean Sea.

In fact sub clover could be grown over vast areas that had previously proved unfarmable, merely by sowing the seed in existing native pasture together with a little superphosphate.

By increasing the capacity of land to carry sheep three- or fourfold, sowing 'sub and super' brought large areas of southern Australia into more-intensive use. But the duet brought its environmental problems. Sub clover is a short plant that grows in winter. Sheep grazing it also grazed down the tall summer-growing *Danthonia* grasses, with the result that in summer some land became almost bare. Erosion became more of a problem.

Even the 'sub and super' formula didn't work on all land, especially on the more-sandy soils. In 1945 scientists began to realize why. The clue came when CSIRO researchers discovered that in parts of coastal South Australia sheep needed doses of copper and cobalt to thrive. It was then realized that in these areas improved pasture plants needed small

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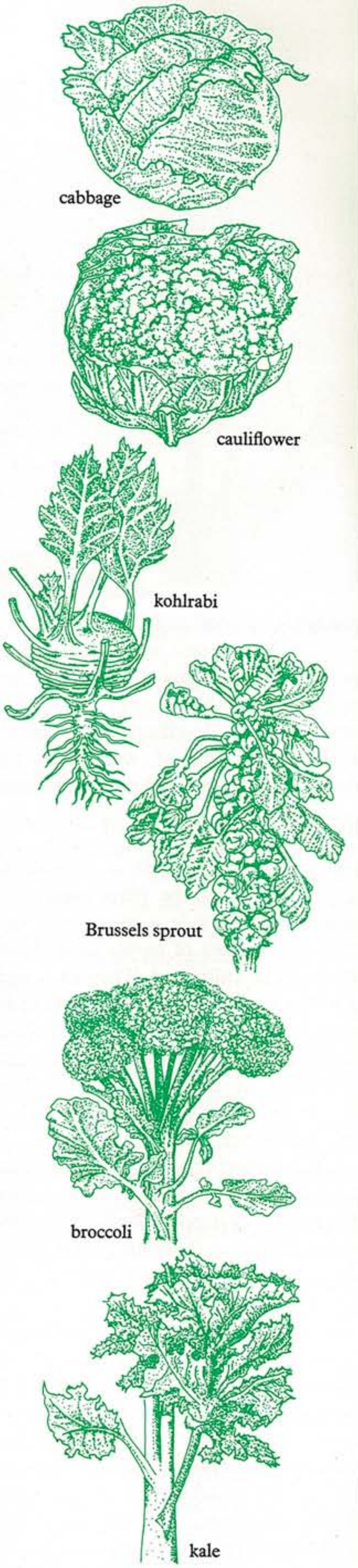
What Man's selecting can do



These vegetables all came from a common ancestor.

What do a cabbage, cauliflower, Brussels sprout, kohlrabi, broccoli, and kale have in common? They're vegetables, true. But more surprisingly they all have the same wild ancestor. This group of vegetables shows well how men can manipulate plants' genes so that much of the energy they make by photosynthesis goes into a selected organ. In Brussels sprouts it's the buds, in cabbages the leaves, and in kohlrabi the stem.

All these variants of the wild plant appeared as a result of selection by farmers. Modern plant-breeders do much the same thing, but they have techniques for speeding up the process. Thus new types of wheat or maize can now be developed in a few years rather than in a few decades.

Enlarging one part of a plant usually happens at the expense of another part. In the most-productive crop plants, a great deal of the sun's energy that is trapped goes into the seed. Consequently they have very small root systems, and their stems merely provide the skeleton that supports the seed head and the leaves, where photosynthesis takes place.

A plant like this must be carefully looked after. It must have copious water and nutrients supplied to it all the time. Weeds must be ruthlessly eliminated, since it would not be able to compete with the lush weed growth that occurs on so much water and nutrients. This is why very productive plants require such a high input of energy to make them produce.

Breeding a plant for one purpose always happens at the expense of other features. Any single type developed with more than one purpose in mind must therefore be a compromise. Take for example the sort of leguminous plant that will be required if the idea of farming the tropics with alternate cereal and pulse crops comes off. The idea sounds perfect—both crops produce grain, and the legume adds nitrogen to the soil at the same time.

But there's a snag. The farmer wants as big a yield (and hence profit) as possible from both crops. But if he uses a high-yielding legume like the modern American soybean, the system won't work. These plants will yield magnificently, but they won't put much nitrogen into the soil. Practically all the nitrogen fixed from the air goes into the bean crop.

Thus the legume used in the rotation will be neither fish nor flesh. It will have to yield just enough grain so that the farmer gets an adequate cash return, but enough of the nitrogen it fixes must go to where it can increase the fertility of the soil. That will be a tricky balance indeed!

It was breeding plants for specific sets of conditions that enabled Mexico, India, the Philippines, and other less-developed countries to raise their wheat and rice production during the so-called 'green revolution'.

By 1970 both India and Mexico had so increased their food production that shortage no longer seemed a problem. Then within the next few years both became major food importers once more. Had the green revolution failed?

It seems not. Things went wrong in the two countries for different reasons. In Mexico, which now imports grain, the population had caught up with the wheat and corn being produced from the irrigated areas. There was plenty more unirrigated land where these crops could be grown, but the local peasants were not interested in raising yields—partly because the returns they could get from the offered package of seed and fertilizer were not great enough.

Mexico is now developing suitable crops and techniques for increasing grain yields under these conditions.

A number of problems caused India's shortfalls in food production. These included poor seasons, a world shortage of fertilizer, and the increases in the price of oil. In addition, 10 million refugees from Bangladesh wiped out the grain stocks built up during previous years. However, in the year 1975–76 India's crop reached a new record of 115 million tonnes—considerably more than the previous best in 1970–71 of 108 million tonnes.

Plant-breeders in the international institutes like CIMMYT in Mexico, ICRISAT in India, and IRRI in the Philippines regard the yield increases achieved so far only as a start. In many places the new plants have proved ill-adapted to local needs, but this can be corrected. The approach of adapting plants for specific needs has been proved.

In many ways the program carried out by what is now the Division of Tropical Crops and Pastures for evolving improved tropical pasture plants has followed the same philosophy. Indeed, overseas scientists have referred to our proving of these pasture plants as Australia's own green revolution.

For more than 20 years now the Division has been introducing likely-looking grasses and legumes from other tropical countries. Some were already domesticated, but many were wild plants previously unused in agriculture. From the wild introductions scientists have bred plants suited to our particular conditions. Perhaps the best-known and most successful is Siratro—bred by Dr Mark Hutton, who retired recently as Chief of the Division. He selected this plant by crossing and breeding from a number of wild lines of the Central American species *Macroptilium atropurpureum*.

Physiological adaptations to performance as crop plants. L. T. Evans. *Philosophical Transactions of the Royal Society of London*, B, 1976, **275**, 71–83.

Crop plants, an international heritage and opportunity. L. T. Evans. *Search*, 1975, **6**, 272–80.

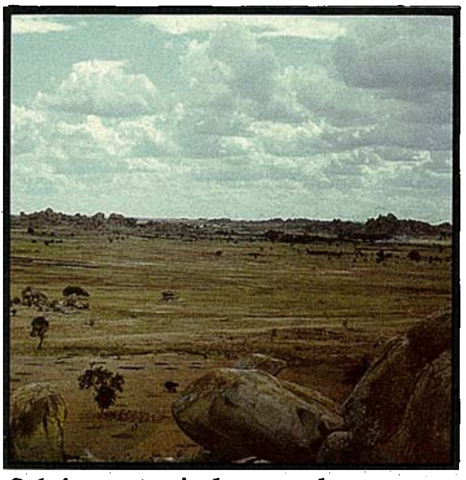
The agriculture of Mexico. E. J. Wellhausen. *Scientific American*, 1976, **235** (3), 128–50.

The agriculture of India. J. W. Mellor. *Scientific American*, 1976, **235** (3), 154–63.

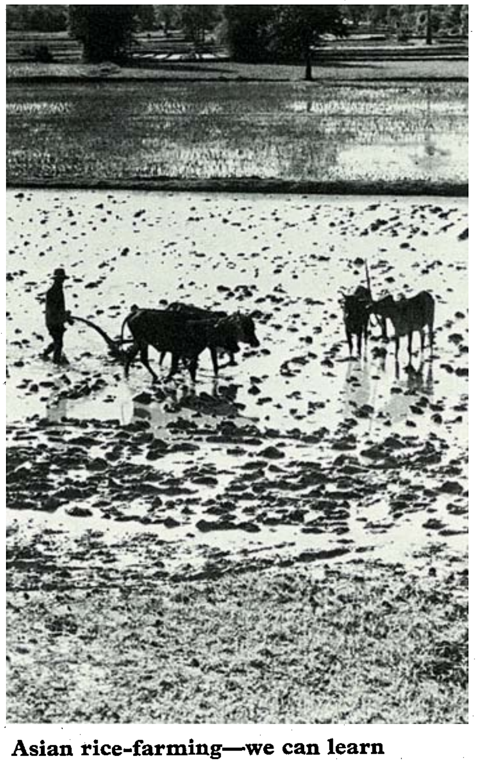
The two agricultures: renewable or resourceful. L. T. Evans. *Journal of the Australian Institute of Agricultural Science*, 1976, **42** (in press).

Irrigation provides the traditional answer to making dry land more productive. Australia could perhaps triple its area under irrigation—at immense cost.

A sorghum crop washes away in a tropical downpour at Tipperary in the Northern Territory. Mechanized farming has yet to come to terms with the tropics.



Subsistence agriculture can be devastating too—as this picture of a once-forested landscape in central Tanzania shows.



Asian rice-farming—we can learn from it.

quantities of these and other 'trace elements' like molybdenum and zinc in addition to superphosphate.

Parts of Western Australia also proved short of these elements, and more recently the falling output of the dairy areas of the Atherton Tableland in northern Queensland has been reversed by fertilizing with small amounts of trace elements. Other areas also lack these substances.

Learning to farm up north

The problems that farmers had to overcome in southern Australia included drought, infertile and erodible soils, unsuitable northern European seed, scarce labour, and the difficulty of moving produce to distant markets without paying more than the value of the crop. In addition, they had to continuously keep ahead of diseases such as wheat rust.

The northern half of Australia, where most of our land that could still be cultivated lies, has all these problems—many on a magnified scale. For example, pests breed faster—as cotton-growers have found to their cost. Even in the dry tropics, it rains more heavily than further south—bringing greater problems of erosion or leaching of fertilizers out of the soil. It's doubtful whether most of our crop-farming systems in the tropics or subtropics are stable in the sense that they will continue indefinitely with present methods, or even for the next 50 years. (Sugar-cane and irrigated rice on the Burdekin are probably exceptions.)

Even that success story of wheat-growing on the Darling Downs of southern Queensland may well have a limited life. The industry has two problems: it's using up nitrogen accumulated in the soil before cultivation began and, although slowed by management, the erosion problem has not been solved.

Ley farming as practised in southern Australia may seem to be the solution on the Darling Downs, as the legume ley would both add nitrogen and rejuvenate the soil. It would also slow the rate of erosion. The snag is that the system may not pay. For example, even to make the pasture ley break even, sheep or cattle would have to be grazed at a rate at least as high as the pasture would be able to support.

Cropping other tropical and subtropical areas presents even more daunting problems. Agricultural scientists in a number of institutions—including the CSIRO Division of Tropical Crops and Pastures, the State Departments of Agriculture, and the University of Queensland—are now grappling with them.

At its Narayen research station some 150 km inland from Bundaberg, the CSIRO Division is now evaluating the results of rotating winter and summer grain crops, like wheat and sorghum, with winter and summer legume–grass pastures. Some results have been quite promising and such a regime may yet prove to be stable. But the economics of the system will make or break it since, like it or not, any agricultural system will only be used if it yields profits.

Leaf from the Asian book

Scientists at the Division are not at all sure that the path to stable farming in our more northerly areas lies with mixed crop and animal farming. Along with their colleagues in the University of Queensland, they suspect that the Asian habit of growing bean and other legume crops off-season on the rice paddies may have more to offer. By alternating cereal and legume crops, it should be possible to obtain two valuable food crops and at the same time maintain the nitrogen content of the soil through the legume crop.

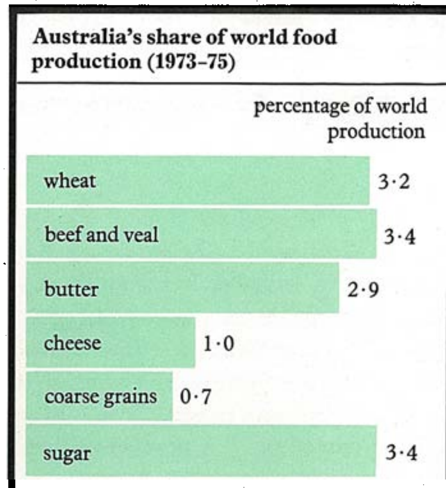
The simple idea of using legume crops alternately with cereals presents many difficulties. For one thing we have very little experience in Australia with growing the grain legumes like mung beans, chick-peas, grams, and pigeon peas that grow in the tropics. They form part of the staple diet of many Asian countries, but there they are grown on subsistence plots, closely tended. We will have to find strains that will grow well in our broad-acre paddocks and that can be harvested mechanically.

As well as alternating their crops, the

We don't know how to farm much of the tropics on a long-term basis.

Asians have traditionally grown mixtures like grain sorghum and pigeon peas. Such mixtures must also maintain nitrogen levels in the soil, and once again we may have something to learn from our neighbours. However, adapting the system to our agriculture would present great problems. It's one thing to harvest a mixed crop by hand, and it's quite another (although not impossible) to gather it mechanically.

Bringing in our wheat harvest uses a lot of fossil fuel. Even so, the grain harvested still contains nearly three times more energy than the fuel that was used to produce it.



We may be a major food exporter, but we only produce a fraction of the world's food.

Boosting energy inputs

So much for increasing the area of land under stable cultivation. How do you increase the amount of food coming off a fixed amount of land? One answer to that question is to increase the amount of energy you expend on the crops.

Solar energy for conversion into carbohydrate and protein is never in short supply—plants usually use less than 1% of the solar energy impinging on them for manufacturing substances that Man can digest. On the other hand, water and nutrients such as nitrogen in a usable form in the soil often are. The plants cannot then make full use of the solar energy available. In addition, the crops must compete with weeds for the energy, water, and nutrients.

The age-old way of solving problems of water shortage has been irrigation. Shortage of nitrogen and other nutrients can be solved to a greater or lesser degree by applying manures or fertilizers, or growing legumes. Cultivation keeps the weeds down.

Cultivating, irrigating, and fertilizing mean that people must expend extra energy so that the plants can use as much solar energy as possible. This extra energy therefore 'subsidizes' the energy coming in from the sun.

The difference between the high-yielding energy-intensive agriculture (so far taken to its most extreme case in the United States and Europe) and, say, the low-yielding subsistence irrigated rice-farming of South-east Asia is the scale of the subsidy. The Asians have traditionally had only man- and animal-power available, so they use general-purpose plants that can resist a wide range of diseases, compete with weeds, and produce some grain with a minimum of pampering. At the other extreme, American hybrid maizes will only yield really well when carefully coddled. They must have plenty of water, and be supplied copiously with fertilizer. Weeds must be ruthlessly controlled. Then they yield a remarkable amount of grain. But the margin for error in their husbandry is small.

The problem with energy-intensive agriculture, as so many environmentalists have pointed out, is that the massive energy subsidy needed to grow the high-yielding crops comes from fossil fuels. These must run out one day, so this type of farming is unstable—unless, of course, some other source of energy can be tapped. Subsistence agriculture will not have this long-term problem, but neither could it support the current world population on its own.

Polluting side-effects

Energy-intensive agriculture has its other much-publicized polluting side-effects too. Mineral nitrogen washes out of the

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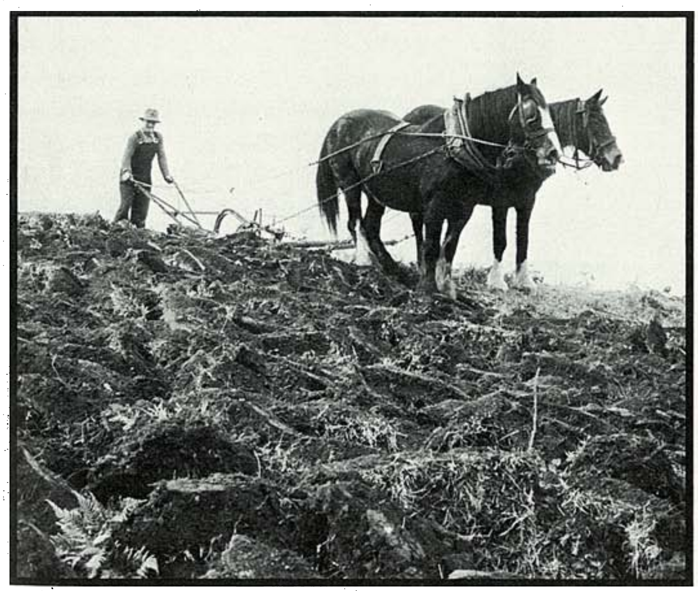
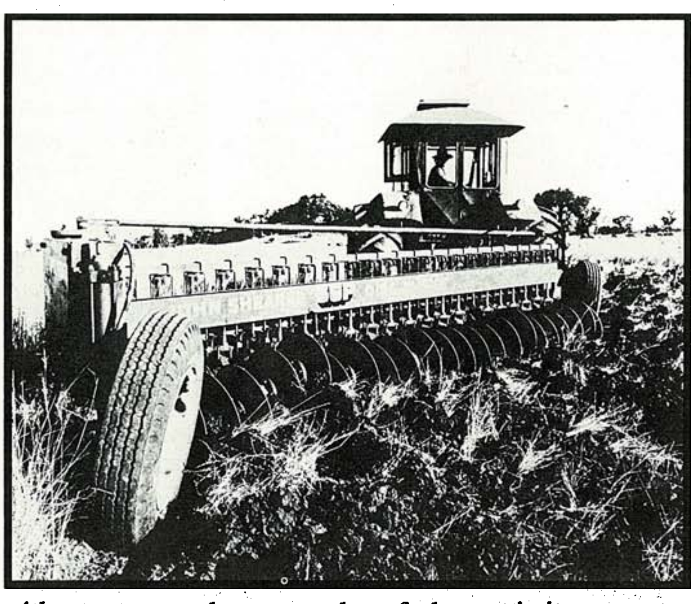




Tractor- or animal-power? You can cultivate much more ground with a tractor—as long as you have fuel to put in it.

Tropical Australia and the less-developed countries

About 40% of Australia lies north of the Tropic of Capricorn. Most of the less-developed countries lie in the tropics.

Much of Australia's tropical land is arid or semi-arid. Some 500 million people live in semi-arid tropical environments elsewhere in the world. Most of the famines of recent years have been in such areas in the less-developed countries of the arid or semi-arid tropics.

Being one of the few developed countries located in the tropics, Australia—as Dr Ted Henzell, Chief of the Division of Tropical Crops and Pastures, points out—seems peculiarly well positioned to assist them.

How similar really is Australia to other lands placed between Cancer and Capricorn? Two features—water and soils—ultimately limit an area's ability to support crops. The map titled 'Tropical climates compared' shows how northern Australian rainfall compares with that in other parts of the tropics. Practically all of tropical Australia has a climate with a wet and a dry season. The wet season may last from a week or two in the centre to between 4½ and 7 months in Arnhem Land and Cape York. Much of India and tropical Africa have similar climates, as do small proportions of Central and South America.

Only a fairly small strip along coastal Queensland has a climate similar to that in the large areas of South America, Africa, and Asia with effective rainfall for between 7 and 9½ months each year.

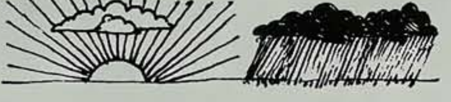
A narrow coastal strip too small to be visible on a world map, which extends from Ingham to Cooktown, represents a rather atypical form of the true wet tropics.

How about our soils—how do they compare? We do have most types of soil found in other tropical regions. However, the proportions are very different. Thus the types commonest in Africa, South America, and tropical Asia occur only in small pockets on Cape York, near Townsville, and in subtropical Queensland and New South Wales. (India is the exception—it has large areas of soils similar to ours.) In addition, in most tropical regions the soils of the uplands are often fertile while in Australia they are usually stony and shallow. Nevertheless, it's possible to find small areas of most types of tropical environments somewhere in northern Australia.

Factors that impede our tropical experience being of value to the less-developed countries are not so much environmental as cultural. Some 80% of the calories consumed in the tropical regions come from cereals, starchy roots, and sugar. Important among the cereals are sorghum, rice, and maize. Cassava, yams, taro, and sweet potatoes account for most of the starchy roots. In addition, these countries grow a wide variety of tropical pulses—like beans, peanuts, cow-peas, pigeon peas, and grams.

We only grow a few of these crops—sorghum, maize, peanuts, and sugar-cane being the main ones. We have no experience at all with growing many of the staple food plants of other tropical regions. So we can hardly think of transferring Australian know-how direct to other tropical countries to help them increase yields from their traditional crops.

Such an idea, as Dr Henzell points out, would be unrealistic anyway, even if we did know how to grow most of the common staple foods. Even where the climate and soils appear to be the same, the social, economic, cultural, and political conditions will almost certainly differ from ours.



Another way sometimes proposed for helping the hungry inhabitants of the tropics is for Australia to grow suitable food here for distribution where it's needed. This alternative has become unpopular among aid experts, partly because it's difficult to move the food to the right places, and partly because providing free or cheap food discourages other countries from concentrating on growing enough to support themselves. Such food would also have to be paid for from our taxes.

Even so, we probably will be asked to provide emergency food for famine relief from time to time. If we do decide to grow as much food as possible in the tropics how many extra mouths can we satisfactorily feed?

In the main article it was suggested that, with our present technology, the food coming from the areas now cultivated in Australia can support about 35 million people at our present standard of living. Dr Gifford and his colleagues have suggested that the continent could be made to support about 75 million people in similar comfort (see *Ecos* 4).

In developed countries like the United States, each person consumes about 900 kg of grain each year, either directly as flour or indirectly as meat. By contrast the Chinese appear to be adequately fed on 200 kg per year. Dr Henzell calculates that if all the 8 million ha of Australian land that could in theory be cropped north of the Tropic of Capricorn yielded 1800 kg of grain per hectare, it could produce food enough for 72 million people consuming grain at the Chinese level. The world's population is currently increasing by about this number each year! (Australia now produces about 1200 kg of wheat per hectare, and the United States about 2200 kg.)

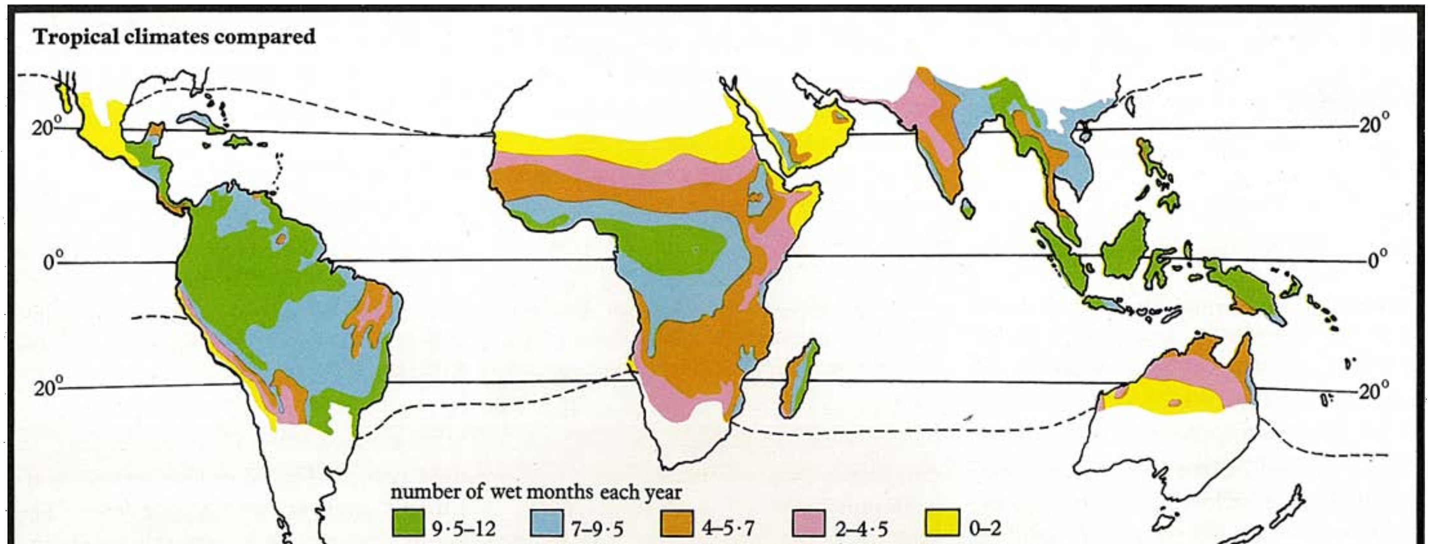
Already, some 84 million ha of land are cultivated in the tropics. Probably there's 20 times as much, mainly in Africa and South America, that could be cultivated—albeit with some devastating results in some areas with present technology. Australia's 8 million are small fry indeed.

So we have little to offer the less-developed countries in the form of crop know-how, and growing food for them is both frowned upon and unfeasible. What then can Australia do?

Like many other informed people, Dr Henzell feels that the aim of aid programs must be to help recipient countries to become self-supporting. Several South American countries wishing to increase their meat production are already successfully using our experience with legume-based tropical pastures. It's debatable how many of the plants bred for Australian conditions will be suitable elsewhere. Nevertheless, we can assist other countries to tread the path blazed by CSIRO and other government scientists in the northern half of our continent.

Animals, however, will only provide a fraction of the food needed to feed tropical countries. Dr Henzell suggests that we can contribute most by helping to train experts from the less-developed countries. We can also give aid experts from non-tropical countries experience with the problems of farming the tropics. Experience gained in Australia should at least help the less-developed countries to work out their own salvation.

What can Australia do to increase food production in the tropics? E. F. Henzell. *Search*, 1976, **7**, 119–24.



Climatically we have most in common with Africa and India. We're much drier than South America and South-east Asia.

fields into rivers and lakes, causing unpleasant eutrophication. Weeds grow with extra profusion on the fertilizer nitrogen and so herbicides have to be used. Some of these have been very persistent. Many of the high-yielding crops are much more susceptible to pests, to which farmers have responded by applying large quantities of broad-spectrum insecticides. These may contaminate the crops, drift onto nearby areas, and pollute waterways.

In time these problems probably can be solved. For example, present techniques of applying nitrogen are very wasteful. But already new methods are becoming available for applying it so that the crop plants use it all. Integrated pest management, which combines biological control with such measures as breeding in resistance to specific pests and judicious use of small quantities of pesticides, is also already becoming an alternative for some crops.

With its preference for using legumes for fixing atmospheric nitrogen into the soil rather than synthetic nitrogen fertilizer, Australia has gone for a compromise between the very energy-intensive and the subsistence agricultures. Our reasons were of course economic rather than ecological—the costs of transporting and applying fertilizer nitrogen to the vast wheat belts and pastures of inland Australia are too high. Nevertheless, our rivers are usually low in nitrogen when compared with those in the United States, and we have usually avoided the problem of eutrophication.

What Australian agriculture has done is substitute fertilizer phosphorus for fertilizer nitrogen. The phosphorus makes it possible to grow the legumes, which in turn add the nitrogen. The result is less

Cutting out cultivation saves fuel. In this zero-tillage unit used by CSIRO, herbicide sprayed from the tank at the front of the tractor kills existing pasture while a seed drill towed behind plants the crop.

We need oil to feed ourselves. Our agriculture and its supply industries use only about one-tenth of the fuel consumed when getting the food to our dinner tables. The rest goes on transporting the produce and processing it—both commercially and in the home.

food per hectare than can be obtained using nitrogen directly, since legumes do not fix quite enough of this element into the soil to cover the needs of other plants. However, we use much less fossil-fuel energy than we would to get the same production using fertilizer nitrogen.

But by using superphosphate rather than fertilizer nitrogen we have substituted one finite resource (phosphate rock) for another (fossil fuel)—albeit one that will last longer.

Scientists' projections of how long the world's supplies of phosphorus will last have varied enormously during the past few years. For Australia, Dr Gifford and his colleagues have calculated that present known reserves in Australia, Nauru, and Christmas Island could support 60 million people for 300 years at our current application rates.

Energy ins and outs

Australia's lack of dependence on ferilizer nitrogen is one reason why energy input to produce one kilogram of food energy is less than that in other developed countries. In Australia we obtain 2·8 times more food energy on the farm than we put in as fossil fuel. The United States obtains 0·7 times, and the United Kingdom only 0·5. By contrast, subsistence agriculture may obtain between 10 and 40 times more food energy than it puts in. (Our ratio of fossil fuel put in to the food energy reaching our dinner tables doesn't look so good when food distribution and processing costs are added in. Every unit of food energy reaching the dining table requires at least five units of fossil-fuel energy to get it there.)

Incidentally, studies by Mr Kevin Handreck and Dr Arnold Martin, of the

For much of our native plant and animal life . . . the 'ecological crisis' came many years ago.

Division of Soils, suggest that there may be room for reducing our energy use by improved management on the farm. In their studies of a number of better farms in the wheat–sheep zone of South Australia, the researchers found considerable variations in the amounts of energy individual farmers put in and got out as produce.

Australian wheat crops yield about 1–1½ tonnes per hectare. The more-intensively managed commercial wheat crops in northern Europe yield 7–8 tonnes per hectare. In practice it seems unlikely that we will greatly increase the productivity of our wheat-producing areas. The late 1940s saw great increases in wheat produced per hectare following the introduction of the legume ley system. However, these increases had levelled off by the 1960s. New South Wales and Victoria, for example, have run wheat-yield competitions for the past 25 years. Yields have not increased during that time. Financial returns are not valuable enough to warrant more expensive inputs, and there don't appear to be any major technological breakthroughs—equivalent to the introduction of leys—around the corner.

Perhaps, when the need arises, the greatest increases in production will be achieved by turning over currently grazed land in the higher-rainfall areas to cropping.

Meat a luxury

Compared with growing crops, producing meat from pastures is an inefficient way of using the sun's energy. Even under ideal feed-lot conditions, 3 joules of grain energy produce only 1 joule of meat energy. Grazing animals would rarely reach this level of efficiency.

Over the years, upgrading the pastures of southern Australia with subterranean clover and superphosphate—and in the wetter areas with sown improved pasture grasses and legumes plus superphosphate—has greatly increased the land's productivity. Tropical pasture plants introduced and selected by the Division of Tropical Crops and Pastures and the Queensland Department of Primary Industries are bringing about similar increases in the northern half too. Nevertheless, meat is mainly a luxury product, eaten in large quantities only in the wealthy countries of the world. When the chips are down, cropping produces much the most food.

Even so, the grazing animal will always have a place. It turns plants we can't digest into edible protein in areas that cannot be cropped. (Remember, only 3 million of the 73 million ha in Mr Nix's northern region could be used for crops.) In addition, dairy cattle produce an easily distributed balanced food in the form of milk, which no doubt will remain a particularly useful commodity for feeding urban populations.

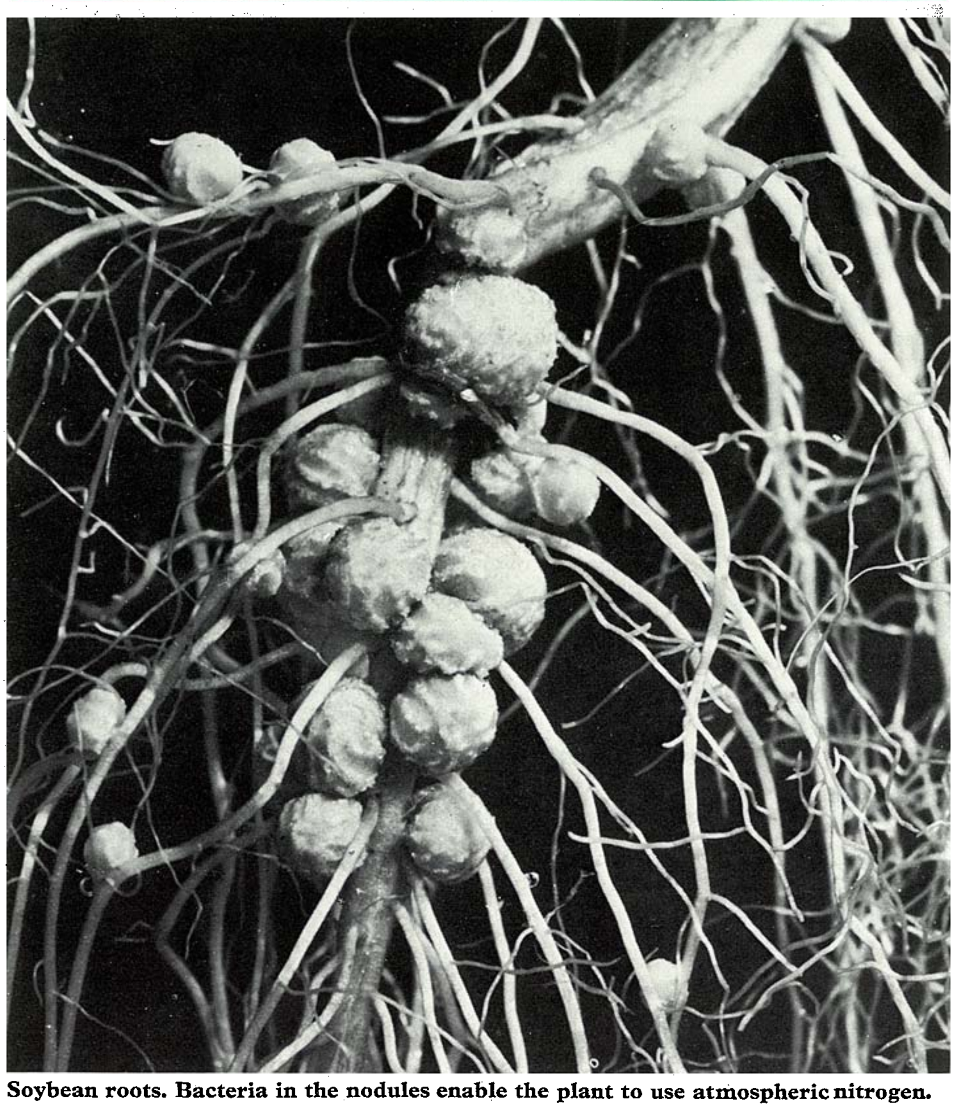
Looking ahead

Not *all* future ways of increasing productivity will necessarily increase the energy subsidy that we put in. For example, current research in CSIRO and elsewhere into mycorrhizas—an association of fungi with plant roots—shows that these in-

How Australia's energy usage compares with that in other developed countries

	energy used to produce food ($\times 10^{15}$ joules per annum)	energy in food ($\times 10^{15}$ joules per annum)	efficiency (input : output)
Australia	97	270	2·8
United States	2390	1750	0·7
Holland	140	90	0·6
United Kingdom	298	135	0·5
Israel	19·5	10	0·5

Australia seems to obtain 2·8 times more food energy on the farm than it puts in as fossil fuel. Other developed countries obtain less energy in the food than they put in as fuel.



Soybean roots. Bacteria in the nodules enable the plant to use atmospheric nitrogen.

It's better to help them grow grain where they need it than to ship food from Australia.

crease the efficiency with which plants take up phosphorus. Manipulating these may one day allow crop plants to make better use of less phosphate fertilizer. In addition, plant breeding will no doubt tune crops more finely to the environment in which they are growing. Further research into the *Rhizobium* bacteria that fix the nitrogen in legumes may well increase the efficiency of this process too.

Perhaps one of the most exciting prospects is the one of being able to get wheat plants to nodulate with *Rhizobium*. One day, it now seems, wheat and the other high-yielding cereals may be able to fix their own supply of nitrogen without the use of legumes—an idea that seems like science fiction.

In the north it's so rocky and the soils are so poor that only 3 million hectares could conceivably be cultivated.

Mining rock phosphate on Christmas Island. By substituting superphosphate for nitrogen fertilizer, we keep our fossil-fuel consumption down.

More about the topic

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