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Page

The major reason why food and energy are considered critical forces for all natural communities, including humans, is that living plants can convert relatively limited amounts of solar energy — only about 0.1% of the sunlight reaching the Earth — into biomass. Before fossil fuels were discovered and used, humans shared with other animals that portion of the sun’s energy captured by plants and subsequently converted to food/energy..

Food, Energy, and Society, Third Edition, David and Marcia Pimentel, 2007.

The Optimum Population Trust (UK): Manchester

<www.members.aol.com/optjournal> & <www.optimumpopulation.org>

INTRODUCTION

My name appears rather too much on the title page, but pages 3 to 9 are merely a compilation of the work of others. William Stanton sent me copies of all his letters to *New Scientist* and gave me free rein to use them. Jim Duguid wrote the greater part of the second piece, sending me the relevant photocopies. The subject matter of both these pieces is of the utmost importance. When I walk in the country with a friend, we often note that we have not seen anyone for hours, and that the fields and woods stretch out to the horizon. We then remark that one can hardly blame people for failing to understand the nature of the problem of overpopulation. It requires a scientific perspective to understand that humans are putting an excessive load on the Earth's complex ecological systems. Yet the pieces show that the very organizations which should be presenting the scientific viewpoint fail dismally when it comes to human population.

New Scientist's Energy Fantasies (pp. 10-11) is an indication of a similar problem, providing an example of such media's tendency to have ungrounded optimism concerning renewable energy, in this example with respect to photovoltaics.

In the next article (pp. 12-14), a long-serving population warrior, physics professor Albert Bartlett, takes up arms against another purveyor of science misinformation. In the *Scientific American and the Silent Lie*, he shows that *Scientific American* is as inclined as *New Scientist* to ignore population. It is not just scientific publications which collude in supporting this delusion. NGOs and many scientists exploring renewable energy are guilty too.

My name is on the next piece too, *Food and Population in 2050* (pp. 15-17), but it is substantially a presentation of the work of Bernard Gilland, who gave me guidance throughout, helping me to bring this perspective on his work to fruition.

The next two pages, pp. 18-19, come from an outstanding journalist whose memoranda are sent out by the Biocentric Institute, William B. Dickinson. The aims of the Institute are to "conduct programs and studies directed toward the enhancement of quality of life for all peoples." As Dickinson's article makes clear, the U.S. and the U.K. face dire population problems.

For both the next two articles, *Malthus over a 270 Year Perspective* (pp. 20-23) and *Food Supply after the Demise of Cheap Energy* (pp. 24-28), I have been helped by advice from David Pimentel. The graph in the second piece is reconstructed from his data and also used in a 1993 book by Lloyd Evans, *Crop Evolution, Adaptation and Yield*, which is a masterly display of scholarship, but it provides yet another example of the failure of some academics to understand the power of population growth.

I need to explain why there is no *Green History* instalment in this edition. Eleven pages were devoted to it in the last edition and since this edition is only 28 pages (the post office have started to be very fussy, and if the mail package is even a fraction of a gram over 100 gms it is sometimes categorized as being overweight) it seemed an opportune moment to skip *Green History* for one instalment, and allow space to keep together a number of things which fitted in well together. The next instalment of *Green History* will be seven pages long and cover Chapters 14 and 15.

Yvette Willey admonishes me for always mentioning her, but as always I am much indebted to her for her assistance in many aspects of the production of these journals.

Editor: Andrew Ferguson, 11 Harcourt Close, Henley-on-Thames. RG9 1UZ, UK

DOCTOR WILLIAM STANTON'S BATTLE WITH THE MEDIA

compiled by Andrew R.B. Ferguson

Geologist William Stanton, author of a remarkable book which shows the history of population growth in every country, *The Rapid Growth of Human Populations 1750 — 2000: Histories, Consequences, Issues, Nation by Nation*, has for many years tried to get the journal *New Scientist* to address the problem of population. As will soon be evident, the editors of *New Scientist* follow the same policy as the editors of *Scientific American*, namely the "Silent Lie," as described by Professor emeritus Albert Bartlett, on pages 12-14.

Twenty three years ago, on 25 April 1985, there was an exception to prove the rule, for *New Scientist* did publish this letter from Stanton:

> There was not a word, in your feature on the crisis in African agriculture about the underlying cause of famine in the semiarid countries. Trying to improve food plants and farming methods is mere tinkering with symptoms. The disease: too many people.
>
> Ethiopia's population has grown from 9.5 million in 1939, to 42 million in 1984. Its neighbour states are increasing by 3 per cent to 4 per cent per year. Logic requires that continued growth at this rate will sooner or later outstrip the capacity of any land to feed its people, and the crunch will come sooner in those countries that have poor soil and an unfriendly climate.
>
> What hope is there for your model village of Miningo in the long term, if it is expanding so fast that two-thirds of its people are under 16 years old?

But all letters subsequent to this were either not printed, or the editor omitted the basic population arguments. Despite this, his efforts continued. Like Albert Bartlett, he really deserves a Nobel prize for his untiring efforts to save the human race from its supreme folly of ignoring the warning that Thomas Robert Malthus gave over two hundred years ago, reiterated by John Stuart Mill a hundred and fifty years ago.

As well as writing to the editor, Stanton tackled columnist Ariadne directly. On 19 January 1986 his letter to this columnist included these words:

> Countries like Ethiopia take about 25 years to merely double their populations, so it takes an effort of thought to realise that what seems on the face of it to be a one-off famine is really an early symptom of chronic lemmingitis in Third-World humanity. Allowing for the 150 to 1 difference in human to lemming demographic timescales, where is the difference between a plague of lemmings and a plague of people? …
>
> The important thing about lemmings, other than not being human, is that the little furry creatures don't devastate the planet in the course of their hopeless struggle for lemmingsraum.

On 3 March 1986, in continuing his correspondence with this columnist, Stanton wrote:

> The range of 'natural balances' must be immense, depending on individual preference, from the hermit living alone in the forests of Canada to the Hong Kong apartment dweller, but I think there are two critical points on the graph.
>
> One is when the human population is still sparse enough that coexisting species are not forced into extinction by human activities. You could call this the 'live and let live' balance. The other is when the population is so dense that its whole environment is geared to simply keeping it from starving. All competing animal and plant species have gone. You could call this the 'struggle to survive' balance, and it is shown to be exceeded when, in bad years, the population of a region suffers famine.

On the 3rd May 1986, Stanton wrote to the editor concerning a review which had described as a "dangerous message" the notion that "Too many people believe that poor people are poor because there are too many of them." Stanton responded thus:

> Our planet, marvellous in its diversity of plant and animal life, naturally evolved over 1000 million years, is being converted in a geological instant to a factory farm geared to feeding a single species, *Homo "sapiens."*
>
> We talk about a nuclear war threatening our survival. It is indeed possible. But to the uncounted myriads of life forms that compete with *H. sap.* for living space, extinction is not just a possible threat. It is a certainty, unless the tide of human population, growing at one million every 5 days, is checked. And when the space that was occupied by non-human species is gone, humans will have to fight for land among themselves — or starve. The recent famines were a foretaste of the inevitable, not-so-distant, future.

On 18th October 1987, Stanton wrote to the editor thus:

> The light-hearted way in which Feedback dealt with some of the 'wild theories' of the doom-mongers' conference made amusing reading, and must have ensured that the report of proceedings was scanned by most of your readers. The 'astounding' statistics quoted were new to me, but the fields of research that gave rise to them, such as proportioning the Earth's biomass between human bodies and their life-support system (the remainder) seem intelligent and relevant.
>
> But why should we readers accept without question that Feedback knows best, and that all these earnest doom-mongers should join the Raving Loony Party? Is it not possible that one or two of my predictions are fairly close to the truth? I suspect that the reason why Feedback — and others— shy away from treating informed doom-mongering seriously is that the implications really are too awful to contemplate. Yet people now alive may suffer them, if the proposed timescale is anything like correct.
>
> I am curious to know whether, in my dotage, I shall witness and take part in the greatest mass-extinction that this planet has experienced.

Stanton has hardly had to wait until his dotage. In 1996 Richard Leakey and Roger Lewin published a book *The Sixth Extinction: biodiversity and its survival*. Since then, the extent to which extinction problems will be amplified by climate change has almost become common knowledge. On 31 July 1988, Stanton wrote to the editor of *New Scientist* thus:

> Michael McElroy concisely reviews the challenge of global change, but I emphatically disagree with him that in founding a new sense of global responsibility "the first step is to develop a deeper understanding of the global life-support system." Rubbish. Thinkers and scientists from Malthus through the pioneers Rachel Carson and Paul Ehrlich down to today's consensus have shown conclusively that massive fundamental changes are affecting the global environment. It is abundantly clear that the cause of these changes is not *what* humans are doing, but the *numbers of them that are doing it.*
>
> The vital next step is not to delve deeper into the intricacies of what is going on, fascinating and intellectually challenging though such research undoubtedly is. Enough is known already. The next step is far more difficult because it must question conventional liberal thinking on the supremely delicate subject of human rights and convictions. …
>
> No, the challenge for scientists now is to persuade governments, the decision takers, to face up to the cause of global change that threatens life on Earth.

Three years into his epic letter-writing effort, William Stanton had come to accept that that letter was not going to be published, and signed himself "Yours resignedly." However he returned to his crusade on 17 September 1994, with a personal letter to a staff member of *New Scientist*:

> I suppose I shouldn't be surprised, having learned your views on population in a phone call last year, that the final piece in your recent population series was by an enthusiast of the 'demographic transition' theory. It's a grand recipe for complacency to be told that as nations achieve a prosperous Western-style standard of living their population growth rate automatically falls to near zero. On this basis there is no 'population problem', only a need for masses of Western aid.
>
> Unfortunately this comforting theory has been found wanting time and again, not least here in England.

If Stanton were writing now, he could point to the USA. Affluence there can surely be agreed — based on average emissions of about 20 tonnes of carbon dioxide per person per year. Yet it is a moot point of discussion whether the present US population of slightly over 300 million will expand to 750 million by 2100 or by 2075 — not much demographic transition there!

Apropos an editorial in *New Scientist*, on 12 June 1995 Stanton wrote thus to the chairman of a charitable organisation, which then called itself *Population Concern* (it subsequently decided that having the word 'population' might deter too many supporters!):

> I was interested that you used a *New Scientist* editorial to rationalize your hopes of success. I have been an occasional contributor to *New Scientist* for some ten years. They printed all my six or seven pieces on aspects of nature conservation, but after one letter in 1985 they consistently rejected or ignored my articles and letters on likely consequences if we don't take the human population explosion seriously. However they do print complacent articles like that editorial: "All Africa needs is research and investment suited to its crops and climate…" …
>
> At first I was just puzzled by *New Scientist's* attitude (mirrored in the Sunday Independent and Telegraph); more recently I have come to think it is deliberate. Last year *New Scientist* even printed an article favouring the long-debunked 'demographic transition' theory. If the magazine consistently suppresses discussion of the down side of the population explosion there must be a reason.
>
> I can think of three good reasons why people evade serious debate on the emotive subject of population planning. First, politically correct people tend to link it with Nazism. Second, ordinary nice people shy away from causing offence by interfering in other people's private lives. Instead they support high-profile charities that claim to be solving world problems by healing the sick and feeding the hungry — but quietly leave the consequent population explosion to sort itself out. Third, calculating people, economists, businessmen and, yes, politicians, equate growth with prosperity and profits, which is a powerful reason not to discourage population growth. …
>
> I think the time has come to ask whose negligence is to blame when millions of Third World people are suddenly massacred or dumped in other countries, and to start pointing the finger.

On 13 July 1995 Stanton wrote this personal appeal to the editor of *New Scientist*:

> May I comment briefly on your faith in the demographic transition theory, which states that improving the economic condition of a poor country, reducing the death rate, leads naturally to a fall in the birthrate and a slowing down or cessation of population growth. One of the first debunkings that I saw was ten years ago in *New Scientist*. Countless other debunkings have followed, e.g. van de Walle in 1987: "Central Africa is one vast contradiction of 'demographic transition' theory: mortality has fallen, and

> fertility has risen, for two generations, with no end in sight." (*Population and Development Review* 13, p. 547).

Skipping over several more letters, this is what Stanton wrote in August 2002:

> Fred Pearce argues that a world population crash caused by declining fertility is a future to be feared. On the contrary, in spite of the economic difficulties inherent in ageing societies, it would be a relatively painless, peaceful, necessary future.

On 8th November of the same year he wrote about the old fallacy of technological fixes:

> High-tech schemes to curb global warming won't succeeed on their own. Greenhouse gas emissions will continue to increase for as long as world population goes on rising. True, the developed nations emit the most gases *per capita*, but their populations would now be falling, due to their low fertility rates, were it not for large-scale immigration from more fertile nations. The immigrants, naturally, aim to emulate their hosts' gas-generating lifestyles. …
>
> If climate change becomes another severe restraint, easing it by technological wizardry will encourage population to expand into yet another crisis. Earth's real problem is too many humans. Why not face it now, when there may still be time to reverse population growth, relatively painlessly, by a courageous approach to family planning?

On 23 December 2003, Stanton wrote thus about a very popular misconception:

> Jeffrey Sachs is wrong to imply that the fall in world population growth rate from 2.1 per cent in the 1960s to 1.3 per cent in 2003 proves that actual growth is slowing down. Applying his quoted percentages to world population of 3.5 billion in the mid-1960s and 6.3 billion in 2003 shows that numerical growth has *increased* from 73 million in 1965 to 82 million in 2003.

Skipping only one letter, on 28 February 2005, Stanton wrote:

> The 26 February issue of *New Scientist* included no fewer than ten articles on current human predicaments, not one of which mentioned their common cause.
>
> They were: diverting river water from Iraq's marshes, increased greenhouse gas emissions from hydroelectric dams, the inescapable global pandemic of Asian bird flu if the virus achieves human to human transmission, grey whales threatened by oil and gas extraction off Sakhalin Island, alleged overfishing of minke whales, the bushmeat trade nullifiying chimpanzee conservation, using GM plants to increase crop yields, harvesting methane from landfills, coping with too much information, using wind power to eke out costly marine diesel fuel, and trying to pacify Jew/Arab conflict in Palestine.
>
> The common factor that turns these situations into serious environmental or social problems is the densely packed human population of our planet. If Earth supported one billion people instead of 6.5 billion, natural global resources and ecosystems would render all these problems, and many others, insignificant.
>
> I do not recall any serious attempt by *New Scientist* to address the consequences of human overpopulation since the supplement entitled "Judgement Day," of 28 April 2001. That was forceful but 'balanced', i.e. it avoided concluding that human proliferation was a problem.

On 22nd November 2005, Stanton wrote thus about another popular fallacy:

> While deploring the felling of rain forests to grow biofuels, Fred Pearce could usefully have questioned whether the felling and burning of trees, followed by planting,

> fertilizing, harvesting and processing the palm or soya oil crop can produce a net energy gain. …
>
> The most practical form of biomass is likely to be wood, from which solid and liquid fuels and organic chemicals are easily made. Forests grow on their own, with minimal energy input, so that a forest products industry could economically be powered by a proportion of its own product.

The trouble is that forests, allowed to grow naturally, produce only about 3 dry tonnes per hectare per year, taking a worldwide view. That is equal to 2 kilowatts per hectare, which is a mere one thousandth part of the sun's energy that falls on that hectare. Moreover if some of that wood is converted to liquid fuels — a conversion for which there is not yet a fully satisfactory solution — then the energy captured in that form is even lower. That problem leads on to Stanton's letter of 22 September 2006:

> Biofuels and other renewables cannot replace fossil fuels, because renewable energy budgets are so unfavourable. Mechanical devices converting wind, water or sunlight to electricity are currently constructed by courtesy of cheap fossil fuel. Reproducing and servicing them using only the electricity they produce would leave little if any surplus energy for public supply. Most biocrops need huge energy inputs in the form of fuel and fertiliser every year.
>
> Renewable energy, mainly biomass-derived, sustained a world population never exceeding 600 million before the mid-18th century. Poverty was universal. Then, the Industrial Revolution, based on fossil fuels, transformed the techniques of food production, enabling continuous rapid population growth to 6.5 billion today. Poverty gave way to affluence in proportion to the amount of oil consumed. In Britain this is ten barrels per person per year.

I finish with an extract from a letter which William Stanton has drafted but he is waiting for a suitable occasion to send. It admirably sums up the great sin of omission committed by *New Scientist*, *Scientific American*, and indeed most of the media, although the latter might argue that they depend on such supposedly scientific magazines as their sources:

> There is only one sure way to stop global warming, and mass extinction of species, and traffic congestion, and water shortage, and Third World poverty, and rain forest destruction, and all the other ongoing disasters that seem to baffle contributors to *New Scientist*. It is: drastically reduce the number of people on Planet Earth. That goal can be achieved, without great pain, by the exercise of human intelligence.
>
> This is my 20th letter to you since 1986 about the terrible consequences of ever-worsening human overpopulation. You have not printed or acted on any of them; indeed you hardly ever mention overpopulation. That a nominally scientific magazine should persistently avoid facing a matter of such fundamental importance to life on Earth is unforgivable.
>
> If *Homo sapiens* is the highest manifestation of intelligent life in the Universe, which so far as we know is the case, you are helping to reverse the forward march of evolution. I can think of no greater betrayal.

References

Leakey R., Lewin, R. 1996. *The Sixth Extinction: Biodiversity and its Survival*. London, Weidenfeld and Nicolson.

Stanton, W.I. 2003. *The Rapid Growth of Human Populations 1750 — 2000: Histories, Consequences, Issues, Nation by Nation.* Multi-Science Publishing Company Ltd, ISBN 0 906522 21 8, 230 pp

OTHER BATTLES WITH THE MEDIA

compiled by Andrew R.B. Ferguson

Next to Doctor William Stanton's battle with the Press must rank the untiring efforts of the late Jack Parsons to get the BBC to address the subject of population. Over 55 years he exchanged many letters with BBC managers, producers and the Director General. Jim Duguid tells me that Parsons' early exchanges were amicable, but over the last 25 years of his life he met only with evasion and complete failure to comply, despite the BBC's own code of ethics stating that, "No significant strand of thought should go unreflected or under represented on the BBC." It seems that something of a vicious circle may be in operation: because the problem is so little recognized by the Press, the BBC can, with some reason, claim that they are not under representing the subject. In his later years Parsons wrote a book, *The Treason of the BBC*, recording the details of his long struggle.

Stanton did not confine his efforts to *New Scientist*. I agree with Professor Jim Duguid that this letter, which Stanton sent to the *Independent* on 17 January 2005 (unpublished of course), gets to the roots of one major problem; one that was current news at the time because the then Chancellor of the Exchequer was stressing the need to help Africa.

> Gordon Brown, crusading to end African poverty, is clearly ignorant of its fundamental cause, which is demographic.
>
> Since 1970, the populations of all 48 mainland African nations have increased by about 3 per cent every year. The rare exceptions relate to civil wars or genocides in countries such as Rwanda, Burundi or Sierra Leone. Compare this to Western European growth rates, typically a small fraction of one per cent.
>
> Poverty worsens in any nation when its population grows faster than its economy. The economic cake has to be shared among ever more people, so the slices get smaller. Financial aid, as offered by Mr Brown, provides short-term relief which facilitates further population growth.
>
> Immense fortunes have been spent in aid to Africa since the colonial period ended, to no effect. The figures are dramatic: between 1960 and 2005 the number of Africans living in poverty multiplied at least three-fold. Mr Brown will waste yet more UK taxpayers' money unless he attaches effective strings, such as Chinese-style family planning, to his financial handouts.

The national media is harder to penetrate on the subject of population than the local press. William Stanton has had considerable success in his own area, the West Country, and so had Jim Duguid, with many letters on population published in *The Scotsman*. The following was one of three that resulted from his efforts to follow up Stanton's unpublished letter to *The Independent*; it was published on 18 March 2005.

> The report of the Commission for Africa has the merit of addressing the problems of bad government and bad trade practices, as well as calling for £26 million a year of aid. But like previous charitable initiatives, it fails to address the need to prevent the aid from increasing the population faster than its wealth, so each person gets less.
>
> In 1989, the World Bank reported that billions of dollars'-worth of aid to sub-Saharan Africa since 1960 was associated with a doubling of population and an increase of poverty.
>
> Fertility rates in poor African countries are about five or six children per woman. Populations outstrip the food supply, and are restrained by the deaths of many malnourished mothers and children too weak to overcome common infections. Aid which provides more food increases the survival rate and thus the population.

> Aid should be concentrated on providing family planning facilities and contraceptive supplies, and on improving the education and social power of women.

With both public broadcasting and national newspapers ignoring population, and only a minority of academics giving adequate warning of the problems ahead, it is little wonder that popular ignorance of the subject is widespread.

Perhaps I may finish with my own very limited success at getting something into the letters pages of *New Scientist*. This was a letter which I sent, a mangled version of which was published on 6 October 2007.

> It is a valuable idea to plot the Human Development Index against the number of planets that would be needed to sustain various lifestyles. Indeed so important is the subject that the graph on page 10 of *New* Scientist, 6 October 2007, deserves to be made into a poster size display. However, the accompanying article omits to discuss the two fundamental related points.
>
> The first is population. The graph shows that if, in 2003, the date of the graph, everyone on Earth were to adopt a Cuban lifestyle, then *homo sapiens* could manage with using 0.8 of the ecological resources of the planet Earth (and afford to leave the rest to other life forms). However, it is generally agreed that by 2070 world population will be about 10 billion, with the consequence that if the average lifestyle of the 10 billion could be constrained to that of Cuba in 2003, 1.3 planet Earths would be needed to support *homo sapiens*. What will happen in reality is that some nations will appropriate far more than their share, leaving others to misery and greatly diminished life expectancy.
>
> The second issue that needs to be recognized is the all-important one of energy, for it is the availability of energy from fossil fuels, stored over hundreds of millions of years, that has made possible the explosion in human numbers. It is generally agreed that by 2070 oil and gas supply will have fallen to below half the present level, so ecological resources will be needed to provide renewable energy, and that will have fateful consequences. We have already seen the writing on the wall arising from misguided attempts to produce biofuels from food crops, resulting in increased food prices.
>
> Since we have no control over the number of planets, it would be more useful to think in terms of the population that could be sustained on the one planet we have. Inverting the figures from the graph, it is clear that for everyone to enjoy Western European lifestyles, world population needs to be about 2 billion, instead of the 6.3 billion it was in 2003.

The letter was so badly mangled by the editors that I almost vowed to write no further letters, but when their regular correspondent Fred Pearce completely failed to mention population, although the article obviously made it relevant, I could not resist writing thus:

> A reasonable conclusion to draw from Fred Pearce's excellent article, on pages 34-41 of the 17 November issue of *New Scientist*, is that with a mighty effort the world could manage to constrain carbon emissions to 4 tonnes of carbon dioxide per person per year (although this would entail huge changes in lifestyle for Americans, at 20 tonnes, and Europeans, at 12 tonnes). But why did the article fail to point to an inescapable conclusion of at least equal importance? It is that since emissions of about 9000 million tonnes per year are about the 'safe' global limit, in order to keep the planet safe for human habitation, the achievement of the 4 tonnes per person goal also requires a reduction of the human population to just over 2 billion people.

It was not published. I now anticipate no further success for 25 years!

NEW SCIENTIST'S ENERGY FANTASIES

by Andrew R.B. Ferguson

The cover of the Nov/Dec 2000 issue of the magazine produced by the World Watch Institute, *WorldWatch,* treated its readers to a spectacular picture of a volcanic flare, with these words to accompany the picture, *The Hydrogen Experiment: Descendants of the Vikings Embark on a Bold New Quest to Transform the World's Energy Economy*. The article itself would have us believe that Iceland was just about to create a "hydrogen economy" for itself, and was then either going to do the same for the whole world, or at least show the rest of the world how to do it. Since then reality has intruded; the Icelanders have substantially abandoned their plans to create a hydrogen economy.

The editors of *New Scientist* show the same flair for dramatic covers. The cover of the 8 December 2007 issue is filled with radiant orange and yellow light with a conductor coming straight down from the sun (featured in the centre of the picture) to a city block below, where doubtless we are supposed to assume that all the occupants are being kept snug, warm and brightly lit by a steady flow of electricity. The text to accompany this reads, "Here comes the sun: our solar-powered future." The Editorial added its voice to celebrate the fantasies:

> Guess the country. It has over half the world's installed capacity of photovoltaic cells and is home to some of the largest solar cell manufacturers. In short, it is the solar-powered capital of the world. Yet it is not in the sun-drenched tropics nor even bordering the Mediterranean. The country is Germany. … Germany is well set for a bright solar future. This sort of bold, creative thinking is just what the world needs if it is to beat climate change.

The related article, *Our Solar Future* (pp. 32-37) by Bennett Daviss, assures the readers that:

> The prospect of relying on the sun for all our power demands — conservatively estimated at 15 terawatts [131,000 billion kWh/yr] in 2005 — is finally becoming realistic thanks to the rising price of fossil fuels, an almost universal acceptance of the damage they cause, plus mushrooming investment into the development of solar cells and steady advances in their efficiency. The tried-and-tested method of using the heat of the sun to generate electricity is already hitting the big time, but the really big breakthroughs are happening in photovoltaics (PV) cells.

We may better understand what is wrong with those high-flown fantasies after we have taken a look at this later paragraph (p. 34):

> Last year, Allen Barnett and colleagues at the University of Delaware, Newark, set a new record with a design that achieved 42.8 per cent energy conversion efficiency. Barnett says that 50 per cent efficiency on a commercial scale is now within reach. Such designs, married to modern manufacturing techniques, mean costs are falling fast too.

The fallacy in those last two paragraphs, and in the rest of the article, is that the load factor of PV is totally ignored. The meaning of "load factor" is the amount of electricity that is produced (measured over the period of a year unless specified otherwise) as a fraction of the electricity that would be produced if conditions were always 'just right'. The relationship between the load factor and the peak infeed is of fundamental importance, since it is no good having lots of electricity when you only want a moderate amount, and none at all when you want a lot. The efficiency of the cells — dwelt on enthusiastically in the last quotation — makes no difference at all to the load factor of PV. The relationship between ambient conditions and the output of the cells is this:

$$\text{Load factor} = k \times (\text{insolation on a horizontal plane in W/m}^2 / 1000)$$

Where k is a constant. As far as it has been possible to assess, the value of k is 0.70 (it might improve slightly with differently designed modules). Essentially the constant takes into account those factors *other than illumination being less than 1000 W/m²* which result in degradation of PV performance, e.g., dust, deterioration, and the sunlight impinging on the module at oblique angles. "Insolation" refers to average annual inflow of solar radiation. The 1000 represents the 1000 watts per square metre illumination used in the laboratory test to assess the efficiency of the modules.

Thus, for the example, in the USA where average insolation is about 200 W/m^2 (it might be lower than that, perhaps closer to 190 W/m^2) the average load factor of PV modules is 0.70 x (200 / 1000) = 14%. Anyone familiar with both the UK and the USA will tell you that bright conditions are not as frequent in the UK, so the load factor in the UK must be lower. When insolation was measured over the period 1978 to 1987 at Reading, Berkshire, the average insolation was found to be 110 W/m^2; but I think UK skies may be clearer these days (we now burn natural gas and everything is manufactured in China!), and also other parts of the UK probably enjoy more sunshine than Reading, which is a city in its own right, and west of once-smoggy London. But even if we assume 140 W/m^2, the load factor is only 10%. It is possible, even probable, that PV modules are now designed to cope better in poor light, so the constant may be slightly higher than 0.70, and consequently the load factor may be improved by one or even two percentage points, but even 14% shows the extreme limitations of PV. The reason that one cannot be more precise about some of these figures is because load factor is something that the PV industry never discuss. The approach that the wind industry took to this uncomfortable reality was to rename "load factor" "capacity factor" and thereby hope that no one would notice that not only is the load factor of wind turbines abysmal compared to fossil-fuel-powered plant, but that the load is delivered when the wind happens to blow, rather than when the customers want electricity. The PV industry took a different approach, and decided that they just would not mention "load factor," and would look entirely blank if anyone mentioned it to them: "Load factor, what's that?" they would say, to anyone audacious enough to ask, "Surely that's nothing to do with PV." I challenge you to prove me wrong by turning up any text from the PV industry which mentions load factor!

Turning back to face reality, for present purposes we can take 10% as a round number for the load factor of PV in the UK. Even if we assume that peak output from the PV modules happily always coincides with peak demand in the system, and install PV modules accordingly, those modules will only produce, on average throughout the year, about 10% of peak demand — that's determined by their load factor. Because average demand (mean demand) is roughly 66% of peak demand, that means that PV will only satisfy 15% of the overall electrical demand throughout the year. That leaves 85% to be filled in by controllable sources. What is more, because PV is an uncontrollable, you cannot add more uncontrollables, such as wind, because the problem created by uncontrollables is additive.

The conclusion is very simple. The article in *New Scientist* does not mention load factor, and so it can safely be filed in the same "Energy Fantasies" category with the *WorldWatch* article on hydrogen. If you collect the stuff, then you will find *New Scientist* at least as rich a vein to mine as *WorldWatch*; and *Scientific American* is to be recommended too.

SCIENTIFIC AMERICAN AND THE SILENT LIE*

by Albert A. Bartlett. Professor emeritus of physics, University of Colorado, Boulder

The September 2006 issue of *Scientific American (SA)* is a "Special Issue" devoted to "Energy's Future Beyond Carbon" with the subtitle "How to Power the Economy and Still Fight Global Warming." As I read the issue I thought of Captain Renault, the Chief of Police in the movie "Casablanca" who says to an assistant, "Major Strasser has been shot. Round up the usual suspects." The implication of the Chief's order is clear. Never mind finding the culprit, just "round up the usual suspects."

The main body of this special issue consists of nine articles relating to global warming, each dealing with one or more of the usual suspects. These are summarized in the first article, "A Climate Repair Manual." There we read that global warming is a major problem: "Preventing the transformation of the earth's atmosphere from greenhouse to unconstrained hothouse represents arguably the most imposing scientific and technical challenge that humanity has ever faced. Climate change compels a massive restructuring of the world's energy economy. The slim hope for keeping atmospheric carbon below 500 ppm hinges on aggressive programs of energy efficiency instituted by national governments." The culprit is world population growth, but *SA* is just rounding up the usual suspects.

Some fraction of the observed global warming most certainly is caused by the release of greenhouse gases from the burning of fossil fuels. As the size of the world population increases, the rate of burning of fossil fuels increases and this can be expected to increase the rate of rise of global average temperatures. The authors of these nine articles have to know that the size of the global population is a major factor in determining the rate of release of greenhouse gases. Yet in a special issue devoted to reducing global warming, *SA* almost completely ignores population size and growth and instead "rounds up the usual suspects" — things we can do to reduce the human contributions to global warming such as the increased use of nuclear power and improving efficiency.

The special issue contains no serious evaluation of the problems of peak production of global oil, which could happen any year now.[1,2] There is even a hint of denial: "Even if oil production peaks soon — *a debatable contention given Canada's oil sands"* (emphasis added).

When one looks at the facts, one can see that production of gasoline from the oil sands won't have much effect on the peaking of world oil production. There is no serious discussion of the net energy in the production from oil sands, or in the production of ethanol from corn. It is just noted that we will have to be more efficient in these endeavors.

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Growth remains sacred. "But holding CO_2 emissions in 2056 to their present rate, without choking off economic growth, is a desirable outcome within our grasp." To meet the growing global demand for energy, "thousands of new power plants must be built." "If the fleet of nuclear power plants were to expand by a factor of five by 2056, displacing conventional coal plants," what will we do after 2056? None of the authors expresses any recognition of Eric Sevareid's law, "The chief cause of problems is solutions.[3] Example: Nuclear power is a solution to the problem of CO_2 emissions from coal burning, but nuclear power comes with its own new problems. There is a lonely isolated touch of reality in the opening sentence of the article on renewable energy: "No plan to substantially reduce greenhouse gas emissions can succeed through increases in energy efficiency alone." The reason behind this reality is that continuing population growth, even at the level of approximately 1% per year, will likely overwhelm the annual savings that can be achieved nationally or globally through improved efficiencies.

The article on hydrogen notes, "it could be decades before it [hydrogen] starts to reduce greenhouse gas emissions and oil use on a global scale." We don't have decades. There is blithe talk about the billions and trillions of dollars that it will cost to rebuild our energy infrastructure to enable the deployment of several of the "usual suspects."

There is no serious evaluation of the impact of such costs on people and on economies. For instance, it costs about $1.50 a watt to purchase a new coal-fired electric generating plant and since utilities budget something like 1000 watts of generating capacity per person, every new person added to the service area of a utility costs the rate payers about $1500. So every time the population of a utility's service area grows by one percent, every person in the service area has to pay approximately one percent of $1500, or $15, just to purchase new hardware for the generation of electricity to meet the needs of new people added to the service area.

The last article, "Plan B for Energy," is prefaced with a futuristic drawing with the caption "Late 21st Century energy sources might include nuclear fusion reactors, hydrogen generated from ponds of genetically engineered microbes, high altitude wind farms [this is a new suspect], orbiting solar arrays, and wind and tidal generators, all linked to a worldwide superconducting grid." The large electric distribution grids that span continents are enormously complex and they have the unpleasant habit of failing in massive and spectacular ways. Even more frightening is the fact that these enormous networks will be managed by people, and people will fail. I hope the future does not work out as it is portrayed in *Scientific American* and I don't think it will. A society that is totally dependent on high tech for the functioning of every aspect of the lives of its people is vulnerable to disruption by acts of God and acts of people. The complexities of our present infrastructure predictably lead to unpredictable failures. More complex infrastructures anticipated for the future will probably experience larger unpredictable failures.

In a short essay before the main energy articles ("Lower Fertility: A Wise Investment" by Jeffrey Sachs[4]), there is a brief mention of population. This does address population growth but in a way I found contradictory and objectionable. "Rapid population growth is not the main driver today of these [environmental] threats." Attention should be given to "high and rising rates of resource use per person rather than to the rise in the sheer number of people." The world's rate of consumption of fossil fuels is the product of the population size and the average per capita annual consumption. Both have to be reduced. A few sentences later Sachs writes, "Yet the continued rapid population growth in many poor countries will markedly exacerbate the environmental stresses." So population growth is not a problem and then is a problem. But shifting the blame to the people of poor countries is the "them, not us" response that is so often encountered when population problems are discussed.[5] Sachs then presents the arguments for working to lower the fertility rates of people in "poor countries," pointing out our funding programs to help with this would be "among the smartest investments that the rich countries could make for their own future well-being." The idea is good. The reason given is selfish and destructive. He seems to be saying that if we reduce "their" numbers, it will be a good investment for us because there will be more resources and better lives for us. If we want to help poor people, we will be helping them increase their per capita rate of resource consumption, which, for the foreseeable future, will increase the rate of global production of greenhouse gases. Only by reducing the size of the world population can we hope to be able to give significant help to poor people. Only by reducing the sizes of populations can we have a reduction in the overall global rate of consumption of fossil fuels and the consequent reduction in the rate of production of greenhouse gases. We must lead by example by addressing overpopulation in the United States.

Scientific American has rounded up the usual suspects but has ignored the perpetrator of the crime. The editors and writers at *Scientific American* know that population growth is the underlying source of the problems, but it is politically incorrect to state this obvious fact. Mark Twain wrote that if one has information that would help others, but does not share that information, then one is telling a "Silent Lie."[6] Because it does not address population size and growth as the main underlying cause of global warming, this issue *of Scientific American* is a serious "silent lie."[7]

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4. Jeffrey Sachs, Director of the Earth Institute at Columbia University and of the U.N. Millennium Project.
5. A.A. Bartlett:, "Malthus marginalized," *The Social Contract 8* (3), 239-251 (Spring 1998).
6. Mark Twain, *The Man That Corrupted Hadleyburg and other Short Works* (Prometheus Books, Amherst, NY, 2002), p. 159.
7. A.A. Bartlett, "Thoughts on long-term energy supplies: Scientists and the silent lie," *Phys. Today* 57, 53-55 (July 2004). See letters and responses, *Phys. Today* 54, 12-18 (Nov. 2004) and 58, 12-17 (April 2005).

FOOD AND POPULATION IN 2050

by Andrew R.B. Ferguson

Abstract: To improve nutrition while population rises to 9 billion, so as to eliminate the problem of more than half the world being malnourished, appears to be an impossible task even before taking into account a host of factors that will make the problem more difficult.

I am indebted to Bernard Gilland for much of this article. He kindly sent me a copy of his 2006 paper in *Population and Environment* (Gilland, 2006). The thoughts below draw heavily on the data in that paper although that is not acknowledged at every step.

The general concern of many politicians has been to improve the lot of the malnourished (more than half the world is malnourished at present, and 800 million go hungry) and thus produce a better world. Do those politicians stop to ask themselves if that is physically possible? Perhaps not, but that is what we will now do.

World annual cereal consumption during the period 1995-2002 was 347 kg/cap, of which 111 kg was used as livestock feed, and thus 236 kg/cap was for non-livestock uses.

With the 2005 world population of 6465 million, total cereal consumption was therefore 347 x 6465 = 2243 million tonnes (Mt).

Using the U.S. Bureau of the Census projection for 2050, namely a world population of 9404 million, at the present per capita consumption rate of non-livestock feed cereal, the non-livestock cereal requirement for 2050 will be 236 x 9404 =2219 Mt.

Now we need to consider the cereals used for livestock feed, taking into account, first, that currently the average animal protein intake of humans is only 27.7 g/day, whereas there is a strong movement towards an average of 40 g/day. This trend will be hard to change, for as Gilland shows, 40 g/day is well below the average for developed countries. Secondly, taking into account the likely increase in population by 2050, the annual livestock cereal feed requirement for 2050 would be 111 x 6465 x (40 / 27.7) x (9404 / 6465) =1507 Mt. Removing malnutrition in this way, namely by achieving an average of about 40 g per day per person of animal protein, would require a more even spread than at present. For example, Spain, France and USA are all well above that level, all being in excess of 74 g/day.

In fact Gilland arrives at a figure of 1940 Mt rather than 1507 Mt, because he assumes that the absolute amount of protein from pasture and fisheries will not increase. That is indeed perfectly possible, so note that the 1507 Mt is more likely to be an underestimate rather than an overestimate.

Proceeding with our optimistic figure, the total annual cereal requirement in 2050 is 2219 + 1507 = 3726 Mt.

This is a (3726 / 2243) -1 = 66% increase over the 2005 cereal supply.

The question is could cropland yields increase as much as 66% by 2050?

Through 1985-2005, global cereal yield increased at a rate of 0.040 t/ha/yr, from a starting value of 2.47 tonnes per hectare (t/ha). If that rate could be sustained right through to 2050, the yield in 2050 would be 5.07 t/ha. Since the yield in 2005 was 3.26 t/ha, that is an increase of (5.07 / 3.26) -1 = 55%.

55% falls short of 66%, but more importantly there are many reasons to suppose that nothing like even that inadequate 55% can be achieved. The chief reasons are these:

1. We are just about at peak oil, and possibly past it (Deffeyes 2005), and peak gas is probably less than fifteen years away, so energy is going to become much more expensive. Producing nitrogen fertilizer is very energy intensive, yet it is also the chief means of raising yields, so it seems unlikely that the rate of increase in productivity that was achieved in the period 1985-2005 will be sustained right up to 2050.

2. Loss of cropland due to building infrastructure is a very serious problem. Vaclav Smil, in his book *China's Environmental Crisis: An Inquiry into the Limits of National Development*, pointed out that a main reason that the Chinese could not achieve American lifestyles was that in the process of building similar infrastructure, they would use up a considerable portion of their arable land. The rapid population growth in the USA will cause a similar problem well before this century is out.

3. Another reason for losing cropland is due to building dams, a loss which is a matter of considerable concern to the people of China and India, although mainly on account of the hardship caused by the displacement of people.

4. In some countries — the USA, China and India are illustrative — water tables and aquifers are being drawing down, with the result that irrigation will become impossible in some areas which are dependent on irrigation for high yields.

5. Pumping up water from underground sources requires energy, and even if there is not a water table problem, irrigation will be difficult to afford as energy becomes expensive.

6. There will be a reduction in productivity due to salinization. Salinization has been increasing rapidly during the past decade. The number of hectares being abandoned per year now equals the loss due to soil erosion, 10 million hectares per year.

7. Climate change makes weather less predictable, and successful farming depends on being able to plan according to the seasonal weather.

8. In order to combat the increasing cost of fossil fuels, large areas of land will be used to provide renewable energy. Gilland mentions that the "medium" projection of the U.S. National Corn Growers Association is that by 2015-16, 37.6% of a harvest of 371 Mt will be used for ethanol production. This looks as though it may be an underestimate, since the Department of the Environment and the US Department of Agriculture are projecting an increase from the present 5 billion litres of ethanol to 7 billion litres for next year, 2008, which would indicate an imminent use of 28% of all U.S. corn for ethanol production.

9. Much of the success that we have had in feeding a large population has been because of the advantages of cheap energy. It gives an ability to carry out timely agricultural processes over large areas, sowing, applying fertilizers and pesticides, and then harvesting at just the right time.. Cheap energy facilitates good storage, and refrigerated transport ensures that the food is delivered to where it is wanted in good condition.

Item 9 may well prove to greatly outweigh item 8 in importance. However, it is almost impossible to predict the extent to which yields will fall when energy becomes really expensive, as it is likely to become by 2050.

The vegetarian objection

It is sometimes argued that the world could feed many more people if everyone became vegetarians. Gilland advances excellent reasons for that being both unwise and unlikely. Apart from the superiority of animal protein, he points out the need for a safety margin:

> From a food security point of view, animal foods are important because when a substantial proportion of the cereal supply is fed to livestock, a drastic fall in supply does not cause famine. The 25% fall in grain production in China in 1959-61 resulted

in 30 million deaths, whereas the 40% fall in grain production in the countries of the former Soviet Union in the 1990s resulted only in a fall in the supply of animal products.

Anyhow, we in OPT prefer to think about an optimum population rather than the maximum that could be sustained, so there are other reasons for including animal protein in diets than the benefits of having a safety margin. The countries which consume 40 g of animal protein per day, or more, include Mexico, South Korea, Brazil, Russia, Poland, Japan, Argentina, Canada, Germany, Ukraine, UK, Italy, Spain, United States, and France, with the last three falling in the band of 74-77 g of animal protein per day. On that basis, 40 g/day of animal protein does not appear an extravagant goal for establishing an optimum population.

However, because nearly twice as much fossil energy is expended for the food in a non-vegetarian diet as in the vegetarian diet (Pimentel and Pimentel, 1996, p. 146), an aim for everyone to be able to have a better diet would require, for energy reasons too, to be accompanied by a shrinking population rather than an expanding one, even though no politicians or economists are taking note of the need for a shrinking population.

While there is indubitably a need for a shrinking population by 2050, in order to achieve the improvements that everyone agrees to be desirable, the problems of excessive population become rapidly more dire thereafter.

The Association for the Study of Peak (ASPO) oil forecasts that by 2050, oil supply, including regular oil, heavy oil such as tar sand oil, deepwater oil, polar oil, and non-gas liquids, will have fallen to about 35% of the peak value. More optimistically than most geologists, ASPO estimates that gas supply in 2050 will not be much different from today. But still ASPO estimates that by 2050 it will be falling at such a rate that is likely to halve in the following twenty years. As suggested in item 9 above, no one knows to what extent food supply can be maintained in the face of this decline in oil and natural gas, let alone heating and other requirements of modern civilization.

For a while, coal will be used to produce coal gas, synthetic gasoline, and electricity, but all these processes will be considerably less efficient due to the need to expend energy sequestrating the carbon. Moreover more energy will be expended mining the coal, as more difficult seams are mined. With such demands placed on it, coal will only provide a continuation of the fossil fuel age for a fairly brief period. Some nations have far greater coal resources than others. To what extent they will be willing to share them with the rest of the world, when they can see the reality of imminent exhaustion, is another question.

There is no need to reiterate the ineffectiveness of renewable energy sources because that has been a main feature of the OPT Journal since it was first published. But the reasons for that ineffectiveness are intractable, stemming essentially from (a) the uncontrollable nature of those sources which offer a moderately high power density (although nothing near that of fossil fuels), and (b) the very low power density of the controllable energy sources.

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William Dickinson writes regularly for the Biocentric Institute, a nonprofit foundation that gives general permission for use of its material. What Dickinson writes is always worth reading, but this 2007 "end of year" perspective is so closely aligned with OPT thinking that it deserves a place in the OPT Journal. The population problems of the U.S. and the U.K. are both dire. In the U.S. there is an apparent inability to stem a veritable flood of immigrants, with the result that population could double in fifty years. In the U.K., we already start from a population which is more than twice the level of a sustainable population, and our politicians show almost no awareness of the problems that lie ahead as oil and gas supplies become scarce.

A PERSPECTIVE ON THE YEAR 2007

by William B. Dickinson, 1617 Alvamar Drive Lawrence, Kansas, wdicki2@LSU.edu

The notion that Earth provides unending resources to feed and power an ever-growing population took a blow in 2007. The year just ending marked a turning point in the one-sided dialogue that has enabled heedless reproduction to continue despite decades of inescapable warning signs. Turns out, our environment is not sustainable without major adjustments in consumption and its concomitant, birth rates.

In key spots around the world, exploding populations have exhausted the sources of plenty — clean air and ample water, cheap fuel, open land, thriving fisheries and lush forests. It turns out that the world is indeed finite. Trying times lie ahead. (Just ask residents of Atlanta, who woke one morning to learn that the lake that supplies the city's drinking water may run dry by mid-2008 unless drought breaks. Explaining the lack of infrastructure, the mayor ruefully explained that no one anticipated so many people moving there.) The classic equations of population, carrying capacity and environmental degradation need to be reinforced. Quality of life is at stake. As environmental biologist Garrett Hardin put it years ago, "The question is, which do we want: the maximum number of people at the minimum standard of living — or a smaller number at a comfortable, or even gracious, standard of living. We are our own caretakers: the choice is ours."

It is not a choice we seem eager to make. How else to explain our dithering over a national energy policy as world oil reserves top out and gasoline prices soar? Admitting that there are just too many of us on this crowded planet involves hard choices and unpleasant associations. Living in denial suits the leaders in most of the poor nations. They seem oblivious to projections that show population growing from today's 6.6 billion to 9 billion or more by mid-century, with 90 percent of that growth coming in their nations. Limiting family size challenges engrained cultural habits and religious dogma. Better to hope that humanitarian aid prevents further hardship.

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Third world leaders are not the only ones who choose not to choose. Writing in *The Guardian* (of London), Madeleine Bunting pointed out that at the current rate of increase, by 2074 Britain will be the most densely populated country in the world after Bangladesh. Common sense, she said, tells us that "if the planet's resources are being grossly depleted, there are just too many of us." Britain would either have to limit immigration, which would seem racist, or limit family size, which would be seen as authoritarian.

Lest we in the United States think we can stand above the fray, consider this: U.S. population that today stands at 303 million is projected to grow by at least another 100 million by mid-century. Immigration, legal and illegal, and the higher birth rates of immigrants, would be responsible for the majority of this increase. States such as California will bear a disproportionate share. According to the California Department of

Finance, that state's population of 36 million is projected to reach 60 million by 2050. Verlyn Klinkenborg put a human face on this statistic when he wrote *(New York Times,* July 18, 2007): "If you said that for every three houses now there will be five in 2050, or for every three cars, ditto, you might be getting a little closer to the visceral feel of the thing." Californians continue to ignore nature and build homes farther into chaparral-covered hills that regularly cause devastating wildfires. The enormous consumption footprint of Californians and other urban Americans may be slowed by environmental awareness, but population growth almost certainly will trump Green.

The arithmetic of steady, exponential population growth doesn't daunt those who believe that technology will save the day. As far back as 1890, British economist Alfred Marshall argued that "knowledge is our most powerful engine of production; it enables us to subdue nature and force her to satisfy our wants." Lest you think that a concept overtaken by events, read a recent advertisement from Chevron that notes that the world is growing by more than 70 million people a year but asks: "So is that a problem, or a solution?" The rhetoric is short on detail and long on hope: "The key to ensuring success is found in...a spirit of hard work, ingenuity, drive, courage and no small measure of commitment. To success, to each other, to the planet. The problem...becomes the solution."

If "ingenuity" and "commitment" are benchmarks of reform, our nation's political leaders and presidential candidates surely are failing the test. Despite dozens of scientific studies to the contrary, some conservatives consider global warming a scam. Liberals mouth all the right warnings about carbon emissions but are short on specifics about next steps. Few dare mention the need to stabilize population.

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And don't look to international organizations to drive the population debate. In a little noticed report on Oct. 25, the United Nations Environmental Program warned that the human population is living far beyond its means and inflicting damage to the environment that could pass points of no return. Climate change, the rate of extinction of species, and the problem of feeding a growing population were blamed for putting humanity at risk. But the program's executive director said forcing people to stop having children "would be a simplistic answer." Rather, we should "accelerate human well-being and make more rational use of the resources we have on this planet." Sounds like more of the same empty rhetoric.

How can we explain the absence of this, the most important conversation political leaders should be having? Prof. J. Kenneth Smail of Kenyon College in Ohio has noted the lack of scientific study of what the long-term human carrying capacity of Earth might actually be. Why, he asks, hasn't overpopulation been taken out of the closet and elevated to the stature of global warming? "Given the issue's global nature and ramifications," Smail concludes, "perhaps the chief reason is simply 'scale paralysis,' that enervating sense of individual and collective powerlessness when confronted by problems whose magnitude seems overwhelming."

True, we can do little to force other nations to reduce their populations. Family planning assistance may be helpful, and foreign aid could be made contingent on declines in birth rates. Within our own country, however, we have both legal authority and responsibility. We need to set an example to the world by acting to solve our own problem first. Setting limits runs against the grain in our consumer-oriented society. But resources and population are irrevocably intertwined. You just have to look at the headlines for confirmation.

MALTHUS OVER A 270 YEAR PERSPECTIVE

by Andrew R.B. Ferguson

In 1798 Thomas Robert Malthus wrote: "Population, when unchecked, increases in a geometrical ratio, but subsistence increases only in an arithmetical ratio." He was well aware that Europeans were taking over the lands of native Americans and thereby introducing more productive agricultural methods. However, taking over other people's lands is a finite process, and when he wrote that "subsistence increases only in an arithmetical ratio," he was referring essentially to the potential for increasing the productivity of the land through improved farming methods.

Over the last two hundred years, he has not been obviously right, at least to the extent that many have proclaimed that he has been wrong, but as we will see, there are reasons to suppose that the truth of his proposition has long been apparent to anyone willing to see it, and the consequence of having ignored it will bear down on us in the immediate future.

The essential logic underlying Figure 1 is that if people are to continue to have enough food to eat, then increase in production must match increase in population, for example, if population changes by a factor of 10 (ten-fold) then food supply must change by the same factor of 10. Initially this can be achieved, in part, by taking more land into cultivation, but today that opportunity is no longer significantly available, so it is increase in yield per hectare that is important. Over the last two hundred years, reasonable estimates for early years, and fairly accurate data for the last sixty years, are available for wheat and rice yields, so those yields will be used as the indicator for increasing cereal yields.

Questions to be addressed are these:

1. Have cereal yields increased to keep pace with an unchecked rise in population?
2. Is it likely that cereal yields will increase in step with population up to 2070?

Little could Malthus have foreseen the improvements that would occur when full use could be made of fossil fuel energy so as to make nitrogenous fertilizers, to produce pesticides, to introduce irrigation schemes, and to build and use tractors and other agricultural machinery, the latter greatly facilitating farming in areas that otherwise would have been unsuitable. Notwithstanding these unforeseen technological developments, which resulted in changing the arithmetical ratio by which productivity could be increased (see Figure 1), his proposition has remained substantially true; and as we will see this should have been apparent to all about fifty years ago.

One crucial question to be asked is, what are the factors that have allowed this increase in yield to be achieved, because that will help to determine whether it might continue.

One factor is irrigation, and as Clive Ponting[1] relates, between 1800 and 2000 the area under irrigation increased to 275 million hectares, a 33-fold increase. He illustrates the significance of this in terms of yields with the fact that in south Asia only a third of the rice growing area is irrigated, yet it produces almost two-thirds of the total crop.

However there are many examples of irrigation leading to water logging and salinisation. In the last quarter of the twentieth century the loss of irrigated land was at a rate of about 1 per cent a year. Since 1978 the newly irrigated area has been increasing at about 1 per cent a year, so overall there has been little net increase during that period.

Apart from the problems of land degradation, limitations are set by the availability of water, since irrigation uses about 70% of water supplies. Between 1800 and 2000, the world's annual water consumption increased at least 20-fold. The amount of water used in recent times has only been available because of overdrawing from stocks. A good example is the Ogallala aquifer which stretches from Texas to South Dakota. The U.S. Geological Survey estimated that there was 3080 cubic km of drainable water left in 1980, so at the present withdrawal rate of about 26 cubic km per year *net of recharge, which is about one eighth of withdrawal*, the water could theoretically last until about 2100. However problems may develop before then: from the 1940s to 1980, the water level dropped about 3 metres on average and more than 30 metres in some places.[2]

The paramount need for water for agriculture becomes clear when it is considered that each kilogram of biomass requires about 1000 litres of water to grow, and yet Clive Ponting lists similar problems with water supply in most parts of the world. In many areas of India the water table is falling at 1 metre a year. In northern Gujarat, over a thirty year period, the water table fell at an average rate of 13 metres per year. "In Pakistan the water table in the area around Quetta is falling at about three and a half metres per year and the area will run out of water in the next decade."

China is in equal trouble, and it has already affected agriculture there (p. 260):

> The water level in the aquifer under the North China Plain dropped three metres in just one year (2000) and around Beijing wells need to be a kilometre deep to reach fresh water. … The wheat harvest in the area fell by 30 per cent between 1997 and 2003. This is one of the major grain-producing areas in China and as a result the Chinese grain harvest fell by almost 14 per cent in the period — an amount equal to the total Canadian grain harvest.

Moreover there is little prospect of greatly increasing water supply by building dams, because these have been found to be environmentally as well as socially damaging. On this subject Ponting says (p. 261):

> The flooding caused by the reservoirs displaces large numbers of people — probably as many as forty million in the last sixty years (half of them in India) and the current rate is about four million people a year.

At the end of his Chapter 11, Ponting sums up the problems that beset agriculture in these words:

> Modern agriculture has, like its predecessors, produced a mixture of achievements, problems and environmental disasters. … The need to bring more land into production and intensification of that production has produced numerous environmental problems — deforestation, soil erosion, desertification, salinisation and the over-loading of land and water with fertilisers, pesticides, and herbicides.

The factors outlined above indicate that yields are unlikely to continue to increase as they have in the past. Moreover other factors need to be taken into account besides the over-arching one that most soils are being used unsustainably, with soil being continually lost. Some factors seem likely to significantly increase the number of malnourished and underfed people:

1. Large segments of the world population are becoming rapidly richer and starting to eat more meat, which requires more cereals, leaving less for the poorer malnourished.

2. So as to avoid facing up to reality, people allow themselves to be deluded into thinking that liquid biofuels can make a significant difference to reducing carbon

emissions by replacing fossil fuels, hence significant amounts of food crops are likely to be used to provide liquid biofuels.

3. Global warming tends to cause crops to be lost, or yields to be reduced, due either to an *excess* of water, or too *little*; or just because farming is difficult when the weather is less predictable than it has been in the recent past.

4. Well before 2070, the scarcity of oil and gas will become apparent. Indeed by 2070 the supply of these is likely to be below half of what it is today, causing very high prices. The consequent increased demand for coal will cause considerable increase in the price, not only because of greater demand, but also because extracting coal from more difficult seams will require more energy to be used as input. With respect to efficiency, there is the further factor that with increased use of coal it will become even more important to sequester the carbon dioxide emitted, so the efficiency of supplying energy will be reduced for that reason too.

It was apparent long before all the above factors became evident that there was an inescapable truth in the logic of what Malthus said, namely that *unchecked* population growth would outstrip increase in food supply. How world population would change without severe restrictions on growth was clear to Malthus, and became empirically demonstrated around 1950, as is apparent from Figure 1, for it is at that point, when the problem of food supply appeared temporarily to have been solved, that the graph takes a sharp upward turn. From 1950 to 2000, the average rate of increase in population was 1.77% per year. Were it not for the constraints that operated from 1800 to 1950, namely shortage of food, inadequate hygiene, and lack of control of diseases, it can be surmised that population would have grown at about that rate, 1.77% a year, right from 1800. At that rate, by 2070 it would reach an obviously impossible 114 billion. Incidentally now, in 2007, the population in the less developed world, of 4 billion excluding China, is expanding at 1.8% per year. Some agricultural scientists have noted that between 1950 and 1984 the growth in cereal yields did increase in a close approximation to a geometrical ratio, but that period was a very small part of the two hundred and ten years that we are surveying. For the last twenty-three years, since 1984, per capita grain production has been falling continuously, and grains make up 80% of world foods.

So Malthus was clearly right. But how blind have humans been since about 1960, when they had before them the plain evidence that population during the last decade had grown at a rate of 1.8%? Simple calculation then would have shown that if that rate were to continue, then by 2070 the population would reach an impossible 21 billion.

And how blind do we remain today? The 2007 Population Reference Bureau Data Sheet shows population growing at a rate of 1.2% a year. Were that rate to continue, then by 2070 world population would expand from its present 6.6 billion (in 2007) to reach an impossible 14 billion by 2070. Yet some governments worry about declining populations.

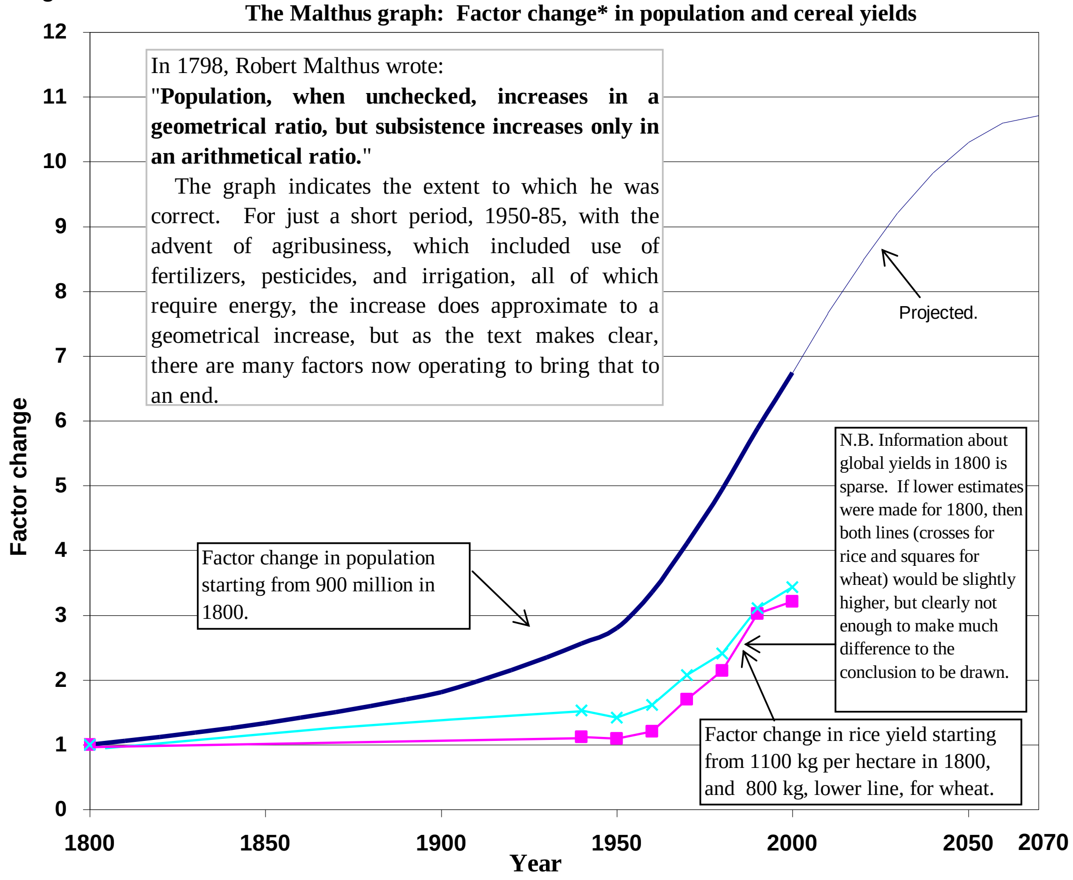
For many decades there has been a wilful blindness to recognize that population is the pre-eminent problem. For instance, both the UK and USA governments have completely overlooked a Royal Commission and a Presidential Commission respectively, both of which warned that existing population levels were already high enough. It was time those reports were taken from the shelves and every effort made to repair the sins of omission that have occurred since they were published.

The factor that will prevent human population from rising much above the line on the graph which is based on a projection of the growth rate dropping off to zero by 2070 is not human foresight, but rather the very one that Malthus feared, namely *intensification of the misery which his checks have always been causing.*

The human population may well not reach the *projected* 9.6 billion (10.8 multiple) shown in Figure 1, because of the many factors now coming into force which will make even the maintenance of present levels of food production difficult. Chief among those factors is the declining availability of fossil fuels. And that provides another case of wilful blindness, for many distinguished petroleum geologists have been doing all they can, over the last forty years, to draw the attention of the public to the predictability of peak oil, peak gas, and the problems of exploiting the remaining coal deposits, e.g. M. King Hubbert, "Buzz" Ivanhoe, Colin Campbell, Walter Youngquist, Jean Laherrère and Kenneth Deffeyes. Two courses of action are obviously urgent: (1) reduce fossil fuel use so that what remains lasts longer; (2) reduce population to a level that can be supported without fossil fuels.

Figure 1

The Malthus graph: Factor change* in population and cereal yields



* The meaning of factor in this context, taking population as an example, is the number by which the starting population needs to be multiplied to arrive at the population at the end of any given period. The phrase "factor change" is used to indicate that the relevant factors are shown over the full period of 270 years.

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FOOD SUPPLY AFTER THE DEMISE OF CHEAP ENERGY

by Andrew R.B. Ferguson

Abstract

The end of fossil fuels, or the demise of cheap energy as the process may be described, will change nearly all aspects of our lives, but none is as fundamental as the food supplies needed to keep the human population alive. While fossil fuels have been available, it has not been necessary to account for the ecologically productive land that is needed to produce energy. After the demise of cheap energy, that land becomes part of the equation of how much ecologically productive land is needed to provide a given amount of food. It is shown that while maize (corn) can now be harvested at the rate of 130 GJ per year per hectare (about 4.1 kilowatts per hectare), in the absence of fossil fuels, delivery of food to the table will be produced at a rate of only 52 GJ per year per hectare of land used (about 1.6 kW/ha), and that is on the optimistic assumption that efforts are made to maintain high-input agriculture. If food supply were the sole determinant of the population that could be supported, and more land could not be appropriated to human use, then to maintain the present food supply, population would need to be reduced to 52/130 = 40% of its present level. Shortage of energy from fossil fuels will put many other demands on land.

Most discussions in the media, and that even includes most academic papers, confine their thoughts about food and energy to the next few decades, at most up to the mid-century. Yet the great majority of people who have studied these matters are ready to agree that by about 2060 oil and gas supplies are likely to be less than half what they are today and that by then coal supply will, in most nations, be somewhat uncertain. Since it takes about a century to make a dramatic change to population numbers, it behoves us to attempt to look ahead for at least a century and try to estimate what the situation will be when fossil fuels become really scarce, that is to say after the demise of cheap energy.

Rapid expansion of population started in 1950. From that date up to 2000 the mean exponential growth rate was 1.77% — a doubling time of 40 years. Today 1.8% is the average growth rate for the 4 billion in the less developed world excluding China. There are over 800 million people who go hungry, and over 2000 million who suffer from malnutrition, but whether these human lives are satisfactory or not, this expansion in population has been made possible by an increase in yields per hectare *as well as* by using more land for supplying food to humans. Immense damage has been done, and is being done, to other species by taking over their habitats for human purposes, so a vital question to ask, in the context of what population can be supported without fossil fuels, is whether, without the benefit of fossil fuels, it will be possible to maintain the substantial increases in agricultural yields per hectare that have been achieved in the latter half of the last century.

In a 1990 paper, *Technological changes in energy use in US agricultural production,* Pimentel et al presented data to show how, between 1945 and 1985, increases in the harvested maize (corn) crop was associated with increasing inputs (Series 1 line in Figure 1). In 2003, Pimentel and Patzek looked again at the Energy Return (ER) ratio of corn in the US (Pimentel & Patzek 2005). During the final period 1985 to 2003 the improvement in yield had slowed to a crawl, taking 18 years to accomplish what had been accomplished in any 17 months between 1975 and 1985 (Figure 1). What did improve was the inputs, for they decreased slightly to 34 GJ/yr/ha. Thus by 2003, with an output of 130 GJ/yr/ha, the ER ratio had improved to 3.8. This was even a slight improvement on the starting value of 3.7 in 1945 (a constant ER of 3.7 is shown by the dotted line in Figure 1). That is relevant from the farmer's point of view. It means that the law of diminishing returns has not yet prevented any further improvement in yields (although the growth in yields is now very slow). However, that absence of diminishing returns arose because with fossil fuels readily available, no account had to be taken of the ecological land needed to produce energy. *Once fossil fuels become scarce, the output per hectare of land used will drop dramatically and the ER ratio will decline rapidly as outputs are increased by using more inputs* (Figure 1). By 2003, with the benefit of fossil fuels, 130 GJ/yr/ha was being gathered as corn from US fields. Without fossil fuels, once all the energy inputs needed have been taken into account by making allowance for the ecologically productive area needed to provide those inputs, the estimate drops to 52 GJ per year per hectare *of land used*. Note that to speak strictly the italicized phrase is needed, because the land used may not be all cropland, but merely ecologically productive land, some of which may, for instance, be suitable only for growing short-rotation woody crops.

When accounting for fossil fuel inputs, it is perfectly acceptable to make no allowance for the land needed for energy inputs, because fossil fuel places an almost negligible demand on ecological resources. Open cast coal does place a demand on land resources but nevertheless the power density is high. Oil and gas make very small demands. So while fossil fuels are available, the demands on ecologically productive land by the need to provide energy can be ignored; thus the Series 1 line shown in Figure 1 is not misleading while fossil fuels are available.

That is not the situation when fossil fuels are scarce. For forests regenerating naturally, the yield is about 3 dry tonnes per year per hectare, so the gross power density is about 60 GJ/yr/ha (60 gigajoules per year per hectare equals about 2 kilowatts per ha). In many places that can be pushed up to a much higher figure, with the use of some fertilizer, probably to about 8 dry t/yr/ha for short rotation woody crops, providing gross energy of 160 GJ/yr/ha. But the real problems appear when the need for liquid fuel is taken into account. The useful liquid yield of ethanol from corn (maize) is about 59 GJ/yr/ha (OPTJ 3/1, p. 12). But the total inputs needed for growing and conversion to ethanol are about the same as the energy in the ethanol output, so if the land needed to provide that energy is also taken into account, the power density would drop to something like half as much. It is impossible to be precise because, for instance, to satisfy the need for heat to distil the ethanol would generate further requirements for liquid fuel for harvesting and transporting heating fuel to the distillation plant, and data on that is lacking. What can be said unequivocally is that the power density of ethanol would be far below 59 GJ/ha/yr once the heat inputs are taken into account.

Various uncontrollable power sources are available, notably wind, which have much higher power densities (e.g. for wind about 380 GJ of electricity/ha/yr), but their uncontrollable nature means that, at least as far as can be securely predicted at present, they will be limited to providing about 20% of the *electrical* supply. Of course there is a great deal of speculation that can surround the average power density that will be achieved when relying on renewable sources, but as I have argued at length elsewhere, a figure of about 3 kW/ha of ecologically productive land (close to 95 GJ/yr/ha), which is also the figure used for the energy footprint in eco-footprinting methodology, is likely to be in the ball park. It has been necessary to go into this question of average power density in detail, because the Series 2 to Series 4 lines in Figure 1 depend on the assumption that the energy inputs needed to produce and deliver the food can be provided at a net energy capture of 95 GJ/yr/ha. The underlying problem inherent in that 3 kW/ha figure is readily apparent because it is only about 0.15% — 15 parts in 10,000 — of the energy that falls on the ground from solar radiation, in the USA.

Arguably the most significant line is Series 4, for this includes the energy needed not only on the farm, but also for processing, transport, retail and bringing the food to the table. The reason that it may be the most significant line is that it seems quite likely that parts of the present system of high input agriculture could not be dismantled without the whole system collapsing. However that argument is not inviolable, so the Series 2 line shows the effect of requiring only that the energy inputs needed on the farm are to be supplied from renewable resources.

It is evident that this already makes the proposition of higher inputs less attractive. First it will be noted that merely providing this input drops the rate of energy capture from 130 to 96 GJ per year per hectare of land used (Series 2 line, Figure 1), and secondly that the slope of the line now indicates a significant decline of the ER ratio as inputs are increased (the dashed line, Series 6, indicates a constant ER ratio of 3.7).

The extent of the problem becomes really apparent when all inputs that are needed to bring food to the table have been included, as shown in the Series 4 line. Providing for all the inputs needed to bring the food to the table takes the rate of energy capture to 52 GJ per year per hectare of land used. The result of using all these inputs is that the ER ratio decreases from a starting value of 2.6 to 1.5 — a clear case of diminishing returns.

For such reasons, it is quite likely that the farmer will decide against high input agriculture with modern distribution, because what matters to the customer is the cost of the food at the table. Admittedly food has to be cooked, and that last part of the chain will not change, but nevertheless the customer will require ecologically productive land to produce the heat energy. It may well be that high input farmers would find they could not compete with other farmers who were abandoning all unnecessary inputs. But even if they all press on in order to do their best to maximize outputs, the result would still be that in delivery of food to the table the rate of energy capture falls from 130 to 52 GJ per year per hectare of land used. If they abandon high input agriculture then output would drop back to a 1945 value of 28 GJ/yr/ha, a mere 22% of the current 130 GJ/yr/ha.

So unless there is actually more ecologically productive land available to be put to human use, then to the extent that people cannot exist on a more frugal diet, even taking an optimistic view about maintaining high inputs, there is need to reduce population to about forty percent of its present level. Of course the developed world can live on a more frugal diet, including becoming largely vegetarian, although the political difficulties of arranging that are considerable. But food supply is only one of many problems that will beset us in the absence of fossil fuels.

The need to keep warm will also place enormous demands on ecologically productive land. The need to have energy in a controllable form to smooth out the uncontrollables and so have a reliable electrical energy supply, and the need to provide heat for industry, will all put extra demands on ecological resources. In fact how the situation will appear to farmers is that now that energy has become so expensive, because demand greatly exceeds supply, any farmer who continues with the practice of high input agriculture will not be able to compete in price with those who decide to forgo the high inputs and settle for a lower output.

This likely change in the farming system is a microcosm of many changes that will have to occur without fossil fuels. Some people predict that without fossil fuels the world will be in much the same position that it was before fossil fuels were discovered, and a sustainable population will be no greater than it was then. Whether that is precisely true is a matter of surmise, but the fact that the "energy transition," which people talk about so blithely, is likely to involve a total change of life style with a much smaller population is almost beyond dispute when account is taken of such matters as those investigated above.

Figure 1. **Energy outputs (as maize) per hectare used, with and without fossil fuels**

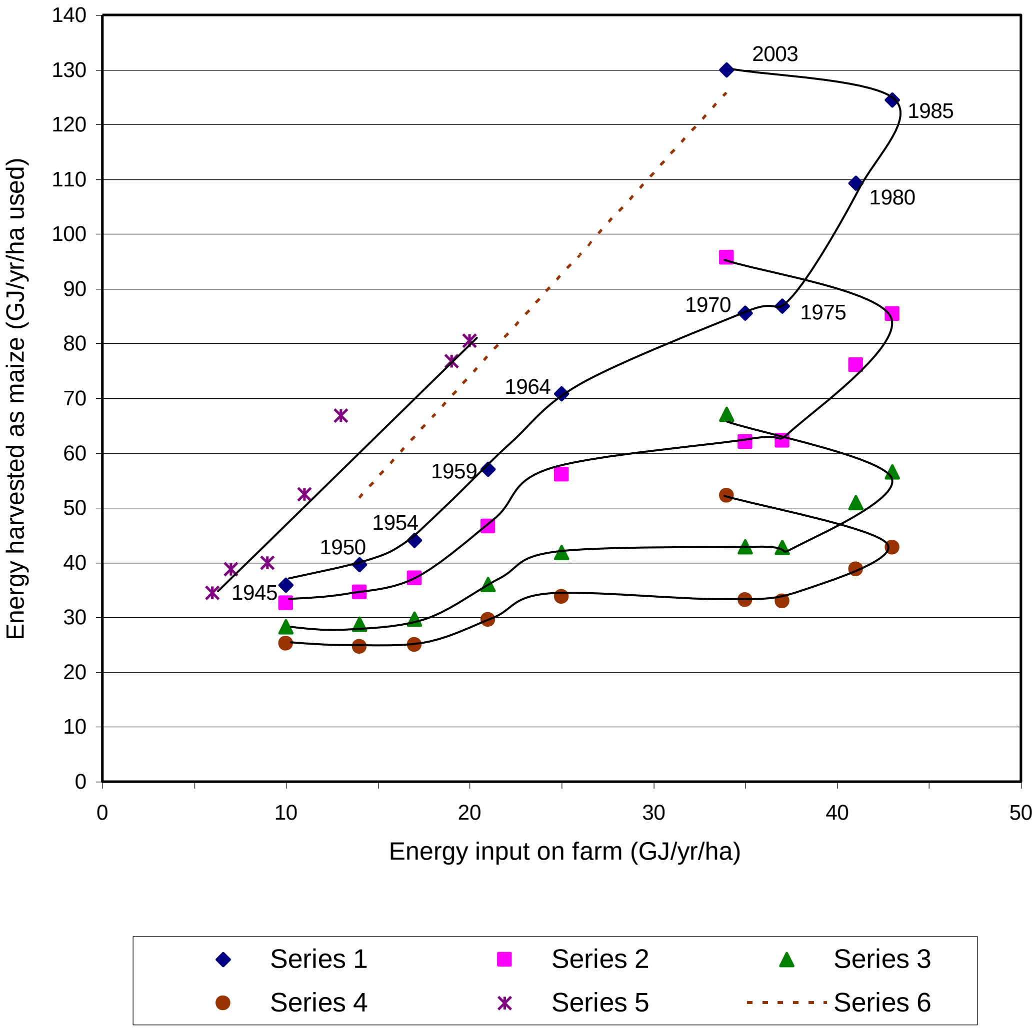

Figure 1 description.

Series 1 up to 1985 is based on data from Pimentel et al 1990, and shows the energy harvested per year per hectare against the amount of energy used as inputs on the farm (shown on horizontal axis). The next data point, 2003, is derived from data from Pimentel and Patzek 2005.

Series 2 takes into account that when fossil fuel is not available as input, additional land will be needed to provide the input energy. Moreover it will be necessary to provide energy for all aspects from growing the food to delivering it to the table. However Series 2 shows the output that would result when sufficient land has been included (energy assumed to be captured at 95 GJ/yr/ha) to provide only for the farm inputs.

Series 3 is similar to Series 2 to except that it also includes the energy needed to cover processing and transport of the food.

Series 4 is similar to Series 3 except that it also includes the energy that is provided to deal with the activities from retail store to table.

Series 5 shows the 1945 to 1975 results based on a reworking of Pimentel's data by Smil et al (1983).

Series 6 shows the hypothetical line which would result from maintaining the initial ER ratio of 3.7.

The calculation of Series 2 and 3 is based on data from Evans (1993, p. 353) that farm inputs represent 24% of inputs, processing and transport 39% and retail to table 37%. This may not have remained constant throughout the period, so the curves shown are only approximations.

Further thoughts on Figure 1

A noteworthy point about Figure 1 is that during the period 1985 to 2003 the improvement in yield slowed to a crawl, taking 18 years to equal the improvement that would occur in any 17 month period between 1975 and 1985. The line flattens out because of that and because there was a significant change in inputs.

There are several plausible reasons for the reduction in inputs during those last 18 years. For one thing, the energy needed to make nitrogen fertilizers, the biggest input, continued to decline. For another there was growing awareness of the environmental problems being caused by excessive use of fertilizers, pesticides, herbicides and fungicides, so greater care was taken to minimise their use. Incidentally, Evans (1993, pp. 364-65) suggests that minimum till agriculture would save energy; and some investigators claim that no-till saves energy, but David Pimentel, quoting appropriate references, told me that this result usually emanates from only accounting for tractor fuel reductions. Other relevant factors are the 23% increase in nitrogen fertilizer required; a 10% to 15% increase in seeds planted because of rotting; and 4 times more pesticides required in no-till production. In spite of the additional energy needed for no-till, Pimentel advocates its use to reduce soil erosion.

It is interesting to look at the background to the seminal work on charting the energy inputs into agricultural systems which commenced with the study by Pimentel et al (1973). That study examined the years 1945, 1950, 1954, 1959, 1964 and 1970 for analysis of the inputs, and related these to three-year-means of yield centred on those years. This work generated much interest, but was criticised for various suggested shortcomings. The data was reanalysed by Smil et al (1983). One weakness found was that in the original study a constant value of 77.5 MJ/kg was used for the energy cost of nitrogenous fertilizers throughout the period, whereas in fact nitrogen fertilizer as applied to the US corn crop fell from 99 MJ/kg in 1945 to 61 MJ/kg in 1974, as estimated by Smil et al (1983). It was also reckoned that the shift towards reduced tillage may have been underestimated, and also the shift to diesel fuel, which gives economy of energy use in machinery. Taking these factors and several more into account, Smil et al recalculated, and found that according to their calculations the change in energy ratio was such as to produce a straight line, over the 30 year period 1945 to 1975, as shown by the Series 5 line. The fact that the straight line runs almost parallel to the dashed line which represents a constant ER ratio of 3.7 can be misleading: because Smil et al start with an ER ratio of 5.5. Their straight line in fact represents a 25% fall in the ER ratio (5.5 to 4.1) over the period.

What can be learnt from this different analysis by Smil et al is that proper accounting of all the inputs is extremely complex, and unless everything is exactly right, there will be imperfections in the line of the graph, but these details are not of much importance to this study. What is important is the amount of additional input that is needed to achieve higher yields, because it is that which transforms the output per year per hectare used when those additional inputs have to be captured from renewable energy sources.

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