Anthropocene: An epoch of our making

Humans have affected the Earth in myriad ways, be it through agriculture, mining or urbanisation. But are our impacts epochal? Absolutely, says **James Syvitski.**

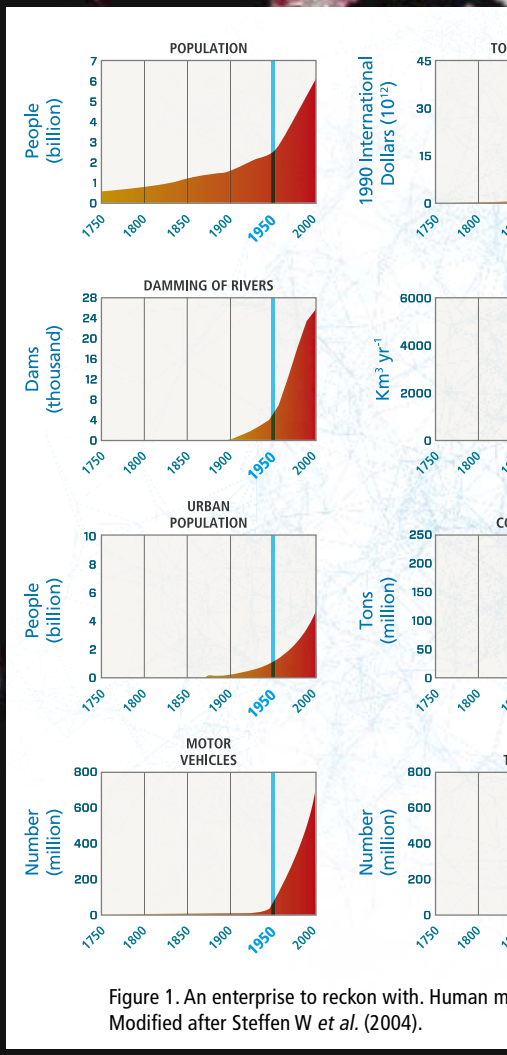
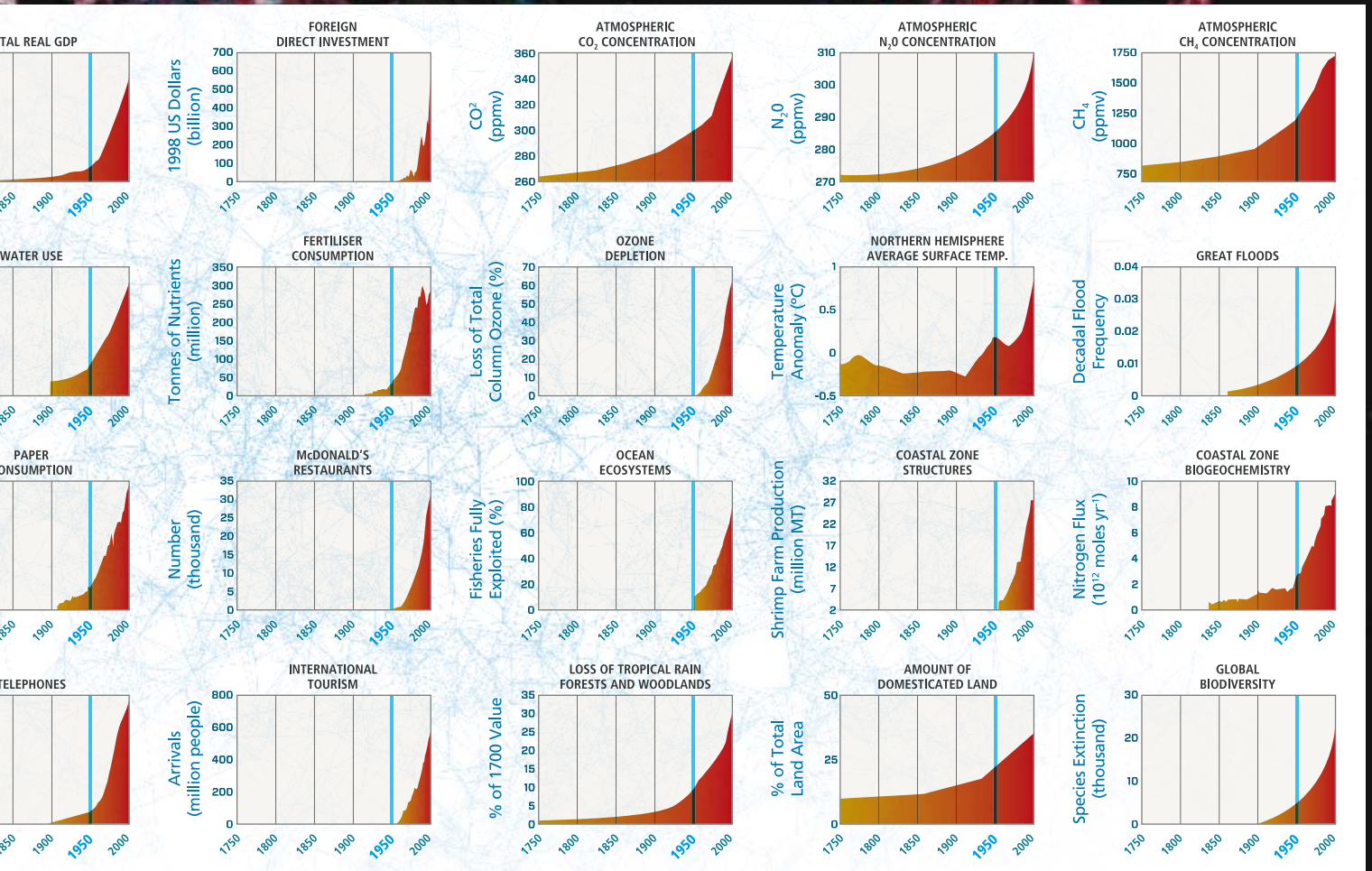


Figure 1. An enterprise to reckon with. Human m
Modified after Steffen W *et al.* (2004).

As rapidly receding ice sheets brought the Pleistocene epoch to an end around 12,000 years ago, the warmer and more stable climate heralded the inception of the Holocene. No longer constrained by the ice age, humans were free to finally make their mark. And make their mark they did. We moved from hunting and gathering to farming; we built major cities and civilisations. We came to rely more and more on technology. At some point, we graduated from adapting to our environment to making it adapt to us. The effects on the Earth were gradual at first: it is huge, after all, and its biogeochemical and physical systems are extremely resilient. As long as our numbers were few and ambitions modest, we had little impact on the planet as a whole. But now we regularly decelerate and accelerate natural processes, focus energy in extraordinary ways and alter, destroy or create ecosystems. Stealthily at first, but then at an astonishing pace, we have left the Holocene behind and embraced the *Anthropocene* (Box 1).

Momentum is building to officially declare the *Anthropocene* a new geological epoch (Syvitski and Kettner 2011; Zalasiewicz *et al.* 2011), prompting high-profile publications and scientific workshops/conferences to discuss the relative merits and demerits of doing so. Interestingly, while portions of society still refuse to acknowledge the role of humans in affecting global climate, they appear more willing to accept that the modern world is anything but pristine and strongly under the influence, if not control, of society.

Epochs are by themselves merely subdivisions of Earth's geologic timescale; it is what happens during these intervals that gives epochs their unique characteristics. The progression from one epoch to another is marked by some easily distinguishable, global stratigraphic 'event', such as a mass extinction, bulk change in the composition of sedimentary rocks or shift from one climate regime to another. The traits of past epochs can be inferred from the rocks that were deposited during those time intervals. Have our activities created a biological, geochemical or sediment signal that will be preserved as a rock record for millions of years (Zalasiewicz *et al.* 2011) and that



anipulation of their environment began in earnest during the Industrial Revolution and accelerated markedly after the 1950s, as IGBP's Great Acceleration graphs show.

Background image created by Gregor Aisch; http://driven-by-data.net/about/global-digital-divide/.

will be sufficiently different from that of the Holocene epoch? If so, where does the Holocene end and the *Anthropocene* begin?

IGBP's Great Acceleration graphs (Figure 1), part of the programme's first synthesis (Steffen *et al.* 2004), collectively highlight the accelerating human enterprise and its impacts on the biophysical Earth system. From these data we can infer that the *Anthropocene* began sometime around the Industrial Revolution in Europe (circa 1800), when new and powerful ways of manipulating the environment became available. Things progressed relatively slowly for a century and half before the stage of great acceleration (1950 onwards). Consumption brought on by affluence and technology overtook population as the greater driver of change (see also page 20 of this issue), a trend that continues to date.

How big is our footprint?

The big regional ice sheets of the Pleistocene epoch removed the soil cover of higher latitude regions, reorganised continental drainage patterns, left large regional areas covered with thousands of lakes and marshes, and mantled continental-scale tracts of land with ice-sheet deposits. Life and ecosystems had to adjust accordingly. Things changed drastically during the Holocene, when everything from ocean circulation to river hydrology or land vegetation responded to the end of the ice age. And of course, human activities accelerated. But are the effects during the past two centuries comparable with, say, those of the Pleistocene ice ages? Do they permit the recognition of a new epoch?

Humans have changed the Earth in a number of fundamental ways (Syvitski and Kettner 2011), many of which are far less known than global warming. This is not surprising when you consider the rapid changes portrayed by the Great Acceleration graphs. Since the 1950s, human population, urbanisation, resource consumption and even the number of Macdonald's restaurants have all grown by leaps and bounds. Granted there are large regional variations, but the impacts on at least some components of the biophysical Earth system have been global and represent similar temporal trends. Atmospheric carbon dioxide, global surface

temperatures and human-induced nitrogen fluxes to the coastal zone have all increased.

Particularly striking is the extent and rate at which we have modified Earth's surface. Deforestation for wood and land clearing for cultivation is an obvious example; the direct effects include soil erosion, hill slope failure and downstream sedimentation. But infrastructure – dams, cities, transportation networks and coastal-management measures – has led to lasting and profound impacts. Prior to human interference, the world's rivers collectively delivered 15 gigatons (Gt) of sediment per year to the coastal ocean. We now easily match the capacity of rivers to move sediment in diverse ways. In the 1930s, a proliferation of small farms employing poor tilling at a time of drought in the US Great Plains region led to one of the world's largest erosion events: 12.5 Gt of topsoil was removed over more than 9 million hectares.

The construction of the Palm Islands will add 520 km of beaches to the city of Dubai, United Arab Emirates, and displace more than 3 Gt of rock, sand and limestone.

But we are also sequestering more sediment on land than would be sequestered naturally (Figure 2). The large dams we have built during the past two centuries trap more than 2.3 Gt of sediment every year in reservoirs. This starves deltas of sediment and, in combination with the mining of water, oil and gas, has led to a situation where large deltas are sinking at four times the rate of sea-level rise. Humans now irrigate deserts throughout the world. We have delayed the flow of freshwater to the ocean by weeks to months through diversions and reservoirs. By any unbiased and quantitative measure, humans have affected the surface of the Earth at a magnitude that ice ages have had on our planet, but over a much shorter period of time.

Clues to our impact are being recorded in sediments that will form part of the rock record in the future. Be it a rapid sediment pulse, a sudden change in composition or evidence for a mass extinction, it will not be hard to distinguish the *Anthropocene* from the Holocene millions of years into the future. Cities could make for particularly interesting deposits, as an article in the May 28 issue of *The Economist* points out cheekily (http://www.economist.com/node/18741749).

Box 1. The emergence of a paradigm

The concept of the *Anthropocene* has manifested itself in the scientific literature for over a century under various guises. In the 1990s the term *Anthroposphere* was widely used in the Chinese science literature under the influence of Chen Zhirong of the Instute of Geology and Geophysics at the Chinese Academy of Sciences in Beijing. *New York Times* journalist Andrew Revkin introduced the terms *Homogenocene* and *Anthrocene* in his 1992 book *Global Warming*. Sometimes the concept appeared without a moniker, as in Vitousek *et al.* (1997).

The *Anthropocene* was formally introduced in 2000 by Nobel laureate and former IGBP vice-chair Paul Crutzen and colleague Eugene Stoermer (1934-2012) in IGBP's *Global Change* magazine (then a newsletter). Professor Stoermer, an ecologist, had been using the term since the eighties. In one 1995 email, Stoermer described terrestrial and neritic oceanic production during the *Anthropocene*. The term and concept quickly caught on, nicely encapsulating IGBP science (Steffen *et al.* 2011). Before 2003, the term yielded 416 web hits; by 2011 that number had increased to over 450,000.

Still, the *Anthropocene* isn't as well known as global warming, which two out of three people had heard of by 2008, according to a Gallop Poll (http://www.gallup.com/poll/117772/Awareness-Opinions-Global-Warming-Vary-Worldwide.aspx). But the former is a more effective paradigm in describing the cumulative impact of civilisation, making global warming and its consequences but one of many ways in which humans have modified the Earth. Narrow focus on global warming might suggest that we simply need to stop emitting greenhouse gases and use renewable energy to abate the planet's pressures. The human footprint is much larger than that.

What are the thresholds we need to worry about?

Living in an Anthropocene world

The preceding discussion might have given the impression that we know a lot about our footprint. And we do indeed. But there is much that we know little about. For example, what are the thresholds we need to worry about and how likely is it for one or more of the so-called tipping points to be crossed? What can we do to prevent this from happening? We need to have a cold hard look at the available evidence and continue to collect missing information. As this is an unfolding story of a change in our Earth system, we must continue to deploy and maintain appropriate observing systems. But we need to do better than repeat the business-as-usual approach that favours observations of the more easily sensed atmosphere and surface oceans. Monitoring the complexities of the terrestrial environment more effectively is just as important.

If addiction is a recurring compulsion to engage in some specific activity despite the knowledge of its harmful consequences, humans are certainly afflicted by one. As discussed on page 20, we continue to extract and consume resources at rates that are clearly unsustainable. Can we change

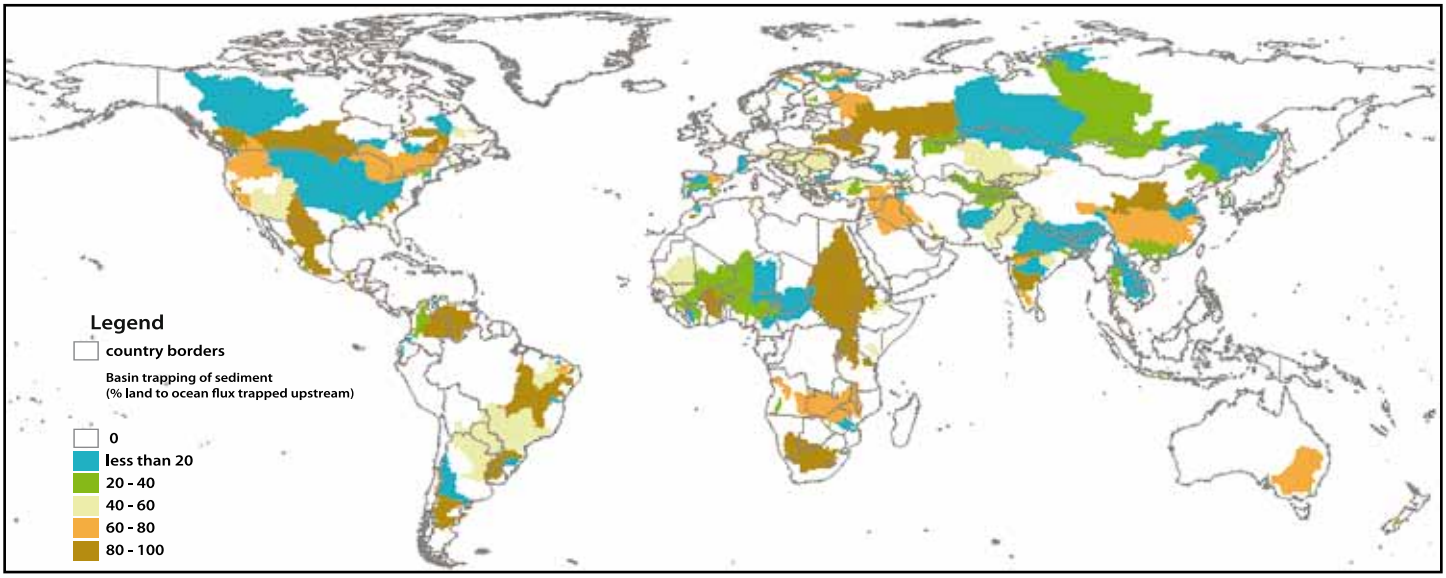


Figure 2. Sediment trapping by large dams. Reservoirs around the world retain sediment that would otherwise have been transported to the ocean. Source: GWSP Digital Water Atlas (2008). Map 51: Sediment Trapping by Large Dams (V1.0). Available online at http://atlas.gwsp.org.

our behaviour and embrace a more sustainable way of living, and if so, how? Unfortunately this is proving to be a far tougher question to answer, for the constraints are not merely poor information or less sophisticated models. What if the answer entails a transformation of our societies, political systems, economies and even international power relations?

Clearly, answering the big questions pertaining to sustainability requires diverse expertise and a solutions-based approach. Existing global-change research programmes like IGBP have contributed immensely to our understanding of the Earth system and of its modification by humans. It is now time to build on this foundation and harness this knowledge to explore creative solutions to the planet's problems. The current research on global change needs to be supplemented by that on societies, policy and economics. Inputs from industry will need to be solicited, for it will need to be part of any solution. The structures that do this aren't in place yet, but the planned Future Earth initiative is a step in the right direction. Contours of the initiative are being worked out at the moment by a team reporting to an alliance that includes the International Council of Science, the International Social Science Council, big funders of global-change research and some UN agencies. The Planet Under Pressure conference in London this year might be a good place to find out how an integrated approach to solutions might look like (http://www.planetunderpressure2012.net/).

We have entered the *Anthropocene*, without question. Some of the changes, for example those brought about by large reservoirs and megacities, are here to stay for hundreds if not thousands or even millions of years. We will simply have to get used to and find a way of living with such changes. But there are things we can and should change to keep improving human wellbeing and to avoid crossing potentially dangerous thresholds. Our strength as humans is the capacity to recognise problems, to understand them and to develop solutions. The final chapter of the *Anthropocene* story is yet to be written: the narrative will depend on our collective self-awareness and the capacity to correct our course, for the relentless pressure on our planet portends unprecedented destabilisation. ▮

The final chapter of the Anthropocene story is yet to be written.

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