CAN OCEANIA RESPOND TO A P CRISIS?

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Abstract

Food security is dependent on many factors, one of which is the availability of phosphate (P) either from the soil resources or applied fertilizers. Of the global production of P, Oceania uses about 4.3% of the world's usage and Australia and New Zealand [ANZ] combined account of more than 99% of the P used in Oceania. On a per capita basis, Australia and New Zealand consume P at almost 8 times the world average; most of this P is from North Africa, China and the USA. This is not going unnoticed in world circles. As a consequence, many will say that ANZ are inefficient users of P and therefore should cease or reduce agricultural activities. This paper will refute these global assertions.

ANZ are exporters of several important staple foods and other agricultural commodities. These agricultural products vary in their P density and hence the rate at which they drain P reserves. Thus it is essential to develop balance sheets for P as a prerequisite to assess the impact of P shortages on the sustainability of an industry. Furthermore, the value of nutrients, especially P, in exported foods needs greater recognition. The long term effects of a negative P balance are likely to be relatively severe for the small islands of Oceania as well as some pastoral industries in Australia.

As P is a non renewable resource, strategies for efficient P utilization and recycling should be developed. This is irrespective of the timing of peak P. Implications for restricted P supply or price spikes on food security are discussed.

Introduction

Our global estimate of the metric tonnage of phosphorus (P) and phytic acid (PA, or myo-inositol hexa*kis*phosphate) removed annually from crop lands in harvested dry seeds, grains and fleshy fruits containing seeds revealed that, on average for 1995-2003, the 2.8 billion metric tonnes (t) produced each year contained over 7.5 million t of P and 20.6 million tonnes of PA (Lott et al 2000, 2002). If corrections are applied for underestimates for clearly stated reasons, the production was likely 4.1 billion, P content of those crops was 12.2 million t and the PA content was 33 million t (Lott et al 2002). The dry cereal grain plus the dry legume seeds produced globally formed 77% of the annual production of these key crops and accounted for about 90% of the total P removed from the land with the harvest of these crops (Lott et al 2002). These are by far the most important food sources and are the dominant component in P utilization, so in subsequent research, we concentrated on the dry cereal grain plus dry legume seed crops and broadened the scope of our estimates to include production, area farmed to grow these crops, yield, P content and did so not only for global data but for Africa, Asia, Europe, North/Central America, South America and Oceania (Lott et al 2009). We also prepared estimates for individual major crops, namely, barley, maize, rice, wheat and soybean; and we related the P removed with all these crops to the mineral P fertilizer applied for all purposes. Asia harvested nearly half the global production of dry cereal grains plus dry legume seeds, used by far the greatest land area to grow these crops, removed the greatest tonnage of P in the harvested crops and used well over half of the elemental P in mineral fertilizers used world wide for all purposes (Lott et al 2009). Recently we studied data on production of cereals plus legumes, area farmed to grow these crops, P removed in these harvested crops, and mineral P fertilizer used for all purposes. When regions were compared, Oceania was distinct in having a very high P fertilizer usage per capita (Lott et al 2011).

The information presented here is a closer examination of the situation in Oceania with regard to usage of P fertilizer, the P content of exports, and gives interesting insights into population growth in Australia, New Zealand and the numerous smaller islands comprising the Oceania designation used by the United Nations.

Materials and Methods

Data for human populations of the world and its regions including Oceania were sourced from UN databases (United Nations, 2010). Population values were very close to data used in Lott et al (2009, 2011) which were sourced from the UN Demographic Yearbooks. The United Nations (2010) does not include a number of small islands in its population statistics for Oceania; based on data provided by Internet World Stats (2011), the United Nations data may underestimate the population of Oceania by about 300,000 ie an estimated error of about 1%.

The Food and Agriculture Organisation (of the United Nations) includes more countries in their statistics for Oceania than does the Population Division of the United Nations. Table 1 lists the countries in these two databases. Thus, the UN Population database underestimates the population of Oceania. Data presented later for the "small islands"[1] whose combined population is approximately 10 million people, have not been corrected but may have an underestimate of 3% cf. 1% for Oceania.

Table 1. Comparison of the Countries listed in the UN Population and FAO Databases that comprise Oceania.

UN Population Database	FAO Database
Australia	UN Population Database PLUS
New Zealand	Kiribati
Fiji	Marshall Islands
New Caledonia	American Samoa
Papua New Guinea	Palau
Solomon Islands	Cook Islands
Vanuatu	Tuvalu
Guam	Nauru
Micronesia (Federated States)	Tokelau
French Polynesia	Niue
Samoa	Northern Mariana Islands (USA)
Tonga	Wallis and Futuna Islands (Fr)

[1] Small islands are defined here as all of Oceania less Australia and New Zealand.

Statistics for global P usage, as well as for countries in Oceania, were obtained from FAOSTAT (2011) for the period from 2003-2009 which are the most recent data. Data from 1995 to 2002 were the data used by Lott et al (2011) and obtained from FAO Fertilizer Yearbook (2004). FAO adopted new methodologies in 2006 that resulted in some re-evaluation of the data for 2002 and subsequent years. Notwithstanding this change, the trends in the data are more important than the variation between the old and new data sets published for 2002.

The concentration of P in major exports (defined here as >100,000 t) from countries in Oceania was obtained from numerous sources some of which are presented in Table 2.

Prices of commodities were sourced from FAOSTAT (2011) and were obtained from official country estimates. Fertilizer prices were obtained from distributors in Australia and New Zealand and were confirmed with ABARES data and historical world prices (Index Mundi, 2012)

Growth rates of the human populations were fitted to the model using PASWStatistics 18.0 (Lott et al. 2011):

$$Population = ae\hat{}cy$$

where a is a constant, e the exponential function, c is growth rate constant and y is actual year. For the purposes of this paper, it is the c value which is the determinant of how fast a given population is growing.

Table 2: Phosphorus concentration in major export commodities from Oceania countries and, in some cases, the P concentration in non Oceania countries or regions.

Species	**P (%)**
Alfalfa/lucerne (Medicago sativa)	0.3
Wheat (Triticum aestivum)	0.32 (Aust) 0.385 (Canada)
Barley (Hordeum vulgare)	0.26
Canola (rapeseed) (Brassica napus)	0.35-0.4 (Aust) 0.7-0.8 (Canada)
Chickpea (Cicer arietinum)	0.37
Orange (Citrus sp)	0.021
Oats (Avena sativa)	0.35
Kiwi fruit (Actinidia chinensis)	0.032
Apples (Malus domestica)	0.016
Pumkins, squash, gourds (Cucurbita sp.)	0.077
Potatoes (Solanum tuberosum)	0.2
Milk	0.083 (NZ) 0.075 -0.092 (Aust) 0.093 (Canada, France)
Tallow	0
Wine	0.0135 (Canada?) 0.017 (Aust)
Meat Cattle	0.2
Meat Lamb	0.2
Butter	0.018
Whole milk dry	0.733
Skimmed milk dry	0.997
Onions	0.032
Cheese	0.48
Sugar	0
Palm oil	0
Molasses	0.013
Malt (barley)	0.303
Cotton lint	0.095
Wool	0.012 (NZ) 0.0137 (Aust, US)
Pet food	1
Water	0.001 (Sydney, Aust)

Various sources including Reuter and Robinson (1997), Lott et al. (2000), Australian Food Standards NUTTAB2010 (2010), Bowes and Church in Pennington (1998) and Ministry of Health (2009) NZ Food Composition Tables.

Results and Discussion

World P Consumption

Global P consumption for agricultural activities has generally increased over the 16 year period with a correction occurring post the global financial crisis (Figure 1). However the most recent available data suggests some recovery in P usage. Asia is the dominant consumer accounting for 65% of the world's current consumption whereas Africa and Oceania each utilize between 2 and 3% of the global consumption.

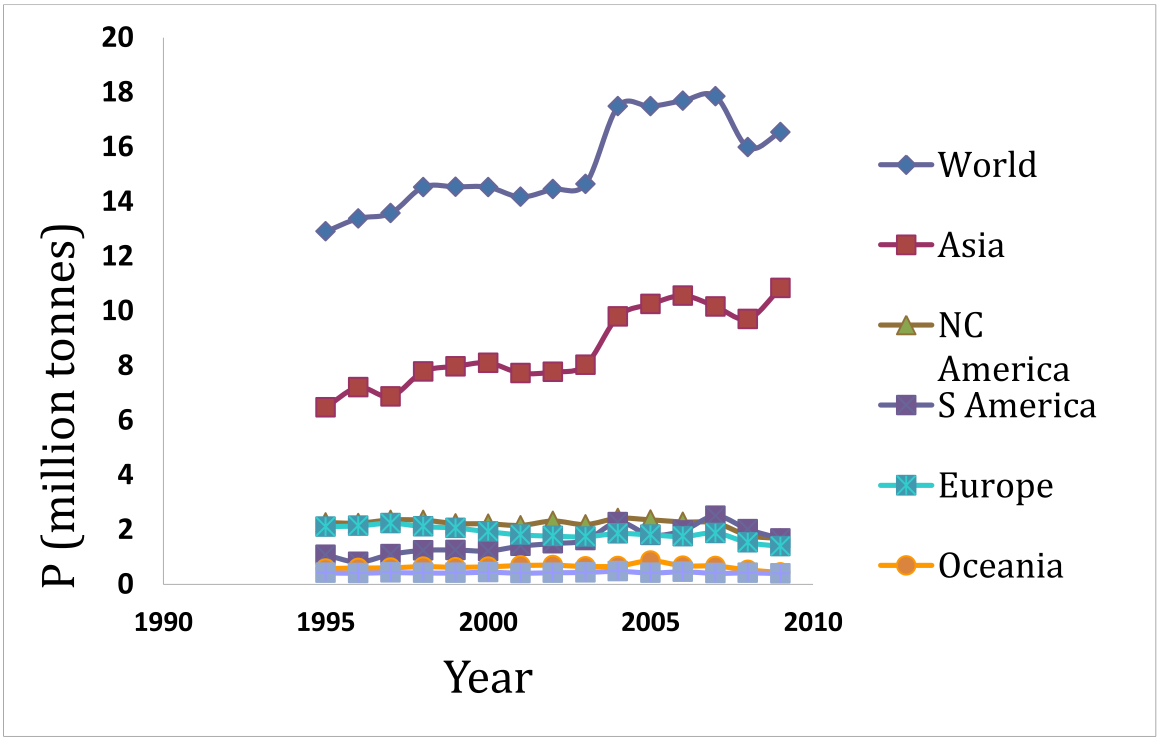

Figure 1. Consumption of P for agriculture in the world and its six major regions.

On a per capita basis, Oceania has used about 8 times the world average over the past 15 years but this has fallen recently to about 5 times the average (Figure 2). Europe's consumption on a per capita basis has remained steady and is close to the world's average. Africa consumes about 0.4kg P/capita and this suggests that crops and pastures in that continent may well respond to P fertilizers. On the other hand, usage of P per capita in South America is increasing ie P is applied to soils at a greater rate than the rate of population increase. North American per capita consumption has declined slightly since the global financial crisis but not as fast as in Oceania

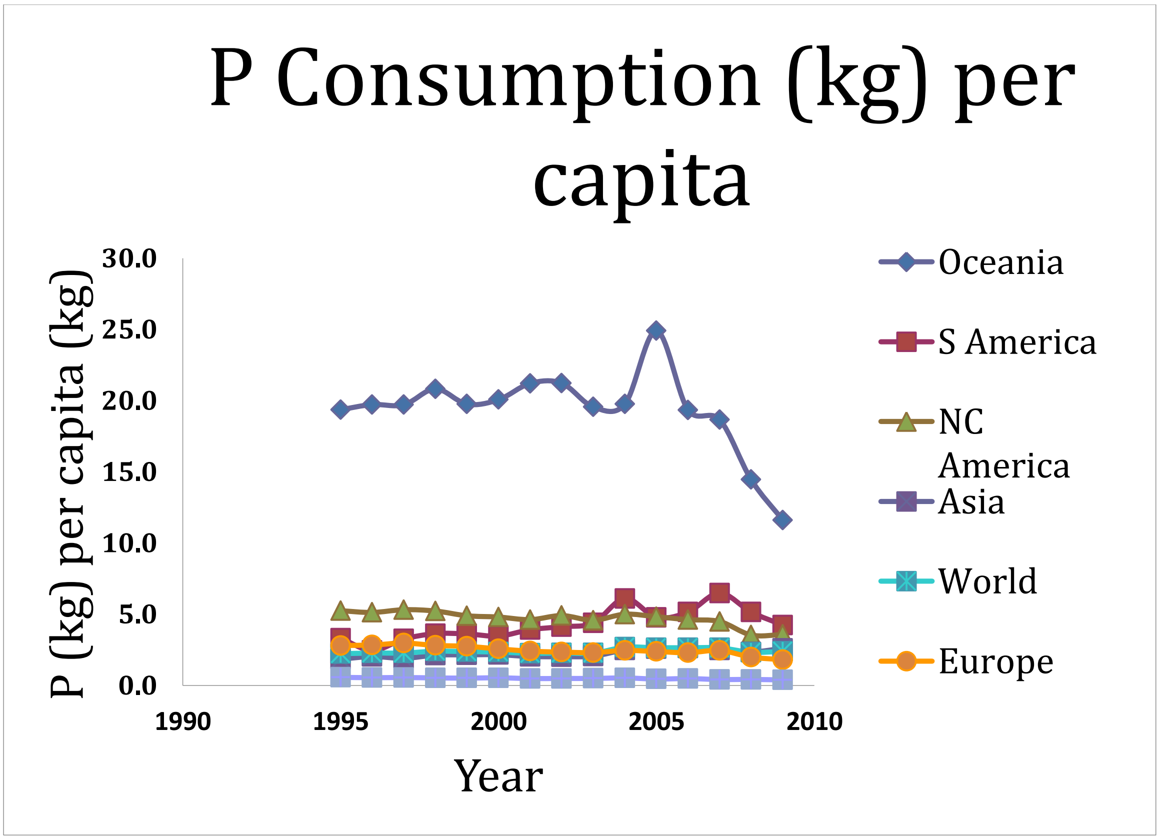

Figure 2. Consumption of P on a per capita basis for the world and its six regions.

Population in Oceania.
The population in Oceania has increased by more than 25% in the 15 intervening years from 1995. This increase in population has been greater in the 'small islands' than in Australia and New Zealand. The population is increasing exponentially in all groups (Figure 3). New Zealand has the lowest population which is increasing slightly at a slower rate than Australia's population. It is likely that the population growth in the small islands is largely natural increase whereas the population growth in New Zealand and Australia includes substantial immigration.

Population growth contributes to many challenges from demographic, to infrastructure to environmental to food security. Typically, as a population grows then the need for more land (for housing) increases. This can be at the expense of agricultural land from subsistence plots to larger peri-urban areas. As a consequence, more agricultural production is required from less land. This may well be happening on a global scale but has not been detected in Oceania due to the highly variable climate (largely rainfall) that affects the area used for agricultural production cf. Lott et al. (2011). Notwithstanding this comment, the vulnerability to decreasing land resources especially of the small islands is increased. Higher production per unit land requires high levels of management and favourable climatic conditions. This does not necessarily occur each season or year. Therefore, the risk of food insecurity increases or leads to increased dependence on 'food' imported from non local suppliers.

As a population increases, there is greater pressure on the environment – from vegetation to soils to water capture to provision of infrastructure. In particular, little attention is paid to the cost per capita of additional infrastructure. In the context of this paper, these factors impinge on P usage from changes in the soil P bank to application of P fertilizers.

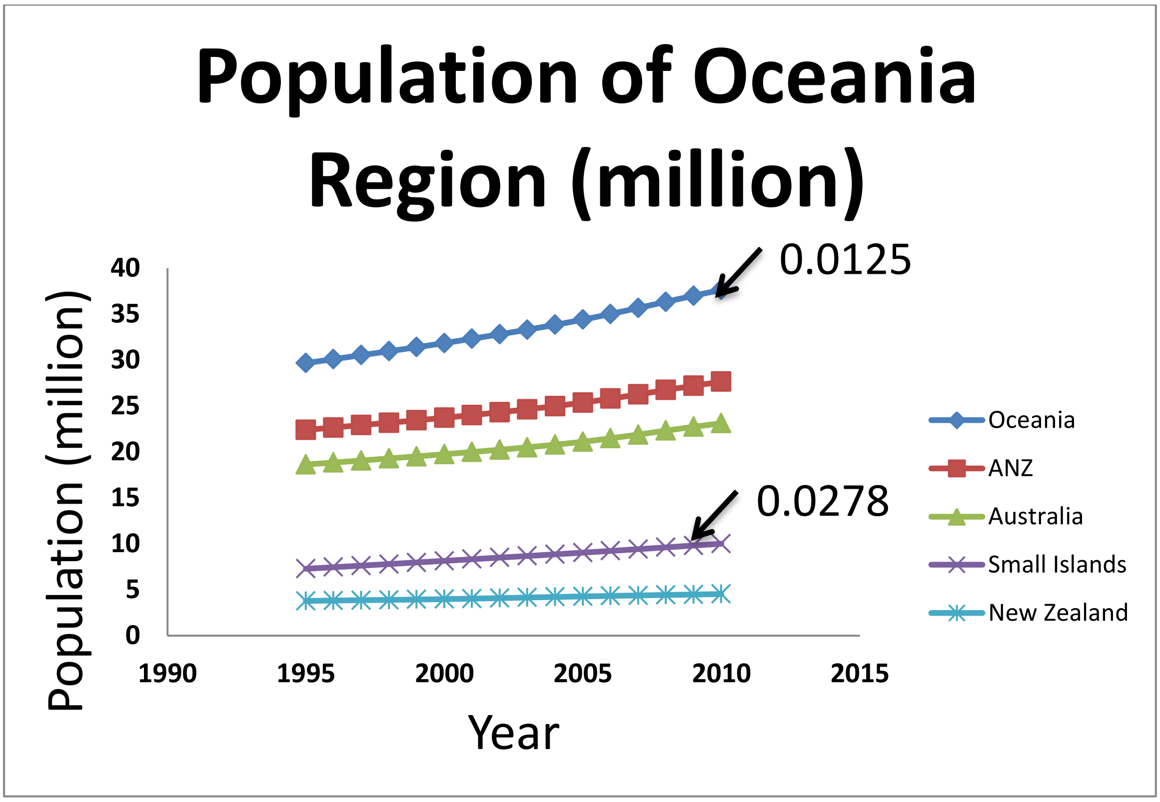

Figure 3. The population of Oceania, New Zealand, Australia and small islands during the period 1995-2010. The number against each curve is the exponential coefficient relating to growth.

Consumption of P in Oceania as influenced by population.

Phosphorus consumption per capita varies widely between various countries in Oceania (Figure 4). On this basis, New Zealand uses more P per person than any other country in Oceania and this usage is about 20 times the world average over the period. It is still about 2.5 times greater than that of Australia. In both Australia and especially New Zealand, per capita consumption has fallen markedly after the global financial crisis and the enormous spike in the price of P that occurred in 2008.

Phosphorus usage per capita in New Zealand is high in part due to the low population and that it is an agriculturally export nation. Notwithstanding this comment, the large increase in P usage in the middle of the first decade of this century does not have a ready explanation. An argument could be raised that there is a degree of inefficiency of P use as evidenced by the huge recent decline in P use per capita. New Zealand's P usage may reflect the proportion of P fixing soils in agricultural areas.

The small islands have low consumption per capita rates of application. In fact, there are some small islands that have no P application at all. Although a couple of the small islands are virtually sitting on P reserves (eg islands exporting or having exported P), there are others that do not enjoy that luxury.

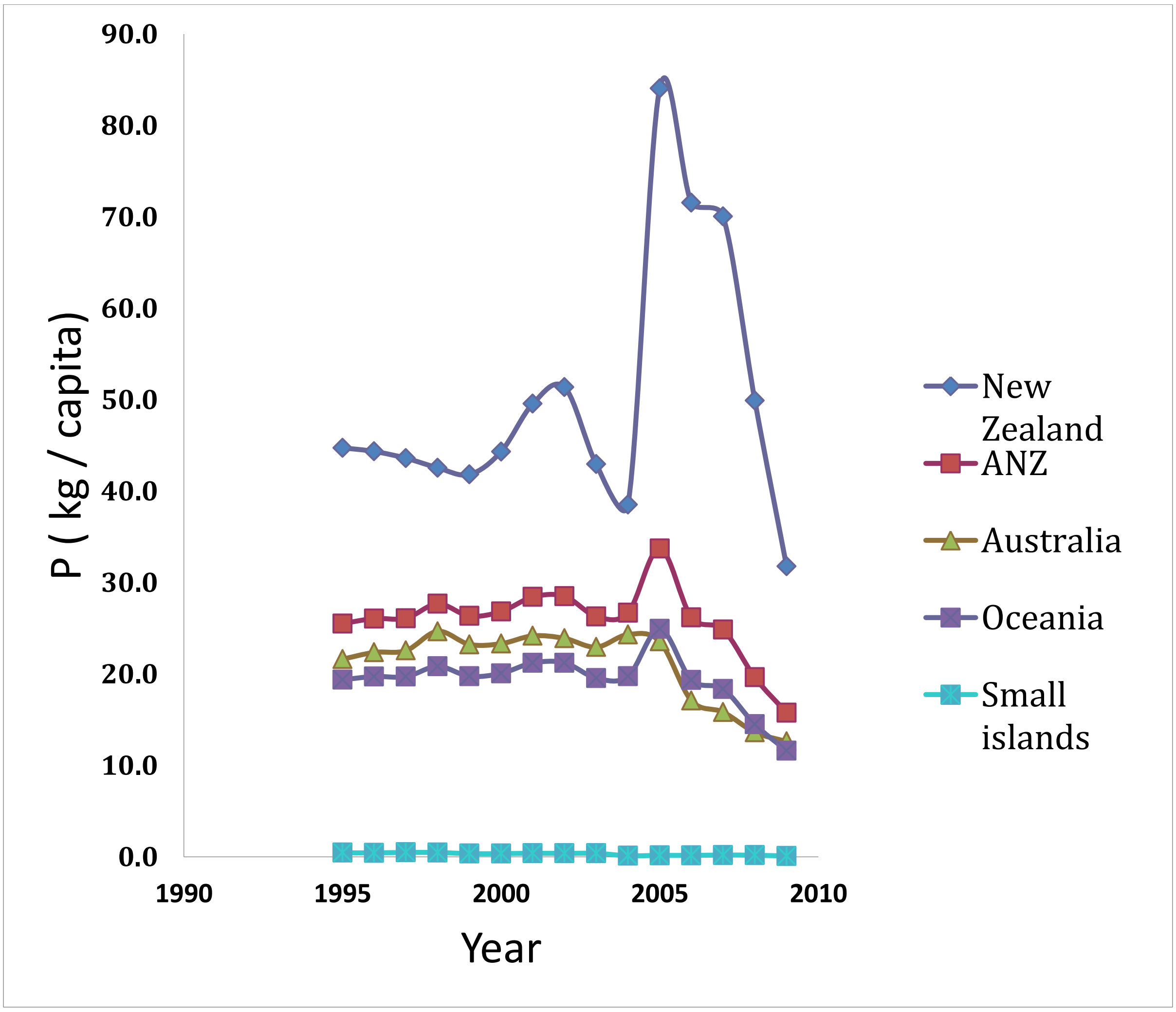

Figure 4. Consumption of P per capita in Oceania including Australia, New Zealand and small islands over the period 1995-2009.

Agricultural commodity exports

Both Australia and New Zealand produce far more agricultural commodities than can be consumed domestically. To some extent, both countries can be considered 'bulk commodity' exporters; a classic example is Australia's wheat exports of some 17 million tonnes. Likewise, dairy products are clearly leading New Zealand's exports. In fact, the major exports of Australia and New Zealand can be grouped into grains, dairy, meat and horticulture (Table 3). All these products have varying concentrations of P and it is this P that is subsequently exported. In contrast, Fiji's major export is sugar which has a negligible P concentration. The question then becomes of recycling P residues and whether this occurs and across which regions of Fiji. Interestingly, Fiji's other major export is water which presumably contains low concentrations of P.

Table 3. Some major exports (>100,000t) of Australia and New Zealand.

Australia	**New Zealand**
Wheat	Whole milk
Barley	Skimmed milk
Lucerne (Alfalfa)	Wine
Canola (Rapeseed)	Cheese
Chickpeas	Sheep meat
Cattle meat	Cattle meat
Skimmed milk	Kiwi fruit
Malt	Butter
Pet food	Apples
Cheese	Onions
Sheep meat	Food Preparations
Oats	

Should P be valued?

As most agricultural exports are relatively rich in P, it follows that part of the value of the commodity should be attributed to the amount of P present. For example, the average value of P exported in grains from Australia is about $NZ 15 tonne of grain (Table 4). In simple economic terms, New Zealand milk products export up to nearly $NZ 50 tonne. When this is compared with the value of the commodity, New Zealand agricultural products have low percentage (<2%) value with respect to P. Nevertheless, it still reflects large amounts (weights) of P being exported. Horticultural produce is particularly low in P.

Australian commodities have a much higher percentage of their value (up to 6%) exported as P. In other words, Australian farmers profit margins are more constrained when compared to dairy farmers.

Although very low in percentage terms, considerable value with respect to P is exported in meats. However, many of the areas where meat is produced have low or nil P inputs; one consequence is that soils in these regions are becoming progressively depleted as the soil P bank declines.

The situation of P in milk is worthy of further research. As P is associated with both milk solids and whey fractions, there may be scope to reduce the concentration of P in one or both fractions. In the Northern Hemisphere, where cows are fed a high percentage of their diet as grains, milk tends to be higher in P than the milk from New Zealand. This suggests that there is an influence of diet on P in milk. However, the effects of breed and climate (temperature) should not be discounted. An alternative research approach is to hydrolyse some of the P associated with proteins or lipids for example. Capture of P from milk is likely to be much effective in the short term compared to changing inputs, breed or climate. If half of the P in skimmed milk could be captured for recycling, the value to dairy farmers would be considerable.

Table 4. The economic value of P exported in some major commodities of Australia and New Zealand

Commodity	Value of P exported ($NZ/t)	The value of P exported as a percentage of the value of the commodity (%)
Wheat (Aust)	15.58	5.8
Barley (Aust)	12.66	5.5
Lucerne (Aust)	14.61	5.2
Canola (Aust)	19.48	3.6
Chickpea (Aust)	18.02	3.3
Oats (Aust)	9.74	6
Skimmed milk (NZ)	48.7	1.8
Whole milk (NZ)	29.71	1
Cattle meat (Aust and NZ)	9.00 (approx)	0.2
Kiwi fruit (NZ)	1.3	0.1
Onions (NZ)	1.22	0.3

Countries with positive and negative P balances

Most countries that export commodities in Oceania have a positive P balance when a crude measure of P exported and P consumed is used (Table 5). Also there are a number of small islands that are neither exporting commodities nor importing P. Of the commodity exporters, the Solomon Islands and, to a lesser extent, Vanuatu are in negative balance. These countries and perhaps with Papua New Guinea are most at risk if a P crisis develops. Furthermore, the populations of these countries are increasing and thus will place more demands on food and therefore P. When one of the human basics is not met, it can easily result in social unrest or migratory pressures.

Table 5. A simplistic balance sheet of P fertilizer inputs less the estimated amount of P exported in commodities from a selection of Oceania countries.

Country	P Balance (+ve or –ve)
Australia	+ve
Cook Islands	+ve
Fiji	+ve
French Polynesia	+ve
New Caledonia	-ve
New Zealand	+ve
Niue	-ve
Papua New Guinea	+ve (marginal)
Samoa	+ve
Solomon Islands	-ve (strongly)
Tonga	+ve
Vanuatu	-ve (moderate)

What may constitute a P crisis?

A number of scenarios could generate a P crisis in terms of reduced P applied for agricultural purposes. Perhaps the most likely reason behind a reduction in P applications is a price spike in P due to an imbalance of supply and demand. Thus the price spike in 2007 was triggered largely by huge demand pressures resulting in P prices increasing fivefold for triple superphosphate (Figure 5). As well as the increased demand for P, input prices, particularly energy, also rose. The sudden decline in prices may be due to reduced demand (at a given price), the global financial crisis, existing on stocks on hand or running down the soil P bank.

Other scenarios that could result in P include: geopolitical factors that stop the mining, embargo of raw P, export controls or tariffs, disruption of transport routes, oil availability and its price, war, P use for non-agricultural activities, depletion of resources including P etc. P resource depletion will occur at some time but there is debate about the time of peak P.

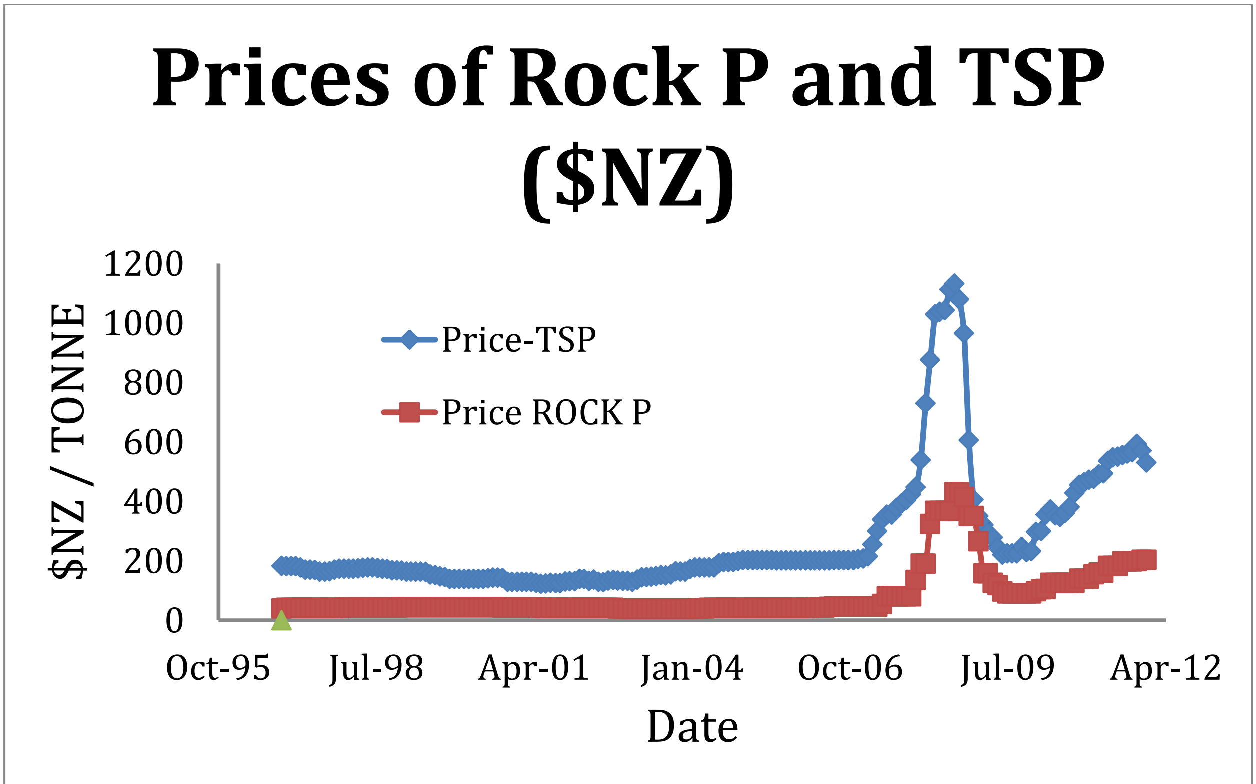

Figure 5. The global price of P over the period 1995-2010. Source: Index Mundi.

Irrespective of the time of peak P, strategies should be developed to meet a P crisis. Some strategies are: (i) maintain a stockpile of P to offset short-term spikes and minor disruptions to the global flow of P (ii) develop [plant] genotypes that exhibit P use efficiency (iii) develop plant root systems that can acquire fixed P in soils (iv) understand the chemistry of soil P fixation with the aim having a chemical solution to the dissolution of P from soils (v) reduction in the human population over a few generations (vi) extraction of P from marine sediments and (vii) various recycling strategies.

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