# A FRAMEWORK FOR ARCHAEOLOGY AND SUSTAINABILITY

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**Contents**





**Summary**

Sustainability or collapse follows from the success or failure of problem-solving institutions. The factors that lead to long-term success or failure in problem-solving have received little attention, so that this fundamental activity is poorly understood. The capacity of institutions to solve problems changes over time, suggesting that a science of problem-solving, and thus a science of sustainability, must be historical. Two archaeological cases show how complexity interacts with social and biophysical factors to make societies, over the long-term, sustainable or vulnerable to collapse. Historical science can reveal how problem-solving develops over time, and archaeology is the only field that can trace this development over extremely long periods and among societies that left no written records. Archaeology is therefore a science essential to maintaining life support systems.

## 1. The Dilemma of Sustainability

If there is any historical generalization that seems beyond dispute, it is that human societies of the past 12 000 years have tended to increase in size and complexity. The components of this trend include growing populations; greater technical abilities; hierarchy; differentiation and specialization in social roles; greater scales of integration; and increasing production and flow of information. Any number of measures could be summoned to show that, in at least the industrial world, human well being has in recent decades benefited from this trend. Our ability to manipulate matter and energy has developed to the point where we now contemplate harnessing individual atoms and electrons to perform specific tasks. Perhaps the most unequivocal of such measures is the increase in average health and lifespan of the past two centuries. We are, on balance, better off for having grown complex.

Ironically, it is this ability to provide ourselves with better lives that leads us to question whether we are degrading our life-support systems in the process. Some authors ask whether a large percentage of the Earth's massive human population can live indefinitely at the industrial standard of living, and whether we might irreparably damage our life-support systems in attempting to do so. Sustainability has become the surpassing question of our age.

This essay will not develop a simple answer to the question of our own sustainability. Sustainability is a historical question: the present and future of any system can only be understood in the context of past structures and processes. The question of sustainability must be approached in the context of human history, and particularly in the framework of increasing scale and complexity just outlined. Thus the purpose here is to outline a framework within which archaeologists and historians can contribute to understanding sustainability in both the past and the present.

Sustainability may be the most difficult question that scientists can address. Sustainability is a matter of not only the biophysical world, but also more fundamentally of human values. We seek to sustain only what we value; yet values are variable, transient, and mutable. For most of the past 5000 years, for example, the ideal landscape for much of humanity has been an agricultural one. A landscape of peasant cultivators produced food for the cities, taxes for the state, and sons for the army. Ancient writers of the Mediterranean considered a landscape reverting to natural vegetation to be degraded, a sign of decline. A landscape of small farmers figures prominently in American political ideals, for it was considered the basis of Jeffersonian democracy. In much of the world it is still the landscape to be sustained. In industrialized North America, however, a landscape of small farmers is largely a quaint remembrance, valued more for nostalgia than for political economy. The United States and Canada today are substantially urban. Many urban residents value land managed to appear "natural" (in their conception) rather than managed to produce commodities. Today environmental advocates value old-growth forests more than the wood that such forests could produce. Yet how we value forests may change in the future, as it has in the recent past. We may wonder why we struggle to sustain forests that take centuries to mature, when centuries from now no one may care.

Sometimes progress can be made on a difficult topic by examining its opposite conditions. One condition opposite to sustainability is collapse, that is, the rapid loss of an established level of social, political, or economic complexity. The trend of history has indeed been toward greater complexity, but often this trend has been punctuated by periods like the European Dark Ages, when complexity collapses. Collapse is a recurrent process to which no society is immune; it is the realization of this fact that makes sustainability such a concern. By examining the processes that make societies vulnerable to collapse—that is, that make them unsustainable—we can develop a framework for evaluating both historical sustainability and our own, and show how archaeological research contributes to understanding both.

## 2. Change, Complexity, and Sustainability

Sustainability is not the achievement of stasis, nor is it a passive consequence of producing fewer people or consuming more limited resources. One must work at being sustainable. The challenges to sustainability that any society (or other institution) might confront are, for practical purposes, endless in number and infinite in variety. Sustainability is a matter of problem-solving, an activity so commonplace that we perform it with little reflection, yet fundamental to human existence. We rarely investigate problem-solving to determine how it is done, its long-term consequences, or how it changes.

The trajectory of problem-solving influences, even determines, the success or failure of sustainability efforts in the long run. Problem-solving can have subtle and deleterious effects, for a solution that is successful now may set the stage for future failure. We need to understand how problem-solving institutions develop over periods of years, decades, generations, even centuries. A science of problem-solving is substantially a historical science.

The success of problem-solving rests to a great degree of the complexity of the effort and, over the long term, on understanding and controlling this complexity. The increases in social complexity over the past 12 000 years have consisted of the development of more parts (institutions, social roles), more kinds of parts (specialization of institutions, activities, and roles), and greater integration of parts (controls, hierarchies, information flow). This complexity has great utility in problem-solving. We usually think that our success as a species comes from such characteristics as upright posture, an opposable thumb, and a large and richly networked brain. We are successful in large part because these features allow us rapidly to increase the complexity of our behavior. At the same time, we are paradoxically averse to complexity. In the full spectrum of hominid history—four million years or so—complexity is recent and rare. This is because every increase in complexity has a cost. The cost of complexity is the energy, labor, money, or time that is needed to create, maintain, and replace systems that grow to have more and more parts, more specialists, more regulation of behavior, and more information. The anthropologist Leslie White once estimated that a society based primarily on solar energy (bands of hunter-gatherers, for example) could generate only about one twentieth of one horsepower per capita per year. This is all the energy such a simple society needs. Today such a quantity of energy would not suffice for even a fleeting moment of complex, industrial life.

Before the development of fossil fuels, increasing the complexity and costliness of a society meant that people worked harder. Thus the development of complexity is one of the wonderful dilemmas of human life. Over the past 12 000 years, we have often responded to challenges with strategies that cost more labor, time, money, and energy, and that go against our aversion to such costs. We have done this for a simple reason: most of the time complexity works. It is a basic problem-solving tool. Confronted with problems, we often respond by such strategies as developing more complex technologies, establishing new institutions, adding more specialists or bureaucratic levels to an institution, increasing organization or regulation, or gathering and processing more information. Such increases in complexity work in part because they can be implemented rapidly, and typically build on what was developed before. While we usually prefer not to bear the cost of complexity, our problem-solving efforts are powerful complexity generators. All that is needed for growth of complexity is a problem that requires it. Since problems continually arise, there is persistent pressure for complexity to increase.

The costliness of complexity is not a mere annoyance or inconvenience. It conditions the long-term success or failure of problem-solving efforts. Complexity can be viewed as an economic function. Societies invest in problem-solving, assuming costs and expecting benefits in return. In any system of problem-solving, early strategies that become institutionalized tend to be both effective and cost-effective. That is, they work and give high returns per unit of effort. This is a normal economic process: humans always tend to pluck the lowest fruit, going to higher branches only when those lower no longer hold fruit. In problem-solving systems, inexpensive solutions are adopted before more complex and expensive ones. In the history of human food gathering and production, labor-sparing hunting and gathering gave way to more labor-intensive agriculture, which in some places has been replaced by industrial agriculture that consumes more energy than it produces. We produce minerals and energy whenever possible from the most economic sources. Our societies have changed from egalitarian relations, economic reciprocity, *ad hoc* leadership, and generalized roles to social and economic differentiation, specialization, inequality, and full-time leadership. These characteristics are the essence of complexity, and they increase the costliness of any society.

There can be no end to the challenges that we confront. No society or other institution can simply enjoy stable or increasing returns to complexity in problem-solving. As the highest-return solutions are tried and exhausted, only more costly solutions remain. As the highest-return ways to produce resources, process information, and organize society are implemented, continuing problems must be addressed in ways that are more costly and less cost-effective. As the costs of solving problems grow, the point is reached where further investments in complexity do not give a proportionate return. Increments of investment in complexity begin to yield smaller and smaller increments of return. The marginal return (that is, the return per extra unit of investment) starts to decline. This is the long-term challenge faced by problem-solving institutions: diminishing returns to complexity. If allowed to proceed unchecked, eventually it brings ineffective problem-solving and even economic stagnation. In the most pernicious form, diminishing returns to complexity have made societies vulnerable to collapse, and have led historically to what are called “dark ages.” A prolonged period of diminishing returns to complexity is a major part of what makes problem-solving ineffective and societies unsustainable.

This principle can be illustrated in two primary areas of problem-solving: producing resources and producing information. In the following examples, people solve the problems of obtaining resources and producing information in ways that are economically rational. They prefer behavior and institutions that are inexpensive. When problems require new ways of meeting their needs, they adopt increasing complexity and experience diminishing returns. This discussion illustrates the path typically followed by problem-solving institutions: increasing complexity, increasing costliness, and diminishing returns to complexity.

### 2.1 Producing Resources

The members of industrial societies are socialized to think that it is normal to produce as much as possible. This is, however, a recent development. Our ancestors typically produced much less than they were capable of, and many people still do. Hobbes's characterization the lives of our ancestors as "nasty, brutish, and short" has made us think of subsistence production as a continuous struggle. Yet when anthropologist Richard Lee studied the !Kung Bushmen of the Kalahari Desert, he found them working only 2.5 days per week to obtain all the food they needed. With a little extra effort they could have produced more, but preferred to spend their time at leisure.

Subsistence farmers also tend to underproduce, so that labor is underutilized and inefficiently deployed. Leopold Posposil observed Kapauku Papuans of New Guinea, for example, working only about two hours a day at agriculture. Robert Carneiro found that Kuikuru men in the Amazon Basin spend two hours each day at agricultural work and 90 minutes fishing. The remainder of the day is spent in social activities or at rest. With a little extra effort such people could produce much more than they do.

Subsistence farmers in more economically developed places have followed similar reasoning, including peasants of pre-Revolutionary Russia. A. V. Chayanov studied the intensity of labor among 25 families in the farming community of Volokolamsk. Chayanov found that the larger the relative number of workers per household, the less work each person performed. Productive intensity in Volokolamsk varied inversely with productive capacity. Even under the harsh conditions in which they lived, these Russian peasants underproduced. Those able to produce the most actually underproduced the most. They valued leisure more highly than the marginal return to extra labor.

The economist Ester Boserup confronted this dilemma in her classic work *The Conditions of Agricultural Growth*. She argued that the key to persistent underproduction is the marginal productivity of labor. While intensification in non-mechanized cultivation causes the productivity of land to increase, it causes the productivity of labor to decline. Each extra unit of labor produces less output per unit than did the first unit of labor. Kapauku Papuans, Kuikuru, Russian peasants, and other subsistence farmers produce less than they might for the simple reason that increasing production yields diminishing returns to labor.

Boserup's argument has been well verified. In northern Greece, for example, labor applied at an annual rate of about 200 hours per hectare is about 15 times more productive (in returns to labor) than labor applied at 2000 hours per hectare. The latter farmer will certainly harvest more per hectare, but will harvest less per hour of work. Sometimes subsistence intensification might amount only to the application of extra labor. In other cases it means increasing the complexity of subsistence production by adding extra steps such as field preparation, weeding, manuring, fallowing, or irrigation.

The principle is exemplified in other systems of production. The American dairy industry, for example, began to practice more intensive dairying between 1850 and 1910. The major changes were extending dairying into the winter months, better feeding, and improved sanitation. Annual yield per cow improved by 50%, but output per unit of labor declined by 17.5%.

In sectors such as energy and minerals production, it is a truism that the most accessible deposits are mined first, so that continued exploitation axiomatically yields lower returns per unit of effort. In the case of energy, the dilemma is energy return on investment, where the ratio of BTUs extracted to BTUs invested continually deteriorates.

## 2.2 Producing Knowledge

Information is central to sustainability. Producing knowledge has as great a role in problem-solving as producing resources. We rarely realize, though, that information has costs. As knowledge grows more complex, its production becomes subject to diminishing returns. This constraint limits its application to problem-solving.

Education provides one example. As any society increases in complexity it becomes more dependent on information, and its members require higher levels of education. This investment may not always be cost-effective. In 1924, S. G. Strumilin evaluated the productivity of education in the nascent Soviet Union. He found that the first two years of education raise a worker's skills an average of 14.5% per year. A third year of education causes its productivity to decline, for skills rise only an additional eight percent. Four to six years of education raise a worker's skills only an additional 4–5% per year.

Fritz Machlup published a comprehensive study of the costs of education in the United States. In 1957–58, home education of pre-school children cost the United States $886 400 000 per year for each age class from newborn through five (primarily potential income foregone by parents). In elementary and secondary school the costs increased to $2 564 538 462 per year per age class (for ages 6 through 18). For those who aspired to higher education (33.5% of the eligible population in 1960), a four-year course of study cost the nation $3 189 250 000 per grade per year. Thus the monetary cost of education between pre-school, when the most general and broadly useful education takes place, and college, when the learning is most specialized, increased in the late 1950s by 1075% per capita. Yet from 1900 to 1960 the productivity of this investment for producing specialized expertise declined throughout (Figure 1). As S. G. Strumilin found in the Soviet Union in 1924, higher levels of educational investment yield declining marginal returns.

Science is humanity's ultimate exercise in problem-solving, but it shows similar trends. The knowledge developed early in a scientific discipline tends to be generalized and inexpensive to produce. Thereafter the work becomes increasingly specialized. Specialized research tends to be more costly and difficult to resolve, so that increasing investments yield declining marginal returns. As easier questions are resolved, science moves inevitably to more complex research topics and to more costly organizations.

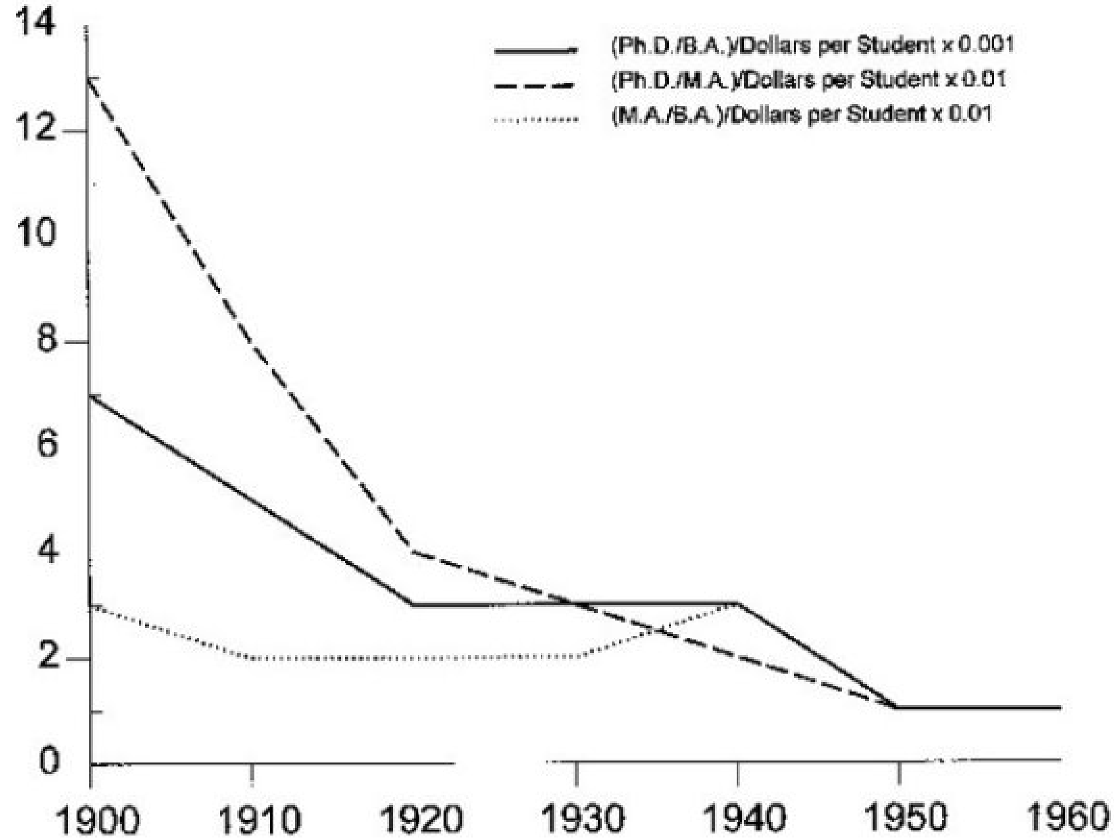


Figure 1. Productivity of Educational Investment for Producing Specialized Expertise, United States, 1900–1960.

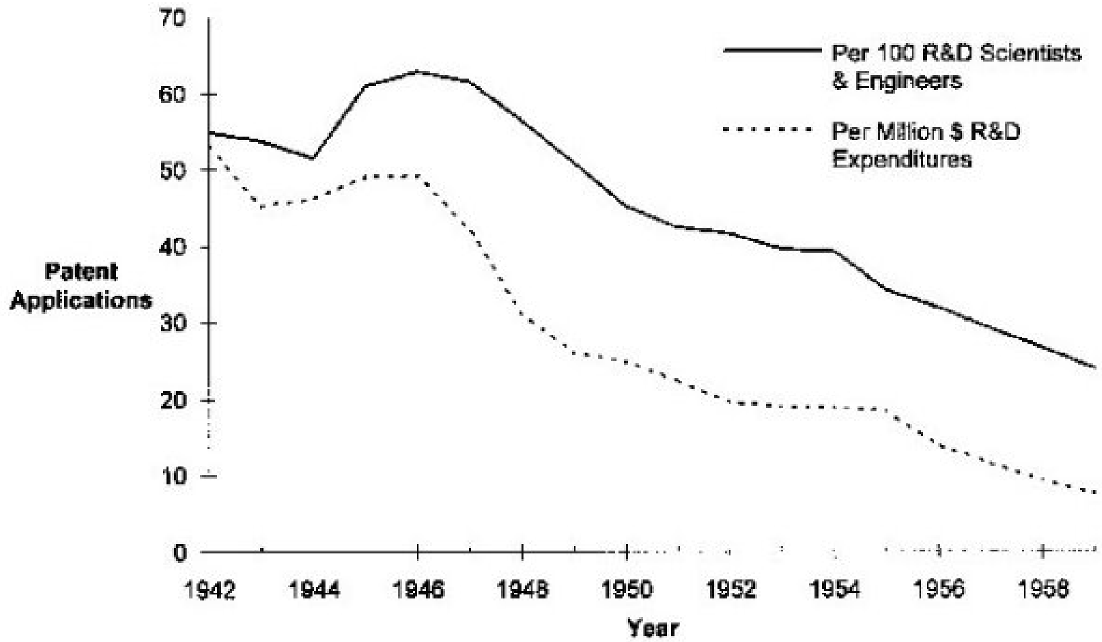


Figure 2. Patent Applications in Respect to Research Inputs, United States, 1942–1958.

Scientists don't usually think about the benefit/cost ratio to their research. If we evaluate the productivity of our investment in science by some measure such as the issuance of patents (Figure 2), however, the long-term productivity of applied research seems to be declining. Patenting is a controversial measure of productivity, but there is good evidence in the field of medicine, where the return to investment can be readily determined. Over the 52-year period shown in Figure 3, from 1930 to 1982, the productivity of the United States health care system for improving life expectancy declined by nearly 60%.

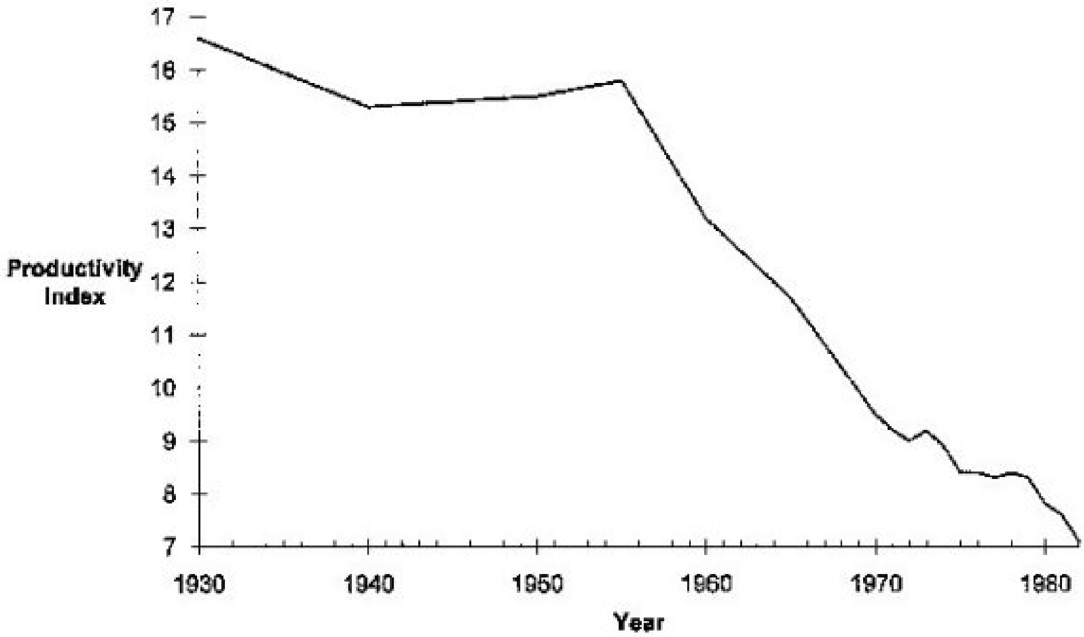


Figure 3. Productivity of the United States Health Care System, 1930–1982. Productivity Index = (Life expectancy)/(National Health Expenditures as Percent of GNP).

The declining productivity of the U.S. health care system illustrates clearly the historical development of problem-solving systems. The productivity of medicine is declining because the inexpensive diseases and ailments were conquered first. The basic research that led to penicillin, for example, cost no more than $20 000. The remaining maladies are more difficult and costly to cure. As each increasingly expensive disease is conquered, the increment to average life expectancy becomes ever smaller. The marginal return to medical investment progressively declines.

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**Biographical Sketch**

**Joseph Tainter** studied anthropology at the University of California and Northwestern University, where he received the Ph.D. in 1975. He has taught at the University of New Mexico and currently directs the Cultural Heritage Research Project, Rocky Mountain Research Station, Albuquerque, New Mexico. Research on the evolution of sociocultural complexity led to the publication of his book *The Collapse of Complex Societies*. In addition to authoring many articles and monographs, he is co-editor of the books *Evolving Complexity and Environmental Risk in the Prehistoric Southwest* and *The Way The Wind Blows: Climate, History, and Human Action*. Dr. Tainter's work has been used in the United Nations Environment Programme (Kenya), the European Joint Commission and the National Nutrition Institute (Italy), the Beijer Institute (Sweden), the Center for International Forestry Research (Indonesia), as well as throughout the United States and Canada. He has been invited to present his research to the Getty Center for the History of Art and the Humanities, and the International Society for Ecological Economics. Dr. Tainter's biography is included in *Who's Who in Science and Engineering, Who's Who in America,* and *Who's Who in the World*.