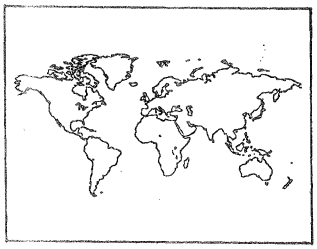

Ecological footprints and appropriated carrying capacity: what urban economics leaves out

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I. INTRODUCTION

THIS PAPER USES the concepts of human carrying capacity and natural capital to argue that prevailing economic assumptions regarding urbanization and the sustainability of cities must be revised in light of global ecological change. While we are used to thinking of cities as geographically discrete places, most of the land "occupied" by their residents lies far beyond their borders. The total area of land required to sustain an urban region (its "ecological footprint") is typically at least an order of magnitude greater than that contained within municipal boundaries or the associated built-up area. In effect, through trade and natural flows of ecological goods and services, all urban regions appropriate the carrying capacity of distant "elsewheres", creating dependencies that may not be ecologically or geopolitically stable or secure. Wealthy nations appropriate more than their fair share of the planet's carrying capacity. The global competition for remaining stocks of natural capital and their productive capacity therefore explains much of the environment-development related tension between North and South. Such macro-ecological realities are often invisible to conventional economic analyses yet have serious implications for world development and sustainability in an era of rapid urbanization and increasing ecological uncertainty.

II. THE ECOLOGICAL PERSPECTIVE

THIS PAPER IS based on the premise that human bio-ecology may soon become more important to understanding the political and socio-economic implications of urban development than economics. There are three simple reasons for this. First, despite our technological wizardry and assumed mastery over the natural environment,

humankind remains a biological entity and creature of the ecosphere.[1] On the simplest level, our fundamental relationship to the rest of the ecosphere is indistinguishable from that of the millions of other species with which we share the planet. Like all other organisms, we survive and grow by extracting energy and materials from those ecosystems of which we are a part. Like all other organisms, we "consume" these resources before returning them in altered form to the ecosphere. Second, the five-fold increase in the scale of human economic activity in the post-war period has begun to induce ecological change on a global scale which simply cannot be ignored in planning for human settlements. Finally, orthodox economic analysis is so abstracted from reality that its ability to detect let alone offer policy advice on socially critical macro-environmental dimensions of global urbanization is severely compromised.

III. RATIONALE: URBAN ECONOMY AS URBAN ECOLOGY

ECOLOGY IS THE scientific study of the flows of energy and material resources through ecosystems and of the competitive and cooperative mechanisms that have evolved for the allocation of resources among different species. Similarly, economics is the scientific study of the efficient allocation of scarce resources (energy and material) among competing uses in human society. Thus, ecology and economics share not only the same semantic roots, but also much the same substantive focus. In fact, it could logically be argued that economics is really human ecology.

Or rather, it should be. The problem is that mainstream economics has deviated markedly from the theoretical foundations that support its sister discipline. Ecology has firm roots in the real world chemical and thermodynamics laws that are the universal regulators of all energy and material transformations in the organic world. Economics, by contrast, had abandoned its classical organic roots by the end of the nineteenth century. Neoclassical economics (currently enjoying a remarkably uncritical renaissance the world over) is firmly based on the methods and concepts of Newtonian analytic mechanics.

The result of this divergence is a dominant economic paradigm which "lacks any representation of the materials, energy sources, physical structures, and time dependent processes basic to an ecological approach." Prevailing theory therefore produces analytic models based on reductionist and deterministic assumptions about resources, people, firms, and technology that bear little relationship to their counterparts in the real world.[2] In short, mainstream economists have abandoned ecological theory entirely, having sought refuge in the more theoretically tractable but environmentally irrelevant realm of mechanical physics. Ironically, economists, the most influential of human ecologists, are also the most ecologically errant.[3]

Four important consequences of this theoretical dichotomy will serve to illustrate the dilemma:

- Economic models often represent the economy as essentially separate from and independent of "the environment."[4] By contrast, the ecological perspective sees the human economy as an inextricably integrated, completely contained, and wholly dependent sub-set of the ecosphere.
- Economic theory treats capital and individual inputs to production

1. There are of course important differences of degree and kind. Unlike other species populations, the human population continues to expand imposing increasing demands on the ecosystems that sustain us. In addition, the ecosphere must cope not only with the natural metabolites of our bodies but also with thousands of industrial metabolites, the syntheticby-products of economic activity. While the former are readily assimilated and recycled, there is often no assimilative capacity for the latter which, in fact, may be toxic to biological functions.

2. Christensen, P. (1991), "Driving forces, increasing returns and ecological sustainability", in Costanza, R. (editor), *Ecological Economics: The Science and Management of Sustainability*, Columbia University Press, New York, NY, pages 75-87.

3. There is a double irony here. Academic ecologists, who do have an appropriate body of theory, do not study humans.

4. The subject-object dualism of our Cartesian (scientific) paradigm turns "environment" into its own pejorative. By definition, it alludes to whatever surrounds some other thing of greater interest or importance. (Rowe, S. (1989), "Implications of the Brundtland Commission report for Canadian forest management," *The Forestry Chronicle*, Vol. 5-7, February).

as inherently productive, ignoring both their physical connectedness to the ecosphere and the functional properties of exploited ecosystems. By contrast, ecology is a science of connectivity, preoccupied with material and energy flows and their relationships to the functional integrity of ecosystems.

- According to neoclassical theory, resource depletion is not a fundamental problem - rising prices for scarce resources automatically lead to conservation and the search for substitutes. Conventional wisdom holds that substitution through technological progress has been more than sufficient to overcome emerging resource scarcities.[5] This enables Nobel Prize-winning economist Robert Solow to argue that "...the world can, in effect, get along without natural resources."[6] By contrast, ecology argues that humankind remains in a state of obligate dependency on numerous biophysical goods and services which have immeasurable positive economic value but for which there are no markets (e.g., the stratospheric ozone layer). In the absence of prices, the already questionable scarcity indicators of conventional economics fail absolutely.

- Finally, the mechanical metaphor describes an economy which is self-regulating and self-sustaining in which complete reversibility is the general rule. From this perspective, the starting point for economic analysis is the circular flow of exchange value. By contrast, thermodynamic reality means that the economy is sustained entirely by low entropy energy and matter produced "externally" by ecosystem and biophysical processes. Thus, all economic production is actually consumption - the ecologically relevant material and energy flows through the economy are unidirectional and irreversible.[7]

This last factor is crucial to any attempt to account for the ecological effects of any economic process, including urban development. Without reference to entropic throughput "...it is virtually impossible to relate the economy to the environment," yet the concept is "...virtually absent from economics today."[8]

Why is any of this significant? There can be no doubt that sustainable urban development requires a sophisticated understanding of human ecology. In today's world, however, the primary values and criteria determining human material relationships with the rest of reality come from ecologically empty economic models. As we strive for sustainability, we would do well to reconsider these models in light of a key cybernetic theorem: "We cannot regulate our interaction with any aspect of reality that our model of reality does not include because we cannot by definition be conscious of it."[9]

IV. URBAN DEVELOPMENT AND ENVIRONMENT

LET'S TURN NOW to the task at hand - accounting for the environment in urban economic development. Traditional environmental economics is most likely to perceive the problem in industrial countries largely in terms of deteriorating local amenities - inadequate open space, air pollution and congestion from an expanding auto fleet, and land-fills approaching capacity from the solid waste stream. The solution may be cast in terms of making more efficient trade-offs between economic growth and environmental quality, improved land use planning, and finding policy instruments that will internalize the costs of pollution to those firms causing the problems (or better still, getting rid of smokestack industries and attracting clean "high-tech" industries). Public pressure is also mounting for

5. Victor, P., (1991), "Indicators of sustainable development: some lessons from capital theory," *Ecological Economics* Vol. 4, pages 191-213.

6. Solow, R.M. (1974), "The economics of resources or the resources of economics," *American Economics Review*, Vol. 64, pages 1-14.

7. Georgescu-Roegen, N. (1975), "Energy and economic myths", *Southern Economic Journal* Vol. 41, No. 3, pages 347-381; Daly, H. (1989), "Sustainable development: from concept and theory towards operational principles," presented to Hoover Institution Conference (Manuscript prepared for special issue of *Population and Development Review*); Rees, W. (1990), "Sustainable development and the biosphere: concepts and principles," *Teilhard Studies* No. 23, American Teilhard Association.

8. See reference 7. Daly, H. (1989).

9. Alternately, "...the regulation that the regulator can achieve is only as good as the model of reality that it contains." (Beer, S. (1981), "I said, you are gods," *Teilhard Review* Vol. 15, No. 3, pages 1-33).

policies that emphasize economic incentives to encourage more ecologically benign waste management, urban land use, and transportation patterns than are achieved at present.

In Third World countries, the emphasis is more likely to be on breaking the debilitating cycle of poverty, environmental decay, and deteriorating public health. Many cities in the Third World are unable to provide basic infrastructure and essential services. The human excreta and other wastes generated by burgeoning populations and unregulated industry overwhelm the capacity of inadequate and poorly maintained waste disposal systems. The poor are particularly hard hit. A quarter of urban residents live in absolute poverty. These millions have no access to sewers or clean water and their substandard housing is crowded, filthy, and noisy. Little wonder that gastrointestinal and respiratory diseases and malnutrition are chronic on a massive scale and the economic losses incalculable. In Third World cities the solutions are naturally oriented to economic measures that will improve allocative efficiency (true-cost pricing) and increase equity (reduced subsidies to the rich); increase economic productivity by improving services and removing constraints; alleviate poverty; and generally generate the wealth needed to upgrade the urban environment.[10]

Clearly, cities both North and South suffer from ecological dysfunction albeit differing in kind and scale, and the prescribed policy measures seem appropriate in the circumstances. Nevertheless, current responses to urban ecological malaise reveal an incomplete perception of the problem. Failure to appreciate the systemic spatial and structural dimensions of the human ecosystem limits the substantive scope for policy responses, confines remedies to the local environment, and often results in the treatment of symptoms rather than causes.

We tend to think of cities as political or administrative entities or, more loosely, as geographic areas dominated by features of the built environment. Economists see them as the locus for intense socio-economic interaction among individuals and firms and the engines of production and national economic growth. By contrast, systems ecology focuses on the broader relationship between the human population, ecologically significant consumption, and the sustainability of essential energy and material flows. This reveals dimensions of the urban system that are invisible to conventional policy models including the total dependency of cities on the productivity of distant landscapes and their negative impacts on the very land that feeds them.

V. THE URBAN ECOLOGICAL FOOTPRINT: APPROPRIATED CARRYING CAPACITY

WE CAN ILLUSTRATE the general idea by relating the novel concept of "natural capital" to the more venerable concept of carrying capacity at the regional level. While arguably central to urban ecology/economy integration, the ideas explored here are ignored in the mainstream policy arena.

a. Living on the Interest of Natural Capital

Some economists have accepted the ecological argument that

10. Bartone, C. (1991), "Environmental challenge in Third World cities", *Journal of the American Planning Association,* Vol. 57, No. 4, pages 411-415; Hardoy, J. and D. Satterthwaite, (1991) "Environmental problems of Third World cities: a global issue ignored?" *Public Administration and Development,* Vol. 11, pages 341-361; World Bank, (1991), *Urban Policy and Economic Development: An Agenda for the 1990s*, The World Bank,Washington, DC.

sustainability depends on the conservation of certain biophysical entities and processes. These "resources" maintain the life-support functions of the ecosphere, the risks associated with their depletion are unacceptable, and there are no technological substitutes. The emerging hybrid discipline of ecological economics therefore regards such assets as a special class of "natural capital" and has advanced a "constant capital stock" criterion as a necessary condition for sustainable development:[11] each generation should inherit an adequate stock of natural capital assets no less than the stock of such assets inherited by the previous generation.[12] In effect, ecological economics argues that, for the foreseeable future, humankind must learn to live on the annual production (the "interest") generated by remaining stocks of natural capital.[13]

b. Carrying Capacity Revisited

The concept of natural capital can readily be linked to that of carrying capacity. Ecologists define "carrying capacity" as the population of a given species that can be supported indefinitely in a given habitat without permanently damaging the ecosystem upon which it depends. For human beings, carrying capacity can be interpreted as the maximum rate of resource consumption and waste discharge that can be sustained indefinitely in a given region without progressively impairing the functional integrity and productivity of relevant ecosystems. The corresponding human population is a function of per capita rates of resource consumption and waste production (i.e., sustainable production divided by per capita demand).[14] This formulation is a simple restatement of Hardin's "Third Law of Human Ecology:" (Total human impact on the ecosphere) = (Population) x (Per capita impact).[15]

The inverse of carrying capacity provides an estimate of natural capital requirements in terms of productive landscape. Rather than asking what population a particular region can support sustainably, the question becomes: "How much land in various categories is required to support the region's population indefinitely at a given material standard?"

Our preliminary data for industrial cities suggest that primary consumption of food, wood products, fuel, waste-processing capacity, etc., co-opts on a continuous basis several hectares of productive ecosystem for each inhabitant, the exact amount depending on individual material standard of living. This average per capita index can be used to estimate the land area functionally required to support any given population. The resultant aggregate area can be called the relevant community's total "ecological footprint" on the Earth.

This approach reveals that the land "consumed" by urban regions is typically at least an order of magnitude greater than that contained within the usual political boundaries or the associated built-up area. However brilliant its economic star, every city is an ecological black hole drawing on the material resources and productivity of a vast and scattered hinterland many times the size of the city itself. Borrowing from Vitousek et al.[16] we say that high density settlements "appropriate" carrying capacity from distance elsewheres.[17]

The lower Fraser Valley of British Columbia, Canada (Vancouver to Hope) serves as an example. For simplicity's sake consider our ecological use of forested and arable land alone: assuming an average Canadian diet, the per capita land requirement for food production is 1.9 hectares, while forest products and fossil fuel consumption

11. For various interpretations of this concept see: Rees, W. (1992) "Understanding sustainable development: natural capital and the new world order", MS under review, UBC School of Community and Regional Planning, Vancouver; Costanza, R. and H. Daly, (1990), "Natural capital and sustainable development", (Paper prepared for the CEARC Workshop on Natural Capital. Vancouver, BC, 15-16 March 1990), Canadian Environmental Assessment Research Council, Ottawa; Pearce, D., E. Barbier, and A. Markandya (1990), *Sustainable Development: Economics and Environment in the Third World*, Edward Elgar Publishing, Hants, England; Pearce, D., and R. Turner (1990), *Economics of Natural Resources and the Environment*, Harvester Wheatsheaf, New York; Pearce, D., A. Markandya, and E. Barbier (1989), *Blueprint for a Green Economy*, Earthscan Publications, London; Pezzey, J.(1989), *Economic Analysis of Sustainable Growth and Sustainable Development*, Environment Department Working Paper No. 15, World Bank, Washington, DC.

12. Note that if existing stocks are merely adequate (or less), then natural capital will have to be enhanced to accommodate added population and rising material consumption.

13. This is related to so-called Hicksian or "sustainable" income, defined as the level of consumption that can be sustained from one period to the next without reducing productive wealth.

14. See reference 7. Rees, W. (1990).

15. Hardin, G. (1991), "Paramount positions in ecological economics," in Costanza, R., (editor), *Ecological Economics: The Science and Management of Sustainability*, Columbia University Press, New York.

16. Vitousek, P., P. Ehrlich, A. Ehrlich and P. Matson (1986), "Human appropriation of the products of photosynthesis", *Bioscience*, Vol. 36, pages 368-374.

17. Wackernagel, M. (1991), "Using 'appropriated carrying capacity' as an indicator: measuring the sustainability of a community", Report for the UBC Task Force on Healthy and Sustainable Communities, UBC School of Community and Regional Planning, Vancouver.

require an additional 3 to 4 hectares of forested land (2 - 3 hectares of this is required to absorb per capita carbon dioxide production and/or to produce the bioenergy equivalent of per capita fossil energy use). Thus, to support only the food and fossil fuel demands of their present consumer lifestyle, the region's 1.7 million people require, conservatively, 8.3 million hectares of land in continuous production. The valley, however, is only about 400,000 hectares. Thus, our regional population "imports" at least 20 times as much land for these functions as it actually occupies. (At about 425 people per square kilometre, the population density of the valley is comparable to that of the Netherlands or less than twice that of the UK.)

VI. IMPLICATIONS OF INTER-REGIONAL TRADE FOR GLOBAL CARRYING CAPACITY

IF ALL HUMAN populations were able to live within their own regional carrying capacities (i.e., on the "interest" generated by natural capital within their home regions) the net effect would be global sustainability. However, no region exists as an independent unit - the reality is that the populations of all urban regions and many whole nations already exceed their territorial carrying capacities and depend on trade for survival. Such regions are running an unaccounted ecological deficit - their populations are appropriating carrying capacity from elsewhere.[18]

18. The relevant imports derive from both commercial trade and natural flows of ecological goods and services. That is, "trade" is defined to include both international transactions in fisheries, forest, and agricultural products as well as the natural biogeochemical cycling of air, water, and essential nutrients.

Regional ecological deficits do not necessarily pose a problem if import dependent regions are drawing on true ecological surpluses in the exporting regions. A group of trading regions remains within net carrying capacity as long as total consumption does not exceed aggregate sustainable production. The problem is that prevailing economic logic and trade agreements ignore carrying capacity and sustainability considerations. In these circumstances, the terms of trade may actually accelerate the depletion of essential natural capital thereby undermining global carrying capacity.

a. Open Urban Economies: The "Distancing" Effect of Urbanization and Trade

Several factor are involved. First, urbanization and trade have the effect of physically and psychologically distancing urban populations from the ecosystems that sustain them. Access to bioresources produced outside their home region both undermines peoples' sense of dependency on "the land" and blinds them to the far-off social and ecological effects of imported consumption.

Importing Carrying Capacity: because the products of nature can so readily be imported, the population of any given region can exceed its local carrying capacity unknowingly and with apparent impunity. In the absence of negative feedback from the land on their economy or life-styles, there is no direct incentive for such populations to maintain adequate local stocks of productive natural capital. For example, the ability to import food makes people less averse to the risks associated with urban growth spreading over locally limited agricultural land. Even without accelerated capital depletion, trade enables a region's population and material consumption to rise beyond levels to which it might otherwise be restricted by some locally limiting factor. Ironically then, the free exchange of ecological goods

and services without constraints on population or consumption, ensures the absorption of global surpluses (the safety net) and encourages all regions to exceed local carrying capacity. The net effect is increased long-range risk to all.

This situation applies not only to commercial trade but also to the unmonitored flows of goods and services provided by nature. For example, northern urbanites, wherever they are, are now dependent on the carbon sink, global heat transfer, and climate stabilization functions of tropical forests. There are many variations on this theme touching on everything from drift-net fishing to ozone depletion, each involving open access to, or shared dependency on, some form of threatened natural capital.[19]

Exporting Ecological Degradation: the importing of sustainability by wealthy industrialized countries may equate to exporting ecological and social malaise to the Third World. Many impoverished countries have little other than agricultural, fisheries, and forest products to offer world markets and current development models encourage the "modernization" and intensification of production of specialized commodities for export. Unfortunately, the consolidation of land and other scarce resources to produce luxury export crops often jeopardizes domestic staples production, contributing to local food shortages and malnutrition. The process also displaces thousands of small farmers, farm workers, and their families from the better agricultural lands. This concentrates wealth in relatively few hands while forcing the dislocated peasants either to eke out a subsistence existence on inferior land that should never go under the plough, or to migrate to already overcrowded cities.[20] Erosion, desertification, and deforestation in the countryside and debilitating social and environmental problems in burgeoning squatter settlements around many Third World cities are the frequent result.

These trends are invisible to First World consumers who otherwise might not feel so sanguine about their imported coffee, tea, bananas, cocoa, sugar, etc. The distancing of consumers from the negative impacts ("externalities") of their consumption therefore only makes things easier for local elites, international capital, and transnational corporations all of whom benefit from the expanding commodity trade. Meanwhile, the Third World country itself becomes increasingly dependent on export earnings much of which must go to pay off the original "development" loans.

Overall this pattern contributes to the net transfer of both wealth and sustainability from the poor to the rich within Third World countries and from the poorest countries to the richest among the trading nations.[21] Ultimately, of course, debt servicing based on commodity exports in an increasingly competitive global market accelerates the erosion of the export regions' best lands and associated natural capital assets. Such capital liquidation both jeopardizes present levels of commodity production and reduces the future potential for more sustainable forms of development.

19. We are now seeing pollution externalities and the so-called "common property problem" extended to essential natural capital on a global scale.

20. In theory, the wealth generated by exporting local carrying capacity is supposed to "trickle down" to ordinary people, enabling them to purchase staple foods imported from more efficient producers at a lower cost than they could grow it themselves. However, trickle-down development theory is largely discredited and the benefits of the so-called green revolution are increasingly called into question. See, for example, *The Ecologist* Vol. 21, No. 2 (March/April 1991) on the role of international development in "promoting world hunger".

21. The latter transfers amount to tens of billions of dollars annually in recent years.

VII. CONCLUSIONS: CITIES AND THE ECOSPHERE IN AN ERA OF GLOBAL CHANGE

THE WORLD'S GREAT cities are among the finest achievements of civilization. In every country, cities are the social, cultural, communication, economic, and commercial centres of national life. However,

typical urban development policies ignore the fact that the city's role in wealth creation invariably depends on the continuous production of ecological goods and services somewhere else. In ecological terms, the city is a node of pure consumption existing parasitically on an extensive external resource base.[22] While the latter may be spatially diffuse "...the relevant knowledge is that it must be somewhere, it must be adequate, it must be available, and it must grow if the city grows."[23]

Consider this "relevant knowledge" in light of current trends pertaining to the state of global natural capital: encroaching deserts (6 million hectares/year); deforestation (11 million hectares/year of tropical forests alone); acid precipitation and forest dieback (31 million hectares damaged in Europe alone); soil oxidation and erosion (26 billion tonnes/year in excess of formation); soil salination from failed irrigation projects (1.5 million hectares/year); draw-down and pollution of ground water; fisheries exhaustion; declining per capita grain production since 1984; ozone depletion (5 per cent loss over North America [and probably globally] in the decade to 1990); atmospheric and potential climate change (25 per cent increase in atmospheric carbon dioxide alone). Far from growing with the expansion of the urban world, the resource base sustaining the human population is in steady decline.[24]

William Catton has detailed the ecological reality behind these disquieting trends: the expansion of the human enterprise, particularly since the industrial revolution, has been sustained first by the "takeover" of other species' niches (energy and material flows) accompanied, more recently, by the "draw-down" of accumulated stocks of resources as shown above.[25] Recent studies have revealed the remarkable extent of the "takeover" component. Nearly 40 per cent of terrestrial net primary production (photosynthesis) is already being appropriated by humans, one species among millions, and this fraction is steadily increasing.[26] Catton argues that humankind has long since "overshot" the permanent carrying capacity of the Earth. His bleak prognosis is that we must now do whatever we can "...to ensure that the inevitable crash consists as little as possible of outright die-off of *homo sapiens*".

The ecological perspective also supports a disturbing interpretation of urban environmental problems, North and South. The pollution, congestion, and landuse problems of Northern industrial cities stem largely from wealth and associated high levels of material consumption. By contrast, the deplorable physical conditions and public appalling health standards of burgeoning Southern cities stem from debilitating poverty and material deprivation. However, there is a connection. Much of the industrial countries' wealth came from the exploitation (liquidation) of natural capital, not only within their own territories, but also in their former southern colonies. As noted above, this appropriation of extra-territorial carrying capacity continues today in the form of commercial trade (as well as natural flows).

To the extent that the restructuring of rural economies in the South to supply the North displaces people from productive landscapes to the cities it is a direct cause of impoverishment, urban overpopulation, and local ecological decay. To the extent that current development models and terms of trade favour net transfers of wealth to the North and the continued depletion of natural capital in the South, both poverty and ecological decline in the South are permanent conditions. There simply isn't sufficient natural capital to support the present world population at Northern material standards. If the

22. In ecological and thermodynamic terms, all material economic "production" is consumption.

23. Overby, R. (1985), "The urban economic environmental challenge: improvement of human welfare by building and managing urban ecosystems", paper presented in Hong Kong to the POLMET 85 Urban Environment Conference, Washington DC, The World Bank.

24. We should note an important corollary to Liebig's law of the minimum in this context: carrying capacity is determined not by general conditions but by that single vital factor in least supply.

25. Catton, W. (1980), *Overshoot: the Ecological Basis of Revolutionary Change*, The University of Illinois Press, Urbana.

26. See reference 16. Vitousek, P., et al. (1986).

entire world population of 5.2 billion consumed productive land at the rate of our Fraser Valley example, the total requirement would be 25.5 billion hectares. In fact, the total land area of Earth is only just over 13 billion hectares of which only 8.8 billion hectares is productive cropland, pasture, or forest. The implication is that we would require an additional Earth or two with existing technology to provide for the present world population at Canadians' ecological standard of living.

Although never stated in quite these terms, the appropriation of most of the world's carrying capacity by the urban industrial North (and reluctance to give it up) and the insistence by the South of its right to a fair share (and the threat to seize it through sheer growth in numbers) was really the only issue at the Earth Summit in Rio in June, 1992. There are other geopolitical dimensions to the increasing inter-regional dependencies created by trade. Populations that rely on imports have no direct control over the natural capital stocks that sustain them from afar. This raises a question as to the inherent stability of trading relationships in an era of global change. To the extent that excess inter-regional dependency threatens geopolitical security we have another argument for policies to enhance regional economic diversity, independence, and self-reliance. In this context, bio-regionalism stands out as an appropriate ecopolitical philosophy. Needless to say, prevailing development rhetoric calls for precisely the opposite - economic specialization, concentration of capital, unrestricted access to resources, freer markets, and expanded trade - as the route to future prosperity.

a. Rethinking Urban Development

Mainstream economists generally reject the concept of carrying capacity outright on grounds that technology will continuously improve productivity, that manufactured capital can substitute for natural capital and that inter-regional trade will relieve any local constraints on growth.[27] As Daly has observed, prevailing economic mythology assumes a world in which carrying capacity is infinitely expandable.[28]

By contrast, the ecological perspective advanced here shows carrying capacity as fundamental to demographic/resource analysis. It reveals relationships and dependencies that are invisible to conventional models - marginal prices and monetary analyses reveal nothing about the functional roles, remaining volumes, necessary quantities, or absolute values of declining stocks of natural capital.

Global ecological change suggests that the productive capacity of some forms of natural capital has already been breached on the scale of the ecosphere. While economic analysis properly treats individual urban regions as open to exchange, it does not recognize that the ecosphere is materially closed and ultimately limiting. Clearly, not all countries or regions can run ecological deficits indefinitely - some must remain surplus producers if the net effect is to be global balance and stability. (We have yet to acquire the means to import carrying capacity from off-planet.) Inter-regional relationships (especially North-South) should be re-examined in light of this reality. For example, given the role of trade in the appropriation of carrying capacity, its use as an economic development tool requires careful scrutiny.

This analysis has made no allowance for potentially large efficiency gains or technological advances. Even at carrying capacity, further economic growth is possible if resource consumption and waste production continue to decline per unit GDP. We would be mistaken,

27. National Research Council (Committee on Population) (1986), Report of the Working Group on Population Growth and Economic Development, National Academy Press, Washington, DC; Muscat, R. (1985), "Carrying capacity and rapid population growth: definition, cases and consequences" in Mahar, D. (editor), *Rapid Population Growth and Human Carrying Capacity: Two Perspectives*, Staff Working Paper No. 690 (Population and Development Series, No. 15), The World Bank, Washington.

28. Daly, H. (1986), "Comments on 'population growth and economic development'", *Population and Development Review*, Vol. 12.

however, to rely on this conventional rationale. New technologies frequently require decades to achieve the degree of market penetration needed to influence significantly negative ecological trends. Moreover, there is nothing to ensure that savings will not simply be directed into alternative forms of consumption. Meanwhile, we are already at the limit in a world of rising material expectations in which the human population is increasing by 94,000,000 people per year. (The minimal food-land requirements alone each year for this number of new people [at 5.5 people/hectare] is about 17,100,000 hectares, nearly equivalent to all the cropland in France.)

Such basic human ecology has serious implications for urbanization and the material basis of urban life in the twenty-first century. At the centre is the disparity between North and South in terms of access to the productivity of natural capital revealed above. The appropriation of a vastly disproportionate share of "net planetary product" by wealthy industrialized nations is likely to become an increasingly destabilizing geo-political factor as evidence mounts that the global economy is pressing on biophysical limits. In any event, to the extent that limited access to resources is a cause of poverty, it remains a serious impediment to the sustainable development of Third World countries.

These problems can only be addressed through structural adjustments to the economy that will greatly affect urban form and function. In Northern industrial cities economic incentives and other planning measures to increase land use efficiency, to reduce consumption of material resources, and to enhance the viability of remaining local stocks of ecologically productive land, should be implemented immediately. In the longer term, the quest for urban sustainability must address at least the following questions:

- What are the necessary ecological conditions for urban/regional sustainability? Are these conditions under active management and control or simply assumed to be available in perpetuity?
- Given the apparent deterioration of the global environment, can we reasonably talk about sustainable urban development without considering the implications of all urban regions simultaneously becoming reliant on ecological productivity "elsewhere"?
- How should considerations of carrying capacity and natural capital affect urban form and the spatial scale?
- How can we correct for excessive abstraction, problems with discounting, and market failure in the economic valuation of land and ecosystems?
- Is the present pattern of Third World urbanization inevitable or is it a by-product of maladaptive development models? How can Third World countries gain the most from their wealth-producing natural capital?
- Should dependent urban regions formalize their relationships with export regions to ensure adequate maintenance of essential natural capital stocks thereby enhancing their ecological security, or...
- Should urban regions (provinces? nations?) develop policies explicitly to support and sustain local/regional agriculture, forestry, fisheries, etc., in order a) to reduce potentially unstable inter-regional dependencies, and b) create a hedge against global ecological change and declining productivity elsewhere?
- What is the appropriate level of government to deal with these matters? Should we move toward regional systems of governance incorporating more life-support landscapes (natural capital)? Does the bio-regional model offer useful guidance?