Dr. Jonathan Tennenbaum

Relationship of Ecology And Economics: Can Man Improve the Planet?

The presentation by Dr. Jonathan Tennenbaum to the Zayed Centre conference, "The Universe and Man's Destiny," given on Aug. 4.

With the dramatic growth in the scale and intensity of human activity on this planet since the industrial revolution, the rapid expansion in world-wide consumption of energy and raw materials, and the growth of the world population from approximately 2.5 billion to 6 billion over the last 50 years alone, man's impact on the Earth's environment has unquestionably taken on unprecedented proportions.

From certain quarters the warning has sounded out, that man's activity is causing irreparable damage to the Earth's ecology and perhaps threatening the future of human life or even life itself on the planet.

In the recent period, two particular warnings have drawn the greatest public attention: 1) "global warming"—a predicted increase in overall atmospheric temperatures over coming decades, as the result of human emission of CO_2 and other so-called greenhouse gases, leading possibly to changes in global weather and climate patterns and a raising of the level of the oceans; 2) the so-called "ozone hole"—the thesis, that man-made substances are destroying the ozone layer which shields the Earth's surface from harmful levels of UV radiation.

These specific warnings, however, are added to a long list of more or less urgent worries, concerning the effects of human population growth and economic activity on the environment, including: depletion of natural resources, including freshwater sources; poisoning of ground and surface water, the soil, atmosphere, and entire food chain by industrial chemicals and waste products; destruction of soil fertility, erosion and desertification, deforestation, including destruction of tropical rainforests; the extinction of many species of living organisms; and so on.

The overall picture is that of a planet being totally devastated. But is this picture accurate? And if so, what should be done? Is man only a threat to the environment, or can man improve the planet?

Exactly the importance of this question for the future of mankind requires, that it be analyzed from a rigorous scientific standpoint, avoiding false assumptions that might have even more disastrous effects than the problems they are supposed to address. In this context, one also cannot overlook the fact, that certain circles in the world have been exploiting so-called environmental issues for economic, political, and geopolitical ends, and to spread a certain negative view of man.

Jonathan Tennenbaum at Baniyas Island, about 300 km from Abu Dhabi, the site of a unique experiment in large-scale transformation of a barren area into a "green paradise."

For these and other reasons, I shall start with some general remarks, which may seem simple and even self-evident to some, but are often overlooked, and have profound scientific as well as economic-political consequences. After that I shall proceed to some concrete examples and proposals for the future.

1. Paradoxes of the Assertion That Man Destroys the Earth

Is man destroying the natural equilibrium of the Earth's ecosystem? Before rushing to answer the question, we should

The Earth's Biosphere does not exist in a state of thermodynamic equilibrium, contrary to widely accepted belief. One simple demonstration of this is the presence of large quantities of free oxygen, whose nonequilibrium nature is impressed upon us periodically by forest fires.

realize that the very formulation contains an implicit assumption: namely the idea that there exists such a thing called the "natural equilibrium."

In fact, as the great Russian biogeochemist Vladimir Vernadsky and other scientists have demonstrated, the Earth's Biosphere—the dynamic system constituted by living and nonliving matter in the region of the Earth, populated by living organisms—not only exists in a state very far from thermodynamic equilibrium; but in the course of evolution it has constantly developed farther and farther away from equilibrium! Thus, the actual evolution of living matter and the Biosphere as a whole, goes in the opposite direction from the tendency of entropic dissipation of energy, which appears to predominate in the domain of non-living matter.

This may be very surprising to people who hear it for the first time, but it is well-established scientific fact. One of the simplest demonstrations is the presence of large quantities of free oxygen, maintained far from chemical equilibrium by the photosynthetic activity of living organisms, and whose nonequilibrium nature is impressed upon us periodically by forest fires and related disasters. But at the same time, the emergence and maintenance of an oxygen-rich atmosphere on the Earth, as a product of photosynthesis, created the possibility for the much higher rates of metabolism in animals and other higher forms of life. The buildup of atmospheric oxygen was connected, in the history of the Earth, with a profound transformation in the whole organization of the Biosphere and its populations of organisms, and an intensification of the flows of energy and matter within the Earth's ecosystem.

Thus, on the scale of geological time at least, it is nonsense to speak about some fixed "natural equilibrium state" of the Biosphere and ecosystem. On the contrary, long before man appeared on the scene, the Earth's Biosphere went through a long history of more or less dramatic changes. In addition, there is evidence that the process of evolution on the Earth did not simply occur gradually, but was accompanied by relatively rapid, "jump-like" changes. Indeed, the image of a supposedly delicate "balance" in the Earth's ecology, is hard to reconcile with the history of sudden large-scale shifts in weather, climate, and the behavior of living species; this history evidently predates man, but continues until today.

These remarks do not imply that there are no problems connected with the effects of human activity on the Earth's environment. They simply underline the fact, that change has always been the characteristic of the Biosphere over billions of years, and we cannot equate change automatically with destruction. Thus, in discussing these matters, it is necessary to establish a criterion for distinguishing between positive and negative types of change.

2. Interaction of Man's Physical Economy with the Earth's Ecosystem

In judging the impact of mankind's activity on the environment, it is a common error for people to focus only on particular aspects such as pollution, overlooking the fact that the flows of matter and energy associated with the long-term development of man's physical economy, are already an integral part of the present structure of the Biosphere. Moreover, mankind's activity is supporting and sustaining that structure

to a very significant extent.[1]

Examining the development of man's physical economy over the long-term sweep of history, two specific aspects are of special significance for the interaction of the economy with the Biosphere as a whole.

First, is the fact that man has increased his potential population density—the maximum number of human beings that can be sustained, on the average, per square kilometer of the Earth's surface—by at least three orders of magnitude in the course of archeological and recorded history. The ability to deliberately increase the population potential, through technological development and analogous improvements in the organization of social activity, distinguishes man absolutely from all other species of living organisms.

Second: The growth in human population-potential is connected with an increasing intensity of flows of matter and energy within the Biosphere, both per capita of the population and per square kilometer of the Earth's surface, as a direct and indirect result of man's economic activity. Vernadsky rightly spoke of man becoming an increasingly dominant "geological force" in the Biosphere.

Central to this are man's agricultural activities, that had already extended to a significant part of the Earth's land surface, thousands, and probably tens of thousands or more years ago. Over time, these activities have transformed, directly and indirectly, the entire system of plant, animal, and microbial life on the planet, and substantially affected the structure of flows of matter and energy within the Biosphere as a whole.

While that transformation is obviously very complex, one of its essential characteristics is the increase in the average rate of production and turnover of living material (biomass) per hectare or square kilometer of agriculturally cultivated area. Indeed, man's deliberate intensification of the process of biomass generation and turnover, through agricultural and related activities, has provided the chief immediate basis for the spectacular increase in the potential population density of the human species.

But, as Vernadsky and others have shown, the tendency toward intensification of the generation of living matter did not start with man, but has been a constant characteristic of the evolution of the Biosphere over 4 billion years. Vernadsky noted that there has been a constant increase in the "free energy" of the Biosphere in the course of biological evolution. This free energy, generated through the capture of solar radiation and its conversion into structural energy of living tissue and other products of living processes, represents a growing potential of the Biosphere to expand and develop.

Thus, human agriculture and related economic activity, to the extent it contributes to the growth of the free energy of the Biosphere, represents a continuation of the "anti-entropic" direction of biological evolution in general.

Man's role in this process of intensification of the Biosphere is typified by what farmers call the improvement of the land, and the extension of such improvements to other categories of land use. Improvement of land refers not only to increasing the soil fertility *per se*, but to the entire range of physical investments and other changes, that permit the farmer to maintain and increase agricultural yields from generation to generation. These include irrigation and drainage systems; plant breeding and improved forms of seeds; inputs of mechanical energy for plowing, planting, fertilization, harvesting; measures for control of plant diseases and pests, and so forth.

The successful transformation of some desert areas into productive agricultural regions, through irrigation and various methods of reclamation and development of soil, provides perhaps the best illustration of the principle of "improvement of land." I shall come back to this point in the final section of this paper.[2]

Carrying out and maintaining improvements in agricultural land use, depends in turn on inputs from the whole physical economy, including mining, manufacturing, infrastructure, and so forth. Indeed, the sustained increase in agricultural yields, achieved in many areas of the world over the last 200 years, has been closely connected with the process of industrialization and accompanying scientific and technological revolutions.

Increasing Potential Population Density

This points to the need to generalize from the case of agriculture, to physical economy as a whole. Accordingly, let us include under the notion of "improvement of land," all

1. By "physical economy" I mean the entire physical process by which a human population sustains itself on a given territory. That includes, first of all, the generation and distribution of energy; the entire network of interconnected productive processes of agriculture, mining, industry and construction, transportation, distribution and consumption of goods; and necessary service activities connected with education, sanitation and medical care, scientific research, etc. It also includes the reproduction of the human population itself, not only in the biological sense, but also in terms of the raising of children into adults, and all household and related activities connected with that.

In recent decades it has become a common belief, in Western countries at least, that man's physical economy has developed at the expense of nature, and that the transition to so-called "zero growth," or even a collapse of the physical economy, would benefit the Earth, by reducing the destruction and disturbance caused by human activity. This, in my view, is a very big mistake. A collapse of man's physical economy, for example, would inevitably generate shock effects within the Biosphere as a whole, triggering a transition of the Biosphere to lower states of organization, and leading (among other things) to mass outbreaks of old and new human, animal, and plant diseases. Signs of this phenomenon of an "ecological holocaust," which Lyndon LaRouche warned about back in the mid-1970s, can actually be observed today in Africa and other areas of the world which have suffered dramatic economic decline.

2. Some radical environmentalists, it is true, would denounce the "greening of the deserts" as a "destruction of the natural ecosystem." Of course, desert areas do represent local ecosystems of a special kind, having their own types of vegetation, microbial, and animal life. But if the weather patterns were to change spontaneously (as they have done repeatedly, even in known history), and the desert were to receive substantial rainfall over decades or centuries, should we regard this as a "destruction"?

There are whole herds of deer and other animals on Baniyas Island, fed by grass farms on the island itself. The project was launched at the initiative of Sheikh Zayed in the 1970s, with the construction of a large desalination plant on the coast, and underwater pipelines linking the plant over 8 km to the island.

physical changes caused by mankind's deliberate action, which contribute to increasing the potential size of human population that can be sustained, at increasing levels of material living standards and longevity, on a given area or region of the Earth's surface. Those changes are closely connected with the development and improvement of basic economic infrastructure—including energy, water system, transport, communication, etc.—leading (among other things) to an increasing intensity of production and consumption of energy and other infrastructural services per capita and per unit area.

This includes also the sorts of large-scale infrastructure projects, such as flood control, reservoirs, dams, canals, irrigation projects, development of transport corridors, major power projects, etc., which have major, long-term effects on both the physical economy and its environment.

In the Western nations, at least, it has become very popular in recent decades to equate industrialization generally with a destruction of nature. Now, there is no doubt that industrial society, in the concrete forms it has assumed up to now, has indeed caused many ugly and damaging effects on the local level. But as I already indicated, those effects cannot be seen only in isolation. We must also take into account the simultaneous intensification of the Biosphere's energy flows and of living activity taken as a whole—as exemplified by the impact of modern agriculture on the generation and turnover of biomass on the Earth's surface; by the increased populations of animal and plant species sustained, directly or indirectly, by human activity; and not least of all by the increased activity of the human population itself.

From this standpoint, the thesis, that the growth of industry has negatively influenced the Biosphere as a whole, appears more than doubtful. Again, due to the erroneous idea of a so-called natural equilibrium, many people have been misled into equating change automatically with destruction. Unfortunately, hardly anyone among the vocal participants in recent environmental debates, has put forward a scientific criterion for what is "good" or "bad" for the Earth's Biosphere![3]

---

3. Ironically, it is not clear whether a so-called "global warming," attributed to an increase in atmospheric CO_2 concentrations due to human activity, would really be a "bad thing" for the Biosphere as a whole. Some scientists argue, not without reason, that both the increase in CO_2 and increase in average temperatures might greatly benefit plant growth on the planet, and also counteract tendencies toward cooling and glaciation, as the Earth gradually moves toward a new ice age according to the well-known geophysical cycle. This does not rule out many unpleasant effects which might result, in different regions of the world, if the "global warming" thesis is true.

On the other hand, the evidence presented up to now in favor of the thesis of "global warming" is far from conclusive, in my view; it does not justify the imposition of a regime of international constraints, that might interfere with economic development decisions of sovereign nations. Without wanting to go here into the scientific issues around "global warming," I would suggest approaching the question instead from an economic-technological point of view:

There is no doubt, that the present degree of one-sided dependence of most nations on simple combustion of fossil fuels, in the present form at least, is an expression of rampant technological stagnation and backwardness in the world economy. This same backwardness and underdevelopment—including in the so-called industrial countries—is the chief source of the destruction of the environment and the human population, which is now going on throughout the world. In fact, we possess technologies such as nuclear power production and electricity-based automated high-speed transport systems, for example, which not only produce orders of magnitude less pollution, but are intrinsically far more efficient and productive than presently dominating technologies.

Unfortunately, the worldwide utilization of nuclear energy was brought to a standstill in the 1970s by the Carter Administration of the United States, as a crucial feature of a neo-malthusian policy to prevent so-called "Third World" countries from obtaining access to advanced technologies, while at

In my view, the only rigorous measuring-rod for the improvement or degradation of the Biosphere, available to us today, is the impact of changes in the Biosphere upon the ability of man to maintain and increase his population potential.

Stated in that way, however, my proposed criterion contains a significant paradox: Practices, which appear to improve man's existence in the short term, might very well lead to a disastrous collapse of the human population in the long term—for example, as the result of exhausting or destroying the natural resources upon which society's existence depends. That paradox takes us into the domain of economic policy.

3. Looting the Environment, As an Expression of Wrong Economic Principles

The recent collapse of the U.S. and other financial markets, underlines the distinction between real profit—derived from increases in the productive powers of labor—and fictitious profit, associated with speculative inflation of paper assets and looting of human and natural resources. In fact, the entire so-called U.S. economic miracle of the 1990s was based on an speculative inflation in financial asset prices, plus a gigantic net inflow of capital and physical goods from the outside world.

The collapse of the U.S. bubble, and with it a large part of the nominal wealth in the global financial system, points to the fact that we must first get a clear idea about the source of economic wealth, before we can define and measure economic growth. Here there are two basic, conflicting schools of thought.

One of them, associated historically with the feudalist tradition in Europe (the tradition of the Roman Empire)—the French physiocrats and the British imperial tradition of Adam Smith and Thomas Malthus—sees wealth essentially as residing in so-called "natural resources"—the soil, minerals, and so forth—whose quantity is ultimately fixed and finite. One consequence of this way of thinking is, that an increase in wealth in one place, must be compensated by a decrease somewhere else.

The idea of fixed, limited resources was revived and popularized in the 1960s and 1970s by the Club of Rome in its famous book *Limits to Growth;* we can find it echoed again in many modern economics textbooks, such as those of Paul Samuelson or Gregory Mankiw, which define economics as "the science of how a society manages limited resources."

But this whole view of man and economy was decisively refuted by Gottfried Leibniz at the end of the 17th Century, and later by such founders of the so-called American or industrial school of political economy as Alexander Hamilton, Henry Carey, and Friedrich List. This second school—which has historical roots in Renaissance thinkers such as Nicolaus of Cusa and Leonardo da Vinci, and is most prominently represented today by the American economist Lyndon LaRouche—sees economic wealth not as lying in natural resources *per se,* but rather in the development of the productive powers of labor through scientific and technological progress. Such progress in turn depends on the creative powers of the individual human mind to discover new physical principles, and to realize such discoveries in new technologies and analogous improvements in the organization of human activity. These are exactly the powers that distinguish man from all other species of living organisms, and have made possible the spectacular, and continuing, increase in the population potential of the human species.

The scientific incompetence of the Club of Rome's "limits to growth" thesis becomes most obvious, when we consider the impact of scientific and technological progress on so-called "natural resources." Reflecting on that, we quickly realize that the concept of "natural resources" and "raw materials" is only a relative concept, not an absolute one. The same is true of so-called "limits" of resources, which never exist in an absolute sense, but only relative to a given state of human knowledge and technology, and relative to a given level of development of human labor power. In fact, scientific progress constantly opens up new types of resources for economic development, while improved technologies expand the range of existing types of resources, that can be exploited in an economic way.

So, for example, the concept of "iron ore" did not exist for the Stone Age man. Similarly, prior to the discovery of nuclear fission, the concept of "uranium fuel" did not exist. But today, using nuclear fission reactors, we can extract from 1 kilogram of uranium fuel, the caloric equivalent of 50,000 kilograms of coal! With the realization of controlled nuclear fusion, we will one day be able to produce, from the hydrogen isotopes contained in a single liter of sea water, the energy equivalent of over 100 liters of gasoline!

Mineral Reserves Grow, Not Shrink

In a less dramatic, but equally important way, we have a constant tendency for growth in the exploitable reserves of mineral resources, as the result of an ongoing accumulation of thousands of small improvements, introduced every year

---

the same time transforming the already industrialized nations into parasitical, so-called "post-industrial societies." Since nuclear energy was key to the "breakthrough" of the world economy into a new technological era, the sabotage of nuclear energy development had the effect of imposing technological backwardness upon the world economy as a whole.

On the other hand, a future growth of nuclear energy does not automatically imply a corresponding decline in the consumption of petroleum products. Rather, we will learn to make better use of petroleum, as a complex and valuable organic substance, than simply burning it up in internal combustion engines in the present manner. In the future, we can expect a larger portion of petroleum to be processed into higher-value synthetic fuels and chemical products. No doubt, the addition of increasing amounts of hydrogen, which can be produced with the help of nuclear energy in a variety of ways, will play a growing role in this process.

into the techniques of prospecting, mining, and processing of materials. It is interesting to study the list of 11 vital minerals which the Club of Rome claimed, back in 1972, might be exhausted by the end of the 20th Century. In practically every case, the known reserves of those minerals, including petroleum, are larger today than they were three decades ago—even through gigantic quantities were extracted and consumed in the meantime! Similarly, existing resources—such as petroleum for example—will find more varied and valuable uses in the future, as a result of technological progress.

For related reasons, it is wrong to speak of fresh water as a limited resource, as is often done. We know how to produce fresh water, in any desired amounts, by the industrial desalination of sea water, the latter existing in practically unlimited quantity in the Earth's oceans.

You have a wonderful example of this right here in [the United Arab Emirates]. Using desalination technologies it will be entirely possible, within this century, to create the equivalent of "artificial rivers," permitting presently desertified regions of the world to be transformed into fertile areas for human habitation. Of course, desalination involves considerable costs in the form of investment into plant and equipment, supplies of energy and other inputs into the process. But those costs, also, are only relative, not absolute: As an economy becomes more productive, under the influence of overall improvements in technology and the qualification of the labor force, the social cost of producing any given material requirements decreases further and further, relative to the total output of the economy.

These considerations are crucial for understanding the very real problem of looting, of natural resources as well as the human population itself, which is occurring today on a vast scale, particularly in the so-called developing countries.

It is no accident that (generally speaking) real destruction of the environment strongly correlates with economic backwardness and lack of technology, as in many so-called developing countries in recent decades; or with a distortion of the economic process leading toward major financial and economic crises.

Fallacy of 'Natural' Resources

Indeed, if we believe, as taught by the traditional "British system" of economics, that wealth is ultimately derived only from natural resources, and not from the creative powers of the human mind, then we will define the most successful economic practice, as the one which is the most effective in stealing from both man and nature! The result of such an economic practice, in the long run, is both to loot natural resources and to collapse the population potential of the human species. Both of these characteristics were rampant in the colonies of the British Empire, as they have become, increasingly, in the developing countries as a whole over the last 30 years, under the policies of the International Monetary Fund and World Bank.

A further side-effect of this fundamentally erroneous conception of economic wealth, is the suppression of real scientific and technological progress. Indeed, apart from a mere elaboration of scientific principles already discovered in the early decades of the 20th Century, there has been a relative stagnation in fundamental scientific and technological progress over the last 30 years. This is, in large part, an effect of a systematic policy of de-emphasizing scientific education and industrial forms of employment, in the United States and other Western nations, in recent decades.

That policy, going hand-in-hand with the shift toward speculative forms of investment, and outright looting of the base of the world economy, has increasingly transformed the United States and other formerly industrial nations into parasitical "service economies," whose populations are falling into extreme forms of moral and intellectual decadence. Should we be surprised, then, to find ourselves now plunged into the worst global financial and economic crisis in modern times?

4. Improving the Planet

The present crisis, and the hysterical response to it from the side of the United States and some other governments, greatly aggravates the risk of war. On the other hand, the collapse of the post-1971 global financial system also represents a precious opportunity to rethink fundamental assumptions and to launch new policies, that can provide for the survival and development of human civilization in the 21st Century. Very soon, I believe, the question of how to rebuild the world financial and economic system will become the number one topic of international discussion.

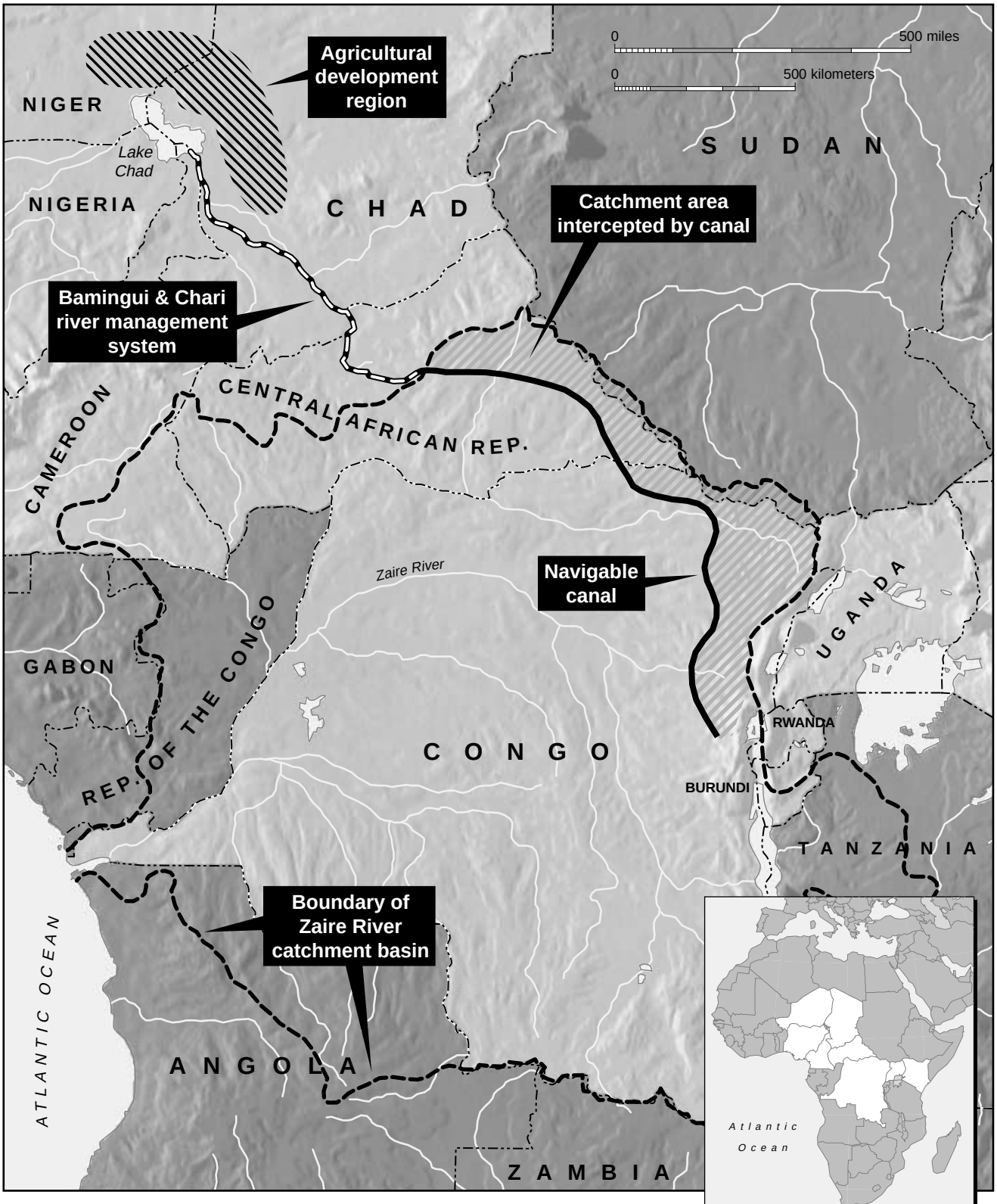
We need a real development perspective for the planet, which is not just nice talk, but is connected with concrete, large-scale projects and endeavors that will transform both the economy and the environment in a positive direction. This is exactly the sense of the interlinked proposals by Lyndon LaRouche and his collaborators, for a "New Bretton Woods" reorganization of the world financial and monetary system, and for the launching of worldwide infrastructure projects centering on the so-called Eurasian Land-Bridge.

I would like to give a concrete example, which shows most clearly how rebuilding the world economy can go hand-in-hand with major improvements in the natural environment of this planet.

Let us resolve to transform, in the course of the 21st Century, substantial portions of the present desert areas of the world into fruitful agricultural and residential regions, using large-scale desalination of sea water, combined with advanced methods of irrigation, water distribution and management, intensive agriculture, gardening and ecosystem development.

Nuclear energy provides, without doubt, the most advantageous power source for this kind of development, particularly in the form of compact, modular nuclear reactors that

FIGURE 1
The TransAqua Project for Central Africa



The plan for water development in Africa, worked out by the Italian engineering firm Bonifica, is an example of the kind of large-scale projects that will transform both the economy and the environment in a positive direction.

can generate both electricity and process heat for desalination and other industrial applications. Thanks to developments of recent decades, it is now possible to manufacture inexpensive, modular high temperature reactors (HTRs), that are simpler and more robust than conventional nuclear plants, and possess 100% intrinsic safety as well as high efficiency.[4] HTRs also have interesting applications to the processing of natural gas and oil into synthetic fuels and other high-value products.

On this basis, let us move to establish a network of agro-industrial complexes, centered on the combination of modular nuclear reactors for power and large-scale desalination of sea water, and other industrial processes utilizing nuclear electricity and process heat. Adjacent to these complexes we build up urban residential areas, modern industrial facilities and regions of high-density, high-yield agricultural production. These complexes will serve both for agro-industrial production, and as centers for education, training, and experimental research—i.e., technical universities—focussing especially in areas related to the uses of nuclear energy, state-of-the-art desalination technology, agriculture and plant breeding, forestation, and Biosphere sciences.

Now, link these centers with each other and with existing, major population centers of the participating countries, by "infrastructure development corridors," centering on modern, high-speed freight and passenger transportation systems (above all high-speed rail and maglev), water pipelines and canals, and energy distribution systems. In this way, settlement and development will be spread from the agro-industrial centers themselves, into the areas along the corridors—where water, energy, and transport will be readily available—and from there more and more into the surrounding regions, providing for rapid growth of the human population.

Combining nuclear-based desalination and agro-industrial production with education and research activities is of the greatest importance, for two reasons. First, mastery of nuclear energy and other advanced industrial technologies provides a "locomotive" for rapid development of the scientific and engineering cadres in developing countries. Second, I am convinced that concentrated efforts of scientific research and development will lead in the coming period to major breakthroughs in the technology of desalination, as well as to developments in biophysics and related areas. These will revolutionize agriculture and medicine, as well as our understanding of how to improve the Biosphere as a whole.[5]

What Is the Real Cost?

When we discuss this plan with people from the region, and in international organizations, we often get the reaction: "but all of this is far too expensive!" I would like to briefly respond to that question.

Firstly, we should ask ourselves: What about the trillions of dollars that have been sucked away from the world's real economy in the recent period, and channeled instead into financial speculation and other forms of waste, and which are now being wiped out in the financial crash? Was that form of so-called investment not "too expensive"?

If it is possible to generate dozens of trillions of dollars of fictitious assets "out of nothing," then why should it not be possible to bring nations together, to create a system of long-term credits for real investment and development of our countries?

Aside from that rhetorical comment, I should like to point out the following: On the level of national or regional economics as a whole, "cost" has only the significance of the difference in rates of development of the productive powers of labor, resulting from alternative courses of policy. We "pay" for a wrong policy by a deficit of development, relative to what would have occurred, had we followed a more correct policy. Whereas, properly considered, we do not "pay" for a correct development policy at all, but only gain from it.

For example, the over-dependence on imports of consumer and other finished goods, in exchange for export of raw materials, constitutes "zero development"; in the long term this is virtually the most "costly" of all policies for a nation, short of war. On the other hand, mobilizing populations for the purpose of great projects and great endeavors, such as the "greening of deserts" during the 21st Century, is the most rapid way to develop the productive labor power of a nation or a group of nations.

This assumes that we have in place a proper and reasonable system of regulation and support of prices, credit and capital flows, and protection of domestic or regional producers, to insure that development policies achieve their intended aims.

Ultimately there is no other source of economic wealth than the improvement of the Earth, and especially of human life, which is its greatest treasure.

---

4. South Africa is embarking on a major program for construction of modular high temperature reactors (HTRs), based on the German "pebble bed reactor" technology, but incorporating a high-efficiency helium turbine and other improvements. A test reactor of this type is now in operation in China. Japan is also operating a high-temperature test reactor of a somewhat different type. In the United States, advanced HTR technology has been developed by the General Atomic Corporation. The French Atomic Energy Commission (CEA) has launched a program for development of HTR technology, including applications to desalination and other industrial processes. Several other countries are also involved in the multilateral cooperation around this technology.

5. In part I have in mind revolutionary implications of current research concerning the so-called "biophoton" emissions of living processes, which relate directly to fundamental questions raised by Vernadsky and Alexander Gurwitsch, concerning the fundamental physical distinction between living and non-living matter. The potential benefits of this research go far beyond the limits of present-day molecular biology and so-called genetic engineering.