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Keynote address

The paradigm of efficiency and sustainability – a dairying perspective

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Abstract

For many, the terms efficiency in food production and sustainability are perceived to be mutually exclusive. This perception is often the result of too narrow a definition of sustainability. This paper reviews the sustainability of efficient dairying systems using the Framework for Evaluating Sustainable Land Management (FESLM), and offers some prediction of the future demand and supply of dairy products globally.

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The Philosophy

"If the cities fell tomorrow, agriculture would continue.
If agriculture stopped tomorrow the cities would fall"

Efficiency is the ratio of energy delivered to energy supplied in a dynamic system. Sustainability is the use of a resource so that it is not depleted nor permanently damaged (Merriam-Webster, 2004). Therefore, a truly sustainable system must, by definition, be efficient. However, postmodernist anti-technology movements would have us believe the opposite, that efficiency in food production and environmental sustainability are mutually exclusive terms. This is a complex and often emotional issue, and progress in the fight against hunger has often been hampered by polarized views and disputes over perceptions rather than meaningful discussions about substantive ways of solving actual problems (DeGregori, 2001).

The term sustainability has become synonymous with protecting the environment at all costs. This is not an accurate or complete definition of sustainability. Sustainability is a difficult concept to grasp because it means different things to people with different goals and agendas (Zinck & Farshad, 1994). Sustainability to animal scientists relates to maximising the productivity of conventional agricultural systems. To economists, economic efficiency, often associated with political issues, controls sustainable development. In comparison sociologists put more emphasis on social variables and ecologists and environmentalists concentrate on the stability of ecosystems and the environment.

Because of this multifaceted nature of sustainability, Smyth & Dumanski (1994) established a Framework for Evaluating Sustainable Land Management (FESLM). They defined sustainable land management as land management that combines technologies, policies and activities aimed at integrating socio-economic principles with environmental concerns so as to simultaneously maintain or enhance production/services (productivity), reduce the level of production risk (security), protect the potential of natural resources and prevent the degradation of soil and water quality (environmental protection), be economically viable (viability), and be socially acceptable (acceptability). This framework recognises that many environmental, economic and social factors will interact to determine if a particular land use is sustainable.

In determining the sustainability of land use it is therefore necessary to take account of all these factors. It also highlights that sustainability is a dynamic concept, depending on the stage of development of an industry and a community. For example a definition of sustainability of land use in developed countries where people are well fed can not be applied to less developed countries where people are undernourished. In agreement with this, the UN suggested that the real objective of technological development should be "to create an enabling environment for people to enjoy long and healthy lives" (Lomborg, 2001). By this definition, the first measure of sustainability must be human health and well being, although acknowledging that this must be achieved within the framework of a global environment that allows other species to thrive alongside humankind.

Put simply, the objective of every species is to survive. There is little reason for humankind to preserve nature for nature's sake, especially if this was to result in people going hungry or dying. In the FESLM this is unlikely to be socially acceptable, is not economically viable, does not improve productivity, and certainly does not decrease the risk of production failure. Environmental sustainability should be to preserve nature so that we, and future generations, can enjoy and make use of natural resources.

This requirement for social acceptability of sustainable land use is supported by the fact that environmental awareness increases with increased wealth or decreased hunger, depending on the measure chosen (Lomborg, 2001). In short, when people no longer worry about the source of their next meal, they become more conscious of the environmental repercussions of their actions. By this argument, one could deduce that the most successful way to improve environmental health is by ensuring there is adequate food for humankind. This is consistent with the definition of sustainability provided by the UN.

Humans are living for longer than ever before, due largely to better nutrition and improved sanitation and medication. Efficient production of food therefore plays a vital role in sustainability, and dairy production is no exception. Dairy production in the future will affect sustainability in three ways; 1. peoples requirement for food; 2. human health; and 3. through its impact on the environment. In this paper we will examine these three points, and how they relate to the framework for evaluating sustainable land management (FESLM).

Producing Enough Food

And he gave it for his opinion, "that whoever could make two ears of corn, or two blades of grass, to grow upon a spot of ground where only one grew before, would deserve better of mankind, and do more essential service to his country, than the whole race of politicians put together" – Jonathon Swift (1726)

The most important item to allow people "to enjoy long and healthy lives" is the provision of food and clean water. Globally, the efficiency of food production has increased dramatically over the last half-century. Cereal yields have increased 3-fold (Borlaug, 2002) since 1960, total per capita food production has increased by 23%, and per capita food production in developing countries increased by a staggering 38% (Lomborg, 2001). This is despite a doubling of the world's population and has only resulted in a minor encroachment on wildlife habitats (Borlaug, 2002).

Some of this improved efficiency is a result of technological advances, and improved crop breeding and husbandry, particularly in developing countries, however by far the most influential of developments have been the increased use of chemical fertilisers, pesticides and herbicides. Compare the yields of organic farms to those of conventional farms. Organic farmers have had access to the same improved genetics and the same improvements in husbandry practices, but yields of organic produce per hectare, rarely exceed 50 to 60% of those produced from conventional agriculture (Avery, 2000). In support of this, Edmeades (2003), in his review of the effect of long term use of fertilisers and manure, reported an 800% increase in the yield of conventionally produced wheat, relative to an unfertilised control, even though the same technology, breeding and husbandry developments were applied to both. Additionally, it has been estimated that without the advent of nitrogen fertiliser the earth would only be able to produce enough food to maintain 4 billion people (Smil 2000, as cited in Siedow, 2001). Without the use of pesticides the cost of fruit and vegetables would double (Lomborg, 2001), resulting in reduced intakes of these foodstuffs and consequent increased incidence of cancer (World Cancer Research Fund (WCRF), 1997 as cited by Borlaug, 2002).

The green revolution, as the biological and technical developments in food production during the latter half of the 20th century became known, has significantly increased the sustainability of land use for food production, increasing per capita yields, decreasing the risk of famine, and reducing the cost of food. All of this has occurred while air and water quality has improved dramatically (Lomborg, 2001) and by only increasing the area seconded to agriculture by 12%, thereby saving an estimated 1.2 billion hectares of wildlife habitat (Borlaug, 2002).

However, even with these successes, in excess of 750 million people are still undernourished and global population is increasing rapidly. Although one could argue that sufficient food is produced globally to feed the world's current population, if people in developing countries attempted to consume a diet based on high-quality animal products similar to most people in the developed world, only half of the world's current population would be fed (Borlaug, 2002). People, when not influenced by emotional issues, desire a diet of animal products (Hamilton, 1987). This is an anthropological fact (DeGregori, 2001) and as a result of increased wealth there is an increased demand for meat and dairy products. For example, in the decade between 1983 and 1993 global consumption of meat increased by 30% and consumption of meat in developing countries increased by 75% (Borlaug, 2002). The International Food Policy Research Institute (IFPRI) predicts an increased global demand for meat of 120 million tonnes by 2020 (65% increases), 100 million tonnes of which will be consumed in current developing countries (115% increase; IFPRI, 2001).

Continued improvements in agricultural efficiency, in particular animal-based agriculture, are crucial if we are to be in a position to feed the world of 10 billion people, predicted for the middle of the current century.

Increasing Dairy Production – "The Milk Revolution"

In the future, dairy product consumption, and hence production, will increase for two reasons.

1. Affluence-based desire for animal products

Increased affluence in developing countries will lead to a greater demand for dairy produce as a dietary constituent and a high quality source of protein. Lomborg (2001) reports that we are three times wealthier now than we were in 1950 and per capita GDP growth has been similar across all regions since World War 2, even though population growth has been higher in developing countries. As population growth stabilises in developing countries we should expect a greater increase in per capita prosperity in those countries compared with industrialised nations. In addition to increased prosperity, food costs less than a third of what it did in 1950. With such significant and long-term trends in prosperity and cost of food, one would expect an increase in the global demand for dairy products.

However, in the short term it is difficult to predict exactly what will happen to dairy production because so much is dependent on the agricultural policies of the E.U., the U.S.A. and Japan. The Organisation for Economic Co-operation and Development (OECD) predicts a 9.5% increase in dairy production between 2001 and 2007, or an annual increase of 1.3%/year. Most of the expected increase in the short to medium term is predicted to come from OECD member countries, most notably New Zealand, Australia, Poland and the United States, although dairy production growth in China and India is also expected to exceed 4%/year (OECD, 2002). However, these nations are starting from a much lower base production and contribution to global milk production will remain small over the next 10 to 15 years. In the long term however, with reduced protectionism and the continued globalisation of trade in dairy products, one would expect that the demand for dairy products will increase with increasing prosperity.

Milk production trends support this assertion. Even though global milk production is estimated to have grown at only 1.1%/year (IDF, 2003) during the last 10 years, this is not a true reflection of the demand for milk. Certain regions (most notably the E.U. and Canada) have artificially reduced the growth in production of dairy commodities through quota disincentives and release of product stores. In addition, consumer concern about the quantity of fat they consume daily, and in particular their consumption of saturated fats, has led to a stagnation and in some cases even a reduction, in the consumption of traditional dairy products by many in the developed world (Parodi, 1996). Globally, exports of dairy products increased 15% between 1998 and 2003 (IDF, 2003) and growth in milk production in Oceania (New Zealand and Australia) has exceeded 4%/year over the last 10 years. Growth in these countries is probably a more accurate reflection of the growth in demand for dairy products, as both of these countries trade unprotected and contribute 45% of butter, 42% of skim milk powder, 48% of whole milk powder and 36% of cheese exported globally. Their increased production and the OECD's prediction for continued growth in these regions therefore reflect increased international market demand.

Additionally, South America has seen a 30% increase in dairy cow milk production over the last decade and in Asia, growth has exceeded 40% (IDF, 2003), not including the almost 50% increase in buffalo milk production. This increase is equivalent to a 4 to 5% increase in global milk. In China alone consumption of liquid milk (including milk drinks, fermented products and yoghurt) increased 2.9 billion kg between 1999 and 2002 (IDF, 2003). A 90% reduction in many of China's tariffs on other dairy products following entry into the WTO will further increase consumption and demand.

The OECD predicts a similar increase in milk production in Oceania and Asia in the next five to ten years, but is unsure of short term growth in dairy production in South America following the Argentinean recession (Argentinean milk production declined 8% during the early 2000s). Irrespective of short-term recessions, long term trends suggest that demand for dairy products will increase.

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2. Milk as a 'natural' medicine

The second reason for increased consumption of dairy products in the future will be a recognition of their bioactive properties and the effect these have on human health and well being. However, before the true benefit in product demand can be realised, education of consumers on the true impact of dietary fat, and in particular fat from dairy products, on human health is required.

Over the last half century, mainstream nutritional science has demonised dietary fat and in particular saturated animal fats. Simplistic nutrition messages which suggest that fats in the diet in general, and cholesterol and saturated fatty acids in particular, are harmful and may contribute to "diseases of affluence", have damaged the image of milk and dairy products as popular, basic, almost obligatory food items (Parodi, 1996).

However, 50 years and hundreds of millions of dollars of research have failed to prove a link between a low-fat diet and increased life expectancy. The creation and marketing of low fat food products has become big business, with over 15,000 of these products on supermarket shelves (Taubes, 2001). Yet, science findings have never been able to prove a link. There is a link between dietary saturated fat and blood cholesterol, although genetics probably plays a greater role. Increased blood cholesterol increases the risk of atherosclerosis (clogged arteries), and clogged arteries increase the risk of heart attack; *Ergo* dietary fat increases the risk of heart attack. *Quad erat demonstradum!*

This would be an acceptable hypothesis, except that on testing, it has not been substantiated (Taubes, 2001). In fact worse, the most comprehensive studies of diet and human health, undertaken by the Harvard School of Public Health, show no correlation between total fat consumed and the risk of heart disease, that monounsaturates lower the risk and that saturated fats, as are found in dairy and meat products, are only marginally worse, if at all, than the carbohydrates that the Food Guide Pyramid suggest be eaten copiously (Taubes, 2001). These studies lasted 20 years and accumulated data on the diet of almost 300,000 Americans.

All that can be taken from the data generated over the last 50 years is that there is a link between obesity and the risk of heart attacks. No linkage between dietary fat and heart attacks is forthcoming. In comparison, milk fat contains a number of components, such as sphingomyelin, conjugated linoleic acid (CLA), butyric acid, ether lipids, vitamin A, B-carotene and vitamin D, which have the potential to inhibit the process of carcinogenesis, and possess antiatherogenic and immunomodulating properties (Parodi, 1996). Components in milk have been shown to provide protection from the catabolic effects of immune stimulation (Cook *et al.*, 1993) and to reduce the development of atherosclerosis (Lee *et al.*, 1994) and diabetes (Houseknecht *et al.*, 1998). A Finnish National Public Health study, which covered 25 years, found a significant inverse association between dietary intake of milk and other dairy products, and the incidence of breast cancer (Knekt *et al.*, 1996).

Yet these health benefits are completely ignored in the over-simplistic anti-fat message of mainstream nutritionists. In fact worse, recent legislation introduced in many countries, requires the content of *trans*-fatty acids in foodstuffs to be included on packaging labels. As 3 to 4% of milk fat is *trans* 18:1 (*trans*-vaccenic acid – TVA; Kay *et al.*, 2004), such negative publicity could further reduce the consumption of milk by health conscious consumers. Ironically, as consumers rush to purchase plant-based alternatives to dairy products, the epidemiological study by Willett *et al.* (1993) demonstrated that coronary heart disease was correlated with the intake of *trans*-fatty acids from plant sources, but not with the intake of *trans*-fatty acids from dairy products. Consistent with these results is the linear reduction in the incidence of mammary tumourigenesis with increasing dietary TVA concentration (Corl *et al.*, 2003), verifying the importance of an animal-derived *trans*-fatty acid in preventing cancer.

As an industry we must be proactive in highlighting the positive health attributes of dairy products, and clinical in dismissing, with scientific findings, the unsubstantiated negative reports. As more becomes known about milk's bioactive properties, and as consumers become more aware about the benefits of these natural health agents, demand for dairy products will increase, and milk and dairy products will regain their pedestal as an obligatory foodstuff in affluent nations.

Where Will The Extra Milk Come From?

In the future, as has occurred with meat production, there will be an increased demand for dairy products as a daily dietary constituent. We contend that this demand will be largely in developing communities because of increasing affluence and sheer population size. However unlike meat production, milk processing requires significant capital investment and it is unlikely that many of the poorer countries will produce significant quantities of dairy products in the short to medium term. Meat protein is likely to constitute the bulk of their animal protein consumption.

However, increased prosperity in many countries, particularly in Asia and central and eastern Europe (CEEC), but also in South America, and interest from international investors will allow significant investment in dairies and processing facilities. This will allow a rapid expansion in dairy production in these countries, but is not likely to impact greatly on world dairy product trade in the short to medium term because these countries are beginning from such a low production base. In addition, many of the CEEC members are primed to become member states of the E.U., and as such will be subject to the same debilitating policies and environmental regulations that current dairy producers in the E.U. are subject to.

Deciding the most efficient and sustainable way to provide dairy products to the 'demanding' consumers should be evaluated using the FESLM. Obviously, the social acceptance criteria has been fulfilled, as that is the reason for increased production, and the whole purpose is to enhance the service (range of foodstuffs) provided to consumers. The criteria that therefore require evaluation are the economic viability of producing dairy products vs. importing them, and the environmental risks associated with the production of these products. There are three major challenges to expanding dairy production (Avery, 2000); feed supply, land requirements of the cows and replacement stock, and effluent disposal.

In general, dairy products are luxury items and countries with sufficient affluence to consider dairy production will generally have succeeded in providing basic energy requirements to their population, as already mentioned, through improved crop yields and fertiliser and pesticide use. Biotechnology will allow even more feed production per hectare as well as providing land that would previously have been unsuitable for cropping. Avery (2000) outlined several advances in biotechnology that will allow new land to be used for food production. For example, acid-tolerant crops are being genetically engineered, which will allow crop production on the world's 400 million hectares of acid savannah. Salicornia, dubbed the "salt water soybean", has been bred up from an ubiquitous saltwater weed. Green chopped it can be fed like lucerne. If left to mature it yields an oilseed similar to soybean. This crop can be grown on the desert and irrigated with seawater. Coastal desert within 5 to 7 km of the sea is now a potential site for saltwater soybeans. Current and future technologies will provide sufficient feed to allow expanded dairy production, but continued improvements in efficiency are essential to minimise its effect on natural areas of biodiversity.

In addition to providing feedstuffs, technology will also provide a suitable animal for the expanding dairy industry. Many of our traditional dairy breeds may be unsuitable, succumbing more to heat stress or perhaps being more prone to many vector borne diseases. On the other hand, the native breeds in these countries do not generally have the yield potential to meet the growing requirements for dairy products, and just milking a greater number of lower yielding cows is not an efficient use of relatively scarce feeds. Biotechnology has the potential to accelerate the development of high yielding dairy cows that are resistant to native pests and diseases. Bioengineering differs from conventional breeding in that only one or two specifically identified genes are typically introduced into a background of tens of thousands of genes (Conko & Prakash, 2002). Traditional breeding resulted in a number of genes being transferred, meaning it was difficult to predict the number or the traits transferred and it was not always possible to predict the resultant characteristics. According to the National Research Council (NRC, 1989), "we are in a better, if not perfect, position to predict the characteristics" of organisms modified by molecular methods.

Land in many countries with growing demands for dairy produce is also scarce. Confinement dairy systems, where cows are housed in stalls (free or tethered) minimise the land requirements for dairying. Although labour requirements and the requirements for modern technology are greater than with grazing pastoral farming, the flexibility of being able to produce milk in regions not suitable to pastoral systems will make these confinement systems attractive, particularly in non-temperate climates. This is not to say that pastoral farming will not have a place in future dairying. Pasture systems hold a number of advantages over confinement systems, requiring less labour and mechanisation, less tillage and less expertise in animal nutrition and husbandry. We contend that pastoral systems will continue to occupy land that is unsuitable for cropping (due to aspect, topography, accessibility), and in temperate regions that do not have a ready access to arable crops. However, even in pastoral dairying, modern technology and husbandry practices will allow large-scale production of dairy products.

Nonetheless, for a number of reasons we believe that the majority of expansion in dairy production will be in confinement systems. Provided sufficient water is available, arable crops tend to be less sensitive than pasture to the vagaries of climate and the yield of dairy products per hectare of feed grown is significantly more in such systems. In addition, there is a greater emphasis on breeding higher yielding arable crops than improving pasture yields and characteristics. Therefore, it is more likely that improved efficiencies in milk production will come from crops that are mechanically harvested for delayed feeding to livestock than from pasture.

Current technologies such as ration formulation software and feed additives, animal health products, such as rumen modifiers and recombinant somatotropin will allow developing countries to reach the milk yields already achieved internationally in the affluent nations.

Dairying and the environment

All agriculture is a disruption of nature (DeGregori, 2001), although in recent years the impact of 'modern' agricultural practices on the environment has become of increasing concern. The root of this concern can be found in the published beliefs of Rachel Carson (Carson, 1962) that the use of chemicals in agriculture was destroying the world and human health. However, most recent concern has focussed on water quality and nutrient management, and, in particular, reducing nutrient runoff and leaching. E.U. nitrate directives and subsequent stocking rate regulations are a direct result of such concerns. It is when sustainability is discussed from an environmental point of view that the FESLM is often abandoned, and ironically it is in this area that it is of most importance.

Dairying can significantly impact on the environment in several ways. There is the potential to replace natural ecosystems and the potential to damage natural ecosystems through release of nutrients. Increasing the production from a given area reduces the risk of natural ecosystems being 'ploughed down' for agriculture, but increased intensity (more production from the same land area) has been shown to have negative effects on river nutrient load. For example, increased cow numbers in the catchment of the Waikato river in New Zealand increased the nitrate load in the river (r^2= 0.69; Vant, 1999). Therefore managing agriculture's effect on the environment is not straightforward.

Water quality has improved dramatically over the last 40 years (Lomborg, 2001; Vant, 2001). However, much of this improvement has been as a result of managing point sources of pollution, such as town and industry, to reduce the nutrient load being emitted. Estimates in New Zealand suggest that agriculture is now responsible for approximately 50% of the mass flow of nitrogen and phosphorus in the Waikato river (Vant, 1999). Collected data shows an increased concentration of nitrogen and E coli from the upper to the lower Waikato, as it winds its way through its agriculturally-based 14,000 km^2 catchment.

This is often where the debate begins; what is an acceptable level of pollution? All food production pollutes. For example, contribution of eutrophication pollutants per kg of milk is similar on organic and conventional farms (Cederberg, 1998). The difference is that where more intensive agriculture produces greater quantities of dairy products, it also produces greater quantities of pollutants. Whether or not this is sustainable needs to be assessed within the FESLM framework outlined earlier. The framework identified 5 important criteria; maintain or enhance productivity, reduce the level of risk, protect the environment, be economically viable and be socially acceptable. By these 5 points, the sustainability of dairy farming will be different in industrialised countries and developing nations. In developed nations, point 1 (improved productivity) is probably less important, as sufficient food is available, and their desire for a pollution free environment is more prominent. Unfortunately, many people in such countries try to impose their definition of sustainability on less developed countries (DeGregori, 2001). This is not acceptable.

For a community whose food demands are not guaranteed, enhanced productivity must take precedence over environment issues as a measure of sustainability in the short term. Enhanced productivity reduces the risk of not achieving desired food production, it increases economic viability and it will be socially acceptable to those people most concerned. To be truly sustainable, the system must first be efficient. Even so, the many risks must be managed, and guidelines must be put in place. However, these guidelines must be based on science findings and must weigh up relative risks. For example, the risk of famine *vs*. the risk of nitrate poisoning or cancer from pesticides should be considered. The majority of environmental protection guidelines that have been laid down for developed countries, are overly strict for developing countries. In other words, the risk of these factors (eg. water nitrate concentrations) having an adverse effect becomes miniscule when compared with the risk of the negative consequences (e.g. low yields, crop failure, famine) associated with adhering to the guidelines. Sustainability, as defined by FESLM, is about balancing risks and prioritising solutions.

It was stated earlier that an efficient system is sustainable by definition. This certainly applies to nutrient management because minimising the environmental consequences of dairying is synonymous with improving nutrient use efficiency. Ledgard *et al.* (2000) have compared the N efficiency (kg N in milk/total

N input) and P efficiency (milk P/total P input) in dairy systems within New Zealand. The important point is that losses of nutrients were inversely related to nutrient use efficiency; the more efficient the system in capturing nutrients in products the lower the nutrient losses to the environment. Furthermore they found that there were major differences between countries in their nutrient use efficiency indicating that by understanding these respective systems much can be learnt to improve nutrient use efficiency.

In considering these data one is forced to the conclusion that environmental compliance in terms of nutrient losses does not necessarily mean low input agriculture. Indeed the highest efficiencies in N and P use in New Zealand dairying were achieved in the highest producing system. What must be done however is better understand the biological system and therefore think smarter about ways of conserving nutrients and thereby reducing nutrient loading, especially of N and P to waterways and waterbodies. For example, it is known that the major loss of N in the New Zealand pastoral dairy industry is from the urine patch during the wet winter months. Currently, management practices being advanced to reduce this source of pollution include such strategies as use of feed-pads with full collection of the excreta, over this critical time, removal of stock from sensitive catchments and applying nitrification inhibitors to the soil to stop the conversion of urine and urea N into nitrate. Other changes at the landscape level are already being implemented such as riparian planting around streams and lakes and the creation of wetlands.

But our thinking should not be limited by what is currently known. More futuristically, other ideas are being contemplated to ensure that the twin goals of production and environmental compliance can be achieved. Intercepting and recovering the N and P from surface and subsurface runoff using artificial anion exchange materials and tile draining pasture-land to turn a diffuse source of loss into a point source, from which the nutrients N and P can be captured, are now not beyond the realms of possibility.

The Precautionary Principle – Managing Risks

The process of managing risk in industrialised, well-fed nations has resulted in the development of ‘the precautionary principle’. This principle requires that even when you can not prove that an event or occurrence will have a negative effect, the mere idea that it might, renders it prudent to take preventative action – absence of evidence is not the same as absence of risk (DeGregori, 2001). This is a luxury that the developed world can ill afford, and is certainly not a luxury that can be afforded by the world’s starving masses.

In *The Culture of Fear*, Barry Glassner reported that the News media are responsible for many people’s fears because of their disproportionate coverage of events (Glassner, 1999). As Christie (2002) said, “we are constantly assaulted by what alarms us, rather than what educates us”. Although true, the media would be unable to provide the unbalanced scary scenarios without the input of another group; the scientists. Scientists are arguably the most important communicators of pessimism because they are generally people with academic credentials and are therefore seen as credible. The constant need to attract scarce funding has encouraged all too many scientists that should (and often do) know better to jump on the environmental/anti-technology bandwagon in search of such research funds. Norman Borlaug, 1970 Nobel prize winner, warns that we must be on guard against these “politically opportunistic, charlatan scientists”, whose pseudoscience in food production is costing the lives of millions of people and who, if allowed to continue, will cause the deaths of billions in the future, not to mention the destruction of vast areas of wildlife habitat (Borlaug, 2002).

Thirdly, the environmental organisations themselves are an outlet for the pessimistic environmental story. Although preserving the world is a valid and noble role, their vested interest in research results and resultant political decisions makes environmental organisations less philanthropic than their title may seem. These organisations have built-in mechanisms for rejecting any scientific conclusions that disagree with their preconceptions, including impugning the integrity of scientists, or suggesting that studies were flawed and incomplete. This has made constructive scientific debate difficult and, ironically, has in fact slowed our progression towards a more sustainable, and in particular a more environmentally sustainable, world.

The precautionary principle has resulted in overly strict regulations governing the environment and food safety. For example, in 1999, Mo Mowlam, the British minister for the Cabinet Office, bragged that the regulatory system governing genetically modified foodstuffs in Britain was so tough, that if it existed in Elizabethan England, there is no way the potato would have been introduced into England (Linden, 1999 as cited by DeGregori, 2001). In the developed world, such a principle does not impact on life expectancy. It reduces productivity, does little for environmental sustainability but is socially acceptable, but only because of consumer ignorance and fear. However, in countries where people remain hungry, implementation of this principle is costing lives. As a scientific community, it is imperative that we continue to provide sound scientific data showing the benefit of modern efficient agricultural practices in preventing hunger and protecting the environment. It is also important that we impart this knowledge to the world through the global media. In order for the world to progress in a sustainable fashion, scientists must regain the confidence of the world.

Summary

"The first farmer was the first man, and all historic nobility rests on possession and use of land. " – R.W. Emerson (1870)

Farming is the oldest respectable profession. Yet in many developed countries, farmers have become pariahs because of the message that postmodernist movements have spread over the last half-century about the dangers of modern agricultural practices and the use of technology. Over the last 100 years, technology's contribution to improved efficiency of food production has been immeasurable. For example, merely to match the 1995 mechanical power of tractors in the United States would require 250 million draft horses. Approximately 300 million hectares, or twice the total area of U.S. arable land, would be required to feed them (Smil, 2000 as quoted by Avery, 2000). Yet U.S. field machinery consumes only approximately 1% of the country's liquid fuels.

Evans (1998), in his book *Feeding the Ten Billion* points out that until the advent of the green revolution, the major contributor to increases in the world's food supply was the extension of arable land. The green revolution represents a milestone in the history of humankind. Global population was able to double and be better fed, with only a minor increase in the area of land used for agricultural production.

As prosperity increases, people will demand more feeds of animal origin. That is an indisputable fact. The trends are already obvious, with increasing dairy production in the developing world, and global dairy production increasing. Even with a static population, annual consumption of liquid milk has increased 2.6 million tonne in China over the last 4 years. The only way to meet that increased demand sustainably is by improving the efficiency of producing dairy products. To do this we must embrace modern technologies and we must educate the population at large about the benefits of efficient agricultural production.

We will end with the words of Dr Norman Borlaug, 1970 Nobel prize winner and founder of the green revolution - "The greatest evils which stalk our earth are ignorance and oppression, and not science, technology and industry, whose instruments, when adequately managed are indispensable tools in overcoming overpopulation, starvation and worldwide diseases" Borlaug (2002).

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