BOOMING ECONOMIES, SILENCING ENVIRONMENTS AND THE PATHS TO OUR FUTURE:

Background Note by the Commission for Environmental Cooperation
on Critical and Emerging Environmental Trends

Note by the Secretariat[1]

SECTION ONE:
INTRODUCTION

Today, more people, commodities and products, more ideas and images, more genes and microbes, will move around the planet than at any other time in human history. Growth in international trade and investment has been remarkable, as the figures below attest:

- World trade increased 17-fold between 1950 and 1998, surpassing US$5.4 trillion per year in 1998;
- More than five billion tons of goods were shipped internationally in 1998, a six-fold increase since 1955;
- Between 1989 and 1999, foreign direct investment doubled to US$981 billion;
- The number of transnational corporations worldwide increased from 7,000 in 1970—when a few people started worrying about their power—to roughly 54,000 in 1998. Total sales in goods and services by such corporations and their nearly 450,000 subsidiaries are twice the amount that is traded internationally, at US$9.5 trillion in 1998. Intra-firm trade, which lies outside any rules of any international trade accords, now represents 40 percent or more of total world trade;
- In late 1999, the US stock market had a capitalization of over US$12 trillion, equivalent to an unprecedented 140 percent of the annual output of the US economy;
- E-commerce—either business-to-business or business-to-customer—comprised US$127 billion in transactions in 1998. That figure is expected to increase to US$1.4 trillion by 2003.

These and other indicators of economic growth, concentration and performance say a lot about the sheer scale and pace of change underway in the global economy. At the same time, they tell little about one question: are there costs associated with the global economy? If so, what are these costs? How are they measured? How are they distributed? And what are their consequences?

A paradox of the past ten years is that, as globalization generates more wealth than ever before, more people than ever before continue to express concern about its course and its consequences.

[1] This background note has been prepared by Jane Barr and Scott Vaughan of the Commission for Environmental Cooperation, in support of the CEC's work on emerging trends. It is intended to stimulate discussion among the parties, the Joint Public Advisory Committee, relevant National Advisory Committees, and the public about the state and future fate of our North American environment. Views expressed here are those of the authors alone and not necessarily those of the Secretariat or of its parties. This is the fourth background paper prepared by the Secretariat in support of the project, "Critical and Emerging Environmental Trends." These papers can be obtained free of charge by contacting the CEC at www.cec.org.

Demonstrations in Mexico in 1996, in Seattle in November 1999 and in Washington in April 2000 mark the most vocal expression of this public concern. Yet, it is hardly demonstrators taking to the streets alone who voice concern about the global economy. In its October 1999 report, the International Monetary Fund (IMF) questioned whether the unprecedented boom in the US economy heralds a new, golden age of high growth and low inflation, or whether recent economic trends presage inherently unstable and unsustainable conditions. The Fund appears to favor the latter interpretation, repeatedly urging "caution" regarding the prospects of the global economy,[1] and warning that US economic growth rates, instrumental in the global economic recovery, are "unsustainable."[2]

If the architects of macroeconomic policy are worried about instability and unsustainability, environmentalists have for some time expressed alarm at clearly established trends of environmental degradation. One measure of how we are doing ecologically—the ecological footprint—suggests that the amount of environmental resources available to each person on the planet has declined steadily over the past century, from the equivalent of five hectares per person in 1900, to less than 1.8 hectares per person in 1995. While the amount of total productive land has shrunk, the average "footprint" of US and Canadian individuals has increased to over eight hectares per person. By contrast, the footprint for Mexico is substantially less.

While imperfect, these figures suggest three things: first, there are biophysical limits to the earth's ecosystems. Second, the per capita supply of productive land worldwide is shrinking, in part because of population growth. And third, the ecological demands of average citizens of countries that are prospering from economic globalization exceed the average per capita supply by a factor of three. Put simply, if everyone on earth lived like the average Canadian or American does now, then we would need *at least three planets to live sustainably*.

While trends in degradation have been clearly identified, important gaps in environmental indicators and their meaning remain. Certainly, remarkable improvements continue in the design, level of aggregation, comparability and degree of public access of environmental indicators. At the same time, indicators of overall environmental quality across key environmental media remain elusive. That is, while tools that show changes in the quality of the air, water, land and biodiversity continue to improve, indicators of overall environmental quality that answer the question—are we getting better or are we getting worse?—are still out of reach.

INTERPRETING ENVIRONMENTAL INDICATORS

How indicators are assembled and interpreted is open to considerable debate, and affects a great deal of technical work. The interpretation of environmental indicators can vary a great deal, from reassurance that we are on the right track, to alarm that environmental quality is deteriorating.

Three recent examples of environmental reports illustrate this point. An October 1999 report by the John Heinz III Center for Science, Economics and the Environment on America's ecosystems begins by underscoring gaps in environmental data for croplands, forests, coasts and oceans. While robust site-specific and regional environmental data exist for these key ecosystems, national data is scarce at best. Despite these data gaps, the Heinz report, characterized by scientific rigor and comprehensiveness, notes that some indicators of environmental quality suggest stability or marginal improvement, while others suggest mounting pressure and deterioration. Among the highlights of this report are:

- Over the past 50 years, the quantity of total crops harvested, fish landed and timber cut in the United States has doubled.

- Crop productivity has also increased steadily over the past 50 years. For forests, more wood grows than is harvested each year, with growth per acre higher today than in 1950.
- The percentage of cropland with highly erosion-prone soil conditions decreased from 30 percent in 1982 to 24 percent in 1992.
- In the United States, high soil acidity affects one quarter of all soils.
- Irrigated acreage has increased by 25 percent since 1965, while the amount of total water supplied per acre has decreased by 25 percent.
- Streams and groundwater around agricultural areas in general have higher concentrations of nitrogen and phosphorous pollution compared to forested areas.
- Although comprehensive national data is needed, invasive (or nonnative) species affect one-quarter of the total forest area studied in California and 20 percent in the Mid-Atlantic region.
- Case studies suggest algal blooms are increasing in frequency, raising significant concerns over fish lesions, cancer and other diseases.[3]

The second report, the 2000–2001 World Resources Report, *People and Ecosystems: The Fraying Web of Life,* includes findings much more unequivocal and alarming. Among the highlights of this WRI-UNEP-UNDP-World Bank report are the following:

- One-half of the planet's total wetland area has been lost in the past century.
- Almost one in ten of the world's tree species are at risk of extinction; tropical deforestation may exceed 130,000 square kilometers per year.
- Fishing fleets are 40 percent larger than the ocean can sustain.
- Nearly 70 percent of the world's major fish stocks are over-fished or are being fished at their biological limit.
- Soil degradation has afflicted two-thirds of the world's agriculture lands in the last 50 years.
- Some 30 percent of the world's original forests have been converted to agriculture.
- Dams and other water diversions fragment almost 60 percent of the world's largest rivers.
- Twenty percent of the world's freshwater species are extinct, threatened or endangered.[4]

The third example is a 1999 report by the World Bank, *Greening Industry: New Roles for Communities, Markets and Governments*. Not a state of the environment report, it outlines recent hybrid and flexible environmental management practices, including public policy incentive schemes, environmental rating and disclosure systems (like the CEC's annual *Taking Stock* reports), education and information technology, and the role of industry in adapting environmental management schemes. It concludes that rates of industrial development can increase while pollution declines and is "hopeful" that sustainable industrial development is within reach in developing countries.

These three reports—one on a combination of different trends in the United States, another a compilation of alarming indicators at the global scale, the third a portrayal of hopeful initiatives in developing countries—reflect a range of interpretations about current environmental trends. They also nicely capture a familiar device used in economic analysis and environmental forecasting: presenting different scenarios describing business as usual, worst case and best case scenarios. The scenarios used in Working Group I of the Intergovernmental Panel on Climate Change (IPCC) is a well-known example of this three-tiered scenario approach.

What is common among these three reports is that environmental protection does not—regardless of one's opinion of the role of economic expansion, liberalization and integration—occur automatically. It requires change and innovation. The degree of policy change required obviously reflects how one interprets environmental indicators: more alarming interpretations are translated into calls for dramatic changes. Interpretations that see few or no problems predictably call for little or no change.

As important as the extent of policy changes required is the scope of policy arenas involved. Put another way, where one draws the line about the dimensions of environmental policy depends in large measure on what one considers the importance of the contribution of underlying economic factors to environmental degradation to be. Although market and pricing failures are now widely regarded as the main underlying causes of environmental degradation, most economic policies remain separate from, and resistant to, incorporating environmental factors.

Such resistance is hardly new. When Rachel Carlson's book, *Silent Spring*, focused attention on the impacts of DDT on birds, the response of the chemical industry—led by Monsanto, American Cyanamid, Velsicol and backed by the US Department of Agriculture—was to denounce her methods, data and credibility. They threatened lawsuits and funded "qualified scientists" on industry payroll to pick out errors and deride findings. Indeed, the chemical sector's portrayal of Carlson as an "hysterical woman" in 1962 helped make her book an international best seller and set in motion the environmental agenda.

The response of industry to environmental data and findings has, for the most part, changed since 1962. At the same time, the response of most macroeconomic policy to environmental considerations is at best resistant. This reflects the view of most economists that well-functioning markets contribute best to economic growth. Economic growth, in turn, best contributes to public welfare in general, including to environmental protection. Indeed, this line of reasoning forms the basis of Chapter Two of Agenda 21.

Yet, if one traces the lineage of trade-environment slogans, from UNCED's "mutual recognition"—which in essence means ensuring open trade and open markets to promote environmental protection and disciplining against any trade-distorting or restrictive policies—to the Seattle demonstration slogans, including "The WTO: Fix It or Nix It," it is fair to say that the public remains unconvinced that unprecedented rates of economic growth are entirely separate and disconnected from unprecedented rates of environmental degradation.

In the trade-environment debate, the relationship between trade-induced economic growth and environmental quality now guides a lot of good work. Analysis by the OECD continues to focus on factors that have been framed by five dynamic, related considerations: scale effects, compositional or structural effects, technology effects, product effects and regulatory effects.

The interplay among these five factors is, as noted, dynamic and complex. Yet, from an environmental quality perspective, the real question is whether scale effects associated with more economic growth (including increased production and consumption of goods and services) are offset by conditioning factors such as technological innovation. One way of looking at this relationship is as a kind of race between scale impacts that draw in more environmental inputs and produce more environmental wastes, and offsetting factors like technology effects that lower the environmental profile of expanded activity.

The economic literature clearly shows an asymmetrical relationship between scale impacts and mitigating factors like technology. There is now strong evidence of a de-coupling of rates of growth from environmental damages. This de-coupling considerably weakens the causal link between growth and environmental quality.

But the real question is, does it break that link? The ongoing debate about the Environmental Kuznets Curve suggests that for some environmental indicators—like $S0_2$ and $N0_x$—the causal link is indeed broken. But for just as many, including $C0_2$ and indicators of biodiversity, the causal link remains, de-coupling does not occur (at least in any practical sense) and environmental degradation therefore rises in tandem with economic growth.

Recent studies tend to underline the need to distinguish between *relative* improvements in environmental efficiency—expressed as reduced levels of pollution intensity per GDP unit, or eco-efficiency—and *absolute* changes in environmental quality. Reports like that of the World Bank (noted above) provide useful case studies of ways of doing a lot more with a lot less environmental damage. And while they say a great deal about relative gains in environmental management—in being more cost-efficient and in re-inventing policies—what matters is the absolute rate of change in environmental quality.

As noted, there are different ways to look at absolute changes. The three CEC parties have helped to ensure that this forward-looking analysis keeps an eye on absolute factors affecting our environment by choosing two methodologies that examine, in different ways, absolute physical flows affecting the environment. These two methods, the ecological footprint approach and materials flow analysis, essentially identify *biophysical limits* to current economic activity. While they are not intended to be forward-looking or anticipatory tools, observed rates of resource flows and impacts can be very helpful in thinking about what our environment might resemble in 2020.

The ecological footprint and materials flow analytical approaches are described in Section Four.

Acceptable Rates of Environmental Change: Who Measures, Who Decides?

A final word about environmental policy and the globalization debate concerns governance. Questions about institutional coherence, global policy architecture and transparency have become as visible as questions about the substantive effects of globalization itself. People continue to ask; how are decisions about the future being made? Who will make them? Who decides whether underlying economic causes are important to environmental integrity and sustainability? Are economic decision-makers either unaware of, or indifferent to, current rates of environmental degradation? And will the decisions we face in shaping the next 20 years tap the commitment and creative talents of a concerned public, or will they be taken in an opaque manner?

It is not only demonstrators outside institutions who raise questions of democracy and governance. People on the inside do as well. For example, in April 2000, the former chief economist of the World Bank, Joseph Steiglitz, wrote; "In theory, the Fund supports democratic institutions in the nations they assist. In practice, it undermines the democratic process by imposing policies." Steiglitz summed up the high price of public policy taking place in private thus:

> "Smart people are more likely to do stupid things when they close themselves off from outside criticism and advice."[5]

As an institution founded on principles of openness and public participation in all matters, the CEC's work on environmental futures is committed to engaging the public through the Joint Public Advisory Committee, National Advisory Committees and, more generally, the public. This project recognizes that the process of thinking about our environmental future is as important as any actual forecast we present. This project is built on the adage that it is better to anticipate and prevent environmental problems, than to react to and attempt to cure existing problems. For example, at a recent meeting of the Mexican National Advisory Committee, the list of trends to be considered under the CEC was as follows:

- shifting uses of soil and soil management,
- land-use regulations as a tool for sustainable development,
- a holistic vision for water management, and
- the introduction of environmental ethics into educational programs.

This project is also committed to building on the considerable amount of good work already underway in forward-looking environmental policy. As the 1999 CEC report on emerging trends noted,[6] a lot of good analysis is underway in environmental forecasting, trends analysis, elaboration of future scenarios and related work. That report describes basic differences in approaches between forecasting—moving forward from what we know today—and futures work. The latter tends to open up the process to consideration of things we might or might not know about today, but which may nevertheless shape our future.

Examples of forward-looking environmental work include analyses by the Millennium Project of the United Nations University's World Institute for Development Economics Research, the Stockholm Environment Institute, OECD, the Environmental Futures Forum of the G8, the World Resources Institute, the Business Council for Sustainable Development and UNEP's GEO project. Other examples include public research initiatives like the US Army Environmental Policy Institute, industrial ecology simulations of the Environmental Protection Agency, the Australian Science and Technology Council, the Japanese National Institute of Science and Technology Policy, the Fraunhofer Institute for Systems and Innovation Research (Germany), and the Central Planning Bureau of the Netherlands. And they include, of course, the Royal Dutch/Shell program, which helped initiate futures-related analysis.

Several dozen distinct methods for anticipating future environmental conditions can be identified. The Battelle Seattle Research Center (January 1997) groups these methods into six categories. The first two, expert opinion and scenario building, underscore the importance of public participation in foresighting. The second two categories, modeling and morphological analysis, place more weight on computer models and other technical analytical tools. The third two categories, scanning/monitoring and trend extrapolation, emphasize that future environmental conditions will be based in large part on present conditions.

It is worth noting that these categories are not mutually exclusive. Indeed, expert opinion and scenario building can set the stage for the use of models and other analytical tools. Models and tools cannot provide answers about our future. But they are indispensable in providing internal consistency to data that go into, and emerge from, scenarios. Section Three employs the scanning method by assembling information from established sources like WRI or UNEP about key environmental indicators already observed and possible trends based on present conditions.

In looking at different approaches, one can either work to improve methods, or make use of imperfect models that already exist and begin thinking about *probable* environmental futures.

It is unwise to do both—to improve methodologies and estimate likely futures. For this reason, this Note does not describe methods and tools. Instead, its point of departure is the instructions of the Parties to the Secretariat in December 1999 about this project:

- Forecast the probable state of the North American environment in the year 2020.
- Make use of forward-looking scenario analysis. In this case, the parties suggested one normative scenario of preferred environmental outcomes.
- Analysis should include key environmental indicators.
- Analysis should include underlying drivers of environmental change, in particular economic factors likely to affect future environmental conditions.
- Of the two methods that could be useful in forecasting future environmental conditions, two are of particular interest to the three parties: the ecological footprint approach and materials flow analysis. These are presented in Section Four.

A final point that bears repeating is that anyone who says they can predict the future of the environment is a fraud, simply because the future cannot be known. When one expands the application of forecasting methods beyond a six-month time horizon to a one-year and then a twenty-year time horizon, as this project does, uncertainty rises dramatically. Even with the benefit of hindsight, we are still struggling to understand the implications of events that took place twenty years ago. For example, in 1980:

- The world's first test-tube baby, Louise Brown, was barely two years old.
- So, too, was the US ban on CFCs, as concern about possible impacts on stratospheric ozone were first raised.
- The theory that the Great Ice Age of 65 million years ago was caused by an asteroid was published by Luis and Walter Alvarez. A decade later, evidence of that catastrophic event was uncovered in Mexico;
- In 1980, the World Health Organization declared smallpox to be eradicated.
- One year later, the first signs of AIDS were detected.
- The invention of the World Wide Web and the Internet protocol by Tim Bernes-Lee was a decade away. Five years after its inception, the number of web users had jumped from 600,000 to 40 million. By January 2000, the total number of users was expected to exceed 700 million.

Given uncertainties in understanding present events, it is unlikely that thinking about the environment in 2010 to 2020 will yield definitive results. Yet, the mere act of thinking about the future may help us set the context for today's environmental issues.

SECTION TWO: DRIVERS OF ENVIRONMENTAL CHANGE

Many variables shape our environmental future. In addition to more familiar challenges, like changes within and between industrial and production sectors, or the relationship between consumer demand for certain foods and durable goods and growth in per capita income, our environment will be shaped by the pace with which new technologies retire old ones, by the links science makes between sources, long-term effects and associated risks of different pollutants, and by public preference for a clean environment for our children.

Other factors aside from technological choice also shape our future. On a global scale, this includes population growth. On a North American scale, this includes the increasing concentration of populations in urban areas. For instance, North America's population is increasingly concentrated in urban areas, whether in small, medium or large cities. Over 70 percent of the population live in urban areas of over 2,500 people, while 30 percent are in cities with populations of 100,000 or more.[7] In Canada and the United States, urbanization involves a move from urban cores to suburbs and/or to small and intermediate-size cities.[8] By contrast, Mexico continues to experience significant urban growth as the borders of Mexico City expand.[9]

At least five obvious environmental factors come to mind when thinking about urbanization. First, between 1982 and 1992, an estimated 17,000 km^2 of prime or unique farmland in the United States, especially in arid regions, were lost to urban development. Second, urban sprawl anchors even deeper dependence on the automobile, especially in satellite communities not readily accessible to public transport, thereby raising the prospect of higher vehicle emissions.[10] Third, as city centers spill outwards, many inner-city industries close, and abandoned brownfields or contaminated lots lay scattered throughout once thriving centers. Fourth, the migration of rural communities to large urban centers can create social disruption, or at least erode the cultural distinctiveness of small communities. And fifth, urbanization often competes head-on with agriculture over both land and, increasingly, fresh water (see Section Four).

If these and other environmental factors need to be weighed when thinking about specific issues such as urbanization and the environment, then how many direct and indirect issues need to be juggled when thinking about macroeconomic policies that exert both economy-wide and sector-specific effects? And, given this degree of complexity, is it worth even trying to address these questions?

The answer is yes. If the trade-environment debate has taught us anything, it is that macroeconomic policy matters both for environmental quality, and for environmental policy, largely because of the profound effect macroeconomic policy reform exerts on relative prices, together with the important implications associated policies—like deregulation, privatization and liberalization—have on environmental governance. These and other factors have been identified in the CEC's *Final Analytical Framework for Assessing the Environmental Effects of the North American Free Trade Agreement*. This Framework, released in mid-1999, is one of the most comprehensive methodologies intended to measure the environmental impacts of trade. In October 2000, a CEC Symposium on assessing the environmental effects of trade will be held, in which the Analytical Framework will be applied. Fourteen research areas—including trade in services, transborder movements of hazardous waste, changes in pollution intensity indicators, and the impacts of trade on fisheries, forests and freshwater—are among the topics to be addressed at that Symposium. Results from this backwards-looking analysis should be helpful in estimating future environmental conditions.

As noted above, one of the central lessons of environmental economics is that environmental degradation is usually caused by market failure or pricing failure. Provided one corrects such failures—and that is the whole purpose of both structural adjustment programs and trade liberalization policies—does one then stand a better chance of protecting the environment?

Work by the IMF, UNEP, the World Bank, David Reed of WWF-US and others has sought to define some of the complex links between macroeconomic policies and environmental impacts. Although too complex to summarize here, four points based on work by the IMF are worth noting:

- Macroeconomic *instability* tends to magnify environmental degradation. For example, periods of high discount rates and short-term returns, which are associated with unstable economic conditions, can be linked to excessive rates of natural resource depletion. Accordingly, macroeconomic stability is generally regarded as preferable to instability with regard to environmental protection;

- Macroeconomic policy reform magnifies pre-existing market, pricing or institutional failures, which in turn magnify environmental costs. The same can be said for trade liberalization: at least in the transitional stages, trade policy reform can reinforce pre-existing patterns of comparative advantage and specialization;
- Sound macroeconomic policies do not ensure environmental quality. Although liberalized markets have higher rates of economic growth compared to closed ones, no automatic link exists between liberalized economies and environmental quality. Put another way, while correcting pricing distortions is a necessary precondition to effective environmental policies, since pricing distortions such as subsidies tend to offset environmental gains, such corrections don't in their own right ensure environmental quality. Hence, robust environmental policies are needed to offset any environmental costs associated with macroeconomic policy reforms. This point is largely tautological. The real issue is whether environmental costs are higher during policy reform;
- The other issue is whether macroeconomic policy reform, including trade policy reform, makes it more or less difficult to craft environmental policies. For example, most macroeconomic policies comprise packages of deregulation, fiscal disciplines including a reduction in non-revenue ministries like the environment, and constraining measures. Given that trade policy reform shows a clear preference for market-based instruments over command and control market interventions, the environmental community remains somewhat at a loss over the scrutiny by the WTO of labeling and environmental taxes for their potentially trade distorting effects.

These and other issues mean that a lot more work is needed in identifying links between macroeconomic policy reforms and environmental consequences. This includes examining lessons learned both at the country and sectoral level in assessing the effects of structural adjustment policies on the environment. This is part of a broader challenge, noted above, to look at the relationship between economic growth and environmental quality. An obvious starting point is to look at projected rates of growth, expressed as changes in GDP, and to try to identify the causes of such growth, including the consequences of economic policy choices. The first is easy. The second is less so.

The IMF is able to forecast short-term economic growth rates. For example, in October 1999, it forecast real GDP rates for Canada and the United States for 2000 of 2.6 percent each, and 4.0 percent for Mexico. But the IMF is reluctant to provide forecasts beyond a year, given the variables at play. The IMF does turn to trend analysis to estimate potential output using observed output data only. (Projections are based on the assumption that the growth rate of potential is constant or varies systematically over time, but are not capable of distinguishing between a trend and a cycle because estimates are "highly sensitive to the end-point of the last observations."[11])

HIGH GROWTH RATES AND HIGH INSTABILITY

Difficult as economic forecasts are under more or less "normal" conditions, predicting what the economy will look like in abnormal circumstances is that much trickier.

The central question that absorbs macroeconomic policy experts is, why is the US economy booming? Is that boom an anomaly or a more permanent kind of economic reordering? Since 1990–91, the US economy has expanded at three percent per year, the longest economic expansion ever seen since the middle of the 19th century, when economic data was first collected. Various factors explain in part the US economic boom: low inflation, a rise in productivity, including higher labor output ratios, the supporting role of new information technologies, and the boom in liquidity and asset prices.

(Among the questions that continue to be examined is the growing gap in manufacturing productivity between the United States and Canada, with some studies showing as much as a 20 percent drop in Canadian manufacturing productivity compared to that of the United States from 1987 to 1997. Of interest in their own right, studies that examine the causes of this gap often focus on areas of relevance to environmental performance, including capital stock, investment-output ratios, human capital [including education] and other factors that influence environmental performance.[12])

What remains unknown is whether the combination of high growth and low inflation is the basis of a new economic paradigm that will characterize the new economy of the future, or whether this boom is an aberration and thus the US economy and, by extension, the global economy, is inherently unsustainable. The Fund suggests the latter, noting that economic instability remains "pervasive" in the world economy, despite advances in core policy areas like the control of inflation, better disciplines affecting fiscal imbalances, etc. It is assumed that disciplines like trade liberalization, deregulation, the privatization of state-owned enterprises, the attempt to reduce moral hazards associated with public-sector bailouts of private investors, and better information regarding price changes across countries, would all converge towards greater price stability today and in the future. One of the Fund's most interesting observations is that as macroeconomic disciplines appear to have taken hold, so too has the risk of excesses in asset markets and the private sector. That is, as countries tame inflation and put public finances on a sound basis in the 1990s, the Fund argues that the challenge facing macroeconomic policy to ensure stabilization becomes greater, not less. Among the chilling observations of the Fund outlook is:

> "Taken together, developments in the global economy in the 1990s and the hypotheses to which they give rise are not particularly reassuring."[13]

The above is relevant when thinking about environmental futures. Any forecasting needs to be based to some extent on assumptions regarding future economic conditions. However, the above commentary of the Fund drives home the point that the new economy is inherently unstable and therefore difficult to predict. One example of that instability is the events of April 2000. In a one-week period in mid-April, an estimated US$2.1 trillion was lost in stock markets, marking the largest market loss in history, equivalent to one-fourth of the total US GDP. These losses were bigger than those of 1929 or 1987. Yet they are widely regarded by financial analysts as market fluctuations.

The prediction of the overall direction of market turbulence is obviously the everyday work of analysts, forecasters and risk managers. Financial risk management, which has honed many of the tools for economic forecasting and assumptions about probability, was first introduced some 300 years ago, as the rapid expansion of international trade created new markets for maritime insurance.

Risk management has become increasingly sophisticated in disciplines involving notions of utility and valuation, and assumptions about the regression to the mean. This latter area, developed a century ago by Francis Galton, posits that—over time—everything returns to normal, with observed regression to the mean based on statistics from a variety of areas, including weather patterns, stock markets and economic cycles.

Although these and other tools—including providing mathematical proof for investment diversification—form the basis of financial risk management, there is a growing sense that mathematical models and statistics can only go so far in predicting and avoiding tomorrow's risks. A case in point is the story of the Wall-Street hedge-fund investors group, Long Term Capital (LTC). Before August 1998, LTC was famous for relying less on the instincts of traders, and more on two Nobel–prize-winning economists, the best and brightest mathematicians and developers of financial risk models, which were among the most sophisticated ever run. LTC was different from other hedge fund investors, since they predicted future market performance based on mathematically-robust assumptions about rational market outcomes. LTC became infamous after August 1998 for losing approximately US$4 billion, and prompting the Federal Reserve Bank to bail them out in order to reduce the risk of spillovers. With the benefit of hindsight, it is evident that the LTC predictive models failed to take into account non-rational aspects of capital markets.

One of the methods used increasingly in financial risk management, in addition to models and mathematical data involving statistical probability to predict future market conditions, is Game Theory. This differs from regression to the mean assumptions in assuming that the economic conditions of tomorrow can never be the same as conditions of today. Yet the reference to Game Theory tells us more about some underlying assumptions of the global economy—how we think about it, and how its structure and dynamics appear to differ in the most basic ways from nature. This is discussed briefly below.

INFORMATION TECHNOLOGIES, THE NEW ECONOMY AND THE ENVIRONMENT

Another reason that economic forecasting becomes harder rather than easier is because of the role of information technologies in economic performance. For example, information technologies are seen as playing an important role not only in explaining productivity growth, but also in understanding the growing gaps in productivity between, for instance, the United States and Canada.

In looking at this constellation of high growth, low inflation and information technologies, the Fund notes that the current US economic boom might not be the advent of a new age so much as a series of "fortuitous but temporary events" that explain growth performance in the late 1990s.[14]

Alan Greenspan, Chairman of the US Federal Reserve Bank, thinks otherwise. At a recent White House-sponsored Conference on Technology and Information Growth (April 2000), Greenspan noted "something profoundly different in the postwar business cycle," whereby productivity growth is being increasingly driven by technological innovation, in which labor-saving equipment is leading to lower prices and improved delivery lead times. Indeed, Mr. Greenspan points to a "period of rapid innovation" propelled by information technologies, a period in which just-in-time deliveries are increasing, inventories are shrinking, output per hour is higher, and total hours worked to address information-related uncertainties are dwindling. Greenspan promises that growth in e-commerce is expected to raise US productivity even further, on the assumption that "knowledge is irreversible."

One way of thinking about future environmental issues is by considering whether the new economy, setting aside its durability for a moment, is inherently cleaner than the old one. When information technologies were being introduced, several pundits promised that the information superhighway would be well-traveled, but much cleaner than the older highways. Telecommunications would mean people could talk more often and exchange more ideas and materials than ever before without having to actually travel to do so.

Indeed, when information technologies were being introduced, there was much speculation about the "paperless office," as all information was to be exchanged electronically.

Certainly, e-commerce is growing at staggering rates. In 1998, an estimated 200 million people were wired together through 43 million computers. Today, one in 40 people has access to the Internet. In 1999, total transactions through e-commerce were worth US$127 billion. By 2003, these are expected to increase to US$1.4 trillion for the United States alone. Yahoo, with a current market value of US$152 billion, is worth more than Ford Motor Company, Walt Disney and Dow Chemicals combined.

Of interest is whether such huge increases in the exchange of electronic information mean that more conventional types of information exchange are being reduced. The answer is no. What is interesting is that it seems all means of communication, conventional and otherwise, are growing at the same time. For instance, given the obvious emphasis the global economy places on speed, a whole new industry of express mail and package delivery has boomed in the last decade. FEDEX began in 1973 with a total delivery of 186 packages and now delivers 3.1 million packages each day, for total earnings (1998) of US$16.8 billion, an increase of six percent from 1997. Of course, FEDEX is hardly alone: UPS, the largest such service, delivers three billion parcels and packages a year with annual earnings (1999) of US$24.8 billion.

It is fair to ask if this new business has shifted activity from older ways of moving mail and parcels through national postal services. In fact, just the opposite is happening: postal services in most countries are on the increase. For example, in 1998/1999, Canada Post processed 9.6 billion pieces of mail, an increase of 400 million from the previous year. The same year (1999), the US Postal Service handled over 200 billion pieces of mail for the first time, an increase of some 30 billion pieces since 1993.[15]

Another consideration is whether all this exchange of information on the Internet and next-day delivery of mail and parcels means, at least, that fewer people are traveling.

Again, just the opposite is taking place. For example, ICAO reports a five-percent increase in 1999 compared to the previous year in total scheduled air traffic, and an increase of six percent in international scheduled air traffic. This translates into 2.630 billion passenger-km for 1999, a figure expected to increase to 3.038 billion passenger-km by 2001. This performance is closer to the expected annual growth rates of seven percent per year. Last year nearly *five billion* tonnes of goods were moved around the globe.

Indeed, the global economy is all about moving people and things from one place to another. US trucking carried the equivalent of 900 billion ton-miles in 1993, for a value of US$4.6 trillion. According to the US Department of Commerce, interstate commerce accounted for one-half of all trucking by value except in three states, and transit through states accounted for one-half of all traffic in 25 states. That same year, according to the US Department of Transportation, there were 615 million vehicles in that country alone, with promises of "rapid growth" in the years ahead. In 1999, Ford Motor Company sold 7.2 million cars worldwide, more than any other year, with record earnings in North America alone of US$6.13 billion on total revenues of US$100 billion.

These figures do not tell us if the new global economy is more or less clean than the old one. But what they do tell us is that information technology is not diverting older ways of doing things, but creating new and expanding markets that help fuel demand for more exchange, over and above existing means of doing so.

And with this one, very limited example, one can begin to flesh out the relationship between scale, technology, compositional and product effects. For example, although the services sector of the new economy is assumed to be cleaner than twilight industries, the point is that any economic activity has environmental consequences. All those parcels and pieces of mail are moved around by airplanes and trucks. FEDEX operates 40,000 trucks and 600 aircraft, UPS has 157,000 trucks worldwide and 500 aircraft, and DHL Worldwide Express operates 320 aircraft around the globe.

These aircraft fleets are over and above the commercial aircraft fleets and cargo fleets that already fly. And without targeting aircraft travel, it is worth noting that the IPCC recently released a report on the contribution that jet aircraft make to climate change, through $C0_2$ emissions and water vapor emitted at high altitudes. In the former area, major North American airports at peak periods are among the largest sources of greenhouse gas emissions. This is in addition to $N0_x$, CO, hydrocarbons, $S0_2$ and carbon emissions that kerosene-burning jet engines produce, with total emissions dependent on the operating conditions, size, and temperature of engines and other factors.

While relative gains continue in engine efficiency, an April 1999 report by the US EPA ("Evaluation of Air Pollution Emissions From Subsonic Commercial Jet Aircraft", Office of Mobile Sources), notes that "commercial aircraft emissions have the potential to significantly contribute to air pollution" in local areas in the United States, and that by 2010, $N0_x$ from aircraft pollution will increase from one percent (1990 levels) to 10.4 percent in absolute terms.

Similarly, a 1996 report by the US Department of Commerce (Environmental Trends and the US Transportation System) noted that while vehicle emissions have declined, the exception is $N0_x$. The report also notes that while air regulations have lowered total emissions, recent data show a "slowing of the improvements" made over the past two decades for two reasons: a total increase in transport (scale effects) and a growth in unregulated off-road vehicles, also known as sports utility vehicles or SUVs (regulatory and product effects).

The scale effects and reversing trends in air pollution are just one sign of the new global economy. Another is biological pollution, recognized by the scientific community as potentially more consequential than conventional chemical pollution.

Today, anywhere from 3,000 to 10,000 aquatic species move around the world in the ballast water of ships moving goods from one port of call to the next. Estimates suggest that nearly one-fifth of the world's endangered vertebrate species are threatened by invasives. In the United States, nearly one-half of all species face extinction, caused in part by invasive species.

In the North American Great Lakes, invasive species continue to pose serious threats to biodiversity, just as hard-won measures to decrease pollution emission levels seem to be gaining ground in environmental conditions. The zebra mussel, first introduced sometime in the mid-1980s, perhaps from the Caspian Sea, is ingesting larger and larger quantities of algae, choking other life. In the United States, kudzu (*Pueraria lobata*), a weed introduced from Japan in 1876, now covers seven million acres and remains on the move, especially in the south, choking almost all other agriculture in its path. Another commonly cited example is purple loosestrife: after remaining low in distribution for over 100 years, it has become a major competitor of native wetland plants, now taking over approximately 200,000 ha/year.[16]

The truly interesting thing about invasive species is the speed with which they can grow in a new territory. Bioinvasions can spread through new ecosystems, growing in geometric progression (doubling and doubling yet again) to the point where the effect does not appear to be proportional to the cause.

It is this question of proportionality that makes predictions about our environmental future (also our health and technological futures) so difficult. Malcolm Gladwell, talking about epidemics in *The Tipping Point: How Little Things Can Make A Big Difference*, notes that "to appreciate the power of epidemics, we have to abandon [the] expectation of proportionality. We need to prepare ourselves for the possibility that sometimes big changes follow from small events, and that sometimes these changes can happen very quickly."[17] One example of how quickly things move in the new economy, supported by information technology, is the spectacularly fast replication of the ILOVEYOU computer virus in May 2000.

Reference to the possible disruption of proportional impacts is made for two reasons. First, one can factor in disproportionate impacts to some extent, as the IPCC has done for some time in thinking about potential feedbacks of climate change. And second, such predictions must take into account the fact that we still know precious little about how ecosystems function and about the biological interplay that takes place within and between ecosystems.

To illustrate this, new research in molecular biology suggests that when millions of individual cells of bacteria form a critical mass they link up to form "biofilms," which construct microscopic columns and channels to absorb nutrients from the host's body and to remove wastes. This arrangement suggests the bacterial equivalent of the type of communal behavior seen among insects. Indeed, coordination, specialized behavior and communication have been found in 300 separate species of bacteria working together for their mutual benefit on one host. The *Financial Times* notes that a biofilm is formed when "the bacteria sense that enough of them are present to change to a collective mode of behavior. Scientists call this relationship between activity and population density 'quorum sensing'."[18]

The above, fascinating in its own right, provides one example of how emerging characteristics of the global economy differ from patterns of biological behavior. Although different interpretations of environmental indicators exist and are valid, the extent of environmental change and, more specifically, of indicators suggesting a collision between biophysical limits and expanding demand, ought to signal a time for change. Instead, the way we continue to manage the environment is often explained by Game Theory, in which models are used to explain different choices and reasons under zero sum gain assumptions, in which it is often assumed that what is good for one is bad for the other. Or, our approach assumes—as in the Prisoner's Dilemma model, a standard illustration for economic behavior—that cooperative action and trust bring uncertainty and an inherently high degree of risk.

Which model one places greater faith in—observed patterns of molecular biology or Game Theory—very much depends on how much one reads into some key indicators of environmental trends.

SECTION THREE:
ENVIRONMENTAL INDICATORS AND EMERGING TRENDS

This section provides an overview of some key environmental indicators, including a summary of what is known, past trends, and possible future issues.

Conclusions in this section are based on a survey of recent reports about global environmental issues and trends as reported by The Worldwatch Institute, the World Resources Institute (WRI), several divisions of the United Nations, The World Bank, the Organisation for Economic Co-operation and Development (OECD) and the Commission for Environmental Cooperation (CEC).

A **trend** can be defined as "a verbal or numerical representation of a series of characteristics that can be estimated over time, providing an indication of the general direction of change. A trend may be a subjective assessment of a situation or an objective/numerical measure. A trend may be increasing, decreasing, or static" (Life Systems Inc. 1996). For the purposes of this report, the first three of the following criteria are needed to validate a trend, namely, that the phenomenon is observed over a period of time; is of global or North American scope; is supported by quantitative rather than qualitative information; is reflected in actual planned resource allocation (economic, human, technological, etc.); is reflected in passed or pending legislation or regulations; and is reflected in action at multiple levels (local, state/provincial, federal, international) " (Life Systems Inc. 1996).

The second term involves critical or emerging environmental **issues**. Issues may be defined as "concerns or problems, actual or perceived, for which an adequate policy or technological response has yet to be developed and/or implemented" " (Life Systems Inc. 1996). Thus, new issues generate concern but are often not supported by sufficient scientific evidence or documentation for there to be scientific consensus about whether they constitute a trend. In addition, they are focused on the present, which precludes extrapolating a forecast as may be done with a trend.

Trends that were deemed to be of a **critical** nature, or those that are serious, urgent and demanding further attention are also underscored, such that trends showing improvements in environmental quality, of which there are an encouraging number, have not been highlighted. Critical trends are also considered to be those that have been recognized for some time and are being addressed by governments in many regions, but remain persistent problems.

This section of the report focuses on **environmental** conditions based on human-induced events or behaviors. It identifies changes in the quantity and quality of forests, agricultural land, urban areas, freshwater, marine ecosystems, biodiversity, and the air. Descriptions of environmental change can neither be divorced from the economic, social, technological, and institutional forces or pressures that drive them nor from the responses to change.

To denote an environmental trend or issue as **emerging**, it needs to involve a relatively new problem or, to use the Merriam-Webster Dictionary's definition of emerging, one that is "becoming manifest." If a change over time signaling a surfacing environmental problem continues in the same general direction, this **emerging environmental trend** could lead to potentially significant impacts on human health or ecological impacts. While this suggests an emphasis on what "new" issues we will face in 2010 to 2020, given the acceleration of economic, technological and environmental change, it is difficult enough to figure out the consequences of new problems we already understand today.

A final definition noted concerns the scope of this project. Although many environmental indicators are grouped as local (e.g., hazardous wastes), cross-border (e.g., acid rain) or global (greenhouse gas emissions), this project attempts to capture **North American** environmental trends. Although NAFTA has helped create a sense of shared economic links among the three countries, the public perception of a shared continental ecosystem remains less well formed, despite the shared environment that binds Canada, Mexico and the United States. A North American trend or issue implies that the problem overlaps at least two of the NAFTA countries.

I. Biodiversity

A CRITICAL TREND: HABITAT AND BIODIVERSITY LOSS

Today, human-induced species' loss is estimated to be 50 to 100 times the average natural rate of extinction.[19] According to IUCN, 12 percent of all plant species surveyed, 25 percent of vertebrate species,[20] 11 percent of all bird species, 34 percent of fish,[21] 25 percent of mammal species and 50 percent of primates are threatened with extinction.[22] The United States and Mexico are among the top 19 countries with the greatest number of threatened species[23] and among the top 10 with the largest numbers of threatened plants (Table 1). In Mexico, for example, the deforestation of critical over-wintering sites for migratory birds may threaten the very survival of some populations.[24]

Table 1: Top 10 Countries with the Largest Numbers of Threatened Plants

Country	Total Species (number)	Percentage of Country's Total Flora Threatened
United States	4,669	29
Australia	2,245	14
South Africa	2,215	11.5
Turkey	1,876	22
Mexico	1,593	6
Brazil	1,358	2.5
Panama	1,302	13
India	1,236	8
Spain	985	19.5
Peru	906	5

Source: Tuxill 1999b, 13

The most endangered species are found in lakes, rivers and wetlands: at least one-fifth of all freshwater fish species have become extinct, threatened, or endangered.[25] Ten North American fish species have disappeared in the past decade[26] and one-third of North America's freshwater fish stocks are threatened or rare.[27] In Mexico, 68 percent of fish species native to river systems in arid regions are threatened with extinction.[28] The United States contains the world's greatest diversity of freshwater mussel species, but now more than 65 percent of them are extinct or threatened.[29]

Half of North America's most diverse ecoregions are now severely degraded.[30] Sixty percent of the critical or endangered ecoregions are in temperate broadleaf and mixed forests, temperate grasslands, and savannas and shrub-land.[31] Habitat loss and degradation are the leading threats to biodiversity.[32] Inability to find suitable habitat has led to the decline of at least 70 percent of threatened vertebrate species.[33] Habitat change is implicated in 93 percent of declines in freshwater fauna.[34]

A Critical Trend: Bioinvasion

Bioinvasion, or the spread of exotic species, is now believed to be among the greatest threats to biological diversity.[35] It is the second most common factor in the loss of freshwater species, affecting about 68 percent of cases.[36] Between 10 and 20 percent of the world's endangered vertebrates are now at risk from competition, predation and other threats from introduced species.[37] Approximately one-fifth of the 4,500 established exotic species in the United States cause serious ecological or economic harm.[38] Increased trade and the expansion of aquaculture provide dangerous opportunities for many more non-native species to be introduced into North American ecosystems.[39]

An Emerging Issue: Genetically Modified Organisms

Although they have enormous potential benefits for agriculture, medicine and other fields, there has been a rising concern over the possible risks associated with living modified organisms (LMOs) to biological diversity and human health.[40] UNEP notes that risks include "unintended changes in the competitiveness, virulence, or other characteristics of the target species; the possibility of adverse impacts on non-target species and ecosystems; the potential for weediness in genetically modified crops (i.e., a plant becomes too resistant and invasive, perhaps by transferring its genes to wild relatives); and the stability of inserted genes (i.e., the possibilities that a gene will lose its effectiveness or will be re-transferred to another host)."[41] Mexico is a leading producer of transgenic foods and, as one of the countries richest in biodiversity, has noted that concerns are being raised about the risks associated with the importation of genetically engineered crops.[42]

An Emerging Issue: Loss of Wild Plant Species

Apart from forecasts of continued dire loss of species, a significant problem for the future is the loss of wild plants related to essential cultivars. Worldwatch Institute warns that the ability to cultivate industrial crops such as cotton or plantation-grown timber may be compromised by declines in their wild relatives, which shrinks the gene pools required for breeding new crops.[43] Such a decline would affect Mexico, the origin of many of the world's cultivated plants.[44] And "in the United States, two-thirds of all rare and endangered plants are close relatives of cultivated species. If these species go extinct, a pool of potentially crucial future benefits for global agriculture will also vanish."[45]

An Emerging Trend: Changes in Ecosystem Functioning

According to UNEP, "the transformation of global biogeochemical cycles, the reduction in the total world biomass, and the decrease in the biological productivity of the planet" are emerging trends that may be even more important than the loss of biodiversity.[46] And World Resources Institute reports that "threats to biodiversity from all sources are quickly reaching a critical level that may precipitate widespread changes in the number and distribution of species, as well as the functioning of ecosystems."[47] Worldwatch Institute notes that there has been extensive and accelerating conversion, degradation, fragmentation and simplification of ecosystems with the related loss of the goods and services that these ecosystems provide.[48]

II. Forests and Woodlands

A CRITICAL TREND: ACCELERATED DEFORESTATION

Forests remain threatened by the rate of forest loss: on a global level, total forested areas are declining,[49] with forest losses accelerating once again[50] after a slight drop in rates from 1990 to 1995.[51] The global rate of forest loss increased from about 12 million ha per year during the 1970s to over 15 million ha in the 1980s, with deforestation continuing at about 13 million ha per year during the 1990s.[52] At least 200 million ha of forest were lost between 1980 and 1995.[53]

Deforestation is concentrated in the developing world, especially in the species-rich tropics, where logging pressures in large, virgin rainforest areas continue to increase.[54] Two-thirds of tropical deforestation is from clearing land for agriculture,[55] with subsistence farming more common in Africa and Asia, and conversion to large-scale ranching most common in Latin America.[56] In North America, Mexico's forests suffer the greatest losses as land is cleared for crops and grazing. Although deforestation rates in the tropical forests of southeastern Mexico have declined somewhat in recent years, these forests are still undergoing high rates of loss. It has been estimated that Mexico has already lost 95 percent of its tropical humid forests, and UNEP ranks it fifth in the world among the top 10 deforesting countries in terms of total forest loss.[57]

A CRITICAL TREND: FRONTIER FORESTS UNDER THREAT

Aside from boreal forests, 75 percent of the world's frontier forests (defined as original forests remaining in large, relatively undisturbed natural ecosystems) are endangered by human activity.[58] Logging represents the greatest danger[59] while exotic invasions, air pollution, vast fires and climate change also exert severe pressures.[60] In North America, over one-quarter (26 percent) of frontier forests are threatened.[61] Old growth habitat in many of the temperate and boreal forests of both North America and Western Europe continues to be lost.[62]

AN EMERGING TREND: FOREST PLANTATIONS GROW, QUALITY DECLINES

Even in regions in which the area under forest is stable or expanding, forest quality is threatened by increases in monoculture.[63] Globally, forest plantations roughly doubled between 1980 and 1995, often at the expense of natural forests.[64] During this period, the area under forest plantations in the developed countries increased from about 45-60 million ha to about 80-100 million ha, while in the developing world, the area in forest plantations grew from approximately 40 million to about 81 million ha.[65] The Worldwatch Institute reports that at least 180 million ha of forest have been converted to tree plantations worldwide[66] and that in the United States, the expansion of pine plantations has come at the expense of natural forests.[67]

The OECD reports that at national levels, most member countries sustain forest resources in <u>quantitative</u> terms.[68] But the health/quality of these forests continues to be damaged by fire, drought, pests, and air pollution.[69] In many regions of North America, forests are becoming increasingly fragmented, biologically impoverished and weakened or stressed. In many areas there has been a change in species composition from fire-tolerant species to those more prone to insect damage, and exotic forest insects, diseases, and weeds have led to losses of species and habitat diversity. In addition, many air pollutants, including ozone, are harming North American forests;[70] this is the case in parts of the forest around Mexico City, for example.[71]

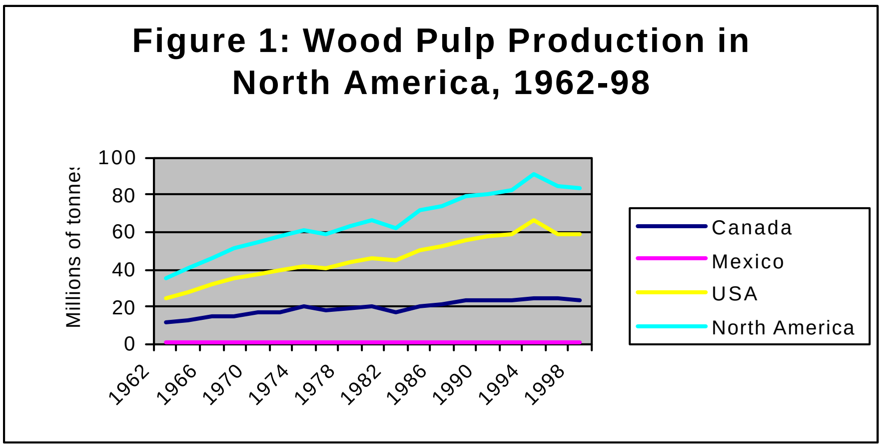
AN EMERGING ISSUE: MAJOR FOREST FIRES INCREASE

Forest fires in Indonesia, Latin America and elsewhere during 1997 and 1998 caused major forest losses. The fires emitted large amounts of carbon dioxide and blanketed a large part of Southeast Asia with haze, causing widespread health and environmental problems. Forest fires were also a major problem in 1998 in Brazil, burning large areas of rain forest and savanna woodland. During Mexico's worst drought in 70 years, smoldering fires burned about 3,000 km^2 of land and sent smoke haze across the southern United States. The Chimalapas forest, harboring many rare species of plants and insects, was particularly threatened by the fires.[72]

A FUTURE PROBLEM: PRESSURES ON FORESTS WILL LIKELY MOUNT

The projected doubling of demand for pulp and paper, lumber, and fuel wood, coupled with population growth, urban sprawl, and the conversion of forests to agriculture, are all forecast to increase pressure on the world's forests.[73] Improved harvesting efficiency and recycling have helped to lower demands for virgin wood:[74] the amount of recycled paper in the global fiber supply for paper nearly doubled between 1961 and 1997.[75] However, total consumption for main forest products increased by 50 percent between 1970 and 1990. Per capita consumption in OECD countries grew even faster[76] and the consumption of virgin-wood pulp is currently expanding at about one to two percent per year,[77] due to increases in population and per capita consumption.

Figure 1 shows the increase in wood pulp production in North America between 1962 and 1998. It is projected that by 2010, global demand for industrial wood fiber will rise by between 20 and 40 percent.[78] The FAO suggests that if current trends continue, overall global wood consumption will increase by 20 percent, paper consumption by 49 percent and fuel wood consumption by 18 percent by 2010.[79]



Source: FAOSTAT 1998

Demand for paper is growing at twice the rate of other major wood products. In the United States and some other major timber-producing nations, it has been predicted that the production capacity of domestic timberlands will be outstripped by increased consumption during the next decade.[80]

By 2050, over one-half of the world's industrial demand for wood will be for pulp and paper manufacture.[81] The Worldwatch Institute points out that even with more recycled and non-wood fiber use, 25-30 percent of global fiber supply for paper will probably still come from virgin wood,[82] and suggests that "one of the most widely recognized costs of paper is the threat it poses to the world's forests."[83] Wood fiber supply is derived primarily from old-growth forests, managed secondary-growth forests and plantations. Expanded production from industrial wood plantations can curb some of the need for further exploitation of natural forests, but under prevailing production patterns, demand pressures will result in more intensive management of existing forests and supplies being drawn from the planet's remaining 'frontier' forests.[84]

III. Agricultural Land

A CRITICAL TREND: DEGRADATION OF AGRICULTURAL LAND

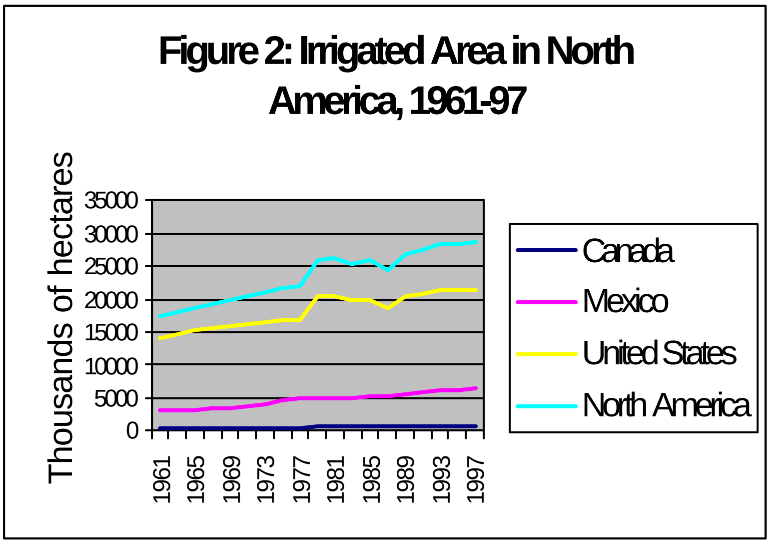
Land degradation remains the greatest threat to agricultural land.[85] Globally, erosion, salinization, compaction and other forms of land degradation affect 25 percent of the earth's land area and continue to impoverish the world's crop and pasturelands.[86] Roughly 1.5–2.5 million ha of irrigated land, 3.5–4.0 million ha of rain-fed agricultural land, and about 35 million ha of rangelands are losing some or all of their productivity as a result.[87] By 1990, an estimated 38 percent of global cropland had already been degraded and each year since, five to six million additional ha of land have been affected by severe soil degradation.[88] In all, about 300 million ha worldwide appear to be severely degraded and 1.2 billion ha, or 10 percent of the earth's vegetated surface, are at least moderately degraded.[89] WRI estimates that, depending on the region, topsoil is currently being lost 16 to 300 times faster than it can be replaced.[90]

Although soil loss through wind and water erosion in North America is generally decreasing due to better conservation practices and programs, soil degradation and loss still outpace gains.[91] About 95 million ha in Canada and the United States are affected by soil degradation.[92] Each year, Mexico loses between 150,000 and 200,000 ha of soil due to erosion, and in 1995 over 32 million ha were considered severely eroded.[93] Salinization affects 1.5 million ha of Mexico's agricultural lands.[94]

AN EMERGING TREND: DECELERATING RATE OF GAINS IN AGRICULTURAL PRODUCTIVITY

Although in absolute terms the world's agricultural lands and technologies associated with industrial agriculture still support a rise in total food production, the growth in yield of world grain harvests slowed during the 1990s, increasing at barely one percent compared with an average annual growth rate of 2.1 percent from 1950 to 1990.[95] Yields of rice and wheat have stabilized over the past few years in Asia.[96] In per capita terms, food production is stagnating, if not declining.[97] The UN reports that per capita grain harvests declined by an average of more than one percent per year since 1984[98] while the Worldwatch Institute maintains that in 1997 they dropped six percent below the all-time high of 1984.[99] Studies also show declines in the average rates of increase in productivity in Canada and the United States.[100]

Gains related to increased inputs in crop and pastureland, crop breeding, irrigation, fertilizers and pesticides are now facing limitations. The amount of land in grain production has dropped by 6 percent since 1981 due to conversion to non-farm uses, other crops, or abandonment because of soil erosion,[101] and there are fewer new productive lands to cultivate.[102] In agricultural sectors of Western Europe, North America, Asia, Latin America and some parts of Africa, a steep decline in available cropland per capita—from 0.43 ha in 1961 to 0.26 ha in 1996—has occurred.[103] During that same period, food production more than doubled. However, some crops now appear to be close to their biological limits[104] as many of the world's major crops approach a "yield plateau" or "yield stagnation."[105] In addition, the capacity of fertilizers to boost yields in many countries may be diminishing.[106] Crop production is also significantly reduced by salinization, which affects one out of five hectares of irrigated land.[107] Finally, after years of increases in the amount of land under irrigation [during the 1960s and 1970s, irrigated cropland area at a global level grew by 2-4 percent annually[108] and in North America it increased from 17.35 to 28.62 million ha between 1961 and 1997 (Fig. 2)], water scarcity is emerging as a serious constraint to extending irrigated area and to growth in food production.[109]



Source: FAOSTAT 1998

AN EMERGING ISSUE: WATER SCARCITY CONSTRAINS EXPANDED FOOD PRODUCTION

Roughly 40 percent of the world's food is produced on the 17 percent of croplands which are irrigated.[110] Farming requires large amounts of freshwater input, accounting for two-thirds of global freshwater withdrawals.[111] Forecasts suggest expanded food production will be constrained by water scarcity.[112] Because demand for cereals and animal protein is projected to increase by 2020,[113] total amounts of cropland are projected to shrink on a per capita basis. In response, irrigation will have to increase to bolster food productivity. One report quotes an estimate that "80 percent of the additional food supplies required to feed the world's population over the next 30 years will depend on irrigation"[114] and another that irrigation capacity may need to triple by 2050 to meet projected crop water requirements.[115] Globally, water withdrawals for irrigation increased by over 60 percent since 1960.[116]

The expansion of irrigated cropland has slowed to less than one percent per year[117] (compared to annual growth rates of 2.3 percent from 1950 to 1995). This is forecast to slow to 0.3 percent in the next few decades.[118] At the same time, withdrawal of water from aquifers for various farming needs is increasing and withdrawals are beginning to exceed rates of replenishment in some areas.[119]

Pumping exceeds natural recharge in about 80 of Mexico's aquifers and in the Ogallala Aquifer underlying the Great Plains.[120] Water from the Ogallala supplies one-fifth of US irrigated land.

Although the rate of water table decline in the latter has slowed in recent years,[121] it is still being depleted at a rate of about 12 billion cubic meters per year.[122]

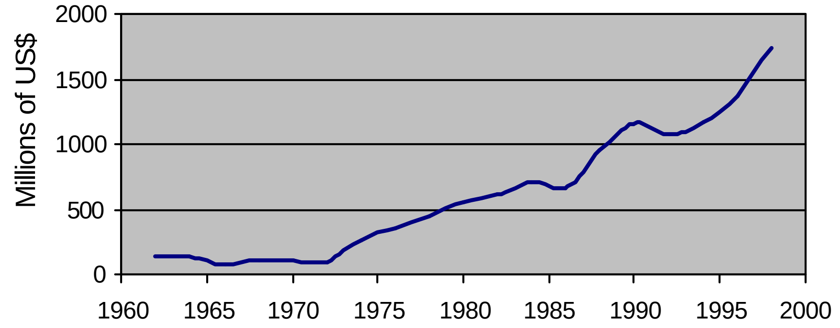
If recent trends are any indication, then competition over water supplies means urban areas win out over agriculture. Accounting for about one-third of total water demand in the mid-1990s, industrial and domestic water demand is projected to increase and reach 45–50 percent of the total by the year 2025.[123] UNEP predicts that at a global level "this reduction in water available for irrigation will affect agricultural productivity and could reduce the ability of water-scarce countries to feed their populations."[124] Furthermore, due to climate change, demand for irrigation is expected to increase in some areas of North America, especially the Great Plains.[125] Already, pressures to use groundwater for irrigation and for a growing population are becoming particularly important issues along the US-Mexican border.[126]

AN EMERGING ISSUE: PERSISTENT ORGANIC POLLUTANTS

Pesticides contribute to expanded food production and, on a global scale, pesticide use is very large and still climbing: over the past half-century, pesticide use worldwide increased 26-fold.[127] While the total consumption of pesticides has declined at varying rates in industrialized countries since 1990, their toxicity has increased since 1975.[128] By contrast, pesticide sales in the developing world are increasing, with some highly toxic insecticides remaining in use.[129]

Of the 12 chemicals called "the dirty dozen," nine are pesticides and most of these are still in use or exist in many countries. All of the dirty dozen are banned or strictly regulated in North America,[130] although banned, restricted or discontinued pesticides continue to be exported from the United States to other, mostly developing, countries. For example, four million tons of chlordane and other pesticides are manufactured by US companies[131] and the World Resources Institute reports that exports of such pesticides from US ports grew from 31,520 tonnes in 1992 to 38,352 tonnes in 1994.[132] Figure 3 shows the growth in the value of pesticide exports from the United States between 1962 and 1998.

Figure 3: Value of Pesticide Exports from the United States, 1962-98



Source: FAOSTAT 1998

Another crisis issue involving persistent organic pollutants (POPs) is the widespread contamination of the Arctic and Antarctic ecosystems, where high levels of POPs are found in wildlife and humans.[133] For example, levels of the pesticide chlordane are 10 times higher in the breast milk of Inuit women than in that of women in southern Canada.[134] The section on trends in air quality, below, includes more information about the long-range transport of such toxic pollutants.

IV. Fresh Water

- *AN EMERGING ISSUE: WATER SCARCITY*

Concerns about coming water scarcities are mounting. Evidence shows that available regional supplies have already begun to outstrip human demands for freshwater. Food insecurity, ecosystem imbalances and political tensions threaten to follow water scarcities.[135] A UN assessment notes that 47 countries, representing one-third of the world's population, experience moderate to high water stress, meaning 20 to 40 percent of available freshwater in those countries is already being used.[136] UN population projections suggest that by 2050, some 40 percent of the world's population will live in countries experiencing water stress.[137] One report sums up a growing consensus: "the world's thirst for water is likely to become one of the most pressing resource issues of the twenty-first century."[138]

Between 1900 and 1995, global water withdrawals rose six-fold, or more than double the rate of population growth.[139] Since 1940, global water withdrawals have increased at an annual rate of 2.5 percent, much faster than that of population growth.[140] Although water supplies are still abundant at a global level, they are unevenly distributed among and within countries.[141] North America, for example, has a large supply of freshwater, but due to unequal distribution and heavy demand in some dry regions, water scarcities occur in many areas, including some parts of Canada's prairie provinces and, in particular, the US southwest[142] and northern Mexico.

Water use is expected to increase by 2010, as expanding populations require more water to live, eat and work. By 2050, between 1 and 2.4 billion people will live in water-scarce regions. Based on current projections, water supplies will run out by the next century.[143]

AN EMERGING TREND: GROWING COMPETITION FOR WATER

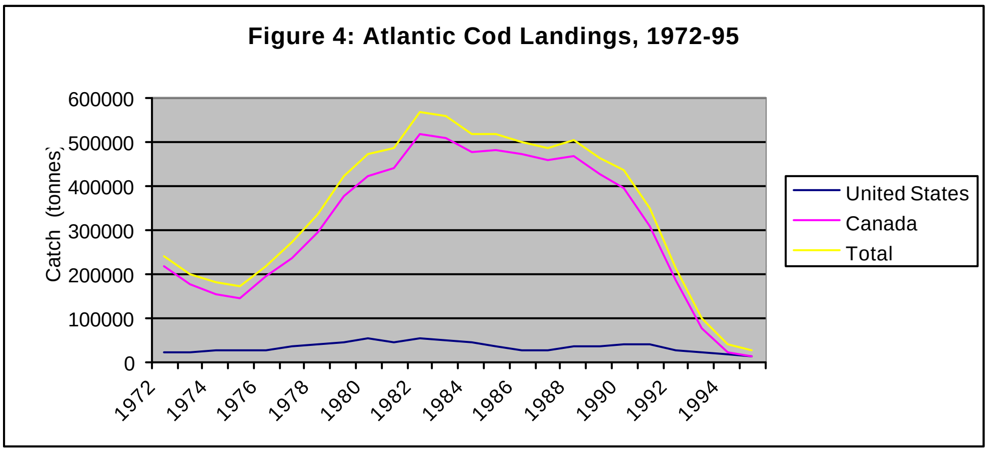
The UN notes a sharp increase in competition between rural and urban users of surface and groundwater in the past few years.[144] City-farm competition for water is increasing in the western United States. Cities in Arizona, California and Colorado, among others, are buying water, water rights, or land with water rights.[145] Cities in the southwestern United States, for example, may gain water rights in rural areas by paying more for them than do farmers.[146] Withdrawals for agriculture in North America have been declining while domestic water use has almost doubled since 1960 due to population growth and urban expansion.[147] And the demand for water is growing in dry areas. It has been projected that dramatic population growth in the dry interior of the western United States will continue and may increase by more than 30 percent by 2020, increasing the need for conservation and water-sharing management schemes.[148]

V. Marine Ecosystems

A CRITICAL TREND: DECLINING WILD FISH STOCKS

Chronic overexploitation of some commercial ocean fish species continues to threaten marine ecosystems worldwide. The total wild marine fish catch has been declining since 1989, when it peaked at 74.4 million tonnes. The record high for the total world fish catch (wild and farmed) was 108.9 million tonnes in 1996, a six-fold increase over the 1950 catch.[149] In 1950 there were almost no overexploited fish species, but by 1996, 35 percent were overexploited and a further 25 percent were close to being exhausted.[150] FAO estimates that 11 of the world's 15 major fishing grounds are seriously depleted and 70 percent of the commercially important marine fish stocks are either fully fished or overexploited, such that reproduction cannot or can only barely keep up.[151] FAO reports show that the rate of increase in the world's fish harvest is approaching zero.[152]

FAO also identifies sequential patterns of exploitation and depletion of regional fishing grounds and of specific fish stocks. Harvests of high-value fish peaked in the Atlantic between the late 1960s and early 1970s, in the Pacific between the mid-1970s and late 1980s, and in the Indian Ocean in the early 1990s.[153] The trend that emerged in peak harvests of different fish species revealed a decline in the catch of high-value demersal fish with substitution by lower-value pelagic fish.[154] Certain fish stocks have experienced precipitous drops, with Atlantic cod, haddock, and redfish stocks all but collapsed in some areas of the North Atlantic.[155] Figure 4 shows the sharp decline in Atlantic cod landings between 1972 and 1995.



Source: CEC 2000
US data represent round weight; Canadian data represent live weight.

The Atlantic finfish catch off the east coast of North America declined from 2.5 million tonnes in 1971 to less than 500,000 tonnes in 1994.[156] Twenty-one of the 43 groundfish stocks in Canada's North Atlantic are in decline, 16 others are showing no signs of growth[157] and nearly one-third of US federally-managed fishery species are overfished.[158]

An Emerging Trend: Aquaculture

Aquaculture is one of the fastest growing sectors in the food industry[159] with worldwide production more than doubling between 1984 and 1994[160] and expanding at an average annual rate of 11 percent between 1990 and 1995.[161] With the decline in many wild fish stocks, that percentage will likely increase; one projection suggests that, under favorable conditions, global aquaculture production could almost double from 1998 levels by the year 2010.[162] In North America, fish farming has developed significantly with harvests increasing from 375,000 tonnes to 548,000 tonnes between 1985 and 1995. In only one year, 1995–96, Mexico's aquaculture sector increased by 7.4 percent. Mexico has a strong and expanding shrimp cultivating industry.[163]

Numerous environmental costs are associated with aquaculture, and these costs need to be weighed against the important role they play in easing pressure on wild fish stocks.[164] Environmental costs include the addition of harmful nutrients from uneaten food and waste material to local waters, diseases spread from farm-bred fish, the escape of genetically modified fish that may harm the integrity of wild stocks, and an often heavy reliance on antibiotics in enclosed areas.[165] Evidence shows that shrimp farming is especially harmful to coastal habitats. In some regions, mangrove swamps are destroyed, eliminating habitat for many aquatic species, exposing coastal areas to erosion and flooding, altering drainage patterns and increasing salt intrusion.[166]

AN EMERGING TREND: INCREASINGLY THREATENED CORAL REEFS

Coral reefs worldwide are increasingly being lost to development, industrial and nutrient pollution, destructive fishing and recreational activities, and dredging.[167] WRI estimates that globally, 58 percent of coral reefs are threatened, 27 percent are at high risk[168] and some 10 percent have already been severely degraded.[169] Overexploitation from fishing and coastal development is the major threat to reefs, affecting a third of all reefs.[170] If current trends persist, a total of one-third of the world's coral reefs will be destroyed within two decades.[171] Coral reefs are among the richest centers of biodiversity and if human pressures continue to increase, it has been suggested that one in five of the species presently contributing to that biodiversity could die out within the next 40 years.[172] Mexico has coral reefs in both the Atlantic and Pacific oceans, with its largest, the Great Maya Reef off the coast of Yucatán, making up part of the world's second largest coral reef system. The United States has 16,879 km^2 of coral reefs, the most extensive of which are found in south Florida and the Florida Keys.[173]

AN EMERGING TREND: RISE IN NITROGEN FIXATION

Nitrogen entering marine ecosystems from land-based activities (agricultural runoff and urban wastewater) has led to a global problem of nitrogen overload.[174] Over 40 million tonnes of nitrogen are transported by rivers and enter estuaries and coastal waters each year.[175] Fertilizer is the dominant source of nitrogen entering watercourses. Global consumption of fertilizer increased tenfold between 1950 and 1989.[176] Nitrogen accounts for 66 percent of fertilizers consumed in developing countries and 55 percent in developed countries.[177] In industrialized countries, the trend toward rearing livestock in intensive feedlots coupled with huge increases in livestock populations (numbers of cattle rose by 40 percent between 1961 and 1997, for example), has led to the deposition of vast amounts of manure into the environment. In the United States, about 40 percent of the nearly 160 million tonnes of manure produced annually is collected from confined animals and must be disposed of. Manure is a source of nitrogen entering the environment, by one estimate accounting for 32 million tonnes of nitrogen each year.[178]

Nitrogen overload now appears to be on the increase in coastal regions globally and this trend will likely continue.[179] Global fertilizer consumption will increase by at least 55 percent by 2010 if current practices continue.[180] By one estimate, nitrogen compounds will increase by at least 25 percent in more developed regions such as North America and will at least double in less-developed regions.[181]

Overloads of nitrogen in aquatic ecosystems initiate a process of overfertilization leading to hypoxia (oxygen depletion), which has been called one of the most serious threats to aquatic environments, particularly in coastal estuaries and inshore waters.[182] There has been a threefold increase in oxygen-starved coastal regions worldwide over the past 30 years.[183] Northern Europe and northeastern North America are already the sites of nitrogen trouble spots. It has been reported that 52 percent of US estuaries experience some degree of oxygen depletion.[184] An hypoxic 'dead zone,' which reaches the size of New Jersey after some episodes of river discharge, appears each summer in the Gulf of Mexico due to this process.[185]

AN EMERGING ISSUE: TOXIC ALGAE BLOOMS AND TOXIC MICRO-ORGANISMS

Toxic algal blooms associated with nutrient loading are increasing, causing harm to fish, seabirds and marine mammals.[186] Such blooms or 'red tides' have increased in distribution, frequency and severity in many coastal areas,[187] have spread to new places and have become more dangerous.[188] Excessive nutrients have also been blamed on creating conditions that have led to an increased frequency in outbreaks of harmful microorganisms in coastal waters.[189] Toxins released from the micro-organism *Pfiesteria piscicida* have led to a number of major outbreaks of fish disease, fish kills and associated human health problems in recent years along parts of the US east coast, while other similar organisms found from the coasts of the Carolinas to the Gulf of Mexico may also become toxic in nitrogen-enriched waters.[190]

AN EMERGING TREND: THREATENED COASTAL AREAS

Today, more than half the world's coastlines are threatened by human activities,[191] but population increases in coastal areas and related development pressures on coastal ecosystems can be expected to grow. About 37 percent of the world's population live within 100 kilometers of a coast. Average coastal population density is twice the global average[192] and 16 of the world's largest cities are located on coasts, including nearly 40 percent of cities larger than 500,000.[193] And coastal populations are growing rapidly worldwide,[194] with much of the future growth expected in the developing world.[195]

More than half of all Americans live within 130 kilometers of the ocean. Coastal populations are growing at four times the national average in the United States,[196] with some of the highest levels of urban growth taking place in small coastal cities.[197] By 2025, it is expected that 75 percent of US citizens will be living in coastal areas.[198] Presently, 23 percent of the Canadian population lives in coastal communities, and Mexico's tourist destinations on its Caribbean and Gulf coasts attract an increasingly heavy tourist trade.[199] Over the next ten years, North Americans will continue to be drawn to the coast to live and to enjoy recreational and tourist activities.[200]

Coastal ecosystems are the richest storehouses of marine biodiversity.[201] The conversion of land in coastal areas to urban uses is associated with a large number of environmental pressures that impact on these fragile areas, including physical degradation from the building of infrastructures, exploitation of marine resources, and pollution from the air and from land-based activities. Especially threatened are the most productive ecosystems such as tidal flats, saltwater marshes, seagrass beds, mangrove swamps, estuaries, and wetlands.[202] The predicted increases in coastal development bodes ill for the health of marine ecosystems.

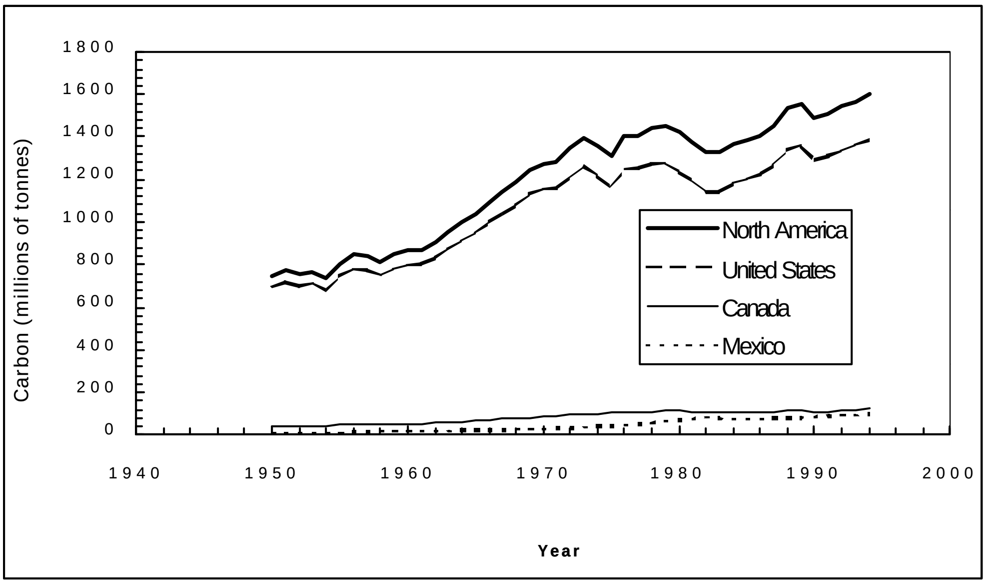
VI. Air

A CRITICAL TREND: GREENHOUSE GAS EMISSIONS

The Intergovernmental Panel on Climate Change (IPCC) concluded that human activities have contributed to a recent warming trend and that global climate change has the potential for serious effects on human and natural systems.[203] Global carbon emissions have risen nearly fourfold since 1950, with emissions from fossil fuel burning reaching a new high of 5.7 billion tonnes in 1997, an increase of 1.5 percent over the previous year.[204] The net increase in carbon to the atmosphere each year is about 3.2 billion tonnes.[205] The burning of fossil fuels is the primary source of greenhouse gases and CO_2 is the dominant greenhouse gas. More than 80 percent of yearly CO_2 emissions come from the production of energy,[206] and motor vehicles account for more than 15 percent of global fossil fuel CO_2 releases.[207]

North America emits more greenhouse gases than any other region except Asia, and emissions are increasing.[208] Worldwatch estimates that the average American accounts for 21 times as much carbon as does the typical Indian.[209] The United States, the leading emitter of carbon, is responsible for 23 percent of total emissions. It also emits more per capita than any other country.[210] Between 1990 and 1996, its output expanded by 8.8 percent, with a 3.5 percent increase in 1996 alone.[211] Figure 5 shows the growth in CO_2 emissions from fossil fuel consumption and cement production in North America between 1950 and 1996.

Figure 5: CO_2 Emissions from Fossil Fuel Consumption and Cement Production in North America, 1950–96



Source: CEC 2000

The Earth's climate has warmed by about one-half degree Celsius this century.[212] The past three decades have seen the most rapid rise with the average global temperature of 13.99 degrees Celsius in 1969–71 rising to 14.43 by 1996–98, registering a gain of 0.44 degrees Celsius.[213] Human-influenced changes in the global climate are likely to cause serious problems in many parts of the world.[214]

FUTURE PROBLEMS: CLIMATE-RELATED IMPACTS

The IPCC warns that if the rate of fossil fuel use remains unchanged, CO_2 emissions are expected to double from pre-industrial levels by the year 2050, and to increase the earth's average surface temperature by 1-3.5 degrees by 2100; a rate of change faster than any observed over the last

10,000 years.[215] Impacts of climate change on ecosystems remain difficult to predict. One report sums up the potential broad-scale results: "changes in the boundaries, structure, and functioning of ecological systems, especially forests where there could be a near-term die back and a shift in boundaries of between 150 and 650 kilometers polewards; a decrease in agricultural production in the tropics and subtropics, even if total global food production does not drop; less predictable availability of freshwater; and the displacement of tens of millions of people from small island states and low-lying deltaic areas, if sea levels increase by one meter."[216] The ideal range for many North American forest species could move 300 km to the north,[217] one of the many potential changes to North American ecosystem as a result of global warming. Already the modest rise in temperature is causing ice caps and glaciers to melt.[218] Some scientists are suggesting that the recent climate change is a significant factor in the increased frequency and severity of some types of natural disasters such as hurricanes and tornadoes in North America.[219]

AN EMERGING ISSUE: AIR POLLUTION AND INCREASED RESPIRATORY AND OTHER DISEASES

On average, urban air quality in Canada and the United States (and most other developed countries) has improved over the past 20 years, although many large cities such as Los Angeles and Mexico City still experience severe air quality problems. Unlike declining levels of CO and lead in most Canadian and American cities, levels of ground-level ozone and fine particulates are not decreasing.[220] Ozone pollution has become widespread in European, North American and Japanese cities because of increases in vehicle and industrial emissions.[221] Of the industrial chemicals included in North American pollutant release and transfer registers, the largest releases occurred to the air.[222] Although the United States contributes 90 percent of the North American total of releases and transfers of chemicals, Canada contributes more than would be expected given its size.[223] High levels of fine particulates and ground-level ozone are also associated with increased urban sprawl and the growth in the number of motor vehicles and the distances they are driven.[224] WHO ozone criteria are exceeded in all OECD member countries; in Mexico City, ozone levels are high despite efforts to control air pollution and in 1995, ozone levels exceeded the national norm on 324 days.[225]

Air pollution is emerging as a key contributor to some respiratory and cardiovascular diseases that are impairing health and killing vulnerable people. Epidemiological data from cities in the United States suggest that large numbers of people face health risks from air pollution. WRI reports that 80 million people in the United States are exposed to levels of air pollution that can impair health[226] and UNEP reports that air pollution may be responsible for 50,000 deaths annually, or more than 2 percent of all deaths in that country.[227] Suspended particulate matter from vehicles and other sources contribute to the deaths of 6,400 people in Mexico City each year and about 29 percent of all children have unhealthy blood levels.[228] Air pollution is now linked to a startling rise in the prevalence of asthma among children and young adults, mostly in affluent countries, over the past two decades.[229] Ozone, a principal component of smog, is thought to exacerbate asthma symptoms. It has been estimated that high ozone levels in 13 US cities were responsible for about 10,000 to 15,000 additional hospital admissions and 30,000 to 50,000 additional emergency-room visits during the 1993–94 ozone season.[230] There is also clear evidence that acidic air pollutants affect the health of sensitive individuals, especially the young, the elderly and those with respiratory ailments.[231]

AN EMERGING ISSUE: LONG-RANGE TRANSPORT OF TOXIC SUBSTANCES

There is increasing evidence that air currents can carry many toxic pollutants over long distances, such that associated health problems have emerged in what were thought to be pristine environments. UNEP reports that there appears to be a global process of distillation whereby winds transport pollutants evaporated in warmer areas as far as the Arctic where they condense and become concentrated in Arctic food chains.[232] High levels of toxins such as PCBs, DDT, toxaphene, hexachlorobenzene, chlordane, lindane, dieldrin, mercury and dioxin have been found in the Arctic.[233]

The long-range air transport of these pollutants is becoming of widespread concern throughout North America.[234] For example, a significant proportion of airborne mercury from the industrial areas of the United States and Canada circulates far beyond its sources,[235] resulting in particularly elevated mercury levels in the northeastern United States, eastern Canada and the Arctic. In the Arctic, elevated levels of mercury appear to be attributable in part to distant sources, including those in Europe and Russia.[236] Elevated mercury levels in fish and marine mammals in the Arctic are placing a percentage of females and the unborn in the "increasing risk" range.[237]

POPs can be transported long distances and many eventually concentrate in northern latitudes because of atmospheric circulation patterns, their tendency to revolatilize many times, and global distillation.[238] A recent CEC report shows that dioxin emissions from North American sources, 74–85 percent of which come from the United States, contribute 85 to 98.5 percent of the deposition at the eight locations monitored in the Canadian polar territory of Nunavut.[239] The appearance of high levels of another POP, chlordane, in the breast milk of Inuit women, has also been noted.[240]

Ground-level ozone, the primary component of smog, is another pollutant that is transported along North American air corridors. As shown above, its effects include significant impairment of lung functioning. It may also lead to inhibition or interference with the immune system. Both symptoms have been viewed as local issues until recently. It now appears that ozone and its precursors (NO_x and VOCs) can travel relatively long distances in the atmosphere and be transported from region to region. Given that its levels are additive, ozone or its precursors arriving from elsewhere can create dangerous conditions even where local emissions are only moderate.[241]

AN EMERGING ISSUE: LINGERING EFFECTS OF ACID RAIN

Acid rain is now emerging as a major problem in the developing world, especially in regions such as parts of Asia and the Pacific in which the use of sulfur-containing coal and oil has surged.[242] Regulations restricting sulfur emissions in industrial countries, on the other hand, have been relatively effective in reducing transboundary pollution. In eastern North America, the quantities of acidic sulfates entering lakes and streams have declined over the past 25 years. But it is now thought that the damage caused by acid deposition may be more fundamental and long lasting than has been believed. Some sensitive areas are not rebounding as quickly as had been expected,[243] and there is some scientific uncertainty about the cause. One EPA study of five North American and three European regions between 1980 and 1995 showed that in a large region from eastern Manitoba through the upper Great Lakes to Quebec and Vermont, streams and lakes had not recovered. It is likely that as sulfate levels dropped, the capacity of the soil to neutralize the acid became depleted. Another explanation is that the problem of acid rain is linked with other air pollution issues arising from the burning of fossil fuels and that these should not be studied in isolation.[244] For example, carbon absorbs UV radiation, but climate change and acidification have led to decreases in dissolved organic carbon concentrations in North American lakes while at the same time depletion of the ozone layer has caused an increase in UV radiation. The result is deeper penetration of UV radiation into lakewaters and higher rates of death and disease in fish and aquatic plants.[245]

SECTION FOUR: ECOLOGICAL FOOTPRINTS, MATERIALS FLOW ANALYSIS AND THE IMPACT/WSM MODEL

Standard economic indicators—those that account for the financial flows in an economy—provide incomplete information on the environmental consequences or implications of economic activity. There is a need for new information tools if we are to be able to monitor progress toward the development of more eco-efficient economies and long-term sustainability. Indicators should measure the physical dimensions of economies, as well as their financial dimensions.

As noted above, the three parties of the CEC have instructed the Secretariat to examine two methods when thinking about the future: the ecological footprint method, and materials flow analysis. Although different in methodology, they are similar insofar as they provide insights to biophysical impacts of current per capita and total production, as well as ways to think about future carrying capacities.

Both methods also help organize complex environmental indicators in ways that are accessible to the public as well as to experts. As noted below, the emphasis of both methods lies in the biophysical consequences of our economies. More important, they introduce to varying degrees the notion of *biophysical limits.*

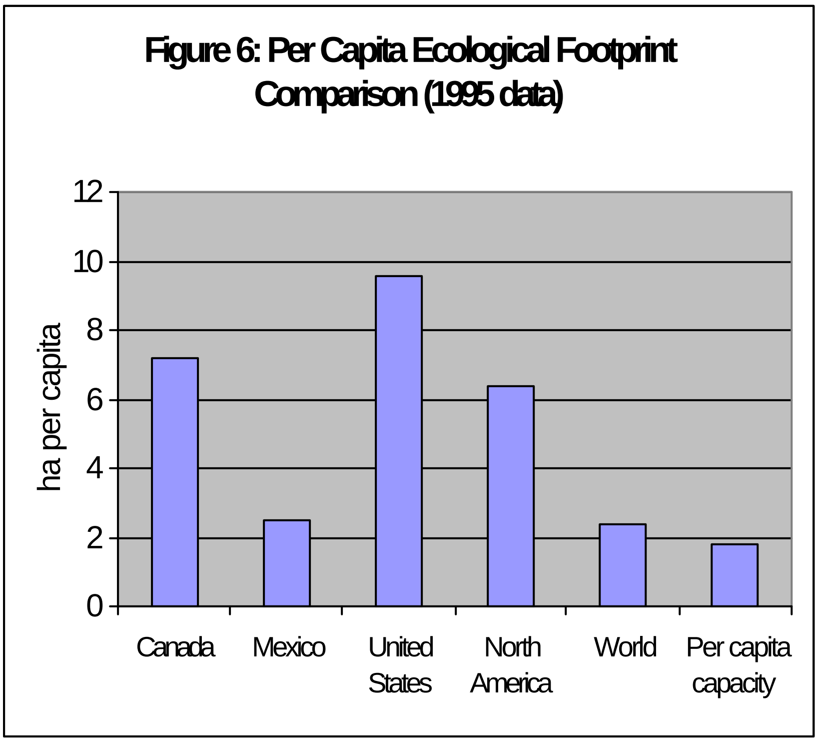
Given the emphasis of both methods, the next step in the CEC project is to examine different environmental indicators using these methods. Indicators that will be examined include changes in land use arising from competition between agricultural use and urban expansion, with a special focus on water use; and changes in land use related to forests, with indicators including total forest cover, changes in forest quality, changes in land use, and changes in areas rich in biodiversity.

I. Ecological Footprint

Among the most popular and easily understood indices or macro indicators of the relationship between material or physical flows and environmental impacts is the ecological footprint (EF) concept. Since it was first introduced, the ecological footprint has been seen as an effective pedagogical device, as well as a robust analytical tool. It is intended to communicate the requirements of current total human resources in ways that are tangible in a biophysical sense, as well as accessible to specialists and non-specialists alike. Indeed, the term, coined and made popular by Rees and Wackernagel in the early and mid–1990s,[246] has entered the lexicon,[247] providing a powerful metaphor and pedagogical tool for understanding human impact and dependence on the environment.[248] This approach is an accounting tool that "aggregates human impact on the biosphere into one number: the bio-productive space occupied exclusively by a given human activity."[249] Wackernagel defines the ecological footprint as "any defined population (from a single individual to a whole city or country)…expressed as the area of biologically productive land and water required exclusively to produce the resources consumed and to assimilate the wastes generated by that population, using prevailing technology."[250] Productive land as a proxy for natural capital and for many resource flows and services rendered by nature "communicates the finite character of the world in readily understandable terms."[251]

The ecological footprint approach uses robust government statistics and adds up human uses of ecological services in a way that is consistent with thermodynamic and ecological principles. Wackernagel and associates point out that the resulting figures actually underestimate the biologically productive areas necessary to sustain people because they assume optimistic yield figures, do not include all uses of nature,[252] and use a very conservative estimate of the amount of bioproductive area to leave relatively untouched for the use of other species.[253]

Calculations for North America reveal the extent to which highly-developed countries have an impact on the global environment. At 1995 consumption levels, the ecological footprint of the average US citizen is estimated to be 9.6 ha, that of the average Canadian to be 7.2 ha, while only 2.5 ha are needed to support the average Mexican citizen.[254] The average North American footprint is 6.4 ha, compared to the world average of 2.4 and the actual available per capita capacity of 1.8 (Fig. 6). Table 2 provides a summary of the calculations employed to arrive at Canada's per capita ecological footprint.



Source: Redefining Progress 1999

Table 2: Sample Calculation: Canada's Ecological Footprint

DEMAND		SUPPLY			
FOOTPRINT (per capita)		EXISTING BIO-CAPACITY WITHIN COUNTRY (per capita)			
Category	Equivalent Total [ha/cap]	Category	Yield Factor	National Area [ha/cap]	Yield Adjusted Equiv. Area [ha/cap]
Fossil energy	3.454369707	CO_2 absorption land		0	0
Built-up area	0.68318694	Built-up area	1.059588	0.227569635	0.68318694
Arable land	1.28915069	Arable land	1.059588	1.547513775	4.645792052
Pasture	0.704789361	Pasture	1.052061	1.037106319	0.479545584
Forest	1.01524594	Forest	0.444279	15.32912727	7.953181893
Sea	0.069114278	Sea	1	3.285117151	0.208539439
		TOTAL existing		21.42643415	13.97024591
TOTAL used	7.215856916	TOTAL available	(minus 12% for biodiversity)		12.2938164

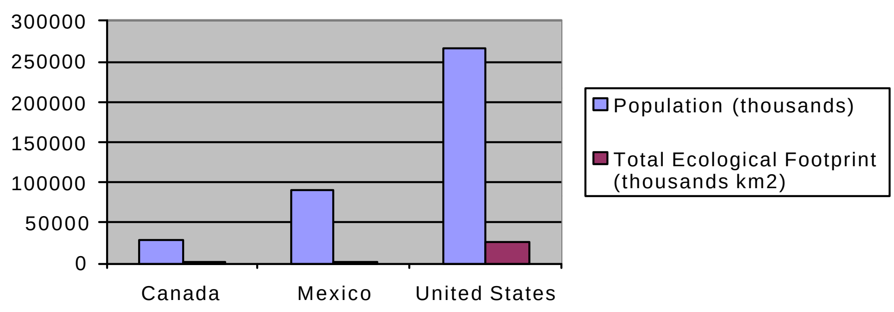
Excerpted from: Redefining Progress 1999

The per capita capacity of the planet available to accommodate the world's population can be calculated by dividing all the biologically productive land and sea space by the number of people. Of the resulting 2.1 ha required for each individual's needs, 1.6 ha are land-based natural and managed ecosystems and 0.5 ha are ecologically productive oceans. If 12 percent of the planet's biologically productive space were set aside as protected areas for the preservation of wild species, the space available for each individual is reduced to 1.8 ha. This, then, is the ecological benchmark for comparing peoples' or nations' ecological footprints. A region's 'global ecological deficit' "refers to the gap between the average consumption of a person living in that region (measured as a footprint) and the biocapacity available per person in the world."[255] By this account, the average North American's footprint exceeds the per capita capacity of the planet by 4.7 ha.

There are two basic approaches to ecological footprint calculations. Compound "footprinting," the most robust and comprehensive approach, is applied at the national level by tracing all the resources consumed and wastes emitted by a nation. Consumption is calculated by adding imports to domestic production and subtracting exports for some 60 categories of materials. Both primary resources and manufactured products flowing through the economy are included. To express resource use in spatial units, the total amount consumed is divided by the respective ecological resource productivity and the total amount of waste is divided by the corresponding capacity to absorb waste. To avoid exaggerating the footprint, each component is screened for double counting by not adding secondary ecological functions once a space has been credited for a primary use. Comparable units of measure are arrived at by adjusting components for their biological productivities, such that land with higher average productive capacity appears larger in the footprint accounts, and by adjusting for the relative ability of a nation's ecological capacity to accommodate footprints. The results give a total national footprint number and a number for the nation's overall biological capacity. The region has an ecological deficit if the footprint exceeds the capacity.

Calculations for North America result in the following; the United States has a total national footprint of 25.5 million km^2 but a total capacity of 14.7 million km^2 (Figure 7). In per capita terms, this means that the country has a deficit of 4.1 ha per capita. Mexico's per capita deficit is 1.3 ha, while Canada still has 5.1 ha of available capacity per person. The former two countries, then, are net importers of ecological capacity. In a ranking of the 52 countries for which EFs have been established, the United States, Canada and Mexico rank first, third and thirty-seventh in the size of their EFs, respectively.

Figure 7: Total North American Ecological Footprints, by Country (1995 data)



Source: Redefining Progress 1999

The study of the ecological footprints of 52 nations shows that most of these import ecological capacity and that humanity's EF is actually larger than the planet's biologically productive space.[256] The total human footprint can exceed the planet's capacity in a situation of 'overshoot' because nature's capacity to render services such as waste absorption can be exceeded for a period of time and resources can be harvested faster than they regenerate for some time before they are depleted. Furthermore, technological advances, cheap energy sources and easier access to distant resources can mask constraints imposed by increasing resource scarcity.[257]

Component-based footprinting, the second basic accounting method, is more flexible and instructive for calculating the footprints of individuals or of organizations. With this method, each category of consumption is added up, but since reliable data for indirect consumption (such as embodied energy in goods) is scarce, this method is more prone to error.[258]

The ecological footprint approach is not a predictive model, as it accounts only for the status reflected by the data inputs. By testing 'what if?' scenarios, however, it can show the degree of change necessary to reduce national footprints to a level within the earth's carrying capacity.[259] For example, calculating the footprints for various options can be used to evaluate different strategies for more resource-efficient ways of meeting human needs.[260] As such, it may be a useful tool for weighing the merits of potential policies for a sustainable future.[261]

The ecological footprint method is attractive in that it arranges very complex resource use patterns into a single, aggregated number: the equivalent land required. As an environmental and natural resource indicator, the ecological footprint method has the advantage of forwarding a single number, a goal that continues to elude just about everyone else working on aggregated environmental indicators.

However, as with any level of aggregation, one needs to be very careful about what is being mixed, and why, and how different indicators are compared, weighed and averaged. Although the ecological footprint may be useful in suggesting some proxy indicators of resource uses, a current area of debate among economists is the extent to which it informs us about carrying capacities, assumed rates of technological innovation, and whether we are moving away from or towards future sustainability objectives.[262]

Although not a predictive tool, the ecological footprint nonetheless does suggest some kind of biophysical equilibrium or carrying capacity for countries, based on a proxy estimate of land equivalent used per capita. Depending on how one factors in rates of technological innovation—that is, will as-yet undiscovered technologies provide some "fix" for environmental problems—coupled with projected rates of population growth, one can use the footprint approach to suggest future directions of resource use. In the instance of the United States, this means reducing the current footprint deficit of 4.1 ha per capita. This reduction becomes more complicated for Mexico, given the current rates of population growth coupled with the current deficit of 1.3 ha per capita.

This method also suggests what the average footprint ought to be, based on a global level. The ecologically productive land available to each person on earth is 1.8 hectares. This includes wilderness areas that should not be used for human activity. Assuming that the typical North American today consumes three times his or her share of available lands based on the global average, then what does this mean for future?

To take a key indicator of environmental quality, fresh water, current projections suggest that four billion people worldwide will experience some water stress, and 2.3 billion will live with high stress. By 2050, one half of the world's population, or close to 5 billion people, will live in areas experiencing water stress, with 3 billion under high stress. One scenario—not based on the ecological footprint method but nevertheless of relevance—suggests that by 2025, 37 percent of Canadian and US residents will experience water stress.[263]

It's clear that the above projections are debatable. Yet what the footprint method helps show is that if current levels of per capita productive land use continue, coupled with population increases, the current ecological deficit will increase. The footprint device serves as a powerful metaphor to bring the concept of ecological overshoot, carrying capacities and sustainability into the public debate.[264]

II. Materials Flow Analysis

Materials flow analysis also uses macro indicators to show the quantities of materials that flow into, through, and out of the economic system each year. The unit of accounting is metric tons. This information is used to create sets of physical accounts at various levels (e.g., national, regional or economic sector) that parallel the System of National Accounts used today in all countries to track financial flows. Physical accounts support the development of indicators that inform us about total quantities of resource use and waste generation, and relate materials use to economic performance over time. Are economies becoming more or less efficient in their use of resources? Are they generating more or less waste per constant unit of GDP? How do different economies compare? Such indicators allow policy-makers to analyze production and consumption activities in terms of their potential impacts on society and the environment. Physical flow indicators are stand-alone metrics designed to complement monetary indicators like GDP; they do not represent modified or "green" versions of traditional monetary indicators.

Using existing data, the chosen indicators help to capture a picture of the amounts of industrial minerals, construction materials, metals, chemicals, fossil fuels and many other materials, both resources and wastes, that move through industrialized economies. Unlike the EF method, materials flow analysis includes an account of 'hidden' flows that do not enter the economy (such as water pollution and landscape disturbance). Analysis can be extended to reveal the environmental pressures and impacts of the sectoral activity.

By aggregating indicators, a Total Materials Requirement indicator can be calculated to show the total amount of physical materials used by a national economy, or the sum of domestic and imported primary natural resources and their hidden flows.[265] Initial work on material flows through industrialized economies is being conducted by the World Resources Institute and has the potential to be applied to all of North America.[266] It shows that the per capita Total Materials Requirement for the United States seems to be leveling off at about 75 to 85 metric tons per year. Economic growth generally tends to be tied to increasing use of natural resources and materials, but over the past two decades the overall US economy grew slightly faster than did its use of natural resources. This modest trend toward the de-coupling of natural resource use and economic activity may be a sign that the economy can grow without increasing the burden on the planet. To generate $100 of income in the United States now requires about 300 kilograms of natural resources, including hidden flows. The OECD member countries have set a target to reduce this ratio by a factor of 10, to 30 kilograms per $100 over the next several decades.[267] Thus, macro indicators such as those used by material flows analysis can help nations to set targets, and eventually to measure the success of policies implemented to attain them.

There is evidence of growing international momentum to develop physical accounts that can be used in parallel with traditional monetary accounting systems. The governments of the United States, Germany, the Netherlands, Japan, and Austria have funded studies to develop national physical accounts for their countries. A joint research report published in 1997 led to similar studies being undertaken in other countries, including Finland, Poland, Sweden, Italy, Australia, Brazil, Malaysia, Egypt, and the European Union as a whole. A number of European Union countries have established long-term national targets for material and energy efficiency, together with indicators for measuring progress, which is likely to stimulate demand for the collection of material flow statistics. The OECD Working Group on the State of the Environment is planning to establish a forum for collaborative efforts on the development and implementation of material flow models.

IMPLICATIONS OF MATERIALS FLOW ANALYSIS FOR POLICY-MAKING

1. In all OECD countries studied to date, the efficiency of materials use has improved dramatically and a number of hazardous flows have been stabilized or reduced. But high economic growth and changing consumer lifestyles have combined to offset many of these gains. Absolute quantities of material inputs and waste outputs have grown steadily since 1975. Flows of hazardous wastes in the United States have increased by up to 30 percent. This suggests that technological efficiency gains and economic restructuring towards less energy- and material-intensive activities are not enough to bring about real reductions in resource use and pollution. Policy measures will be required if material flows of economic, strategic, environmental, or human health concern are to be controlled.
2. Physical accounts and indicators capture material flows at every stage of the material cycle, from "cradle to grave." Current environmental policy tends to focus on controlling emissions and discharges at the processing and manufacturing stage but many hazardous materials are embedded in products, where they may or may not receive appropriate treatment at the

disposal stage. Materials flow analysis suggests a need for policy measures that focus more on resource extraction and the initial design and material components of products, in order to permit the reduction of problems managing hazardous substances at later stages, when they enter the environment during use or disposal.

3. Such a large number of materials are in industrial use, and their patterns of use within and among countries have become so complex, that regulation aimed at specific substances or technologies cannot adequately protect against hazardous waste flows. To complement such narrowly focused regulation, governments increasingly are enacting broad waste minimization and take-back requirements, thereby shifting some of the management burden to industry and, in some cases, consumers. The actions of both industry and consumers are judged to be more effective in implementing remedial actions. MFA supports the design of broad waste management requirements by documenting the quantities, uses, and disposal routes of the material flows of greatest concern.

Based on the instructions of the Parties to the CEC, this project will employ the materials flow analysis methodology to illustrate changes in key environmental indicators. The CEC will work with the World Resources Institute—the research leader in this method—to provide an overview of existing methods and data, and to focus future analysis on North America.

Clearly, not all resource flows can be examined simultaneously. Therefore, the materials flow analysis will focus on one set of environmental indicators linked to changes in North American forest cover. This will provide data based on the materials flow analysis on changes in forest cover, changes in quality and associated changes in land use. Such information can, in turn, provide valuable baselines for changes in biodiversity indicators.

Other environmental indicators can also be examined through the above focus. For example, the forestry sector is one of the largest energy consumers in US manufacturing and its energy use helps determine the overall carbon intensity of the US manufacturing sector. Since 1975, the pulp and paper industry has reduced its carbon intensity through increased use of renewable forms of energy. Of an increase in total energy use from 115 to 180 million tons of various energy carriers, almost 90 percent was supplied by renewable fuels, mainly wood wastes from the industry's own operations. Improvements in energy efficiency tell a mixed story. In 1975 about 0.4 tons of energy carriers (all fuels on a mass basis) were required to produce one ton of finished paper product. This figure had not changed by 1991. On a BTU basis, there was an improvement from about 40 million BTUs per ton of paper to about 35 million BTUs.

III. The Impact/WSM Model

A related area of analysis will involve the question of resource competition and ensuing environmental consequences. Specifically, analysis will concentrate on competition between agricultural production and expanding urbanization.

As noted above, current trends suggest that urban sprawl is exerting pressure on productive lands, thereby accelerating the conversion of lands to urban areas. Increased urbanization concentrates demand for water into smaller geographical areas, thereby increasing pressure on water supply and sanitation infrastructure. This can result in a significant increase in the cost of water supply and delivery, as well as a number of environmental costs, including overexploitation of water sources and their pollution and contamination, which in turn increases demand. The impacts of environmental degradation on freshwater transcend water supply issues through direct links to economic performance, human health, social stability, and even international security.[268]

Among the environmental issues that need to be examined are the future impacts of competition between agriculture and urbanization upon water scarcity, food production, non-agricultural water use and associated changes in land use.

As noted above, water availability for agriculture is considered to be one of the most critical factors for food security in many regions of the world. To explore the relationships between water availability and use and food supply and demand, comprehensive analytical tools are needed at various spatial scales, ranging from river basins, countries or regions, to the global level. This part of the CEC project presents a global modeling framework that integrates these levels of analysis and then applies them to the North American (US) case. It combines an extension of the International Food Policy Research Institute's (IFPRI) International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) with a newly developed Water Simulation Model (WSM). The WSM simulates water availability for crops, taking into account total renewable water, nonagricultural water demand, the water supply infrastructure, and economic and environmental policies at the basin, country, or regional levels.

This analysis will be used to provide forecasts of current trends and future conditions of water availability. Such information is useful in thinking about future impacts of water use, land use changes, impacts on biodiversity-rich ecosystems like wetlands, and other environmental indicators.

Endnotes

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[2] Stanley Fischer, IMF, 4 April 2000.
[3] John Heinz III Center 1999.
[4] WRI et al. 2000.
[5] The New Republic 2000.
[6] CEC 1999.
[7] CEC 2000, 50.
[8] CEC 2000, 50.
[9] WRI et al. 1996, 9.
[10] CEC 2000, 51.
[11] GDP forecasts from IMF 1999. Reference to Trend Analysis from the same source, 75.
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[13] IMF, October 1999.
[14] IMF October, 1999, 73.
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[16] CEC2000b.
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[18] Financial Times, 22–23 April 2000.
[19] Watson et al. 1998, 17.
[20] Tuxill 1999, 97.
[21] Brown 1998a, 21; Tuxill 1998, 128; WRI et al. 1998, 190.
[22] Brown 2000, 8; Brown 1998a, 21; Tuxill 1997, 100.
[23] Tuxill 1999, Table 6-2.
[24] UNEP 1999a, 145.
[25] Abramovitz 1996, 60.
[26] Abramovitz 1996, 61.
[27] UNEP 1999a, 146.
[28] Tuxill 1998, 128.
[29] CEC 2000, 29.

[30] CEC 2000, 29.
[31] UNEP 1999a, 147.
[32] CEC 2000, 29.
[33] Tuxill 1999, 100; Tuxill 1998, 128.
[34] Abramovitz 1996, 61.
[35] CEC 2000, 30. WRI et al. 1998, 197; Tuxill 1998, 128; Platt McGinn 1999a, 87.
[36] Abramovitz 1996, 62.
[37] Tuxill 1998, 128; WRI et al. 1998, 197.
[38] UNEP 1999a, 145; WRI et al. 1998, 198.
[39] CEC 2000, 30.
[40] CEC 2000, 16; UNEP 1999b.
[41] UNEP 1999b.
[42] CEC 2000, 16.
[43] Tuxill 1999, 104.
[44] CEC 2000, 16.
[45] Tuxill 1999, 100.
[46] UNEP 1999b.
[47] WRI et al. 1998, 140.
[48] Abramovitz 1997a, 98.
[49] WRI et al. 1998, 185.
[50] UNEP 1999b.
[51] The period between 1990 and 1995. WRI et al. 1998, 185.
[52] Watson et al. 1998,18, 86.
[53] Abramovitz and Mattoon 1999, 60; Abramovitz 1998, 124.
[54] WRI et al. 1998,l 186.
[55] DPCSD 1997, 37.
[56] WRI et al. 1998, 186.
[57] CEC 2000, 13.
[58] WRI et al. 1998, 188.
[59] WRI et al. 1998, 188.
[60] Abramovitz and Mattoon 1999, 60.
[61] CEC 2000, 11.
[62] Watson et al. 1998,18, 86.
[63] Sugal 1997, 96.
[64] Matoon 1998, 126; Abramovitz 1998, 124.
[65] WRI et al. 1998, 186.
[66] Abramovitz 1998, 124.
[67] Abramovitz and Matoon 2000, 107.
[68] OECD 1998, 55.
[69] WRI et al. 1998, 186; Abramovitz 1998, 124.
[70] CEC 2000, 11; UNEP 1999a, 143.
[71] WRI et al. 1996, 67.
[72] UNEP 1999b.
[73] WRI et al. 1998, 163, 186; Watson et al. 1998, 18; Abramovitz and Mattoon 1999, 60.
[74] Abramovitz and Mattoon 1999, 65.
[75] Abramovitz and Mattoon 2000, 110.
[76] FAO 1999.
[77] Abramovitz and Mattoon 1999, 70.
[78] Mathews and Hammond 1999, 8.
[79] Abramovitz and Mattoon 1999, 73.
[80] Abramovitz and Mattoon 1999, 73.
[81] Abramovitz and Matton 2000, 105.
[82] Abramovitz and Matton 2000, 112.
[83] Abramovitz and Matton 2000, 104.
[84] Mathews and Hammond 1999, 8, 41.

[85] Gardner 1997a, 48.
[86] Watson et al. 1998, 85.
[87] Watson et al. 1998, 85.
[88] WRI et al. 1998, 156-7.
[89] DPCSD 1997, 34.
[90] WRI et al. 1998, 157.
[91] CEC 2000, 14–15.
[92] UNEP 1999a, 141.
[93] CEC 2000, 15.
[94] CEC 2000, 15.
[95] Halweil 1998, 42.
[96] OECD 1998, 59.
[97] UNEP 1999b.
[98] DPCSD 1997, 34.
[99] Brown 1998b, 28.
[100] UNEP 1999a, 141.
[101] Brown 1999, 120; Brown 1997, 26.
[102] Brown 1998a, 16.
[103] Mathews and Hammond 1999, 12.
[104] UNEP 1999b.
[105] WRI et al. 1998, 152.
[106] Brown 1998a, 16; Halweil 1998, 42.
[107] Postel 2000, 41.
[108] DPCSD 1997, 37.
[109] Brown 1998a, 16; Brown 1998b, 28; Brown 1999, 130; Halweil 1998, 42; UNEP 1999b; Watson et al. 1998, 39.
[110] Gardner 1999, 44; Postel 2000, 40.
[111] Gardner 1996, 86.
[112] Brown 2000, 6; Brown 1998a, 16; Brown 1999, 125, 130; UNEP 1999b.
[113] WRI et al. 1998, 152; Brown 1998a, 17.
[114] Watson et al. 1998, 21.
[115] Gardner 1999, 44.
[116] OECD 1998, 50.
[117] DPCSD 1997, 37;
[118] Halweil 1998, 42.
[119] Gardner 1999, 44.
[120] CEC 2000.
[121] CEC 2000.
[122] Postel 2000, 43.
[123] Gardner 1996, 87.
[124] UNEP 1999b.
[125] UNEP 1999a.
[126] CEC 2000, 21.
[127] Platt McGinn 2000, 83.
[128] Platt McGinn 2000, 83.
[129] WRI et al. 1998, 46.
[130] UNEP 1999a.
[131] Platt McGinn 2000, 87.
[132] WRI et al. 1998, 44.
[133] See the section on transboundary air pollution, below.
[134] UNEP 1999b.
[135] Postel 1996, 40.
[136] Watson et al. 1998, 19; WRI et al. 1998.
[137] DPCSD 1997, 52; Watson et al. 1998, 38-9.
[138] WRI et al. 1998, 188.

[139] Watson et al. 1998, 38; WRI et al. 1998, 188;
[140] DPCSD 1997, 45.
[141] WRI et al. 1998, 188.
[142] UNEP 1999a, 148.
[143] UNEP 1999b.
[144] DPCSD 1997, 47.
[145] Postel 2000, 45.
[146] Gardner 1996, 87.
[147] UNEP 1999a, 148.
[148] CEC 2000.
[149] Platt McGinn 1999a, 83
[150] Platt McGinn 1999a, 79; WRI et al. 1998, 195.
[151] DPCSD 1997, l 33; Watson et al. 1998, 22, 87; UNEP 1999b; Brown 1998a, 16; Strauss 1998, 34; Platt McGinn 1999a, 83.
[152] Mathews and Hammond 1999, 56.
[153] Mathews and Hammond 1999, 54.
[154] Mathews and Hammond 1999, 54; Platt McGinn 1999b, 36.
[155] WRI et al. 1998, 195-6.
[156] UNEP 1999a, 150.
[157] UNEP 1999a, 150.
[158] CEC 2000, 62.
[159] Platt McGinn 1998, 36; WRI et al. 1998, 158-9.
[160] WRI et al. 1998, 158-9.
[161] Platt McGinn 1998, 36.
[162] WRI et al. 1998, 159.
[163] CEC 2000, 64.
[164] CEC 2000, 64; Platt McGinn 1998, 36; WRI et al. 1998, 159.
[165] CEC 2000, 64; Platt McGinn 1998, 36.
[166] Mathews and Allen 1999, 60; WRI et al. 1998, 159.
[167] CEC 2000, 28.
[168] CEC 2000, 28; Platt McGinn 1999a, 79; WRI et al. 1998, 193.
[169] Watson et al. 1998, 21.
[170] UNEP 1999b; WRI et al. 1998, 193-4.
[171] Watson et al. 1998, 21.
[172] UNEP 1999b.
[173] CEC 2000, 28.
[174] Gardner 1998, 132.
[175] Mathews and Hammond 1999, 21
[176] Mathews and Hammond 1999, 13, 19.
[177] Mathews and Hammond 1999, 13.
[178] Mathews and Hammond 1999, 16.
[179] Gardner 1998, 132
[180] Mathews and Hammond 1999, 8.
[181] Munn et al. 1999, 468.
[182] Gardner 1998, 132; Mathews and Hammond 1999, 21; WRI et al. 1998, 179.
[183] Mathews and Hammond 1999, 21; Platt McGinn 1999c, 126.
[184] Mathews and Hammond 1999, 21.
[185] Brown 1998a, 20; Gardner 1998, 132-3.
[186] Mathews and Hammond 1999, 21; Platt McGinn 1999a, 86; Platt McGinn 1999c, 126; WRI et al. 1998, 179-80.
[187] Mathews and Hammond 1999, 21; Watson et al. 1998, 87; Platt McGinn 1999a, 86.
[188] Platt McGinn 1999c, 127.
[189] UNEP 1999a. 151.
[190] CEC 2000, 27.
[191] Platt McGinn 1999a, 79; WRI et al. 1996, xiv.

[192] UNEP 1999b; Platt McGinn 1999a, 85.
[193] WRI et al. 1996, x.
[194] WRI et al. 1998, 68.
[195] WRI et al. 1996, 60.
[196] CEC 2000, 26.
[197] WRI et al. 1996, 60.
[198] UNEP 1999a, 150.
[199] CEC 2000, 26.
[200] UNEP 1999a, 152.
[201] WRI et al. 1996, 248.
[202] CEC 2000, 27.
[203] CEC 2000, 38; WRI et al. 1998, 173; Watson et al. 1998, 13; Dunn 1998, 66; O'Meara 1998a, 68.
[204] Dunn 1998, 66; WRI et al. 1998, 171.
[205] Watson et al. 1998, 13.
[206] WRI et al. 1998, 170
[207] WRI et al. 1998, 172.
[208] CEC 2000; OECD 1998, 17.
[209] Dunn 1998, 66.
[210] UNEP 1999a, 153.
[211] Dunn 1998, 66.
[212] Watson et al. 1998, 13.
[213] Brown 2000, 5.
[214] Watson et al. 1998, 14; UNEP 1999b.
[215] Brown and Flavin 1999, 14-15; Dunn 1998, 66; OECD 1998, 18; Watson et al. 1998, 13-14, 81; WRI et al. 1998, 63, 171.
[216] Watson et al. 1998, 81.
[217] UNEP 1999a, 144.
[218] Brown 2000, 6.
[219] CEC 2000, 69.
[220] CEC 2000, 34.
[221] WRI et al. 1998, 65.
[222] CEC 2000, 54.
[223] CEC 2000, 54.
[224] CEC 2000, 52.
[225] WHO 1997.
[226] WRI et al. 1998, Overview.
[227] UNEP 1999b.
[228] WRI et al. 1996, 22.
[229] WRI et al. 1998, 30.
[230] UNEP 1999a, 153; WRI et al. 1998, 65.
[231] CEC 2000, 54.
[232] UNEP 1999b.
[233] UNEP 1999b.
[234] CEC 1997, viii.
[235] These are coal-fired electric power plants, waste incinerators and landfills, among others.
[236] CEC 1997, 10.
[237] CEC 2000b (forthcoming)
[238] CEC 1997, 14. Revolatilization refers to the 'grasshopper effect' in which some pollutants re-volatilize into the atmosphere after being deposited on land and water, travelling further with every 'jump'. Global distillation refers to the fact that re-volatilization and rates of degradation are reduced at cold temperatures, resulting in higher concentrations of POPs in cooler, northern ecosystems (CEC 1997, 14, 18).
[239] CEC 2000a (obtain reference to the dioxin report).
[240] See the section on POPs, above (UNEP 1999b).
[241] CEC 1997, 12-13.
[242] O'Meara 1998, 134; UNEP 1999b; WRI et al. 1998, 182.

[243] WRI et al. 1998, 183.
[244] O'Meara 1998, 135; WRI et al. 1998, 183.
[245] WRI et al. 1998, 183-4.
[246] See Wackernagel and Rees 1996.
[247] See the San Francisco Examiner 1999.
[248] Costanza 2000; Deutsch et al. 2000; Holmberg et al. 1999; Moffatt 2000.
[249] Wackernagel 1999, 2. This description of the EF method is drawn primarily from Wackernagel 1999.
[250] Wackernagel 1999, 1.
[251] Wackernagel et al. 1999, 377.
[252] Freshwater consumption and an array of waste streams including toxic pollutants are not calculated due to insufficient data, for example.
[253] Wackernagel 1999.
[254] Redefining Progress 1999.
[255] Wackernagel et al. 1999, 385.
[256] Wackernagel et al. 1997.
[257] Wackernagel and Silverstein 2000.
[258] Simmons et al. 2000; Wackernagel 1999.
[259] Rees 2000.
[260] Holmberg et al. 1999; Simmons 2000.
[261] Wackernagel 1999, 5. Critics, however, suggest that it is too aggregated to be an adequate guide for policy purposes at a national level (Ayers 2000) and that the methodology cannot serve as an ultimate and objective decision-making tool (Deutsch et al. 2000).
[262] See for example "Forum: The Ecological Footprint," Ecological Economics, 32 (2000)
[263] SEI 1998, 34-5; A-25.
[264] Herendeen 2000; Holmberg et al. 1999; Rees 2000; Wackernagel and Silverstein 2000.
[265] WRI 1999a.
[266] See WRI et al. 1997.
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