NUTRIENT DISCUSSION PAPER

Nutrients and the future of Australia

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Summary

Nutrients are the "oil" of the 21st century. They hold the key to the ability of humanity to feed itself through the steepest growth in population numbers and food consumption in history.

Based on past history and current trends, the cost of nutrients is likely to rise by 500-1000 per cent by the 2030s in response to growing populations, demand for better diets decreasing availability of fertile farm land and higher oil prices. Today's nutrient management involves the waste of very large volumes of nutrients off farm, from industry, in consumption and in waste disposal. Most of these wasted nutrients end up in the ocean: recycling is low. Australia has an opportunity to lead the world in replacing this unsustainable practice with a comprehensive approach to nutrient re-use and loss minimization.

In view of global nutrient scarcity likely to emerge towards the mid-century, there needs to be an informed national debate on the need to develop the world's first national nutrient plan to maximize re-use of nutrients at all points in the cycle.

This paper outlines some opportunities for re-designing the national nutrient budget.

A global nutrient crisis?

By the mid C21st, world food demand will grow by 100-110 per cent over current levels, due to a combination of a 50 per cent increase in the human population to 9.2 billion and rising living standards, involving better diets, in developing and newly-industrialised nations.[1] UNEP projects food demand to rise by 300 per cent in Africa and West Asia, by 100 per cent in the Asia Pacific, by 50 per cent in Latin America and by 13-15 per cent in North America and Europe.

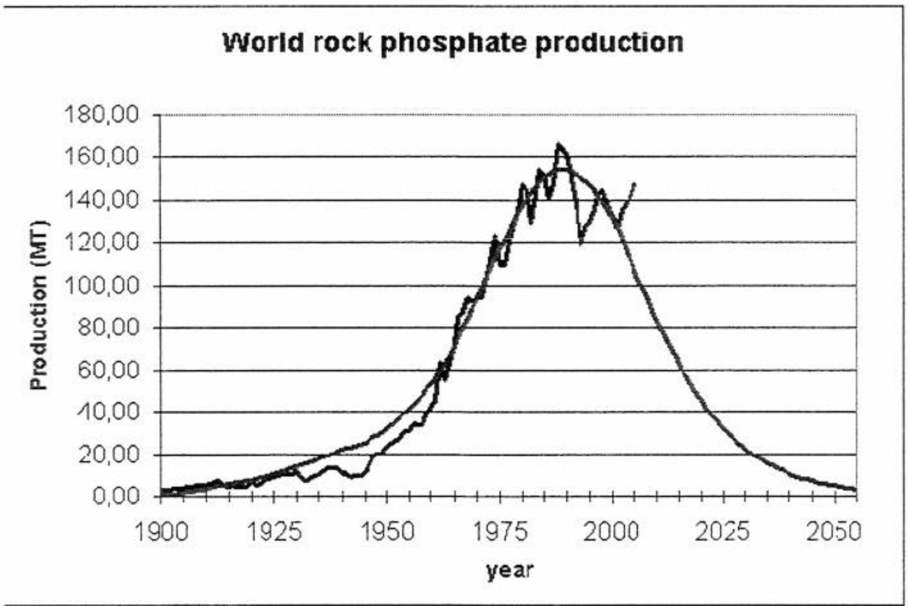
This massive increase in demand for food of all types will throw a proportionate pressure on the supply of nutrients to grow the necessary livestock, crops and fish. On the face of it, a doubling in food production would require a doubling in the nutrients needed to support it.

Entomologist Dr Peter Raven, one of Time Magazine's "Heroes for the Planet" and a former scientific adviser to the US President, has pointed out that humanity must live within the regenerative capacity of the environment – and that currently "We use, destroy, or divert about 45 percent of net terrestrial productivity".[2]

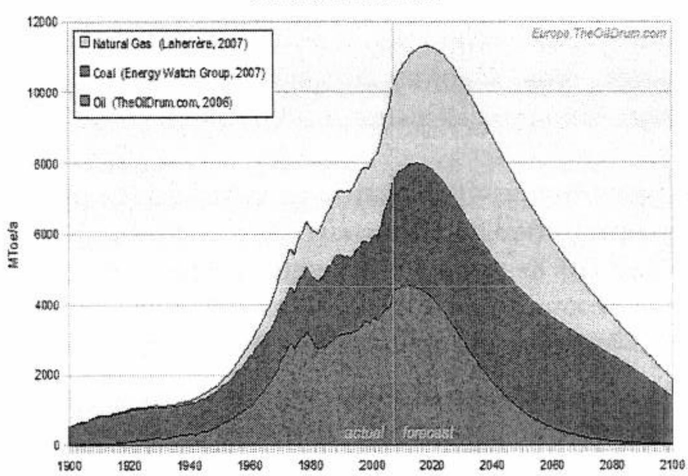
The primary source of this productivity lies in nutrients. Simple nutrients support all life on Earth. From microbe to plant to human being, every living organism relies on the molecule ATP (adenosine triphosphate) as the essential energy carrier in its cells. This makes the element phosphorus indispensible to all living things, while nitrogen is essential to all plant growth.

Nutrients used in advanced farming systems are mainly either mined (eg phosphorus, potash) or extracted from gases (nitrogen). On a world-wide basis they constitute about 28 per cent of agriculture's energy inputs and their prices are strongly affected by the price of energy, notably crude oil, for their extraction, manufacture and delivery. Adventitious disruptions in oil supply due to conflicts, trade rows, political and climatic events affect the world price of fertilisers.

While global supplies of phosphorus appear large, they are finite and will be subject to upward price pressure as world demand for food rises and oil prices rise and as the quality of mineable reserves declines. There are clear signs that the world has passed its peak in mined phosphorus production, though supplies remain adequate for day-to-day use. Canadian physicist Patrick Déry estimates the peak was passed in 1987.[3]



A similar situation applies to low-cost nitrogen fertilisers made from natural gas, which are likely to experience diminished supply as global natural gas reserves decline owing to 'peak oil'. The yellow component in the following graph is natural gas. Although it is possible to produce N fertiliser from air using other sources of hydrogen, these are more expensive and less efficient than the current Haber-Bosch process which is used to make 97% of the world's N fertiliser. The most obvious alternative, coal, has serious greenhouse issues.



FAO rates current global fertiliser supplies as "ample", noting consumption is currently around 205 million tonnes a year and that short-term demand growth for both N and P of 1-2 per cent a year is within the world's present capacity to supply.[4]

However as countries ascend the development curve and disposable incomes rise one of the first things to take effect is a change in diet from grains and vegetables towards protein products: meat, dairy, poultry, fish and eggs. Since it requires from 7-15 kilos of grain to produce a single kilo of meat, significantly larger volumes of crops are needed to satisfy this demand for meat – and hence demand for fertiliser to sustain the growth also increases many times. FAO estimates world meat production alone will grow by 185 million tonnes by 2050 which, if true, will require of the order of 2 billion tonnes of grain to feed the animals, and about 150 million tonnes more elemental nutrients to grow the grain.

If China attains western diets, Chinese per capita protein consumption can be expected to double (meat consumption has already tripled off a low base in the last 15 years and is now about one third that of the western diet). If Africa achieves them, its protein consumption will triple, and if India achieves them, protein consumption will increase fivefold in the subcontinent. This is in addition to any growth due to population increase.

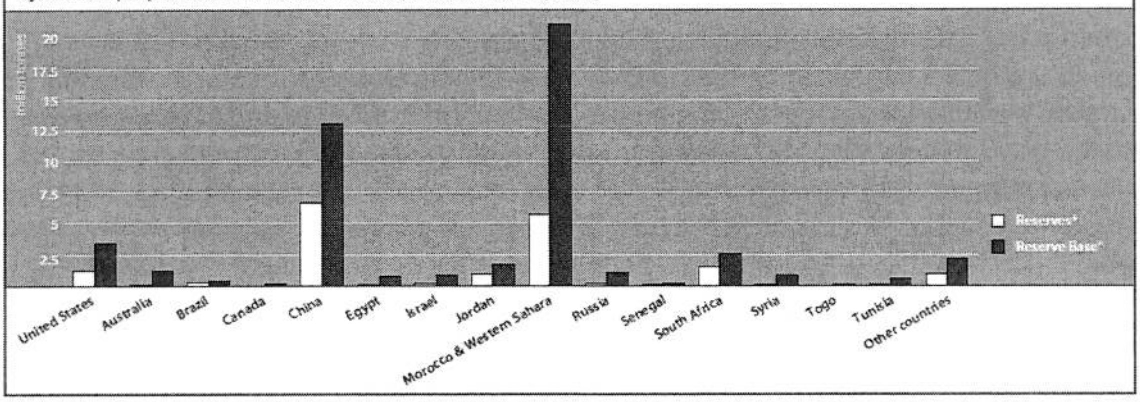
UNEP predicts the average person on earth with consume about 3000 calories a day in 2030, compared with 2800 today and 2600 in the 1960s.[5] This involves significant increase in demand for fertiliser.

Another important factor is the rate of increase in land degradation and the diversion of prime land for non-agricultural uses. It is currently estimated about 25 per cent of the world's farm lands are seriously affected by erosion, loss of nutrients, salinity and soil structural decline (FAO 2008)[6]; significant areas face desertification involving almost total nutrient loss; furthermore by mid-century the global urbanised area is likely to exceed the area of either China or the USA,[7] and consume some of the world's best soils. Reductions in arable area, the intensification of farming systems and the loss of nutrients through degradation will all increase global demand for fertilisers.

A third factor, not insignificant, is that in nations such as Brazil and the US, large volumes of crops are now turned into transport fuels. This move to biofuels signals that in future more fertilisers will be required to produce energy, rather than food. Even the transition to so-called "second generation" non-farm biofuels, such as oils made from algae, will require significant inputs of nutrients, and compete with those needed to grow food.

The most significant, yet largely unrecognized fact is the decline in quality of the world's rock phosphate reserves. Most of the high quality reserves have now been consumed and those remaining either have much lower levels of phosphorus or are in harder rock, meaning it may require from 3-4 times the amount of fossil energy to extract the same amount of nutrients. The following table, from Rabobank, illustrates the balance between high and low (base) quality phosphate reserves: [8]

Figure 9: World phosphate rock reserves* and reserve bases^ (million tonnes of rock product)



The table illustrates another issue of strategic concern – that the world's supplies of raw nutrients are in very few hands and if countries such as China (or Russia or Canada in the case of K) were to hold their reserves for domestic use entirely, other countries would find fertiliser very hard to obtain and very expensive.

A credible scenario for the coming half-century is therefore one of rising world nutrient prices in response to multiplying demands, dwindling supplies of mineable phosphate, potash and natural gas and potential withholding of stocks from the global market. This will echo the alarming upward spiral in fertiliser prices in the latter third of the 20th and early 21st centuries, when oil prices rose sharply prior to the economic slump.

The Australian price of single superphosphate rose from $16 a tonne in 1971 to $226 a tonne in 2005 – an increase of 1300 per cent - while the cost of a tonne of urea rose from $79 to $445, or 460 per cent.[9] On average Australian fertiliser prices have increased 10-fold (ie 1000 per cent) in the past 30 years in response both to rising energy costs and growing global demand for nutrients. This is roughly twice the rate of increase of oil prices.

A medium-term forecast by the International Food Policy Research Institute is for a 45 per cent increase in global fertiliser consumption within the coming 14 years.

Table 1--Fertilizer use, 1959/60, 1989/90, and 2020

	Fertilizer Use			Annual Growth	
Region/Nutrient	1959/60	1989/90	2020	1960-90	1990-2020
	(million nutrient tons)			(percent)	
Developed countries	24.7	81.3	86.4	4.0	0.2
Developing countries	2.7	62.3	121.6	10.5	2.2
World total	27.4	143.6	208.0	5.5	1.2
Nitrogen	9.5	79.2	115.3	7.1	1.3
Phosphate	9.7	37.5	56.0	4.5	1.3
Potash	8.1	26.9	36.7	4.0	1.0

Sources: FAO data, and IFPRI authors' calculations for 2020.

Notes: East Asia excludes Japan. West Asia/North Africa excludes Israel.

Based on the above, it is conceivable that global nutrient prices will rise of the order 500-1000 per cent by 2030, or in real terms by around 2 to 5-fold. This is a very conservative estimate.

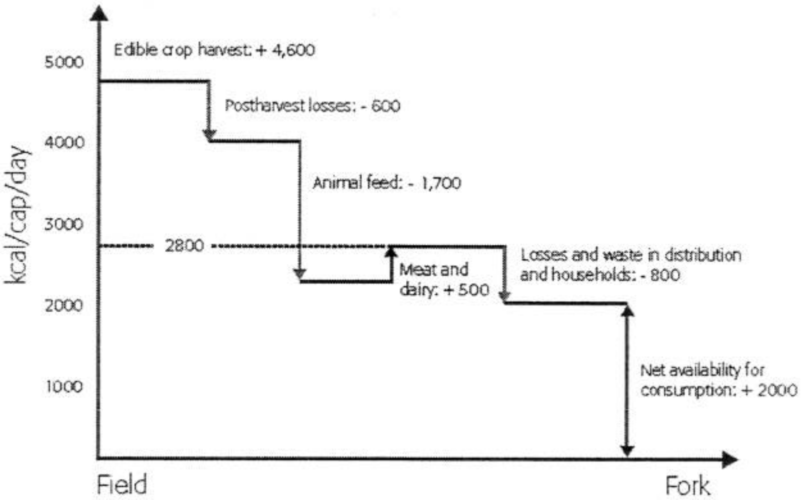
A wasteful system

For the first time in human history, the current pattern of global nutrient use is open-ended and unsustainable.

Nutrients are mined or extracted mostly from finite resources, used to grow crops and livestock on farms where they partly leave as produce or else leak into the environment. They travel to food processing plants where they either leave as food or waste, or leak into the environment. They are consumed by citizens whose waste either leaks into the environment (septic disposal or poor treatment systems) or else is usually disposed of in rivers and eventually the ocean.

This overall pattern of human nutrient use is one of waste. Eventually, most nutrients enter the sea. It is estimated that human activity is now releasing as much as 150 million tonnes of N and 10 million tonnes of P into the environment above what would be generated naturally, posing a growing and serious global pollution hazard, and threatening profound change to major ecosystems such as the oceans.[10]

The following table, from the Stockholm International Water Institute, illustrates how, of every 4600 kilocalories of food produced, the world currently wastes about 2600:



Arable and grazing systems also cause widespread erosion of soils and the loss of their natural nutrients to the ocean, by runoff, leaching or wind. This loss is taking place in accelerated geological time and signals that within a few decades nutrient levels will be seriously depleted in many countries, especially the poorer and drier regions.

At the same time shallow seas fed by large rivers such as the South China Sea, the Baltic, the Gulf of Thailand, the Mediterranean, the Black and Caspian seas, are being contaminated with nutrients at growing rates. The effect of this is to replace normal sea life – fish, crustacea and seagrass meadows – with blooms of microalgae and bacterial mats. The loss of nutrients from the land is thus also destroying harvestable primary productivity in the sea, and contributing to a reduction in the potential global seafood supply. Nutrients also contaminate fresh water supplies and marine estuaries and bays, making the water unfit for other beneficial uses including drinking, livestock production, food processing, recreation and aquaculture. In extreme circumstances some scientists fear there is a risk of creating a 'Canfield Ocean', an ocean devoid of oxygen and all higher forms of life, as probably occurred during the Permian and other great extinction episodes.

The Australian continent as 'teacher'

Australia, it has often been noted, is an ancient weathered continent whose inland nutrients have largely been stripped away over tens of millions of years since it entered the earth's dry, mid-latitude climatic bands. While there are areas of richness, chiefly on the coastal margins, around 70-75 per cent of the continent is officially rated as desert. Significantly, Australia shares these climatic features with nearly half of the world's population, including many of the poorest countries.

Australians first confronted the nutrient issue in the late-C19th, when crop yields began to collapse after only a few years of cultivation in newly-cleared native soils. The solutions, such as the 'sub & super' revolution, have sustained the nation's agricultural and general prosperity for the ensuing century and a half.

The droughts of the 1890s and 1940s, and 80s exposed a new hazard in the form of accelerated erosion, with many millions of tonnes of topsoil and nutrients displaced in individual dust events, much of it eventually being lost over the ocean. Recent studies indicate Australia again entered a "Dust Age", or period of increased topsoil loss, starting in 2002.

From the 1970s onwards the continent began to warn farmers of a new peril: salinisation. This often took decades to appear but by the mid-1980s was widespread enough in the wheatbelt to cause alarm, leading to the National Salinity Action Plan.

More recently still, the increasing frequency and extent of algal blooms in inland rivers and lakes, reservoirs, coastal lagoons and estuaries and even on the Great Barrier Reef, have raised concerns about the hazards of excess nutrients in ecosystems adapted to low-nutrient regimes, and their impact on water quality.

In each case, the Australian landscape has sent its occupants a clear and unequivocal warning of the consequences of unsustainable management, through the speed, extent and impact of the observable changes.

The continent of Australia is a 'teacher', providing rapid feedback on human activities which cause an imbalance in the cycles of water, soil and nutrients laid down over 60 million years. These experiences are by no means unique to Australia, but in other environments often occur far more slowly and less visibly, causing less alarm as changes take place over several generations and so elude the power of human memory. Each new generation accepts the landscape condition it finds as the norm, rather than as a waypoint in a centuries-long process of degradation. Only recently has science been able to reconstruct past environments to give some idea of the magnitude of the changes wrought by human activity.

Australians, in a sense, have "made all the right mistakes". The continent itself has exposed the consequences of our actions rapidly enough for government, industry and society to take heed and initiate remedial action. To its credit, the nation has largely begun this.

This places Australians in a position to better understand the processes involved in landscape degradation, including nutrient loss, to design appropriate solutions – and to share the knowledge with societies worldwide facing similar challenges.

It is no exaggeration to say that, in the 21st Century when human demands are on collision course with the planet's capacity to supply, this knowledge will prove of high value and may eventually constitute one of Australia's most distinguished contributions to human history.

Australia and the nutrient cycle

The past 10-15 years have seen a rapid advance in the consciousness of farmers of the consequences and extent of nutrient loss. This has been led by the dairy industry, in which sophisticated nutrient management is a necessity for maintaining high levels productivity, but is also a key issue in intensive livestock industries, the irrigation sector and coastal industries such as sugarcane.

Nevertheless, of the 2 million tonnes of fertiliser distributed annually on Australian farms it is possible up to half may escape into the environment by one route or another – in soil erosion, heavy rainfall and groundwater leaching. Research indicates that from 10-60 per cent of applied fertiliser is not used by the target plants[11].

Consequently Australian farmers are unintentionally fertilizing a large part of the environment which doesn't need it, and which may be adversely affected as a result. They may also be investing >$1 billion a year in nutrients which make no contribution to farm output, but add only to weeds, pollution of waterways and reduced water quality.

Put another way, the nutrients presently lost to the Australian environment could, if captured and used, feed up to 30 million more people on a western diet.[12]

One of the most striking aspects of the present nutrient debate is that fertilisers are regarded as an opportunity when they enter the farm – and a threat when they leave it (in an unintended fashion). If Australia loses up to a million tonnes of fertiliser nutrients a year, then not only is this a serious cost on farmers – but also an unexploited opportunity. It carries the theoretical implication that, other things being equal, food output could potentially double if only the nutrients could be retained and targeted to production. If they can be re-used more than once, production could increase significantly beyond this.

It is in changing this fundamental attitude to 'waste' nutrients that great opportunity lies – to view them instead as an immense and unexploited resource which can, with ingenuity, persistence and smart technology, be reclaimed.

While agriculture is losing nutrients, the off-farm food processing sector is also wasting an equivalent amount. Companies which process farm production together spend around $750 million a year in disposing of waste byproducts, as they are required to do by law. It is estimated that if this waste were recycled as fuels, feeds, fertilisers, bio-plastics and advanced biomaterials it would yield an income of around $500m and generate 8000 full-time regional jobs.[13]

Beyond the food industry, the catering industry and individual families are estimated to throw away from one third to a half of all the food wholesaled or retailed in Australia, representing a further huge loss of nutrients[14] (about one sixth of all the produce grown in this country, worth $5bn at the farmgate). This food mostly goes to landfill where its nutrients are wasted and can contaminate groundwater. In theory, our dumped nutrients could potentially feed a further 6-10 million people.

The following illustration, based on USDA data, shows how much food is wasted by the typical western family in a month:

Recycling – a semi-fashionable concept

Australians think nothing of recycling a beer can, glass bottle or cardboard carton, but many recoil at the thought of drinking water recovered from sewage effluent and purified. This is in spite of the fact that the selfsame H2O molecules have been through the digestive tracts of countless animals and people since they were first formed 4000 million years ago.

It has been estimated that Australia recycles around 2 per cent of all water used. Recycling of effluent water averages 10 per cent nationally, but in major cities is still only around 2-5 per cent, with the highest recycling in Adelaide, around 11 per cent.[15]

Nonetheless, public support for recycling of water in cities, in industry and on-farm is growing rapidly as the consequences of future water shortages and price rises became more widely known. Several cities now have effluent water recycling targets around 20 per cent, and most have a model recycling development such as Sydney's Olympic Park.

The objection is sometimes raised that wastewater or effluent may contain toxic heavy metals and other contaminants, as well as biological and other forms of contamination. However many advanced purification systems now exist which use membrane technology, metal scavenging, adsoprtion, phytoremediation, biofilters, oxidation and numerous other techniques capable of turning even the most polluted water to drinkable quality, at a price. Some of these can be used to harvest nutrients.

Recycling of mineral products, such as aluminium, is widely accepted and Australia currently re-uses the metal from over two thirds of aluminium cans. Globally 60% of the aluminium from cans and 95% from transport and other applications is recyled, supplying about a third of the world's new aluminium metal production.

Conceptually, there is no reason why Australia should not seek to 'close the loop' and re-use nutrients in a similar fashion to the aluminium and water sectors. This will involve significant savings in natural resources, energy, imports and environmental contamination.

The nutrient-neutral farm

The nutrient-neutral farm is an ideal in which all the nutrients which enter the farm as fertiliser are captured in the production process and leave it as livestock, milk, fodder or other produce.

While this is technically extremely difficult to achieve, owing to the range of pathways by which different nutrients may leave the farm under varying climatic, soil, topographical and management conditions, it nevertheless represents a goal worth striving for. The development of best management practices and decision support tools, like the Better Fertiliser Decisions guide, takes rural industry a significant stride towards achieving this ideal.

Examples of techniques that are helping the Australian dairy industry to reduce nutrient losses include:

- soil and plant tissue testing for better fertiliser planning
- whole-farm nutrient budgets and smart fertiliser software
- timing and choice of fertilisers to minimize potential losses
- improved riparian management and vegetated zones to reduce runoff to waterways
- use of deep-rooted pastures and trees to reduce soil leaching
- fencing stock out of waterways
- better irrigation management and use of tailings ponds
- improved capture, storage and recycling of effluent and crop wastes
- farm and catchment 'best practice' standards
- precision farming methods to distribute nutrients only where needed to maintain yields
- accurate prediction of pasture nutrient responses, leading to tailored application
- mapping of 'hot spots' where nutrients are prone to leak to the environment, and remedial action
- recovery of nutrients locked in soils of waterway sediments for re-use on farm
- collaborative efforts between farms in a catchment to reduce nutrient flows
- wide adoption of technical advice from nutrient experts and NR managers.

Widespread adoption of these techniques demonstrates the dairy industry's credentials as a leader in thinking about the issue of minimizing nutrient losses and finding practical ways to recycle them on-farm. Scientifically it has also invested heavily in understanding the pathways and conditions under which nutrients migrate within the landscape and waterways, and is thus in a position to provide knowledgeable advice on their wider management.

Towards a National Nutrient Plan

Just as it is the goal of the good farm manager to waste no nutrients, it should be the goal of a sensible Australia to preserve its productive potential into the future by minimizing the loss of nutrients in all situations and maximizing their re-use.

The nutrients currently lost out of agriculture, manufacturing and the food industry, urban sewerage systems and domestic consumption should be viewed not as a problem, but as a vital and valuable resource in a world in which they will become increasingly scarce and expensive.

The goal is to use, re-use and re-use nutrients again and again, as many times as possible before they make their ultimate way into the deep ocean

The nation which can most successfully 'close the loop' on nutrients by recycling in this fashion will be at a global economic, nutritional and competitive advantage as well as having cleaner water and a healthier natural environment. They will be more food secure on a planet destined for global food insecurity.

Possible ways in which nutrients can be re-used more effectively in Australia:

1. A national strategy for capturing and recycling of nutrients in urban sewage treatment plants into fertilisers and soil amendments, based on well-researched techniques developed by CSIRO and others, and advanced bioprocessing
2. A nationwide campaign to recycle or compost waste food in the catering industry and homes and a ban on sending food to landfill
3. Widespread development of algae farms and other advanced bioprocessing techniques for reprocessing waste from food and other rural manufacturing industries into fertilisers, biofuels, stockfeed, fine chemicals, bioplastics etc.
4. Wider on-farm use of perennial crops, deep-rooted crops, agroforestry and strip-farming techniques to intercept nutrients in groundwater and recycle them into timber, particle board, fruit, charcoal, flowers, bio-pharmaceuticals, fodder and stockfeed, electricity and biofuels.
5. Development of new urban food producing industries ("green cities") using recycled water and nutrients to grow vegetables, fruits and fish by hydroponics or aquaponics.
6. New urban food production systems using recycled water and nutrients to grow nourishing foodstuffs in bioreactors from microbial, fungal or plant cells.
7. Use of instream aquaculture and algae culture to harvest nutrients in running water, reservoirs and lagoons, including polyculture (eg prawns, shellfish and algae in sequence)
8. Creation of 'farmable wetlands' and phytoremediation to harvest nutrients from surface runoff or urban landfill sites and convert them to crops of economic value as food, fodder, silage, organic fertiliser, cut flowers etc.

9. National infrastructure standards for design of farms, roads, buildings, urban developments etc that minimize nutrient loss and allow for their capture and re-use eg urban stormwater traps and ponds, aquifer recharge, advanced bioprocessing.
10. Development of strategies for remobilizing nutrients trapped in sediments in drains, rivers, weir pools, reservoirs, lagoons and estuaries for re-use.
11. Development of sophisticated bio-farming techniques which use tailored suites of soil micro-flora and –fauna to mobilize trapped nutrients and increase their availability to crops and pastures.
12. Development of filtration and harvesting techniques for gathering algal blooms in lagoons and estuaries and reprocessing them into usable products.
13. Breeding of less nutrient-dependent crop and pasture cultivars
14. Extensive scientific research into 'organic' farming methods to identify those with optimal proven potential to conserve, recycle and mobilize nutrients
15. Development of extensive[16] marine 'grazing' systems that enable sustainable wild harvest of fish, shellfish and algae inshore to recapture nutrients one more time before they enter the deep ocean
16. Mining or phyto-mining of enriched aquatic sediments for nutrients
17. Advanced measures to curb wind and water erosion within the landscape, and especially large dust storms
18. Public education on the important of nutrient conservation.

These are intended to illustrate the types of approaches which could be developed under a National Nutrient Plan aimed at maximizing the re-use of nutrients within Australia by 2050 and reducing national dependence on imported and artificial fertilisers.

The benefits of doing this include:

- Lower farm input costs
- Cheaper food
- Increased food security
- Reduced import dependency
- Reduced environmental damage / healthier landscapes and water bodies
- Cleaner water
- Enhanced soil fertility (and increased carbon lockup)
- More competitive food exports.

Is nutrient recycling feasible?

Nutrient recycling is as old as agriculture, from the manuring of fields and the planting of legumes to Chinese urban night-soil collection. However the advent of huge volumes of industrially-produced fertilisers in the mid 20th Century has replaced these formerly sustainable techniques and introduced instead a culture of waste which would appall our ancestors.

It could be Australia's mission to reverse this attitude and instill a culture of re-use.

Nutrient recycling is difficult in a farm context, because of the way different nutrients move through the farm landscape in response to climatic drivers. Nevertheless the dairy industry has successfully demonstrated a wide array of management tactics which improve the retention and re-use of nutrients. Many of these principles can be applied in other farming industries, and in the wider community, including urban settings (eg recycling urban organic waste, creating nutrient traps etc). At the national level the challenge is great, but is enhanced by the fact that our cities themselves are vast nutrient traps gathering huge quantities of these precious substances in sewage plants, food factories, stormwater systems, urban landfills etc.

There are several preconditions for a National Nutrient Plan to emerge:

- greater awareness in the community and among policymakers of the extent and dangers of nutrient loss, informing a national policy decision to tackle the issue over the long term
- greater awareness and dialogue about the national economic, social, industrial and environmental benefits of harvesting and re-using nutrients
- a strong alliance of industries and groups with an interest in the issue, such as:
    - dairying, beef feedlotting, pork, poultry & aquaculture
    - sugarcane, legume and grain producers
    - organic and biodynamic producers
    - the water and waste management sector
    - the food, fibre, timber and other processing industries
    - environmental protection and clean-up
    - biotechnology and bioprocessing
    - industries based on the products of nutrient re-use (food, fuel, electricity, chemicals and biomedical, stockfeed, fertiliser, aquaculture etc)
    - urban design, engineering, infrastructure
    - local, state and federal government
    - green technology exporters
    - consumers.
- a national forum for discussion of nutrient issues, technologies and ideas
- a triple bottom line analysis of costs and benefits from an NNP
- development of a nutrient industry export cluster to foster industry standards and knowledge exports in the field.

Conclusion

Nutrients are the "oil" of the 21st century. The nation which looks after and re-uses them will prosper both economically and environmentally. It will never hunger.

Nations which fail to safeguard their nutrients will pay a high price in soaring food costs, growing scarcities and resulting political instability, government failure and even war.

It is not a difficult choice to make.

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[7] Sundquist B, "Urbanization-Caused Topsoil (Cropland) Loss," chap. 6 in *Topsoil Loss and Degradation,* http://home.alltel.net/bsundquist1/se6.html#D
[8] Rabobank, "Fertiliser: A Precious Commodity," Rabobank Global Focus report, summer 2007, fig. 9.
[9] ABARE: Australian fertiliser prices, by type, 2006
[10]Johan Rockstrom et al., "Planetary Boundaries – A safe operating space for humanity", Nature, September 23, 2009.
[11] Blaesing D., Controlling N losses – can we learn from the European experience? 2005
[12] Australia exports approx. two thirds of its farm production. Since it feed 22m people with the remaining third, it follows that the country annually supports the equivalent of 66m people globally, or even more on a lower diet. If half our nutrients are lost, this represents an opportunity to feed half as many people again.
[13] CRC draft proposal.
[14] University of Tucson, Arizona (2004) estimated 40-50% of US food is currently discarded. UK Government (2005) estimates one third of British food is wasted.
[15] Water Recycling in Australia, ATSE 2004.
[16] EG re-seeding of marine stocks of fish, shellfish etc in bays, estuaries and coastal lagoons to harvest nutrients lost from the land . This extensive form of management may be thought of as undersea "pastoralism" as distinct from intensive aquaculture which is often fraught with nutrient and disease problems.

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