Economic Development and Environmental History in the Anthropocene

Perspectives on Asia and Africa

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Environmental Impacts of Colonial Dynamics, 1400–1800: The First Global Age and the Anthropocene

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Introduction

Could one apply the concept of the Anthropocene to the First Global Age, understood as the period between 1400 and 1800? Is there enough evidence, qualitative and quantitative, to support such a claim? For the purpose of this debate, this chapter will discuss the dynamics of European colonialism in the First Global Age and how they contributed to environmental changes at a global level.

In a context in which historians hardly dare to apply the expression *Anthropocene* to a period preceding the late eighteenth century, two climatologists, Lewis and Maslin (2015), openly claimed the existence of that possibility, based on geological markers. They identify two dates as having left the kind of Global Boundary Stratotype Section and Point (GSSP) generally required as the marker of a new geological epoch. These were 1610 and 1964. Their discussion favours the earlier date.

Appealing as it could be for a historian of the Early Modern Age to identify the markers of this 'new' era in that period, the complexity of the problem is such that it opened a very vivid and intense debate, not to say strong reactions from historians, geologists and ecologists. In the aftermath of their proposal, a plethora of answers and replies arose. The debate clearly shows how contentious this claim can be.

What moves academia and fuels the debate is twofold: first, the definition of the expression (which has already acquired so many meanings – in geology, ecology, philosophy, history and the humanities – that it is becoming difficult to use as a

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concept); and second, the timeline on which one can identify the emergence of an era, or just a period, identified as the *Anthropocene*. It is still contested whether the Anthropocene is a new geologic era, subsequent to the Holocene, or part of it (Lewis and Maslin 2015). There is not even consensus on the dates or even the timelines proposed for its inception: the beginning of the Great Acceleration (1945–1954) (Syvitst et al. 2005; Steffen et al. 2007; Syvitst and Kettner 2011; Zalasiewicz et al. 2015) and the beginning of the Industrial Revolution in Europe, taking as a symbolic mark James Watt's steam engine patented in 1776 (Crutzen and Stoermer 2000) are, as explained in the Introduction, the best candidates. In both circumstances the new era is connected with evidence of induced climate change and the rise of CO_2 and CH_4 concentrations in the atmosphere (Crutzen 2002: 23).

Lewis and Maslin are not the first to propose an earlier beginning for significant human impact on the environment (or the functioning of the earth system, as insistently claimed by Hamilton (2015). Accepting that humans are not outsiders or invaders, but rather an integral part of nature and the ecosystems (still a recent idea in ecology), scientists now argue for an earlier date for the inception of a new era: the one in which the earth system is dominated by humanity.

One point seems consensual: all authors refer to Western societies as the catalyst of such an era. Those who believe in 1945 as the symbolic beginning of the Anthropocene even specify that it signals 'unambiguously the dawn of the era of global economic domination by the United States of America, which was intimately tied to the economic boom of the post-war years and so [to] the rapid increased [*sic*] in greenhouse gas emission and associated warming' (Hamilton 2015: 105). Maslin and Lewis follow the same reasoning when trying to interpret the data revealed by the 1610 GSSP marker as the impact of Europeans upon the Americas, as if one could, within the worldwide dynamics created by European colonization, isolate specific factors affecting a continent and discard all the balances and imbalances involving the others. The concept of 'connected worlds' seems to be strange to scientists who otherwise maintain that measurements are only valid if observable at a global level.

History is by tradition a good auxiliary in exercises put forward by scientists who would normally disregard its existence as a discipline. It is perceived as a useful tool to contextualize and justify assumptions and policy goals (Linnér and Selin 2013; Uhrqvist and Linnér 2015: 159). Hardly precise or strictly rigorous in the data submitted for evaluation by the 'real' scientists (especially for the pre-statistical era), driven by heavy source criticism as a standard methodology, focusing on particulars rather than on general rules, denying the existence of general laws as regulating societies over time, historiography is an easy resource available either to be used as a mere contextual framework or to be manipulated as a data provider. Both sides in the *Anthropocene* debate are evidence to this. Between them, however, they have opened a clear space for historians to enter the debate.

Reacting to Lewis and Maslin's proposal of 1610 as a chronological marker to the Anthropocene, Hamilton claims:

> When other scientists and historians begin to examine more closely the historical correspondences and the scales of the various claims about colonization, population decline, the spread of crop varieties from Europe to South America and back the other way, pollen in marine sediments, rates of forest regeneration, atmospheric CO_2 and the course of the "Little Ice Age" the Lewis-Maslin story will surely fall apart. (Hamilton 2015: 3)

This may very well be so, but validating or invalidating this new claim is an enterprise that requires active cooperation between history, ecology, geology, earth system sciences and other disciplines. History has to be taken as a partner to clarify hypotheses, rather than to be used as a weapon in a fight between academic currents.

At the risk of stating the obvious, what is expected from any discipline is to define concepts, to debate hypotheses according to clear theoretical assumptions, to collect empirical evidence and to submit conclusions to further debate. This chapter will try to do just that by debating the concept of *Anthropocene* as applied to the First Global Age 1400–1800.

Let us begin by asking whether it is even worth debating the applicability of the concept to that period. If one takes the Anthropocene as an era in which the earth system is driven by human action, the latter having an impact as massive as other forms of nature, such as meteorite strikes or volcanic eruptions (Lewis and Maslin 2015: 138), then the signals of such an era can only be read at a global level and supported by global dynamics. In this framework, the pertinence of this kind of analysis for this period is clear, if one keeps in mind that we are dealing with a period that tends to be consensually interpreted as 'The First Global Age', when global economic systems and global circulation of men, commodities, ideas and technologies prevailed.

But can one subscribe to the idea that, during that period, the omnipresence of humans and their actions over the ecosystems affected the earth system in such a way that human performances overcame 'Nature' (for better or worse) as an influential element of the earth system? It can only be discussed if one takes, layer by layer, the dimensions that define the Anthropocene.

Traditionally, there are some basic parameters by which one can measure the impact of man upon nature. One is soil exploitation. During the First Global Age, a colonial economy, ruled by European markets, introduced new patterns of territory management, property regimes and soil exploitation. Colonial plantations, based on monoculture and *latifundia*, tended to dominate or overlap other ways of soil appropriation or use. That is a proven fact, at least in some parts of the planet. Another parameter is energy consumption: during this period the massive cultivation of products designed for European markets consumed tropical forests and fertile soils in a quest for arable land and for the energy needed to operate sugar mills or smelt metal, for instance. This is largely acknowledged, even if its real scale and differential geographical representation still require further research.

A third aspect is species extinction. The disappearance of vegetable species during this period is well documented, as is the elimination of some animals from both the land and the oceans. One should add to this panorama, however, the emergence

of new hybrid species, resulting from the transfer of organisms across oceans and continents disconnected until then (Thomas 2013; Polónia 2014), which resulted in a global homogenization of the earth's biota. Such trans-oceanic exchanges are considered unique since Pangaea, and taken as not having any geological analogy (Lewis and Maslin 2015; Maslin and Lewis 2015: 110).

This period saw a large-scale exchange of animals, plants, seeds, and also of bacteria, viruses and diseases. This points both to the global ecological flows between continents, across oceans, and the problem of their impact upon local environments in Africa, Asia, America as well as in Europe.

In view of this, discussing the application of the concept to this period is justified. In fact, there was an ongoing and vivid historiographical debate, well before the *Anthropocene* concept arose, and an anthropocentric scrutiny of that biological exchange at a global level took place: well-established analyses emphasize the importance of the actions and intentions of the colonizers over nature, assuming from the outset their supremacy in all respects, as well as their responsibility for developments which led to depletion or exhaustion of resources, frontier conflicts, damage to ecosystems, introduction of invasive species, bacteria and germs, and the destruction of species, to the very point of their extinction at an unknown level – most of them coinciding with the described effects of the Anthropocene.

This view assumes that part of what happened was the result of imperial-oriented policies and colonial agendas, including the unintentional and uncontrolled actions of European colonizers trying to replicate their own way of living in foreign geographies. Typically, it adheres to the concept of 'ecological imperialism', seen as 'The Biological Expansion of Europe' (Crosby 1986). According to Crosby, ecological imperialism is the ultimate expression of colonialism. Let us revisit this core proposal.

Ecological imperialism

The 'early modern age' (1400–1800) is consensually seen as a time of growing interconnectivity among several continents and oceans. This opened the door for the creation of a world economy (and a world system) as much as for environmental impacts resulting from global transfers, from which new syncretic biomes emerged. During this period, Europeans invaded old and new worlds aiming for a quick, effective and profitable use of their resources. The Europeans moved towards old-world continents, such as Africa and Asia, and projected themselves into newly discovered continents and subcontinents, including the Americas, Australia and Oceania. The invasions were organized through state-run monopolies (sponsored by the crowns of Portugal and Spain), and chartered trading companies (sponsored by England, France, the Netherlands, Sweden and Denmark). Overseas settlements and long-distance trade were established, and economic emporia and political empires were created, changing the world systems for good.

According to the ecological imperialism perspective, Europeans tried to replicate, as much as possible, their way of living in the new territories, implying an intense

projection of their influence upon them. A colonial economy, ruled by European markets, introduced new patterns of territory management, property regimes (Prem 1992) and soil exploitation.

In America, colonial plantations, based on monoculture and *latifundia*, tended to dominate. Along with cattle breeding, they unbalanced old equilibria and the profile of autochthone economies (Poppino 1949). Sugar, coffee, cocoa, tobacco, tea and rice were transplanted to regions where they had never existed, replacing old plantations or totally invading unexploited lands. Their cultivation consumed fertile soils, together with timber and tropical forests, in a quest for arable land and for the energy necessary to run sugar mills.

Native societies and communities, along with their cultures and economies (agrarian or not) were first pushed back, then partly or totally shattered by the new plantation regimes, the new patterns of land exploitation and the new norms of landed property, imposed by force or deception. The uses of land and environmental management became driven by new requirements and rationalities. Africa and America were continents heavily affected by these new rationalities.

In the Americas, first mining and then extensive colonial plantations of tobacco, cotton and sugar invaded the Antilles and extensively contributed to the annihilation of local tribes and their environment and economies. During the short period between 1492 and 1542, the Tainos of Hispaniola, the most numerous indigenous group, nearly became extinct (Crosby 1967: 321–37; Guerra 1988: 305–25; Guerra 1993: 313–27; Richards 2003: 306, 315–33). Famine, cultural depression and infectious diseases, mostly influenza, resulted in high mortality rates. In some of the Antilles, what mining and colonial plantations did not accomplish in terms of environmental impact and ecosystems, cattle breeding and ranching did (Gordon 1993: 65–121).

On the Spanish American mainland, gold and silver exploitation, extensive livestock rearing and epidemic outbreaks, side by side with the impact of indentured or enslaved labour through the *Encomienda* and the *Repartimiento* system, provoked both the depletion of ecosystems and human depopulation as high as 90 per cent in some Mexican regions (Reff 1991: 9–32; Cook 1998).

Increasingly, formerly unexploited lands were taken by Spanish settlement and ranching, changing the natural and environmental equilibria (Richards 2003: 334–79). Mining in Spanish America emerges as similarly responsible for the exhaustion of resources (Powell 1952) and, more than that, for long-lasting pollution exacerbated by the use of mercury (Bakewell 1990, 2: 131–53; Martínez-Cortizas et al. 1999).

Portuguese settlement in Brazil followed similar patterns even if with less immediate and extensive effects. Apart from the shoreline and the more intensive exploitation of the coastal fringes of Portuguese captaincies, there were the substantive activities of the *bandeirantes*, informal expeditions searching for precious metals and capturing indigenous people, acting without frontiers all over South America. More than anything, it was the period of gold and diamond exploitation, from the end of the seventeenth century, that was responsible for a more extended and aggressive predation of Brazilian territory and ecosystems.

Even where, in the East and Far East, Europeans were one group among many others who had settled in the region for centuries, imposing different empires, political rules, or just adapting to a trade regime in which plurality of partners was the norm (Chaudhuri 1978, 1985; Subrahmanyam 1990), their footprint was substantial, for example, by the transportation of new seeds and germs from other regions and the introduction of plantations of other species within the Indian Ocean world. That is the case, for instance, with some kinds of Southeast Asian spices the Portuguese introduced to the Indian subcontinent, more specifically in the Goa region and on the Malabar Coast. The British imperial impact in India, especially after 1800, seems to have been more extensive still. Under British imperial rule, India's forests were depleted not only by the expansion of cultivated land, but also by both commercial timber operations and plantation cropping for European markets (Tucker 1988: 118–40; and see, further, Parthasarathi's chapter in this book). The same could be said about the impact of Spanish colonialism, in particular in the Philippines, as shown in the work of Greg Bankoff for a later period (Bankoff 2007).

Before 1800, a comparable impact of European systems of exploitation is acknowledged for South Africa and latterly for Australia, initiated respectively by the Dutch and the British. In the Cape region, the southern corner of Africa, opportunistic plantations, first aiming to provide European crews with food, wine and supplies in order to guarantee trans-oceanic navigations, then directed to export, transformed local ecosystems into agrarian landscapes. As stressed by Richards, by the end of the Dutch period (1795), nearly all the larger fauna of the entire Cape region had been depleted by inexorable hunting, even more lethal once the new settlers used firearms. Elephants, rhinoceroses, hippopotamuses and other large, vulnerable animals tended to disappear. As the European frontier expanded, wildlife diminished (Richards 2003: 274–306).

At the same time seas were changing in a direct relation with European colonialism, and some species of fish and animals were threatened by large-scale catches. Those were imposed by the demands of distant consumption markets, ruled by European needs, and commanded by European merchant rationalities. Cod, tuna and whales were just some of the species targeted by this aggressive predation. Massive catches of mammals, particularly cetaceans and other marine species (Brito and Costa 2011), were undertaken from the very first moment of contact, in Africa or on the Brazilian coasts.

Portuguese, Breton, Norman and Basque fishermen dominated New World cod fisheries throughout the sixteenth century (Pope 1997; Abreu-Ferreira 1998: 100–15) as much as did the English (Lounsbury 1934; also Jansen 2012). If the impact of such activity is not comparable to recent times, due mostly to technological changes, the pattern of exploitation was already settled in the sixteenth century. The same applies to hunting sea lions for their skins; the catching of civet cats for the secretion of their glands; the near-extinction of American beavers, to dress fishermen in Northern Europe and for the leather industry all over Europe; and the killing of whales for their oil, which was used to illuminate large European cities such as London (Haines 2011: 159–75). Those behaviours, driven mostly by economic causes, entailed significant costs for environmental and ecological stability.

The new explorers are seen as taking the inexhaustibility and everlasting existence of species for granted or not even considering it. Just as indigenous people did not have legal status in the eyes of most of the European colonizers, autochthone ecosystems did not have any kind of regulation (unlike in Europe) designed to prevent their exhaustion and extinction, at least until the eighteenth century, when ecological concerns begin to be discernable both among European scientists and colonists (Grove 1995). Botanic species were totally destroyed in the Atlantic archipelagos which had, until then, been uninhabited, as in Madeira, the Azores and the Canary Islands; in the same way, the original human inhabitants of the Canary Islands disappeared together with their ecosystems (Crosby 1986: 104–31).

Environmental colonialism seems, in this context, much more important than any other. Ecological and environmental equilibriums were unbalanced, not in a long-term process, but in a short and invasive onslaught of transformation and depletion. The exploitation of indigenous natural resources on the one hand, and the introduction of European animals, seeds, plants and diseases, on the other, were two sides of the same coin (Crosby 1988: 114–15).

Summing up, the 'ecological imperialism' thesis claims that the aggressive behaviour of European agents towards pre-existent environments led to a heavy appropriation of primary products for human use by land appropriation against the needs of other species and other cultures; the depletion of natural resources; the extinction of vegetable and animal species; the destruction of ecosystems and the drastic changes in landscape.

'Ecological imperialism' versus 'Ecological adaptation'

The 'ecological imperialism' perspective reflects a Eurocentric, or else Western-centric model, according to which the local agents, the colonized, are usually excluded from the dynamics of colonial processes, with the global interpretations centring almost exclusively on the determining performance of European powers, agents and policies. In doing so, it ignores the important processes of adaptation and evolution that result precisely from the entanglement of nature and nurture, which necessarily accrued to all those peoples and environments involved.

Therefore the ecological imperialism perspective needs to be reviewed. Examples are provided by the outputs of the so-called post-colonial studies, developed since the 1980s. The more recent perspectives centred on a connected history of the colonial empires (Subrahmanyam 2007), or the agenda of a highly prolific world or global historiography[1] have been contributing to a revision of Eurocentric interpretations of colonial phenomena (e.g. Boyajian 2008; Darwin 2008; Andrews 1984; Polónia 2012),

[1] See the abundant publications, for example, in the *Journal of World History,* the *Journal of Global History, Itinerario* and the *Asian Review of World Histories.*

as reflected in recent publications (Antunes and Polónia 2016), and the organization of scientific panels and conferences on the subject.[2]

Such a historiographical revision is also settled on the adoption of concepts and models of analysis stemming from self-organization and cooperation theories (Nowak 2006a,b; Santos, Santos and Pacheco 2008; Ribeiro 2016), first developed in economics, biology, anthropology, psychology, physics and mathematics (Ostrom 1990; Fehr and Gächter 2000; Hammerstein 2003; Fischbacher 2004; Richerson and Boyd 2005; Hagen and Hammerstein 2006; Herrmann, Thöni and Gächter 2008) and now applied to history. In the language of cooperation, the fact that interactions are generally repeated and bidirectional in time offers to those interacting the opportunity to reciprocate, thus sharing the benefits and costs that accrued to both entities involved, in our case, colonizers and colonized.

The application of this theory and model of analysis by environmental historians clearly has something to offer to a reanalysis of the environmental effects of European colonialism in Asia, Africa, America or Oceania during the First Global Age. Indeed spatio-temporal models of cooperation, which go well beyond strict collaborative efforts between equal parties, will allow one to assess how far the unequal roles played by the parties involved affected cooperation, adaptation and reciprocity. New directions can be defined in order first to question how local actors and Europeans interacted in order to use and manage available natural resources and, second, which mechanisms of adaptation existed, both for Europeans to survive in totally different and frequently adverse environments and for autochthonous people and environments to react, resist or voluntarily adapt to the new ecological elements. This new trend, already happening in the economic, social and cultural analyses of empires, remains to be applied in the framework of environmental history.

In this analytical approach, self-organization theories may provide an adequate complementary perspective of analysis (Vasconcelos, Santos and Pacheco 2013), as they reflect processes where some form, order or coordination arises out of the interactions between the components of an initially disordered system.

George Modelski employed the concept of self-organization to discuss long-term processes in global politics and economics, and world macrodynamics generally (Modelski 2000; Modelski, Devezas and Thompson 2008). According to him, 'Dynamic physical, biological, and social systems evolve in such ways that order increases so that several parts are mutually adapted in what are evolutionary processes' (Modelski n.d.; Barabási and Albert 1999). Another connotation of self-organization, for the understanding of historical processes, lies in the realm of so-called evolvability: the capacity of certain collectives, groupings, areas or ensembles

[2] 'The power of the commoners: informal agent-based networks as source of power in the First Global Age', org. Amélia Polónia at the Social Science History Conference 2010 (Chicago); 'Beyond Empires: Self-Organizing Cross Imperial Networks vs Institutional Empires, 1500–1800', coord. Amélia Polónia and Cátia Antunes', European Social Science History Conference 2012 (Glasgow; 'Fighting Monopolies, Building Global Empires', coord. Amélia Polónia and Cátia Antunes in conference on 'Colonial (mis)understandings: Portugal and Europe in global perspective (1450–1900)' Lisbon, 2013); 'Cooperation under the Premise of Imperialism', coord. Tanja Bührer, Flavio Eichmann and Stig Förster (Bern, 2013).

to produce spontaneous order, at least in the form of organized patterns. Evolution, innovation (or mutation), cooperation and conflict, which act under selection (natural or cultural), are key elements of an evolutionary paradigm. Away from the assumptions of the Darwinian natural selection, this understanding coincides with current trends of evolutionary ecology (see Russell 2011).

Self-organization theories emerge thus as a possible contribution to a renewed analysis of the colonial processes, including its environmental impacts (Polónia 2010). Self-organization occurs and can be studied in a variety of social and cognitive systems, but also in the realm of physical, chemical and biological processes (Watts 1999; Sawyer 2005). This can be a powerful tool to re-examine the processes conventionally considered in the framework of 'ecological imperialism'.

Frequently the 'ecological imperialism' perspectives forget that European powers and settlers interacted with an environment that, far from constituting a 'natural' blank slate, had already been created by pre-installed cultural systems. Such an approach further disregards the way ecosystems reacted to the invaders and become themselves builders of different environments – in other words, it overlooks the evolution and adaptability of ecosystems, as well as the adaptation of Europeans to pre-existent environments.

Aware that, just as there is no natural determinism to human action, there is also no human determinism to nature or to the configuration of ecosystems, it has been claimed that 'the role of European policy should not be overemphasized in discussing eco-history, even if it is true that the indirect and often unintended impact of the European presence profoundly and permanently altered the direction of the ecological evolution of [a] region. In short, the interaction between political form and ecological transformation has always been reciprocal and dialectical' (Weiskel 1988: 145–46).

Evolutionary ecology contributes also new insights to this revision of 'ecological imperialism', stressing that through the millennia there were no stable environments: evolution and transformation are permanent trends and essential ingredients of living systems. When describing evolution and adaptation of ecosystems, modern thinking and modelling in ecology includes nature and nurture (Keller 2010; Goldhaber 2012), and treats space and time on an equal footing, including their interdependence (Levin 1992; Santos, Pacheco and Lenaerts 2006).

Instead of the classic perspective that defines European colonialism as a single, all-encompassing process, understood as 'the Columbian exchange', this chapter argues, within the current discussion on the Anthropocene, that one has to clearly differentiate among colonial experiences. The 'Columbian exchange' tends to be taken simplistically, as if the nature of the contacts and exchanges was limited to the encounters with new worlds (to the Europeans), whether in the Americas, Oceania or the *Tropical Island Edens* (Grove 1995). Instead, much of the European colonization and colonial exchanges happened in Africa (Morocco and Ethiopia, already known to the Europeans, as well as the Sub-Saharan, 'new' Africa), as much as in Asia – part of it an old world and an old partner of the Europeans. Nobody could claim that the new scale of exchanges did not have environmental impacts, but it certainly did not have the same effects as those recognized in America or Oceania – a part which tends to be taken for the whole.

Establishing a linear cause-and-effect correlation between the claimed (and debated) loss of 50 million American inhabitants as a result of colonial-driven outbursts of violence and a GSSP geological marker (Lewis and Maslin 2015) implies disregarding the population dynamics operating at a global level during this period. By that time not only was America demographically strengthened by the arrival of millions of African slaves, but the world population levels give evidence of the migration of species that contributed to food regimes capable of feeding growing populations. The evolution, roughly estimated as an increase from 350–400 million as of 1450 to 900 million by 1800 (McNeill and McNeill 2003: 155–211) resulted from exactly this trend, due to the action of humans as transporters of new species, but also to the role of nature as an integrative force, creating new natures. Here, adaptation, syncretism, hybridism and evolution are key concepts that apply both to men and nature, to ecology and culture.

Adding to this, the first contacts and settlements led by the Portuguese and Spanish in the fifteenth century cannot be perceived as equivalent to those spawned by the Dutch or the British in the seventeenth and eighteenth centuries, or even the Iberian ones in the eighteenth or nineteenth centuries. Instead of linear perspectives according to which the colonized territories were blank sheets where European wrote their history, led by their own agenda, one must investigate the different periods in light of their aims, capacities and market demands, and the existing and changing ecosystems, economies and societies, where topography, geomorphology, biodiversity and climate were as paramount as culture – the local cultures. If one agrees to apply the concept of an *Anthropocene* to this time period, it will have to include the performance of all mankind.

Not only were environments different between and within Australia, Asia, Africa and the Americas, one has to consider explicitly the different models of colonization and the different arrangements within each colonial empire. Let us take the example of mining. Portuguese settlement in Brazil followed quite different patterns from that of the Spanish in Latin America. Even if the amount of gold extracted in Quito and Potosi (Castillan Indias) and in Minas Gerais (Brazil) was comparable, the social and ecological pattern was not the same. Not only were the extraction techniques different (open, through hydric extraction, or by mining) but also the transformative processes (the smelting processes, the use or non-use of mercury) brought quite different impacts. Moreover, the means by which the labour force was obtained, whether by massive forced migration (the slave trade), as in Brazil, or by extracting labour from the indigenous population (by the *Encomienda* and *Repartimiento* systems), as in Peru, had different implications.

Even in the same colonial context, for instance Potosi, the extraction and smelting techniques underwent developments to increase production. This included the adoption of local techniques to separate metal through a casting system with lead, wherein the Amerindians would grind the ore in stone mills and then fuse it in clay ovens and also the replacement of that method by the amalgam system using mercury. This process, introduced from 1554 in Pacoa and from 1572 in Potosi, allowed increased and improved output, and faster separation of the ore. This implied the need to increase the workforce for metal extraction, higher levels of health risk and

pollution, and thus more striking environmental impacts (Richards 2003: 366–72). Although this is well known, the historiography tends to neglect the fact that, on the other hand, as far as copper transformation is concerned, traditional indigenous techniques still prevailed until the late eighteenth century. This was, due both to the Spaniards' inexperience with that kind of metal transformation and to less pressure on a market for copper commodities, quite different from that of gold or silver. In fact, very little has been written on the environmental impacts of mining in Spanish America. Among it the 2010 Studnicki-Gizbert and Scheter contribution stands as a state of the art paper. However, even this only deals with silver production (Studnicki-Gizbert and Schecter 2010).

Africa offers still a very different picture. Here, gold mining still followed traditional patterns of exploitation until 1800, despite Portuguese domination of the export trade, both in the Mina region on the west coast and in the Monomopata (or Mutapa) Kingdom in Zimbabwe, which exported via the Zambezi. On the western coast, the Portuguese increased demand. They opened different markets with different conditions of exchange and tried to divert trade from the caravans to the caravels. But they did not interfere directly in the gold exploitation system, largely because they did not penetrate African territory or take extensive possession of the raw material primary sources before the late eighteenth and early nineteenth centuries. Even then they would still depend on local populations and extraction techniques.

As for the eastern coast, the Portuguese brought Monomopata territories, villages and metal resources under their influence by integrating and trying to control the local social, economic and territorial organization, with the 'Prazos do Zambeze' as a clear example (Isaacman 1972; Newitt 1973). Zambezia came under Portuguese influence and was ruled by the captain of Mozambique. The intention was to integrate under Portuguese rule the administration and agrarian exploitation of the huge properties granted by the Bantu chiefs. Those were *latifundia* transformed into royal Portuguese properties and granted by the Crown for three successive generations, in return for an annual fee paid in gold dust. This territory became relevant after the 1607 and 1629 treaties with the Monomotapa Kingdom, which acknowledged the Portuguese Crown as owner of vast areas in exchange for military support. These grants not only involve the use of the land but also jurisdiction over the African people living there. However, though the demand for gold extraction increased and the circuits tended to be controlled by the Portuguese, neither the techniques nor the extraction methods seem to have changed enough to make a noticeable and structural environmental impact, such as that caused by the use of mercury in Spanish Americas.

Summing up, from the sixteenth to the eighteenth centuries, mining was quite different in West Africa, East Africa or Brazil. This is relevant if one seeks to evaluate ecological impacts – because nature and culture (the local cultures) matter in the processes of empire building.

Similarly, it is well known that the Portuguese, Dutch or British models of settlement on the Indian Ocean world differed from each other and that they used varying degrees of imposition and adaptation to local economies, societies and cultures – all interwoven with environmental dynamics. Studies, for instance, of

the role of women as intermediaries in the Portuguese colonial world (Polónia and Capelão forthcoming) suggest high degrees of transfer not only of land but also of food regimes, implying ecological interactions between indigenous women and Europeans who, in fact, had to adapt to the locals. In a different political and social context, the same could apply to Amerinidan women and to African women in the diaspora. The Africanization of the archipelagos of Cape Vert and San Tome by the massive presence of African women (enslaved or free) in social and family structures did not prevent the introduction of sugar plantations into San Tomé, for instance, but was certainly responsible for a different cultural (and economic, and political) appropriation and use of the soil and the natural resources, quite diverse from the Antillean archipelagos, for example.

A quite different model of colonization; a quite different way of empire building; a quite different degree of regulation were responsible for diverse ecological and human impacts. Such an approach is equally important in analysing the spread of diseases and epidemic outbreaks. Different models of interaction with local populations, different models of urbanization, nucleation or aggregation of autochthone inhabitants (stimulated by induced or forced migration patterns), affected disease transmission by the spreading of virus and bacteria. *Encomiendas, repartimientos, congregaciónes* in Spanish America, Jesuit missions in Brazil; nucleation of population in Africa (Garcia Bernal 1978; Weiskel 1988; Neto 2012; Bernier, Donato and Lüsebrink 2014); different degrees of cohabitation and sexual intermingling between colonized and colonizers are essential variables in these complex and dynamic processes. Their form and extent depends on colonial models. A complex equation has to be put forward in which variables and corresponding nominal values are to be determined, but in which population dynamics prove as essential as the epidemiological characteristics of the diseases (Guerra 1988; Reff 1991; Guerra 1993).

One must, indeed, realize the fundamental differences that accrued to different models of colonization. In Brazil, for instance, the survival of Amazon forests can be directly correlated with the weakness of the Portuguese crown. Similarly, the environmental heritage disputed nowadays on the fringes of wild Brazil – where the possibility of preserving indigenous cultures is still under debate – results from the (fortunate) Portuguese incapacity to match the efficiency of their Spanish, British or even Dutch and French counterparts. The intensity of soil exploitation, the territorial expansion and the appropriation of land are fundamentally different when we disentangle the ecological impact of colonialism. Indeed, these are ingredients that change the dynamics of evolving populations, in a way that precludes the rationalization of colonialism into a single and unified model.

For instance, when Douglass North, William Summerhill and Barry Weingast (2000) argue that the differences in development between Latin America and Anglo-Saxon America derived from the inefficiency and inadequacy of Iberian institutions to promote modern growth, they inadvertently demonstrate the important role that time and the environment of contact plays in the genesis of institutional systems and property models. Daron Acemoglu, Simon Johnson and James Robinson went further with their claim that economic development in former colonies is a function of the institutions imposed by the colonists (2001). However, the equation

is much more complex than that. One can easily accept that very different models of colonization involving quite different ways of state and empire building, different degrees of regulation and different property regimes, necessarily and naturally led to very different ecological dynamics and to diverse ecological and human impacts. This does not mean, however, that the determining force of institutions is to be taken as read. One must take into consideration that environmental differences between the regions largely accounted, reciprocally, for the institutional differences (Engerman and Sokoloff 2012). To conclude: overstating the clarity of state intentions and the capacities of the colonizers sets a bias in the historical discourse that obscures – more than reveals – the identification of the processes that occurred; thus, no single, general model of analysis seems adequate in this domain. On the other hand, this does not preclude the identification of those principles that are common to (and those that distinguish) different models of ecological dynamics.

Another central argument in favour of the existence of an ecological adaptation instead of the ecological determinism associated with 'ecological imperialism' arises when we argue that the European cultural patterns in colonial spaces were not the only ones operating in the field, and not even necessarily the predominant ones. The Europeans had to adapt, intermingle and survive in a world totally unknown to them. Indeed, they frequently depended on the knowledge and the assistance of local populations to deal with new, wild and dangerous endeavours, features that surely were in place in the tropics and rainforests. *The Mosquito Empire* (McNeill 2010) certainly gives evidence to that. Resource exploitation was not an immediate outcome, neither was appropriation a guaranteed result. One has to remember that, at a basic level, facing totally different worlds, in Asia, Africa and the Americas, the survival of Europeans depended on the efficacy of their adaptation to new environments and cultures from which intense material transfers resulted. Europeans had to be receptive to new patterns of food, hygiene, daily agendas, new techniques of exchange and new linguistic and cultural paradigms. The history of science has produced enough examples of those transfer patterns and intermingling, essential to the understanding of the globalization processes at stake. Recent literature points to the importance of the concepts and dynamics of both locality and circulation (Livingstone 2003; Raj 2007), being themselves dependent on processes of complex cultural translation. While those strands were largely cultural, similar mechanisms might be found for ecological trends. The strength of locality – as a producer and as receptacle – was as important as the pressure for circulation, and thus for globalization.

Interdependencies between worlds necessarily went further, disrupting the static view that is often offered. Instead, adaptation prevailed, both from the colonized to the presence and methods of the colonizers and vice versa. Survival in such different worlds as Asia, Africa and the Americas inevitably implied adaptation and acculturation, for Europeans too. In other words, the lives of the first settlers, or group of settlers, would most probably accelerate reciprocal acculturation processes, different from those expected or described by the traditional imperial historiography. These circumstances should have led, in fact, to inevitable mechanisms of exchanges, namely in the processes of resource identification, location and appropriation.

More often than not, colonizers depended on autochthones to provide them with the requested resources, sometimes counting on their own methods, sometimes transferring technologies that would unbalance the ecological standing equilibrium. Hunting and the use of firearms are just an example. Trade was definitely established between colonizers (together with other competitive traders) and the colonized, which implied adaptation. Registers of fur trading in North America (Marin 1979; Yerbury 1986) and Brazil indicate amounts traded that are incompatible with the view of autochthonous tribes as seldom communicating and never trading (Teixeira and Papavero 2009, 2010).

Those are, however, domains in which we often lack measurable testimonies, precisely because they occurred out of the frame (or at least the focus) of the conventional 'empires'. Only a systematic analysis of these dynamics will be able to provide an appraisal of the long-term ecological impact of such cooperation between colonizers and colonized, with the former benefitting from the environmental knowledge of the latter. A one-sided view focusing on the action of colonizers alone is far from sufficient for such understanding.

Concurrently, we need studies of the way colonial species 'colonized' European worlds and how they reciprocally affected other European overseas settlements. In fact, transfer flows, interaction, adaptation and assimilation processes were never unidirectional. In this sense, there is a range of tropical and Asian products which should be of particular interest because of their massive and structural impact on the food regimes of Europe and Africa. Corn (maize) and potatoes became the basis of the European food regime and helped prevent famines; maize and cassava (manioc), from America, became the basis of the diet of a large part of the African population (for a more detailed analysis of the travel of seeds and plants, see Ferrão 1992; Patiño-Rodriguez 2002; Dean 1991; Widgren's and Austin's chapters in this book). These are just the most prominent examples, with rice, sugar, tobacco, coffee, cocoa and tea being other cases in point.

Seen from this perspective, 'this' Anthropocene generated much more than destruction, pollution, depletion and imbalances. In fact, new balances emerged, transforming land use, property regimes, protein availability and population dynamics in Europe as well. The 'corn revolution' is just one of the most well-known processes (Dubreuil et al. 2006; Mir et al. 2013).

This process was thus far from being unidirectional, as stressed before. We can easily understand this argument taking the more recent example of the 'Green Revolution', as analysed by Jonathan Harwood. The Green Revolution is usually portrayed as an agricultural development programme in which crop varieties and expertise were transferred essentially from North to South. Against this background, according to which the earliest programmes were initiated by US foundations and a US government agency, based on a technological revolution that had begun in Western Europe and the United States in the late nineteenth century, the author argues that this picture is highly misleading. According to him, many varieties, practices and people central to these programmes in fact originated in the South and important approaches to improvement have been developed through the fusion of knowledge and expertise from *both* hemispheres. From this point of view, the Green

Revolution is better characterized as a collaborative achievement of North and South (Harwood 2012).

Summing up, two main ideas should be stressed: reciprocity, syncretism and evolvability are paramount to understand ecological processes (no species survives without assimilation by the receiving ecosystem and cultures) and, besides destruction patterns and stressful mechanisms projected onto the ecosystems as led by colonial actions, one should also look at the mechanisms of adaptation, both by humans and by the environment, and analyse the degrees of resilience of ecosystems and human communities to different kind and degrees of stress. They showed a surprising adaptability and created alternative patterns of survival through the emergence of syncretic biomes as well as alternative behaviours and cultural patterns. This kind of analysis might even contribute to vital questions of the present: how to adapt to different climatic and biological conditions, and how to create sustainability in a world which tends inexorably to be unsustainable? When worlds collide they also intermingle, creating new worlds.

The main issue is still whether the consequences and the impact of these exchanges went far enough, in scale and in spread, to have transformed the world as a whole and to have interfered with the earth system itself. This leads us to discuss the linkage between the local and the global and the extent of the identified structural and irreversible impacts, sufficient to leave geological marks on the globe. Methodological considerations are necessarily implied in this discussion.

Anthropocene in the First Global Age?

In accordance with our claim that time and space matters when analysing colonial environmental impacts, did the local and regional phenomena described have a global expression? Since we are not geologists, only concrete empirical enquires would be able to provide an answer to this question. We claim that such collection of aggregate data needs to be pursued at local, regional and inter-regional scales. Accepting this rationale implies, as a consequence, that no historical phenomenon, even if recognizable worldwide, can be understood without observations at a deeply observable scale. No glacial register will provide the historian or the social scientist with more than a hint of the kind of answer able to close this debate. Furthermore, evaluating, on a stable basis, long-term changes and environmental processes for the pre-statistical era seems frequently an impossible task. That is also why local inquiries and micro-analyses facilitate evaluations in a context in which macro-level approaches cannot be pursued, at least from a historical point of view. 'Think globally, act locally', expresses this exact conviction (Vasconcelos, Santos and Pacheco 2013; Polónia 2015). You may think globally, but as for your analysis goes, local is the available scale of scrutiny, in early modern History. David Armitage, responsible for some of the major trends in Atlantic History, Digital Humanities and Big History, calls precisely for a micro-macro interplay as a fundamental dialectic to provide meaning to historical analysis (Armitage and Guldi 2014).

But how to identify those impacts objectively, even on a local scale? The answer seems simple for economic historians: measure them. But how to measure when one does not possess serial, systematic and coherent data to work with? This is the reality both for the European pre-statistical era and for the kind of registers provided by other cultures, based on other systems and criteria of registers. The answer requires interdisciplinary methods and interdisciplinary teams.

Since the 1990s, studies in environmental history have attempted to bring to the fore an all-encompassing perspective, instead of embracing the ideologically driven discourse that prevailed before. Our approach tries to bring the analysis to a new level, by combining historical information with anthropological knowledge of the communities of contact and mathematical modelling, based on evolutionary ecology and reciprocal cooperation. This new paradigm intends to combine historical sources of information, dating from the pre-statistical era, with predictive models of ecology, cooperation and evolution. These will hopefully provide the scaffolding within which scattered historical information will fit into a coherent structure.

Monographic and monodisciplinary approaches have been the rule in environmental history studies. Some of the previously mentioned topics of analysis were dealt with by historians, biologists, epidemiologists, demographers, anthropologists, economists – separately. Given the demonstrated usefulness of these concurrent yet often separate approaches, what if we bring these disciplines together, promoting the interplay between their concepts, their methods and their knowledge (both from social sciences and the natural sciences), thus providing a new paradigm of approaching this topic?

One may argue that this quest is not entirely new. Indeed, it has been acknowledged by recent scientific associations, research teams, group discussions and publications, and has been implemented in research areas other than environmental history, where this goal remains unreached, although recent publications acknowledge the principle (for instance, Emmett and Zelko 2014). Today more than ever, academics are encouraged to work across disciplines. The consensus seems to be that, while disciplinary research has its merits, the future lies in cooperation across disciplines. Rigid adherence to the borders of academia is a twentieth-century relic, scholars are told; the challenges of the twenty-first century (and beyond) will require historians to talk to botanists, literary critics to talk to physicists, and anthropologists to talk to astronomers. Nowhere is this attitude more evident than in environmental disciplines (Emmett and Zelko 2014: 5).

The renewal of environmental studies does not depend, in fact, only on new theoretical positioning: it also depends on the concrete application of new methodologies to historical analysis. The use of quantitative methods is not new in history. Economic history and even econometrics possess a full range of tools able to pursue a measurable analysis of some historical data and realities: except for the fact that those statistical, quantitative analyses depend on availability of serial, statistical data. On the other hand, the combination of mathematical modelling (resulting from complex systems analysis) with pre-statistical data gathered from historical sources to define possible evolving scenarios impossible to obtain from historical analysis alone is certainly new, in particular in the scope of historical environmental studies in the

First Global Age. This is precisely the aim of the 'Circulating Natures' team project, an ongoing research project based on interdisciplinary bases.

We witness, at present, the enormous success and predictive capacity of mathematical models in forecasting local and global behaviours as diverse as the weather and the spatio-temporal unfolding of new epidemic threats (Colizza, Pastor-Satorras and Vespignani 2007; Grenfell 2004). However, the success of these models relies on the availability of precise, and coherent, spatio-temporal data. Thus, mathematicians, physicists, computational biologists and ecologists will have to face the following challenge: how to ensure predictive capacity of forecasting models given that inputs are sparse and scattered in space and time? As harsh and challenging as these constraints may be, they have a seductive power to practitioners of the natural sciences that should not be overlooked. Challenged by these questions and prerequisites, natural scientists will have to develop means of testing and anticipating the robustness of their predictions given the limited data available.

On one hand, historians have to identify sources able to provide a consistent base for modelling exercises, or rather question traditional sources in a different and more innovative way. On the other hand, models will guide historians in what kind of data they must seek. In the end, new scenarios can be scrutinized by historical analysis. Given the limited availability, and the non-linearity of the models involved, it is crucial to be able to get point-like information in the vicinity of what experts designate by 'tipping points' – decisive moments in space and time where small variations may lead to large divergences (Scheffer et al. 2012). This implies interplay between researchers from different fields which will foster a new generation of researchers. It also requires a new paradigm for facing the challenges of understanding history. Finally, history will gain from the attempt to quantify the scale of environmental impacts, while it will check the historical functioning of diverse variables, such as time, space, territory, climate, cultural arrangements and colonial models of settlement and dominion. From a historiographic point of view this constitutes an opportunity; from a modelling approach, it is a fascinating challenge. Three examples will illustrate the potential of this approach.

One could resume the subject of the impact of mining and metal smelting processes on ecosystems. As stated above, early-modern mining in the colonies has received extensive attention by historians, but there existed no serious studies of its environmental dimensions. The contribution by Studnicki-Gizbert and Schecter established rhythms and scales of fuel wood consumption, the main source of energy for silver smelting and refining, for mining districts located along the length of New Spain (Chihuahua to Taxco) from the beginning of colonial mining (1522) to the turn of the nineteenth century (Studnicki-Gizbert and Schecter 2010). This was made possible by the survival of good serial data for silver production in Mexico, recorded by the *Cajas Reales*. They had been already used by Richard Garner (Garner 1988) to calculate the historical evolution of the New Spanish silver industry and are now analysed from a totally new perspective (data published by TePaske, 1982–90 and available at Richard Garner's webpage, http://www.insidemydesk.com/hdd.html). Those data, combined with account books of two *Haciendas de Beneficio* containing the amount of charcoal consumed in the course of producing silver in two periods

of time, 1611–12 and 1782–3, allowed the authors to develop a fascinating approach, not only to the energy consumption required by mining but also to its connection with an emerging pastoralism and agriculture, and its social and ethnic dimensions (Studnicki-Gizbert and Schecter 2010).

Their conclusions mostly apply to silver production, driven by a colonial agenda and highly demanding external markets. The study of copper exploitation and transformation offers, apparently, a different case and promotes different impacts, because this process adapted, integrated and depended on indigenous technological knowledge. The smelting facilities were located near the fuel sources, on the high plateau of central Michoacan, some 120–200 kilometres away from the mines, basically because local vegetation was not considered suitable for preparing the right type of charcoal (Garcia Zaldua forthcoming). The idea of locating the facilities in these areas went hand in hand with the policies for the creation of *congregaciones de indios* nearby. The *congregaciones* displaced and relocated a significant social mass of specialized metallurgists, operating side by side with the charcoal makers (*carboneros*). Both were active agents who, forcefully or through negotiation and cooperation, were responsible for manufacturing new landscapes. The need for wood thus worked as a lever for multiple ecological transformations and adaptations. The comparison of both models of forest use, based on effective data source and/or on mathematical modelling, would probably make a case for a comparative approach and a provocative debate about to what extent higher degrees of adaptation of colonizers to colonized technological patterns implied less negative impacts in ecological systems (or not).

The second example can be provided by the sugar cane exploitation in island environments. Here a more circumscribed territory and a higher propensity for the exhaustibility of resources would make a case for the study and measurement of the impact of sugar cane cultivation on a large scale. Taking the example of Madeira Island and Martinica, for instance, one could proceed with a comparative approach involving different ecosystems, different colonial economies (in Madeira sugar was never a monoculture) and different colonial systems: Portuguese and French. In both cases, there are fiscal sources allowing us to calculate the yearly production of sugar cane. The impact upon soil depletion, deforestation, soil drainage and human migration of free or enslaved labour includes variables whose interference could be examined. Again, mathematical modelling could offer an opportunity for a promising analysis of the possible outcome in terms of environmental impact of the same colonial product exploitation. The scarce approaches to this issue (Smith 2010: 51–77) give evidence that historians alone cannot succeed when more complex processes are at stake. Conversely, without a historian, or a team of historians, natural scientists cannot grasp the correlation data between human and other components in the ecosystem, when the human past is involved.

The last example is the fur trade.[3] A French ship, *La Pélerine*, was sailing back to Europe from the coast of Pernambuco, where she had stayed from March to July 1531,

[3] We thank Fabiano Bracht for the suggestion to take this as a case study and the discussions over the subject.

when she was captured by the Portuguese in September of that year, near the Canary Islands, still with all its load (Guedes 2002: 156): 5,000 quintals of Brazil wood; 300 quintals of cotton; 300 quintals of grain; 600 parrots, who already knew a few words of French; 3,000 skins of leopards and other animals; gold ore, and medicinal oils. All in all, the freight was valued at 62,300 ducats (Guénin 1901: 44).

The numbers are considerable. The 600 parrots who arrived alive in the Canary Islands suggest that a substantially higher number were loaded aboard in South America. Even more amazing than that is the number of animal skins: 3,000. Of these, according to Nelson Papavero and Dante Martins Teixeira (Teixeira and Papavero 2010), at least 2,800 were jaguar (Panthera onça), the largest cat in the Americas. This data sheds light on a very interesting problem, which can be mathematically modelled. To do this, we have to add to this data some complementary information. Like all cats, the jaguar is a carnivore. While the average weight of the animals varies greatly in relation to the territory in which they live, females can reach about 75 kilograms and males 100 kilograms. In some regions where food is readily available, 140-kilogram cats were measured. Individual adults of approximately 80 kilograms need approximately 5 kilograms of meat per day, although they can eat up to 30 kilograms at once, after a long period without food.

Jaguars do not live in groups. They meet in small groups of one male and two or three females during the mating season. Females are sexually mature after two years and have an average of two cubs (though usually only one reaches adulthood), who live with their mother for about a year and a half to two years. Outside this period, they are solitary animals. Studies indicate they are extremely territorial. Females usually hunt in a semi-exclusive territory of about 25–40 square kilometres. The territories of two females may eventually overlap, although this is uncommon. Males reserve for themselves territories whose average varies between 50 and 80 square kilometres, usually encompassing the territories of the females. They defend their areas against other males. Current figures show a wide variation in population density. In the Pantanal, there are currently about six individuals per 100 square kilometres, and on the Amazon, two animals in an area the same size. For the sixteenth century, issues such as the lack of cattle ranches and farms must be taken into account.

From this data, the first question that can be raised relates to the extension of the area where the animals were captured. Even taking into account the possibility of the locals having skins stocked, and given the breeding habits of the animal, a small area would take too long to be resettled to provide such a great number of skins. Knowing the distribution of native peoples in the area (in 1530 the Portuguese occupation was restricted to trading posts scattered along the coast), their hunting grounds could be estimated, given the fact that the food-gathering areas of those tribes, although semi-nomadic, did not overlap. That would help to calculate the area involved.

Once the density of leopards has been estimated, and in view of their territorial and hunting habits, one can conjecture projections of the impact of those captures upon the density of their prey. The same applies to the estimate of the whole energy balance impact over the area concerned, as well as for the establishment of assumptions concerning the levels of optimal foraging for the period studied. Needless to say, this will tell us something about the negotiating capacities of

the tribes involved, in order to provide sufficient supply, in time, for the French merchants arriving at the coast.

The possibilities go far beyond that, and present rich, innovative and enticing challenges to all involved. The above are just some examples to illustrate the potentialities deriving from the integration of historical data, ecology and mathematics.

Epilogue

The aim of this chapter was not to prove or disprove to what extent one can apply the concept of the Anthropocene to the First Global Age. Rather, we took the opportunity offered by an ongoing debate in order to show the complexity of the variables involved. We also claim that, including in the equation historical as well as biological, chemical and geological data, none of these disciplines alone should have the presumption to try to resolve the issue alone. It is not the Lewis and Maslin observation of a GSSP in 1610 that will reinforce the conviction of the historian that definitively his time period of analysis can be claimed as a landmark to the beginning of the Anthropocene. Likewise, we take the assumptions of a quite simplistic view of 'Ecological Imperialism', attractive and appealing as it could be, as misleading, even if we concur with some of the conclusions drawn within it.

We took the opportunity to draw attention towards two basic ideas presumed by the discussion around the Anthropocene: the complexity of the framework until now simplistically seen as the 'Columbian Exchange' and the need for an active interdisciplinary dialogue, of which – besides historians – ecologists, biologists, geographers and geologists, mathematicians and specialists on modelling complex systems should be part.

Summing up, assuming that the cultural systems of colonizers and indigenous peoples were mutually interdependent, this chapter discussed three ideas: (1) When worlds collide they also intermingle. As opposed to the unidirectional perspective of 'ecological imperialism', we argue that syncretism¸ mutual adaptation and assimilation were integral parts of a transformative process of environment; (2) European cultural patterns were not the only ones responsible for altering landscapes. These did not change drastically in colonial spaces alone and, last but not least, if there is an 'Anthropocene' in the First Global Age, this was not a mechanical result of the agency of Europeans; and (3) Human actions alone cannot determine the evolution of nature or the configuration of ecosystems. Through the millennia culture was a permanent feature to be taken into account, but nature always found new ways of reinventing ecosystems, as stressed by evolutionary ecology. Thus, both social and ecological systems should not be treated independently, but as a single, interconnected system (Levin 2012).

The possible input of this new approach to environmental history for the period under scrutiny, if any, is twofold: in one way, it might contribute to the comprehension of human dynamics and human behaviours responsible for environmentally

stressful changes and their long-term consequences; in another way, it might help to understand the limits of ecosystem survival and the ability to adapt to changing environmental frameworks. Understanding environmental dynamics in the long term is a key aim of environmental studies, but it is maybe even more important to understand the costs and the mechanisms which can lead, in the long term, to a point of environmental unsustainability. European colonialism is far from the only variable in these complex ecological equations.

Human-induced environmental change also occurred where European impact was muted and indirect. While change before 1500 tended to be evolutionary and slow, in the period under analysis, there was a dynamic of economic growth (with rising productivity in industry and agriculture) which resulted in demographic increase, intensified international trade, combined with estate-building processes based on a professionalized military strength (Richards 2003: 24). Except that those states were not only European. The seventeenth-century Mughal Empire in India, for instance, was one of the most populated territories of its time, with a productive economy, and counted among the most successful states in the world (Richards 1993).

Environmental history should not present human-induced environmental change as 'an unrelieved tragedy of remorseless ecological degradation and accelerating damage' (Richards 2003: 13), as it is currently seen by most of those who refer to the Anthropocene as the era of the humans. In this sense, to underestimate the resilience of ecosystems and to overestimate human-induced impacts as opposed to natural processes is to risk producing an analysis that may prove too simple in the long run. Climate, geomorphology and culture also forcefully intervene with evolutionary ecosystems. Concurrently, ecosystems affected by human action during the period of colonialism are not necessarily sterile, unbalanced or degraded. They changed then, as they keep changing now, and will remain changing – an attribute of living systems. Eventually, an environmental history that contents itself with deploring the many negative impacts of European colonization upon the non-European world neglects the role played by ecological and cultural dynamics of adaptation during the process, as much as the role of the non-European populations and the other cultures – and this is a perspective which needs to be overcome. Any discussion over the Anthropocene has to go beyond European and Western societies and transcend the technological and development topics. Clean and green technologies are possible and available; sustainable ways of living and interacting within complex ecosystems are offered by a multiplicity of cultures. The connection between the Anthropocene debate, economic development and environmental history is certainly pertinent and a highly relevant topic of discussion but not the only one when debating the Anthropocene, particularly when applied to the First Global Age.

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