The Limits to Growth

Abstract established by Eduard Pestel. A Report to The Club of Rome (1972),
by Donella H. Meadows, Dennis l. Meadows, Jorgen Randers, William W. Behrens III

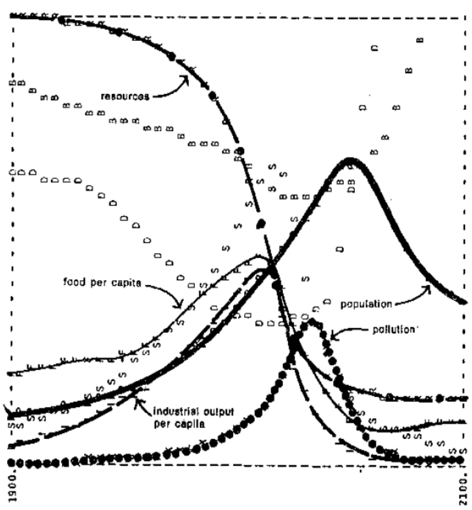
Our world model was built specifically to investigate five major trends of global concern – accelerating industrialization, rapid population growth, widespread malnutrition, depletion of nonrenewable resources, and 1
a deteriorating environment. The model we have constructed is, like every model, imperfect, oversimplified, and unfinished. … We feel that the model described here is already sufficiently developed to be of some use to decision makers.

Our conclusions are :

1. If the present growth trends in world population, industrialization, pollution, food production, and resource
depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred 2
years. The most probable result will be a rather sudden and uncontrollable decline in both population and industrial capacity.
2. It is possible to alter these growth trends and to establish a condition of ecological and economic stability that is
sustainable far into the future. The state of global equilibrium 3
could be designed so that the basic material needs of each person on earth are satisfied and each person has an equal opportunity to realize his individual human potential.

If the world's people decide to strive for this second outcome rather than the first, the sooner they begin working to attain it, the greater will be their chances of success.

Figure 35 WORLD MODEL STANDARD RUN



All five elements basic to the study reported here--population, food production, and consumption of nonrenewable natural resources--are increasing. The amount of their increase each year follows a pattern that mathematicians call exponential growth. … None of the five factors
we are examining here is independent. Each interacts constantly with all the others. We have already 4
mentioned some of these interactions. Population cannot grow without food, food production is increased by growth of capital, more capital requires more resources, discarded resources become pollution, pollution interferes with the growth of both population and food.

Furthermore, over long time periods each of these factors also feeds back to influence itself. In this first simple world model, we are interested only in the broad behavior modes of the population-capital system. By behavior
modes we mean the tendencies of the variables in the system (population or pollution, for example) to change 5
as time progresses. A major purpose in constructing the world model has been to determine which, if any, of these behavior modes will be most characteristic of the world system as it reaches the limits to growth. This process of determining behavior modes is "prediction" only in the most limited sense of the word.

Because we are interested at this point only in broad behavior modes, this first world model needs not be extremely detailed. We thus consider only one general population, a population that statistically reflects the average characteristics of the global population. We include only one class of pollutants--the long-lived,
globally distributed family of pollutants, such as lead, mercury, asbestos, and stable pesticides and 6
radioisotopes--whose dynamic behavior in the ecosystem we are beginning to understand. We plot one generalized resource that represents the combined reserves of all nonrenewable resources, although we know that each separate resource will follow the general dynamic pattern at its own specific level and rate. This high level of aggregation is necessary at this point to keep the model understandable. At the same time it limits the information we can expect to gain from the model.

Can anything be learned from such a highly aggregated model? Can its output be considered meaningful? In terms of exact predictions, the output is not meaningful. On the other hand it is vitally important to gain some
understanding of the causes of growth in human society, the limits to growth, and the behavior of our socio- 7
economic systems when the limits are reached. All levels in the model (population, capital, pollution, etc.) begin with 1900 values. From 1900 to 1970 the variables agree generally with their historical value to the

extent that we know them. Population rises from 1.6 billion in 1900 to 3.5 billion in 1970. Although the birth rate declines gradually, the death rate falls more quickly, especially after 1940, and the rate of population growth increases. Industrial output, food and services per capita increase exponentially. The resource base in 1970 is still about 95 percent of its 1900 value, but it declines dramatically thereafter, as population and industrial output continue to grow.

The behavior mode of the system is that of overshoot and collapse. In this run the collapse occurs because of nonrenewable resource depletion. The industrial capital stock grows to a level that requires an enormous input
of resources. In the very process of that growth it depletes a large fraction of the resource reserves available. 8
As resource prices rise and mines are depleted, more and more capital must be used for obtaining resources, leaving less to be invested for future growth. Finally investment cannot keep up with depreciation, and the industrial base collapses, taking with it the service and agricultural systems, which have become dependent on industrial inputs (such as fertilizers, pesticides, hospital laboratories, computers, and especially energy for mechanization). For a short time the situation is especially serious because population, with the delays inherent in the age structure and the process of social adjustment, keeps rising.

Population finally decreases when the death rate is driven upward by lack of food and health services. The exact timing of these events is not meaningful, given the great aggregation and many uncertainties in the
model. It is significant, however, that growth is stopped well before the year 2100. We have tried in every 9
doubtful case to make the most optimistic estimate of unknown quantities, and we have also ignored discontinuous events such as wars or epidemics, which might act to bring an end to growth even sooner than our model would indicate. In other words, the model is biased to allow growth to continue longer than it probably can continue in the real world. We can thus say with some confidence that, under the assumption of no major change in the present system, population and industrial growth will certainly stop within the next century, at the latest.

To test the model assumption about available resources, we doubled the resource reserves in 1900, keeping
all other assumptions identical to those in the standard run. Now industrialization can reach a higher level 10
since resources are not so quickly depleted. The larger industrial plant releases pollution at such a rate, however, that the environmental pollution absorption mechanisms become saturated. Pollution rises very rapidly, causing an immediate increase in the death rate and a decline in food production. At the end of the run resources are severely depleted in spite of the doubled amount initially available.

Is the future of the world system bound to be growth and then collapse into a dismal, depleted existence? Only if we make the initial assumption that our present way of doing things will not change. We have ample
evidence of mankind's ingenuity and social flexibility. There are, of course, many likely changes in the system, 11
some of which are already taking place. The Green Revolution is raising agricultural yields in non industrialized countries. Knowledge about modern methods of birth control is spreading rapidly.

Although the history of human effort contains numerous incidents of mankind's failure to live within physical limits, it is success in overcoming limits that forms the cultural tradition of many dominant people in today's
world. Over the past three hundred years, mankind has compiled an impressive record of pushing back the 12
apparent limits to population and economic growth by a series of spectacular technological advances. Since the recent history of a large part of human society has been so continuously successful, it is quite natural that many people expect technological breakthrough to go on raising physical ceilings indefinitely.

Will new technologies alter the tendency of the world system to grow and collapse? Let us assume, however, that the technological optimists are correct and that nuclear energy will solve the resource problems of the
world. Let us also assume a reduction in pollution generation all sources by a factor of four, starting in 1975. 13
Let us also assume that the normal yield per hectare of all the world's land can be further increased by a factor of two. Besides we assume perfect birth control, practiced voluntarily, starting in 1975.

All this means we are utilizing a technological policy in every sector of the world model to circumvent in some way the various limits to growth. The model system is producing nuclear power, recycling resources, and
mining the most remote reserves; withholding as many pollutants as possible; pushing yields from the land to 14
undreamed-of heights; and producing only children who are actively wanted by their parents. The result is still an end to growth before the year 2100.

Because of three simultaneous crises. Overuse of land leads to erosion, and food production drops. Resources are severely depleted by a prosperous world population (but not as prosperous as the present US
population). Pollution rises, drops, and then rises again dramatically, causing a further decrease in food 15
production and a sudden rise in the death rate. The application of technological solutions alone has prolonged the period of population and industrial growth, but it has not removed the ultimate limits to that growth.

Given the many approximations and limitations of the world model, there is no point in dwelling glumly on the
series of catastrophes it tends to generate. We shall emphasize just one more time that none of these
computer outputs is a prediction. We would not expect the real world to behave like the world model in any of
the graphs we have shown, especially in the collapse modes. The model contains dynamic statements about 16
only the physical aspects of man's activities. It assumes that social variables--income distribution, attitudes
about family size, choices among goods, services, and food--will continue to follow the same patterns they
have followed throughout the world in recent history. These patterns, and the human value they represent,
were all established in the growth phase of our civilization. They would certainly be greatly revised as
population and income began to decrease. Since we find it difficult to imagine what new forms of human
societal behavior might emerge and how quickly they would emerge under collapse conditions, we have not
attempted to model such social changes. What validity our model has holds up only to the point in each output
graph at which growth comes to an end and collapse begins.

The unspoken assumption behind all of the model runs we have presented in this chapter is that population
and capital growth should be allowed to continue until they reach some "natural" limit. This assumption also
appears to be a basic part of the human value system currently operational in the real world. Given that first
assumption, that population and capital growth should not be deliberately limited but should be left to "seek 17
their own levels", we have not been able to find a set of policies that avoids the collapse mode of behavior.
The hopes of the technological optimists center on the ability of technology to remove or extend the limits to
growth of population and capital. We have shown that in the world model the application of technology to
apparent problems of resource depletion or pollution or food shortage has no impact on the essential problem,
which is exponential growth in a finite and complex system. Our attempts to use even the most optimistic
estimates of the benefits of technology in the model did not prevent the ultimate decline of population and
industry, and in fact did not in any case postpone the collapse beyond the year 2100. Unfortunately the model
does not indicate, at this stage, the social side-effects of new technologies. These effects are often the most
important in terms of the influence of a technology on people's lives. Social side-effects must be anticipated
and forestalled before the large-scale introduction of a new technology.

While technology can change rapidly, political and social, institutions generally change very slowly.
Furthermore, they almost never change in anticipation of social need, but only in response to one. We must
also keep in mind the presence of social delays--the delays necessary to allow society to absorb or to prepare
for a change. Most delays, physical or social reduce the stability of the world system and increase the 18
likelihood of the overshoot mode. The social delays, like the physical ones, are becoming increasingly more
critical because the processes of exponential growth are creating additional pressures at a faster and faster
rate. Although the rate of technological change has so far managed to keep up with this accelerated pace,
mankind has made virtually no new discoveries to increase the rate of social, political, ethical, and cultural
change.

Even if society's technological progress fulfills all expectations, it may very well be a problem with no technical
solution, or the interaction of several such problems, that finally brings an end to population and capital growth.
Applying technology to the natural pressures that the environment exerts against any growth process has
been so successful in the past that a whole culture has evolved around the principle of fighting against limits 19
rather than learning to live with them. …Faith in technology as the ultimate solution to all problems can thus
divert our attention from the most fundamental problem--the problem of growth in a finite system--and prevent
us from taking effective action to solve it.

On the other hand, our intent is certainly not to brand technology as evil or futile or unnecessary. We strongly
believe that many of the technological developments mentioned here--recycling, pollution-control devices,
contraceptives--will be absolutely vital to the future of human society if they are combined with deliberate 20
checks on growth. We would deplore an unreasoned rejection of the benefit of technology as strongly as we
argue here against an unreasoned acceptance of them. Perhaps the best summary of our position is the motto
of the Sierra Club : "Not blind opposition to progress, but opposition to blind progress". We would hope that
society will receive each technological advance by establishing the answers to three questions before the
technology is widely adopted.

…We end on a note of urgency. We have repeatedly emphasized the importance of the natural delays in the
population-capital system of the world. These delays mean, for example, that if Mexico's birth rate gradually
declined from its present value to an exact replacement value by the year 2000, the country's population would
continue to grow until the year 2060. During that time the population would grow from 50 million to 130 million. 21
We cannot say with certainty how much longer mankind can postpone initiating deliberate control of its growth
before it will have lost the chance for control. We suspect on the basis of present knowledge of the physical
constraints of the planet that the growth phase cannot continue for another one hundred years. Again,

because of the delays in the system, if the global society waits until those constraints are unmistakably apparent, it will have waited too long.

If there is cause for deep concern, there is also cause for hope. Deliberately limiting growth would be difficult, but not impossible. The way to proceed is clear, and the necessary steps, although they are new ones for human society, are well within human capabilities. Man possesses, for a small moment in his history, the most powerful combination of knowledge, tools, and resources the world has ever known. He has all that is 22
physically necessary to create a totally new form of human society--one that would be built to last for generations. The two missing ingredients are a realistic, long-term goal that can guide mankind to the equilibrium society and the human will to achieve that goal. Without such a goal and a commitment to it, short-term concerns will generate the exponential growth that drives the world system toward the limits of the earth and ultimate collapse. With that goal and that commitment, mankind would be ready now to begin a controlled, orderly transition from growth to global equilibrium.

An Extract from

Limits to Growth, The 30-Year Update

Donella Meadows, Jorgen Randers, Dennis Meadows (2002)

In a new study, Limits to Growth: The 30-Year Update, the authors have produced a comprehensive update to the original Limits, in which they conclude that humanity is dangerously in a state of overshoot. While the past 30 years has shown some progress, including new technologies, new institutions, and a new awareness of 23
environmental problems, the authors are far more pessimistic than they were in 1972. Humanity has squandered the opportunity to correct our current course over the last 30 years, they conclude, and much must change if the world is to avoid the serious consequences of overshoot in the 21st century.

… The World3 computer model is complex, but its basic structure is not difficult to understand. It is based in system dynamics —a method for studying the world that deals with understanding how complex systems change over time. Internal feedback loops within the structure of the system influence the entire system behavior. World3 keeps track of stocks such as population, industrial capital, persistent pollution, and cultivated 24
lands. In the model, those stocks change through flows such as births and deaths; investment and depreciation; pollution generation and pollution assimilation; land erosion, land development, and land removed for urban and industrial uses.

The model accounts for positive and negative feedback loops that can radically affect the outcome of various scenarios. It also develops nonlinear relationships. For example, as more land is made arable, what's left is drier, or steeper, or has thinner soils. The cost of coping with these problems dramatically raises the cost of 25
developing the land —a nonlinear relationship.

Feedback loops and nonlinear relationships make the World3 dynamically complex, but the model is still a simplification of reality. World3 does not distinguish among different geographic parts of the world, nor does it 26
represent separately the rich and poor. It keeps track of only two aggregate pollutants, which move through and affect the environment in ways that are typical of the hundreds of pollutants the economy actually emits. It omits the causes and consequences of violence. And there is no military capital or corruption explicitly represented in World3. Incorporating those many distinctions, however, would not necessarily make the model better. And it would make it very much harder to comprehend.

This probably makes the World3 highly optimistic. It has no military sector to drain capital and resources from the productive economy. It has no wars to kill people, destroy capital, waste lands, or generate pollution. It has no ethnic strife, no corruption, no floods, earthquakes, nuclear accidents, or AIDS epidemics. The model 27
represents the uppermost possibilities for the "real" world.

The authors developed World3 to understand the broad sweep of the future —the possible behavior patterns, through which the human economy will interact with the carrying capacity of the planet over the coming century. 28
World3's core question is, How may the expanding global population and materials economy interact with and adapt to the earth's limited carrying capacity over the coming decade? The model does not make predictions, but rather is a tool to understand the broad sweeps and the behavioral tendencies of the system.

… Limits to growth include both the material and energy that are extracted from the Earth, and the capacity of the planet to absorb the pollutants that are generated as those materials and energy are used. Streams of material and energy flow from the planetary sources through the economic system to the planetary sinks where wastes and pollutants end up. There are limits, however, to the rates at which sources can produce these materials and energy without harm to people, the economy, or the earth's processes of regeneration and regulation. 29

Resources can be renewable, like agricultural soils, or nonrenewable, like the world's oil resources. Both have their limits. The most obvious limit on food production is land. Millions of acres of cultivated land are being degraded by processes such as soil erosion and salinization, while the cultivated area remains roughly constant. Higher yields have compensated somewhat for this loss, but yields cannot be expected to increase indefinitely. Per capita grain production peaked in 1985 and has been trending down slowly ever since. Exponential growth has moved the world from land abundance to land scarcity. Within the last 35 years, the limits, especially of areas with the best soils, have been approached. 30

Another limit to food production is water. In many countries, both developing and developed, current water use is often not sustainable. In an increasing number of the world's watersheds, limits have already been reached. In some of the poorest and richest economies, per capita water withdrawals are going down because of environmental problems, rising costs, or scarcity. 31

Another renewable resource is forests, which moderate climate, control floods, and harbor species, from rattan vines to dyes and sources of medicine. But today, only one-fifth of the planet's original forest cover remains in large tracts of undisturbed natural forests. Although forest cover in temperate areas is stable, tropical forest area is plummeting. From 1990 to 2000, the FAO reports that more than 370 million acres of forest cover —an area the size of Mexico— was converted to other uses. At the same time that forests decline, demand for forest products is growing. If-the loss of 49 million acres per year, typical in the 1990s, continues to increase at 2 percent per year, the unprotected forest will be gone before the end of the century. 32

… Using the World3 computer model, Limits to Growth: The 30-Year Update presents 10 different scenarios for the future, through the year 2100. In each scenario a few numbers are changed to test different estimates of "real world" parameters, or to incorporate optimistic predictions about the development of technology, or to see what happens if the world chooses different policies, ethics, or goals. Most of the scenarios presented in Limits result in overshoot and collapse —through depletion of resources, food shortages, industrial decline, or some combination of these or other factors. 33

… The final four scenarios suggest **some general conclusions**: 34

- A global transition to a sustainable society is probably possible without reductions in either population or industrial output.
- A transition to sustainability will require an active decision to reduce the human ecological footprint.
- There are many choices that can be made about numbers of people, living standards, technological investment, and allocations among industrial goods, services, food, and other material needs.
- There are many trade-offs between the number of people the earth can sustain and the material level at which each person can be supported.
- The longer the world takes to reduce its ecological footprint and move toward sustainability, the lower the population and material standard that will be ultimately supportable.
- The higher the targets for population and material standard of living are set, the greater the risk of exceeding and eroding its limits.

…In 1987, the World Commission on Environment and Development put **the idea of sustainability** into these words: A sustainable society is one that "meets the needs of the present without compromising the ability of future generations to meet their own needs." 35

From a systems point of view, a sustainable society is one that has in place informational, social, and institutional mechanisms to keep in check the positive feedback loops that cause exponential population and capital growth. This means that birthrates roughly equal death rates, and investment rates roughly equal depreciation rates, unless or until technical change and social decisions justify a considered, limited change in the levels of population or capital. Such a society, with a sustainable ecological footprint, would be almost unimaginably different from the one in which most people now live. Before we can elaborate on what 36 sustainability could be, we need to start with what it need not be.

Sustainability does not mean zero growth. Rather, a sustainable society would be interested in qualitative development, not physical expansion. It would use material growth as a considered tool, not a perpetual mandate. Neither for nor against growth, it would begin to discriminate among kinds of growth and purposes for 37
growth. It would ask what the growth is for, and who would benefit, and what it would cost, and how long it would last, and whether the growth could be accommodated by the sources and sinks of the earth.

A sustainable society would also not paralyze into permanence the current inequitable patterns of distribution. For both practical and moral reasons, a sustainable society must provide sufficiency and security for all. A sustainable society would not be a society of despondency and stagnation, unemployment and bankruptcy that current systems experience when their growth is interrupted. A deliberate transition of sustainability would take 38
place slowly enough, and with enough forewarning, so that people and businesses could find their places in the new economy.

A sustainable world would also not be a rigid one, with population or production or anything else held pathologically constant. One of the strangest assumptions of present-day mental models is the idea that a world of moderation must be one of strict, centralized government control. A sustainable world would need rules, 39
laws, standards, boundaries, social agreements and social constraints, of course, but rules for sustainability would be put into place not to destroy freedoms, but to create freedoms or protect them.

Some people think that a sustainable society would have to stop using nonrenewable resources. But that is an 40
over-rigid interpretation of what it means to be sustainable. Certainly a sustainable society would use nonrenewable gifts from the earth's crust more thoughtfully and efficiently.

The authors do suggest **a few general guidelines** for what sustainability would look like, and what steps we 41
should take to get there:

- Extend the planning horizon. Base the choice among current options much more on their long-term costs and benefits.
- Improve the signals. Learn more about the real welfare of human population and the real impact on the world ecosystem of human activity.
- Speed up response time. Look actively for signals that indicate when the environment or society is stressed. Decide in advance what to do if problems appear.
- Minimize the use of nonrenewable resources.
- Prevent the erosion of renewable resources.
- Use all resources with maximum efficiency.
- Slow and eventually stop exponential growth of population and physical capital.

The necessity of taking the industrial world to its next stage of evolution is not a disaster —it is an amazing opportunity. How to seize the opportunity, how to bring into being a world that is not only sustainable, functional, 42
and equitable but also deeply desirable is a question of leadership and ethics and vision and courage, properties not of computer models but of the human heart and soul.