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Adapting to Population Growth: The Evolutionary Alternative to Malthus

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Abstract

A long-standing debate on the dynamics of population growth in human history has become polarized between a Malthusian stance and a Boserupian one. The former tends to view population growth as limited by carrying capacity, dependent on environment and technology, whereas the latter sees population growth itself as a major inducement to social, economic and technological developments. In this paper the authors experiment with approaching this debate by using recent developments in evolutionary theory. According to these, evolutionary principles, as expounded by Charles Darwin and subsequent evolutionary scientists, apply not only to biological evolution but also to social or cultural evolution. Here, the role of genes is taken over by culture and, since culture is much more pliable than our DNA, evolution speeds up. As the only organisms on Earth whose evolution relies as heavily on culture as on genes, humans have become extremely adaptable. Their hyper-adaptability suggest that humans, through their cultural evolution, have managed increasingly to adapt to their own growing population, thus succeeding in accommodating ever-growing numbers. This hypothesis fits the Boserupian approach to population very well but less so the Malthusian one, perhaps indicating a gradual shift from a Malthusian regime to a Boserupian one in human history. The hypothesis is discussed and examined through four case studies: The beginning of farming around Göbekli Tepe in southeast Turkey, the productive farming systems of Tiwanaku in South America, the population crisis of late medieval and early modern Iceland, and the 'collapse' of Rapa Nui (Easter Island).

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Introduction

Humans are no ordinary animals. Our adaptation to the environment is no longer only genetic but also cultural. Although a few other species show some signs of culture it is only humans that have evolved culture to such an extent that it has now at least equalled and, to some extent, replaced genes as the dominant adaptive mechanism. Since culture is far more flexible and easily copied than genes, the result is a greatly enhanced adaptability for our species (Wilson 2007). Almost alone among the species of the earth, humans have managed, over the past tens of millennia, to steadily increase their numbers, taking over more and more of the Earth's biosphere.

How did we pull this off? What is it that makes humans so special? Our big brains certainly played a part, but the Neanderthals had brains at least as big and yet they became extinct although some of us still carry a few of their genes (Sankararaman et al. 2014). Perhaps the answer is a bit more complicated and, even though our brains were essential to the process, they may not have been enough.

In this article we shall be looking at this question from an evolutionary perspective and utilizing recent developments in evolutionary theory that considers culture as an evolutionary phenomenon, analogous to genes.

Culture as an Evolutionary Mechanism

When the occasion arises, modern evolutionary theorists have a tendency to adhere to Malthusian demographics rather than to more recent alternatives. This is not surprising since Charles Darwin himself referred to Malthus's observation that a population always has a tendency to outgrow its resource base; that far more new individuals are constantly being born than can possibly survive (Darwin 1859: 63–4; cf. Malthus 1826). Malthus's essay on population was first published in 1798 and has had a powerful influence on population studies ever since. However, Darwin in his *Origin of Species* took this idea further and asked what determined who survived and who didn't. He concluded that some were better adapted to their environment than others and these survived in greater numbers. If the abilities that facilitated survival were hereditary then the next generation would be somewhat different and better adapted than the earlier one. In this way, organisms gradually changed or evolved.

All of this makes perfect sense. Malthus's principles seem to apply to most organisms and Darwin's theory of evolution is uncontested in modern science. However, some problems arise when Malthus's principles are applied to humans as we seem to be able to increasingly circumvent them with the result that our population, for some time, has shown a tendency to exponential growth. The standard explanation, provided by scholars who share Malthus's general approach, is based on technological progress that is supposed to have allowed humans to escape a 'Malthusian trap' where food production could not keep up with population growth and thus restricting it through poverty. We don't find this particularly convincing (below) and we think that Darwin's theory itself may provide better answers, especially when new developments in evolutionary theory are taken into account.

Leaving aside the dated and unsavoury ideology of social-Darwinism, a branch of the biological sciences, well known for its attention to human societies, is called *sociobiology*, a term that seems to have been coined by E.O. Wilson (1975). It has been rather unpopular among practitioners of the humanities and social sciences, probably for a tendency to a kind of genetic determinism that tries to explain most things by reference to genes and how they struggle to survive. Dawkins's theory of the *selfish gene* is a well known example of this way of thinking (Dawkins 2006). However, with the relatively recent emergence of *multilevel selection theory* a paradigm shift may have occurred that could satisfy many in the humanities and social sciences (see Wilson & Wilson 2007; also Sober & Wilson 1998).

The key concept here is *group selection*, an idea favoured by Darwin himself but nonetheless long regarded as heresy. Recently, however, there appears to be a growing consensus that group selection is not only valid but necessary to explain the formation of groups and cooperation. Basically, group selection means that natural selection not only affects individuals but also groups of individuals that cooperate. Some groups have a greater chance of survival than others and thus selection applies not only to the individuals but also to the group as such. Groups that have become adaptive units are often referred to as *superorganisms* (e.g. Hölldobler & Wilson 2009). Altruism can emerge in such groups, often as nepotism but even between unrelated individuals, which strongly suggests that the group has become an adaptive unit (Sober & Wilson 1998; Klein 2014).

One may perceive the formation of multicellular organisms as analogous to group formation and this can even be applied to the genes themselves. Each level in the hierarchy of life is made from cooperating units of the level below. Genes work together in chromosomes and cells, cells in individuals and individuals in groups. Natural selection takes place at all levels of this hierarchy and therefore we speak of *multilevel selection* (Wilson 2007). The evolutionary forces on different levels may even exist in partial discord. Such is the case with humans who are constantly conflicted about doing what is altruistic and good for the group and what is selfish, only good for ourselves and even harmful to other group members. Multilevel selection theory seems to admirably explain this human dilemma.

According to recent trends in evolutionary theory, evolution in the Darwinian sense applies not only to biology but also to culture. Both entail the adaptation of individuals or groups to their habitat. We know a lot about how genes govern biological adaptation but the idea that cultural adaptation is a similar process has been gaining ground in recent years (see Richerson & Boyd 2005; Mesoudi 2011; Turchin 2015, Ch. 2). Biological entities thus have at least two possible ways to evolve and adapt their behaviour so that it improves their chances of survival and of passing on that behaviour. One is the genetic or biological evolution in the strict sense that changes the phenotype and thereby inherent behaviour, but cultural evolution is somewhat different. When discussing culture in an evolutionary sense, we can define it as *socially,* rather than genetically, transmitted information, capable of affecting behaviour (cf. Richerson & Boyd 2005, 5; Mesoudi 2011: Ch. 1). In this sense, culture is not confined to human beings. Many animals have some culture, passed between members of their group (Mesoudi 2011: Ch. 9). Animals that have a significant capacity for learning and are more or less social usually have some elements of culture. Wolves, dolphins, chimpanzees, and ravens (see Heinrich 2006) can all learn behaviour from other members of their group and thus evolve behavioural patterns that improve their adaptation. This is undoubtedly culture in an evolutionary sense.

A primary difference between how genes and culture act as mechanisms for controlling behaviour is that the latter is much more quickly and easily copied and, therefore, evolves far more rapidly (Perreault 2012). No longer is there a need to wait for beneficial genes to gradually spread throughout the population—the population can adopt the beneficial behaviour right away simply by imitation. The evolutionary biologist D.S. Wilson (2007: 218) put it like this: "Our capacity for culture shifted evolution into hyperdrive."

Cultural evolution doesn't replace genetic evolution or make it redundant. Both evolutionary mechanisms are working at the same time and interact with each other in a complex manner (Richerson & Boyd 2005: 191–236). The ability to learn and acquire culture is genetically determined but cultural evolution can in turn stimulate genetic changes that again improve the ability to use culture as can be seen in the evolution of language.

No organism on Earth even comes close to human use of culture. Ravens and chimpanzees have some cultural elements, while we have become cultural organisms. Unlike the culture of most other animals, our culture has become *cumulative* as it builds up over time when new innovations are built on older ones, improving our adaptability, but is also *symbolic,* allowing us to transmit meaning not just through imitation but also through language and writing (Mesoudi 2011: Ch. 9; Jablonka & Lamb: 2005: 193–231). Our behaviour probably is governed about equally by culture and genes. In this respect, humans are a completely new phenomenon in the history of life on Earth and it is precisely this that has made us the 'masters of the Earth' as we sometimes like to think (cf. Wilson 2010). By becoming cultural organisms, humans have multiplied their adaptive capacity and thus the speed of their evolution or, in other words, how quickly they can adapt to their environment.

Anatomically modern humans have been around for about 200,000 years although it is only in the last 10,000 or 15,000 years that cultural evolution has really been speeding up. 10,000 years is like the blink of an eye in the history of life on Earth and yet the way we live has been revolutionized not just once but at least twice; first when people began to actively produce their food by farming and again when societies became industrialized. Actually, this whole period is one of continuous change. Such rapid evolution has never before been seen on Earth—nothing even comes close. The reason is that with humans, a cultural organism has emerged that is capable of evolving and adapting far more rapidly than any other animal.

Hyper-adaptability

What does this vastly improved adaptability mean for our species? Is it possible that our reliance on culture as an adaptive mechanism has allowed us to react differently to population pressure than other species do? Let us examine this as a thought experiment and try to imagine how hyper-adaptability changes the relationship between a species and its environment.

What would happen on any life-harbouring planet if there emerged an organism that was able to adapt so quickly to changes in its environment that it managed to bypass Malthusian controls? Let's imagine an organism with the ability to shift its survival strategy, as soon as its population grew beyond a previous level, thus allowing it to accommodate the increase. In this event, instead of having to reduce its numbers through starvation, it could support at least a part of the increase permanently. The growing numbers of such a species would inevitably affect the environment but the species could adapt to such changes and still keep the population growing. For such fast adaptation this would probably be a cultural organism—an organism that relied mostly on its evolving and cumulative culture to adapt to its rapidly changing environment. There are various ways that this could be achieved such as by utilizing more food resources than before, shifting down the food chain, actively managing and engineering the environment for food production, and to take up symbiotic relationships with other species. Such agriculture, for that is what this amounts to, is much more than just mutualism but rather a range of cultural methods that help the species continuously adapt. An organism like this would unavoidably start increasing its numbers and it would take over more and more of the planet's biosphere.

If this sounds familiar it is simply because this appears already to have happened to our own species. What *would* happen in this thought experiment seems to *have* happened already on Earth. If this scenario is accurate then not only would our numbers increase, they would do so at an increasing rate. When a hyper-adaptable species first starts to adapt to its own population growth it does so only in a limited way but if it also gets more adaptable as its numbers grow, its population growth starts to resemble exponential growth (see also Richerson et al. 2009). A graph of approximate human population growth since 10,000 BCE clearly shows its exponential nature even if the rate has been variable. Generally, the growth rate has been increasing even if it has slowed down recently, particularly in rich countries although no one would argue that they could not feed their population.

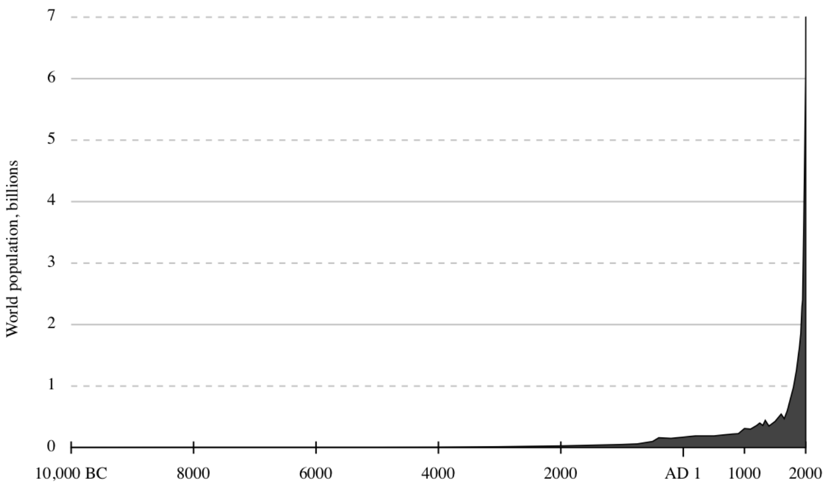

Figure 1. World population growth since 10,000 BC. Source: http://commons.wikimedia.org/wiki/file:population_curve.svg. Accessed 25 Sep. 2014.

For the moment, at least, it seems that humans have managed to more or less completely accommodate their population growth, as never before in human history has a lower proportion of humanity suffered starvation (Lomborg 2001: 60–7). As the population grew over the centuries and millennia, we indeed seem to have become better at accommodating a growing population. In other words: the more people there are in the world, the less likely they are to starve. This may seem counterintuitive but it is undoubtedly a valid generalization when considering human population history in its broadest spectrum even if it doesn't apply to short term variations. Is this simply a reflection of the transformation brought to us by industrial modernization? Perhaps, but nevertheless it is tempting to hypothesize that, as a general rule and notwithstanding special circumstances such as during colonization or major pandemics, complex societies are better equipped than simple ones to accommodate a growing population. Since there is a certain correlation between complexity and population size this would mean that, for relatively stable societies, large ones are generally more likely to be able to grow further than small ones.

The rationale behind such an hypothesis would be the fact that we are social animals with a rich culture that helps us adapt. Collective or group intelligence exists in groups of many animals and recent research indicates that larger and more informed groups tend to react more intelligently. This holds true even for species with little or no culture (King & Cowlishaw 2007; Morand-Ferron & Quinn 2011). However, culture makes us hyper-adaptable. Not only does it work faster than genes as an adaptive mechanism but it should also work better and faster the more there is of it (see e.g. Mesoudi 2011: Ch. 4; Richerson et al. 2009). Small societies, especially if isolated from other similar ones, have less culture than large ones and can even lose culture as seems to have happened to the early Tasmanians (Henrich 2004; see also Diamond 1997: 256–8, 312–3).

The amount of culture a society can hold depends on several factors such as population size, specialization, the number of social relations, and peoples' ability to learn new behaviour which can be enhanced through technology such as writing. Generally speaking, a society's capacity for culture grows with its size and complexity. And since complexity also correlates with size it would seem that the size of the population is a factor in determining cultural capacity including, of course, technology (see Frenken 2006; also Kauffman & Macready 1995; Kauffman 2000: 222–9; Fleming & Sorenson 2001).

If culture shifted evolution into 'hyperdrive' it must mean that culture enhances adaptability. More culture, therefore, should mean greater adaptability. Large complex societies hold more culture than small simple ones. They have more collective experience and knowledge, more options when confronted with environmental changes, more collective brainpower to think up new solutions, and more opportunities to try out these solutions. In other words: more culture makes large complex societies more adaptable than small simple ones and, therefore, they should stand a better chance of accommodating population growth.

If true, this has profound implications because it leads our species towards exponential population growth. As cultural adaptation allowed early human societies to accommodate a few more people, their capacity for culture grew ever so slightly. But this added culture improved adaptability and thereby society's capacity for further growth. We then get a positive feedback loop with continuous growth of population, culture, and adaptability, slow at first but gradually picking up pace. Eventually, growth ceases to be limited by food production at all and could theoretically be exponential, at least for a while, were it not restricted by social relationships and the occasional pandemic or other calamity. As shown in the graph above, the population history of the world seems to have approached such exponential growth, although with a growth rate considerably lower than the biological potential, which may be explained by social restrictions, periodic setbacks, and other variations.

We cannot claim as a fact that this is what happened in human evolution but it seems a very reasonable hypothesis and it could logically explain the main trends in human population history—something that Malthusian demographics struggle with. In Malthusian demographics, population is essentially a passive element. It is a kind of box that automatically fills up but the size of the box is determined by external things like the environment or technology. However, for some time now, a very different way of looking at population has been gaining ground; a way that sees population as a very active element in human history and society.

Boserup and Malthus

In 1965 the economist Ester Boserup published an essay called *The Conditions of Agricultural Growth*. In a way she turned Malthus on his head and argued that instead of population normally being restricted by food production it was the size and growth of the population that determined how food was produced and how much. It was the population growth itself that caused the growth in productive power (Boserup 1965). In her book, she discussed how population growth stimulated new technologies that increased food production. However, she especially emphasized the role of shifting subsistence strategies, how people could increase the food supply by changing these strategies, even in the absence of any new technology. The reason this was not normally done until population pressure was felt was the law of diminishing returns. As long as people had plenty of land they could get by with little work by only utilizing resources that required little labour. As their numbers grew they needed to use more resources even when these required more work. They had to shift from extensive land use, where the productivity of labour was high but that of land was low, to a more intensive system with higher productivity of land but lower of labour. Sometimes such adaptations required new technologies but often they did not, they simply entailed the willingness to put more work into food production—a willingness that came from the need to provide for more people.

Boserup's theory has sparked a debate between Malthusians and 'Boserupians' that is still not resolved although some scholars seek to reconcile the two (e.g. Turchin & Nefedov 2009: 6–8). Scholars with Malthusian leanings often tend to deemphasize or ignore the part of Boserup's model that has to do with adapting through changing subsistence strategies and instead concentrate on adaptation through technology (e.g. Korotayev et al. 2006: 128; Lemmen 2014). In this case, the difference between the Boserupian and Malthusian models becomes minimal but it is clearly a misrepresentation of Boserup's ideas.

In the present context it is worth noting how well Boserup's theory fits to the evolutionary approach proposed here. Apparently, Boserup did not consider evolutionary theory at all when formulating her ideas. However, when she considered the human ability to actively adapt to population growth by changing the productive strategy, she was in full accord with the notion of humans as a species that adapts to its environment through culture. Boserup's theory has greatly influenced our thinking on demographics. She has also been the main impulse behind the activity of scholarly communities like historical ecology (Erickson 1992). We have saved until now to mention her contribution because we wanted to show how approaching the problem from an evolutionary standpoint leads to a similar conclusion as did her economics.

It should be added that the Malthusian model works very well for most animals; only humans show a significant departure from it. It is not a question of all or nothing, either Malthus or Boserup. We propose that our species has gradually been evolving from a Malthusian regime to a 'Boserupian' regime, as its adaptability through culture improved and thereby its ability to accommodate a growing population.

Malthus is often considered one of the founding fathers of classical economics. However, there has been a long string of scholars, other than Boserup, that have questioned their principles, especially their application to pre-modern societies (but recently even modern ones, e.g. Kahneman 2013). Prominent among them are, for example, A.V. Chayanov (1986), K. Polanyi (1957) and K. Lunden (1974). Chayanov is especially relevant here as his analysis, based on extensive empirical research on Russian peasants, showed that these tended to produce enough to fulfil their needs rather than as much as they could. Peasant families were usually far removed from commodity markets and aimed instead at self-sufficiency. The theories of Boserup, Chayanov, and others have shown us peasant societies that are highly adaptable and in tune with their environment and these tend to contradict such notions as a 'Malthusian trap' where population is seen as growing faster than the economy and thus negating any improvement in living condition (e.g. Korotayev et al. 2011).

There often was no pressing need to use every possibility the environment had to offer to maximize food production, as long as peasant societies employed methods to restrict population growth. This is what Malthus himself called 'preventive checks' (Malthus 1826: 12–5) although, like most of his supporters, he tended to underestimate their importance and thought of them mostly as a way to stave off hunger.

Malthusian models usually neglect preventive checks. As already indicated, peasant societies tend to employ a subjective criteria to production, family planning, and organization of daily life that can limit population growth. These include delayed marriage, measures to prevent conception, and even infanticide. Population growth in peasant societies seldom exceeds 0.2–0.3% annually, and on the whole is usually about 0.1% (Livi Bacci 2007). There are exceptions, such as when farmers colonize virgin territory or in the population explosions during expansion cycles that habitually occur in competitive systems (Kristinsson 2010). However, failing to take preventive checks into account when modelling pre-modern populations amounts to ignoring a major variable. In many cases, preventive or social checks on population growth came into play long before environmental checks and effectively neutralized them. Their importance can be gauged by the fact that when such checks were weak the population grew much faster despite all diseases and environmental precariousness. Higher birth rates seem much more important than lower death rates in these cases. An annual growth of around 3% appears to have been achieved for example among the ancient Etruscans (Barker & Rasmussen 2000: 143–9) and 18th century Americans (Galenson 1996; Haines 2000).

At the same time, it is important to note that preventive checks are usually not in place specifically to prevent population growth and thus for the common good. Instead they seem designed to defend the quality of life for important groups. In Europe, the well-to-do peasantry, fearful of poor-relief and having to split up their holdings, seem to have been key players in implementing them and their effectiveness appear proportional to the social clout of this group (cf. Jones 1981: 12–6). In practice, it often meant limiting marriages to those holding farmland (Dyer 1989).

There are also some indications that the weakening of this group can lead to faster growth as the upper class is normally more willing to split up holdings in order to increase the number of their dependents. Population surges, such as in the High Middle Ages in Europe (Kristinsson 2010: 250–1, 261) or 18th and early 19th century Ireland, may be of this ilk. In the latter case, the growth is often attributed to the introduction of the potato but as Ireland was not the only country to grow potatoes but the only one in Europe that experienced such rapid growth, the causation is probably reverse. The Irish grew potatoes because families had to maximize their yields from ever-smaller plots of land (Lloyd 2007; Fraser 2003).

Perhaps such lifting of preventive checks can sometimes lead to a Malthusian crisis where the population grows faster than the economy with deteriorating living conditions (e.g. Korotayev et al. 2011), although this rarely seems to actually stop population growth. Jones (1981) indeed argued that what set Europe apart from Asia was an emphasis on moderate population growth, allowing increased prosperity at the same time. But even in Malthusian crises, preventive checks are a deciding factor and need to be considered seriously.

In the short run, it often seems possible for human populations to adapt to rapid population growth, approaching their full biological potential. However this probably will not work for extended periods of time even if a lesser growth rate is permanently manageable. Agrarian societies in historical times, at least in European cultures, certainly seem to have been able to permanently accommodate a growth rate of at least 0.1–0.3%. Epidemics, famine, and war surely helped contain the growth but preventive checks seem much more important as shown by the rapid growth when they were relaxed.

The Malthusian paradigm was revived in the sixties and seventies of the twentieth century after having been severely criticized in the nineteenth and early twentieth centuries. This neo-Malthusian model was popularised by authors like Paul Ehrlich (1968), who were alarmed by the extremely fast growth of world population and what they saw as the resulting depletion of resources. It seemed obvious at the time that world population would soon outgrow any attempt to keep food and other material production in line with population growth.

However, the Boserupian view developed at the same time and took a very different view of the possibilities of humankind. Even if it was mostly empirically based on research in pre-industrial societies, its optimism was soon realized. It was also based on the very successful accommodation of population growth in western societies since Malthus's time and increasingly also in the third world. Malthus's gloomy predictions simply didn't come true and it seems that most of humanity has now escaped the Malthusian trap, if it was ever caught in it.

The Boserupian population regime means that there are preventive checks on population growth, which is usually limited but quite manageable. This is not necessarily different from how Malthus saw things. However, he and especially his disciples seem to have imagined that humans normally existed quite close to 'carrying capacity', leaving little room for growth without new technologies. However, it can be argued that, in the Boserupian paradigm, this concept is of questionable utility when applied to human societies because when population changes, subsistence strategies also change, even if technology remains the same. Estimates of carrying capacity need to take this flexibility into account but rarely do (Kristinsson 2000). If they don't they can easily end in a circularity where estimated carrying capacity is bound to approximate the actual population because subsistence strategies are designed to support this existing population rather than as many people as possible.

According to the Boserupian model there usually was room for substantial growth irrespective of technology. People, like other living things, have the biological potential for exponential growth although this is rarely actualized to the full. The reason, according to Malthusian logic, is that such growth cannot be accommodated and this seems to apply to most organisms on Earth, even our own ancestors. However, using Boserupian logic, somewhere along the way this changed for humans who acquired the ability to adapt to population growth as well as limiting it through preventive checks. These were sometimes lifted, causing population explosions, showing that it was something other than environmental or technological constrains that limited growth.

Many scholars have roundly criticized the neo-Malthusian interpretation of ecological and socio-economic development put forward in sweeping interpretations like those of Jared Diamond (2005). The tendency to counter the Malthusian view already present in the writings of Boserup, Chayanov, and others was also visible in the work of key environmental historians like Alfred Crosby (1986) and especially William McNeill (1976). Several examples of what neo-Malthusians have pointed to as pre-capitalist ecocides have been questioned through empirical scrutiny (see *Questioning Collapse*). This goes for one of the favourite examples of the neo-Malthusians, the 'fate' of Easter Island, dealt with in detail below. Whole works of science and fiction, and indeed science fiction, are based on dubious interpretations of the dramatic environmental history of this small island in the Pacific (e.g. Winterson 2007).

Part of the problem is a kind of transfer of modern-day fears of overpopulation, overexploitation of resources, and a potentially catastrophic over-reliance on fossil fuels to (largely imagined) examples of social collapse in the past. A necessary distinction between the mode of exploitation in pre-capitalist societies and modern ones tends to become muddled when discussing the possible empirical verification of the Malthusian hypothesis (Lindert 1985). The present fears of overpopulation, which were perhaps more acute in about 1970-1990, have subsided somewhat, but the fears of the danger of a wholesale environmental collapse caused by an unsustainable rate of economic growth are very much present.

To simplify matters we concentrate our examples on pre-capitalist formations, where social exploitation, if it happens, appears in the form of extra-economic coercion. In that case, taxation or rents only become additional consumption items for a system where a balance between consumption and production is already the basic underlying logic.

The instances of rapid population growth in peasant or pre-capitalist societies are few and far between, whereas instances of such growth abound in capitalist societies. Population growth in pre-capitalist societies is usually slow, but it is not absent, and gradually a pressure builds up that tends to be resolved with sudden large-scale changes in the subsistence strategy. The time scale of such changes tends to be hundreds or thousands of years, for example the north-western part of Europe underwent four major re-organizations of agriculture between 4000 BCE and 1800 CE (Myhre & Øye 2002; Slicher Van Bath 1963). A sudden population fall caused by a pandemic is a much more drastic event, but it often occurred in pre-capitalist social formations, and it also lead to large-scale changes in subsistence strategy.

Peasant societies have at their disposal an extensive range of existing technologies, used more or less and taken into increased use if and when the need arises. For example the hunting of seals was a well known subsistence method in Norway and Iceland, but in Norse Greenland it became the main subsistence method. It also became more important in Iceland in years with a lot of sea ice (Arneborg et al. 2012). The utilization of eels has always been shunned in Iceland to the exasperation and incomprehension of Danes, who love eating them (Hastrup 1990). In the North Atlantic environment, and in every pre-capitalist environment we have looked at, there is a range of survival strategies to choose from, in this case a scale from grain growing to dairying to fishing, seal or whale hunting, but usually all strategies are used to some extent. Therefore, it is very questionable to think in terms of absolute carrying capacity which if overstepped causes an environmental collapse. The various subsistence strategies available to each group are usually far too flexible and elastic for this to happen (Campbell 1991; Boserup 1965).

Slow population growth in peasant societies is not caused by restrictions of available technology. It certainly has something to do with the fact that young children tend to die in large numbers in such societies, but primarily, at least in North-western Europe (Laslett 1977), with the organization of reproduction, which is much underappreciated in the Malthusian world.

Peasant societies usually organize reproduction very carefully and with much foresight, and the exceptions to this rule are few and far between. At first sight this might look like a cultural adaptation to a Malthusian situation of limited resources, but this is an illusion: It is linked to the interaction between production and reproduction, with an age-determined division of labour and the power play between different social groupings.

In the following four case studies we aim to demonstrate how a Boserupian or cultural evolutionary approach can better fit the evidence than a strictly Malthusian one. The first two cases show how this approach can apply to complex archaeological material, which the Malthusian approach struggles with. The last two show that some of the most famous examples of Malthusian traps are very questionable indeed.

Göbekli Tepe and the beginning of farming

One of the most interesting archaeological discoveries of recent years is that of Göbekli Tepe in south-eastern Turkey. The site contains monumental stone structures, many decorated with pictograms and animal reliefs, not all of which have yet been excavated (Dietrich et al. 2014, 2015). The place seems not to have been permanently inhabited but functioned as a sanctuary or cult centre (Notroff et al. 2014). Obviously, the construction of the site took a lot of effort and would seem to indicate a level of social complexity and concentration of power normally associated with societies that practiced farming. Therefore, it is quite surprising that these monuments predate the beginning of proper farming, even if only by a small margin.

Göbekli Tepe is right in the middle of a region that may have been the first to develop farming (Watkins 2010; Wilcox 2005). But this only happened around 9,000 BCE whereas the monuments date to the 10th millennium BCE. Previously, it was commonly believed that such concentration of effort, and the complexity this seems to indicate, was only possible once farming had increased the food supply and allowed greater concentration of people, wealth, and power. The site shows that this is not what happened; complexity was increasing before farming emerged. Göbekli Tepe has forced us to think again (Schmidt 2010; Dietrich et al. 2012).

The chief excavator at Göbekli Tepe, the late Klaus Schmidt, interpreted the evidence as indicative of the importance of ideologies; that before humans could change from hunter-gatherers to farmers an ideological transformation had to take place, creating a 'symbolic material culture' that emphasised group identity, competitive feasting (Dietrich et al. 2012), and induced people to seek improving nature's productivity (Schmidt 2010: 253–4). This interpretation is primarily based on the ideas of Jacques Cauvin (2000), originally published in 1994. In a very knowledgeable and perceptive discussion of ideologies and emerging agriculture in the Near East, Cauvin traces the beginning of farming to a new kind of religious ideology emerging among the settled hunter-gatherers in the region and directly causing them to seek new ways of utilizing nature.

Presently, the leading hypotheses for the emergence of farming see it as a result of socio-cultural processes although not necessarily in the same way as

Schmidt and Cauvin did (e.g. Byrd 2005; Willcox 2005). The alternative view is to see it determined by environmental factors (e.g. Richerson et al. 2001). Most would agree that the stabilizing climate after the end of the Ice Age was beneficial to the process.

The present authors would have a tendency to seek explanations for emerging agriculture in population pressure but Cauvin tells us there is no indication of a growing population at the time (Cauvin 2000: 38–9; this refers especially to the Sultanian (Jordan valley); see also Byrd 2005: 258). Ideology is, of course, important but in this case we would rather see it as a part of a complex process rather than a prime mover. It is hardly mere chance that the right kind of ideology didn't appear say 5,000 years earlier in China. Given the fact that farming was invented independently several times in different parts of the globe and each instance happened within a relatively short timeframe between ca. 9,000 BCE and 3,000 BCE (Richerson et al. 2001: 400; Smith 1995), it seems implausible that this was due to chance occurrences of new ideologies. Indeed, the excavators of Göbekli Tepe argue for a close relationship between ideology, food production, and community-building (Notroff et al. 2014) but the nature of this relationship remains unresolved.

By 10,000 BCE the hunter-gatherers of the Near East were no longer typical since many of them had already given up a nomadic lifestyle and settled down, especially in the Natufian culture of the Levant. Where there is a concentration of rich natural resources this sometimes happens but around this time the Near East was probably the place in the world where sedentary hunter-gatherers were most common by far. Some even think sedentism more important than agriculture or discuss such hunter-gatherers as 'complex' or 'domesticated' (see Byrd 2005; Hayden 1995: 277–8; Watkins 2006, 2010). Permanent settlements over a large area, restricting traditional hunter-gatherer nomadic movements, would seem to indicate an unusually dense population. To us, this indicates that population growth did indeed play a part, even if agriculture was not simply a matter of responding to population pressure. It is generally accepted that there was a significant population increase in the late Upper Palaeolithic and Epi-Palaeolithic (Stiner et al. 1999; Bar-Yosef 2002; Watkins 2010: 624–5).

Our hypothesis is that the on-going human adaptation to its own population growth paved the way for the emergence of farming in creating sufficient population densities and permanent settlements. However, the transformation from a hunter-gatherer to a farming lifestyle is not necessarily a desirable one. It is usually accompanied by increased physical labour and a poorer nutritional status (Bowles 2011; cf. Hayden 1995: 275–6). Therefore, one can surmise that people would be reluctant to make the transformation unless there was a pressing need. A slowly building population pressure is not the only thing that can create such a need.

When we find several autonomous polities (tribes, chiefdoms, states, etc.) within a single cultural region we frequently get what we call *competitive systems*. Well known examples are state systems such as in Ancient Greece or Early Modern Europe (Kristinsson 2010). When such systems form in prehistoric or non-state societies they are sometimes referred to by the term 'peer polity interaction' (Renfrew 1986). The most basic characteristic of such systems is that, in spite of shared culture and lively interaction, the member polities engage in intense and often escalating competition forcing them to take all necessary steps to ensure survival. This leads to rapid social change and unusual cultural dynamism; a well known characteristic of state systems.

The archaeological site of Göbekli Tepe could itself indicate the presence of a competitive system in the surrounding area, the Mureybetian part of the PPNA culture, in whole or in part; the same culture that possibly 'invented' agriculture (Cauvin 2000: 34–50, 55–7; see also Heun et al. 2008). Our idea of a Mureybetian competitive system is quite similar to the ideas expressed by Watkins (2008).

Think of Göbekli Tepe as a Mureybetian Delphi, a sanctuary common to the whole system, a place of great cultic significance and truce between the competing tribes. Just as in Greek Delphi the various polities erected their monuments at this centre, which would explain the large number of similar structures. These 'temples' advertised the power, prestige, and resolve of each tribe, strengthening identity and internal cohesion, deterring enemies and inducing others to make alliances. Of course, such an ideological battleground would crystallize through religion and could easily stimulate rapid evolution of religious ideas (cf. Wilson 2002). This competitive interpretation of Göbekli Tepe finds at least a partial support in the interpretation of the excavators themselves (Notroff et a. 2014). The ideological transformation discussed by Cauvin, Schmidt, and others is probably perfectly real although we see it not as the root cause of the social transformation but simply a necessary part of it.

As hunter-gatherers in the Levant settled down, their societies or groups probably had a tendency to become larger since permanent settlement is often a response to a growing population and in turn tends to encourage more frequent births (Bocquet-Appel 2008). However, as human groups become larger they tend to lose their natural internal cohesion. Research indicates that the human brain limits the size of effectively interacting groups to about 150 people (Dunbar 1992, 1993; cf. Watkins 2010: 631). A group that grows significantly beyond this number it is going to need some tools, going beyond personal relationships, to enhance internal cohesion and solidarity. Amongst such tools, religion is possibly the most important (Wilson 2002) and this would explain the increased significance of religious activities in Göbekli Tepe (see also Watkins 2008 and 2010). The advantage of this hypothesis is that religion here has a reason for emerging, is a part of a logical process rather than something appearing out of the blue and singlehandedly transforming everything (see also Atkinson & Whitehouse 2011).

Once we have a collection of relatively large sedentary groups with enhanced group identities, chances of conflicts will rise markedly. In such a situation a competitive system might emerge, even if these were still 'only' hunter-gatherers. In a competitive system we should expect rapid social change brought on by the pressure of competition. This may easily lead to increased emphasis on cultivation.

In this situation we can envisage agriculture emerging as part of the competitive process (cf. Bowles 2011: 4764). For example, more manpower with more warriors would have been an advantage (cf. Turchin 2015). Tribes may have purposely encouraged population growth as a way to keep up with or overawe hostiles. To feed this larger population, especially when it was concentrated in relatively large settlements, increased emphasis on cultivation was necessary (cf. Richerson et al. 2001). Access to food reserves may also have played a direct role in the emergence of farming, for example through 'competitive feasting' (e.g. Hayden 1995; Dietrich et al. 2012; see also Byrd 2005: 259). If cultivation provided a polity with a competitive advantage, it is easy to understand why it spread throughout the system, even at the cost of a lower quality diet and more hard work. To use the evolutionary terminology, it is the group that is the *adaptive unit* in this case, not the individual. Therefore, the interests of human beings are made subservient to the interests of the tribe. It is the group, rather than the individual, that benefits from adopting farming.

If there was a competitive system in the northern Levant, such a system could presumably generate an *expansion cycle*, with rapid population growth pumping people out of the system (Kristinsson 2010, 2012). The resulting migrations would have helped spread agriculture and even languages.

The wider implication of Göbekli Tepe and other transitional sites is that agriculture as such is not as important as we have been accustomed to think. Food production is not the be all and end all of human society, an idea that is anyway based on a very Malthusian assumption. Professor Trevor Watkins (2010: 624) concludes that population growth in the Epi-Palaeolithic shows "that the 'normal' forces that should have ensured that human population density stayed within limits were no longer operating."

The 'normal' forces are presumably the Malthusian ones that apply to all other species—but only partly to humans. Here, we should instead be looking at the complex interaction between culture and population. Larger societies become more complex, contain more culture and need a strong ideology to maintain cohesion. At the same time, they need to feed more people which encourages food production, directly or indirectly.

Tiwanaku

The Tiwanaku and related cultures high in the Andes, around Lake Titicaca, is a case of cultural adaptation to a difficult environment. Moreover, it is a case of a very successful adaptation, where agrarian innovations produced a sustainable system, at least in the middle run, of extremely productive agriculture largely based on potatoes. A series of strategies were available, from extensive grazing, through terraced fields to raised fields. These methods were taken into use in turn, if and when the need arose. Lastly it is a system researched and interpreted by a long-standing community of scholars who explicitly rejected the neo-Malthusian paradigm by introducing the Boserupian one, a community of scholars who call themselves historical ecologists (Erickson 2006).

The origins of the potato as a domesticated plant can be traced to the highlands of the Andes on the border of Bolivia and Peru. It originated about 6000 BCE. Communities of hunters and gatherers who had entered South America at least 7000 years before began domesticating wild potato plants that grew around Lake Titicaca. Andean farmers cultivated many food crops, including tomatoes, beans and maize, but their potato varieties proved particularly suited to the *quechua* or 'valley' zone, which extends at altitudes above 3100 m along the slopes of the Central Andes. Farmers also developed a frost resistant potato variety that survives on the alpine tundra of the *puna* zone at up to 4300 m (Yamamoto 1982; Spooner & Hetterscheid 2006).

Tiwanaku was a pre-Columbian city in the western part of Bolivia. Its territory extended into both Chile and Peru and the state is considered the most powerful and the best organized in South America until the rise of the Inca state, early in the 13th century (Kotala 1993). Tiwanaku lay to the south of Lake Titicaca, which is the highest navigable lake on Earth. Among the resources available was an abundance of fish, fowl, lush vegetation, and grazing (Bruhns 1994).

The Tiwanaku culture made use of a very special method of cultivation, the so-called *suka kollus* or raised field agriculture. This kind of agriculture was only one of a variety of strategies available to the farmers in Tiwanaku. Irrigation, grazing, terraced fields, and fish farming were also used. Raised field agriculture was a system with soil ridges and canals of freshwater between them. Edible plants, primarily potato varieties, would be cultivated on these ridges. The system had several advantages, described in more detail below.

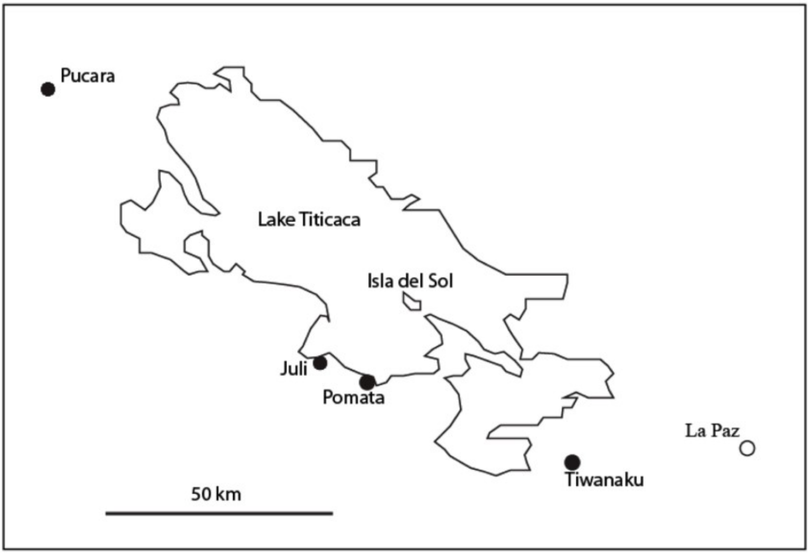

Figure 2. Places mentioned on Lake Titicaca

In the modern period the potato yield in this area is around 2.4 tons per hectare. Modern agriculture provided with artificial fertilized, weed killers, and fossil fuel machines has a yield of 14.5 tons. The raised field system, on the other hand, yielded a harvest of 21 tons of potatoes per hectare (Kotala 1993).

The existence of an extremely productive agricultural system in the plain around Lake Titicaca in earlier times is a recent discovery. How and when did it develop? At present, this area is considered a marginal landscape for agricultural pursuits. There are basically two kinds of land in this area, on one hand heavy and waterlogged soils in the flat plains, and on the other hand thin and poor soil on the steep slopes. Frosts, droughts, and flooding often occurs. Crops have low productivity (Erickson 1992).

The fact that this area was totally recreated by past human societies in order to attain very high yields, verified by archaeological research, shows how a cultural evolutionary process, occurring in a rather hostile environment, can produce yields far beyond the Malthusian imagination. The Malthusian approach is usually accompanied by a rather low opinion of the possibilities of pre-modern agricultural systems and would have a hard time explaining their existence and development. In fact, the land in the Lake Titicaca region was used much more intensively in the pre-Columbian past than it is today (Erickson 1992).

In the Juli-Pomata region that formed a part of the Lake Titicaca cultural area, the total population living near the raised fields increased by 50% from 400 BCE to the period of the peak of the Tiwanaku state around 600 CE. Apparently, raised field agriculture had reached maximum capacity in the Juli-Pomata area because there was no more room for raised field construction. In the southern basin of Tiwanaku, on the other hand, raised field agriculture expanded dramatically. It is estimated that at its height the Tiwanaku state was cultivating 19,000 hectares of fields in the three southern valleys of the Titicaca basin, with a population of at least 100,000, more than five people to each hectare of fields. At least one and a half million people lived in the whole Lake Titicaca basin.

The raised field agricultural system had very special characteristics. From its beginnings in about 800 BCE it was distinguished by soil modification and disturbance, production and recycling of nutrients, microclimate modification, and several other environmental enhancements. These are interrelated features of a very sophisticated system of land management, which was recreated in a series of experiments with the indigenous population in the Lake Titicaca basin in 1981–1986 (Erickson 1992: 291; see also Stanish 2007).

This system greatly modified natural soil conditions and local plant communities. The excavation necessary to create raised fields was a major undertaking as canals were at least 1 meter below the present surface. Soils were modified in various ways. The area is waterlogged because of heavy seasonal rainfall, but construction of raised fields and canals changed the local hydrology by elevating the planting platforms out of standing water and waterlogged soils. A complex network of canal reservoirs, spillways, dikes, embankments, and raised aqueducts controlled the optimal water levels throughout the year.

In years of severe droughts the system was able to produce some crops, whereas different kinds of nearby fields failed completely. The raised field system was also able to deal easily with heavy rainfall and massive flooding. One of the most important advantages of the system was that it extended the rich productive environment of the lake and river marsh artificially into the dry grassland. Aquatic vegetation and aquatic animals rapidly colonized and filled the canals surrounding the raised fields. Such wetlands could produce up to three or four times more biomass than grasslands.

The canals were also efficient in capturing sediments from hill-slope erosion where they were reused in raised fields. Aquatic plants, detritus, rotting vegetation, animal and crop remains also accumulated at the bottom of the canals and this could periodically be removed and used as green manure. Experiments show that continuous production may have been possible on the raised fields without the application of fertilizers other than those produced locally in the canals. Lastly, the raised fields had important effects on the microclimate. The water and the aquatic vegetation in the canals functioned as a heat sink for capture of solar radiation. This heat was gradually released at night, covering the fields in warm air. This was important to limit frost damage to crops, which was a constant danger at this high altitude. Lake Titicaca is about 3800 meters above sea level (Erickson 1992: 294–7).

Raised field agriculture was developed in the period leading up to 800 BCE, along with other, less intensive strategies. The method was then used increasingly by the population surrounding Lake Titicaca and formed one of the most important resource bases of the state of Tiwanaku. The intensive, innovative, and sustainable agriculture of the Tiwanaku period stands in sharp contrast to the extensive methods used at present. The population of the Andes region fell by up to 90% with the invasion of the Europeans around 1500, which caused devastating pandemics among the native population. Consequently, land use in the Andes area became much more extensive.

Let us now look at another example of cultural evolution, which has some similarities to the development around Lake Titicaca, especially regarding the upkeep of a very productive system until a population shock changed the dynamics of land use.

Iceland

The interaction between humans and environment in Iceland has been presented as a story of people blindly and greedily abusing the land they settled in the 9th century (Diamond 2005). In this narrative, it isn't even the case that the settlers used the available resources up to the point where more could not be extracted and population growth was cut off, but the settlers were supposed to have actively destroyed the resource base by abusing the commons—cutting forests and overgrazing the highlands, resulting in a steadily shrinking resource base (Radkau 2008; Friðriksson 1987: 191).

Newer accounts point out that even if a large part of the woodlands disappeared within the first 50–100 years of settlement, and even if there is evidence of increasing erosion in some grazing areas, especially from about 1100–1400, the carrying capacity of the island would not have been approached by population growth (Kristinsson 2000). The resource base was too large for that to happen.

One of the cornerstones of the idea that woodland steadily decreased in the whole period of settlement until about 1900 is a research article published by Hákon Bjarnason in 1937 (Bjarnason 1937). It was a reconstruction of the development of forest cover in one area in the period 1600–1900 or so. Earlier changes in woodland size were unknown and not illuminated by any research.

Later pollen analysis from areas all around Iceland showed an entirely different picture of woodland history before 1500 (Einarsson 1961; Hallsdóttir 1987). It became clear that birch trees and shrubs mostly disappeared in a very short period of time after the first settlers arrived, in about 870 to 920. This result was both surprising and in direct contradiction to the earlier account. However, further support for this interpretation began to emerge. Medieval documents from the 13th to 16th centuries showed that woodlands mostly existed in the same places as in the 20th century. There are some exceptions, but on the whole the picture of woodland management appears to be that after an initial period of clearance, the woodlands that were left were managed and maintained as a resource without much reduction in area for at least 800 years or so (Júlíusson 1997; Júlíusson 2013: 121, 171).

The environmental history of the highlands is a similar case. The story of how the Icelandic people abused the highlands by overgrazing them (Thórarinsson 1961) has, since the nineteen-fifties, gradually been replaced by a very different account. It now seems that the highlands were left alone for long periods of time without any grazing and then became the venue of capitalist sheep farming in the 19th and 20th centuries. This finally led to some overgrazing, but possibly only in the period 1880–1980 or so (Thórhallsdóttir et al. 2013; Sigurjónsson 1958). The idea that the resource base in the Icelandic countryside had been fully exploited at around 1100 and then slowly declined because of overexploitation is being re-examined (Harrison 2013; McGovern et al. 2013; Júlíusson 2013: 75; Brewington et al. 2015).

The long-term development trend in Icelandic pre-modern agriculture was a steady increase of the sheep ratio *vis-à-vis* cattle. This occurred on a very long time-scale, beginning in about 1400 and continuing right up to the 20th century. The increase in the proportion of sheep against cattle primarily happened in a few shocks, after pandemics like the Black Death in 1402–1404, the Later Plague in 1494, and the smallpox epidemic in 1707–1709. The shocks of an immense fall in population in a few terrible pandemic blows caused a reorganisation of agriculture immediately afterwards.

For example, the ratio of sheep to cattle in Iceland in the 14th century was on average about 3:1, with some differences between regions. This meant that by far the largest amount of farm produce came from cattle, up to 85% of the total in some areas. After 1400 the ratio changed, it was now on average about 6:1. In the situation after the pandemics, with immense shortage of labour, it was rational to increase the numbers of sheep in proportion to cattle. It was also very feasible because grassland was plentiful in Iceland (Júlíusson 1997).

In the 18th and 19th centuries the proportion of sheep to cattle went first up to 10:1 after the smallpox epidemic in 1707–1709, and then as high as 97:1 in some locations, because of an increase in international demand for sheep products (Hicks 2014). New grazing areas were opened up in the 19th century, and more of the outfield was used for making hay during the summer.

The development of the agricultural system used in Iceland was not indigenous, because Iceland was uninhabited until about 870 CE. The system was a result of 5000 years of agricultural evolution in Norway, where each successive step provided livelihood for more people. The history is analogous to the one that has been reconstructed for the Lake Titicaca area. There were several important systemic changes in Norwegian agriculture during this period, some of the most important occurring around 1000 BCE when byres were developed and cattle kept in them all winter to collect dung for fertilizing the grain field in the spring. Around 200 CE, the infield-outfield system appeared with continuous cultivation, fertilization of the infield, and development of permanent farming sites (Myhre & Øye 2002). This system had several components just like Tiwanaku; there was a heavily fertilized and cultivated infield where grain grew each year, and in the outfield there was the possibility for cultivating grain every four or five years, for harvesting hay for winter fodder, and for grazing. In the highland there were shielings, where in summer cattle, sheep, and goats were kept and milked, protecting the home outfield and infield from grazing, and utilizing formerly underused resources.

This system was recreated with minor changes in Iceland after 870. It is quite surprising how exactly the settlers copied the original farming pattern. At the farm of Reykjavík, where the capital now stands, the ratio of sheep to cattle was still 1:1 as late as the 14th century, just like it was in western Norway in the 9th century (and in fact also the 14th). In the whole of western Iceland the ratio was seldom higher than 2:1, but in the eastern part of the island it was a bit higher, 3:1 or so, sometimes even higher (Júlíusson 2013: 122–123). Iceland also seems to have adopted the system of summer farms or shielings from Norway (Hitzler 1979).

This shows very limited adaptation to Icelandic conditions. It was in fact a rather intensive way of doing farming, in the Icelandic context. It meant that most of the produce of the farming economy came from cows, and they need a lot more care and work than sheep for example. Cows need good hay during the winter. This hay came from the intensively farmed infield, fertilized and sheltered from all grazing during the whole summer. It meant that up to 70% of all farm produce was based on small infields that covered only about 2–4% of the whole of the farmland. The rest was not intensively used before 1400. A farm often had 150–300 hectares of grassland. The typical infield was usually only about 3 or 4 hectares, but most of the cows' winter fodder came from that rather small area.

Ewes, like cows, where kept in shielings or at the home farm during the summer, and milked. The lambs were taken from them two weeks old in the spring and driven to grazing areas along with any wethers. This means that pressure on highland grazing land was limited.

One major change that followed settlement in Iceland was the systematic removal of woodland in order to gain access to grazing resources. Woodland had been cleared from farmlands in the settlers' homelands where it had been denuded of forests for close to 2000 years (Myhre & Øye 2002: 29–20); open land is what the settlers were used to. Apparently, cattle do not eat birch leaves, which was the main crop of the woodlands, however, other kinds of leaves, such as willow, were used as fodder. Therefore, in order to utilize the land for cattle farming, there was no alternative to clearing the birch woods. This led to probably one of the largest environmental management projects in Europe during the Middle Ages, the clearance of much of Iceland's woodlands. This also increased land erosion, especially in the vulnerable areas of the volcanically active zone that lies across the island from the South-West to the North-East.

Why did the system remain unchanged all this time, from 870 to 1400? It shows that adaptation does not occur automatically. The Norwegian system worked well in Iceland and there was little reason for change. Only after a major catastrophe, with severe labour shortage, did a re-evaluation become necessary.

The make-up of Icelandic farming ecology gave the possibility for a different system from the Norwegian one. The new system in Iceland after 1400 neglected or minimized intensive strategies, such as grain growing, the use of shielings, and cow herding, and increased extensive strategies, especially the huge possibilities for sheep grazing offered by Iceland as compared to Norway. From the beginning, farmers in Iceland had on average far larger areas of vegetation at their disposal than did Norwegian ones, and this gave them the possibility of making the farming system more extensive. This possibility was always latent, and it was finally put into effect after 1400 because of a sudden and extreme shock to the population. Of course, this shock was not unique to Iceland but there are indications that recovery came later than in many other places and was interrupted, especially from the late 17th to the 19th century. The reasons are probably complex but the devastating effects of infectious diseases on semi-isolated islands may well have played a part (Crosby 1986: 52; cf. Cliff & Haggett 1984).

The known effects on ecology after 1400, besides the large scale desertion of farms and slow regrowth of population, was a rapid and long term regrowth of shrub and even forests in many areas. It took at least 250 years, or until the middle of the 17th century, for pressure to increase again on the scrubland (Jónsson 2009). Another consequence was an abandonment of highland grazing for long periods of time in many areas. The result would have been regrowth of vegetation cover in the highlands.

To sum up: A highly developed and productive agricultural system was moved to Iceland, and it was upheld there until the 15^{th} century—even if some other system, such as one using more sheep than cattle, would have been much more effective in terms of human labour. This system did not cause any unsustainable harm to the environment in the new country, precisely because it was such an intensive system, copied directly from a country with more meagre resources per farm.

This was a very Boserupian de-intensification of land use through decreasing the proportion of cattle and increasing that of sheep. It is a fine case of what happens in a country that looses a part of its population and the agricultural system becomes more extensive as a result, which is exactly what Boserup predicted.

Rapa Nui (Easter Island)

A recent meta-analysis of radiocarbon dates indicates that Polynesian expansion in the Pacific mostly took place in a span of less than three centuries between ca. 1025 and 1290 CE (Wilmshurst et al. 2011). This would seem to overturn older ideas that the colonization took place earlier and over a much longer period of time. If Wilmshurst et al. are right—their arguments certainly seem persuasive—the suddenness and speed of the expansion could point to an *expansion cycle* originating in the Samoan Islands (see above for Göbekli Tepe and Kristinsson 2010, 2012). Savai'i, the largest of the Samoan islands, is the namesake of the ancestral homeland in many Polynesian legends. The colonization of Easter Island or Rapa Nui, as the native inhabitants call it, occurred towards the end of that expansion, sometime in the 13^{th} century. It is a small (164 km^2) isolated island at the eastern extreme of Polynesia with few native species of plants and animals and, as often happens in such cases, a very fragile ecosystem. Soon after the colonists arrived the island's environment underwent profound changes. Several species became extinct and an island that was once covered with lush forests turned into bleak grassland.

The massive stone heads, the *moai*, and other archaeological remains indicate a once thriving culture on Rapa Nui, however, by the end of the 19^{th} century hardly more than a hundred natives remained (Peiser 2005: 523–4). The population had crashed. This combination of dramatic environmental changes and equally dramatic population collapse has caused many scholars to connect the two and argue for an ecological suicide or *ecocide*; that the reckless overutilization of natural resources led to their eventual destruction, critically impairing the population's ability to feed itself. This argument has most famously been pursued by Jared Diamond in his book *Collapse*, where he presents Easter Island as a sombre lesson for mankind and "the clearest example of a society that destroyed itself by overexploiting its own resources" (Diamond 2005: 118; see also Flenley & Bahn 2003 and Stenseth & Voje 2009 who suggest that climate change also played a part).

Although many scholars believe that complex societies sometimes collapse and, in recent years, this is most often attributed to environmental stress, a growing number of academics are having serious doubts (see especially Middleton 2012; also Peiser 2005; Shennan et al. 2013; and *Questioning Collapse*). We do not maintain that collapse through overexploitation of resources is theoretically impossible. However, for it to actually happen we would need to have unusually rapid population growth in an unusually confined space so that the growth would outpace the population's ability to adapt and neither could it solve the problem by emigrating. An isolated oceanic island would seem to fit the bill if we add to the mix rampant competition between several tribes that forced them to maximize population growth in order not to be overrun by their neighbours. There is indeed evidence suggestive of small local groups on Rapa Nui rather than an island-wide organization (Lipo et al. 2010). In other circumstances this would lead to expansion and migration. However, this island population had nowhere to go. They couldn't even build boats since the forests were gone and the excess population had to be accommodated at home leading to steadily increased pressure on the environment. The erection of the moai and their later overturn could indeed be signs of such competition. This would be an *expansion cycle* without the possibility of migration (see Kristinsson 2010: 300–17 and *passim*). De la Croix & Dottori (2008), have presented a model that could explain an Easter Island collapse and would seem to fit this scenario exactly. All of this appears quite plausible in itself and therefore it is almost a shame that when we take a closer look at the evidence there are some things that just don't seem to fit. It turns out that Diamond's 'clearest example' isn't clear at all.

The anthropological team of T.L. Hunt and C.P. Lipo have been at the forefront of the re-evaluation of evidence for ecocide on Rapa Nui and the difference between their interpretations and the ecocide camp crystalizes in a number of crucially dissimilar positions.

First of all, new evidence places the original colonization in or around the 13th century CE, much later than earlier interpretations (Wilmshurst et al. 2011; Hunt & Lipo 2010: 28–9; see also Mann et al. 2008: 24) although some scholars still support early colonization (see Flenley & Bahn 2007: 11–2; Cañellas-Boltà et al. 2013). If the former are right it means that the environmental impact of the settlement came almost immediately; there was no protracted initial phase when people had little impact on their environment. Recent research also seems to cast some doubt on how well wooded the island was before human impact (Rull et al. 2010). However, Hunt and Lipo agree with Diamond that the deforestation was caused by human occupation although they argue that the causes for this were more complex than Diamond assumes. The erection and movement of *moai* may not have required large quantities of wood as they have shown that it is possible to use their delicate balance to make them 'walk', guided by ropes, to their destinations and it seems likely that this was precisely the method used (Lipo et al. 2013). They also argue that the accidental or deliberate introduction of the Pacific rat (*Rattus exulans*) by the first settlers played an important role in destroying the forests. Without any natural enemies on the island these animals bred very quickly and by eating the seeds of trees and palms critically reduced their reproduction, a repetition of a similar process that seems to have occurred on the Hawaiian islands a little earlier (Hunt & Lipo 2010: 30–6). However, elements such as fires and human activity may well have been more important in destroying the forests and by the 17th century they had mostly disappeared (see Mann et al. 2008; also Mieth & Bork 2010 and Rolett 2008, who reject the rat hypothesis). According to Peiser (2005: 517–20), the extinction of Rapa Nui trees and palms was not completed until the early 20th century.

Diamond (2005: 91, 108–9) assumes that the disappearance of the forests was crucial to lowering the island's carrying capacity through reducing fertility and water accessibility. In his view, the 15,000 strong population could not be supported after the forests were gone. There seems little doubt that human occupation of the island severely affected the natural environment and that it seems likely that this was, at least partly, due to the peculiarities of a relatively cool and dry climate (Rolett 2008). Hunt and Lipo estimate pre-contact population as less than 5,000 and claim that the disappearance of the forests had a relatively limited effect on its viability. Much of the islanders' nutrition came from ingenious rock gardens where stones were gathered as mulch around cultivated plants to improve soil conditions and provide protection from weeds and the elements (Hunt & Lipo 2009: 605–6; Ladefoged et al. 2013). These horticultural methods were not affected by deforestation and it seems clear that in spite of it, Rapa Nui was capable of supporting quite a significant population (Peiser (2005: 520–1).

Although there is little or no actual evidence for it, Diamond (2005: 118–9) and others assume a massive collapse around 1680. Peiser (2005: 527–8) shows that this date actually comes from Thor Heyerdahl's rather dubious ideas. Recent research seems to indicate continuous settlement and land use up to and beyond European contact (Mulrooney 2013). When the first Europeans arrived in 1722, the Dutchman Roggeveen described the island as fertile and thriving although devoid of trees (see Peiser 2005: 520; Hunt & Lipo 2010: 26) and no drop in population seems indicated before the latter half of the 18th century (Mulrooney 2013; cf. Ladefoged et al. 2013). Hunt and Lipo claim that this reflects the impact, not of starvation, but of Old World diseases that we know for a fact devastated many populations around the globe that lacked previous exposure to them, a process, somewhat ironically, emphasised by Diamond himself in an earlier work (Diamond 1997). According to Peiser (2005: 532–4), the big population crunch only came in the 1860s and '70s when slave raids and forced transportations coupled with smallpox left little more than a hundred survivors, a genocide rather than ecocide (see also Rainbird 2002). Finally, Hunt and Lipo (2009: 607) suggest that sheep grazing and other modern farming practices are partly to blame for the present impoverished condition of the Rapa Nui environment (see also Peiser 2005: 519).

Diamond's primary response to Hunt's and Lipo's criticism is to dismiss it because of archaeological evidence that clearly shows large scale environmental degradation before European contact (e.g. Diamond 2010: endnote 16; cf. Diamond 2007). Rolett (2008) similarly jumps from environmental degradation to social collapse without bothering to show how one led to the other. However, this retort misses the point. The environmental impact of human settlement is not in dispute but rather the *assumption* that this caused society and population on Rapa Nui to collapse (see the reply of Hunt & Lipo 2009). We say assumption because there doesn't seem to be any hard evidence for this, only a quite imprecise correlation in time. However morally reprehensible some may find this, it is perfectly possible for humans to massively impact their environment and still survive, even prosper. It is precisely the ability of the Rapa Nui people to survive in spite of great environmental changes that we find most interesting. The debate on Rapa Nui will no doubt continue for some time but at least it seems that Diamond significantly overstated his case when he claimed Rapa Nui to be a clear case of overexploitation.

There are two main lessons we can take from Rapa Nui. It reminds us that an approximate correlation in time between two events, in this case deforestation and population crash, does not constitute a causal relationship. Of course, most scholars are aware of this but it doesn't hurt to demonstrate that seemingly plausible causal relationships aren't necessarily real (see also Middleton 2012: 268–70). It is worth considering that of all known human societies, Rapa Nui may be the only one to show approximate correlation in time between human induced massive environmental degradation and social collapse. These may have been caused by vulnerabilities derived from isolation, making the environment fragile and the population prone to pandemics, or it may be pure chance. But there is very little evidence that one caused the other.

More importantly, Rapa Nui seems to demonstrate that people are remarkably resilient and can often adapt to extreme environmental changes. It doesn't follow that such adaptation is always possible, although examples to the contrary seem hard to find. We are in fact left without a clear example of such a catastrophe *resulting from people's own misuse of the environment* (see *Questioning Collapse*). Ecological suicide or 'ecocide' may be possible but perhaps it is only a theoretical possibility.

Conclusions

The study of human history is riddled with all kinds of determinisms that see history's driving force in single sets of phenomena. We have technological determinism, environmental determinism, economic determinism, and even ideological determinism. We certainly don't want to replace these with yet another—demographic—determinism. All of these elements are important. However, from an evolutionary point of view, change usually represents adaptation and we contend that this holds true not only for biological evolution but also for human history. Therefore, it is adaptability that is crucial to how quickly human societies are able to adapt to changes, whether these changes are its own growing population or other internal developments, conflict with other societies or environmental alterations. Adaptability, as it seems, has been growing over the centuries and millennia in a positive feedback-loop with increased culture and complexity. Population is an important element in this growth but it is not the only one that matters.

This model of the relationship between demographics, adaptability, and social evolution is based both on modern evolutionary theory and on Boserup's observations. We do not claim to have proven its relevance but simply offer it up as an alternative to what we consider a simplistic Malthusian-style model. It should be up to each researcher to decide which better explains the observable facts of the evolution of human populations. We think there are very significant problems with the Malthusian model, problems that the evolutionary or Boserupian model is able to solve. Neither do we reject Malthusian population models in general. We only reject the notion that Malthusian models can alone offer a basic understanding of *human* population history.

Our main contention is that over thousands of years the human population has slowly been evolving from a Malthusian to a Boserupian regime. In a Malthusian regime, food determines population; in a Boserupian regime it is the other way around, the population creates its own food supply. The Malthusian regime is the original one and controls every living animal on Earth other than humans and their domesticates, for whom it has only partial relevance. The population in modern industrialized societies is obviously not controlled by the food supply.

Instead it is determined through biological, technological, and social processes whereas food production is determined by the demand of the population.

The case studies illustrate various aspects of this evolution. Göbekli Tepe shows the origins of farming not as a prime mover but rather as a response and adaptation to circumstances. In Tiwanaku, agricultural systems developed productivity that even surpasses modern systems and thus shows the great potential of pre-industrial farming. In Iceland, loss of population triggered changes that made the productive system more extensive and less productive as a whole; the expected opposite effect of a growing population. Finally, Rapa Nui shows that even massive environmental degradation does not necessarily lead to starvation or 'collapse' because people are extremely adaptable.

It is this adaptability that has allowed us to increasingly adapt to our own population growth and shifted us from a Malthusian to a Boserupian population regime. However, there are limits to our adaptability and exceptional environmental changes can lead to disaster, although examples where humans themselves cause such catastrophes are hard to find. We do not reject this latter possibility. Indeed, when we started researching this article we thought that Rapa Nui would be such an example. However, we found that this probably is not the case and, as we have yet to find a good example of this scenario, we must conclude that it is, at best, extremely rare. What is to be *expected* is that people adapt to their changing environment—including their own impact on this environment and population growth continues. This is what humanity has been doing for the past tens of millennia, is still doing, and is actually getting better at.

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