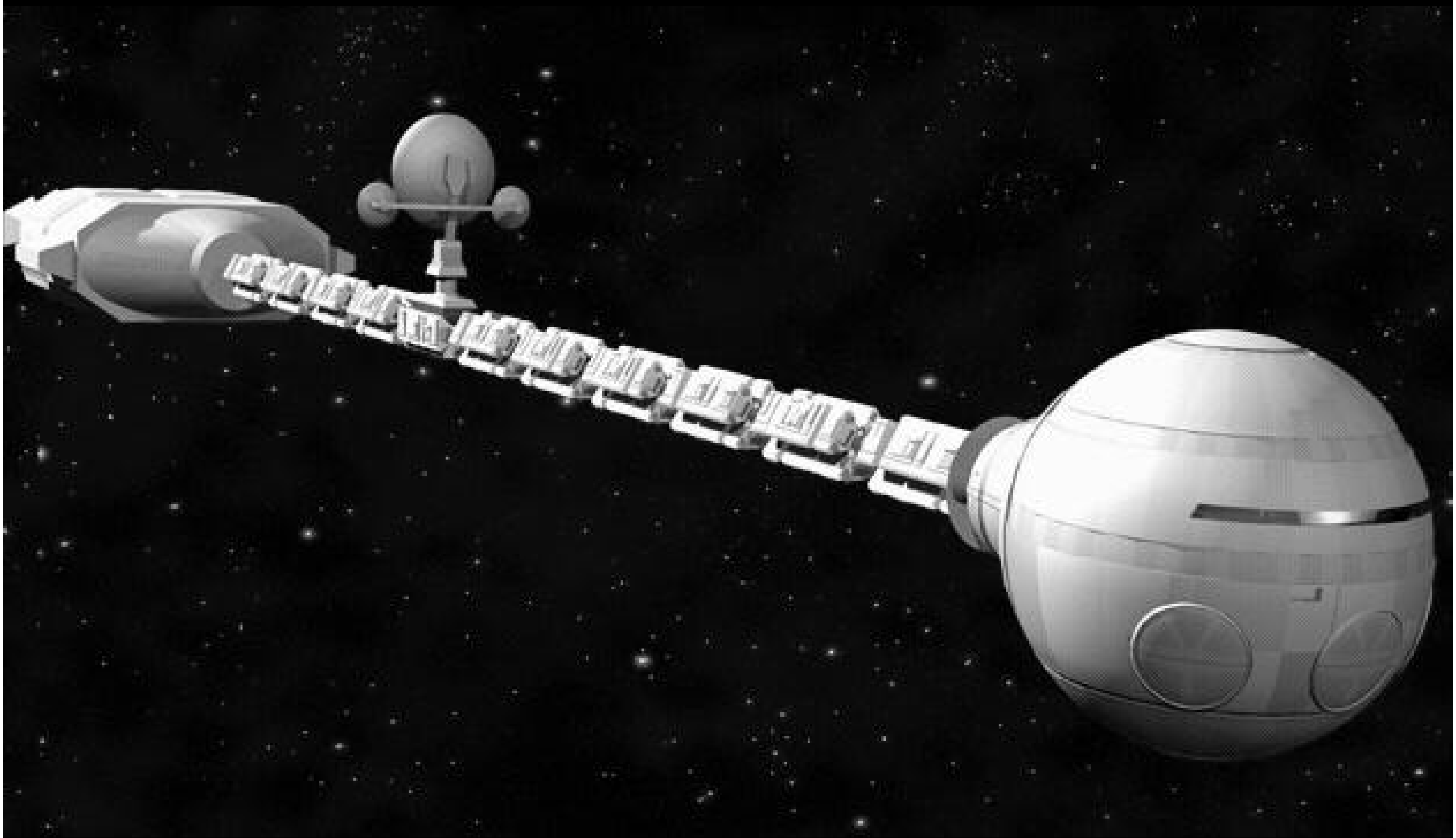
Growth Unlimited



Amrit Bart
Karl Iver Dahl-Madsen
Nguyen Thi Kim Oanh
Vilas M. Salokhe
Gajendra Singh
Willi Zimmermann

School of Environment, Resources & Development
Asian Institute of Technology

Proceedings of the 6th SERD Seminar, June 99

Development and Environment in the Next Millennium: Unlimited Growth vs. Ecological Doomsday

Editor

Vilas M. Salokhe

School of Environment, Resources and Development

Asian Institute of Technology

Bangkok, Thailand

January 2000

ISBN 974-8202-60-7

The editor wishes to make it clear that any statements or views expressed in the collected papers are those of individual authors. The editor assumes no responsibility for the accuracy, completeness or usefulness of information given in these papers. The papers were not refereed but reviewed for their technical contents. Editing was restricted to matters of language, format and general organization.

Signe Dahl-Madsen has edited and revised Growth Unlimited for PDF publication.

Table of Contents

The 6 billionth person of the world will be born in June 1999. She will be an Indian, who will be poor. However she will die 100 years old having obtained a quality of life similar to the now existing level in Europe. The Economist, New Year, 1999

Introduction and Welcome

Vilas M. Salokhe

It is a great pleasure to welcome you all to the 6th SERD (School of Environmental, Resources and Development) Seminar on Development and Environment in the Next Millennium: Unlimited Growth vs. Ecological Doomsday.

The SERD seminar is a welcome value added component on the academic calendar of SERD. This fine and unique tradition of school wide seminar series was started in 1994 with a strong support from the former and founding Dean, Professor Karl E. Weber. The idea was initiated with the aim to increase cohesiveness and interaction between faculty, staff and students of the school.

Previous seminars were arranged on different themes:

- The 1st SERD seminar was held in February 1994 on Selected Aspects of Environment.
- The 2nd SERD seminar in November 1994 was held on Selected Aspects of Management of Resources.
- The 3rd SERD seminar was arranged in October 1995 on Selected Aspects of Sustainable Development.
- The 4th SERD seminar was held in March 1997 on Gender and Technology.
- The 5th SERD seminar was held in October 1997 on Relevance of Outreach in Technology Transfer.

This seminar is on a relevant and timely theme: 'Development and Environment in the Next Millennium'. The seminar will provide some relevant and timely information and show the readiness of the SERD for the next millennium.

It was not an easy task to continue the SERD Seminar Series, taking relevant and timely topics into analysis and discussion. It was a team effort, depending on the keen interest and support by many individuals. I admire the people who directly or indirectly contributed to the 6th SERD seminar.

First of all I want to express my deep appreciation of DANIDA for providing financial support for the organization of this seminar. A special thanks to Karl Iver Dahl-Madsen for his personal efforts to obtain this financial support. I would like to extend sincere thanks to Prof. Jean-Louis Armand, the President of AIT, for his active participation in the seminar despite his busy administrative schedules, and to Dean of SERD, Prof. Chongrak Polprasert for his constant encouragement and support.

My sincere thanks to all speakers for their stimulating presentations. Though all of them are too busy in thesis corrections, they prepared their presentations in a short time.

Special thanks also to Mr. Bill Savage who accepted to moderate the panel discussion as well as giving editorial assistance. I would like to record with appreciation the assistance received from Ms. Tasana and Ms. Zhang Jianxia from AASE Program. Special thanks are also due to Dr. Li Lanhai for his help during the presentations.

Finally, I would like to express my personal thanks to all participants. This seminar would not have been successful without their keen participation.

Prologue

Limits to Growth: Political Will, Not the Resources, Nor the Environment

Gajendra Singh

In general (and on average) there is an improvement in quality of life:

1. Life expectancy has increased significantly. This is mainly due to improved nutrition as well as better health care facilities.
2. Education levels have improved significantly, equipping people to face even bigger challenges.
3. Income levels have increased: the share of income spent on food has been decreasing with time, as has the real cost of basic food items.

All these changes are related to structural transformations, which depend upon political structures. People are the problem and people are the solution. A small number of powerful (bad) politicians are responsible for most problems; they can stall growth or even retard it. Fast growth requires democratic participation of the majority of people in the process, by providing incentives to release their energies for productive activities.

A few examples of political structures and their effect on growth: North Korea and South Korea, Mainland China and Taiwan, East Germany and West Germany.

Japan developed very rapidly with meager energy and mineral resources mainly through human resource development and harvesting their potential by providing incentives. The most important resource is the people: They will generate all resources depending upon political will.

Act 1

A Humane Environment: High Economic Growth Is the Solution, Not the Problem

Karl Iver Dahl–Madsen

Introduction

> *The global environment is steadily improving. Environmentally induced diseases are on the decline, and the life expectancy of human beings is increasing at an unprecedented speed. The long-term outlook for the global environment is very positive. There is no reason to believe that environmental problems in the long run will in any substantial way constrain the growth of human living standards, health and quality of life.*

Yes, I know these are not the usual lamentations, which are made public all the time by the media, more or less well meaning NGO's and concerned citizens. Nevertheless, even while acknowledging that some serious environmental problems still exist, I will at this seminar try to argue the case that the above statement is a much more realistic evaluation of the environmental state of the world than the "litany". Furthermore, I will make the case that undue concern for questionable or even non-environmental problems actually siphons off resources, which could be used for alleviating poverty and other much more fundamentally serious development problems.

What is a Good Environment?

This huge disagreement in the interpretation of environmental facts, ranging from the End is at Hand to the speedy arrival of Ecotopia, can be quite confusing. However, I believe that the disagreements are caused by different implicit definitions of the term: A Good Environment. To make the premise for the discussion below more clear, I would like to explicitly define A Good Environment. There are two mainstream points of view:

1. The anthropocentric view states that A Good Environment is an environment, which benefits human beings. The natural environment is often extremely dangerous, very unproductive and, at the least, thoroughly uncomfortable. Nature has to be managed and controlled to allow human beings to survive and thrive.

2. The ecocentric view states that A Good Environment is nature untouched or marginally touched by human activities. The natural environment is inherently valuable; it is beautiful, nice and good, and any change induced by human beings is for the worse. Nature needs to be left alone and human beings have too sneak around as unobtrusively as possible.

There is no doubt that human activity are changing nature to a high and, in some cases, even increasing degree. Consequently, seen from an ecocentric point of view, the environmental conditions are obviously and rapidly declining. However, seen from the anthropocentric point of view, we are influencing and changing nature for the specific purpose of making a better environment for the survival, health and reproduction of human beings. As we are obviously succeeding, the environment is getting better.

I am firmly in the anthropocentric camp. Firstly, I do not accept the basic ecocentric view of the goodness of nature. Quite frankly, I find this to be a type of mysticism, which is contradicted squarely by the facts. Secondly, I also believe that human beings are part of nature, and their activities are natural, and must be judged by normal human-centered ethical guidelines. Of course, I believe that nature has some intrinsic value. However, only human beings are conscious of this value, and for this reason only human beings can, using normal democratic procedures, decide when conserving pristine nature is more important than other concerns.

Environmental Trends

One of the problems with discussing environmental trends is that environment means different things to different people. In many fields of human endeavor, we have commonly recognized aggregated indicators for the state of development, e.g. GNP for wealth, life expectancy for health, HDI for development and food per capita. In the field of environmental science there is no such common indicator, by which one convenient number can illustrate the state of the environment, in a country or in the world at large. There have been attempts at developing such aggregated indicators. However, in my opinion, these attempts are futile, as it is very difficult to weigh different environmental concerns in relation to each other. What is more important: The concentration of sulfur dioxide in the air of Copenhagen? The oxygen concentration in the Chao Praya river in Thailand? Or the level of DDT in the milk of an Eskimo mother from Greenland? To try to aggregate such disparate information is like comparing apples and oranges.

Consequently, as environmental scientists we show the public a very conflicting and chaotic picture of the state of the environment in which some environmental trends are up and some are down. And the state varies from region to region and even between neighboring countries. Of course, we always discuss our immediate concerns, which are the existing problem areas, and tend to forget the areas where we already have solved problems. Furthermore, the strength of the public environmental outcry is not in any way related to the significance of the problems. Just recently, the EPA in Copenhagen permitted the application of twenty grams of acrylamide for tunnel construction purposes for the new Copenhagen metro. This tiny amount, applied according to the EPA guidelines, has no environmental impact whatsoever. Yet, the outcry from “concerned scientists” and green organizations made prime time television news in Denmark. Other examples of environmental non-events are discussions about beer cans (small: cans versus recycled bottles, big: the disposal of the Brent Spar oilrig in the North Atlantic). This all adds up to providing the public with information showing a world filled with environmental problems, when in fact we are seeing the result of our success in solving the big environmental problems, urging us to move on to smaller and smaller problems towards even non-existent ones.

Subsequently, I will try to illustrate this movement from big to small with examples chosen from the field of environmental science.

Hygienic conditions and waterborne diseases

The “WHO report 1999: Making a Difference”[1] shows a staggering number of deaths (2.2 million) from diarrhea diseases, about 4.1% of all deaths in 1998. These diseases are mainly caused by poor people drinking water contaminated with feces. The problem can be solved simply and inexpensively by supplying people with healthy bottled drinking water. The statistics also show that these diseases are insignificant in the developed world. Very importantly, the number of deaths caused by polluted drinking water has been declining dramatically on a global level both in absolute terms and relative to other deaths and to the population. The estimates in the Worldbank 1992 report[2] for the same diseases were about 3 million deaths, which indicates that mankind within the last decade has been able to reduce this problem by about 25%.

The exclusive cause of the continued existence of this problem is lack of political will. A human being merely needs a few liters of water each day for drinking purposes. This is 1-2 percent of the per capita use for other purposes in areas with a good water supply. The amount is so small that physical availability of fresh water will never be a limitation for this purpose. A population of 10 billion people can be supplied with healthy drinking water corresponding to double the amount flowing from the Chao Praya River every year, or about 5 billion m^3.

The economy is not a constraint here. For the cost of four USD/m^3, which is the (very) high consumer price now paid by Danish consumers, the cost for supplying one person with healthy water for drinking is four USD/yr. Even the poorest of developing countries ought to be able to prioritize this sector, and not allow their own citizens to suffer and die from water-borne diseases.

Air pollution

We normally consider outdoor air pollution as the main air pollution problem. However, this is not true. As stated by the WRI[3]:

> *By far the greatest threat of indoor pollution, however, still occurs in the developing countries, where some 3.5 billion people—mostly in rural areas, but also in many cities— continue to rely on traditional fuels for cooking and heating. Burning such fuels produces large amounts of smoke and other air pollutants in the confined space of the home a perfect recipe for high exposure. In these circumstances, exposure to pollutants is often far higher indoors than outdoors.*

The WRI report refers to an estimate of a staggering 2.8 million deaths per year from this cause. This number may be in the high range, but it is within the total number for total number of deaths from respiratory diseases in low and middle income countries: 3.1 million given by WHO 1999. This type of pollution is obviously very directly related to poverty, and my estimate is that it is a rapidly declining problem, declining at the same rate as poverty is alleviated.

---

[1] The World Health Report 1999 -Making a difference http://www.who.int/whr/
[2] Worldbank 1992. Development and Environment
[3] World Resources Institute, Health and Environment, 1998-99. http://www.igc.org/wri/wr-98-99/airpoll.htm#biomass

Outdoor air pollution is generally ascending in the industrializing countries, and is declining in the industrialized countries. It is a serious environmental problem as it affects many people's health and life expectancy. WRI estimates the mortality caused by air pollution, mainly from small soot particles, is in the interval from 200.000 to 500.000 per year, a large number, but still about one magnitude smaller than the deaths caused by drinking polluted water and inhaling smoky indoor air.

This problem is closely related to the degree of industrialization and traffic but not as easy to solve, as industrialization and traffic are prerequisites for rapid economic growth. In the cases of poor water supply and indoor air pollution, the solutions are obvious and all, even the poorest countries, can afford to be responsible for solving these problems. For outdoor air pollution, some trade-off between economic growth and environmental stress must be accepted. The problem is much smaller and much more expensive to solve than the two problems presented above. Furthermore, even if, as stated by ADB[4], it may well be profitable to relieve this problem as such, it may be still more profitable, from an environmental point of view, to invest the limited monetary resources in water supply and clean fuels for houses. This will obtain a much better result in the form of dramatically decreased mortality.

Fertilizer and nutrients

The use of fertilizer for effective agriculture has to increase quickly in countries that have to produce more food for an expanding population. The political notion found in many western countries, that food should be grown organically, i.e., without the use of fertilizer and pesticides, is a very luxurious and ill-advised notion. There is no way, as demonstrated by Gajendra Singh, that the world can produce high quality food in sufficient amounts for 10 to 20 billion people without help from these powerful chemicals.

Consequently, we can expect that fertilizer use will increase to the same levels in the developing countries, as the levels seen in highly intensive agricultural countries like Denmark and Holland. The resulting unavoidable spillage from the fertilizer utilization will increase nitrate in groundwater and eutrophication of lakes and coastal waters all over the world.

This is one of the pollution forms, which we are very concerned about in my country, Denmark. Actually it does not in any way compare in seriousness to the problems discussed above. There are a few human health aspects, like the effect of too many nitrates in groundwater giving rise to cases of infant methemoglobinemia, and nutrient enrichment increasing blooms of toxic algae affecting drinking water and bathing water quality. However, the magnitude of the problem from a human health angle is extremely small. My estimate is that mortalities on a worldwide basis are in the hundreds, or may be even tens, of persons per year.

Actually, nutrient enrichment to a certain level is beneficial for fish production as any aquaculturist educated at the AIT AARM program knows, and which any well-educated biologist ought to know.

From an ecocentric view, the excess nutrients are producing a pronounced impact in the coastal zones of countries with intensive agriculture. The coastal marine ecosystem is impacted, giving rise to increasing algal biomass, decreasing transparency and decreasing oxygen conditions. To reduce this problem, we have in Denmark decided to invest about 2 billion US dollars.

Artificial substances

Another emerging problem, which attracts the attention of the public, mainly in the developed countries, is the increasing application of artificially produced chemical substances and the resulting occurrence in the environment. Actually, evidence of any significant impact on human health from the occurrence of these substances in the ambient environment is very weak.

[4] Asian Development Bank, Dr. Lohani, AIT-wide lecture, 1998

The evidence clearly shows that excess deaths in developed countries are caused by lifestyle. People are basically eating, drinking and smoking too much, and exercising too little. Any influence from exposure to artificial substances on human health is either marginal or non-existent. This does not mean that we should not be concerned, merely that we should be more concerned with the major problems.

As human life expectancy is steadily increasing, the case for presenting the use of artificial substances as a serious health risk has a poor basis. On the contrary, the application of some of these substances has saved millions of lives. A good case story is DDT, which may very well be the one chemical besides penicillin that has saved most lives by eradicating malaria. DDT is of course an awkward compound as it is both bioaccumulative and very persistent. However, it is not very toxic to human beings. Particularly for a poor country, it seems to be a very reasonable trade-off to use DDT to save many human lives, even at the cost of reducing some wildlife in the region for an intermediate period.

Biodiversity and forests

Human beings are removing forests and decreasing biodiversity. Absolutely true, and this is a very good thing. Very few people can live in a forest, and only by accepting a short life in poverty and deprivation. A lot of organisms are not wanted by human beings. For instance, I did not hear any outcry from Greenpeace when Humanity decreased biodiversity by eradicating smallpox.

In a quiet hour, I cannot help being a little bit ashamed of my countrymen from rich western countries going to developing countries, contending that biodiversity is a major issue, and that all forests should be left absolutely alone. The story about the Danish forests may illustrate how hypocritical this attitude is.

Denmark is a naturally forested country. If there were no human beings there, we would have a forest cover of 100%. In late 1700's[5] we had more or less used all our forests, for agricultural land and for building warships for the king. An ecological disaster of sand drift and desertification were imminent. Some competent people organized the planting of sturdy grasses on the sand dunes to prevent this from happening. For many years the Danish peasants had to use a significant part of their productive time for the hard work of securing the sand dunes. Eventually the work succeeded and furthermore the king decreed that no trees could be cut without immediately replanting a new tree. In the next couple of hundred years, the Danes succeeded in increasing the forest cover from near zero to about 10%.

The amount of primeval forest untouched by human activities is now barely one percent of the area of Denmark. This fact has not hindered our development to a modern, wealthy and productive country. We have solved most of our basic material problems and can now afford to be concerned about nature conservation and restoration. We are now restoring some parts of our forests to a primeval state, dechanneling streams back to their original state, and even restoring streams in the middle of Danish cities. It is expensive, but we want, and can afford, the added quality. We can foresee a future where the increasing surplus production of agricultural products in the European region, combined with increased global food trade, makes it possible to take even more agricultural land out of production. Consequently, we can plant more forest and create more recreation areas and wildlife reservations.

All in all, I have nothing against conserving biodiversity - however, not at any price. Human beings are more important than plants and animals, and their needs must have priority. One of the main arguments for conserving biodiversity, the jungle medicine argument, is actually of purely anthropocentric origin. It says that we should protect all rain forests, as we may at a later date find some medicine, which may save many lives. I accept the chance that this might happen, but this reasoning

[5] Danish Revolution, 1500 – 1800; An Ecohistorical Interpretation; By Kjaergaard, Thorkild//Translator: Hohenn, David; October 1994; Cambridge University Press

should be subjected to a stringent cost-benefit analysis. The money earned from cutting the forest may well be more wisely invested in research and education, producing the necessary medicine much quicker and more directly by using modern biotechnological methods.

Economic Growth and Environment

I hope the above discussion of trends has made the crucial relationships between the economy and environment painfully obvious. The main relation is to poverty as WHO 1995[6] stated:

> *The world's biggest killer and the greatest cause of ill-health and suffering across the globe is listed almost at the end of the International Classification of Diseases. It is given the code Z59.5 -extreme poverty.*

As a major proportion of this mortality is environmentally induced, we can safely say that poverty is the major cause of bad environmental conditions.

For some forms of environmental stress, the relationship is a bit more complicated. For example, air pollution seems to increase with increasing wealth, but then again decreases again after topping out. This relationship is called the Environmental Kuznets Curve (EKC) (see Fig. 1 below from UNEP[7]).

An interesting aspect of the curve is that UNEP expects parallel developments of environmental stress for industrialized and developing countries. However, the level of stress is expected to be smaller for developing countries because of improved technology and the ability to learn from best practices.

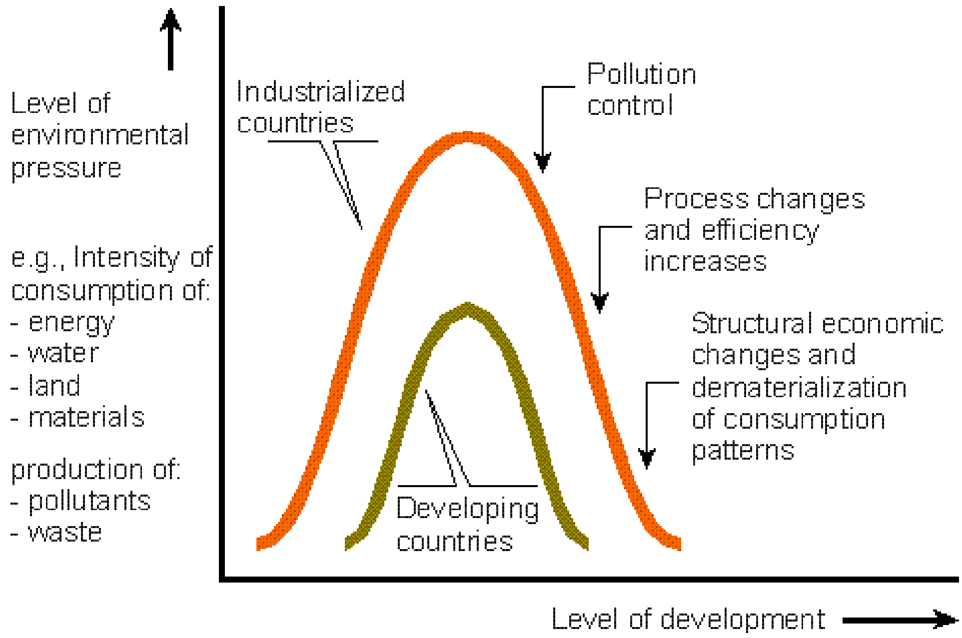


Fig. 1: Environmental stress corresponding to different development levels

The UNEP figure is most likely based on the milestone 1992[8] report from the World Bank. The report presents a set of figures (Fig. 2) showing different relationships between the environment and GNP.

[6] WHO World Health Report 1995 http://www.who.int/whr/1995/state.html
[7] Global Environmental Outlook-1, UNEP 1997, http://www-cger.nies.go.jp/geo1/
[8] World Bank 1992, Development and Environment

The curves for air pollution C and D compare most directly to the EKC. The water supply and sanitation curves show a steady decline with GNP, while the curves for solid waste and CO_2 show an increase with GNP.

It can be argued that all the relationships are specific examples of a general curve representing all types of pollution problems. However, the GNP level where they max out depends on the seriousness of the problem seen from a human needs angle: Bacterially-polluted drinking water kills many people and is therefore cleaned very early in the economic growth phase. Organic pollutants, on the other hand, represent a very small problem from the point of view of human survival and well being and are consequently cleaned up much later. It should be noted that the Y-axes are scaled differently relating to the type of environmental stress.

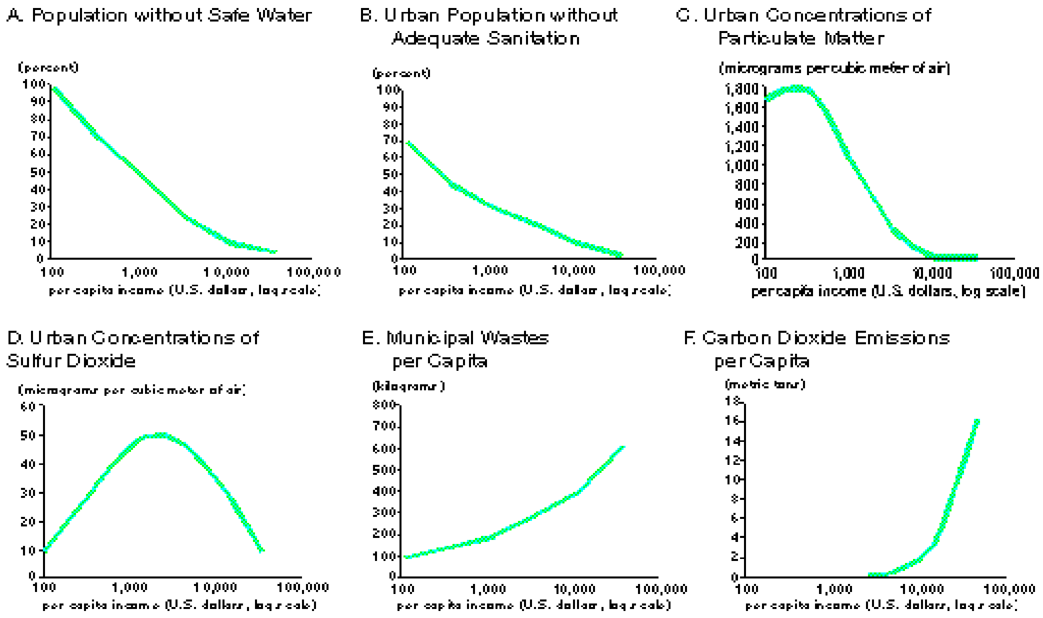


Fig. 2: Environment and GNP

Another way of describing these relationships is by constructing an environmental demand pyramid, which simply divides the priorities of the environmental needs into primary, secondary and tertiary sectors (Fig. 3).

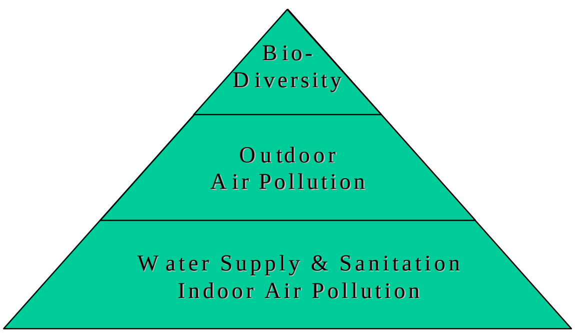


Fig. 3: Environmental demand pyramid

As discussed above it is difficult to find a common indicator. However, if we take a purely anthropocentric view, we can weigh the three sectors after their estimated impact on human mortality as in Table 1.

Sector	Problem	Mortality millions per year
Primary	Water Supply and Sanitation, Indoor Air	5
Secondary	Outdoor Air Pollution	0.5
Tertiary	Biodiversity, CO_2, Chemicals, Eutrophication	0.05

Table 1: Sectored impact on human mortality

When discussing environmental limits, it is fashionable to use a model of the world. I would like to be fashionable, so I have made my own world model. The basic equations are:

$$\frac{dG}{dt} = rG$$

where G = GNP per capita

r = GNP per capita growth rate

$$\frac{dP}{dt} = r_p(G)P$$

where P = population

r_p = population growth rate, a function of G

$$ES = ES_C P$$

$$ES_C = e^{-0.5(\ln G_{max} - \ln G)^2}$$

where ES = Environmental Stress

ES_C = ES per capita

G_{max} = max. GNP on the Kuznets curve

Fig. 4 shows the standard runs for the Kuznets model. The model shows that a command and control approach to environmental abatement, allocating an undue amount of the global output to this purpose will actually *increase* environmental stress. The mechanism is that the over allocation will slow economic growth, thereby slowing the demographic transition (more wealth means lower population growth) resulting in a higher population of poorer people, which again increases environmental stress.

Environmental Myths

In the discussion about environment and resource problems many ill-defined terms and even myths are floating, creating confusion and a poor background for sound environmental management. I will briefly address some of these terms.

One of most misused terms is the S-word, “sustainable”. This concept is used in many contexts. It is a typical buzzword, lending an air of resourcefulness to the user. However, it is an absolutely useless term, as it has about as many definitions as there are users. In fact it is very difficult, even impossible, to define precisely. We have decided not to use this term in the seminar. However, I would like to add that we can continue (sustain) economic growth for a very long time without resource and environmental limitations. Most countries of the world are developing in a healthy way, but we need to get all on board by demanding good governance at the national and international level.[9]

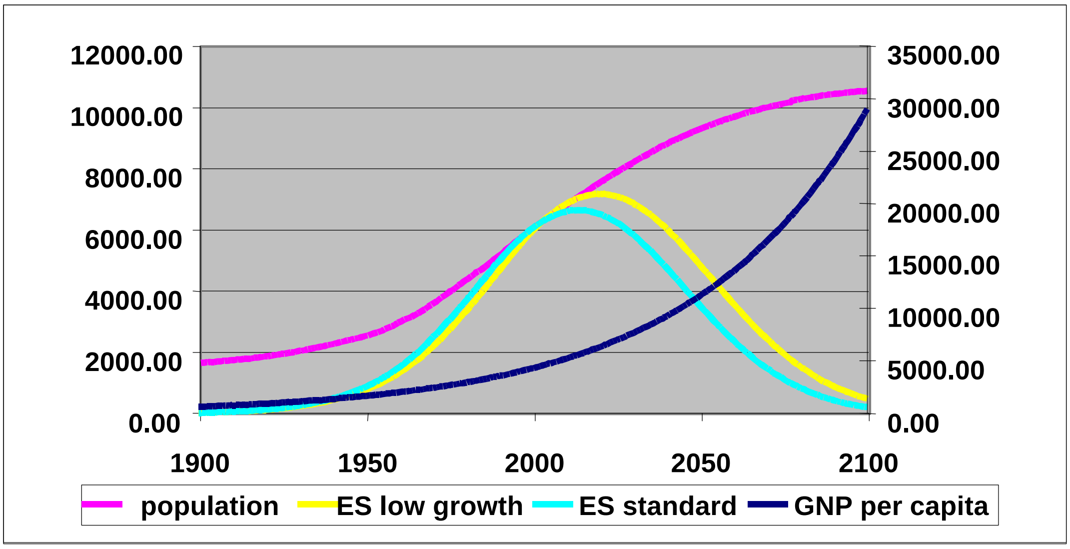


Fig. 4: Standard runs for the Kuznets Model

Carrying capacity is a somewhat better defined term. It is of course correct, that under given assumptions about number of people, living standards, resource and energy use, and assimilative capacity, a carrying capacity for the world can be calculated. What many people unfortunately do not recognize is the simple fact that carrying capacity is a dynamic variable, which can be changed by human activities. Even in nature we have organisms which are changing the environment to increase its carrying capacity, and of course human beings, because of their intelligence, can influence its carrying capacity to a much higher degree. The history of mankind is the history of technological breakthroughs making a bigger carrying capacity possible. From the arrival of toolmaking about 100,000 years ago, to the invention of agriculture 10,000 years ago, to science and industry a few hundred years ago. What we are seeing now is probably a logistic growth approaching the new level of carrying capacity defined by the revolution in science and industry. What we have already seen is that the primary environmental concerns can be solved by well-known methods and relatively inexpensively. The secondary and tertiary concerns will not in any significant way be limiting for human well being or living standards.

Carrying capacity has a cousin called "ecological footprint". This is a nonsense concept, which normally states that we need three planets to support the people already living on the earth. This concept does not take into account that carrying capacity can be increased, nor does it acknowledge trade's added value to the world economy. On the contrary, we can support at least three times as many people as we are now.

The discussions on resource limitations are closely related to the above concept. Many authors[10,11] have by now proven beyond any reasonable doubt, that resources for human activities are not limited in any significant degree. Resources become more available and cheaper as time goes on, and the mechanisms are new technology for mining, increased use efficiency (for instance by recycling) and substitution. One of the major examples is substitution of optical fiber for copper cables.

[9] UNDP, Human Development Report 1999
[10] Julian L. Simon, The Ultimate Resource II
[11] Bjorn Lomborg, Verdens Sande Tilstand (in Danish)

However, some stubborn myths related to resources still exist. One of the worst is that developed countries are using 50 times as many resources per capita as developing countries. That may well be. However, developed countries are also producing 50 times as many resources. Another myth is that by using resources now, we are depriving future generations of their rightful share. This is absolute nonsense: By not using resources now, we will cause a reverse Robin Hood by transferring money from the poorer (our generation) to the richer (the next generation), who in all likelihood will have twice our income. Furthermore, some of the resources, which we are not using now, may even be valueless in the next generation, as new technology may have totally substituted those.

Precautionary principle

The precautionary principle is a beautiful concept. It works as a joker card, which can finish any serious discussion about environmental management. If somebody doubts the proposal of a very expensive measure to abate a disputable environmental risk, or stop development of a new technology related to some environmental risk, you merely have to say "precautionary principle". You will then supposedly have won the exchange, for who will not want to be rather safe, than sorry. However, unfortunately the precautionary principle is a useless concept except for political purposes.

Firstly, the precautionary principle is not operational, as it does not specifically state the level of risk, which is acceptable for a given problem. For this reason, the precautionary principle is a buzzword that can be used to end all discussions, and thereby solve no real problems. Secondly, it is lopsided, as it does not consider the opposite side of the coin, which can be the cost of doing nothing in relation to a disputable environmental problem or the cost of losing the good effects of a new technology.

If the precautionary principle was operational, and if it was combined with a bravery principle, the combination might provide a good background for serious environmental discussions. As of now, the use of the principle in the field of environment is merely a shrewd way of convincing the politicians to over-allocate resources to the environmental sector.

Irreversibility

One of the main public fears about environmental decisions is the fear of making irreversible damage to the so-called "highly vulnerable" ecosystem. The risk exists, but it is much smaller than normally suggested. Ecosystems are actually not very vulnerable. They are in most cases quite resilient, as nature itself is stressing our ecosystems most of the time with chaotic impacts. In this respect, people are merely another impact stressing the ecosystem. If ecosystems are destroyed, they can in many cases be restored. It is expensive, and it might make sense not to make the impact in the first place. However, again, if there is conflict between basic human survival needs and some ecosystem's needs, it is difficult to defend setting the needs of the ecosystem above the needs of human beings.

Development and Environment

In conclusion:

1. A contemporary environmental policy should be based firmly on the anthropocentric principle: People above and before nature; living people are more important than living fish.

2. Poverty is the main cause of the primary environmental problems: bad drinking water and indoor smoke. The solution is efficient poverty alleviation combined with fast economic growth.

3. Some secondary environmental problems, like air pollution, are for a time adversely affected by economic growth. However, the beneficial consequences of fast economic growth on the primary environmental sectors clearly outweigh the harmful consequences

in the secondary sector. For this reason, economic growth should not be slowed by untimely allocation of pollution abatement resources to the secondary sector. In other words, get it over and done quickly.

4. The tertiary sectors (biodiversity, forest conservation, eutrophication, artificial substances, CO_2 and many others) are not very important in a development situation. Those matters can safely wait until they can and will be afforded.

5. Environmental concerns are not finer or better or above other concerns. Resources should be democratically allocated to the environmental sector in transparent competition with other sectors like primary health care, basic education, job creation, etc.

Act 2

Population and Food: Why India is Prospering Instead of Starving

Gajendra Singh

Introduction

> *"The battle to feed all of humanity is over. In the 1970s and 1980s hundreds of millions of people will starve to death in spite of any crash programs embarked upon now. At this late date nothing can prevent a substantial increase in world death rate." (Paul Ehrlich, The Population Bomb, 1971)*

I studied in the United States from 1967 to 1973. I had known about food shortages in India during 1965-66. I was a college student in India. I realized the seriousness of the food shortage problem from the media and people in the United States. Starvation was the main news item in the media about India during 1967. As a Ph.D. student I was awarded a Ford Foundation Fellowship through the Food Research Institute of Stanford University to do research in India. After returning to the University of California, Davis to write my doctoral dissertation, I had an opportunity to listen to Paul Ehrlich. At the end of his presentation, I told him that I completely disagreed with his analysis and forecast.

World Population

It is expected that the world population will reach 6 billion in October 1999. The world population will grow at 1.33 percent per year between 1995 and 2000, which is significantly less than the peak growth rate of 2.04 percent in 1965-1970, and less than the rate of 1.46 percent in 1990-1995. The annual population increment also declined from its peak of 86 million in 1985-1990 to the current 78 million. It will further decline gradually to 64 million in 2015-2020, and then sharply to 30 million in 2045-2050 growing at the rate of only 0.34 percent. The world population is expected to reach 7.9 billion in 2025 and 8.9 billion in 2050.

From 1804, when the world passed the 1 billion mark, it took 123 years to reach 2 billion people in 1927. It took 33 years to attain 3 billion in 1960, 14 years to reach 4 billion in 1974, 13 years to attain 5 billion in 1987 and 12 years to reach 6 billion in 1999. It will take 14 years to reach 7 billion in 2013, 15 years to reach 8 billion in 2028, and, with the slowing down of population growth, it will take 26 years to reach 9 billion in 2054. Oerke et al. (1994) projected that the world population will stabilize at about 11.5 billion shortly after the year 2100. Deevey (1960) as cited by Oerke et al. (1994), believed that the world population would stabilize at about 10 billion. The mid-1998 world population stood at 5,901 million, with 4,719 million (80 percent) in the less developed regions and 1,182 million (20 percent) in the more developed regions. Asia accounted for 3,585 million, that is 61 percent of the world total. During the last two years, Africa's population (749 million in 1998) became larger than Europe's (729 million). The population of Latin America and the Caribbean is estimated at 504 million and that of North America at 305 million.

Ninety-seven percent of the world population increase takes place in the less developed regions. Every year the population of Asia is increasing by 50 million, the population of Africa by 17 million, and that of Latin America and the Caribbean by nearly 8 million. Africa has the highest growth rate among all major areas (2.36 percent). Middle Africa, Eastern Africa and Western Africa have growth rates of 2.5 percent and over. Europe, on the other hand, has the lowest growth rate (0.03 percent), with a negative rate of -0.2 percent in Eastern Europe.

Currently two out of five people in the world live in either China (1,256 million) or India (982 million). Sixty percent of the world population increase is contributed by only ten countries, with 21 percent contributed by India and 15 percent by China (Table 1).

According to the medium variant, by 2045-2050, 56 countries will experience a negative population growth, including all European countries, Japan and China. The population of the more developed regions as a group is expected to reach a peak of 1,617 million in 2020, then it will start a gradual decline and by 2050 will be 2 percent smaller than in 1998.

Table 1: Top ten contributors to world population growth, 1995-2000
(net annual additions in thousands)

No.	Country	Net addition	Percent	Cumulative per cent
1	India	15,999	20.6	20.6
2	China	11,408	14.7	35.3
3	Pakistan	4,048	5.2	40.5
4	Indonesia	2,929	3.8	44.2
5	Nigeria	2,511	3.2	47.5
6	United States of America	2,267	2.9	50.4
7	Brazil	2,154	2.8	53.1
8	Bangladesh	2,108	2.7	55.9
9	Mexico	1,547	2.0	57.9
10	Philippines	1,522	2.0	59.8
	Sub-total	46,494	59.8	59.8
	World total	77,738	100	100

By contrast, the population of the less developed regions will increase by 64 percent, from 4,719 million in 1998 to 7,754 million in 2050. The fastest population growth will take place in Africa: its population will more than double during the first half of the 21st century; and Africa's share in the world population growth will increase from the current 22 percent to 55 percent in 2045-2050.

Different demographic growth rates lead to a redistribution of the world population among major geographic areas and groups of countries. While in 1950, Europe and North America accounted for 28.5 percent of the world population, their share of the world total decreased to 17.5 in 1998, and it will further decline to 11.5 percent in 2050 (Table 2). Conversely, Africa's world population share increased from 8.8 percent in 1950 to 12.7 percent in 1988 and is projected to reach 19.8 percent in 2050. The shares of Asia and Latin America are relatively more stable at approximately 60 and 10 percent, respectively. All projection variants yield similar results with respect to the distribution of the world population.

Deevey (1960) subdivides the history of mankind into three cultural epochs. The first, which lasted a million years, was the epoch of hunters, gatherers and the first toolmakers. The second, the epoch of agriculture, started about 10,000 years ago; this was a settled way of life and marked the beginnings of modern civilization in various parts of the world. The last epoch was the rise of science and industrialization. Hunters and gatherers used their own energy. Farming, involving the use of draught and pack animals and irrigation systems, increased the available energy many times over. With the rise of science and industrialization came the means of energy production from fossil fuels (coal, oil and gas) and non-fossil fuels (nuclear and solar energy, wind power) which have provided a much more broadly based supply of energy for contemporary population growth.

Table 2: Population of the major regions of the world, 1950, 1998 and 2050
(Population in millions, medium variant)

	1950	1998	2050
World	2,521	5,901	8,909
More developed regions	813	1,182	1,155
Less developed regions	1,709	4,719	7,754
Africa	221	749	1,766
Asia	1,402	3,585	5,268
Europe	547	729	628
Latin America and the Caribbean	167	504	809
North America	172	305	392
Oceania	13	30	46

Source: United Nations Population Division, *World Population Prospects: The 1998 Revision*, forthcoming

Potential Global Food Production

Any calculation of agricultural capacity done in response to sustained population growth has to be based on an estimate of the resources available. The more accurate the information about the extent and quality of the potential resources, the more reliable the estimate will be. There are three main variables. The first is the total area of land suitable for tilling. Arable farming is the most productive form of land use. The reserves of potential arable land can be calculated by subtracting the total area now being farmed from the total area, which could potentially be cultivated. The second is soil fertility, which varies in the different climatic zones; however, here too it is necessary to distinguish between current yield and the theoretical maximum yield. The third variable to be considered is the level of consumption or the target standard of nutrition. A global agroclimatic audit is needed to obtain the first two values, the total cultivable area and fertility of soils. The criteria for assessing nutritional status are based on our knowledge of human nutritional requirements.

The estimates quoted here are based on detailed models devised by Dutch agronomists at the University of Wageningen (Linnemann et al, 1979). This model is used to compute the capacity of 222 soil regions to produce carbohydrates by photosynthesis as a function of climatic factors (e.g. intensity of solar radiation, degree of cloud cover (clear, cloudy), temperature, precipitation, evaporation, leaf area index), soil quality and the supply of water. The computations are based on a standard crop with the properties of a C_3 plant (e.g., wheat, barley, rye, and oats) and a grain-to-straw ratio of 1:1. The potential output from an area is expressed first as carbohydrate/hectare/year and then converted to dry matter production and finally to grain equivalents. This value represents the theoretical maximum potential of an area, called the Maximum Production of Grain Equivalents (MPGE). The absolute theoretical maximum food production of the world can be calculated from the geographic distribution of the six classes of soil fertility, potential arable land (PAL) and arable land already under cultivation (Tables 3 and 4).

Table 3: Geographic distribution of soils, classified into six categories based on their productivity Worldwide, 106 hectares of Potential Arable Land (PAL)

Region	Soil class, based on productivity (MPGE)[a]					
	I	II	III	IV	V	VI
	<=5	5-10	10-15	15-20	20-25	>=25
	in t grain equivalents per ha per year					
	(10^6 ha)					
South America	12	-	108	287	185	3
Oceania	60	68	26	19	49	-
Africa	93	92	95	335	135	5
Asia	197	51	352	214	135	69
North and Central America	-	342	87	144	48	-
Europe	1	151	224	12	4	-
World 3, 6 X 10^9 ha	362	704	892	1,011	556	77
in %	10	20	25	28	15	2

[a] Calculated by MOIRA as Maximum Agricultural Production in Grain Equivalents (MPGE) per hectare of PAL.
Source: Linnemann et al. 1979

Worldwide, up to 3.6 thousand million hectare of land could be cultivated. The soils of 1.6 thousand million hectare or 44% of this land are of class IV to VI. The maximum potential yield from these soils is in excess of 15 t/ha.

The tropical regions (Australia, Africa, South America) still have the largest reserves of land which could be cultivated (Table 3). There are also appreciable reserves in North and Central America and in Asia. In Europe, only 19% of potential agricultural land have yet to be brought into cultivation (Table 4, column 3). The data in column 5 indicate how many people it theoretically would be possible to feed. Based on the high standard figure for consumption of 1000 kg per person per year, if the world population stabilizes at the estimated figure of 11.5 thousand million, it will take 23% (11.5 X 109: 49.8 X 109 = 0.23) of the absolute maximum food production of the world to feed them.

Limits and constraints

The calculation of the maximum possible agricultural production from all the cultivated land of the earth, a purely theoretical exercise, is based on the assumption that optimum farming methods are being used everywhere. It takes no account of economic, social, political and natural constraints, temporary or permanent, on the rapid expansion of food production in the specific regions. Nor does it take into account the ecological impact of the progressive replacement of trees and other forms of vegetation with intensively farmed arable land and pasture. Cultivating more land increases the risk of erosion, because the natural vegetation protects the soil structure better. It is also important not to underestimate the huge input of time, capital, research effort and education needed to bring yields close to the theoretical maximum. It is also difficult to forecast the effect of long-term changes in external factors such as international economic trends, technological developments and climatic changes.

The capacity of the water, air and soil to absorb the substances produced by industry is limited. Certain sites, such as catchment basins, are particularly vulnerable if fertilizers and agrochemicals are used in an uncontrolled manner without taking into account their impact on the environment. So the use of any aid to boost yields must be optimized.

Table 4: Maximum Agricultural Production in Grain Equivalents (MPGE)

Region	Arable land[a]			MPGE[b]		
	Cultivated in 1983	Potential	Col. 1 as % of col. 2			
	(10^6 ha)		(%)	(t/ha/year)	(10^9 ton)	as a %
	(1)	(2)	(3)	(4)	(5)	(6)
South America	139	617	22.5	18.0	11.0	22.3
Oceania	47	226	20.7	10.4	2.3	4.7
Africa	183	726	24.0	14.3	10.8	21.8
Asia	506	1,082	46.8	13.2	14.3	28.6
North and Central America	273	629	43.4	11.3	7.1	14.2
Europe	322	399	81.0	10.5	4.2	8.4
World	1,473	3,748	39.3	13.4	49.8	100.0

[a] Including permanent crops. 182 million ha of the arable land of the CIS was allocated to Europe and 50 million ha to Asia.

[b] Calculated as Maximum Agricultural Production in Grain Equivalents (MPGE)
Source: Linnemann et al. 1979, FAO Production Yearbook, 1983

Weather fluctuations and climate change. Global warming's effects on food production are uncertain. Some research suggests that growing conditions will deteriorate in current tropical areas (where many of the developing countries are located) and improve in current temperate areas (where many of the developed countries are located). However, effects on productivity and production will occur over a long period of time and will be very small in any given year. Therefore, it is reasonable to believe that policies and technologies can be developed to effectively prevent or counter the negative productivity effects of global warming.

Growing water scarcity. Unless properly managed, fresh water may well emerge as the key constraint to global food production. While supplies of water are adequate in the aggregate to meet demand for the foreseeable future, water is poorly distributed across countries, within countries and between seasons. And with a fixed amount of renewable water resources to meet the needs of a continually increasing population, per capita water availability is declining steadily.

Growth in irrigated areas is projected to slow significantly. Worldwide, irrigated areas are projected to grow at an average annual rate of 0.6 percent per year during 1995-2020, less than half the annual growth rate of 1.5 percent during 1982-93. In developed countries, irrigated areas are projected to increase by only 3 million hectare. Irrigated areas in developing countries are projected to increase by 37 million hectare to 227 million hectare in 2020. The largest increase in irrigated areas is expected in India (17 million hectare); public investment in irrigation has remained relatively strong and private investment in tube-wells has been rapid. The agriculture sector is by far the largest water user, accounting for 72 percent of global water withdrawals and 87 percent of withdrawals in developing countries in 1995. Reform policies that have contributed to the wasteful use of water offers consider-able opportunity to save water, improve efficiency of water use, and boost crop output per unit of water.

Declining soil fertility. Improved soil fertility is a critical component of low-income countries' drive to increase sustainable agricultural production. Although some of the plant nutrient requirements can be met through the application of organic materials available on the farm, or in the community, such materials are insufficient to replenish the plant nutrients removed from the soils and thus to further expand crop yields. But the use of chemical fertilizers has decreased worldwide during the last few years, particularly in the developed countries and in parts of Asia. Although reduced use of fertilizers is warranted in some locations, because of negative environmental effects, it is critical that fertilizer use be expanded in countries where soil fertility is low and a large share of the population is food insecure.

Of particular importance to maintaining and enhancing soil fertility is the adoption of integrated plant nutrient management (IPNM) practices. The goal of IPNM is to integrate the use of natural and human-made sources of plant nutrients to increase the productivity in an efficient and environmentally benign manner without diminishing the productive capacity of soil for present and future generations.

Ways of expanding food production

To increase food production, farmers rely on the steady flow of scientific and technological innovations and greater use of material resources. In the past, important ways in which food production was expanded were:

1. The change from an economy based on hunting and gathering to arable farming, animal husbandry and pasture farming. This change is now virtually complete worldwide.

2. The introductions of better methods of agriculture and crop production. The steady stream of new ideas to agriculture is the most important way of increasing food production.

3. Cultivating more land.

4. Irrigating more land.

5. Expanding sea fisheries and intensifying freshwater fisheries.

6. Use of manufactured or mined plant nutrients.

7. Land once used to grow feed for draught animals can be used to grow food for human consumption. Mobile and stationary power sources (engines) are being used increasingly to do work, rather than humans and animals.

Declining official development finance

Official development finance has decreased almost 40 percent between 1991 and 1996 to US$ 41 billion. Between 1995 and 1996 alone, official development finance declined by almost 25 percent. Of course, in real terms the reduction is even sharper. Agriculture had been one of the sectors to suffer the most from the decline in international assistance to developing countries. In real terms, external assistance to developing country agriculture almost halved from a peak of US$ 19 billion in 1986 to US$ 10 billion in 1994.

Food Availability

According to IFPRI, during the next quarter century the world will produce enough food to meet the demand of people who can afford to buy it (Tables 5 and 6), and real food prices will continue to decline (Table 7).

Table 5: Per capita cereal production (kg)

Period	Asian developing countries		All developing countries	Developed countries	World
	East Asia	South Asia			
Early 1970s	186	163	185	591	303
Early 1980s	223	165	199	678	325
Early 1990s	257	182	214	690	327

Source: FAO, Report of the Eighth Session of the FAO Regional Commission on Food Security for Asia and the Pacific, APCFS/97/REP, 1997

Table 6: Projected average annual growth rates in production of major commodities, 1990-2020

Commodity	World			Developed countries			Developing countries		
	Area[a]	Yield	Production	Area[a]	Yield	Production	Area[a]	Yield	Production
Beef	0.72	0.70	1.43	0.40	0.49	0.90	1.09	1.16	2.26
Pigmeat	1.44	0.60	2.04	0.29	0.32	0.61	2.36	0.90	3.28
Sheepmeat[b]	1.02	1.27	2.30	0.33	1.01	1.34	1.41	1.47	2.90
Poultry	1.42	0.56	1.99	0.82	0.41	1.23	2.11	0.90	3.03
Total meat	1.20	0.66	1.87	0.33	0.56	0.89	1.86	1.08	2.95
Eggs	…	…	2.20	…	…	0.86	…	…	3.23
Wheat	0.19	1.35	1.55	0.01	0.99	1.00	0.39	1.77	2.17
Rice	0.19	1.43	1.62	0.10	0.76	0.86	0.19	1.46	1.66
Maize	0.40	1.08	1.49	0.07	0.92	0.99	0.56	1.52	2.09
Other coarse grains	0.28	1.02	1.31	0.00	0.94	0.94	0.57	1.48	2.05
Total cereals	0.26	1.24	1.50	0.02	0.96	0.97	0.40	1.54	1.94
Roots and tubers	0.47	0.90	1.38	0.02	0.74	0.76	0.61	1.04	1.65
Soybeans	0.45	1.47	1.92	0.38	1.40	1.78	0.50	1.56	2.08

Source: Global Food Projections to 2020: Implications for Investment, IFPRI, 1995.

Note: Leaders (. . .) indicate not applicable.

[a] For livestock products, area means number of animals slaughtered.

[b] Includes goat meat.

However, if the global community continues with business as usual, prospects for food security will be bleak for millions of people and degradation of natural resources will continue. Policymakers, researchers and others must take proactive steps to minimize uncertainty in the future world food situation in order to achieve food security for all people. In developing countries, policymakers need to ensure that their policies promote broad-based economic growth, especially agricultural growth, so their countries can produce enough food to feed themselves or enough income to buy the necessary food on the world market. Policymakers in developed countries should consider reversing the decline in aid flows and redirecting aid to the most vulnerable developing countries. A world of food-secure people is within our reach, if we take the necessary actions.

Table 7: Projected real world prices of major commodities, 1990 and 2020

Commodity	1990	2020	Change
	(1990 US$ per metric ton)		(percent)
Wheat	156	132	-15
Rice	231	181	-22
Maize	109	84	-23
Other course grains	89	67	-25
Soybean	247	219	-11
Roots and tubers	148	122	-18
Beef	2,062	1,947	-6
Pigmeat	1,664	1,500	-10
Sheepmeat	1,907	1,825	-4
Poultry	739	662	-10
Eggs	897	668	-26
Total cereals	144	116	-19
Total meats	1,587	1,441	-9

Source: Global Food Projections to 2020: Implications for Investment, IFPRI, 19

Worldwide per capita availability of food calories is presented in Table 8 and that of protein in Table 9. The former is projected to increase around 7 percent between 1993 and 2020, from about 2,700 calories per person per day in 1993 to about 2,900 calories (Table 10). Increases in average per capita food availability are expected in all major regions. China and East Asia are projected to experience the largest increase, and West Asia and North Africa the smallest. The projected average availability of about 2,300 calories per person per day in Sub-Saharan Africa is just barely above the minimum required for a healthy and productive life. Since available food is not equally distributed to all, a large proportion of the region's population is likely to have access to less food than needed.

Table 8: Per capita food availability (calories/day)

Year	World	Developed Countries	Developing Countries	China	India
61-65	2,308	2,995	1,994	1,789	2,047
66-70	2,376	3,093	2,071	1,974	1,970
71-75	2,417	3,151	2,127	2,046	1,995
76-80	2,495	3,206	2,230	2,193	2,043
81-85	2,607	3,237	2,388	2,521	2,146
86-90	2,679	3,315	2,475	2,625	2,266
91-95	2,698	3,223	2,545	2,697	2,357

Concerns about feeding China

With one-fifth of the world's population and one of the fastest-growing and most rapidly transforming economies in the world, China has the potential to significantly affect global food security. It depends on the extent of China’s future demand for cereals, its capacity to meet its needs through production, and the degree to which it enters world markets to satisfy its unmet needs. Concerns about how China will meet its food requirements escalated recently, when China shifted from being a minor net exporter of cereals in 1992-94 to a substantial net importer in 1995. China has since returned to past levels of virtual self-sufficiency in grain, with small net cereal imports of 2-4 million tons annually. In any case, the concerns arising from China's shift to being a net cereal importer in 1995 seem misplaced given that China has been a net importer in 13 of the 18 years since 1980.

Table 9: Per caput protein availability (grams/day)

Year	World	Developed Countries	Developing Countries	China	India
61-65	63.26	90.46	50.80	46.20	52.12
66-70	64.08	93.44	51.68	47.92	49.82
71-75	64.60	95.94	52.28	48.48	49.54
76-80	65.92	97.84	54.20	51.00	50.28
81-85	68.42	98.80	57.94	58.60	52.88
86-90	70.64	102.32	60.52	62.84	55.54
91-95	71.42	98.56	63.18	67.78	56.68

Table 10: Per caput food availability: 1990 and 20
(calories/day)

Country/Region	1990	2020
World	2,773	2,888
Developed	3,353	3,517
Developing	2,500	2,834
Latin America & the Carribean	2,722	3,054
Sub-Saharan Africa	2,053	2,136
Near East & N. America	2,988	3,301
Asia	2,500	2,999

Views on the size and dominance of China's food economy in the 21st century vary widely, with some forecasting that China will be a major cereal exporter and others cautioning that China might become a major cereal importer, if not the world's largest importer. Impact projections indicate that, in the baseline scenario, total cereal demand in China will increase by 42 percent, to 490 million tons, between 1993 and 2020, and cereal production by 31 percent, to 449 million tons. At 41 million tons, China's net cereal imports in 2020 would represent 18 percent of the developing world's projected net cereal imports. While sizable, China's projected imports are unlikely to pose an intolerable burden on the global food situation. For meat, China's production is projected to almost keep up with increases in demand. China is already a significant player in world food markets and is likely to become increasingly important. However, it does not represent a major threat to world food markets.

Population and Food in India

With its population to reach one billion in 2000, India is the second most populous country in the world after China. Like China more than a decade ago, India is in the midst of major economic reform. If it succeeds, incomes in India will rise much faster than they have in recent decades, with profound effects on food demand and food security. India is projected to have an average annual economic growth rate of 5.5 percent during 1993-2020. Daily per capita calorie availability is projected to increase from around 2,400 to 2,780 calories.

With a total land area of 328 million hectare, India represents all kinds of climates and is demarcated into 20 agroclimatic zones. An estimated 142 million hectare is cultivated area, of which about 55 million is irrigated and the remaining 87 million rainfed. The increase in the production of food grain and other agricultural commodities has kept pace with the increase in the population since 1951 (Table 11). The present population of livestock in India is estimated to be about 500 million, which is the largest in the world (Table 12). It has a tropical coastline 8,129 km long and an Exclusive Economic Zone of 2.02 million km^2 that permits a year-round fish harvest. Although the share of agriculture in India's gross domestic product has declined to about 25% in 1997-98 from 56% in 1950-51, about 70% of the population is dependent on agriculture for their livelihood in 600,000 villages. The population of India is expected to reach 1.16 billion in the year 2010 and 1.5 billion in 2050. The biggest challenge before the agriculture sector of India is to meet the growing demand for food to feed its growing population.

Table 11: Population and food in India

Year	Population (million)	Foodgrains (million ton)	Oilseeds (million ton)	Milk (million ton)	Egg (billion)	Fish (million ton)	Potato (million ton)	Onion (million ton)	Sugarcane (million ton)
1951	361,1	50,8	5,2	-	-	0,8	1,7	-	57,1
1961	439,2	82,0	7,0	-	-	1,2	2,7	-	110,0
1971	548,2	108,4	9,6	-	-	1,8	4,8	-	126,4
1981	685,2	129,6	9,4	31,6	10,60	2,4	9,7	2,5	154,3
1991	846,3	176,4	18,6	53,9	21,10	3,8	15,2	3,2	241,1
1997	936,0	199,4	24,4	68,3	27,49	5,3	24,2	4,2	277,6

Agricultural research and education in India

The Famine Commission 1880 found that India had two bad seasons to every seven good seasons and disastrous famine every 12 years. The Imperial Council of Agricultural Research (ICAR) was set up in 1929 to promote, guide and coordinate agricultural research throughout India. After 1947, ICAR became the Indian Council of Agricultural Research. In 1965, ICAR became the nodal agency for coordinating agricultural research in the country. It gained administrative control over various institutions and commodity research institutions.

At present the ICAR employs about 5,000 scientists in its 46 central research institutions including four national institutions; four national bureaus: for plant, animal, fish genetic resources and soils; ten project directorates; 26 national research centers; the National Academy of Agricultural Research Management and 84 all-India coordinated research projects.

The goals of increased production can only be achieved through application of science and technology to agriculture, for which trained personnel is a "requirement". While the Indian Agricultural Research Institute, New Delhi, and the Indian Veterinary Research Institute, Mukhteswar, were forerunners of the Land-Grant College System in 1958, the Gobind Ballabh Pant University of Agriculture and Technology is the first state agricultural university to have been established at Pantnagar, Uttar Pradesh, in 1960. By 1968, there were eight agricultural universities and their number has swelled to 29 that includes one Central Agricultural University for the North-East Hills Region. In addition, there are four deemed universities within the ICAR system: IARI (New Delhi), IVRI (Izatnagar), NDRI (Karnal) and CIFE (Bombay), and three central universities each with a separate agriculture faculty: AMU (Aligarh), Vishwa Bharati (Shantiniketan) and BHU (Varanasi). These institutions employ about 25,000 agricultural scientists and provide undergraduate education in 11 fields of specialization with 168 constituent colleges capable of enrolling 10,000 students in the postgraduate program. Degrees are awarded in veterinary science, agricultural engineering, forestry, home science, agricultural science, horticulture, food science, dairy technology, fisheries, sericulture, marketing and banking, and cooperation. There are 55 disciplines in which specialization at the postgraduate level is available.

Table 12: Livestock population of India

Animals	Number of animals			
	1977	1982	1987	1992
Cattle	180,140	192,453	199,695	204,584
Buffaloes	62,019	69,783	75,967	84,206
Sheep	40,907	48,765	45,703	50,783
Goats	75,620	95,255	110,207	115,279
Horses & Ponnies	916	900	797	817
Pigs	7,647	10,071	10,626	12,788
Mules	89	131	167	193
Donkeys	978	1,024	958	967
Camels	1,068	1,078	1,001	1,031
Yaks	132	128	36	58
Mithuns	129	154	129	154
Total	369,645	419,742	445,286	470,860

Source: Agricultural Statistics at a Glance. Ministry of Agriculture, Government o

With a well-developed infrastructure for agricultural education and research, India is in a strong position to make use of science and technology in the development of its agriculture, not only to feed its own population but also to export agricultural products in significant quantities.

India and the World

Yield of major food crops in selected countries from 1961 to 1998, including India, is given in Table 13 (rice), Table 14 (wheat), Table 15 (maize), Table 16 (potato) and Table 17 (soybean). It is clear from these tables that the average yields in India are very low compared to average yield in many countries. In the case of rice, the average yield in India is only 2.9 tons/ha compared to 7 tons/ha in Korea and over 6 tons/ha in China, Japan and the United States. Similarly, the yield of wheat in France, the United Kingdom and Germany is above 7 tons/ha, whereas in India the yield is only 2.6 tons/ha. The maize yield in India is very low (1.6 tons/ha) compared to yield of over 8 tons/ha in Italy, USA, Germany and France. The yield of potato is 16.7 tons/ha in India and the yield in the USA, the UK, France, Germany and Japan is well above 30 tons/ha. Soybean yield is also low in India (0.96 tons/ha) as compared to the USA (2.62 tons/ha) and Italy (3.50 tons/ha). The yield of all these crops in China is also higher than that of India.

Table 13: Yield of rice crop in selected countries (ton/ha)

Year	USA	Japan	Republic of Korea	China	India
1961	3.82	4.88	4.15	2.08	1.54
1965	4.73	5.01	4.29	2.98	1.40
1970	5.10	5.48	4.63	3.29	1.67
1975	5.10	5.85	5.47	3.51	1.69
1980	5.17	5.58	5.51	4.24	1.86
1985	5.99	6.32	6.40	5.31	2.22
1990	6.36	6.12	6.23	5.61	2.62
1995	6.62	6.55	6.36	6.02	2.84
1998	6.35	6.22	7.00	6.06	2.89

Table 14: Yield of wheat crop in selected countries (ton/ha)

Year	France	Germany	UK	China	India
1961	2.40	2.86	3.54	0.56	0.85
1965	3.08	3.32	4.05	0.97	0.82
1970	3.62	4.01	4.21	1.17	1.23
1975	4.08	4.29	4.39	1.64	1.31
1980	4.99	4.80	5.65	2.05	1.54
1985	5.97	5.95	7.01	2.98	1.92
1990	6.50	6.24	6.99	3.11	2.22
1995	6.77	6.98	7.73	3.57	2.47
1998	7.60	7.20	7.56	3.67	2.58

Table 15: Yield of maize crop in selected countries (ton/ha)

Year	USA	France	Germany	Italy	China	India
1961	3.92	2.53	2.90	3.29	1.18	0.96
1965	4.40	3.61	3.64	3.49	1.57	0.99
1970	5.15	5.12	4.96	4.67	2.00	1.05
1975	5.15	4.26	5.00	5.81	2.51	1.07
1980	6.47	5.46	6.16	6.89	3.04	1.10
1985	7.20	6.25	6.42	7.13	3.76	1.29
1990	7.18	6.72	7.05	7.60	4.33	1.51
1995	7.92	7.96	7.42	8.84	4.94	1.55
1998	8.44	8.15	8.16	9.32	5.21	1.61

Table 16: Yield of potato crop in selected countries(ton/ha)

Year	USA	UK	France	Germany	Japan	China	India
1961	22.20	22.48	16.10	18.06	17.70	9.92	7.25
1965	22.79	24.08	18.67	21.24	18.05	9.06	7.72
1970	25.30	27.19	22.88	21.43	21.30	10.46	8.96
1975	28.34	25.57	20.77	20.15	23.94	11.96	10.43
1980	30.23	32.89	28.46	23.59	26.46	10.89	12.64
1985	32.51	36.25	31.27	27.62	29.42	10.82	14.16
1990	33.11	35.92	29.85	27.75	30.97	10.97	15.97
1995	37.79	39.37	34.26	34.91	31.18	13.75	16.47
1998	38.40	39.64	36.47	39.40	32.69	15.92	16.71

Table 17: Yield of soybean crop in selected countries (ton/ha)

Year	USA	Italy	China	India
1961	1.69	1.92	0.63	0.45
1965	1.63	1.86	0.83	0.44
1970	1.83	2.01	1.04	0.44
1975	1.76	2.71	1.02	0.91
1980	1.99	2.70	1.10	0.68
1985	2.14	3.19	1.36	0.71
1990	2.26	3.48	1.37	0.87
1995	2.56	3.60	1.72	0.98
1998	2.62	3.50	1.68	0.96

Future prospects for food production in India

The main reason for high crop yields in many countries is that they use more inputs, better technology and management. For example, the fertilizer use in all the countries with high yields is very high (Table 18). India has a tremendous potential to increase its crop yields by increasing the level of inputs, improved technology and management. The average annual yield of food grain in Punjab State of India is about 5.3 tons/ha with fertilizer input of about 250 kg/ha (Figure 1) and power availability of 3.9 kW/ha (Figure 2).

Table 18: Fertilizer consumption for crop production in selected countries (kg/ha)

Year	China	France	Germany	India	Italy	Japan	UK	USA
1961	6,9	113,2	257,5	2,1	55,9	268,5	192,1	41,9
1965	25,6	155,2	323,0	5,5	68,2	317,8	210,9	63,3
1970	40,5	242,4	381,7	14,0	96,2	364,5	252,1	80,0
1975	62,2	255,4	405,6	18,8	113,5	388,8	257,9	97,3
1980	144,5	301,2	408,0	33,4	174,8	412,3	315,5	108,2
1985	147,0	300,7	386,2	50,1	171,6	433,9	369,4	96,2
1990	208,7	301,7	295,2	72,7	159,9	401,7	354,0	99,6
1995	252,0	251,7	236,4	82,0	171,2	378,0	366,8	111,7

The annual average yield for India was 2.1 tons/ha with fertilizer input of 74 kg/ha and power avail-

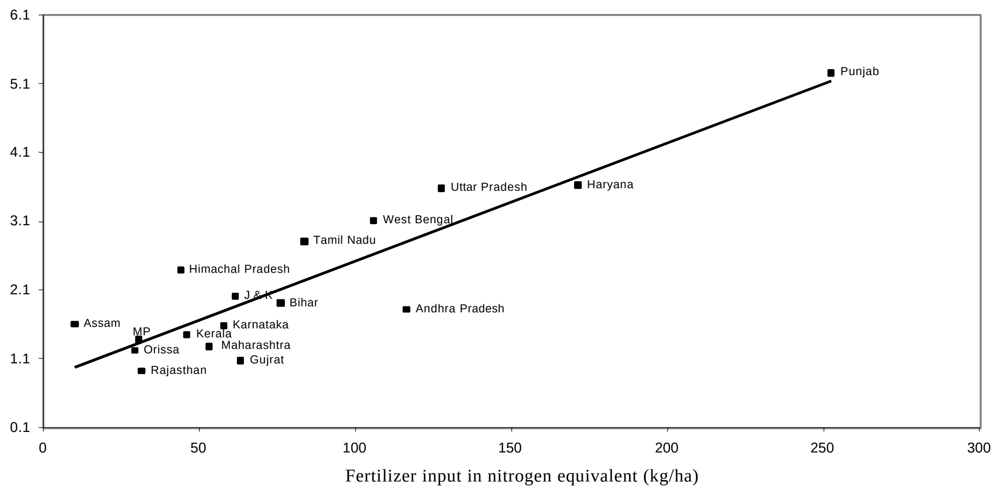


Fig. 1: Relationship between fertilizer input and grain yield in different states of India

ability of 1.1 kW/ha. If the average yield of India is increased to yield level of Punjab State in 1997, then the food grain production of India will be about 485 million tons in comparison to 199 million tons. At the present level of food consumption (194 kg/person/year), it will be sufficient to feed a population of 2.5 billion people. The population of India is expected to stabilize around 1.6 billion people. Even with food grain consumption of 250 kg/person/year, using the present level of technology practiced in Punjab, India will be able to export 85 million tons of food grains after using 400

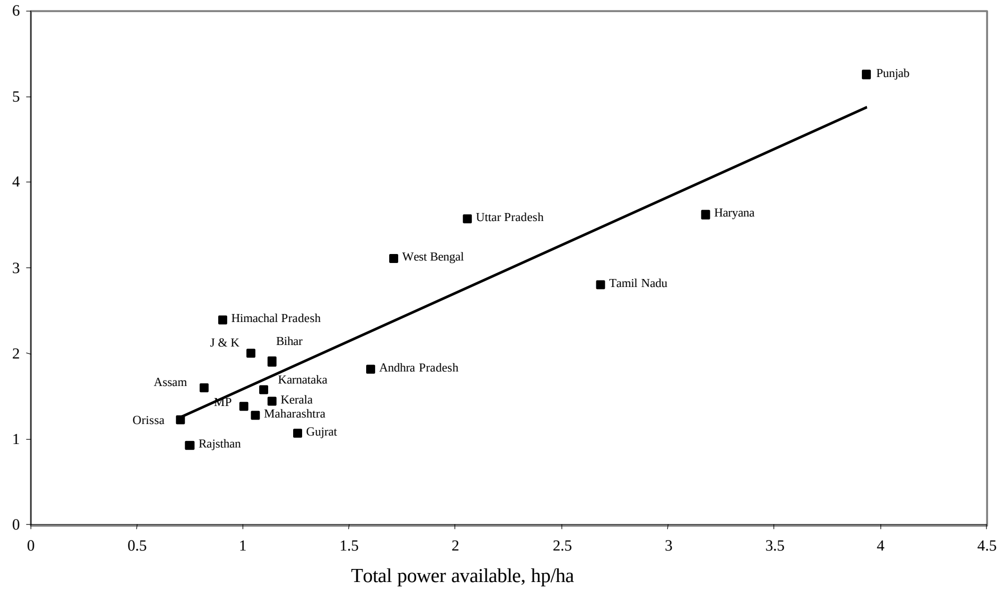


Fig. 2: Relationship between total power available and grain yield in various states of India

million tons to feed its own population.

All of this is possible if there is a political will to provide for five “Is” for agricultural growth:

- *Incentives.* Remunerative prices for agricultural produce and products.
- *Innovation.* Strong national agricultural education, research and extension systems (both public and private) to generate and disseminate productivity-enhancing technologies.
- *Infrastructure.* Good roads and transport systems, power supply and irrigation systems.
- *Inputs.* Efficient delivery systems for agricultural services, especially for modern farm inputs, agro-processing and credit.
- *Institutions.* Efficient, liberalized markets that provide farmers with ready access to domestic and international markets and effective public institutions to provide key services where they cannot be devolved to the private sector.

References

Agricultural Statistics at a Glance, 1999. Directorate of Economics and Statistics, Ministry of Agriculture, Government of India.

Food and Agriculture Organization of the United Nations, 1999. Agriculture Data, *FAOSTAT database*, FAO Homepage.

Global Food Projections to 2020: Implications for Investment, IFPRI, Washington D.C., 1995.

Oerke E-C., H-W. Dehne, F. Schonbeck, and A. Weber, 1994. *Crop Production and Crop Protection*. Elsevier Science B.V., Amsterdam, The Netherlands.

The World Food Situation: Recent Developments, Emerging Issues, and Long-Term Prospects, IFPRI, Washington D.C., 1997.

World Population Prospects: The 1998 Revision, Forthcoming. United Nations Population Division, New York, USA.

Poverty Alleviation and Food security in Asia: Lessons and challenges. Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, Bangkok, December 1998.

Act 3

Global Climate Change: The CO_2 Thermometer?

Nguyen Thi Kim Oanh and Karl Iver Dahl-Madsen

> *The improver of natural knowledge absolutely refuses to acknowledge authority, as such. For him, scepticism is the highest of duties; blind faith the one unpardonable sin.*
> Thomas H. Huxley

Introduction

From an economic point of view at least, global warming is the most important environmental concern mankind has ever encountered. Decisions and policies on this matter will affect the well-being of all people for many years to come. Nordhaus (1999) has estimated the cost of the Kyoto Treaty to the Annex 1 countries at 243 billion US dollars and the benefits at 150 billion. Thus, a huge amount of money to be spent on debating greenhouse gas emissions could be used to solve many immediate poverty-related problems.

The issue of climate change is consequently a reality in today's world, not because the climate itself started to change, but because of the actions that the international community launched to minimize the risks of global warming in the next century. There is consensus among the scientists on the scientific background of the greenhouse effect, but not on the current and future magnitude of the effects on the earth's climate. This paper discusses critically the available facts and artefacts that lead to the controversy without attempting to make any authoritative conclusions.

Does the Greenhouse Effect Exist?

The answer is a resounding yes.

The atmosphere is nearly transparent to solar radiation, but absorbs most terrestrial radiation which is mainly infrared (max. at 10-12 µm). Part of the absorbed energy is radiated back to the earth's surface, which results in an increase of the surface temperature. The atmospheric gases absorbing the terrestrial radiation thus act in the same way towards the radiation as glass in a greenhouse, i.e. to put a lid over the earth to prevent part of the terrestrial IR to escape into the space (Figure 1). They are called greenhouse gases (GHG) and the temperature increase is called "greenhouse effect". It is the "natural greenhouse effect" that keeps the earth around 33°C warmer than it otherwise would be. Without the greenhouse effect, the average surface temperature of the earth would be approximately 18°C instead of the observed value of 15°C (McIlveen, 1986), and life as we know it would not exist.

Of all the natural greenhouse gases present in the atmosphere, water vapour is the most significant, especially in the lower part of the atmosphere (Perkins, 1974; Wark et al., 1998). CO_2 is the second important greenhouse gas and one hundred years ago, in 1898, the Swedish scientist Svante Arrhenius warned that CO_2 emissions could lead to global warming. But it was not until the 1970s that a growing understanding of the earth-atmosphere system brought this previously obscure scientific concern to wider attention (USGCRP, 1998).

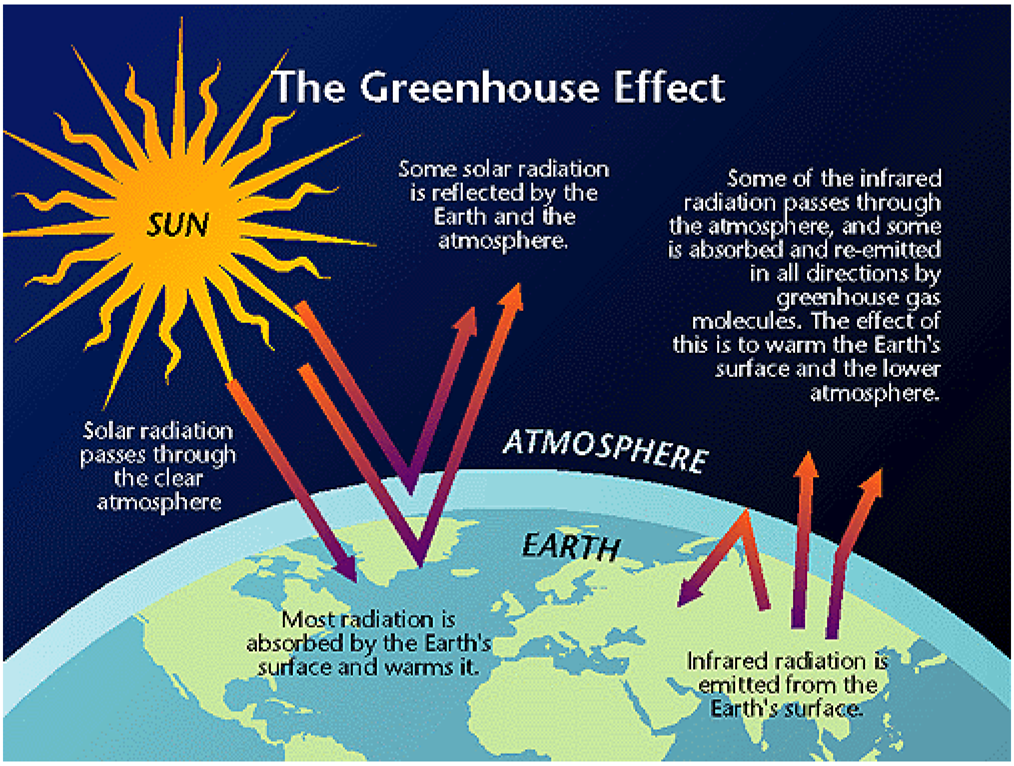


Fig. 1: Greenhouse effect; Source: IPPCC (1999)

Are We Influencing the Composition of the Atmosphere?

Again, the answer is a clear yes.

CO_2

The atmospheric concentrations of CO_2 have increased significantly since the industrial revolution about 200 years ago. Mass consumption of fossil fuel is the main reason for the increase. This source will be of increasing magnitude in the near future. Destruction of forests and reduction of the atmospheric CO_2 consumption in the photosynthetic process also disturb the natural balance of atmospheric CO_2.

Global cycles of CO_2, however, involve complex pathways. A change in a given part of the cycle will cause changes in other parts. Atmospheric CO_2 is only a small fraction of total CO_2 in the environment. Hence, it is sensitive to variations in other reservoirs.

Other GHGs

Several other greenhouse gases are building up steadily, e.g., methane and nitrous oxide (N_2O). Some chlorofluorocarbons (CFCs), which are strictly from anthropogenic sources, are both ozone-depleting and GHGs. Industrial production of these substances began in the 1930s and, since then, the atmospheric concentration of these gases has increased to the present level. Ozone is also a strong infrared absorber and is a potential GHG. Global warming potentials (GWP) of the ozone-depleting substances including all CFC, HCFC and halons thus are a sum of both direct (positive-warming) components and indirect (negative-cooling due to ozone destruction) components, which depend strongly upon the effectiveness of each substance for ozone destruction. Generally, halons are likely to have negative net GWP, while those of CFC are likely to be positive over both 20- and 100-year time horizons (IPCC, 1999).

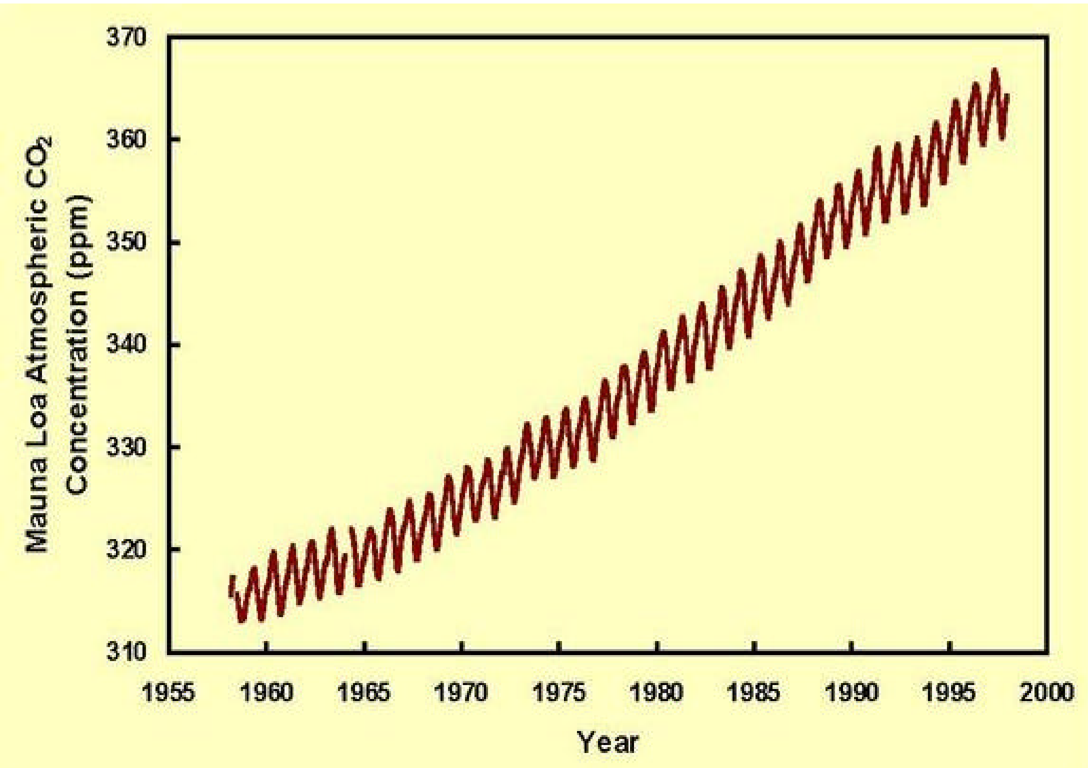


Fig. 2: Atmospheric CO_2 in the recent past; source: http:// www. CO_2 science. org/fact/

The list of GHGs regulated by the Kyoto Treaty in December 1997 includes four individual gases: CO_2, CH_4, N_2O, SF6, and two gas groups (HFCs, perfluorocarbons) (IPCC, 1999).

Atmospheric aerosol particles

Tropospheric aerosol is mainly composed of sulfate particles, of which 50% are anthropogenic. In the stratosphere, there is also an aerosol layer which is located at 15-20 km with nearly 90% by mass as sulfate and ammonium (Mezaros, 1981). Atmospheric aerosol particles affect the earth's radiation balance directly by surface reflection, scattering and absorption, or indirectly by acting as cloud condensation nuclei (CCN). Effects of aerosols are manifold and not fully understood. Aerosols absorb incoming solar radiation to the earth, and hence may result in a cooling effect, especially when the layer is high, such as dust from volcanoes.

Is the Climate Changing?

Again the answer is yes; the climate is changing all the time and very much so.

Over geological time the global climate has been extremely variable, with warmer and cooler (glaciation) intervals of the system alternating. The variations over the last 2,000,000 years (Fig. 3) show that we are now fortunately living in one of the few relatively warm periods of recent geological time. In most of the last 2,000,000 years ice has covered large landmasses.

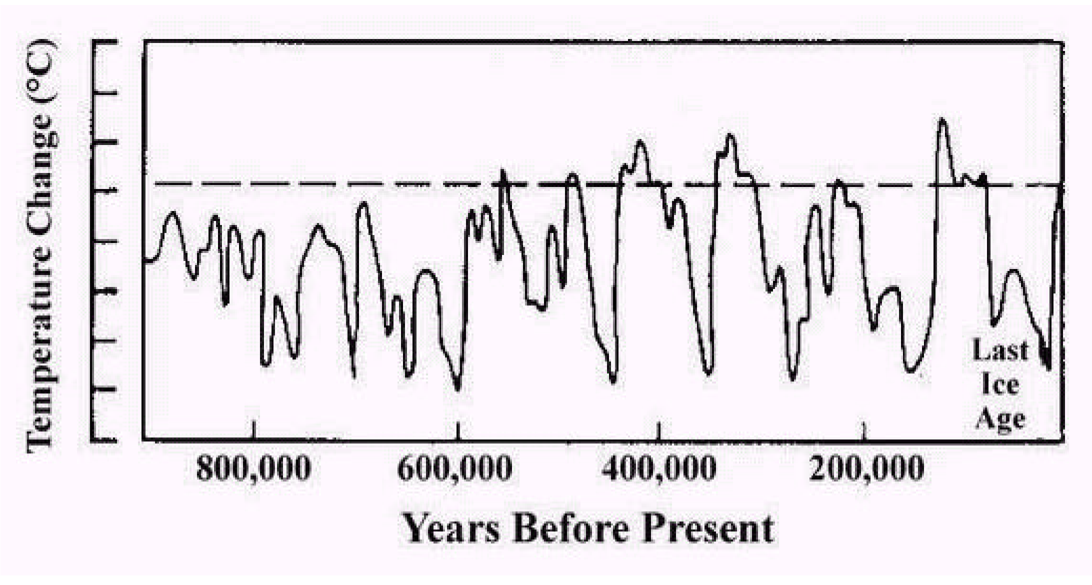


Fig. 3: Variations of Temperature over the Past

Temperature in the last 8,000 years has been relatively constant with variations of 1-2^{o}C (Fig. 4).

Since the beginning of our era, a medieval warm period was registered between the year 1000-1400, a time when Greenland actually was green. A short cold period was noted after 1200 and between 1550-1700 (Fig. 5). Recently, it has been established that in the Little Ice Age (about 1400-1850), the annual temperatures of the Northern Hemisphere were about 0.5-1^{o}C cooler than today (USGCRP, 1998).

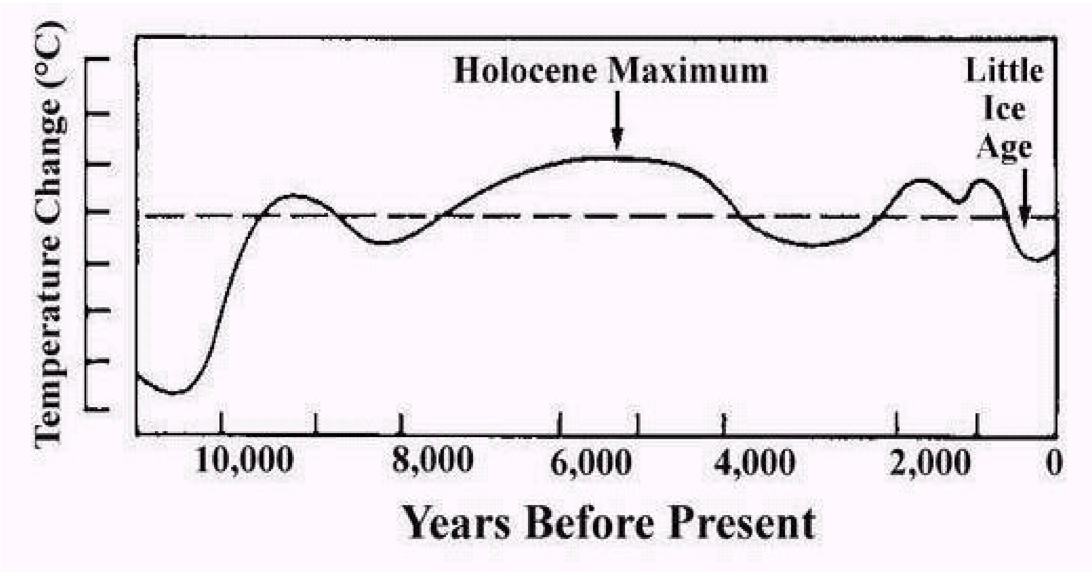


Fig. 4: Temperature variations in the past 10,000 years

Is The Earth Actually Warming Up In Our Time?

The first question which it is difficult to answer, as there is no scientific consensus on the subject. The answer is most likely yes, but probably only regarding the last twenty years. Here are some facts for you to consider:

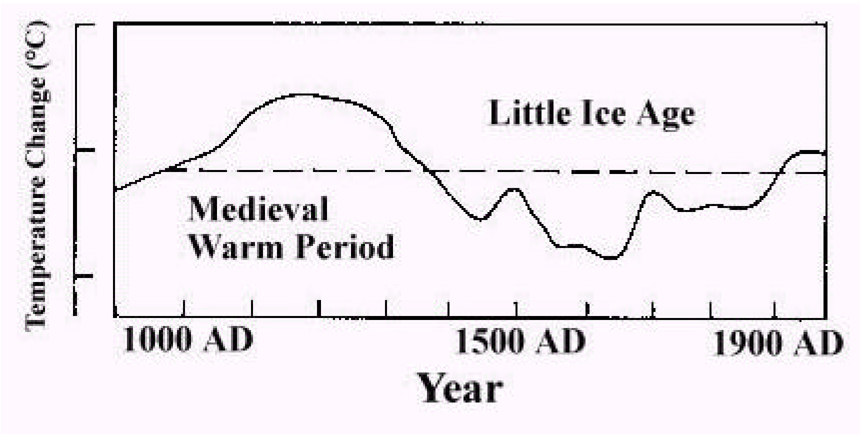


Fig. 5: Global average temperature in our era (Source: http://www.co2science.org/fact/figures/)

Temperature measurement methods

In out time the global temperature has in our time been measured by three methods: ground-based, satellite and radio sound balloons producing different temperature records. There is no consensus in the climate community on which temperature measurement method produces more reliable records.

Ground-based measurements started in 1880 at meteorological station networks, which recorded the earth surface temperature. These measurements show that over the last century, the average surface temperature of the earth has increased by 0.3-0.6°C. The earth atmospheric temperature steadily increased from 1880 to 1945 at a rate of 0.008°C/year. The amplitude of the variations is higher at higher latitudes. The fluctuations of temperature in the past are given in Figure 6. The warmest years are in this decade.

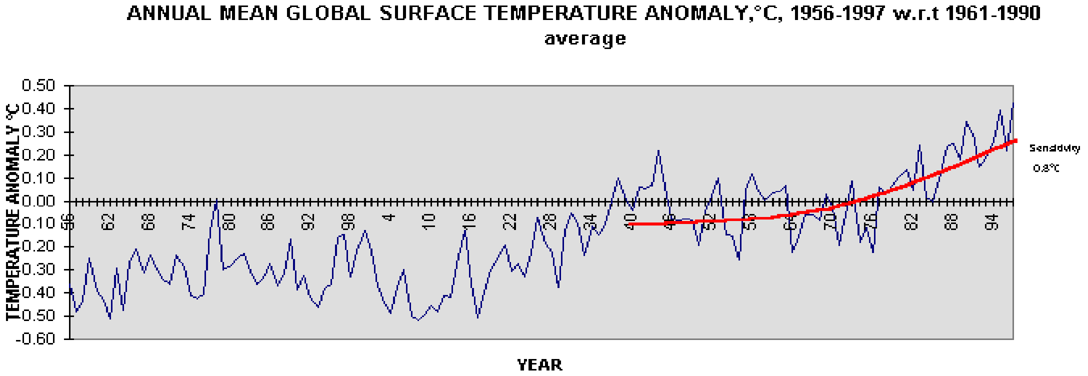


Fig. 6: Temperature in the past (ground-based measurement) (Source: http://www.co2science.org/fact/figures/)

It can be argued that the ground-based measurements in cities and towns are affected by an urban heat island effect, which can not be corrected properly. Some wealthier countries accurately maintain the records, while poorer countries may not produce reliable records. Furthermore, the records are predominantly from land areas, which cover only 25% of the planet, not from oceans and ice caps covering the other 75%.

Satellites started temperature measurement in 1979 and record temperatures of different layers of the atmosphere up to a height of 30,000 feet. Though satellite records may be free from the constraints encountered by the ground-based ones, there may be other sources of errors. However, the satellite and radio sound balloons method, both measuring atmospheric temperatures above the smog and heat islands, are reported to produce records in good agreement (Dally, 1999). The measurement results from 1979 until early 1999 by satellite method are shown in Figure 7.

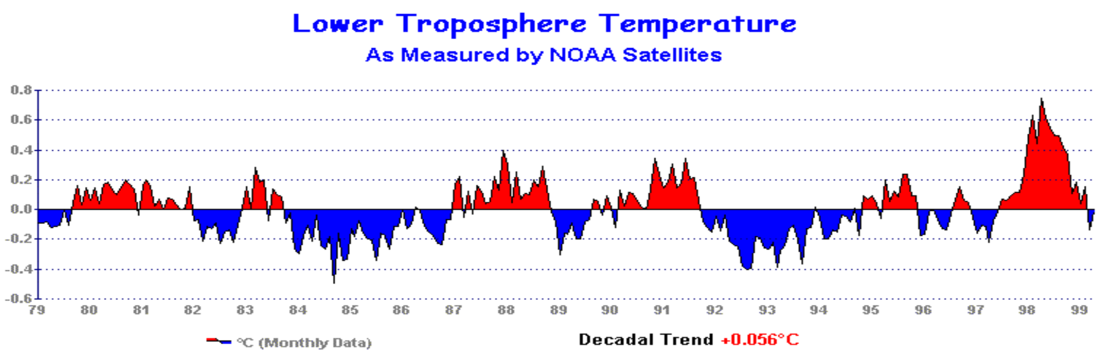


Fig. 7: Lower troposhere temperature by satellites (Source: http://wwwssl.msfc.nasa.gov/newhome/headlines/)

The satellite measurements confirm the warmest year to be 1998, but does not, contrary to the ground measurements, reveal any significant warming trend in the last 20 years.

Is CO_2 Making a Discernible Impact on Global Temperature?

The answer is a resounding maybe.

The IPCC in its summary for policy makers 1995[i] says discernible:

> *Our ability to quantify the human influence on global climate is currently limited because the expected signal is still emerging from the noise of natural variability, and because there are uncertainties in key factors. These include the magnitude and patterns of long-term natural variability and the time-evolving pattern of forcing by, and response to, changes in concentrations of greenhouse gases and aerosols, and land surface changes. Nevertheless, the balance of evidence suggests that there is a discernible human influence on global climate.*

However, note the first two sentences about the uncertainty. These are rarely quoted in the public debate.

Basically the earth is warm for two reasons. The sun is shining and we live in a greenhouse. The sun is obviously the prime mover here. As earlier mentioned, without the greenhouse effect, the sun would warm an average of -18°C. The greenhouse effect heats the earth with an additional 33°C. Below are the main cause-effect relationships.

Fluctuations in the earth orbit

The most recent information on long-term climate changes is presented by Petit et al (1999).

The authors analyzed the deepest ice core ever recovered, at a depth of 3,623 meters, from the Vostok station in east Antarctica and reconstructed trends of temperature and CO_2 concentration over a period of 420,000 years (Fig. 8).

As seen in Fig. 8, there is a variation in surface temperature over a range of approximately 12°C during this period, while atmospheric CO_2 concentration varied from a low of 180 ppm to a high of 290 ppm. The authors described the overall series as "the same sequence of climate forcing operated during each termination: orbital forcing followed by two strong amplifiers, greenhouse gases acting first, then deglaciation and ice-albedo feedback."

The main factor here is the orbital forcing, which afterwards is enhanced by greenhouse gases. It must be noted that the warming is leading the increase in CO_2.

Variations in solar activity: sunspots

Lassen and Friis-Christensen (1991) have shown a very good correlation between short term changes in temperature and sunspot activities (Figure 9).

Svensmark and Friis-Christensen (1997) revealed a possible cause-effect relation between sunspot activities producing cosmic rays, which are influencing cloud cover, a major determining factor for the earth’s temperature. This relationship seems to explain an important part, but not necessarily all of the temperature variations in recent times.

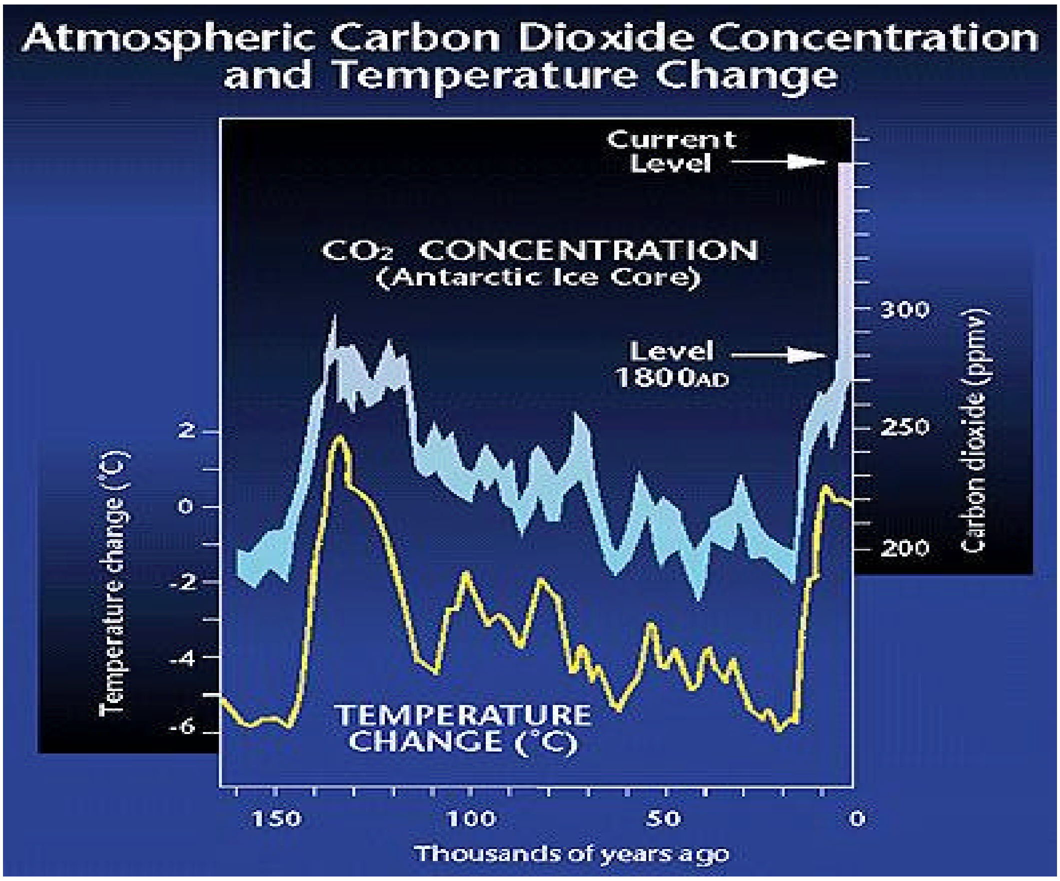


Fig. 8: Variations of temperature and CO_2 over the past (Source: http:/www.co2science.org/fact/)

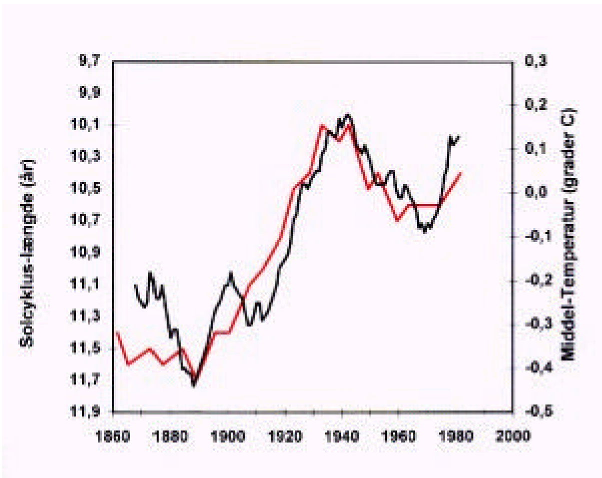


Fig. 9: Change of sunspot activities and temperature in the past (Source: Lassen and Friis-Christensen, 1991)

Variations in oceanic circulation: el Niño and La Niña

We are all aware that el Niño and la Niña have a major influence on the earth's climate. Dally (1999) presents the relationships between Southern Oscillation Index (SOI). SOI is the normalized difference in atmospheric pressure between Tahiti, in the mid-Pacific, and Darwin, Australia. The SOI measures the pressure gradient across the tropical Pacific, which, in turn, is an indicator of the equatorial wind variations. SOI is negative for el Niño and positive for la Niña. The relationship between SOI and temperature is presented in Fig. 10 where the SOI values are inverted.

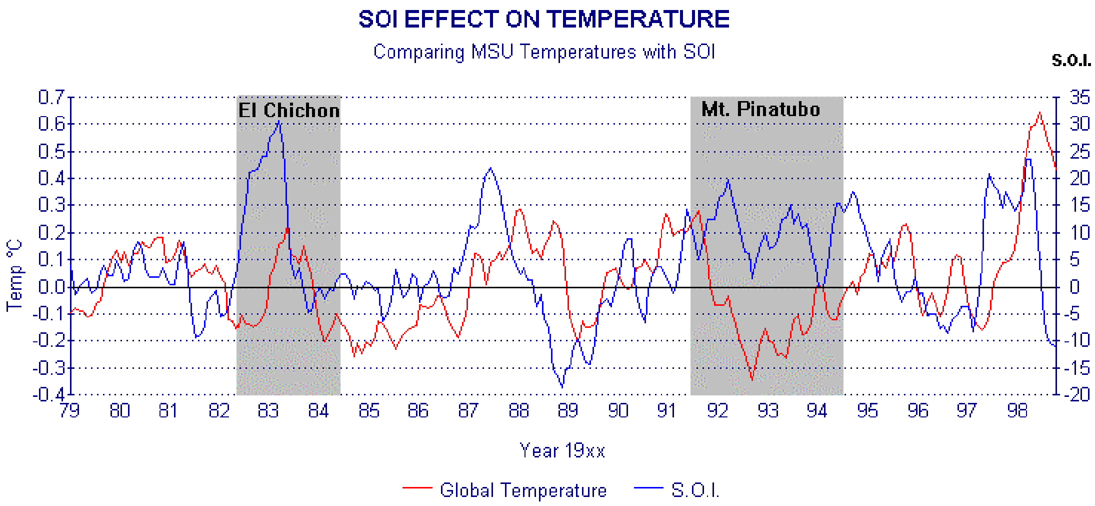


Fig. 10: Relationship between temperature change and SOI (inverted)
(Source: Dally, 1999)

Note that the temperature change is trailing the SOI six to nine months. The warmer episodes in the graph match el Niño events in 1983, 1987, 1995, 1997, and 1998 and solar maxima in 1980 and 1990-1991. The cooler episodes match la Niña events in 1988-1999 and 1996, solar minima in the mid-1980s and mid-1990s and the two volcano eruptions as indicated in Fig. 10. Note, furthermore, that major volcanic eruptions, el Chicon and Mt. Pinatubo, are dampening the warming effect of el Niño.

The obvious question is then, what is causing SOI to vary? El Niño and la Niña are subjected to external forcing by the sun's varying activity. Landscheidt (1999) hypothesizes a relation between sunspot activity and SOI. According to him, the present la Niña will continue for the next 12 months at least followed by an el Niño late in 2002.

Intransitivity of the earth-atmosphere system

Solar radiation in the atmosphere is absorbed, scattered and reflected by constituents such as gas molecules, dust, haze, smoke and cloud particles. As explained above, the anthropogenic discharges to the troposphere of aerosol particles, as well as volcanic eruptions, are influencing temperature by changing the intransitivity of the atmosphere.

Fluctuations of the atmospheric chemical composition: greenhouse gases

There is apparently a correlation between the increase of CO_2 concentration in the atmosphere and the global surface temperature (Fig. 8). The correlation is somewhat weakened by the fact that the surface temperature decreased in the period from 1940 to 1970.

Correlation does not necessarily say anything about cause-effect relationships. Even if the correlation is perfect, it may just be a coincidence or result related to the same cause. Indeed, if a correlation is bad, there may still be a cause-effect relationship masked by variations in other factors.

Over a very long time-scale, the changes in CO_2 have been closely matched by similar changes in global temperature. The question is which is the cause and which is the effect. According to the greenhouse effect concept, changes in CO_2 concentration will lead to changes in temperature. However, Dally (1999) and Calder (1999) noted that the CO_2 gains followed the temperature gains during the past 160,000 years and there are time lags between the peaks of the two curves, which are of several centuries. The temperature fluctuations in the past led to increases in the amount of CO_2 released from the ocean reservoir which in turns led to increasing atmospheric CO_2. This directs us to the CO_2 thermometer concept given by Calder (1999): "the carbon cycle acts as a natural thermometer and year-by-year increments in CO_2 measure temperature deviations similar to those reported by man-made thermometers".

Indermuhle et al (1999) found that the CO_2 trapped in ice at Taylor Dome, Antarctica, produced a high-resolution record of atmospheric CO_2 over the Holocene epoch and concluded that "the global carbon cycle has not been in steady state during the past 11,000 years. Analysis of the CO_2 concentration and carbon stable-isotope records suggests that changes in terrestrial biomass and sea surface temperature were largely responsible for the observed millennial-scale changes of atmospheric CO_2 concentrations."

How Well Can Climate Models Predict the Climate?

When reviewing the available data on climate, it seems that there is no clear-cut empirical evidence either for or against a "discernible" anthropogenic influence on the climate. Various numerical models have been developed to predict concentration of GHGS and the greenhouse effect on the earth-atmosphere system climate. These climate system models (so-called general circulation models) supply "best guess" we have so far. Experienced mathematical modelers of complex natural systems will state that using mathematical modeling for forecasting climate change cannot be done with high accuracy. Of course, models are being used for this purpose, basically because the construction of the models is the only available procedure for systematically acquiring and testing knowledge on the basic cause-effect relationships of such complex systems. The knowledge accumulated into these models may prove to be extremely valuable for understanding and even withstanding dramatic natural climate changes, e.g. a new ice age. However, there are serious concerns about the prognostic ability of the existing climate models. Below are four examples of concerns:

1. In the presence of chaos

   The long time-series of data shows clear signs of chaotic elements in the climate. These are revealed by the wide fluctuations, even within the same regime, of forcing factors. In systems and modeling terms, chaotic behavior simply states that quite similar initial conditions can give rise to very different end results. In meteorological forecasting this is evident, as it is not possible to give meaningful weather forecasts for more than approximately seven days. The climate is subjected to heavy forcing from sun activity and greenhouse gases, and can be forecasted for much longer periods. However, the chaotic elements make long-time, accurate climate forecasting inherently impossible.

2. Model resolution and clouds

   The models divide the world into a large number of finite segments. Even if the modelers have access to some of the world's most powerful computers, there is still a limit to how small the model segments can be. The current segment size is of 480*480 km^2 (http://www.co2science.org/fact/). This size makes it impossible to accurately model cloud formation, which is a crucial weather and climate feed back process. The cloud formation is then parameterized, which means that some model parameter is introduced to enable the model to calculate the aggregated effect of the cloud formation for the total model segment.

IPPC (1995) commented on this uncertainty:

> *Feedback from the redistribution of water vapour remains a substantial uncertainty in climate models. Much of the current debate has been addressing feedback from the tropical upper troposphere, where the feedback appears likely to be positive. However, this is not yet convincingly established; much further evaluation of climate models with regard to observed processes is needed.*

The cloud effect is a coin with two sides: positive and negative feedback (Fig. 11). The climate models count for the positive feedback only, which leads to extra warming.

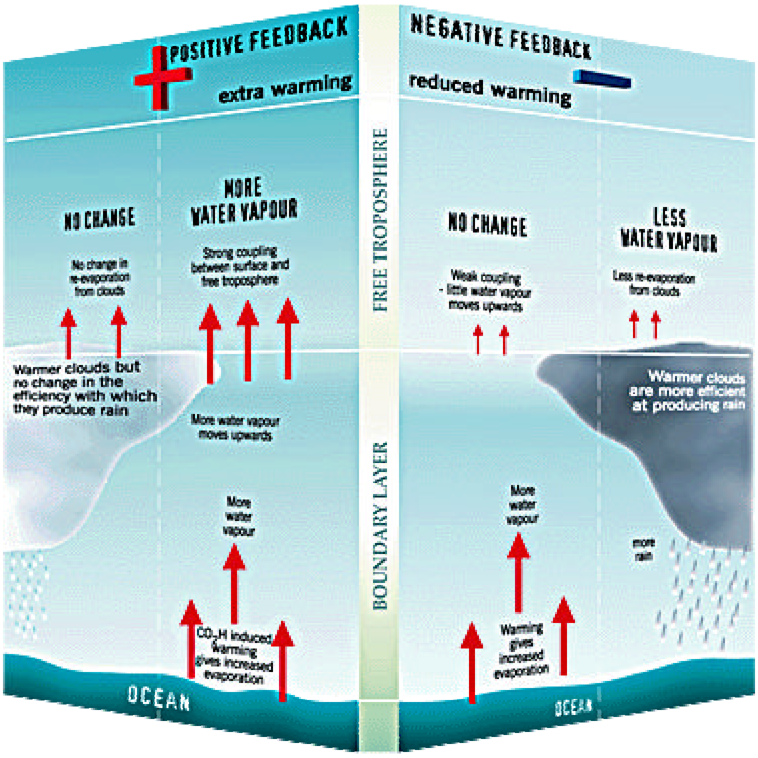


Fig. 11: Negative or positive feedback? (Source: http://www.co2science.org/)

Hoyt (1999) has stated:

> *A major factor to convert the small greenhouse effect into the "enhanced" greenhouse effect is that the models have a positive feedback involving clouds. In the models, more greenhouse gases lead to warmer weather, which causes more moisture to enter the atmosphere and more vigorous convection to occur. This increased moisture and convection in turn leads to fewer clouds. Hence, more sunlight strikes the earth's surface giving even more heating. There are two problems with this feedback loop model scenario: 1) Moister air and more convection always lead to more clouds and not less clouds. 2) If fewer clouds were created, it is an egregious violation of the second law of thermodynamics. Apparently the models have never been constrained to follow the second law of thermodynamics. Finally, a decrease in*

cloud cover would cause an increase in the diurnal cycle of temperatures, but a decrease in the diurnal cycle has been observed.

If the sign on the climate models parameter is wrong, i.e. if there is a negative feedback, GHG increases may well have a diminutive effect on the climate.

3. Models and Data

Any modelers know that models used for forecast should be able to hindcast, i.e. to describe historical data, and of course the model predictions should be verified against data. Our belief in any particular natural law cannot have a safer basis than our unsuccessful critical attempts to refute it (Popper, 1979).

The historical data, i.e. the past temperature change, used for model validation include natural variability and possibly the effects of GHG. The calibration thus may show agreement with past data but not with the temperature change due to GHG. And the applicability of the models for future prediction is questionable.

4. Tropospheric particles

Currently, the tropospheric aerosols pose one of the largest uncertainties in the model calculations. The aerosols are used in the models for explaining the cooling observed from 1940 to 1970. The major uncertainties are not just in knowing the effects of various particle concentrations, but in the fundamental science of how particles are modified and deposited and how secondary particles are formed (ACE-Asia, 1999). The present day global mean radiative forcing due to anthropogenic aerosols particles is estimated between –0.3 and –3.5 Wm^{-2}, which must be compared with the present day forcing by greenhouse gases between +2.0 and +2.8 Wm^{-2} (ACE-Asia, 1999). The global distribution of aerosols is extremely inhomogeneous due to their relatively short lifetimes (4-5 days). The negative forcing due to aerosols will focus on particular regions and subcontinental areas. Hence, there will be regional scale effects on climate patterns (Fig. 12).

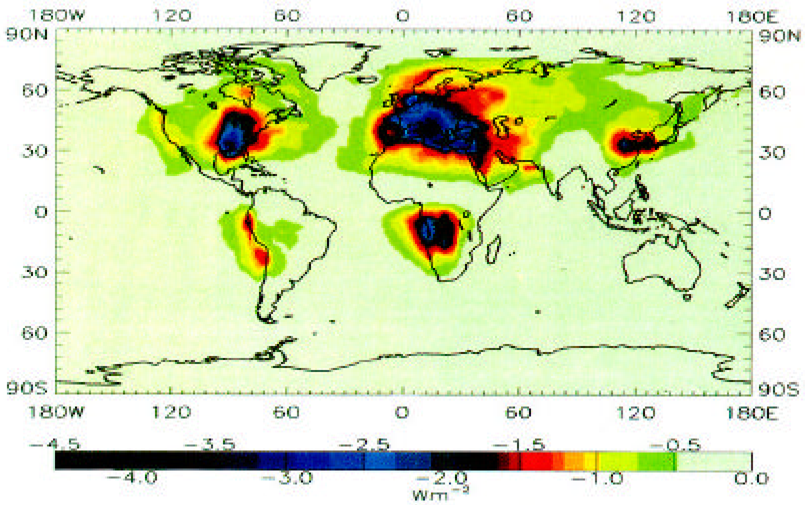


Fig. 12: Effect of Aerosol (Source: WMO, 1986)

With all their uncertainties, the models are used by IPCC (Year) for forecast. For the midrange IPCC emission scenario, IS92a, assuming the "best estimate" value of climate sensitivity and including the effects of future increases in aerosol concentrations, models project an increase in global mean surface temperature relative to 1990 of about 2°C by 2100.

This forecast shows a faster rate of climate change, than any other experienced during the last 10,000 years, the period in which modern civilization developed.

Are Climate Changes Only Bad?

Again, the answer to the question is not self-evident. There will be positive as well as negative consequences of a climate change.

Here is a list of examples of some consequences of global warming:

1. Increased sea water levels

   The sea levels are currently rising about 0.06 cm/yr. This warming effect is not only related to melting of ice from polar caps, but mainly to expansion of seawater with temperature. The rise presents a problem for nations like Holland, which are below the sea surface, and to other lowlands near the coasts of Bangladesh and the Maldives that will be more subjected to flooding.

2. Enhanced food production or "CO_2 fertilization"

   High CO_2 content in the air will stimulate photosynthetic growth and productivity rates of most plants, provided water and nutrients are available. In the late 1980s, scientists established the existence of a net CO_2 sink in northern hemisphere terrestrial ecosystems. The effect of CO_2 on photosynthesis, long known from laboratory studies, was proposed as one factor causing the additional ecological uptake of CO_2, or "CO_2 fertilization" effects. In the mid-1990s, it was recognized that the ability of plants and soils to store carbon through CO_2 fertilization is limited by availability of nitrogen. Several researchers have also shown that increased nitrogen turnover resulting from human activities could, unintentionally, be creating a substantial terrestrial sink of CO_2.

   The increase in temperature would self-evidently mainly be beneficial in cold countries like Denmark that may enjoy an increase in temperature of 1-2 degrees. White Christmas may be less frequent, but the loss would be well compensated by a reduced heating bill. In the warmer countries, more heating would, of course, be mainly disadvantageous.

3. Tropical diseases

   These disease vectors are likely to spread to wider areas and could cause trouble in unprepared countries. However, it is evident that the climate is only one factor relating to disease control. Man learns to manage nature for his benefits. Malaria disappeared in many parts of the world not because the temperature came down, but because human beings started managing nature according to human needs.

4. Biodiversity changes

   Natural systems may not adapt quickly enough to fast climate changes. Hence, biodiversity could be affected, and more species could become extinct. As sea levels rise, salt-water tolerant species may be increased. Some species may benefit from higher temperatures while other might not, e.g. some plants may die due to drier land, while algal blooms may be more frequent. Reduction in winter grounds and inland prairies would lead to loss of birds.

5. Precipitation pattern and forest growth

    Climate change would result in changes in regional precipitation and evaporation patterns. Evaporation would increase due to temperature increase, which in turn increases evapo-transpiration and alters precipitation patterns. On a regional scale precipitation may be increased in some areas but decreased in others. High temperature may result in more rain than snow. Thus, run-off would be increased, which will cause changes in water resources management and increase potential for hydropower.

    Concerning forestry, higher temperatures may lead to drier land, which may result in more frequent forest fires. Besides, forest growing seasons could be lengthened by 40-50 days in the mid-latitudes, and hence, an increase in forest development. Mid-latitude agricultural yields may be reduced due to increased summer dryness.

One of the myths about global warming is that it will result in more extreme weather events such as hurricanes, flooding and drought. There is, however, no evidence to that effect. On the contrary, there are indications that heating actually could diminish these occurrences. IPPC (1996) stated: "There is no evidence that extreme weather events, or climate variability, has increased, in a global sense, through the 20th century".

It is evident from the list above that the changes caused by global warming cannot simply be regarded as bad. A change is good, if it favors the needs of human beings, and bad if it does not. In this context global warming may be good for the world by increasing rainfall, agricultural production and comfortable temperature zones.

The Cost and Benefits of Greenhouse Gas Reductions

Let us assume that climate change will impose economic costs on society through its negative effects. What are the costs of global warming effects, and what are the costs of reducing GHG emissions?

On one hand, it is very difficult to make economic estimates for these complex scenarios, and it may be questionable to use money as the sole indicator unit for costs and benefits. On the other hand, it would be extremely irresponsible to make important decisions on a global scale without having at least some idea of the costs and benefits of the resulting actions.

All industrial and economic growth requires an abundance of available energy supply. Anything that inhibits energy supplies reduces economic activity. To reduce CO_2 emissions requires cutting fuel supplies and, therefore, economic activity. Nordhaus (1999) has calculated the costs of global warming expressed as a percentage of the global output and related this to the possible temperature increase (Fig. 13).

It can be seen from the figure that with an expected temperature increase of 2°C, the damage is estimated to be less than 2% of the global output. It must be noted that the relation is non-linear, with relatively higher damages at high temperatures, illustrating the fact that the likelihood of catastrophic events increases with increasing temperature.

Nordhaus' (1999) calculations of the cost-benefit of a group of possible abatement scenarios are shown in Table 1.The table shows numbers related to a base scenario, where we do nothing: the laissez-faire scenario. The first column is the costs of the abatement measures and the second column is the benefit seen as reduced global warming damages. The optimal policies are those which, in the least expensive way, reduce the damages maximally.

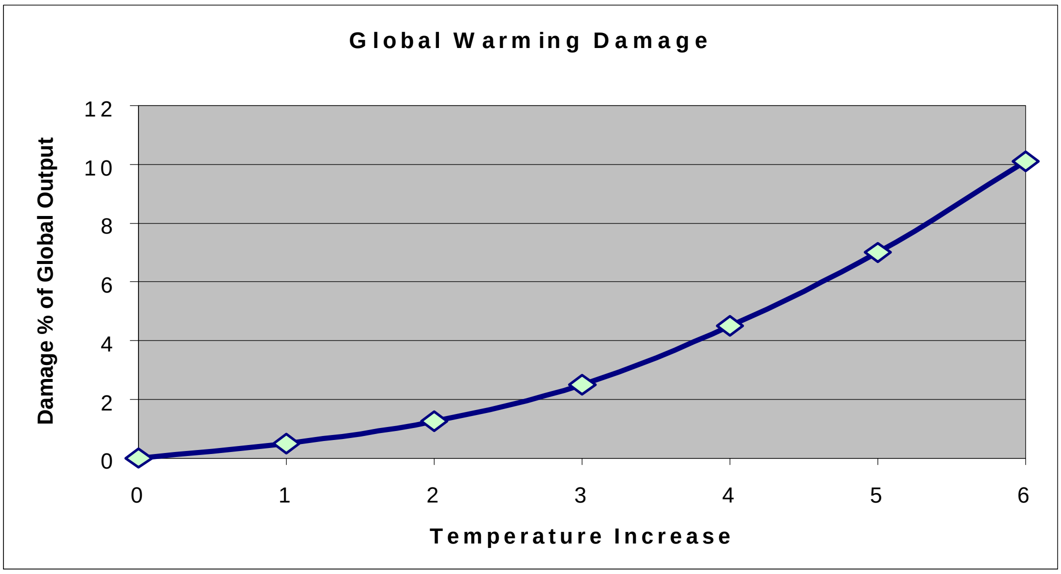


Fig. 13: Cost of global warming as percentage of global output

Even the optimal control option will have a net benefit of only around 400 billion dollars in present value, i.e. about 1.5% of the world output today. All other control solutions will cost more than the benefits they actually bring about, along with the prevented damages. Note, furthermore, that the extra cost of waiting ten years before making up our mind is negligible. And note that the Kyoto agreement, with estimated costs of 243 billion US dollars reduces damages by merely 150 billion US dollars.

	Change in Costs	Change in Damages	Total
Base (laissez-faire)	0	0	0
Optimal			
Policy in 2000	-235	658	423
Policy in 2010	-216	635	419
Limit emissions			
1990 Global	-2,481	1,356	-1,125
80% of 1990 Global	-5,085	1,690	-3,395
Kyoto: Annex I	-243	150	-93
Kyoto: OECD	-703	143	-560
Limit concentrations			
Double CO_2	-459	794	335
Limit temperature			
2°C increase	-1,221	1,131	-90
1.5°C increase	-3,971	1,657	-2,314

Table 1: Costs and benefits of different policies (in present value, billions of 1990 $)
Note: a positive sign indicates an increase in economic welfare. Hence, a negative sign on costs indicates an increase in costs, while a positive sign on damages indicates a reduction in climate damages. A positive sign on total indicates a net economic gain.

Climate Change and Developing Countries

Although developed countries are responsible for more than two-thirds of historical greenhouse gas emissions and approximately 75% of current annual emissions, their strong economies and institutions leave them better positioned than other countries to cope with changes in climate. The annual costs to developed countries of a world with twice the pre-industrial levels of carbon dioxide could equal 1-3% of their aggregate gross domestic product (GDP). The estimated costs for developing countries are 2-9% of GDP. Some studies have created a "vulnerability index" showing that developing countries are, on average, about twice as vulnerable to the negative impacts of climate change, as are developed countries; small island developing countries are about three times as vulnerable (IPCC, 1999).

At the global level, industrial emissions are projected to grow dramatically as developing countries industrialize; slowing their rate of emissions growth will require that they have access to the most efficient technologies available. Thus, in the future, the major increase in CO_2 will come from developing countries, which will need vast amounts of cheap energy to facilitate their development.

It is necessary to debate if the money now being reserved for emissions reduction could be used more efficiently for enhancing development. There are at least three options to consider:

1. *Increasing direct development aid.* It is obvious that developed economies are much more resilient to climatic changes than developing countries. Hollanders would merely build their dikes half a meter higher and go on with business as usual. Bangladeshis would not be able to do that, and would suffer from significant excess mortality and economic damage in a global warming situation. Consequently, it may well be that direct, substantial investment in development would be a more efficient means of reducing global warming damage than any other investment.

2. *Investing in environmental improvements in developing countries*. Even the scariest global warming scenarios do not even begin to approach the level of human suffering, mortality and general damage now caused by polluted water supply and indoor and outdoor air pollution in developing countries. These problems are very well known and abatement measures are possible with known technology and within budgets, which could easily be met by merely a fraction of the expense now reserved for CO_2 reduction.

3. *Investing in modern power production in developing countries*. An emissions reduction could be obtained much cheaper by constructing efficient power plants in the developing world than in the developed world where the reduction is marginal and very costly.

Policymakers should not overlook the importance of equity. Choosing policies that are both cost-efficient and fair is not easy. Traditional economics rigorously explore how to formulate flexible and cost-effective policies; it has less to say about equity. Because countries differ considerably in their vulnerability to climate change the costs of damage and adaptation will vary widely unless special efforts are made to redistribute them. Policymakers can pursue equitable solutions by promoting capacity building in poorer countries and reaching collective decisions in a credible and transparent manner. They could also develop financial and institutional mechanisms for sharing risks among countries.

While some damage from human-induced climate change seems likely, policymakers can try to limit the risks. The Climate Change Convention may be able slow the rate of change to ensure that ecosystems and human societies can adapt.

It is generally believed that it will be possible to reduce climate change damages and adaptation costs while generating economic benefits, such as more cost-effective energy systems and greater technological innovation. Some climate change policies can also bring about local and regional environmental benefits, such as reductions in air pollution and increased protection for forests and thus biodiversity.

For example, it is fortunate that many measures reducing toxic and hazardous air pollutants also help to reduce GHG and vice versa. Most GHGs such as CO and CH_4 are also air pollutants. The emissions of both GHG and other pollutants could be significantly reduced through energy-efficient technologies. These technologies enhance increase of energy conversion efficiency and more complete burning of fuels. The world average conversion efficiency of 30% could be more than doubled in the longer term. The best available coal- and natural gas-fired power plants already convert fuel into useable energy with an efficiency of 45 and 52% respectively. Raising the efficiency of a typical coal-fired plant from 40 to 41% would cut the plants CO_2 emissions by 2.5% (IPCC, 1999).

Let's Wait and See

The earth's climate has periodically warmed and cooled in natural cycles that have lasted from decades to millennia. The climate will continue to vary due to these cycles and possibly the human-enhanced greenhouse effect. Climate change impacts due to GHG emission will not be felt for many decades. It is, therefore, difficult to influence policy-making processes especially in developing countries, to prioritize GHG reduction. Yet, toxic pollutants, which have proven to have direct effects on human health and property, are not being properly addressed in these countries.

The greenhouse effect does exist. However, it is very uncertain whether or not the anthropogenic CO_2 increase actually will affect the global climate to any significant degree—and if a possible global warming will be more damaging than beneficial. It is evident that the proposed cure of excessive CO_2 emission reductions may well be far more costly than the disease of global warming.

Therefore, many parties have proposed to be precautionary in investing staggering amounts of money in an uncertain effect. This is supported by the Nordhaus 1999 cost-benefit analysis, which shows that the resulting damage from waiting ten more years before starting action may be negligible. The period of waiting should be made fruitful by working hard to reach a better understand of the global climate system. More reliable monitoring data would be generated and better climate models developed. In the meantime, speed up the global investment in efficient development of ever more economically healthy countries. Countries that will be highly resilient to any natural disasters, be they manmade or natural.

References

ACE-Asia (1999): http://saga.pmel.noaa.gov/aceasia/

Calder N (1999): The Carbon Dioxide Thermometer and the Cause of Global Warming. In http://www.vision.net.au/~daly/

Dally (1999): http://www.vision.net.au/~daly/

Hoyt (1999): http://www.erols.com/dhoyt1/annex2.htm

http:/wwwssl.msfc.nasa.gov/newhome/headlines/essd06oct971htm

http://www.co2science.org/fact/

Indermuhle A., Stocker T. F., Joos F., Fischer H., Smith H. J., Wahlen M., Deck B., Mastroianni D., Tschumi J., Blunier T., Mayer R. and Stauffer B. (1999): Holocene Carbon-cycle dynamics based on CO_2 trapped in ice at Taylor Dome, Antarctica, *Nature* **398**, 121-126, [11 March 1999] www.nature.com

IPCC (1999): http://www.unep.ch/ipcc/pub/sarsum1.htm

IPCC (1995), Houghton J T, Miera Filho L G, Callander B A, Harris N, Kattenberg A, and Maskell K (eds), *Climate change 1995: The Science of Climate Change*. Cambridge University Press, Cambridge, UK.

Petit J. R., Jouzel J., Raynaud D., Barkov N. I., Barnola J-M, Basile I., Bender M., Chappellaz J., Davis M. Delaygue G., Delmotte M, Kotlyakov V. M., Legrand M., Lipenkov V. Y., Lorius C., Pepin L. Ritz C., Saltzman E., and Stievenard M. (1999): Climate and Atmospheric History of the Past 420,000 years from the Vostok Ice Core, Antarctica. *Nature* **399**: 429-436.

Landscheidt T. (1999): http:/www.microtech.com.au/daly/sun-enso/sun-enso.htm

McIlveen J. F. R. (1986): Basic Meteorology – A Physical Outline, Van Nostrand Reinhold (UK) Co. Ltd.

Mezaros E. (1981): Atmospheric Chemistry – Fundamental Aspects, Elsevier, Amsterdam-Oxford-New York.

Nordhaus (1999): http://www.econ.yale.edu/~nordhaus/homepage/

Svensmark H. and Friis-Christensen (1997): Variation in Cosmic Ray Flux and Global Cloud Coverage: a Missing Link in Solar-Climate Relationships. *J. Atmospheric and Solar-Terrestrial Physics*, **59**: 1225-1232.

USGCRP (1998): *Our Changing Planet, An Investment in Science for the Nation's Future*. A Supplemental to the President's Fiscal Year 1999 Budget.

Wark K, Warner C F and Davis T W (1998): Air Pollution: Its Origin and Control. Haper & Row, New York; Call No. TD883. W28 1998.

WMO (1986): World Meteorological Organization, Our Atmospheric Environment, Fact Sheet June 1996, WMO, Geneva Switzerland.

Perkins H. C. (1974): Air Pollution,McGraw-Hill Kogakusha, Ltd. Tokyo. TD883.P45.

Act 4

Marvelous Megacities: Saviors of the Future

Willi Zimmermann

Introduction

Cities have been declared dead[12]*. Cities will survive and should be the major targets of AIT and of SERD.*

There are many types of cities. We think of the glorious cities in Mesopotamia, of Egypt, of ancient Rome and Athens. We also think of Hiroshima, Nagasaki, Sarajewo, Bhopal and Phnom Penh. This ‘dichotomy’ is reflected in European mythology. There have been two types of cities; the Babylon type, the city of the devil, the city of the apocalypse,[13] while the Jerusalem type is the city of God, the paradise on earth, the center of culture, marvelous palaces and arcades, order and wealth.

This presentation focuses on the positive functions of cities, for the author of Act IV in this ‘divine comedy’, as well the initiator and organizer of this SERD Seminar, Karl Iver Dahl-Madsen, count themselves as belonging to the ‘animal type of incorrigible optimists’, originating in the 1968 movement. Is it not amazing that most scientific books and articles about cities focus almost solely on the problems of cities and, without exception, conclude that cities have problems, nothing but problems. Hardly ever are there any positive words about cities, such as cities as the motors of innovation and

[12] Among them Chombart de Lauwe, P.H., La fin des villes, 1982.
[13] A recent article in Asiaweek (October 1998, p. 52) spoke of Delhi in a state if siege, of worsening quality of life and the city seemingly falling into the hands of criminals.

generators of wealth. One can go further than this. Cities have been and will be the sole guarantors of the future. They will not die.

Cities will survive

Our ancestors lived in poverty, their bodies bent by hard labor, their faces bearing signs from diseases and with almost no rights at all. They lived in caves, in the forests, the swamps and savannas. The process of urbanization changed all this, although only gradually.[14] It started many centuries ago, and increased rapidly with industrialization. Living in cities is the most natural thing on earth. Table 1 shows that, for example, urbanization is an old phenomenon in Europe (without Russia), that the number of cities has increased, while the distance between big cities decreased.

Date	No. of big cities	No. of cities in neighbor-hood	Distance between big cities
1500	4	27	313
1600	10	40	169
1700	12	46	169
1899	18	74	134

Table 1: European cities in the past[15]

Cities are an old phenomenon. I mentioned Babylon because it is the oldest city, taking shape more than two thousand years before Jesus Christ. Almost all researchers point to the fact that by the year 2025 we will all live in cities. From 1950 until today the number of cities in Europe with more than 1 million inhabitants increased from 49 to 112, while in the so-called developing world it increased from 34 to 213 cities. Thirty years from now, the population of the developing world will be urban: more than 50% will live in cities. The number of residents will exceed more than four billion, the double of today's total. Cities in the developing world are expected to expand at a rate of 62 million inhabitants annually, that is, the equivalent of adding a country's population of the size of France or Egypt every year.[16]

Urbanization started thousands of years ago, with the first sedentary forms of life.[17] Now, urbanization has spread its wings all over the world, and we all live urban lives (Fig. 1[18]).

This is natural, too. The mega-cities of the future will have 240 million inhabitants, will spread over 100,000 km^2, and cover large parts of continents.[19] Welcome to the urban countryside. What have cities to offer? Cities have led the way and will lead the way from the past into the future. Among their great achievements is their function as cultural and spiritual centers.

Cities as cultural and spiritual centers

In a certain period, the Spanish city of Cordoba was called the 'Mecca of the West', the second most important city of Islam, with wonderful castles and mosques. It was surpassed in splendor and cultural

---

[14] On the rise of the cities viz. Bairoch, P., La proximite urbaine, une perspective historique, in: Huriot J.-M., La ville ou la proximite organisee, Anthropos, 1999, p. 13. In the language of the Sumerians, Babylon meant the door of God.

[15] Bairoch P., La proximite urbaine, une perspective historique, in: Huriot J.-M., La ville ou la proximite organisee, Anthropos, 1999, p. 13.

[16] Annez Patricia, Livable Cities for the 21st Century, in Society, Vol. 35, No. 4, May/June 1998, p. 45.

[17] There are still large numbers of NGO's working in the rural areas. One might ponder why. It may be out of sheer tradition, it might be out of ignorance, not having realized that the urban lifestyle started thousands of years ago. This process will be accelerated by globalization.

[18] Raskin P., et al., Bending the curve: Toward global sustainability, Stockholm 1998, Sheet D-2.

[19] Viz. also MVRDV, Metacity/Downtown. 010 Publishers, Rotterdam, 1999.

leadership only by Constantinople (today's Istanbul) with palaces and arcades of marble, with hundreds of open fountains and beautiful parks.

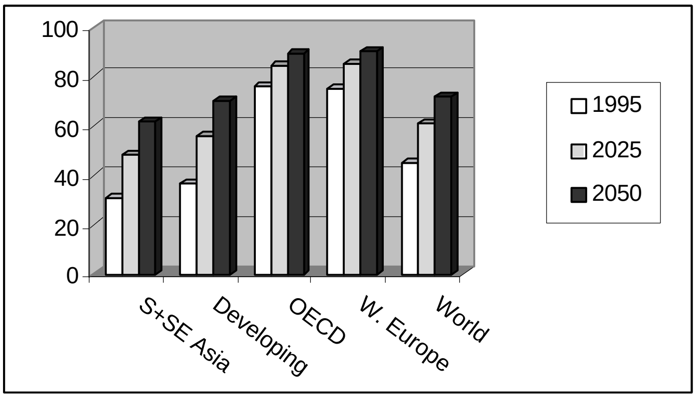


Fig. 1: Urbanization in Future

Baghdad, on the River Tigris, surpassed both of these cities. Among its splendors we count the huge orchards of the caliph, silk and cotton production, several centers of commerce, large numbers of villas and over 1,500 public baths. One could mention the grandiose Buddhist cities of Angkor, Kyoto and Hangshou and many others.

Cities have given rise to all sorts of aesthetic production, have inspired artists and film producers. Who does not know Metropolis, produced by Fritz Lang, or Charlie Chaplin's Modern Times? Who has not heard of Dos Passos' Manhattan Transfer, a busy railway station in New York, the nervous city to which people become addicted?

Since AIT's new President is French, one should also mention that Balzac and Zola have their heroes living and fighting social injustice in Paris. Woody Allen and Wim Wenders have tried to solve the mysteries of cities, and of urban life in almost all of their films.

Cities as centers of innovation

Cities have created cultural systems, which change only very slowly, in the process of hundreds and thousands of years. Nevertheless, within this slow process of change, cities give scope for innovation, and animate for innovation. In the context of Europe, one could mention the early Greek city-states, which invented a certain type of democracy. Aristotle defined the citizen as one who takes part in governing the city and sits in the courts. In more recent times, ecology was brought up; it is an urban invention for good reasons: the seriousness of the problems called for this.

As we sit here in a regional university, we should not forget that many of today's universities have their origins in cities. Some sort of university was the famous medical school in the city of Salerno in the 9th century. The first true western university was founded in Italian Bologna late in the 11th century. The Universities of Paris and Oxford followed it. We think of Prague University, founded in 1438, we think of the first European technical universities, almost all of which are located in cities and founded in the mid-nineteenth century, in the process of rapid industrialization.

Last but not least, cities were and still are centers of commerce and industrialization. The process of globalization started hundreds of years ago in Venice and Amsterdam. The Silk Road connected western European cities with Asian cities, centers of production and commerce. If we follow the famous German sociologist and political economist Max Weber, the rise of capitalism and rationalism is closely related with cities. By the way, the first real European bank was founded in Italy, in the city of Siena in 1348.

Cities as centers of work

Cities are closely related with industrialization and business. Cities in India and Great Britain have their past in the cotton industry. Other cities in Europe and Asia are closely linked with shipbuilding, and others with the car industry.

Nowadays, people live in and migrate into the cities, for it is here that they find work. Estimates of the world's infrastructure requirements vary greatly; they are all considered to be massive, most of them required in cities. The World Bank estimates that the Asian region alone will spend between 150-200 billion US dollars per year over the next ten years on urban infrastructure. The world market for infrastructure is estimated at being above the value of 3 trillion US dollars for the same period, carried out in approximately 2,300 projects.[20]

Industry and service do like cities. Stanford Research Institute and others have identified 20 criteria, which play an important role in locational decisions of enterprises. These criteria all speak pretty much in favor of cities, among them you find:

- proximity of market
- logistics (infrastructure)
- availability of technical-scientific competence
- proximity to centers of political decision-making
- cultural identity (contributing to the enterprise's identity and reputation)
- quality of life (for the satisfaction of the employees)
- Prices (e.g. taxes and salaries etc.)[21]

In many cases, the so-called 'technology oriented complexes' vary much in origin and development. However, many are directly linked to cities or urban agglomerations such as Silicon Valley in the south of San Francisco, or Route 128 in the area of Boston. It remains to be seen whether the Armand Industrial Complex, called AIC, will be born in the near future. I really hope that the 'C' will also stand for Champagne. It is still uncertain whether the Karl-Iver Technical Center for Maximum Feasible Misunderstandings will be created.[22] For the latter, there are reasons for hope as Danida's support can almost be taken for granted.

Cities as centers of hope

Cities provide work, schooling and health facilities. These factors contribute to the fact that cities are an important factor of hope. We can assume that even slum dwellers hope that through their work, earnings and little savings, their children will have more education and a better life. The workers hope that their children will get higher education and schoolteachers hope that their children will make it to the university, for instance AIT, if it still exists. Perceived opportunities and hope are a part of cities.

If the trend towards democracy prevails, then there is hope for improvement: Rodrik has convincingly argued and proved that there is a statistically significant association between the extent of democratic

[20] The World Bank, cited in National Round Table on the Environment and the Economy, Sustainable Cities Initiative, Toronto, 1998, p. 11
[21] Among many, see also Haentjens Jena, Strategies urbaines et strategies d'entreprises, in: futuribles, mars 1998, p. 69 ff.; Healey M. J. and Ilbery B. W., Location and Change, Oxford University Press, 1990
[22] These are references to the new President of AIT and to the organizer of this workshop.

rights and wages received by workers. In other words, democracies pay higher wages.[23] This gives rise to hopes of introducing good governance at the different levels of government.

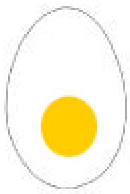
Cities as centers of diversity

Diversity implies many things, among them diversity of different types of cities, but also diversity within a city. As far as the diversity of the forms of cities is concerned, I should not forget to introduce an uncommon typology. It is derived from the joys of the city. Bangkok alone has 45 cinemas, 30 orchestras, 150 nightclubs, more nightclubs, 270 hotels and 345 restaurants.

By presenting the following typology, I also plead in favor of the happy sciences, full of jokes and nonsense. There are four types of cities:[24]

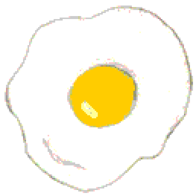
The Boiled Egg City

In the middle ages, walls surrounded cities. Even today one finds cities that have a compact center and pretty sharp 'edges'.



The Fried Egg City

The edges disappear, and the city begins sprawling. Several processes lead to the creation of suburbs.

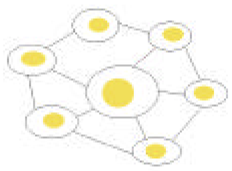


The Scrambled Egg City

Centers and periphery become indistinguishable.

The Smart City System

I should like to add a fourth type, the smart boiled city-system. It is the shape of the future city-system. It leads towards concentrated decentralization, where each city and urban agglomeration reconstructs its center, its identity.



[23] Rodrik Dani, Democracies pay higher wages; Working paper 6364, National Bureau of Economic Research, Cambridge MA, January 1998.
[24] Similiar Moenninger M., Einleitung: Tendenzen der Stadtentwicklung im Spiegel aktueller Theorien, in: Moenninger M., (editor), Stadtgesellschaft, Frankfurt 1999, p. 7

Tendencies towards smart cities are a reality. Several European and US cities have reconstructed their centers, making them attractive again for business. In other cases, so the message goes, the self-organizing capacity of slum-dwellers is and will be used, hopefully enhanced by responsible politicians and business people[25]. The city reproduces itself manifold, thus following the 'laws' of fractals. This is the future of the urban countryside, as we mentioned before.

Concerning the diversity within the city, cities serve purposes of recreation, trade, shopping, professional services, higher and often also technical education and also in terms of lifestyles and quality of life. The quality of modern life implies for many people the ability to choose, between different types of work, spatial locations and among different lifestyles. Cities are lived diversity. They are locations of change and exchange. Cities, science and the *homo urbanicus* have some common characteristics: it is their unavoidable incompleteness.[26]

The stroller, today's homo urbanicus

Munro Ferguson once presented the evolution of work in a humorous way.[27] Work was done first by slaves, then by serfs, afterwards by peasants. These became wage laborers, then salaried employees. In the next stage of development they were unemployed and ended up as free-lancers. The free-lancer is the role-model, he is today's *homo urbanicus*. He has the traits of a stroller, in French, Mr. President, 'le flaneur'.

Why should a stroller be the *homo urbanicus*? Social relations of everyday life are associated with uncertainty and complexity, with independence and individualism. The stroller faces these challenges; this is his lifestyle. He wants to live in the ever dynamic and ever changing city. He looks for stimulation, change, and adventure. He is a free-lancer, and does not rely on donor agencies or collective public management in order to diminish uncertainty. He accepts and furthers the competitive management of uncertainty. Thus, it would be too difficult for him to live at AIT.

There is Uncertainty in terms of economic reproduction. 'External controls' of economic and labor markets cycles determine the reproduction, determine one's position and values. The free-lancer is performance-oriented and cannot rely on kinship and status. He could not live at AIT.

There is uncertainty also in terms of time. Time has contracted and accelerated. The past is almost void; one cannot rely on it. The present is extremely short; the only reliable time is the unreliable future. *Homo urbanicus* is future-oriented just as modern universities and think tanks are; thus, unlike AIT, the sleeping beauty of the past, living the glories of the past.

Homo urbanicus is a stroller. In his daily life as well as in mental activities he goes for short leisurely walks; he may even go from place to place and give performances. However, he or she constantly explores new trajectories, tries to find new ways, new strolls, going to new frontiers, systematically trying to transcend boundaries.

I use this metaphor to talk about modern universities. They, unlike AIT, try, like the stroller, to anticipate trajectories of urban development, urban society, urban industrial development and technological development. They relate trajectories to urban environment, to urban ecology and urban sustainability. One such trajectory could be researching processes of dematerialization of processes of production and transport. Cities are the natural partners of progressive research, for here researchers find counterparts in the administration, in big infrastructure projects and in urban industry. They target cities,

---

25 Promising participative projects are going on in Santiago, Lyon and Montreal: viz, Economie et humanisme, No. 346, November 1998

26 This expression is borrowed from Beauregard R. A. and Haila A., The unavoidable incompleteness of cities, in: American Behavioral Scientist, Vol. 41, No. 3, November/December 1997, p. 327

27 In Funday Times, a supplementary of the Sunday Times

monitor them and their development. The size of the task ahead demands think tanks, for the individual researcher is too much of a lonely wolf. Wolves are strollers, and work within well organized packs.

If one puts AIT in the context of the evolution of work and cities, then it is still a village, stuck in the middle ages, without a common perspective, with no relevant issues to research and to communicate to the cities, to the citizens and to urban industry. I believe that it has nothing much to say about their future, about the effects of technological choices upon society, natural resources and nature. Nevertheless, AIT has started introducing urbanization. It now has 4^{th} Street West, the 4^{th} Street SW. One still misses the strollers, the free-lancers. In this village one also misses the cozy pub, where we can go for a pub-crawl, where we can get drunk. I think we should go for stroll, go to the lily pond instead of the pub and anticipate the future of AIT. For only cities, strollers and pubs will survive. Thank you very much.

Important city links in the WEB

WHO Healthy Cities Project

http://www.who.dk./tech/hcp/index.htm

European Union

General access: http://europa.eu.int/index.htm
European Environment Agency in Copenhagen: http://www.eea.dk/

NORC

The National Opinion Research Center is a not-for-profit corporation that conducts survey research in the public interest. Its data make important contributions for the analysis of life-styles. Affiliated with the University of Chicago since 1946, NORC specializes in large-scale and national surveys, offering services in sampling, survey and questionnaire design, data collection, processing, analysis and reporting.
http://www.norc.uchicago.edu/homepage.htm

ICLEI

The International Council for Local Environmental Initiatives (ICLEI) is the international environmental agency for local governments. We know from concrete experience that local actions can have a global impact. Global consumption and waste production is increasingly concentrated in urban areas. The concentration of people in cities provides unparalleled opportunities to both meet human needs and reduce and manage wastes. Meanwhile, by strengthening rural communities we can reduce the pattern of ecological destruction and population migration, which is often a result of rural poverty and desperation.
http://www.iclei.org/iclei.htm

Local Sustainability (EURONET / ICLEI Consortium)

Welcome to "Local Sustainability," the European Good Practice Information Service. This guide to sustainable good practice is developed and operated by the EURONET / ICLEI Consortium and has been developed with the financial support of the European Commission, Directorate General XI for Environment, Nuclear Safety and Civil Protection
http://cities21.com/europractice/index.htm

ECOCITY

An Electronic Network for Sustainable Urban Development (ECOCITY) for forum on current and future issues related to cities of the future. ECOCITY was established in 1994 as a Swedish contribution activities at the HABITAT II (1996) with the joint initiative of the Swedish Ministry of Environment and Natural Resources and the UNESCO Microbial Resources Center, Karolinska Institute in Stockholm. It is now an independent international Internet group focus on electronic forum and activities on sustainable urban development.
http://www.ias.unu.edu/vfellow/foo/ecocity.htm

International local government homepage

http://world.localgov.org/

International City/County Management Association (ICMA)

Founded in 1914, the International City/County Management Association (ICMA) is the professional and educational association for more than 8,000 appointed administrators and assistant administrators serving cities, counties, other local governments, and regional entities around the world. ICMA's mission is to strengthen the quality of local government through professional management.
http://www.icma.org/

Sustainable communities network

http://www.sustainable.org/

Governments on the WWW: Table of Contents

http://www.gksoft.com/govt/en/

Libweb currently lists over 2000 pages from libraries in over 70 countries compiled by the University of Berkeley

http://sunSITE.berkeley.edu/Libweb/

Library of Congress: Country studies

A continuing series of books prepared by the Federal Research Division of the Library of Congress under the Country Studies/Area Handbook Program sponsored by the Department of the Army. This online series presently contains studies of 85 countries. Countries that were previously in multi-country volumes are now available individually.
http://lcweb2.loc.gov/frd/cs/cshome.html

Urban Environmental Management

A network of planners has launched an Urban Environmental Management Research Initiative (UEMRI). It has also created a website as means for disseminating information (keywords, definitions, networks, email addresses etc.):
http://www.soc.titech.ac.jp/uem/

Act 5

Water World: The Promise of Technology to Solve Water Related Problems and Produce Food

Amrit Bart

Introduction

If there is a problem of global water shortage, it is not because there is insufficient supply, but because, similar to the food shortage, it is used inefficiently and distributed unevenly. There are a relatively small number of countries that suffer from annual shortages of fresh water.

In this paper I argue that there is, in fact, no shortage of water as a whole. Where there is shortage it can be overcome by efficient and appropriate use. A number of measures such as reuse, efficient agricultural practices and market pricing of water will go a long way in extending available water to meet the current and future demand. I will also argue that ultimately, we will once again have to rely on modern and innovative technology to achieve efficiency of water use for food production. I propose sea ranching and aquaculture (the use of marine or aquatic environments to grow food). The ultimate water saving will come from genetic engineering and biotechnology. Genetic engineering will allow us to produce terrestrial plants tolerant of high salt conditions. Biotechnology will also help produce plants and animals more efficiently resulting in lower water loss. The pace of adaptation of these designs will be impeded only by social and ethical implications. Benefits of these modern varieties will be felt by developing nations more acutely as they are under greater pressure to save water and produce more food for the increasing population.

There is plenty of water for all of us

> "If all the present humans were reduced to soup and spread evenly over the Earth's surface, including oceans and continents, the film would be about 0.5 μm – half a millionth of a meter-thick" (Cohen, 1995). If all of the world's total water supply were to cover the Earth's surface, we would be almost three kilometers under water."

Exact estimation of the earth's water is difficult. Consequently, estimates from hydrobiologists and engineers differ by over 100% in some cases (Cohen, 1998). If the relative estimates are correct, the total water on the earth is approximately 1.4 billion km^3. Over 97% of this are in the ocean. Of the remaining fresh water, glaciers and icebergs hold 69% or 26 million km^3. This leaves 11 million km^3, of which groundwater holds 8 million, leaving 3 million km^3. However, rivers, lakes and reservoirs account for only 200,000 km3. In addition, rain annually releases, 110,000 km^3, of which 70,000 km^3 evaporate and 40,000 runs-off to replenish rivers, lakes and groundwater aquifers. Actually, only 9-14,000 km^3 is the useful runoff because much of this runoff is immediately lost to floods and enters the sea. In other words, 214,000 km^3 is available for use.

The purpose of this accounting is to demonstrate that the earth holds a great deal of water and what we use is comparatively a small amount. One simple way to visualize this is to look at a four-liter jug filled to the brim as an example of the total water the earth holds. Only a teaspoon of this would be available as freshwater. Clearly, sea water supply is unlimited in relative terms. We primarily need to be concerned about freshwater supply.

Let us assume that for the moment, the estimated 209,000 km^3 is the actual available freshwater. Current global water use is only 4,500 km^3 or only 2% of estimated available freshwater (Falkenmark, 1993). It does not take a rocket scientist to figure out that we in fact have an oversupply of fresh water. The renewable freshwater from rain alone (9-14,000) is more than twice the current level of use. Why then the fear of scarcity?

Water uses are generally divided into three areas: domestic, industrial and agricultural. Agriculture alone uses 80% of the total available freshwater and even more (91%) in low-income countries (World Bank, 1992). The water used by agriculture even with the modest estimates, is only 30-40% efficient. In other words 60 to 70% of this could be saved only by simple modifications (with existing technology) in our agricultural practices.

The above numbers suggest that neither fresh nor marine water is limited by volume. Yet there are approximately 20-30 countries that are considered water stressed. Those countries feel this scarcity with fresh water resources of 1,000 m^3 or less per capita during the drought years. Bangladesh is one of the water-stressed countries and every year excess rainfall inundates a large portion of this country. Again, the issue is not total availability, but governance and efficient utilization of water.

Of course, this is part of a larger problem involving national and international governments and their massive subsidies and distorted incentives for water use. Correction of these subsidies and distorted incentives alone will create sufficient incentive to move towards more water conserving practices.

Water is cheap

In Denmark, a citizen pays 4.0 US dollar/m^3 of water, while in the United States it costs only 36 cents (depending on your residence).

Capital investment decisions are exclusive of the costs of management and distribution. Thus, both urban and rural water users enjoy massive subsidies. Irrigation water is not even priced. The cost of water to supply urban areas is not even sufficient to cover the price of delivery (Rosegrant, 1997). The solution to the problem is simple; beyond what is required for drinking, people will use less of it if they have to pay for it. A three-fold increase of price decreases the discretionary water use six-fold (Cohen, 1997).

Unlike fresh water, seawater for human consumption is virtually limitless. With proper pricing schemes and improved technology, desalination processes have the potential to supply the vast majority of water stressed arid nations with coastlines. Desalination today is accomplished using simple distillation or reverse osmosis. The efficiency of this technology is improving rapidly. Capacity to desalinate has increased significantly with over 13 million m^3 desalinated every day. The cost of desalination remains comparatively high (i.e., 0.40-0.60 US dollar for brackish, 1-1.60 US dollar for seawater). This cost is actually lower than the amount an average European citizen already pays (in Denmark, 4.0 US dollar/m^3) for water. Rosegrant, a research fellow at FPIRI, predicts that desalination efficiency will increase with improved technology to a level that is reasonable. Hence, we do not have to worry about ever running out of water.

Water is too important to use it only once

Proper valuation would also drive people to recycle and reuse wastewater. In California, wastewater is reused for crops, industrial cooling, irrigation of parks and golf courses, and saltwater intrusion. The potential to increase available water by recycling holds great promise as technology improves to upgrade wastewater for domestic consumption.

Agriculture needs water yet agriculture wastes water

Domestic use of water is a drop in the bucket when compared with agricultural use. While an average person uses 37 m^3/year for domestic consumption, the water required to grow food for her or him to live on a vegetarian diet exceeds 415 m^3/ year and ten times more for a diet containing beef steak or animal protein.

Lack of sufficient water affects a plant's ability to expand its leaves fully, resulting in absorption of fewer photons. With crops such as wheat, maize, rice and alfalfa, increased yield is simply not possible without sufficient water. Unless we intend to change the kinds of crops we rely on for food, we had better look for a way to grow them with less fresh water.

Agriculture uses over 80% of available water and even higher (91%) in some low-income countries. Irrigation is the largest culprit with tremendous water loss due to inefficient use. This waste is partly because of the undervalued price of water. Real capital costs of irrigation have increased annually since the 1970ies. Sub-Saharan Africa, in particular, has the highest average capital infrastructure with an average cost of 18,000 US$/hectare. Since this capital cost is not accounted for in the valuation of irrigated water, the cost of irrigated water appears rather cheap.

A number of existing technologies alone could reduce significant water losses. The drip method of irrigation using low-cost plastic pipes holds great promise for developing countries. High-pressure sprinklers and downward sprinkling systems are efficient in many locations. Surge irrigation has numerous advantages over continuous water release. Additionally, system operation using real-time management of water release from dams, in concert with telemetric monitoring of weather and stream flow conditions, would improve efficiency of water use and prevent losses to the ocean. The ultimate efficiency would come from an irrigation system that can deliver water to individual farmers on demand and charge them appropriately for the real cost of water delivered. Clearly these capital-intensive measures are only feasible when the valuation of water affects the cost of delivery.

Grow food in the sea; there is no water shortage there!

The marine environment holds enormous potential for food production. This remains minimally explored. Ocean ranching and sea farming are presently at an experimental stage with reasonable food production potential for growing high value products such as prawns, kelp, groupers and sea bass.

Aquaculture in marine environments produces around 18 million tons of food annually. The sea kelp, *Laminaria japonica*, exemplifies a glimpse of what is possible. For example, it topped the list of aquaculture production in 1996 with a level of production at 4 million tons and a value of nearly 3 billion US dollar. It ranked 4^{th} largest in value. Aside from being a valuable consumable commodity, these huge kelp forests on the ocean floor serve several additional purposes, including removal of nitrogenous waste and a CO_2 sink with a potential to lower the greenhouse effect and global warming.

Giant black tiger prawn, *Penaeus monodon*, topped the list of highest value product with nearly 4 billion US dollar per year although it did not even make the top 10 list of volume. In fact, only two major species of plants and a small number of finfish, bivalve and crustacean species are commercially cultivated in the ocean. With over 75% of our water resources and space in the ocean, it makes sense to continue exploring the ocean as a ground for food production. Tremendous bio-diversity of fish species, environmental conditions, thermal vents and mineral nodules in the ocean flora present limitless opportunities for growing fin fish, mollusks, crustaceans and even aquatic plants with various temperature, pressure and mineral requirements.

Japan and the US are experimenting with sea ranching as well as submerged cage culture of marine species in the open ocean. Sea ranching experiments involve release of hatchery reared and acoustically trained fingerlings into a bay. Computer monitored automatic feeding stations strategically placed at various locations of the bay, equipped with acoustic transducers, call fish to feed in much the same way that cows are herded to feed in feed lots. Trapping does harvesting when fish approach the feeding station with as much as a 60% rate of recovery. Innovative food producing technology such as this are needed. This will quickly become reality as it becomes economically profitable not only to relieve pressure on cropland but also to move from land-based into sea-based culture systems.

Magic of biotechnology

> *"The environment cannot be improved in conditions of poverty. Nor can poverty be eradicated without the use of science and technology"* Indira Gandhi

The 2020 Vision for Food, Agriculture and the Environment (International Food Policy Research Institute, IFPRI, 1996) recommends that "investment in international agricultural research to support national agricultural system must be substantially increased. A clear policy on the agenda for biotechnology research must be developed."

More efficient and increased food production in the future will come from technology and research rather than acquisition of new land. IFPRI, in 2020 Vision, points out that the objective of strengthening the agriculture sector in poorer countries is not simply to increase their food supply, but to generate income and employment through agricultural growth. If we accept this line of reasoning, agriculture must be intensive and technology driven. Past predictions of the future have often underestimated the impact of technology. We are fast approaching an era of technological boom with biotechnology at the center stage. Many new food challenges are likely to be solved with new technique of biotechnology and molecular biology.

The magic of biotechnology is its ability to reengineer plants and animals to contain desirable traits. Some of the success stories of biotechnology include genetically engineered "Flaur Saur" tomatoes that have a long shelf life and are resistant to parasites. A "super fish" has been produced using genetic engineering techniques. The patented Aqua Advantage fish, by a biotech company, spliced and ligased parts of flounder and salmon growth hormone genes to stimulate the over-production of growth hormones. This "redesigned" fish grows 400% faster. A/F Protein Inc., based in Waltham, Massachusetts, intends to market these reengineered fish by 2002. As we push back biological boundaries at the molecular level, we will have to rethink the way we produce plants and animals for our consumption.

This extremely rapidly evolving technology is already forcing us to think about how to produce plants with drought resistant genes, with lower evapo-transpiration rates, faster growth rates, disease resistant genes and cold and heat tolerance. Preliminary studies of salt tolerant bananas and rice have already shown great promise for culture. The science writer, Michael Stoll of the Christian Science Monitor, predicts that genetically altered aquatic food will initiate the blue revolution" feeding a burgeoning global population and boosting profits. I would take this one step further and suggest that our ability to redesign food organisms has more far reaching implications than feeding the masses and generating income. The ethical and environmental issues of this, however, are likely to challenge us for decades.

Implications for the developing world

Continued technological advances by greater investment in agricultural research are needed to make water use more efficient. Developing country governments' investment in agricultural research is less than 0.5% (2-5% in more industrialized countries) of the production, although agriculture accounts for the largest share of their employment and income. Emerging water saving technology is likely to play a key role in future food production, particularly in water stressed countries. Advances in biotechnology have the potential to benefit developing countries. Benefits of these modern technologies will be felt by developing nations more acutely as they are under greater pressure to save water and produce more food for their increasing population.

Conclusions

The scarcity of water resources is limited to fresh water in a few areas and during drought periods. Overall, the problem is not with scarcity but with inefficiency and governance of use. There is waste in water utilization fueled by distorted pricing and subsidies. Market solutions alone will improve the efficiency of agricultural practices, reuse and desalination efficiency sufficient to maintain the current growth rate of the global population for several decades. Additionally, marine environments that occupy most of the earth's surface have water that is virtually limitless. The use of the oceans to grow food for the growing population has already been demonstrated to have potential.

The power of new technology has often been underestimated in solving a number of global problems in the past. New and innovative technology will once again save the day. Genetic engineering using biotechnology tools is already enabling us to redesign plants and food organisms to suit our tastes and preferences. It is likely that this will revolutionize the way we produce food within the next decade.

References

Cohen, J.E. 1995. How many people can the earth support? W.W. Norton and Company, New York..

Falkenmark, M. 1996. Global water crisis-Differences in regional predicaments. International Shiga Form, Otse, Japan 25-27 November 1996.

IFPRI 1996. Feeding the world, preventing poverty, and protecting the earth, A 2020 vision. International Food Policy Research Institute publication, Washington, D.C.

Rosegrant, M.W. 1997. Water resources in the twenty-first century: challenges and implications for action. IFPRI Publication, Washington D.C.

Epilogue

Explode into Space:[28] Infinite in All Directions[29]

Karl Iver Dahl-Madsen

> “This is my long-run forecast in brief. The material conditions of life will continue to get better for most people, in most countries, most of the time, indefinitely. Within a century or two, all nations and most of humanity will be at or above today's Western living standards. I also speculate, however, that many people will continue to think and say that the conditions of life are getting worse." Julian L. Simon, in The Doomslayer, Wired, 5.02[30].

Introduction

We have demonstrated that the rumors of imminent doomsday are highly exaggerated. We can feed up to 50 billion people with existing technology, and we find the median UN population scenario of 10 billion plus highly plausible. We have abundant energy available, and can create all the resources we need. We can live in beautiful, exciting, smart megacities. We are increasing our life expectancy and income at a fast rate, while we are cleaning up the environment and starting to conserve and cre-

[28] Steppenwolf: Born to be Wild
[29] Freeman Dyson
[30] http://www.wired.com/wired/archive/5.02/ffsimon.html

ate even more pristine nature for our recreation and joy. The human ability to advance science and technology, and its consequent ability to find ingenious solutions to all material problems, is rapidly increasing. These fundamental positive developments do not always proceed as fast as we would like and sometimes the transition produces more suffering than necessary. However, the reason for this is entirely political; we can do what we set our will to do. There are no physical, technical or biological limitations for securing a very high material standard of living for all human beings on the earth.

But what about the future? Must there be some limits? Growth Unlimited—can it really be possible? My answer is a resounding "Yes". I completely agree with Julian Simon. Growth will continue indefinitely.

Before I start the forecasting part of the Epilogue, I want to present a few quotes.

First reservations:

> *Predictions are very difficult, particularly so about the future.*
> Robert Storm Petersen, Danish Humorist & Writer.

> *Against stupidity the very Gods Themselves contend in vain.*
> Johann Christian Friedrich von Schiller, German Poet, The Maid of Orleans

Then an endorsement:

> *By contrast (to the doomsday prophets) the prophets of abundance, who insist that no crisis is looming, get little media coverage. They are irrepressibly, sometimes irritatingly, optimistic. So far, they have also almost always been right.*
> The Economist, Dirt Poor, March 21st 1998.

Population

So having warned and been endorsed, I will start by looking at the near future (next 100 years) perspective.

The UN median scenario: a leveling of the world population at 10 billion plus seems entirely plausible. We do not need any command and control measures to regulate population growth. If we continue the economic growth, people will do what they find best for themselves and their families, and this phenomenon, the demographic transition, stops population growth. I believe that the rate of economic growth and consequent transition is actually underestimated, and that it is very likely that the near future population forecasts will be too high. We have seen dramatic drops in birth rates in Europe, down to 1.3 in Italy and far below the level (2.1) necessary for maintaining a constant population. Many European countries now have to rely on immigration to keep up the population. Immigration is for a number of reasons a good thing, however outside the scope of this discussion.

In the not-so-near future (100-1000 years from now), the world population may start growing to a level of between 20 and 100 billion. The size of the future population will surely not be limited by ecological restrictions, but only by conscious individual decisions made by enlightened human beings. Future technologies will make it possible for us to supply even such a huge population with material goods in abundance. There may, however, be a sufficiently strong popular demand for pristine nature and wide-open spaces, for the world community to desire to conserve large areas for this purpose.

Nevertheless, there will obviously be an urge towards continued population growth as people are the ultimate resource, whose creativeness and sociable inclination will always be in demand. Major breakthroughs in art and science grow from the minds of outstanding individuals. The likelihood of the birth of a new Einstein or Mozart is proportional to the total amount of births, and the creations of such minds belong to all Humanity. Major development projects in arts and sciences are more affordable when many people share the costs. Consequently, the social and spiritual richness, and diversity of the world, will within reason be proportional to its population size.

Space

Twenty to one hundred billion people is a huge, if limited, amount. It makes no sense from an energy and resource point of view to export a surplus population to space.

However, we are now developing the ability to colonize space. Some of our artifacts have already passed the boundaries of the solar system, and satellites are integrated in our daily lives. We have a space station where people are living for months at a time. Space colonization has already started.

The possibilities for colonizing the planets of our solar system are likely limited to Venus and Mars, which after terraforming can carry populations of a few billion each. The space population explosion will essentially happen when, during the next 100.000 years, we colonize about 100 million inhabitable planets in our galaxy, to a total galaxial population of 10 billion times 100 million, or 10^{18} people. We might meet someone out there, which may limit the expansion of Humanity, but sentient life as such can expand forever within the lifetime of the universe. And our galaxy is only one out of millions of galaxies, in one out of how many universes? So where are the limits?

Wealth

Fair enough, you may concede that there are no practical limits to population growth, and thereby economic growth. However, there *must* be some limits to per capita growth!?

Again, concerning the near future I will have to answer: absolutely not. The average wealth in 1995 was 14,000 US dollar (PPP 1985) per capita in developed countries and 2,500 US dollar per capita in developing countries. The least we can expect for the developed countries is that they can catch up with the developed countries, as Japan has demonstrated previously and as the tiger economies are currently doing. So growth rates of at least 1-2 percent per year for the developed countries and 5-10 percent per year for developing countries adapting to good practices can be expected. This will make for an average level of about 30,000 US dollar per capita (as in Denmark now) in the year 2100. And we have still have scope for increase to the level of an ordinary American software engineer in Silicon Valley (100,000 US dollar plus per year excluding stock options). As I have never heard any person complaining about earning too much money, I am sure that GNP per capita will increase for at least the next couple of hundred years.

The ultimate good, a long and healthy life will also surely continue increasing. Life expectancies of more than 100 years are within reach using existing technology, and who knows what will happen when the biotech revolution seriously affects the development in human medicine.

For the not-so-near future my crystal ball gets hazy. Even in a few hundred years from now, the technology will be so different from the present, as to appear like magic to us. Most certainly, technology will make much longer and more active lives possible, and technology may even enhance our capacity for living more intensely.

Consequently, I will bravely predict that the development of advanced technologies combined with the feedback of information, arts and science from our colonization of space will for all foreseeable future make human lives increasingly more intense and richer in life experience.

Panel Discussion

Panel

Professor Jean-Louis Armand, AIT President
Professor Chongrak Polprasert, SERD Dean
Mr Karl Iver Dahl-Madsen, Visiting Faculty, Environmental Engineering Program
Mr William Savage, Associate Professor, CLET (Moderator)

Mr William Savage: The purpose of the panel discussion is clearly to provide some feedback and reactions to the presentations that we've heard throughout this extremely interesting afternoon. Like me, I hope that you have been keeping track of rather controversial statements which appear at odds with conventionally accepted contemporary public views which many of us share. I applaud the organizers, in fact, for presenting the views that they have this afternoon, because it's only by listening to, understanding and being able to react to these views that we're able to clarify our own. I know that there are plenty of people in the audience who would like to offer alternatives to those we've heard here. I think that is the intention of the organizers.

On the panel this afternoon we have the president of the institute where this debate is situated, as well as the dean of the school which has started this debate, and the organizer, inspiration, perhaps, or director: Karl Iver from the Environmental Engineering Program. The format for the panel now is to hear brief statements from panelists and then to open the floor for discussion. Karl Iver has indicated that he thinks he's talked enough already, so he's actually not going to make a statement as a member of the panel, but rather react to people's comments, and thus we will hear brief statements from Dean Chongrak and President Armand.

Professor Chongrak Polprasert: Since the purpose of this panel discussion is to provide opposing or different views, I'd like to also share and offer some views which are different from the speakers so far. I agree with all the speakers that growth can be unlimited. We can have infinite growth for all of us in this world, because we human beings are considered at present supreme beings. We can do almost anything we like or imagine to do because we have capacity to think, to act and also the power to create many things from the earth. But I am not sure whether this kind of unlimited or infinite growth will be long-lasting or sustainable. This is because of the human body that we are born with and our brain. If our brain is like a computer, with only a logic part, then I agree with all the speakers. We can grow to be 20-30 billion and we can live as close or as luxuriously as we like. Unfortunately, our brain consists of two parts: one is the logic and one is the emotions, and unfortunately or fortunately, the emotional part of the brain is the one that acts quickly, and also is very essential. In fact, it has the feelings of love, hate, greed, anger, jealousy and so on. All kinds of problems, like world wars or even personal conflict, normally arise from this emotional feeling that is not logical at all. Every day I have some problems and I know most of them are emotional, not very logical. So we should do our best to develop, but in a balanced way, thinking about the carrying capacity of our world, thinking about the impact on society, and the emotional feelings. I'm not sure whether unlimited growth can be long-lasting or not.

Professor Jean-Louis Armand: I'd like to address the issue of power. It's basically a statement made by Professor Singh: good or bad politicians need advice. Now who's going to advise politicians, because politicians are in power? We vote for them and they decide for us. There's a lot of tremendous work done by us academics. How do we get this work to be heard, to be listened to by politicians? Politicians read, or are supposed to read. I don't know if you've ever seen a Member of Parliament of your own country. Every day when he sits in his office, he's got a thick stack of reports. There is so much information on the topics we discuss. Going to the next millennium, how is man going to adapt to all the challenges, all the changes? There's a lot of advice. Just use the Internet and you find a tremendous amount of information. How do we get this information to the politicians, to the ones who decide, to the ones who we trust to make the decisions?

Let me tell you briefly of an experience, which was initiated in the US, called the Office of Technology Assessment, which was unfortunately discontinued three years ago. It was extremely successful. It was working for the Congress of the US and the Republican Congress felt that the money was wasted. It came up with wonderful reports you can find on the Internet. It started from what happened after WWII, with this great concern by mankind about the future. It's something, which I really wanted to address to you as the question here. This Office of Technology Assessment was a wonderful example of an attempt by the citizens to warn the politicians about the goods as well as the bads of technology and science. All these movements started right after the end of WWII, with the use of the nuclear bomb. It started a movement of, in a sense, fear for science and technology, for the evil application of science and technology. Then came this appreciation of the environment. Now is there any hope? Are we able to advise our politicians? In Europe, we have started the equivalent of the Office of Technology Assessment, and the Danes are very much advanced with technology. They and some of the other countries in Europe are engaged in such reflection. The problem is, will this exercise remain an exercise in futility or will it turn into politicians really taking notice and taking advantage of all this advice being given to them?

The second thing I'd like to say is there is tremendous hope. Usually about going to the next millennium you hear all these concerns being voiced, that doomsday is around the corner and this obviously cannot be true. Man is so resourceful. This is something, which I believe is a matter of hope and respect. It's clear that the turn of the century is around the corner, it's a fact, and that man and woman will adapt. Going through the year 1000 in Europe, there was lots of concern. Thailand has already passed the year 2000 without any concern, since we are 500 years ahead of 2000. I have tremendous hope and respect for the ability of man to adapt.

Natural disasters have always existed. Of concern, though, is the fact that, it seems that as we move more and more to civilization, that natural disasters are less well-handled than they used to be. Maybe this is an impression. Maybe it's a question I'm putting forward to the audience. So I would like to conclude with two questions to you. First, power: how do we raise the consciousness of politicians or the ones who make decisions? The second one is how can man cope with natural disasters and gain a better appreciation of natural disasters?

Mr William Savage: Professor Chongrak introduced the idea of not only the human logic but also our emotions and how these play out. Professor Armand introduced the issues of power, politics and the evil applications of technology. Can we please have comments and questions from the floor?

Professor Jean-Louis Armand: I will start. I was very impressed this afternoon by what I heard. What this exercise is all about is basically raising the awareness of scientists and engineers towards social sciences and the implications of what they do. This is very important; it's an ethical issue. How do we make sure that engineers and scientists fully appreciate the consequences of their work? I wish to announce, maybe to kick off the discussion, because I'm going to ask him to say a few words that Professor Weber has been assigned a special mission. He will introduce into AIT, into all curricula, a special transverse curriculum called Science, Technology and Society. I view this as some kind of kick-off of this whole exercise. In the next batches, in the next years at AIT, we want to make sure that no engineer, no manager, no social scientist, leaves AIT without some exposure to topics such as today. Professor Weber, can say a few words, if you don't mind?

Professor Karl Weber, Agriculture, Conservation and Rural Development: What I had in mind spontaneously is first of all to propose a new name of SERD. Perhaps after this afternoon full of inspiration, it should be renamed School for Enlightenment, Reflection and Destiny. I am very encouraged, because those who have known me for a couple of years will remember that I have shared these concerns. But I'm afraid to say I have never been radical enough. I admire my good colleague Karl Iver for having made a breakthrough. I suppose it's a breakthrough; the atmosphere was marvelous. Just take into consideration the absolute silence when we listened to music and when we admired this most famous painting by Vermeer.

On the matter proper, I should like to thank for the assignment and the confidence to develop, and of course not to develop it unilaterally, not to do work in an ivory tower, an academic venture, Science, Technology and Society, with a strong focus and emphasis on Asia. I'm personally delighted that I have been given this opportunity. First, because I am by training an anthropologist and a sociologist, so I'm grateful that I have had a place in AIT for 21 years. Second, during these 21 years I suppose I have had a sufficiently strong exposure, precisely because I'm proud of the record of interdisciplinary work with colleagues of mine, some who are present this moment. It started as early as 1978 with my good friend Gajendra Singh. So I see great potential for us to forge ahead. I would like to try to draw a conclusion from this afternoon's sessions and say that such is the challenge before SERD. We should indeed think big. We should not feel intimidated because this is the spectrum; this is the broad scope; this is the agenda. SERD has reason to be proud that it has made a breakthrough, is leaving the beaten track and exploring what might have been considered unthinkable a couple of years ago. I personally am very pleased and I would like to be party to this new endeavor. I close with my best wishes for success.

Professor Jean-Louis Armand: I would also like to say that on the occasion of the 40th anniversary of AIT, on the 8th of September, we're honored to have Dr. Toepfer as a keynote speaker. Dr. Toepfer is former German minister of the environment. He's also the Director-General of UNEP, the United Nations Environment Program, and he's based in Nairobi, Kenya. That should be a very enlightening experience. These are announcements. Let's get to the nitty-gritty, please.

Mr Karl Iver Dahl-Madsen: If I could answer some of the questions put up here. First, I would really like to thank Professor Weber for a very nice conclusion and I especially appreciated what he said about the about the Enlightenment. You know and I know that this picture was from the period of Enlightenment. But I think we tend to forget that we are and have been an enlightened species and we should keep on trying to be rational. I would like to answer Dean Chongrak. Of course, it's not just about logic. However, I think you have to admit that there has been a certain amount of emotion put into this session today. We feel for what we are saying and doing, and I'm certainly sure that people's emotions are part of the reason that they want to live in cities and in high densities, so they can interact more frequently with each other. It's very simple to conceive of some global village system where you have computers sitting decentrally in distributed houses all over the place and only communicate electronically. That's not how we want to live. We want to be together and therefore, I don't think emotions will hinder us in having high densities if we want to do it.

About the president's two questions. I would go a step backwards about the politics, because the thing here is not how we in democratic, modern countries advise our politicians. It's how we get the countries, which are not democratic to be so, because that's the real issue: too many countries are governed by corrupt, tyrannical, non-democratic governments. Until we change that, we'll still have a lot of problems.

About the natural disasters, I have a very simple answer: get richer. All evidence shows that the richer you are, the better you can cope with natural disasters. As Kim Oanh said in her introduction, the Hollanders can just build the dikes a little bit higher if the sea rises. It costs them a little bit of money, so they have to drink less red wine. However, the Bangladeshis have a certain problem because they don't have any dikes. They simply cannot control natural disasters yet, because they don't have the organization and the wealth to do so. So that's my answer: richness causes resilience. Hence, economic growth is the answer.

Professor Jean-Louis Armand: I disagree with this statement about being rich and coping with disaster. On the contrary, in the US now, look at what's happening with all these landslides, mudslides, floods and hurricanes. It seems that as mankind gets richer, we can cope less because roots with the past have been severed.

Mr Karl Iver Dahl-Madsen: It's an important discussion and, of course, it's correct that we are in some places trying to force ourselves into a bad situation. Also in Europe we have flooding because we're trying to live very close to the rivers and don't give them any room. But realize the very important difference between the rich and poor countries. In the rich countries, we're always warned. Very few people actually die. In the poor countries, tens of thousands of people die when these things happen. That's the major difference because then it's only an economic loss for us, which is bad enough, but it's not loss of human life on the scale which happens in poor countries. So for this reason, again, I claim that to be wealthy is to be resilient and able to solve these problems.

Professor Peter Edwards, Aquaculture and Aquatic Systems Management: I agree it's been a very wonderful afternoon with a high degree of optimism. But surely the term unlimited growth is tongue-in-cheek. I'd like to ask our panel, do they really believe in this? The president mentioned one of the objectives of this workshop is to lead to everyone at AIT being exposed to social issues. But I think it would also be valuable if everyone here was also exposed to ecological issues. Chongrak shocked me somewhat in referring to the human species as the supreme being, which is an old idea that goes back to the origin of Christianity, about man being above nature. There have been a lot of rather serious ecological disasters in the world and there are a lot that are still on going, and we're not quite sure the way they're going to turn out.

I'd like to ask Karl Iver, does he really believe in unlimited growth? He mentioned 50-100 billion people in the world and let's all enjoy living in densely crowded cities like chickens in coops. I think there's quite enough people in Lad Phrao where I live at the moment, and I find it quite stressful at times. I'd like to go out into nature and enjoy a little bit of peace and tranquility. So I'm no quite sure that we should accept this concept of unlimited growth unconditionally. Ecological doomsday, yes. A lot of the more rash statements of the past have been shown to be false so far. But let's not assume engineering and human ingenuity can conquer nature so that we're all going to come out on top. I think we need to look at this a little bit more carefully.

The president also mentioned, as Chongrak, about humans and politicians, and who makes the decisions and how they are going to be better informed. One thing that concerns me is rank consumerism. There is one expression: there's enough in the world for everybody's need but not for everybody's greed, which is related to consumerism, and unnecessary spending. We've got to control this also if we're going to have a sustainable society in future. Please, my two engineering colleagues, I'd very much like for you to come back and comment on this thing of unlimited growth. Do you really believe in this?

Professor Chongrak Polprasert: I agree with Peter that unless human beings develop or evolve to cope with changes, then unlimited growth will not be possible at present, because of the human thinking, the human brain. I agree that if there is unlimited growth now while the human body is still as it is, then we will have doomsday for sure. But if we have controlled growth, then there's going to be a possibility for all.

Professor Jean-Louis Armand: All I said was that engineers need to be better prepared to think about the consequences of what they do. I didn't say that I believed in all these things, unlimited growth and so on. It's very important to have engineers, scientists and technologists think about the consequences of what they are designing or doing. You're absolutely right, Professor Dahl-Madsen, in the sense that it is in the most democratic countries that we care about ethics in science, ethics in engineering, questions like this. But globalism is around the corner and what's been done in one country is going to move to another country. It's just a matter of time. I'm very confident in the sense that we need to educate engineers and scientists to be more prepared for the full consequences of their acts. I'm referring to the debate in the 50s about the atomic bomb, the Birdwatch Movement and so on. That's now a long time ago, but it has evolved into a tamer type of debate which now concentrates on technology and its good and evil. One topic I just mentioned a few seconds ago is globalism. We are in an era of globalization. Will this have any consequences on the issues we discussed?

Mr Karl Iver Dahl-Madsen: Basically, I don't think mass consumerism is a problem at all: people buy what they want to buy. Now is the first time ever in this century that a lot of people actually can decide for themselves who they want to vote for and what they want to buy. Let them decide for themselves.

Next, unlimited growth: of course, there are physical limits to how many people there can be on this planet. What I'm saying is that it's not resources, energy or foods supply which are restricting the growth. Restrictions are our own conscious decisions of how close and dense we want to live. Couldn't we go back to the marvelous cities? We actually prefer to live in cities. Cities are actually nice, so why degrade living in a city if that's what everybody wants to do and enjoy doing. Think a little bit, everyone, for yourself, how often do you actually go out into pristine nature? How important is that to you compared to, for instance, seeing the new Star Wars movie? Please be honest to yourself. I know the politically correct answer, but be honest to yourself, what do you really prefer? What do you want to do? That's what I think we should think about.

Then there is these eco-disasters. What eco-disasters? A big disaster is that a lot of poor people get such bad drinking water that they die too early. This is a disaster, but not an eco-disaster. The eco-disaster is some animal disappearing from some forest in some tropical country. That's an eco-disaster, but I don't think it's the same scale of a problem as the first one. So again, I don't think we experience eco-disasters, or I think we experience very few. I would rather say that bad things have happened to some eco-systems. I agree to that, but "eco-disaster", it's too much.

*Dr Virendra Kumar Tewari, Agricultural and Food Engineerin*g: I'm very glad to be here for this SERD seminar. I find in this topic four words. Take the second and third words: growth and ecology. For growth, you have to have energy. For ecological balance you need energy. Now, more and more we have growth, and more and more we have energy. But the moment we think of having higher growth, higher energy is required. Then we go to the first word, which is unlimited. We have to know where we are growing, where we are heading. Think of a simple example. We have to think of what our target is. When we do linear programming we think of maximizing our objective function. We have our own constraints. If we do not have constraints, you can't think of where we head. We will definitely not have a function then. We will not have the programming altogether. That is why we will then lead into a problem which will create a new sense, and ultimately doomsday.

One thing that has been proposed is whether the politicians can be educated so that they can put things to order. I very much agree with the system and that sort of statement. I'll take an example of India where I come from. You see the politicians who have been for so many years ruling the country. For a while we had a very brilliant Prime Minister, our Narasimha Rao. We had Indira Gandhi and so many. I would not like to take the credit for what they had done, but I'll just offer a small example. The new economy that we see today is the result of the knowledge of the good Prime Minister. He had the political will. He saw that our country, the Indian nation, could only proceed if he had a real knowledge of what is happening and how growth can take the nation ahead. That is why I say that, yes, political will is a must for growth anywhere.

Dr Edward Webb, Agriculture, Conservation and Rural Development: I'd like to thank Karl Iver for his very interesting comments. I should say that it'll be a little sad to see you go because our interests and philosophies diverge. I'd like to comment especially on your two proposals. First of all, I'd like to say that I would contend that people don't really like to live in cities per se. They like to live in civilization. If you equate cities with civilization I think we would probably differ in some respects there.

My main comment is on the philosophy of humans as being the Supreme Being. There's sufficient evolutionary and biological evidence to show that humans are sort of a process, and we live within in the process rather than dictating the process. I have yet to come across an argument by anyone that states that humans should dictate the processes of the world, for any other reason besides the facts that a) we are more sentient than other beings, or b) we have the power to do so. If you can convince me otherwise, I'd be happy to hear that.

I have a couple of other comments for the panelists. This is directly related to your talk. First of all, can a Dane tell another country how to manage their forests? It's an interesting question and I would actually say yes. I wouldn't say dictate. I would say educate. We can perfectly justify going to other countries and educating about things like birth control, which have huge environmental impacts. We should also be able to go and educate about resources management. So I would have a difference of opinion with you there.

Finally, regarding the original issue of humans modifying the environment and dictating the ecological processes that go on. It's difficult. It's sort of a black box. We don't really know where to draw the line. The reason is particularly with things like utility of species. I would content that there's an inverse correlation between economic growth or development and utility of native species. Look at ethnobotanical uses. In developed countries, ethnobotany has declined precipitously, whereas still in rural countries, where development is considered low, utility of native species is high. So where do you draw the line? Moreover, where do you draw the line in the future for species that you decide whether or not you're going to save them for human purposes?

Mr Karl Iver Dahl-Madsen: I still think that cities are civilized and that's where we want to be because that's what we are. But of course, if other options come up which are more interesting and we can choose them, then maybe you are right. But for the time being I vouch for the cities.

About people as the Supreme Being and so on, I just have to say that we are the sentient being and who else can decide what is right and wrong? We can decide that it's best for us to treat animals and nature in a humanitarian way, but we still have to make the decision. I think that it was in the 16^{th} century in France that there were actually lawsuits against animals in French courts. I know from a French philosopher named Luc Ferry that they made lawsuits against some insects who destroyed the crops, because at that time they had no clear distinction between God's creations. If they were man or insects, they were more or less equal. But I again have to say this is a little bit rubbish-like. Let's be simple and engineering-like and say we are the sentient species, so let's make these decisions.

About the changes of nature, the utilitarian argument: That's OK but that's a purely anthropocentric argument. We preserve nature because we can benefit from it in some way or another. I don't mind that, but that's a cost-benefit analysis. Then you can discuss what is most efficient, to do this or do that? I will happily discuss that. But you don't need to preserve bio-diversity as such, which I don't think is useful. A thief can also teach the police how to catch the thieves, and in that respect, of course, a Dane who's cut all his forest can tell other countries that they shouldn't cut them. But then maybe we shouldn't go and be so self-righteous. Maybe we should go and say it as it is. It may be necessary for you to cut down parts of your forest. It may be a very reasonable thing to do. Actually we had to do it at some point in our development, so who gives us the right to tell you that you shouldn't do it? What we could do is say of course they shouldn't do it out of pure greed or in ways that is irreversibly damaging. But to have a lot of forest just standing around, representing a lot of money at the same time as one's country has a lot of urgent needs for health care and education doesn't make any sense to me. I think it's perfectly alright to cut down that forest.

Mr Virgilio Panapanaan, Asian Society for Environmental Protection: My question is for Dr Dahl-Madsen as well as for Dr Singh. The first one is for Dr Dahl-Madsen. Are you really in favor of promoting this anthropocentric view of the environment wherein you undermine the issue of sustainable development as well as capacity, as if we don't have our children or the capacity of our children's children to live in the future? Because it seems to me that you undermine a lot of issues, when we say we could just be the owners of the world. We can use the world. How do you call it? We can change the nature to fit our own needs. I don't think it's just as easy as that, knowing that nowadays, we are feeling, if not really experiencing, all these global environmental problems, global climate change, deforestation, flooding etc. It's all in our midst now. But we still have to promote this kind of world-view of being anthropocentric.

The other question is for Dr Singh. He's saying that it's better to have more people because people are a resource. Of course they are, but how far can we go in terms of it? It's like we're going into the debate between Paul Erhlich and Simons wherein one is claiming that people are a resource. On the other hand, it's not because the resource is running out faster than people multiply themselves, then we're running towards the real disaster.

Mr Karl Iver Dahl-Madsen: Again, from an anthropocentric view, it doesn't make any sense to destroy nature, of course, to have flooding and all these kinds of things. So if global warming is true and if is harmful, then of course, I would want us to take some abatement measures. It wouldn't be wise not to do. But still I would not do it just to preserve some pristine nature. That's what we are talking about here, that there are eco-centrics who want to preserve nature untouched by man. I don't like that. I think we should be more direct in saying what we are doing: we are trying to adapt nature to man's needs. I think that's perfectly OK.

Professor Gajendra Singh, Agricultural and Food Engineering Program: I'm not sure whether I said we need more people. I said that people are the problem and people are the solution. I did project that the population might stabilize at around 10 billion or so. I think my argument was that we are capable to feed these people very easily because we are using one-third of the land resources. With the technology, which we are using in the developing countries, and what technology is already available in parts of developed countries and developing countries also, we can very easily multiply the food production to take care of these people many times more than we have the people now. I still feel very strongly that people are the most important resource. I again emphasize that it's not the number of people alone. Remember we were trying to emphasize that this human resource has to be developed to be more productive and to be more effective. So please don't tell anybody, just keep on multiplying people. We were saying that we need more productive people, because these people who are trained and educated are capable of solving the problems. So more people in that sense. More capable people are not a problem if they are trained, if they are developed. The problem is very few people, the trouble-makers, the bad politicians I think the president mentioned, and the bad leaders, whether it's at a national level, at a regional level or even an organizational level.

I think we don't see trends of people, as Karl Iver said, going to 50 billion, because once you get economically better of, as a matter of fact, you also become lazy. You don't want to take responsibility of taking care of even too many children. So actually the economic growth itself decreases the population growth. So there is a balance. You can call it disbalance which comes from what Chongrak said, if you take from the feelings and sentiments and all that. The better off you are economically, I think different kinds of sentiments take over, and I won't elaborate those. I think its individualism. People would like to act and live more as an individual, because economic development gives you economic freedom, which is really the one which drives you to, what we in many spiritualities, also call towards detachment. Actually in the old religions, you will find that you stick together, and big family systems were basically an economic necessity. Economic growth reduces this economic dependence and breaks down the bondage. The bonds become weak and when you don't have a necessity to depend on others, why do you create others dependent on you? I think what happens is that economic growth and population are inversely related. You've seen this all over. So if we progress fast, though we say unlimited growth, actually, growing fast, we limit growth in population much faster.

Mr Daniel Savin, Energy: I would like to go back to what Jean-Luis Armand said about the responsibilities of the scientists and engineers. I think this is absolutely crucial, mainly in higher education institutions like ours. I don't want this sentence to be skipped and I want to make a proposal. We had a philosopher in the 16th century in France, Montaigne, who said, “science without conscience is only the destruction of the soul”. I would suggest that this could be the motto of AIT.

Professor Jean-Louis Armand: I'm sorry I disagree with you, because it's Rabelais: s*cience sans conscience n'est que ruine de l'âme*. Montaigne said, it's better to have a well-rounded head than a full head. Thanks for the statement. It's nice to refer to. I don't want this to be a forum of western thought and philosophy. One of the reasons I chose to come here is to enlighten myself and Asia is a wonderful occasion to get enlightened. I'm also happy to hear what Professor Weber said because Science, Technology and Society at AIT are unique. It already exists, by the way, at MIT, at Stanford, at many institutions. It's a curriculum, which is well established now for the past ten years. It's basically western thought, although we know that most of the engineering students at Stanford and at MIT are Asians. We have a tremendous opportunity here to look at the Asian perspective and also the contribution of some countries in which the democratic way has not reached the same level as some of the countries on earth. So it's very important to view this as an exercise in philosophy, in ethics, in democracy and view it in an Asian perspective. I'm very confident that we really can make a definite imprint if we establish such a transverse curriculum, again throughout all the schools at AIT.

Let me give you an example. Some of you are here from other schools. I'm glad to see it's not only SERD. I'm a good example because I was appointed a professor in Civil Engineering. I'm very proud to announce this. I see some colleagues from the School of Advanced Technologies. What is advanced technology in this region, in Southeast Asia? The meaning of advanced technology should be different. We have a science park, which is being built just across the road on the land that belongs jointly to Thammasat and AIT. Some of you are curious when we say the end of the campus. You walk about a mile and you're going to see these buildings which are being currently built. It's very impressive. Nobody yet knows what's going to go into these buildings, but it's going to be a science park. It's basically the Silicon Valley of Thailand. Do you think we should import Silicon Valley and its values here? I think that would be a terrible mistake. This is a typical example in which the designers of the science park would seek and need advice from AIT and such reflection. Thanks again for the wonderful quote: "science without conscience is the wreckage of the soul".

Dr Brahmanand Mohanty, Energy: We were all really enlightened with the presentations that were made in a very positive note because we keep on arguing that we don't know where you are going, especially for people who are in the science and technology field. What was shown was that there is no immediate danger, and we are all working toward solving problems so that we can go further and to help humanity go much further. That was the essence of the different presentations made. When we talk about unlimited growth, I think it's a question of how we put the word. Unlimited doesn't mean there's no end to it. We are talking about growth in a manner that is going to benefit everybody. When you talk about unlimited growth, speakers talked about at the cost of nature, not at the cost of other people. I don't talk about nature; I also talk about other people. We talk about equity. That's a very important issue. I will go back to the definition. We talked about enough. What is enough? You ask yourself. Enough is something that I don't have today. So you always strive to get enough and you're never satisfied with it. I think that's the beauty of human beings because we are always aspiring for something better. So I think it was a very positive approach. There are constraints, and we are all working towards solving those problems.

Ms Lucia Sukhanenya, Aquaculture and Aquatic Resources Management: I think unlimited growth would be better stated as "unlimited potentials". The potentials and resources are unlimited but Humanity's capacity or capability, and policies limit the growth. So if this is realized at least the potential is there for growth. People can go for it and advance technology and science to reach there and then they have a great resource for that. I feel optimistic with politics because nowadays countries don't stand alone. They now go by groupings like ASEAN and EU. Now even the bad guys or bad politicians can't do just what they want.

Professor Peter Edwards, Aquaculture and Aquatic Resources Management: First of all, I agree with the last few speakers about the need for ethics. We should teach ethics and attitudes in SERD. We should teach knowledge and practical skills. Those are the three great things we should teach, and if you miss any one of them then it's hopeless in terms of turning out a well-tuned professional.

I wanted to come back to this business of mass consumerism, which relates also to ethics. Karl Iver said he doesn't believe in trying to control the mass market and that people should have what they want. I'm not completely sure that's a good idea. It relates back to ethics and how we better use the world's resources, which are not unlimited, which comes back to the environment again. Can't we have a balance? Can't we leave some nature alone rather than trying to engineer it all and dominate it? We're not really sure what we're engineering. In the book I'll lend you, *How Many People Can the World Support?*, one person proposed the first law of ecology, that every action has consequences that are unintended or unanticipated. We really do not know what we're doing with nature. So we'd better be careful and this has led to also what's now called the precautionary approach. Let's tread very slowly, because it's a gigantic experiment and we're not sure what the outcome's going to be. If we get it wrong, good-bye.

Dr Nguyen Luong Bach, Urban Environmental Management: I'm very pleased to be here today, especially when I look at the SERD Seminar team in the Bulletin about the unlimited growth versus ecological doomsday. The reason is very simple. My background is systems dynamics and the doomsday issue was concerned with that approach in the 1970s by a group of systems dynamicists. So I have some concern here like this. Here I have the chance to listen to all of the predictions in the future. But we know that everything in the future depends on what you want to assume. If you change the assumptions, different scenarios will change. So I think it's better if we change the debate into the assumption issue, not the scenarios.

Even if we believe in unlimited growth, questions arise that are multiplied further. The first one is how realistic it will be. The second is how long the unlimited growth can be materialized. Maybe we will die before we can make any growth. How feasible will it be? Of course we can do whatever we like, but the problem is how it can be feasible. Otherwise, it becomes ideological. We can dream, we can imagine, maybe in another century, it's up to us.

The first question is it's better if we change the theme to debate on the assumptions about the future, not the predictions, because we will all agree that all the predictions are very difficult, if not impossible. Even if it can be made, the reliability is very low, if not zero. So it's better to work more on the assumptions, because these things are not quite new. The training should be new about the assumptions.

The second one is, suppose we all agree its unlimited growth. So what is the implication for AIT, or for SERD, or for any other program at AIT in relation to the vision? If I just listen to some of the speakers, some solutions should be grow food in the sea, another solution should be go to space, to conquer space. Does it mean that SERD should open a program for space exploration, another program for food growing in the sea? We can talk but the implications are more important.

Dr Gunner Hansen, Agriculture, Conservation and Rural Development: I have heard a lot this afternoon, which I don't agree with. But there's also something I agree with. I would like to take up the comment by our president. He said that we should be careful not to implement too much western technology. At the moment, and I think it's also in agreement with what Karl Iver said, we can see donors supporting something like organic farming and this kind.

Once I went to the northern part of Vietnam. They couldn't get the food. We found out that if they applied 15 kg of phosphorus on the terraces it would solve the problem. I met one from another Scandinavian country. She was going around telling farmers that they should use organic matter because it is so popular in our countries—in the western countries where we have enough food.

So we should be careful about deforestation and forestation. Of course on the slope land, there is another case than we have on the lowland. But at the moment there is a tendency, also between donors, that they should support the environment. I agree at least that we should first solve the poverty and beyond that we can't solve the environment. It's quite clear.

Mr Karl Iver Dahl-Madsen: There are many questions. At least I will start with the latest one from Gunner Hansen. I perfectly agree with him that this organic farming idea, trying to impose that on countries which are still lacking in food production, that's not good to say the least. That's completely crazy. It makes no sense. I really think AIT has a position to object to these things. They shouldn't just do it because some donor comes along and says we have some money for you, if you do some crazy thing. They should say, no this is bad for us. Please do something useful.

I'd also like to answer Peter. I think that fear is a very useless emotion when we are talking about developing Mankind. I think we should be brave. I don't think we should stop doing something useful and necessary because there might be some risk far out in the future that something bad will happen. I also think we should do very important, fantastic, risky things. I wish I could have been one of the sailors on Columbus' trip to America. He didn't even know if America was there, but he went. I hope that some of my children or grandchildren will be part of the space exploration and they will take the risk, because if we don't take the risks, Mankind cannot solve these problems. Of course we also have to have the counterweight. It's nice that we have Peter so that we discuss things a little bit before we take the risks. You can call that ethics. However, if I should finalize about the ethics, in Denmark we say that when the devil gets old, he goes into the monastery. So I would say that when an engineer gets past 50, he starts thinking about ethics.

Professor Jean-Louis Armand: All I would like to say at this point is that I was very thrilled by the comments we received. This is a very well run seminar. I wish to thank the organizers and all of the audience, because you are so good. I'm just amazed. I'm not used to that. It's wonderful. It's a nice cut from administrative duties, which are not always as pleasant as the one this afternoon.

I'm afraid I was brought back to my office for an urgent matter. I wish to apologize to the speakers I didn't listen to, but I'm sure that all this will be made available and I will be able to share this knowledge with you. I'm very confident about a place like AIT, which can foster such programs and such a school. I wish very well to SERD and to this new initiative, which by the way is across the board. Professor Weber, it's more than SERD, right? It's the whole of AIT, which will get into ethics.

We talk about French philosophers. Let me say also that we highly respect German philosophers. They have really brought practical thinking to most of us throughout the world, in the western countries, I should say. The impact of German philosophers has been very impressive and we're also very impressed by the Danes. This is democracy at its best. The Danish government is an example. I'm a European. I've been working within the European Union, and especially the European Parliament. The Nordic countries, especially Denmark, are very well known for their openness and the way they make sure that issues are handled by everyone. Everyone is involved in the final decision making, through advice, all the way through to decision-making. Again, it's no surprise to you that the stakeholders' meeting, which will help re-define and shape AIT's mission and goals, will be held as a town meeting. My Viking friends here know what I mean by the town meeting. It's an interesting exercise to hold in Southeast Asia. It's interesting to me, a bit of Viking culture.

Let's not bring western technology here. Let's come here in the spirit of cooperation and we have to learn.

Professor Chongrak Polprasert: Like the president, this seminar is really educational for me. I have learned a lot from the discussion today. This seminar has affirmed my belief in our SERD mission to try to link technology and society. I used to say before that a school is great not because we make a lot of money. We are great because we are doing something that is serving society. In SERD, we are doing our curriculum in poverty alleviation, we are doing something for environmental improvement, and doing something for society and development. So I am sure that with all your support, with the president's support, I'm really confident about SERD's future in the next decades to come.

Bill Savage: At this moment I would like to declare the end of this panel discussion as we have already passed the time allocation for that. On behalf of SERD I would like to thank all the panelists as well as participants for their participation in the stimulating and brainstorming panel discussion. Thank you.