GMO
JEREMY GRANTHAM
VIEWPOINTS

SUSTAINABILITY OR BUST: THE SHEER IMPOSSIBILITY OF ETERNAL COMPOUND GROWTH

Workforces decline for the foreseeable future, resources get scarcer, climate damage escalates, and the squeezed environment becomes toxic to life

Jeremy Grantham | March 2024

Nothing Can Compound Forever

13 years ago now, in a quarterly letter,[1] I made the point that if Egypt's population at the start of its run in say, 2500 BC, had gone on to 500 AD growing at a tiny 1% a year – much less than the average population growth in my lifetime – it would not have doubled (as it actually did), nor would it have grown by 30 times (which is 1% without compounding). No – at a measly 1% compounded over 3,000 years, the original population of Egypt would have grown by a staggering 9 trillion times! (Check it for yourself!) You can see how compound growth and long timescales do not go together. How about physics? Using energy of any kind means you have to diffuse the waste heat all energy produces, the "heat island" effect, if you will. This effect is currently dwarfed by the great effectiveness of carbon dioxide and methane as greenhouse gases – this year will be over 1.5°C above the old pre-industrial level and the warmest year ever – and that greenhouse effect represents 95% of the heating effect of human energy use, and the heat diffusion effect less than 5%. But if humanity were to keep up the last 250 years' 2.3% compound growth in energy use for just 450 more years, the heat diffusion effect alone – this currently modest 5% – would be enough to boil the oceans![2] No, eternal growth will not work. Sorry about that.

But even though the presence of natural limits has always been a completely rigorous argument, it has always been completely unsaleable to any material percentage of the public: who needs to consider mathematical or physical limits when we are armed with 'the infinite capacity of the human brain'? (I will argue as always that every civilization, Roman, Mayan, or Khmer, had our identical brains yet failed. Still, it's a very appealing thought that never seems to die off.)

Unsaleable or not though, here we go once again with the same old question: how could you grow forever on a finite planet? One of my very few economist heroes Kenneth Boulding did say over 70 years ago: "Anyone who believes that exponential growth can go on forever in a finite world is either a madman or an economist."[3] He was 90 years ahead of mainstream economics in recognizing the limitations and importance of energy and other resources. I say 90 years to allow economics 20 more years to get the point that to make bread you need wheat and heat, in addition to labor and capital. Mainstream economics decided back in the 1950s to basically ignore the limits imposed by natural resources and environmental services, including

1 Time to Wake Up: Days of Abundant Resources and Falling Prices are Over Forever (Grantham 2011).

2 Murphy, Galactic-Scale Energy, Do the Math, July 12, 2011.

3 Jackson and Victor, Unraveling the Claims For (and Against) Green Growth, *Science* 366, no. 6468 (November 2019): 950-951.

the downsides of waste products. In their methodology, capital, labor (and innovation, if you insist) were always going to be enough. Externalities were ignored and considered outside their equilibriums. 'It's only a question of price,' although quite soon, that may mean that only the very rich can pay the necessary price while the rest starve. Steady productivity gains do not buy you much time mathematically either, and are in any case mostly offset quickly by the Jevons effect: the cheaper the product, the more you use.

The Long Term Is Now

The blunt and unpleasant truth is that our civilization is already living beyond its means. We have overshot any possibility of a sustainable level. We are using up finite resources more quickly than technology is creating substitutes. We are crowding out nature and undermining its ability to provide us with hugely important services such as clean water, air, fertile land, biodiversity, and a generally healthy environment. In terms of the remaining "sugar" – energy and other natural resources – still available to our ongoing economic experiment in perpetual growth, we are beginning to notice increasing shortages and are feeling a little hungry. In the distance we can just about make out the rim of our petri dish.

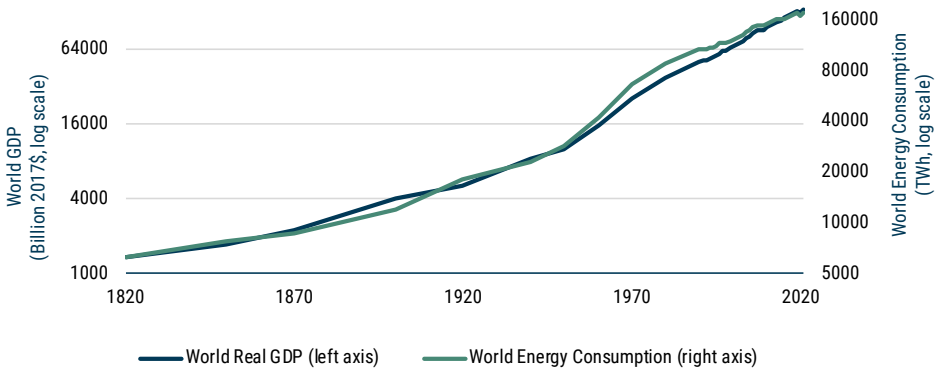
Some will say that the case for limits is too long-term to worry about yet. I will argue here that we are already decades into the period where we are feeling the restraints of overshoot, of living beyond our means, and are already feeling the associated pain: increasing climate damage, floods, droughts, and fires in particular; increasing problems with agriculture; rapidly increasing problems with water availability; growing shortages of important resources; and most importantly and threateningly, the rapid increase in environmental toxicity and its effect on flora, fauna, and humans.

Some will also say that negative arguments in the past turned out to be false or exaggerated and were handled easily and therefore this series of negatives will be handled also. I have argued in the past, and will do so again, that their argument is wishful thinking and ahistorical: it flies in the face of a long history of civilizations, some much longer lived than ours, eventually failing, often mainly by living beyond their means and depending too much on hubris – 'we have withstood so many threats and challenges, won so many wars, built so many aqueducts, that we will always pull through.' And they did pull through, over and over again, until one day they didn't. (Please read the opening to my 2013 paper, The Race of Our Lives, enclosed here in the Appendix).

Fasten Your Seatbelts: The Bumpy Road Begins

I know this story of limits to growth is one that no one wants to hear. As in really, really doesn't want to hear. We have all our hopes for ourselves and for our children tied up in a world where everyone gets to use more energy and more resources to lead steadily better lives, for the indefinite future, or if you prefer, forever. And let's agree that it is our increased use of these resources per capita that has led to better lives, or what has generally been perceived as better lives. Indeed, the long-term correlation between energy use and GDP growth is over 0.95 (see Exhibit 1). That is the equivalent of saying that since the industrial revolution – which was really based on the introduction of fossil fuels into our economy – almost all our gains have been dependent on increased resource use. Without new sources of effective energy, cheap and in vast quantities, there would have been very little science, and very little productivity. And without productivity, little capital would have been created, and labor without capital would have remained as near useless by modern standards as it was in 1750, with just a few windmills and canals.

EXHIBIT 1: WORLD REAL GDP AND WORLD TOTAL ENERGY CONSUMPTION, 1820-2021



As of 2021 | Source: Our World in Data

But happily, for my generation in particular (the old fogeys), we did have growing access to cheap fossil power, and through that, to mining more cheap materials. So we prospered, by conventional measurements.

Resource Limitations

But even as we prospered, early signs of finite limits began to surface. From the 1970s oil crisis onward, energy prices clearly stopped dropping, and this was followed (around 2000) by the prices of a broad range of commodities starting to rise. This was a dramatic shift, for on average the real prices of these same commodities (i.e., after inflation) had fallen by 70% over the previous 100 years, albeit with great volatility around the two world wars and the OPEC crisis.

Just as we began to notice the limits to the availability of cheap resources, environmentalists also began to complain that the unprecedented post-WW2 global growth was continuously damaging nature: chopping it down, bulldozing it, eroding it, and poisoning it with waste and chemical toxins. We also began to calculate the economic and health benefits of a fully functioning natural system that we were beginning to lose. Environmental economists calculated that fully costed natural services – services, that is, like fresh water and healthy soil – might have an economic value equal to or greater than global GDP.[4] If that is even half true, then our calculated GDP growth is an overstatement. Our best guess is that environmental damage amounts to at least 40% of stated GDP gains and possibly very much more. If all new production were calculated a la Hicks,[5] that is, only after the costs of leaving all assets including the entire natural system in the same state as it was found, then we have probably only been making modest forward progress in GDP for a few decades, and possibly none at all.

Waste and Toxicity

Together with the unprecedented global growth of population and GDP after WW2, and with the even larger growth in raw materials necessary to sustain that, came an equally unprecedented rise in waste: waste from mining and oil drilling with associated toxicity and loss of natural habitat; waste in terms of used up products and their packaging; waste

4
Costanza et al., "Changes in the Global Value of Ecosystem Services," *Global Environmental Change* 26 (May 2014): 152-158.

5
Nobel Prize-winning British economist, Sir John Hicks (1904-1989).

greenhouse gases and particulate matter from fossil fuels with all that involves for damage to climate and human health; and the unexpectedly large damage from plastic waste. Even old-fashioned wastefulness in consumption and general lifestyle increased by orders of magnitude since 1945.

Plastic production was particularly seductive. Plastics appear at one level to make our lives easier and better. But below the surface their commercial virtue of indestructibility has become an increasing vice as ultra-persistent plastics have rapidly accumulated, and have been slowly broken down into smaller and smaller pieces becoming steadily more dangerous along the way. Finally, as nanoplastics, they are everywhere and in everything: absorbed by almost all life forms, now found even in our brains,[6] from the ice cap of Greenland[7] to the oceans and all their myriad life forms from plankton to whales.[8] Meanwhile, as our emissions of greenhouse gases – mainly CO2, methane, and nitrous oxide – grow exponentially, they have come to fill enough of the atmosphere to cause now rapidly rising temperatures, which in turn create surging fires, droughts, and floods. Waste and toxic chemicals – many permanently indestructible in nature and produced in almost unimaginable variety (350,000 types[9]) and quantity (2,400 million tons per year[10]) – as with plastics, permeated everything, even rain! The net effect of all this has been to poison our entire global habitat and threaten the long-term survival of all life forms, notably including ours.

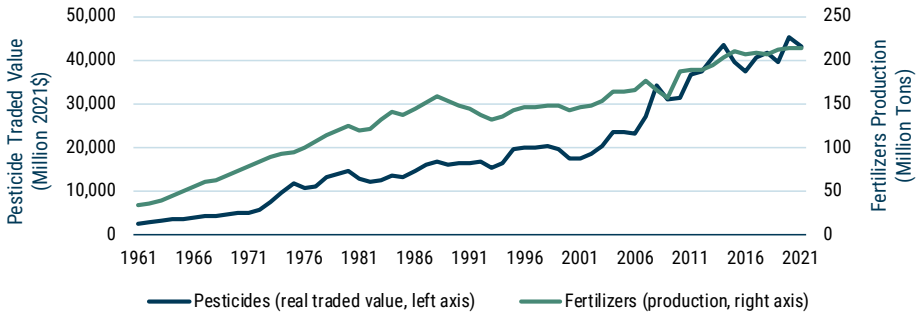
This toxicity has led human sperm counts to fall by more than half in the last 50 years,[11] with similar results for testosterone,[12] along with measurable increases in miscarriages,[13] and now widely remarked-upon declines in sexual activity across the developed world. It is a major underrecognized contributor to falling birthrates globally.

Agricultural Problems

"Big Ag" in the U.S., a consortium of vested interests of giant corporations producing fertilizer, seed, and pesticides (etc.), along with large buyers and government institutions like the USDA that are largely controlled by the giant corporate oligopoly, have created a system in which the growth in fertilizer and pesticide use has outpaced practically any other measure of general growth like population or income. Exhibit 2 shows the tonnage increase.

EXHIBIT 2: WORLD TOTAL PESTICIDE AND FERTILIZER PRODUCTION

Pesticides by real $ value of trade; fertilizers by tonnage



Data as of 2021 | Source: FAOSTAT

6
Prüst et al., The Plastic Brain: Neurotoxicity of Micro- and Nanoplastics, *Particle and Fibre Toxicology* 17, no.24 (June 2020).

7
Utrecht University, Polar Ice Contaminated with Nanoplastics, phys.org, January 20, 2022.

8
Lim, Microplastics Are Everywhere — But Are They Harmful?, nature.com, May 4, 2021.

9
Wang et al., Toward a Global Understanding of Chemical Pollution: A First Comprehensive Analysis of National and Regional Chemical Inventories, *Environmental Science & Technology* (January 2020).

10
Production Capacity of Petrochemicals Worldwide from 2018 to 2022, Statista, February 2023.

11
Levine et al., Temporal Trends in Sperm Count: A Systematic Review and Meta-Regression Analysis of Samples Collected Globally in the 20th and 21st Centuries, *Human Reproduction Update* 29, no.2 (March-April 2023): 157-176.

12
Travison et al., A Population-Level Decline in Serum Testosterone Levels in American Men, *The Journal of Clinical Endocrinology & Metabolism* 92, no. 1 (January 2007):196–202.

13
Rossen et al., Trends in Risk of Pregnancy Loss Among US Women, 1990-2011, *Paediatric and Perinatal Epidemiology* 32, no.1 (October 2017): 19-29.

This onslaught has killed off most of the microscopic life in the soil, one teaspoon of which, if unspoiled, should have more living creatures than there are humans on earth! The standard techniques and inputs of Big Ag have also largely taken away the natural fertility of the soil (which now needs increasing amounts of fertilizer and pesticides to produce a crop) and dramatically reduced its ability to retain water or resist flooding. Now any farmer who is not up for brave regenerative experiments is reduced to taking the advice of Big Ag and buying an increasing quantity of extremely expensive inputs while pumping out food of decreasing nutritional value and increasing toxicity, with rapidly growing consequences for human health. Caught between a few giant buyers and even fewer giant sellers, U.S. farmers are often described as the only people who have to buy at retail and sell at wholesale.

Squeezing The Life Out of Nature

Many readers may not be aware of how overstressed nature is today because of the remarkable industrial growth of the last 200 years, how rapidly the stress is increasing, and the growing damage that this guarantees. So let us look at a few important segments of nature and see how things are going.

We can start with insects. It is not a naturally sexy field and both corporations and governments have seen little immediate financial return likely to result from research designed to find out about the state of the insect world. The best one can do is ask senior experts what they believe. E.O. Wilson (the 'Ant Man'), for example, used to say that nature can thrive without humans but that without insects, the current more or less stable working of our environmental systems would simply unravel: dung and all other debris would largely stop recycling; fruits and flowers, both commercial and natural, would not be pollinated; those birds and amphibians dependent on insects would fail; and so on…cascading through the whole system of life. The precise steps of this unravelling cannot be proved for a lack of funds and a surfeit of complexity. But such a dangerous unravelling is their best guess, and they are the best positioned to make such guesses. It would seem risky to ignore them.

So how are we doing on the insect front? In the last 50 years alone, we have lost 50% or more of the biomass of all insects (their collective weight) and some estimates go as high as 75%.[14] As far as can be measured, the continued loss of insect biomass is around 2% a year – a rate that will halve your numbers in 35 years and divide them by eight in 105 years – the estimated life expectancy of the luckiest 20% born today. (If some or all the issues I am going to discuss in this series don't get in the way!)

Amphibians are also suffering. In the U.S., their population is said to now be declining at a staggering 3.8% a year,[15] a rate that will reduce their population by 98% in a century. This decline is believed to have started in the 1950s or 1960s, alongside the invention of and dramatic increase in petrochemicals. Today, of the vast quantities of different chemicals used for, well, everything, and being produced by the millions of tons, less than 10% are thoroughly tested for toxicity. And absolutely none are tested in combination, which is not only how they usually occur in the environment, but also known to increase the toxicity of many. Amphibians, because they have porous skins, are exceptionally hard hit by pollution and toxic chemicals. Like insects, their rapid decline suggests that this explosion in toxic pollutants has dramatically harmful effects on the health of most living things.

Moving on to mammals, we have similar estimates of their loss of biomass in the last 60 years – from 50% to a horrifying 70%.[16] And we even have a new word for it: defaunation. It is perhaps easier for most readers to get their brains around the sum of elephants, kangaroos, deer, and their ilk than insects, so let's embroider this idea a bit. A few hundred thousand years ago, homo sapiens and their friends, cattle and domesticated pets, did not exist and 100%

14
Sánchez-Bayo and Wyckhuys, Worldwide Decline of the Entomofauna: A Review of Its Drivers, *Biological Conservation* 232 (April 2019): 8-27.
15
Why Are Amphibian Populations Declining? U.S. Geological Survey, usgs.gov, accessed March 12, 2024.
16
Living Planet Report 2022: Building a Nature-Positive Society, WWF, October 2022; Ritchie, Wild Mammals Have Declined by 85% Since the Rise of Humans, But There Is a Possible Future Where They Flourish, Our World in Data, April 20, 2021.

of mammals were wild creatures. By 12,000 years ago, we can guess that the numbers were perhaps 1% and 99%. By 3,000 years ago, as cattle and reindeer were herded and dogs became pets, perhaps it was 5% and 95%. In horrific contrast, today humans with their cattle and pets total an astonishing 96% of all mammal biomass, and all the elephants and every other remaining wild creature total 4%![17] If this isn't heartbreaking, you should have spent more time in nature.

If new technologies beyond our wildest dreams, say not just hot fusion but also cold fusion – you get my point – were to provide infinite cheap green energy and our population was enabled to continue to rise and everyone, everywhere were able to get richer in terms of the energy and other resources they use, it would absolutely guarantee that wild life and nature in general, with all the 'free' benefits it provides, would be crushed out of existence. The remaining wild biomass would quickly fall from 4% to 2% to 1%, with the rat population and a few others hanging on by their teeth and the last of the rainforests turned into palm oil.

Upcoming Papers on This Complex Mess

The complexity of the various interrelated issues that make up the limits to growth is so extreme that I have been writing myself in circles for almost a year. So, I am going to cheat by making this paper the first of a series of six, breaking out four subtopics to this general idea of limits to growth (each in their own right really major). I will address the various investment implications of those subtopics in their corresponding papers.[18] Those four are in addition to this introductory paper:

- **Toxicity and population** – The increasing impact on nature in general and on human health and fertility in particular. Having babies is becoming more difficult and because of that (and other complex reasons) baby cohorts throughout the developed world will drop like a stone and defy encouragement to rebound.

- **Natural resources** – Limitations are increasingly restraining growth and on increasingly calling for ingenuity and capital. Resources will go from one bottleneck to the next amid temporary gluts, which will always be the nature of the beast.

- **Climate damage** – Increasing threats not just to farming, but to the broad ability to increase incomes and well-being. 2023 was by far the warmest year in human history or prehistory. (Where are you now, you miserable climate deniers?)

- **Agriculture** – All impacts and the political and economic consequences of restraints on food production. Food prices will lurch, but appear to trend irregularly upwards, even as measured food quality continues to fall.

It is reasonably clear that each of these issues separately poses threats to our collective well-being that are either existential – that is, capable of taking us humans out of business – or nearly so. Collectively, they are of course an even more serious threat. If these problems continue to deteriorate at the current rate (and some of them seem to be accelerating) they do not pose an existential risk. Rather, they guarantee the failure of our species.

17
Ritchie, Wild Mammals Make Up Only a Few Percent of the World's Mammals, Our World in Data, December 15, 2021.

18
So far it seems as if the substantial acceleration in climate and toxicity damage, the severe deterioration in global geopolitics, the implosion of the birth rate, and the slow fraying of the social contract across the developed world have all been greeted with impressive and surprising enthusiasm by the market. It would seem reasonable to assume that the near extinction of our species might seriously dint portfolios, but come to think of it, if the Fed really eases, who knows?

The Glimmer of Hope: Declining Population

This paper and the four follow-ups, parts 2 through 5, will establish what a severe battery of long-term issues are now upon us. In this sense, the long term has become now. Problems we felt we had a few years to worry about have quite suddenly caught up with us.

Given the rate at which our current environmental damage compounds and our safety margins narrow, we would seem to have about 100 to 150 years to solve our problem: the need to establish an economy that could be sustained indefinitely. If not solved by then, I believe we are highly unlikely to be able to maintain a stable enough society to ever solve these problems.

We are however offered one totally unexpected help: a declining population.[19] My next paper will detail how shockingly fast the baby bust is developing, how remarkably underrecognized it still is, and the completely underrecognized contribution of environmental toxicity. I will also argue that without a large population reduction, there is no reasonable chance that we will reach a sustainable economic system, i.e., one that can be maintained indefinitely and still deliver a good life for most of humanity. I believe that there is little or no chance of getting there – to a much smaller population that is – through leadership and good sense. Based on our record, it is too big an ask. On one hand, we have been programmed for the millions of years it took for us to develop as a species to grab all the resources we could as soon as we could to thrive and multiply. And yes, eventually we learned, no doubt the hard way, to put aside a few acorns for the winter. But beyond that, forget it.

On the other hand, my hero Kenneth Boulding put forward the idea of Spaceship Earth, hurtling through space with only those very finite resources it could carry and with no space depots or stations at which to refuel, resupply and fix problems. And every science fiction fan knows the first requirement of a multigenerational trip to a distant star system is that the regenerative gardens are precisely limited to the 8,000 crew members and families. Of course, the population can't grow at will. It must be meticulously calculated at optimal replacement level. Well folks, whether you like it or not, we are on just such a limited spaceship and we have been breaking these laws. And the giant leap from instinctively grabbing everything you can immediately to long-term restraint on fertility and resource use was always going to be far beyond our natural grasp.

This beneficial outcome of a much lower population is not planned for or deserved in any way: it is, ironically, an unforeseen outcome of our behavior, partly bad, but mostly just thoughtless. It is simply unanticipated and undeserved good luck if we can take advantage of it. With a much-reduced population over the next few generations, we will have much better chances of managing the existential risks we face. We will require a lesser need for unlikely levels of brilliant technology and the kind of profound wisdom that we have so seldom delivered. Thus, if we get below 4 billion people in the next six generations, which now looks quite likely, we may have the get-out-of-jail-free card with which we might just make it. By 'making it,' I mean reaching a smaller, less wasteful, sustainable world with a larger emphasis on long-lasting products and, above all, on the quality of life with, critically, continued scientific progress.

The Problem with Population Decline: The Need for Goldilocks

One of the main risks on this journey will be having the population fall and age so rapidly in the next three generations that it will stress our current brand of growth-oriented capitalism beyond its breaking point, causing us to lose social cohesion and the economic sufficiency

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Births and Deaths per Year, World, Our World in Data, 2022.

needed to navigate our several problems. The good luck here would be to have the population fall steadily for a long while without ever collapsing. And this Goldilocks speed of 'just right' will have to be influenced on the job by trial and error, judgement, and luck. But the largest factor in this population puzzle is always likely to be luck, of which we will need a lot.

Some Final Thoughts on 'Growth': It's Quality Not Quantity, Stupid

The main point of my thesis is that whether measured GDP is slightly negative or positive is not the major issue. Overall, measured GDP is likely to shift over the rest of this century from growing, to flat, to slowly declining as labor forces shrink. Our consumption of fossil fuels and finite metals, and our impacts on the ecosystem and climate, will be falling as they sorely need to. But if we can still deliver technological advances focused on quality of products and quality of life, rather than on increasing use of physical resources, we will be able to thrive and lead satisfactory, improving lives whether or not population and measured GDP are growing. But our society and economy will have to learn how to invest in and value qualitative, rather than quantitative, improvements. Along the way we will hopefully develop a more meaningful measuring rod of success than GDP, which is currently more a measure of cost[20] than a measure of quality of life.

The final, sixth paper will look at some of the immediate problems of a population crash on economic and political life, which are now certain to be massively complicated by the rise of AI – introducing as it will new uncertainties and new risks, along with the hope of substantial labor-saving that might offset some of the extreme pressures associated with a declining global labor force. Further, I will speculate on some of the other problems that will be introduced by such an epic shift away from growth at any price to sensibly living within our long-term limits, and using our brains to maximize and, hopefully, at least slowly increase the quality of life.

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For example, producing tanks and blowing them up, or repairing hurricane damage, increases GDP.

Jeremy Grantham

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Disclaimer

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APPENDIX

The Race of Our Lives (2013)[21]

"Our global economy, reckless in its use of all resources and natural systems, shows many of the indicators of potential failure that brought down so many civilizations before ours. By sheer luck, though, ours has two features that might just save our bacon: declining fertility rates and progress in alternative energy. Our survival might well depend on doing everything we can to encourage their progress. Vested interests, though, defend the status quo effectively and the majority much prefers optimistic propaganda to uncomfortable truth and wishful thinking rather than tough action. It is likely to be a close race.

The Fall of Civilizations

"The collapse of civilizations is a gripping and resonant topic for many of us and one that has attracted many scholars over the years. They see many possible contributing factors to the collapse of previous civilizations, the evidence pieced together shard by shard from civilizations that often left few records. But some themes reoccur in the scholars' work: geographic locations that had misfortune in the availability of useful animal and vegetable life, soil, water, and a source of energy; mismanagement in the overuse and depletion of resources, especially forests, soil, and water; the lack of a safety margin or storage against inevitable droughts and famines; overexpansion and costly unnecessary wars; sometimes a failure of moral spirit as the pioneering toughness and willingness to sacrifice gave way to softer and more cynical ways; increasing complexity of a growing empire that became by degree too expensive in human costs and in the use of limited resources to justify the effort, until the taxes and other demands on ordinary citizens became unbearable, so that an empire, pushed beyond sustainable limits, became vulnerable to even modest shocks that could in earlier days have been easily withstood. Probably the greatest agreement among scholars, though, is that the failing civilizations suffered from growing hubris and overconfidence: the belief that their capabilities after many earlier tests would always rise to the occasion and that growing signs of weakness could be ignored as pessimistic. After all, after 200 or even 500 years, many other dangers had been warned of yet always they had persevered. Until finally they did not."

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From The Race of Our Lives (Grantham 2013).