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Approaching the limits:
Feeding +9 billion humans whilst sustaining civilisation

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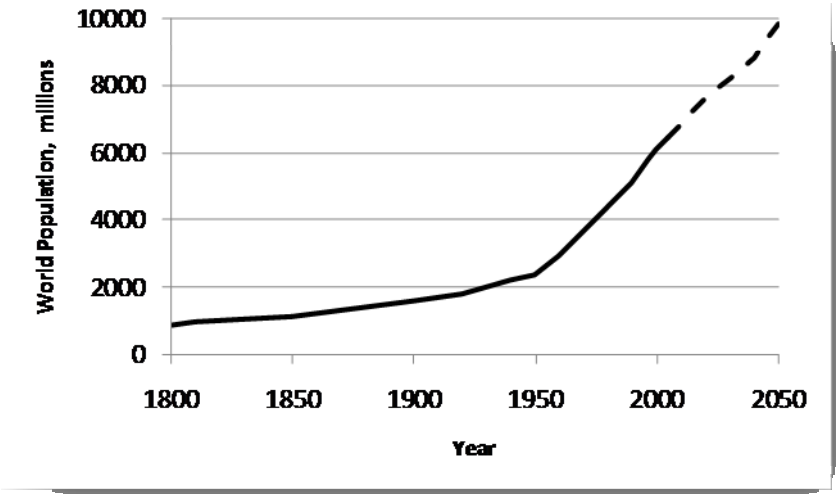
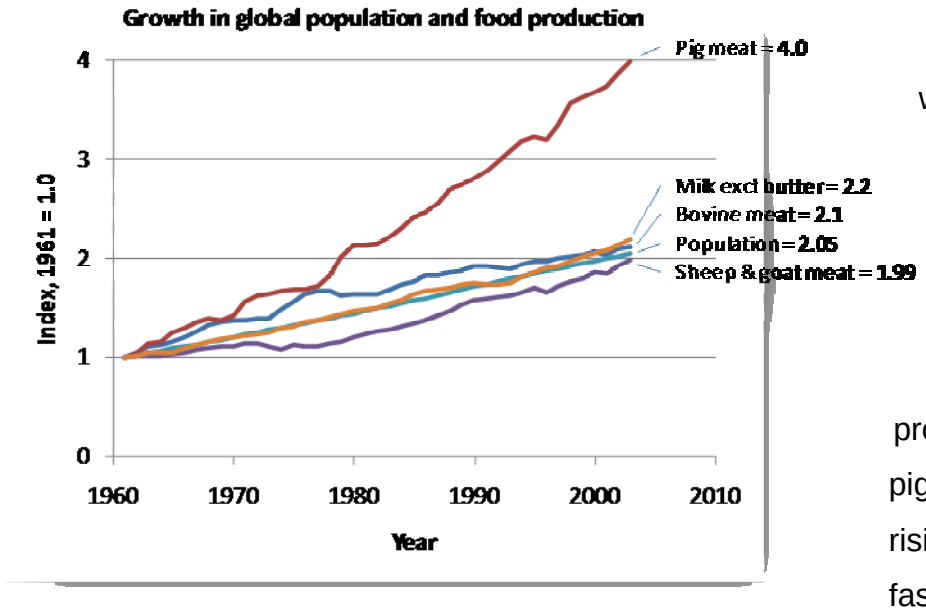
The human species faces a range of serious crises of which, today, I shall briefly touch on three; overpopulation, resource depletion and pollution. I shall explore their current and implied future impacts, and how New Zealand's pastoral sector may respond in producing ruminant animals and their derived products.

Overpopulation

We are now experiencing the largest accumulation of humans ever experienced; from one billion humans in 1800 to six billion in 2,000 and nine billion or more forecast by 2050 [1]. This 'J-shaped' population curve is more typical of insects than it is of mammals. Insect populations typically crash following exponential population growth. Civilisation must strive to avoid that fate



The world with a billion humans or less was a much quieter place than it will be with the eight billion humans forecast to inhabit the planet in 2030. However, not only will there be a lot more people in 2050 than there are now – approximately three billion more – but there will also be greater wealth and, with that wealth, there will be far greater demand for more expensive-to-produce, animal-derived products. Consumption of pig and poultry protein is rising four to eight times faster than human population growth, and demand for red-meats and milk is matching growth [2]. About one third of grain grown in advanced economies is fed to livestock [3].



Resource depletion

The growth in demand for food is worrying because, at current levels of farming efficiency, there is simply insufficient unexploited land to convert to food production. In 1960, the average hectare of arable land supported 2.4 people. In 2005, the same hectare supported 4.5 people and FAO estimates that each hectare will have to support between 6.1 and 6.4 people by 2050 – less than one fifth of a hectare per person [4].

At the present time, however, humans are continuing to destroy existing ecosystems to exploit the land for production of foods for themselves. Worldwide net deforestation is 7.3 million hectares a year [5]. Loss of original ecosystems and their replacement with monoculture or something like it is the biggest contributor to extinctions. We are now experiencing the sixth great

(known) mass extinction event in the planet's history, with the rate of extinction now being 100 to 1,000 times greater than the geological background rate [6]. For example there are just 5-7000 tigers left in the wild compared to 100,000 just a century ago [7].

We are also depleting resources that support food production at a fearsome rate. To increase food supply by 70% – which is the minimum experts believe we need to feed 9 billion people adequately [8] – requires the application of even more fresh water each year than the 2620 km^3 that is withdrawn for irrigation at present. One forecast for 2050 is 2906 km^3 [9]. We are now witnessing serious depletion of some freshwater resources. For example, in 2000, China had an average freshwater availability of about 2000 m^3 per capita but this is expected to fall to less than 1800 m^3 per capita by 2030, and to about half of that in the northern provinces. This compares with the global freshwater availability of 7000 m^3 per capita and 9000 m^3 per capita in the United States [10].

Pollution

World fertiliser consumption has risen ferociously – by 900% between 1961 and 2005 [11], and that rise shows no signs whatsoever of abating. As a consequence, we have witnessed eutrophication that affects around half of a set of lakes around the world that were included in one survey [12].

However, the most serious form of pollution is that of the atmosphere, where human-induced (or anthropogenic) increases in carbon dioxide, methane and nitrous oxide gases are quite likely to increase the *average* surface temperature of the planet by 4°C in the coming century, compared with a pre-industrial baseline set in 1890, which will probably destroy the remainder of the Amazon forest, possibly halt monsoons in southern China and northern India, and make a minimum 200 million humans refugees. The 4°C average increase translates into average increases of more than 12°C in the central landmasses of the USA, Canada, Brazil, Russia and Eastern Europe; effectively the present major food bowls for humanity [13]. Climate change will

thus serve to exacerbate mass extinction, reduce freshwater availability in what are currently important areas of food production and redistribute pests, weeds and diseases.

We can see the steady impact of global warming from the accumulated rise in sea level and sea temperature. It is the temperature of the sea, which absorbs most of the Sun's energy trapped by greenhouse gases, that is the crucial, cumulative indicator of what is happening; the planet is steadily warming.

Gaia

The reason there is a growing fear amongst ecological scientists, like myself, is because we have now come to understand that our planet is more than a ball of rock. It has a biosphere on its surface which is the sum total of all living things and their aggregate interaction with and effect on the physical environment. The biosphere continually evolves and does so in a way that generally (and unknowingly if one is not religious) produces stable environments conducive to life. Some call it Gaia. Humans are profoundly perturbing Gaia with their resource consumption and pollution, especially through global warming.

A prime risk is that we might flip Gaia into a 4-5°C warmer steady state than it currently operates at – in historical terms Gaia is currently operating in a cool state. As I have mentioned, an average, pretty-much permanent temperature rise of this magnitude will cause huge changes to rainfall distribution, patterns of wild fires and patterns of pestilence. Our capacity to respond will be diminished because these sorts of changes will be starting to occur as population peaks at nine billion. We have to roughly double food production whilst massively struggling with the climate. This is a huge challenge, perhaps even an insuperable one.

The most pernicious image currently circulating around humanity is that of Gaia in a pair of human hands. This is an exceptionally dangerous postulation. Gaia does not need saving, civilisation does. The image should be reversed.

Response

What then might be humanity's response to this massive challenge? It will certainly affect farming! Fortunately, human fertility is already starting to fall, which explains the peak, forecast population of nine billion. Effort will probably be made to contain further population growth through birth control technologies, education, support for increased wealth in developing countries and the like, so if lucky nine billion humans will be the absolute peak for the entire existence of our species.

With maybe less than one fifth of a hectare per person for food production there is going to be a massive drive towards efficient and sustained use of soils, fertilisers and freshwater. Once again, fortunately there is huge potential to use land, nutrients and freshwater more efficiently, and in biology the breakthrough technologies are biotechnologies, particularly around genetic modification. If GM can help us contain land use and cap the rising pressure on existing ecosystems, thereby sparing other species extinction, then I believe that we have a moral obligation to use it.

Sources of energy are clearly going to change. Putting nuclear fusion to one side – humans have yet to master materials science sufficiently to contain and exploit a miniature Sun – the three long-term sources of energy (I'm talking one to two thousand years here) are the Sun, gravity and the earth's core (remember that the Sun drives the climate that drives wind energy). We will eventually need to adjust our aspirations to what these (relatively) eternal sources of energy can provide – which, by the way, is a lot.

So much for science and technology. We also need as a species to change our collective aspirations and behaviours. It won't be reasonable to aspire to own multiple houses, cars, boats, and manicured land. Our "rights" will be further constrained. The definition of excessive consumption will alter to some degree; the question is by how much?

Even if, through science and technology, we can maintain a high degree of per capita resource consumption, we may choose to eschew that. What has always surprised me is our collective indifference to the extinction of so many species. It seems likely to continue – after all, if we can send a species as iconic as the tiger extinct in my lifetime – will we collectively care about *any* other individual species? But we may selfishly care about whole existing ecosystems because they contribute to Gaia maintaining an environment conducive to human civilisation as we know it.

Human diet is going to change. Animals are expensive to produce ecologically, especially ones with low reproductive rates – that is, ruminants. A philosophy is already developing that veganism is the only responsible human lifestyle, not just to help alleviate climate change, but also to spare other species extinction through loss of existing ecosystems to farming. Animals or rather their feed use a lot of land, some less than others of course, like poultry or Vietnamese catfish. There will definitely be a drive towards veganism and a promotion of the rights of other species to co-inhabit Gaia.

NZ response

So how might New Zealand respond? Currently we are a nation of greenfingers with about four and half million humans inhabiting a land mass larger than the UK and one third the size of Germany. Our remote location on a tectonic plate boundary in the middle of a massive ocean with low ozone concentrations above us has given us high luminosity, plentiful freshwater, high rates of erosion and thus plentiful minerals and low levels of endemic pestilence. We produce biomass and with a folded landscape we use ruminants to harvest plants where machines cannot economically go. We produce enough calories to feed about 28 million people.

We heavily depend on ruminants for our livelihood and that, as I have asserted, must be a significant concern for us in the future. I submit that New Zealand as a sovereign nation is likely to respond as follows:

- It will increasingly afforest its steep hill country – land that is now under pasture for sheep; these trees will eventually be used for cellulosic bioethanol and for biomaterials;

- It will look to grow food crops for humans on some of its flat land, although it will have to husband its relatively fragile soils carefully;

- It will greatly reduce the environmental footprint of its ruminant livestock through more efficient use of nitrogen and phosphorus fertilisers, sequestration of carbon in pastoral soils and an absolute reduction in methane and nitrous oxide emissions from ruminants and pastures;

- It will use every component of every ruminant for products esteemed by humans rather than, say, just using cows for milk and ignoring their ultimate value as meat and as biomaterials and biochemicals;

- It will operate integrated value chains, whereby ruminant production is closely linked to demand from wealthy consumers, thereby ensuring that ecologically-expensive to produce ruminant products achieve a market and commercial premium; and

- It will increasingly rely on sustained production techniques such as rainfall or irrigation from stored water rather than irreversible depletion of aquifers and nitrogen fixation rather than application of synthetic nitrogen fertiliser.

In conclusion, massive change is now inevitable during the next 100 years and beyond. Farming is not the villain. It is a saviour. However, how we farm and what we farm are going to change radically, influenced by population growth, resource depletion, pollution and the possibilities advanced by new science and technology. As the FAO says, we need to invest US$83 billion annually from now on in developing countries alone to help feed 9 billion

people [14]. And that $83 billion doesn't include R&D. That's going to require another huge sum of money I'd guess. Look on it as defence spending.

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